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WILLIAM A. URICCHIO, EDITOR

39th ANNUAL MEETING
East Stroudsburg State College
East Stroudsburg, Pennsylvania

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THIRTY-NINTH ANNUAL MEETING
PENNSYLVANIA ACADEMY OF SCIENCE

April 12 - 13, 1963

EAST STROUDSBURG STATE COLLEGE
East Stroudsburg, Pennsylvania

BASIC CONSIDERATIONS IN TEACHING AEROSPACE PHYSIOLOGY

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Marine Corps Air Facility, New River
Jacksonville, North Carolina

ABSTRACT

Biology today is a rapidly expanding science, and teachers of biology must keep abreast of each new field of development. One of these fields is that of aviation and space biology. The basic considerations in teaching aerospace biology include the effect of G forces and altitude on sensory perception or general physiology, and the food, water and oxygen problem of prolonged space flight. It is suggested that rather than teach a unit on space biology, the teacher include the material in the related lessons.

The rapid expansion of two fields of biology within the past decade has produced a vacuum in the modern college and high school basic biology course and related textbook content. These fields, cytogenetics and space biology, have grown from the seeds of academic speculation into widespread public attention. Whenever such a rapid expansion occurs in any science, teachers in the field are faced with a basic question, "Where do I start in presenting this new material?" Biologists have long prided themselves in teaching material with a great deal of practical carry-over to the daily lives of their students. National news media are now carrying many articles on DNA, RNA, and the like, to say nothing of the tremendous attention paid to recent space efforts. There is, therefore, an immediate need to present material from these fields with the same passion we have applied to presenting Mendel's laws or dissection of the frog in the past, for our students now need an appreciation of this new information. This paper will deal with acrospace physiology, and I hope it will serve as a guide to starting points in teaching this material.

Perhaps the most commonly known factor in space flight or piloting high velocity aircraft is the *G* force. When a force of acceleration is applied from head to foot or vice versa the person is said to be experiencing *radial G* forces. If the force is applied from back to chest or vice versa, the person is said to be experiencing *transverse* accelerations. Because of the structure of the primate organism transverse accelerations are more tolerable and astronauts are positioned perpendicular to the flight path of their vehicle during acceleration.

Radial accelerations are extremely hazardous. When a force is applied to the human body from foot to head causing "upward" acceleration, body fluids, due to inertia, tend to pool in the lower extremities causing blackout, a loss of blood from the brain, which is termed the *positive G reaction*. The human organism can tolerate only $+5G$ for any sustained period of time. *Negative G forces* are caused by action opposite that of above and blood pools in the brain. Commonly termed "red-out", this $-G$ reaction is dangerous because of the possibility of capillary rupture in the brain. The human organism cannot tolerate more than $-3G$.

Special clothing, the *anti-G* suit, automatically places pressure on the circulatory system to restrict the pooling of blood under strain of acceleration. Perhaps you have thought of the scarf worn by early aviators as merely a manifestation of the ego. However, this item was actually the forerunner of the anti-*G* suit, for the long end was held between the knees by the pilot, and, as he pulled his "whistlin' jenny" out of a dive, he tightened his scarve's chokehold on his neck to retain blood in the head and thereby prevent blackout!

An obvious hazard to high altitude and space flight is the physiological effects of low density atmosphere or no atmosphere at all. If you consider two physical laws, one which states that as the temperature of a liquid increases its rate of vaporization increases and another which states that as pressure is reduced on the surface of a liquid its rate of vaporization is increased, little imagination is needed to imagine what would happen to the 98.6°F body fluids of a human being exposed to the atmosphere of 65,000 feet.

The greatest problem caused by altitude is, of course, the lack of oxygen for normal respiration. Regardless of altitude the percentage of oxygen in the air generally remains at about 21%. However, the quantity decreases with an increase in altitude, even if the percentage of the total air mass is the same at all altitudes. Aircraft are equipped with a 100% oxygen source to increase the percentage of oxygen through a regulator that will keep the quantity equal to a given amount needed to prevent hypoxia. However, a point is eventually reached where an atmosphere of 100% oxygen at the low pressure of high altitude is equal to the *quantity* of oxygen comprising that 21% of the atmosphere at a low altitude. Another way to look at this is as follows. At sea level the partial pressure of oxygen is about 3.1 psi (21% of 14.7 psi). At approximately 33,000 feet the atmospheric pressure is 3.1 psi and therefore to keep a partial pressure of oxygen at this value the percentage must be one hundred. To prevent a case of hypoxia above this altitude oxygen at 100% is fed under pressure to the aviator, but forced exhalation is then necessary. In space craft the answer has been an artifically pressurized atmosphere, which has eliminated this and several of the following problems.

Air embolism, commonly called "the bends," is also a problem. An increase in altitude, and therefore a decrease in pressure, allows nitrogen in the blood to come out of solution, generally collecting in the joints. The problem is more easily solved by aviators than by deep sea divers. For the aviator can find relief by descent to a lower altitude.

Lack of oxygen also effects vision and other sensory perception. Aviators in the Naval Service, for example, may not exceed 5000 feet of altitude at night or 10,000 feet in the daytime without an artificial source of oxygen. Rapid ascent and descent produces a lag in pressure adjustment across the tympanic membrane via the Eustachian tube which can easily interfer with hearing.

Vertigo, spatial disorientation, due to angular accelerations or weightlessness cannot only incapacitate a pilot or astronaut navigating by sole reference to instruments, but can produce illness in a person not trained in handling himself when old terra firma is not around as a reference to which is up and down or which is right and left. Two structures and the theory of their contribution to sense perception may be used to help explain this phenominon. These structure are the semicircular canals and the utricle (and saccule).

The semicircular canals are generally thought of as three mutually perpendicular canals containing endolymph with fine filaments lining the walls projecting from special nerve cells. Accelerations, and the fluid motion produced by the inertia associated with acceleration, causing the bending of these filaments is interperted by the central nervous system as the sensations of motion. Let us consider the horozontally orientated canal. A pilot is flying in the clouds without reference to the ground. He en-

ters a gentle right turn, and his semicircular canal turns with him, but the endolymph lags do to inertia, bending the nerve receptor filaments causing a normal sensation of motion. In a gentle turn, however, the fluid will eventaully catch up with the canal and an incorrect sensation of straight flight will be experienced. Should the aviator or astronaut believe a sensation such as this he will gradually increase his rate of turn. When the turn is actually completed and straight flight resumed, an opposite sensation will be produced—the feeling of a turn in the opposite direction.

The utricle, for the purpose of simplicity, can be thought of a spherical structure containing endolymph and also lined with filament type nerve endings. Furthermore, for simplicity, we shall say it contains a small calcium carbonate particle called the *otolith*. When standing erect this particle rests on the bottom filaments of the utricle producing the sensation of uprightness. Project yourself into the cockpit of a aircraft or capsule, flying with reference to instruments only. You could roll inverted in the aircraft and pull "back stick" causing the nose of the plane to move towards the center of the earth (or perform a similar action with the space craft). With a force of $+1G$ or more the otolith will rest in exactly the same position it does when you are upright. You may feel the sensation of being right-side-up when actually in an inverted dive. Many other unusual sensations can be explained with reference to these two structures. If you have access to a swivel chair and can anchor same, place a blind-folded student in the chair and give him a spin, allowing the chair to slow at its own rate. The student, in relating his sensations during the ride, will normally claim he has stopped before the chair actually has, and when the chair actually does stop the student will report the sensation of a turn in the opposite direction.

And then there is weightlessness. Aerospace physiologists have found that well trained individuals have few problems with the zero G condition. Perhaps more problems will be encountered when space vehicles are large enough to move about within. After a space vehicle is settled down on its long journey somewhere no beds will be necessary for sleeping. Just go to your chamber, brace yourself away from the wall and go to sleep suspended. Adjusting to this sensation might well be quite different from zero G experiences while strapped to a seat. And one could not breathe to hard in his sleep, lest he propel himself into a bulkhead.

The problem of food, water, and oxygen bulk is the subject of many papers on the biology of space travel. These include academic computations and speculation on recovery techniques, e.g., putting wastes to work. Further dealing with this material is beyond the scope of this paper.

And so my fellow biologists, I hope this gives you a few starting points from which to expand in dealing with the physiology of modern aviation and space travel. For, as you know, space travel is no longer the Buck Rogers comic book myth of the past, but a very real part of the present and certainly of the future, and so we have work to do.

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INCLUDING SCIENTISTS IN SCIENCE COURSES

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In an article entitled *Science for the Citizen: An Educational Problem,* in *Science,* 28 December, 1962, James H. Mathewson, research chemist at the University of California, calls attention to the fact that "Responsible participation in the functioning of a free society requires that each of us understand the meaning for us of the endeavors of our fellow citizens, and that in turn the purposes of our own work be understood."

We who are engaged in the sciences are all more or less familiar with lack of understanding on the part of others of what we are thinking about and doing. Most of us have had experiences that have made us aware of indifference or of downright hostility on the part of non-science members of faculties trying to decided what science and how much science shall be required of all students for graduation. We are aware of misunderstanding and even contempt on the part of some specialists for fields of science other than their own. Physical scientists argue that the life sciences do not require the rigorous mental discipline that astronomy, chemistry, and physics demand. Life scientists argue that modern biology includes chemistry and physics and is, therefore, more demanding than any of the physical sciences when they are restricted to the study of non-life. Astronomers and chemists and even some biologists question whether or not psychology is a science, and so it goes. Meanwhile, all of the sciences continue increasingly to affect all of our lives, and all citizens are affecting the degree of freedom of all kinds of scientists and are determining to what uses their findings shall be put.

In addition to observing lack of understanding on the part of our teaching colleagues, we who teach science observe that students who do not elect a field of science as their major are seldom seen in the science building after they complete the minimum science requirement for their graduation, and we sense reluctance on the part of science majors to take courses in fields of science other than their own. If colleagues and students discuss with us their attitudes toward science as a whole or toward fields of science other than their own, we learn that: 1, they have never felt any aptitude or interest for science or for a particular field of science; 2, the courses they have taken have been either pure boredom or pure torment; and 3, they intend never to have anything to do with science or with a particular field of science again. The first two findings may well be true for them; in regard to the third, however, they have no choice. Whether they like it or not, people are being born, nourished, clothed, sheltered, made sick, hurt, healed, entertained, harassed, employed, moved about, dying, and having their bodies disposed of in accordance with the findings of the various sciences. In addition to all that, they themselves are determining consciously or unconsciously what kinds of scientists and scientific procedures shall shape their lives and the lives of their offspring. In spite of or because of all this, citizens tend to have conflicting attitudes toward science. They cannot help having respect for the power of science and the scientist, but at the same time they fear and mistrust, in some cases, science as a whole, and in other cases, certain fields of science and the people who are engaged in them.

In the article already mentioned, Mathewson points out certain deficiencies in the educational system which he feels

are at least partially responsible for the situation described, and he has some suggestions for improvement. Here I shall not go into the deficiencies but limit my discussion to one suggestion only. He points out, that to be a competent citizen, a man or woman does not need an understanding of scientific facts so much as he needs an understanding of the men and women who are scientists, and that science does not need to be understood so much as scientifically inclined men and women need to be understood.

Obviously with the amount of scientific knowledge that is extant and increasing by leaps and bounds, it is impossible for anyone to be well versed in any but a very limited field. In fact what a student learns in one year may well, by the next year or two, be recognized by scientists as inaccurate. So it is not so much the scientific knowledge that is important to the citizen, but rather those fellow human beings of his whose genes make them curious about the natural world, and which make them strive continually to satisfy their curiosity as they attempt to control the natural world. The citizen needs to know what these people were like as boys and girls, what are their pleasures, their difficulties, and how they fit into human society, as workers, producers, consumers, family men and women, and as citizens themselves.

How can teachers of science assist coming citizens in acquiring this needed understanding of scientists? Mathewson's suggestion is by the inclusion of scientists, the kinds of people they are, in science courses; not by studying, for example, only Allen's rule (Allen, 1877), Gay-Lussac's law (Tilden, 1921), or Mendel's laws (Iltis, 1932), but by learning to know what Allen, Gay-Lussac, Mendel, and others were like as human beings, what motivated them, and what their lives were like.

Many of us are already doing this kind of teaching to some extent. Most biology teachers tell their students that Mendel was a monk, but how many do as one teacher does (Barish, 1963)? This biologist teaches not Mendel's laws, but Gregor Mendel himself, the plump little man that he was, the circumstances of his life, the gardening plans he devised for his 30-by-7-foot patch and which he carried out painstakingly for a number of years, the kinds of peas he selected for seed, the actual numbers of various kinds of pea plants he obtained, and the steps in his analysis of these numbers, including his unverifiable hypotheses. This teacher's students think of Gregor Mendel as a human being, share his thinking, sense his problems, and they themselves arrive at conclusions about heredity in much the same way that Mendel himself did.

Each teacher who adopts this method of teaching selects individual scientists who appeal to him. These may be scientists of the past or present; they may be the teacher's own professors in undergraduate or in graduate school; they may be colleagues whom he understands; or in some cases, the teacher may appropriately use his own circumstances and his own work, leaving it to the students to figure out what kind of a man he is, what his problems are, and what his contributions, if any, are likely to be.

For this method, a long list of possible examples of scientists from Aristotle to Rachel Carson comes to mind. Certain individuals are more suitable than others, depending largely on the type of course and its particular goals. For my purposes here, Charles Darwin (Barlow, 1958) and Albert Einstein (Frank, 1947) are satisfactory examples. In many students' minds (I trust that you all note your own responses), these two names call up textbook photographs of two old men, one with a long white beard,

and the other with an electrically-charged white halo. If any words come to students' minds, they may be evolution and relativity, or they may be something different, monkeys and atoms, for example.

When students learn, however, that both Charles and Albert were slow learning to talk, hated school, that Charles's father yanked him out of grammar school at sixteen because he was fit for nothing but "shooting, dogs, and rat-catching" and growing up "to be a disgrace to yourself and your family," and that Albert at fifteen would have been a high school drop-out but the fact that just as he was about to drop out, he was asked to leave because, "Your presence in the class destroys the respect of the other students," —they, that is, our students, may possibly feel a chord being struck.

Neither teacher nor students want to leave Charles and Albert at that point in their lives. They want to know how they did get around to the scientific achievements described in the textbooks. They wonder how they ever did, when they find out, for instance, that Charles married his first cousin and that in the first seventeen years of their married life, they achieved ten productive pregnancies, six boys and four girls, and that Charles played with them and helped take care of them through the children's diseases. They wonder at Albert too, who at twenty-two years of age married a most unresponsive physics student, had two sons in rapid succession, separated from this family, and later married his first cousin.

Some students find it interesting that, throughout his life even to the time of his death, Charles Darwin insisted that neither Lamarck's writings nor those of his own grandfather, Erasmus Darwin, had any influence on his thinking, when to readers of today, it is obviously impossible for their ideas not to have affected his. Most students are surprised and possibly somewhat comforted by the knowledge that Albert Einstein with all kinds of excellent recommendations simply could not get an assistantship in physics either in teaching or in research at the university level, nor could he get any teaching other than temporary jobs at the secondary level, and so in the same year that he married, he took a job as a patent clerk in Switzerland.

Some students, not all, of course, are sufficiently stimulated by their realization that scientists are human that they delve in the library for more information on particular individuals and their work, and in so doing, get a grasp of what it is like to be a scientist with ideas, but with all the problems that other people have of making a living and getting along with a family, with employers, and possibly with employees. With this kind of insight, whether they completely comprehend the details of the scientists' findings or not ,they are in a better position to decide what kind of science and scientist they want their society to support.

Giving time to this kind of humanistic study means that less time is available for the details of the science itself, but which is more important? that the student memorize facts and perform laboratory experiments many of which he may not fully comprehend and which he will very likely forget, or that he understand that some people are born with traits which incline them scientifically, but who can achieve what they might only with adequate support from the tax-paying and voting citizenry? That is our choice. Mine is the former.

I believe that as Lewis Mumford (1963) said recently, "We had better map out a more positive course; namely, the reconstitution of both our science and our technics in such a fashion as to insert the rejected parts of the human personality at every stage in the process.

This means gladly sacrificing mere quantity in order to restore qualitative choice . . . We must ask, not what is good for science or technology, . . . but what is good for man: not machine-conditioned, system-regulated, mass-man, but man in person, moving freely over every area of life."

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SOIL SCIENCE SERVES ALL OF PENNSYLVANIA

Frank Glade Loughry
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Traditionally, soil science has been treated as a branch of agriculture. To many, it has been applied to agriculture and nothing more. But new uses for basic soils information are appearing. New applications involving soils engineering, soil mechanics, forest soils, and land planning for urban uses, are being brought into focus through the standard soil survey. Thus, virtually all the people in Pennsylvania, both rural and urban, are now being served either directly or indirectly by the standard soil survey.

The survey does this through the interpretations that can be made of the basic data. The standard soil survey is a physical inventory of the soil resource based on morphology and composition of the soil and some of its most obvious environmental factors. Soils are classified and mapped on the basis of their characteristics. The most important internal characteristics are: depth, particle size, color, structure of aggregates of particles, consistence, parent materials, acidity, and the sequence and relationship of the various layers or horizons within the soil. Important external features are: slope, exposure to flooding, evidence of erosion by water, wind, or mass movement, and the presence of boulders or rocks. Some chemical and mineralogical characteristics are related to the observable physical features and are used in the classification when confirmed by laboratory tests. Soil areas identified by these features can be outlined on suitable maps and described.

After mapping and describing are complete, interpretations can be made. Interpretations for agriculture are for: crop productivity, crop adaptation; and management needs covering the whole range of erosion control, drainage. irrigation, tillage, fertilization, and crop rotation.

Among other important interpretations are those for engineering. These may be for highway engineering as: suitability for fill, subgrade, or top soil; stability under loading; resistance to frost heaving; drainage; flooding hazards; and depth to rock. For housing development the soils can be interpreted in terms of: foundation stability; seasonal high water table; flooding hazard; and the suitability for septic tank disposal systems. Also for housing, there are questions of controlling erosion, establishing lawns, trees, and gardens. For general construction, many of the same interpretations apply, but, in addition, there is concern for water holding in ponds, reservoirs, or lagoons; cost of excavating for pipelines; corrosion on underground pipelines; and possible sources of sand, gravel, or stone for construction materials.

Earlier soil surveys collected data and produced maps for service to agriculture. Other interpretations were a by-product. The survey of Delaware County was made with full recognition that the other uses would overshadow the ordinary farm uses. The soil survey report for the combined Chester-Delaware County area, introduces a section on Rural Development which deals with the soil factors in conversion to urban or suburban land use. When the soil survey of Montgomery County was starting, the county government contributed $30,000.00 to the cost to accelerate the field work and assure the degree of detail needed to furnish maximum data for community and county planning. That survey is just about finished and already we are working on 23 special interpretations for

suburban planning. That is four more than were made in the Chester-Delaware soil survey report.

As population increases in the suburbs and the rural countryside, sanitation and the protection of water supply become almost universal problems. Soils differ in their suitability for septic tank operation. At the request of the Pennsylvania Department of Health, the soils of the State have been grouped in four classes as follows:

1. Those suitable for septic tank operation including deep, permeable well-drained upland soils which provide adequate percolation plus filtration. 13 percent.

2. Those unsuitable for consistent good operation of septic tank because of shallowness to bedrock, seasonal high water table, flooding, or slow permeability. 43 percent.

3. Those which vary from suitable to unsuitable within short distances and require on-site testing. These are mostly moderately deep soils over stratified bedrock. 39 percent.

4. Those which have satisfactory percolation rates but overlie cavernous limestone or beds of gravel and coarse sand and do not provide enough filtration to protect against pollution of the groundwater. 5 percent.

The numbers following each definition are an estimate of the percentage distribution of Pennsylvania soils in these classes. They are based on a 2 percent sample of the soil survey as used for the Conservation Needs Inventory.

The Pennsylvania Department of Health is sufficiently concerned with this and other soil problems to have added a full-time soil scientist to their staff in Community Planning. The Washington County government is applying for Federal Housing and Home Finance Administration planning funds to help accelerate the soil survey of rapidly urbanizing areas.

Some areas of Pennsylvania are concerned with recreational uses of land and seasonal uses. The soil survey offers help in this planning. It can be used in designing vegetation patterns for regulated shooting grounds, locating building sites, establishing sanitary facilities, building access roads, and building ponds. Somewhere between agriculture and urban use is the growing of better grass on parks, lawns, golf courses, athletic fields, and ski slopes. Pike County has only a few farms, but the soil survey has a high priority for use by clubs and individuals who use the land for recreation. In Mercer and Crawford Counties, the soil survey is involved in the development of marshes and lakes for waterfowl as well as the management of upland areas with food and cover for small game.

Forest owners, and especially the large pulpwood companies, use soil surveys in estimating woodland productivity, planning layout of access roads, location of road building materials, and selection of the best species for planting open land.

Engineers and geologists planning the Small Watersheds Flood Control structures and those making River Basin Studies use the soil survey. It provides data on hydrologic characteristics of the watershed, helps locate borrow material for earth structures, and is useful in planning revegetation of structures, emergency spillways, and borrow pits.

Over 13 million acres of Pennsylvania land has been surveyed in detail, using aerial photographs on a scale of 1:15, 840 or larger as base maps. With 45 percent of the State mapped, the survey has progressed most rapidly in the southeast where high value agriculture and rapid urbanization have combined to give

a high priority. Other concentrations can be found in the area east and northeast of Pittsburgh and in the central part of the State.

Present activities show 28 field soil scientists of the Soil Conservation Service working in 24 counties.

Published reports with a modern format are available for Carbon, Clarion, Erie, Lancaster, and Potter Counties. Chester-Delaware, Jefferson, Lehigh, and York will soon join this list.

The Soil Characterization Laboratory at The Pennsylvania State University and the Soil Survey Laboratory at Beltsville have provided detailed data for at least 2 profiles each of 97 soil series.

The Soil Testing Laboratory of The Pennsylvania Department of Highways and the U. S. Bureau of Public Roads have provided engineering test data on three or more profiles each for more than 115 series.

Progress of the soil survey is at the rate of about 1¼ million acres per year. It will take at least 12 more years to complete the field work needed to cover the State.

THE PITCH OF ULTRA-SONIC FREQUENCIES HEARD BY BONE CONDUCTION

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ABSTRACT

Several investigators have reported that high intensity sound in the ultra-sonic region above 20 kc can produce auditory sensations in individuals with normal hearing, and the senior author has reported bone conduction thresholds from 5 kc to 100 kc. This study was performed to investigate the pitch characteristics of ultra-sonic frequencies heard by bone conduction. The results of pitch-matching tests on three subjects indciate that the pitch of bone-conducted, ultra-sonic frequencies approximates that of a bone-conducted pure tone at 16 or 17 kc.

INTRODUCTION

Hearing may be regarded as the result of two types of proceses which occur within the auditory system: one of these is mechanical; the other, neurophysiological (Wever, 1949; Wever and Lawrence, 1954). The mechanical activities involve the conduction of sounds from the external environment through the peripheral auditory apparatus to the sensory cells lying deep within the cochlea. The neurophysiological activities occur within the sensory cells and consist, presumably, of electrochemical changes which are represented in the neural excitations propagated centrally in the auditory fibers of the eighth cranial nerve. The mechanical portion of the hearing process may be subdivided into two further segments depending upon the route followed by the physical sound waves in their passage through the peripheral structures of the ear to the cochlea. The usual route is by air conduction, in which aerial sound waves generated by a distant vibrating object enter the external auditory meatus, impinge on the tympanic membrane, pass through the impedance-matching ossicular chain, and enter the cochlea at the oval window. An alternate route is provided by bone conduction, in which direct contact must be made between the vibrating sound source and the bones of the skull. The acoustic vibrations travel primarily by means of an osseous pathway from the first skull bone to the cochlear capsule which is set into motion according to a translatory, compressional, or some other mode of vibration. In any case, the contents of the cochlear capsule are activated, producing displacements of the basilar membrane in the cochlea which result in auditory sensations.

The question of critical significance for auditory theory is whether the pattern of stimulation of the cochlear sensory structures is the same for both air conduction and bone conduction. Apparently it is, at least for tones within the clinical range of frequencies, *i.e.*, approximately 100 cps to 8 kc. The work of von Békésy (1932), Wever and Bray (1936), and others has shown that not only do the two forms of stimulation involve the same final auditory pathways, but that both involve the same sensory cells and produce the same patterns of displacement in the cochlea (Wever and Lawrence, 1954). If the conclusion is correct that air-conduction and bone-conduction involve essentially similar systems with respect to cochlear functions, then the upper frequency limit of

hearing should be identical for the two modes of transmission.

Recent evidence indicates, however, that high intensity, bone-conducted sounds in the ultra-sonic region above 20 kc can produce auditory sensations in individuals with normal hearing. Pumphrey (1950) reported that three observers were able to hear only air-conducted sounds below 16.5 kc, but when the transducer was pressed firmly on the mastoid bone in the temporal region, hearing was present up to at least 100 kc. Deatherage, Jeffress, and Blodgett (1954) obtained a threshold value of approximately 140 db re 0.0002 dyne/sq. cm. at 50 kc when a small part of the jawbone was brought into contact with the surface of the water in a bucket holding the transducer. Corso and Oda (1962) reported data for fifty male and fifty female subjects which showed that the mean threshold of hearing for bone-conducted sounds was approximately 40 db re 1 microbar at 20 kc and 78 db at 95 kc. The threshold curve showed a very sharp rise between 10 kc and 20 kc with a slope of approximately 50 db/octave, and a gradual rise from 20 kc to 100 kc with a slope of approximately 18 db/octave. The maximal discrepany between men and women was approximately 5.5 db (at 14 kc).

Since these data reveal that auditory sensations can be produced by high intensity bone-conducted sounds for frequencies above the upper limit of hearing by air conduction, the present study was designed to establish the pitch characteristic of ultra-sonic frequencies heard by bone conduction.

EXPERIMENTAL PROCEDURES

The subjects in this study were three male students, 18 to 20 years of age, who volunteered from an introductory course in psychology. All subjects had normal hearing and showed no otological abnormalities. All subjects had participated for several weeks in previous stu-

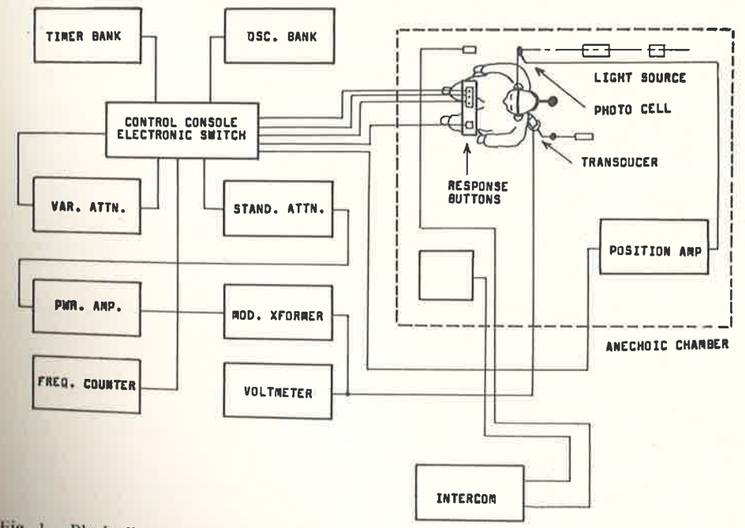

Fig. 1. Block diagram of apparatus used in the study of the pitch characteristics of bone-conducted tones in the ultra-sonic frequency range.

dies on ultra-sonic stimulation and were considered to be trained observers.

Figure 1 is a block diagram of the apparatus used in the study.
Essentially it consists of several functional sections; these deal with the generation and the calibration of the acoustic stimulus, the acoustic transducer, and the experimenter's console for controlling the tonal input to the subject.

The subjects were presented with a standard stimulus at a sensation level of 5 db (*i.e.*, 5 db above threshold) and one comparison stimulus which could be manipulated by the experimenter to produce continuous changes in frequency and in intensity. The method used in the experiment was a variant of the method of average error; the subject was asked to tell the experimenter how to change the comparison tone in order to match it in pitch and in loudness to the standard tone. Three ultra-sonic standard frequencies were used: 57 kc, 64 kc, and 94 kc; in addition, one sonic frequency of 14kc was used as a standard. Each subject matched each of the four frequencies twice; this required eight one-hour sessions for each subject. A mean of the matches for the two trials was obtained for each subject and then a group mean was computed.

RESULTS AND CONCLUSIONS

Table 1 shows the mean frequency match for three ultra-sonic tones of 57, 64, and 94 kc and one sonic tone of 14 kc. The mean match for 14 kc was 14,084 cps which is quite accurate for this method and indicates that the subjects using the method can make appropriate judgments. The 94 kc tone was matched at 17,352 cps and the 57 kc tone was matched at 16,681 cps. (Note that only two subjects were used in the 64 kc match. The data for one subject were lost due to a calibration error which was not detected until after the completion of the study.) The mean match for the two remaining subjects at 64 kc was 17,656 cps. It should be pointed out that the judgments finally arrived at by each subject were somewhat below their upper frequency limit of hearing by air conduction. In other words, for each subject there was some comparison frequency which was judged too high in pitch, so that the comparison stimulus had to be lowered in frequency to attain a pitch match with the standard. It is concluded that the pitch of bone-conducted, ultra-sonic frequencies approximates that of a bone-conducted pure tone at 16 or 17 kc.

TABLE I

PITCH MATCHING DATA FOR SONIC AND ULTRASONIC FREQUENCIES

Standard Frequencies	SONIC 14, 000 cps.	ULTRASONIC 57, 000 cps.	64, 000 cps.	94, 000 cps.
Number of Subjects	3	3	2	3
Mean of Judgments	14, 084 cps.	16, 681 cps.	17, 656 cps.	17, 352 cps.

DISCUSSION

In the study of hearing, considerable attention has been directed to the establishment of the frequency and intensity characteristics of acoustic vibrations which serve as adequate auditory stimuli. The comparison of air-conduction intensive thresholds and bone-conduction intensive thresholds has provided a useful diagnostic technique for the evaluation of various hearing disroders. Unfortunately, while bone conduction has been of extreme importance in clinical diagnosis, little attention has been directed towards bone conduction in relation to auditory theory.

The present study was designed to investigate the problem of pitch perception by bone conduction in the ultra-sonic frequency range. The study has demonstrated conclusively that frequencies above the conventional upper frequency limit of hearing by air conduction are capable of eliciting auditory sensations when presented by bone conduction. However, the pitch of these bone-conducted ultra-sonic frequencies remains essentially constant from approximately 20 kc to 94 kc and resembles that of a bone-conducted tone of approximately 16 or 17 kc. This finding is in general agreement with the statement of Deatherage, Jeffress, and Blodgett (1954) who suggest that the pitch of sounds "is the highest pitch a given subject is capable of hearing."

Anatomically, the cochlea is a part of the bony labyrinth which is embedded in a relatively soft segment of porous bone. It is hypothesized that when sound energy impinges on the labryinth, the cochlea vibrates as a whole or in parts, but is prevented from completely free vibration due to the attachment of the stapes of the middle ear to the oval window of the cochlea. It is suggested, therefore, that the relative motion between the cochlea and the stapes is sufficient to induce excitation of the basilar membrane in the region of the oval window. This relative motion could be attributed either to differences in the inertial mass of the cochlea and the ossicular chain or to differences in the phase of vibration of the two structures. Stimulation of the basilar membrane near the oval window would account for the present findings, since the receptor cells in the basal turn of the cochlea are held to mediate the perception of high frequency tones. Thus, the tonal sensation arising from bone-conducted ultra-sonic frequencies would be expected to correspond to that produced by air-conducted sounds near the upper limit of audibility, since in both instances identical receptor elements on the basilar membrane would be activated by the acoustic energy.

An alternate explanation of the origin of the traveling wave in bone conduction has been proposed by Tonndorf (1962). In this view, it is suggested that a steady-state signal "applied anywhere along the cochlea cannot simply displace the partition at a point directly between input and output. It has first to find a 'gate' where it is admitted. This 'gate' is constituted by that region along the partition in which the bandwidth is sufficiently wide for the signal in question. For all but the lowest frequencies, this is the basal region of the partition, the distal limit being the point where the bandwidth becomes insufficient for passing the signal. Consequently, the traveling wave must always commence in the basal portion and progress toward the cochlear apex . . ." Since this view postulates that excitation of the partition initially occurs in the basal region, *i.e.*, near the oval window, it is compatible with the findings of the present study and provides an alternative hypothesis for the explanation of the results.

SUMMARY

In an earlier study, the senior author reported bone-conduction thresholds from 5 kc to 100 kc and confirmed previous fragmentary reports that auditory sensations were produced by ultra-sonic fre-

quencies. The present study was performed to establish the pitch characteristics of bone-conducted sounds from 14 kc to 94 kc at a sensation level of 5 db. Three subjects were accordingly tested in a pitch-matching experiment by means of a modified method of average error. The results of the pitch-matching tests indicate that the pitch of bone-conducted, ultra-sonic frequencies approximates that of a bone-conducted pure tone at 16 or 17 kc.

ACKNOWLEDGMENTS

This investigation was supported by Grant B-2006 (R1) from the National Institute of Neurological Diseases and Blindness of the U. S. Department of Health, Education, and Welfare. The authors gratefully acknowledge the contributions of both Dr. Fujio Oda, who designed and calibrated the special instrumentation used in this study, and Mr. John Searle, who provided technical services throughout the course of the study.

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CORRELATION OF BLOOD-CLOTTING TIME AND POPULATION DENSITY IN THE VOLE (*MICROTUS CALIFORNICUS*)

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ABSTRACT

Blood-clotting time in voles at low or moderate population densities ranges from 15 to 30 seconds. In a captive population allowed to increase to extreme density and "crash" clotting time increased to as much as five minutes. Checks on a natural population undergoing similar extreme density changes confirmed the altered clotting time.

INTRODUCTION

Many physiological responses appear to be associated with changes in population size. Particular attention has been directed toward mammalian species whose numbers fluctuate widely but do so in rhythmic cycles. Attempts to explain both the upper limits to population numbers and the cycling character of changing numbers have normally centered on single autoregulative factors. Among extrinsic factors invoked in explanation are food (Bendell, 1959); predation (Pitelka *et al,* 1955); and intraspecific strife (Clarke, 1956). Single intrinsic factors are as widely represented: fecundity rates (Kalela, 1957); changes in viability (Chitty, 1957); adrenal exhaustion (Christian, 1950); hypoglycaemic shock (Green and Larson, 1938); and so on. Increased adrenocortical weight (Christian, 1950) and decreased eosinophil (Louch, 1956) numbers are two widely used measures employed as indirect indices of systemic disturbances occurring at high population densities. Each of the measures or their application to theories of population regulation may be challenged but there remains an obvious need for reliable indicators capable of assessing antagonistic interactions between individuals at varying population densities. Most desirable would be a single, simple indicator of overall physiological state applicable to randomly selected individuals from the field.

Observations made during a recent study (Houlihan, 1963) propose questions concerning these intrinsic measures when used as sole indicators of the condition of a population. During this study it was shown that monthly eosinophil counts were more indicative of environmental changes than of interactions within a population of increasing density. Eosinophil counts from a sparse population of California voles were the same as from a very dense population of voles. Adrenal glands weights also did not indicate a population being subjected to severe traumatic experiences even though the population underwent a drastic "die-off" during that study. The adrenal glands from the population at high density were the same weight as the adrenal glands from a sparse population. At the time of the above mentioned "die-off" several indications of a general metabolic disturbance such as a decreased I_{131} uptake and liver glycogen were noted. However, prior to this time when the growing population appeared to be in good condition an observation was made which did give an indication of the approaching decline; the blood obtained for analysis began to fail to clot. The present report is an outgrowth of this observation.

MATERIALS AND METHODS

The methods used in this study were dictated by the previous observation. Thus, even though these methods were not the usual ones or for that matter the

most accurate, it was felt that the previous observation had to be verified and subjected to a field test.

A small area of about one third acre was selected for this test. This area consisted of a non cultivated gradually sloping land, covered with annual grasses. Since this area was adjacent to a steep hill essentially devoid of vegetation ,the voles more or less stayed in the area. The voles were censused by live-trapping, toe clipping, release, and retrapping. The trap lines were set 3 meters apart with the traps about one meter apart in the line. After the census was determined the captured voles were brought into the laboratory and bled by heart puncture. Two tenths ml. of blood was drawn into a tuberculin syringe and then carefully expelled onto a clean slide producing a small pool. At five second intervals a needle was moved through the blood until a fibrin strand or the clot was picked up. The time elapsed between the filling of the syringe and the formation of fibrin or a clot was noted.

RESULTS AND DISCUSSION

The results of this study are shown in figure 1. In this figure it can be seen that the population density increased from about 40 voles per acre in March to

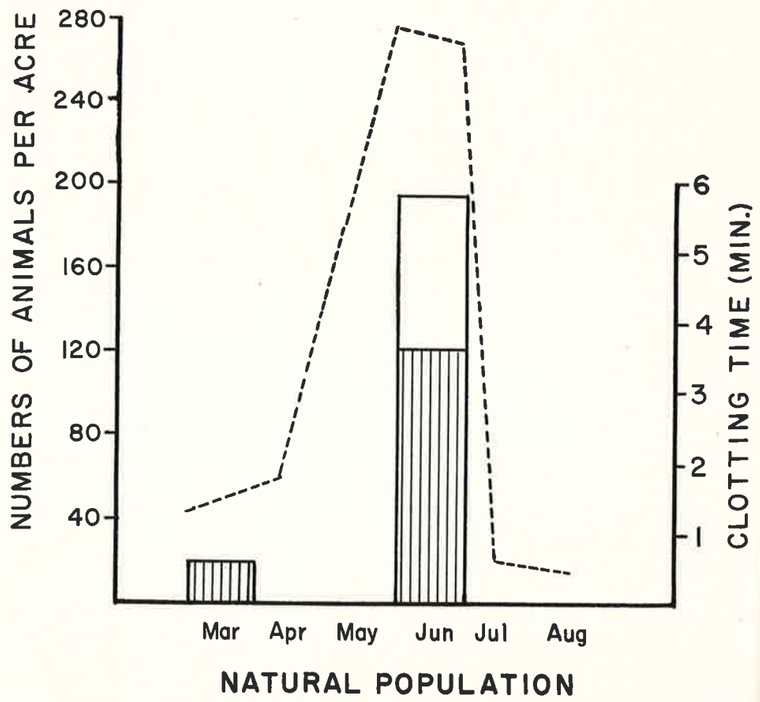

Fig. 1. Correlation of blood-clotting time and numbers in a captive vole population. The dashed line indicates population changes during a ten months period . Columns show clotting time for the months indicated and are read on the right-hand ordinate. The clear area capping some columns approximates variation in clotting time where noticeable.

about 280 voles in May and June. By July the number of animals had declined to about 20 voles per acre. The fate of the lost individuals could not be traced. The apparent correlation of this population with the previous mentioned captive population (figure 2) leads this investigator to believe that there had been a "die-off" in this field population. Since the ground cover in the area still had adequate feed and since the surrounding area had poor cover and feed it doesn't appear that emigration would account for this decline.

A more important facet of this study is the change in clotting time related to the condition of the population. Figure 2 shows that the clotting time of the captive population increased from 15 to 30 seconds when the population numbers were low and that the clotting time of nearly 50 voles increased to about 5 minutes when the population density reached a maximum. Following the population "crash" clotting times returned to normal. Decreased reproductive success was the only other effect that was obvious during this time.

Figure 1 indicates that the same condition existed in a natural population. Although the variations of clotting time were large when the density of the natural population reached a plateau, the difference in clotting time between these animals and those from the same population when the numbers were much less was considerable. It should also be stated that this change in clotting proclivity occurred in populations prior to a decline and that this occurrence was seen in the absence of other reported indirect measures of increased population pressure. It, therefore, must be concluded that no single cause and effect can be given for intrinsic population control which is usable in natural populations subjected to varying environmental factors.

The change in clotting proclivity is another effect which can be added to the

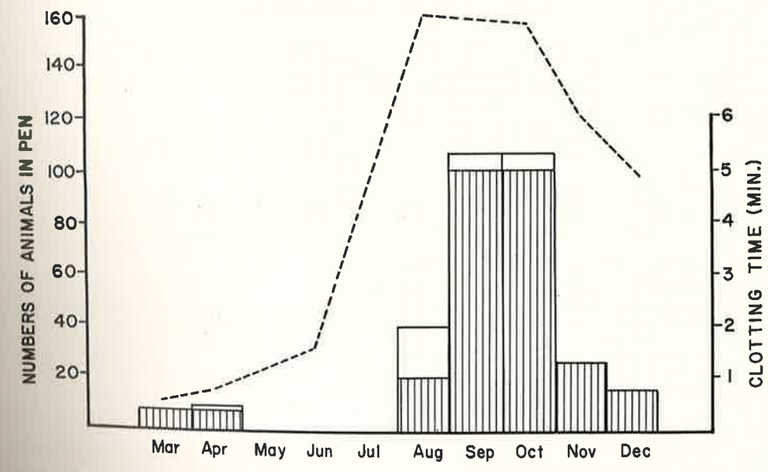

Fig. 2. Correlation of blood-clotting time and numbers in a natural vole population. Description is as for fig. 1. Note that the period of observation was only five months.

list of physiological changes observed in animals at times of high population densities. As this list grows, it becomes more evident that no single endocrine abnormality can account for the rapid population decline. Indeed, clotting time may unify a number of other single-factor "causations" that have been evoked to explain rapid population declines. Character of food, "stress" of numbers and disease are seemingly interacting influences. Each is either directly or indirectly associated with others and all affect the general metabolism of the body. Selection of single-factor end effects can lead to an over-simplification of a complex problem.

It is suggested that a further search of correlations of all the independent effects might lead to the solution to the problem by pointing to the underlying cause of each manifestation of population interaction.

SUMMARY

Two populations of the vole (*Microtus californicus*) were maintained for nine months in outdoor pens. One population was maintained at moderate density; the other was allowed to grow freely and it ultimately "crashed." During the course of changing density many observations and measurements of behavioral and physiological state were made. One variable—blood-clotting time—was unexpectedly increased. This observation was tested in a natural population.

When the density of the natural population and the high density experimental population increased the blood-clotting time increased to five minutes or more for the highest densities. Following rapid declines in numbers, clotting times once again approached normal. No indication of adrenocortical involvement as attested to by adrenal weight could be found in either of the high density populations. It is suggested that an answer to the basic problem of intrinsic population control should be sought in correlations of the many effects seen in studies of natural populations rather than in trying to establish a single effect which could be a result of the "die-off".

Addendum: Following submission of this paper a study was reported at the Federation of societies for experimental biology proceedings which indicate alterations of the antihemophilic factor and thromboplastin generation when animals are subjected to known stress intensities or neural stimulation.

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OVARIAN FIXATION OF THYROXINE I^{131}*

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ABSTRACT

Ovarian uptake of thyroxine I^{131} was increased by thiouracil feeding for 15 days, by chorionic gonadotrophin administration for 5 days and by the combination of treatments. Thiouracil only was most effective. After thiouracil feeding for 30 days, ovarian uptake of thyroxine I^{131} did not differ from that of euthyroid controls but thiouracil combined with 20 days of gonadotrophin treatment significantly reduced the uptake of isotope.

INTRODUCTION

Iodine content of mammalian ovaries reveals a concentration of this halogen which is exceeded only by the thyroid gland (Carter, 1932; Maurer and Ducrue, 1928). Furthermore, the iodine content of the cow ovary is known to vary with the physiological state of the animal, being reduced during preganancy (Roche and Desruisseaux, 1950).

Administered radioactive iodine is quickly trapped by the thyroid gland. However, doses of I^{131} which are insufficient to destroy the mouse thyroid gland do cause ovarian sterilization (Gorbman, 1950). Furthermore, the offspring of mice injected with 200μc of I^{131} on day 17 of gestation had a reduced reproductive capacity as the result of a decreased number of oocytes (Speert, Quimby and Werner, 1951). The rate of accumulation by the ovary of I^{131} and thyroxine I^{131} may be associated with the rate of metabolism (Bengtsson, et al. 1963; Brown-Grant, 1961; Ford, Corey and Gross, 1957; Giedosz and Mach, 1959). Since the accumulation of iodine by the ovary appears to be related to physiological state, it seemed worthwhile to examine the effect of hypothyroidism, gonadotrophin treatment and the combination of hypothyroidism and gonadotrophin treatment on the ovarian accretion of thyroxine I^{131}.

MATERIALS AND METHODS

Hypothyroidism was induced in female Sprague-Dawley rats weighing 65 to 75 grams by feeding a 20 per cent casein diet containing 0.5 per cent thiouracil for 15 and 30 day intervals. Human chorionic gonadotrophin (HCG)** was injected subcutaneously daily in 10 i.u. amounts for 5 and 20 day periods. Two hours before autopsy on the day following the last injection of gonadotrophin, thyroxine I^{131} (T_4 I^{131}) was injected intraperitoneally in 1 μg amounts. The rats were anesthetized and sacrificed by exsanguination, ovaries were then removed, dissected from their bursae and hydrolyzed in 2 ml of boiling 10 per cent KOH. Samples were counted in a well type scintillation counter, using a thallium activated sodium iodide crystal detector. All samples were corrected for background and read against a standard. Results are expressed as per cent of total injected dose per milligram of ovarian wet weight. Counts were corrected to 100 grams body weight to eliminate the diluting effect of body weight on the isotope.

RESULTS

Hypothyroidism induced by feeding 0.5 per cent thiouracil was followed by the characteristically slower gain in body weight and the increased sensitivity of the ovary to administered gonadotrophin (Table 1).

Hypothyroidism resulting from thiouracil feeding for 15 days was associated with a significant increase in ovarian uptake of T_4 I^{131} in comparison with euthyroid control rats. However,

Table 1

PER CENT UPTAKE OF I^{131} LABELED THYROXINE IN CONTROL AND THIOURACIL-FED RATS GIVEN DAILY INJECTIONS OF CHORIONIC GONADOTROPHIN

Treatment	Number of Animals	Body Weight	Ovarian Weight	Per Cent Uptake x 104 per mg
		gm	mg	
Casein x 15	6	121 ±5	36.6 ±4.7	6.4 ±0.4
Casein x 15 + CG x 5	8	108 ±3	91.5 ±5.4	8.0 ±0.2
Casein + Thiouracil x 15	8	89 ±3	18.1 ±2.0	9.9 ±0.5
Casein + Thiouracil x 15 + CG x 5	7	89 ±3	104.0 ±6.4	8.9 ±0.1
Casein x 30	20	166 ±2	52.9 ±2.6	5.6 ±0.2
Casein x 30 + CG x 20	16	161 ±3	153.8 ±18.6	4.1 ±0.8
Casein + Thiouracil x 30	13	103 ±4	26.7 ±2.1	5.5 ±0.4
Casein + Thiouracil.	25	110 ±2	260.4 ±33.2	4.0 ±0.2

the ovaries from rats fed thiouracil for 30 days no longer exhibited an increased capacity to take up T_4 I^{131}. In fact, the ovaries from both euthyroid and hypothyroid rats fed for 30 days actually incorporated less I^{131} that the euthyroid rats fed casein for 15 days.

Ovarian fixation of isotope was significantly increased in euthyroid rats fed casein for 15 days and injected with chorionic gonadotrophin during the last 5 days. Extending the treatment of gonadotrophin to 20 days provided ovaries in which T_4 I^{131} uptake did not differ from euthyroid controls. The incorporation of I^{131} was significantly greater in ovaries from rats treated with HCG for 5 days than in those treated for 20 days (Table 1).

Thiouracil feeding for 15 days associated with HCG treatment during the last 5 days resulted in an increased uptake of T_4 I^{131} by the ovaries. The per cent uptake while greater than in tissues from euthyroid-HCG treated rats was nevertheless not as great as in the ovaries from rats given thiouracil only. After 30 days of thiouracil feeding and 20 days of HCG administration, the cystic ovaries exhibited an incorporation of I^{131} which was less than euthyroid or hypothyroid rat ovaries but equalled those of euthyroid-HCG treated ovaries.

DISCUSSION

Rate of accumulation of iodine by the ovary is influenced by its physiological state (Brown-Grant, 1961; Ford, Corey and Gross, 1957; Giedosz and Mach, 1959), which agrees with our observations of ovarian T_4 I^{131} fixation. The biological significance of iodine accumulation by the mammalian ovary may be related to steroid hormone production (Dawson, 1958). This contention is supported by Steinetz's observation

(1954) that P^{32} uptake by the ovary, which is suggestive of steroid synthesis (Albert and Johnson, 1952), was greater in ovaries from hypothyroid rats injected with HCG for 10 days than following 20 daily injections. The present studies indicate that HCG treatment for 5 days enhances ovarian biosynthetic activity, whereas, after 20 injections of HCG, ovarian tissue is less active.

ACKNOWLEDGMENTS

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ELECTROPHORETIC ANALYSES OF SERUM PROTEINS IN RATS AND MICE EXPOSED TO SIMULATED HIGH ALTITUDES

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ABSTRACT

Electrophoretic analysis of serum proteins and hematocrit studies were made on rats exposed for 1-14 days and mice exposed for 2-7 days to a reduced pressure of 365 mm Hg. Both strains exhibit a marked increase in hematocrit assosciated with transitory changes in the relative amounts of albumin and globulins. Since hyperalbuminemia disappears within 2 days in rats and within 4 days in mice, it does not represent a permanent feature of altitude acclimation.

INTRODUCTION

The acclimation of animals to hypoxia, whether this occurs with a reduction in ambient pressure or at high altitudes, involves a number of physiological changes which lessen the degree of tissue anoxia. Some of these adaptive responses occur very shortly after the onset of exposure to hypoxia, such as the increased rate of blood formation (1), loss of body weight (2), and reduction in thyroid function (3). This rapid series of metabolic responses is in keeping with the current belief that some of the initial compensatory changes are probably triggered by a blood-borne humoral agent (1), which is produced in response to a lowered arterial partial pressure of oxygen.

Since serum proteins are often used as an index of metabolic changes (4), electrophoretic analyses were made of proteins in the serum of rats and mice exposed to reduced pressure (*ca* 365 mm Hg) for one to fourteen days. The aim of the present study was to determine the nature and extent of serum protein alterations which occur in animals during the onset of acclimation to hypoxia.

MATERIALS AND METHODS

The decompression chamber used in the present study was the same as that used in earlier investigations (2). The chamber, which has a walk-in lock, was maintained at a barometric pressure of 380-350 mm Hg. This corresponds to a simulated altitude of approximately 18,000 to 20,000 feet above sea level. Control animals were maintained at an ambient pressure level of 728 mm Hg corresponding to the elevation of University Park (1,200 feet above sea level).

A total of 63 adult male CFE rats (Carworth Farms, N. Y.), weighing 200-250 grams were used for electrophoretic analyses of blood sera. Of these, 46 were placed in the decompression chamber and groups of 9-14 rats were removed for serum analyses after 1, 2, 4, and 10-14 days exposure, respectively. Four to five untreated rats were bled at corresponding times for a total of 17 serum analyses of control animals. The data from the controls were combined since the electrophoretic pattern of rats kept at ambient pressure remained constant throughout the course of the experiment. Rat blood was drawn by cardiac puncture and no rat was used for more than one bleeding.

A similar study was made on 40 altitude-exposed and 40 control C57 BL/6 male mice (Roscoe B. Jackson Labs., Maine) weighing about 20-25 grams. Experimental mice were exposed to the same pressures as the rats for periods of 2, 4, and 7 days respectively and blood samples were removed from the postorbital sinus (5) for serum analyses.

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During the course of the above studies duplicate determinations were periodically made on rat and mouse serum samples to check on reproducibility of serum analyses and the operation of the apparatus. A Beckman model R paper electrophoresis apparatus equipped with Durrum type hanging strip cells was used. Serum samples (.006 ml) were run at 2.5 ma (constant current) per cell and 60 volts for a period of 20 hours. Veronal buffer (pH 8.6, ionic strength, .075) and Schleicher and Schuell 2043A-mgl. paper strips were used. After separation, the proteins were stained with bromphenol blue and densitometric analyses made using a Beckman-Spinco Analytrol.

In addition to the electrophoretic analyses, records were kept of the body weight changes of rats and mice used in the studies of serum proteins. Each animal was weighed prior to being introduced into the decompression chamber and at the time of blood sampling. Supplemental data were also obtained on the hematocrit response of separate groups of mice and rats following exposure to reduced pressure. A total of 21 male C57 BL/6 mice and 24 male CFE rats were used in these latter studies.

RESULTS

Five distinct protein fractions were obtained from the electrophoretic separation of both rat and mouse sera. These serum proteins, listed in the order of increasing migration from the point of origin (electrophoretic mobility), are: γ—globulin, β—globulin, α_2—globulin, α_1—globulin and albumin. Analyses of normal sera reveal that the general electrophoretic pattern of serum proteins was similar in untreated rats and mice. However, strain differences were apparent in the percentages of some of the protein fractions. The normal serum protein values and the data on the effects of exposing rats and mice to simulated altitude are summarized in tables 1 and 2.

From the data obtained using rats (Table 1) it is evident that changes in the serum protein fractions of rats primarily occur during the first day of altitude exposure. After the second day,

TABLE I. ELECTROPHORETIC ANALYSIS OF SERUM PROTEINS FROM CONTROL AND ALTITUDE EXPOSED RATS

		Serum Protein Fraction ± S. E.*				
Days of Exposure		Globulins				Albumin
		γ	β	α_2	α_1	
Control	(17)	6.6 ± .58	12.9 ± .55	7.4 ± .29	7.9 ± .42	63.5 ± 1.0
1 Day	(10)	5.0 ± .26 **	11.3 ± .59 **	5.9 ± .30**	7.5 ± 1.2	70.3 ± 2.1**
2 Days	(13)	5.9 ± .34	14.5 ± .82	7.1 ± .69	10.9 ± 1.2	61.5 ± 2.3
4 Days	(9)	7.1 ± .98	13.4 ± .59	7.1 ± .91	7.8 ± .74	64.6 ± 1.7
10-14 Days	(14)	5.5 ± .30	13.4 ± .55	6.8 ± .53	11.6 ± 1.1	62.7 ± 1.8

*The mean ± S. E. is expressed as per cent of total protein.

**Significant at a 5% level of confidence using the Student's t test.

Numbers in parentheses indicate numbers of animals.

TABLE II. ELECTROPHORETIC ANALYSIS OF SERUM PROTEINS FROM CONTROL AND ALTITUDE EXPOSED MICE

Days of Exposure	Serum Protein Fraction ± S.E.*				
	Globulins				Albumin
	γ	β	α_2	α_1	
Control (40)	5.8 ± .2	16.4 ± .7	12.7 ± .4	7.4 ± .4	57.7 ± 1.2
2 Days (12)	5.1 ± .4	14.4 ± .8**	13.4 ± .8	5.2 ± .5***	62.0 ± 1.9 **
4 Days (18)	5.8 ± .4	17.9 ± .9	12.6 ± .8	4.0 ± .3***	59.8 ± 1.6
7 Days (10)	4.8 ± .7	20.0 ± 2.0**	11.2 ± .8	3.2 ± .3***	60.8 ± 2.2

*The mean ± S.E. is expressed as per cent of total protein.

Numbers in parentheses indicate numbers of animals.

**Significant at a 5% level of confidence using the Student's t test.

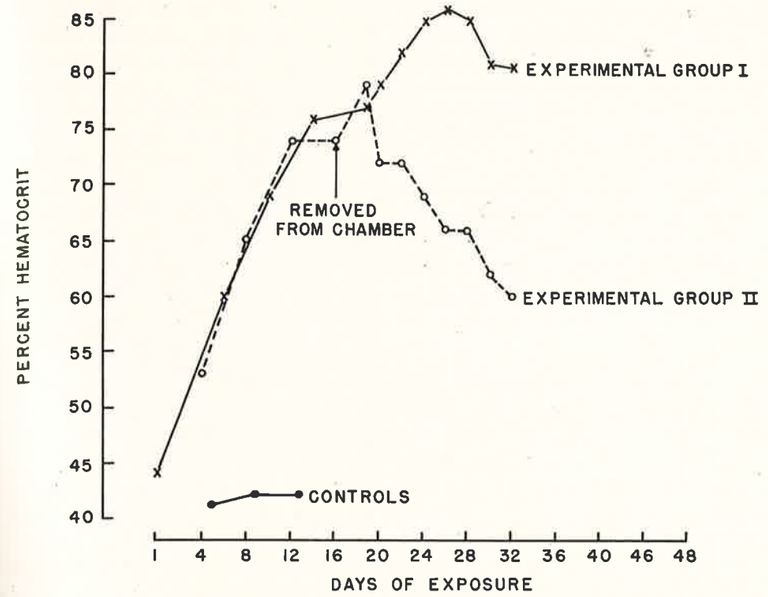
***Significant at a 0.1% level of confidence using the Student's t test.

the relative distribution of serum proteins reverts to that found in untreated control rats. The major protein components involved are albumin which increases 24 hours after exposure ($P<.05$) and three of the globulins which show a concomitant decrease ($P<.05$) in one-day exposed rats.

A somewhat similar serum protein response was observed in mice exposed to reduced barometric pressures. In two day exposed mice there was a significant increase in the albumin fraction ($P<.05$) with a decrease in relative amounts of both the β—globulin and α_1—globulin fractions. Mice exposed to reduced pressure for 4 and 7 days exhibited normal serum albumin values as was observed in rats exposed for 2-14 days. The serum globulin response of mice, however, differed from that observed in rats. The α_1—globulin fraction continued to decrease in mice after 4 and 7 days of exposure ($P<.001$). It should be emphasized, however, that electrophoretic analyses provide no information about changes in the absolute amounts of either albumin or globulins. They merely show whether any alteration occurs in the percentage of various fractions as a function of time. Thus, the data summarized in tables 1 and 2 clearly indicate there is a shift in the relative amounts of serum proteins within 24 hours of exposure to reduced pressure in rats and within 2 days following exposure of mice. This is reflected in the average albumin/globulin ratio which is significantly increased in both rats and mice during the initial period of altitude exposure.

The A/G ratios (± S.E.) for rats as calculated from the electrophoretic data were as follows: controls, 1.9 ± .1; 1 day exposed, 2.5 ± .2; 2 day exposed, 1.8 ± .2; 4 day exposed, 1.9 ± .1; and 10-14 day exposed, 1.8 ± .1. The A/G ratio of mice was also significantly higher than controls (1.4 ± .1) after 2 days of exposure (1.7 ± .1) but not after 4 days (1.6 ± .1) or 7 days (1.6 ± .2).

Both rats and mice were also found to exhibit a marked increase in the hematocrit within the first few days of exposure to reduced pressure. Figure 1 shows the typical hematocrit response of



MOUSE HEMATOCRIT DATA IN RESPONSE TO REDUCED BAROMETRIC PRESSURE (380 mm Hg = 18,000 ft)

14 mice housed in two separate cages of 7 mice each. The hematocrit of both groups increased from a normal value of 42 ± .4% to an average value of 74 ± .9% in about two weeks. After 16 days of exposure 7 mice (Group II) were returned to the ambient pressure level (728 mm Hg), whereas group I continued to be exposed to reduced pressure (*ca* 365 mm Hg.). It can be seen from the graph that in the mice which remained in the chamber the hematocrit continued to increase to a maximum level of about 85 ± 1.6% after 24 days of exposure and then dropped to a level of about 80% after 30-32 days of exposure. In contrast, in the mice removed from the chamber on day 16 the hematocrit commenced to drop reaching a level of about 60% during a span of 16 days at ambient pressures.

Similar hematocrit responses were obtained in studies using rats. In one experiment the hematocrit of 5 rats was found to be 52.3 ± .6% at the onset of altitude exposure as compared to 59.7 ± .9% in 7 rats kept at reduced pressures

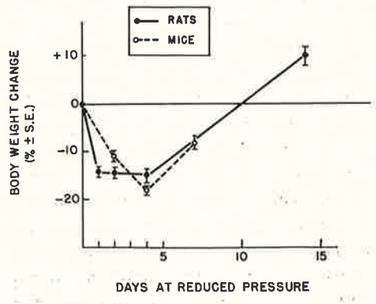


FIG 2. BODY WEIGHT CHANGES IN MICE AND RATS EXPOSED TO REDUCED PRESSURE (*ca* 370 mm Hg)

(*ca* 365 mm Hg.) for 14 days. In a separate study, 6 untreated rats had a hematocrit of 52 ± 1% at ambient pressures whereas 6 rats which were exposed to reduced pressure (*ca* 350 mm Hg) for a period of 50 days had an average hematocrit of 85 ± 2%.

During the course of the present study data were also obtained on body weight changes of animals exposed to reduced pressure. These data are summarized in figure 2 where each point represents averages of 6-8 rats and 12-18 mice.

DISCUSSION

The major finding in the present study is that the onset of altitude exposure is associated with changes in serum proteins. Since alterations in the relative amounts of albumin and globulins were transitory in both rats and mice, this protein response cannot be considered a permanent feature of the acclimatized state of the animal. It is more logical to assume that the observed shifts in the electrophoretic pattern merely reflect an overall metabolic readjustment to acute hypoxia.

In both animal strains, the most marked change was an increase in the relative amounts of albumin which occurred within the first two days of altitude exposure in mice and within one day in rats. The physiological mechanisms underlying the albumin increase and the corresponding reduction in the proportion of the globulin fractions are not understood. However, the most reasonable explanation which fits the available data is that the transient serum protein response is somehow related to the rapid dehydration of the animals when they are introduced into the decompression chamber. It is known that animals exposed to acute hypoxia experience a precipitous loss in weight which is attributable to a transient negative water balance (6). It is also known that dehydration is one of the few metabolic disturbances normally associated with hyperalbuminemia and a diminution of serum globulins (4). This interpretation is also in keeping with the rapid hematocrit response observed in mice and rats shortly after the onset of exposure to reduced pressure. The hemoconcentration which is effected through a reduction in plasma volume is a well documented feature which characterizes the onset of altitude acclimation (7).

Most of the physio-pathological conditions associated with increased protein catabolism cause a reduction in the absolute and relative amount of serum albumin. For example, decreased serum albumin occurs in cases of dietary insufficiency (8), in endocrine deficiencies (8, 9), and generally in any morbid condition associated with a negative nitrogen balance (4). The transient increase followed by a return to normal levels of the albumin fraction in altitude-exposed animals indicates that the major body weight changes observed in the present study are probably not due to protein catabolism but to dehydration.

It is noteworthy that all of our data from the present and from earlier studies support the conviction that animals become acclimated to reduced pressures very rapidly, within a matter of days. Some of the adaptive changes appear to be temporary expedients which lessen the degree of tissue anoxia until more permanent systemic changes are brought about. Diuresis, which results in hemoconcentration (6), and transient hypothyroidism (3) are examples of temporary changes. On the other hand, several permanent alterations are also evidenced within a few days, such as hemopoiesis (1), increased blood volume (10), cardiovascular hyperplasia (11) and increased myoglobin (2). Thus, within a week or two, animals maintained at reduced pressure are fairly well acclimated. That is, they have established a new homeostatic physiological state which appears well adjusted to the new environment which they occupy. This is apparent from the fact that most of the bodily functions closely approximate those of control animals. It is significant that most of the adaptive features which characterize altitude acclimated animals. are gross, systemic alterations. In other words, the amount of functional tissue appears to be altered in altitude acclimated animals. The specific functions of the cellular components of the tissues remain unaffected.

ACKNOWLEDGMENT

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INFLUENCE OF STEROID HYPERTENSION ON ELECTROLYTE AND SERUM PROTEINS

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ABSTRACT

Hypertension will develop in female rats given saline and desoxycorticosterone acetate (DCA). The hypertensive rat has an elevated serum sodium, an increased sodium and a decreased potassium concentration in the kidney but no change in the aorta. Total plasma protein increased in hypertension due to an increase in plasma albumin, alpha-1 globulin and beta globulin.

INTRODUCTION

Hypertension can be induced in rats following unilateral nephrectomy by the concomitant administration of salt and desoxycorticosterone acetate (DCA) (Prado et al., 1947; Selye and Stone, 1948). Neither of these treatments alone will effectively elevate blood pressure (Selye and Pentz, 1943). Accompanying hypertension is a change in sodium and potassium of the plasma, cardiac muscle and aorta. In general, sodium concentration is increased whereas potassium is decreased (Daniel and Dawkins, 1957; Freed, St. George and Rosemann, 1958; Freed and St. George, 1959). However, the ratio of sodium to potassium may have more meaning in hypertension than do individual concentrations (Freed and St. George, 1959).

The effects of adrenal steroids on plasma proteins might also be considered in relationship to hypertension. Administration of desoxycorticosterone to rats caused proteinuria (Addis, Marmorston and Goodman, 1950) and consequently plasma albumin decreased (Allison et al., 1961). The plasma albumin changes might also reflect kidney damage which accompanies hypertension (Skelton, 1955; Omae and Masson, 1959).

The present study seeks to examine electrolyte and protein changes in rats in which hypertension has been induced.

MATERIALS AND METHODS

Adult Sprague-Dawley female rats (weight 120-170 grams) were divided into four groups of 6-8 animals each. One group served as initial controls whereas all other animals were fed a purified diet containing 18 per cent casein for thirty five days. Prior to being fed the purified diet, two groups of rats were unilaterally nephrectomized, one group then received 1 mg of desoxycorticosterone acetate (DCA) subcutaneously daily; the other group was given the steroid and 1 per cent saline as drinking water. The fourth group of animals remained untreated but served as dietary controls.

Systolic blood pressure was determined in each rat by the cuff method using a photoelectric cell to indicate the flow of blood through the leg (Kersten et al., 1947). Serum sodium and potassium were estimated with a Baird Flame Photometer (Dryer, 1956). Tissue sodium and potassium were determined on dry tissue. Dry tissues were ashed in a muffle furnace at 600°C for 6-8 hours and then dissolved in concentrated nitric acid (o.1 ml. per 10 mg of dry tissue). Electrolyte determinations were made on the dissolved tisue after adequate dilution. Serum proteins were separated by paper electrophoresis (Beckman Methods Manual, 1961). Total serum proteins were estimated by Biuret (Gornall et al., 1949).

RESULTS

The blood pressure of normal animals fed an 18 per cent casein diet increased significantly over a thirty five day period in comparison with initial controls but these blood pressures were not at hypertensive levels. Administration of DCA alone did not elevate blood pressure in excess of the normal but when the adrenal steroid was administered to rats given saline, a hypertensive state was induced (Fig. 1).

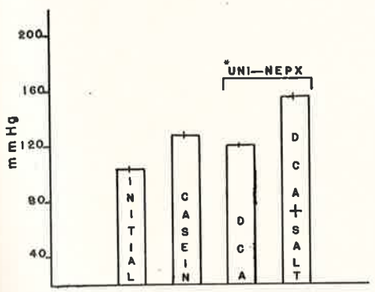

FIGURE I

Influence of DCA and Saline on Systolic Blood Pressue. The lines through the bars record standard errors. *Uni-Nepx = Unilaterally nephrectomized.

Serum sodium and potassium concentrations remained essentially normal in rats injected with DCA but when the steroid treatment was combined with saline, serum sodium concentrations increased significantly. Potassium levels were not influenced by hypertension (Table 1).

Normal rats fed the 18 per cent casein diet for thirty five days exhibited an increase in the sodium concentration in the thoracic aorta. In contrast, sodium concentration of the kidney decreased. No change in potassium was noted in either organ or in the heart. Administration of DCA alone to unilaterally nephrectomized rats caused an increase in sodium and potassium in the aorta and an increase in sodium in the heart without affecting the kidney. Combining DCA and salt treatment to induce hypertension failed to exert an influence on the electrolyte composition of the aorta but instead markedly altered the kidney. This latter organ, which remained unchanged under DCA treatment alone exhibited an increase in sodium and a decrease in potassium in the hypertensive animal (Table 1).

Thirty five days of feeding an 18 per cent casein diet increased total serum protein from 4.71 to 5.68 gm per cent. This increase in serum protein was due primarily to an increase in plasma albumin and to a minor extent by an increase in gamma globulin. Administration of DCA permitted an even greater increase in total serum protein which again was primarily related to the increase in plasma albumin. However, alpha-1 as well as gamma globulin were now increased. The hypertensive animal exhibited the greatest amount of total serum protein (7.10 gms per cent) and the greatest increase in albumin. The hypertensive animal also presented an elevated alpha-1 globulin level and a significant increase in beta globulin, the latter fraction was unchanged in the normotensive rat (Table II).

DISCUSSION

The involvement of plasma and tissue electrolyte concentrations in steroid and renal hypertension has been noted by previous investigators. The manner in which the electrolytes are involved in hypertension is not very clear. However, it seems that the significant increase of sodium concentration with lowering or no change of potassium concentration accompany hypertension or, at least, a tendency towards an elevation of blood pressure. A relative excess of sodium probably has a depressing effect on arterial contraction, thereby causing hypertension(Bohr, 1958). Another possibility could be a waterlogging in the aorta cells because of an increase in intracellu-

TABLE I

Influence of DCA and Saline on Serum and Tissue Electrolytes

Treatment	Serum		Tissues					
			Heart		Aorta		Kidney	
	Sodium meq/1	Potassium meq/1	Sodium meq./kg	Potassium meq./kg	Sodium meq./kg	Potassium meq./kg	Sodium meq./kg	Potassium meq./kg
Initial Control	138.63 ±0.89	5.27 ±0.20	184.89 ±7.71	339.08 ±5.98	190.47 ±6.29	106.82 ±6.39	269.79 ±7.26	335.02 ±4.40
18 per cent casein	141.83 ±0.68	4.63 ±0.20	168.46 ±2.72	333.67 ±3.88	228.82 ±8.75	90.17 ±8.43	233.27 ±7.53	336.26 ±2.69
*uni-nepx + 18 per cent casein + 1 mg DCA	138.11 ±3.01	4.28 ±1.75	200.77 ±3.40	322.41 ±3.41	278.89 ±4.92	127.25 ±2.63	250.08 ±9.01	318.98 ±3.08
*uni-nepx + 18 per cent casein + saline + 1 mg DCA	170.77 ±3.12	4.48 ±0.14	216.03 ±4.83	305.72 ±5.90	246.25 ±3.30	110.32 ±5.27	323.07 ±13.69	292.17 ±3.25

* Uni-nepx = Unilaterally Nephrectomized

TABLE II

Influence of DCA and Saline on Serum Proteins

Treatment	Total gm. per cent	Albumin gm. per cent	Globulin			
			Alpha-1 gm. per cent	Alpha-2 gm. per cent	Beta gm. per cent	Gamma gm. per cent
Initial Control	4.71 ±0.09	2.48 ±0.09	0.69 ±0.03	0.46 ±0.02	0.63 ±0.04	0.45 ±0.04
18 per cent casein	5.68 ±0.04	3.05 ±0.06	0.69 ±0.03	0.47 ±0.001	0.68 ±0.03	0.79 ±0.04
*uni-nepx + 18 per cent casein + 1 mg DCA	6.13 ±0.61	3.56 ±0.34	0.98 ±0.14	0.43 ±0.03	0.74 ±0.05	0.71 ±0.08
*uni-nepx + 18 per cent casein + saline + 1 mg DCA	7.10 ±0.21	3.71 ±0.13	1.47 ±0.20	0.51 ±0.04	1.01 ±0.07	0.64 ±0.04

* Uni-nepx = Unilaterally nephrectomized

lar cations, which might increase the resistance to blood flow (Tobian and Redleaf, 1958).

A decrease in plasma albumin, partially due to kidney damage associated with high blood pressure, had been previously reported (Allison et al., 1961). On the contrary, the present study indicates high albumin level also accompanies hypertension. Possibly, a decrease or an increase of serum albumin depends on the dosage of DCA without having much of a relation to hypertension. On the other hand, the increased levels of alpha-1 and beta fractions of globulin might have some specific relation to steroid hypertension.

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THE DETERMINATION OF SALIVARY ELECTROLYTE LEVELS IN MAN

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ABSTRACT

The utilization of serum electrolyte values in clinical medicine is well known and its value can hardly be disputed. The authors feel, however, that electrolyte values for other body fluids, and in particular those of saliva, might be better utilized in evaluating disease processes. This paper reviews the literature pertaining to salivary electrolyte values in disease and presents some experimental data gathered in this regard.

INTRODUCTION

The determination of serum electrolyte concentrations is a standard and widely utilized diagnostic procedure in clinical medicine. It is the authors' contention, however, that the electrolyte concentrations of other body fluids, in particular saliva have not been fully explored as a source of diagnostic information in pathologic states. There have been, of course, studies done relating various disease states to aberrant salivary electrolyte concentrations (1, 2, 3). However, such studies have been essentialy limited in their potential clinical utilization by the presence of either more definative tests or by the relative infrequency of the disease in question. It was our purpose to explore the possible clincial applications of salivary electrolyte concentrations in man and one such study in this regard is reported herewith.

The conventional measure of body potassium has been the serum concentrations, but this is often an unreliable index. High levels of serum potassium may not be indicative of excess body potassium, but may rather manifest an excess loss from damaged cells or result from intravenous potassium infusion. Conversely, although a low serum potassium is usually an indication of true potassium depletion, an intracelluar deficit of potassium may co-exist with normal serum levels. It seems reasonable that assays of tissue biopsies would provide an accurate measure of body potassium, as potassium is largely intracellular, but this procedure requires surgical management and is not feasible as a mass testing procedure. Accordingly, another, more accessible, means for the accurate determination of body potassium is desirable, and it was felt that an approach to this problem might be the determination of potassium concentration in saliva.

Thaysen et. al. (4) and Hildes (5) have reported that the potassium concentration of random samples of parotid gland saliva in man is 3-4 times that of the plasma level. The theories offered as an explanation for the high concentration of potassium in saliva agree that potassium is not only delivered into the salivary secretion by arterial plasma, but that potassium is extruded from the cellular stores of the gland as well. This cellular contribution of potassium has been studied in detail by Burgen (6), who loaded the parotid glands of dogs with K^{42} isotope and found that the isotope was recoverable in the salivary outflow upon stimulation. Burgen (7) then followed the potassium loss, from the gland during stimulation, by the balance method. He measured the potassium concentration, in the arterial supply to the gland, the salivary outflow, the gland itself, and the venous effluent of the gland. At rest, he noted that the venous effluent had a lower potassium concen-

tration than the arterial supply to the gland. However, upon stimulation, potassium loss from the gland proceeded at a very rapid rate for the first minute. At the same time, the concentration of the venous blood as well as that of the salivary outflow were much above the arterial level. Other investigators (8, 9, 10) studied the potassium rise in the early phase of secretion, and it became evident from their experimentations that as great as a twenty-fold increase over arterial levels was obtainable in the initial salivary outflows. This initial rise in potassium concentration has been referred to as the potassium transient and is believed to be a cellular contribution.

On the basis of the above work with dogs, which indicates that the first minute's parotid potassium was of intracellular origin, it was reasoned that in man the initial parotid gland secretion might be used to indicate gross abnormalities of tissue potassium concentrations in disease states. A second aim of this work was to determine if the parotid gland transient, reported by Burgen in dogs, occurs in man.

METHODS

A modified Lashly cup (11) was utilized to obtain uncontaminated parotid gland saliva by the method of Barbero and Chernick (3). This cup is placed over the orifice of Stenson's duct and maintained in position with suction. Two samples were collected from each subject after an orange lifesaver was placed on the dorsum of the tongue as a reflex stimulus for salivation. The initiaal three drops of saliva were discarded, and then the first sample was collected for one minute and a second sample collected during the second minute's time. The volumes of saliva in these collections were read directly in tuberculin syringes, and the potassium concentration of the samples determined by Baird flame photometry, using lithium as an internal standard.

RESULTS

Twenty-five subjects were studied according to the methods detailed above. Six subjects were healthy adults, and nineteen subjects were patients on the medical wards of the Hospital of the University of Pennsylvania. The hospitalized patients studied had serum potassium values ranging from 3.3 mEq/L to 6.7 mEq/L.

The volumes in the minute samples of all subjects collected danged from 0.3 cc. to 1.8 cc. There was no difference in the range of volumes obtained from the hospitalized patients when compared to that of the healthy subjects. There was no correlation found between potassium concentration and volume of collected saliva sample, and there was no correlation between volume of saliva sample and serum potassium level. Finally, no pattern of difference was shown in comparing the volumes of the first and second minute samples.

In twenty-three of the twenty-five subjects, the potassium concentration in the first minute of stimulation was higher than the potassium concentration of the sample collected during the second minute (Table I). A highly significant difference was seen between the mean potassium values for sample #1 and sample #2 ($p<0.001$). However, the range of values for the healthy subjects was quite comparable to the range of values obtained for the hospitalized patients.

The range of potassium concentrations in all parotid saliva samples varied from 15mEq/L to 37 mEq/L (Table I). No significant relationship was found between the serum potassium concentration and the salivary potassium concentration of the parotid gland samples. The ratios of potassium concentration of sample #1 to the potassium concentration of sample #2 were calculated (Table II) and found to vary between 0.9 and 1.7.

Table I

Potassium Concentration in Parotid Outflow
Taken During First Minute After Stimulation (Sample 1) and
During Second Minute After Stimulation (Sample 2)

	Sample 1	Sample 2
Subjects (number)	25	25
Mean K Concentration - mEq/L	27	22
Range - mEq/L	19-37	15-29
Standard Deviation	±4.5	±4.5

$t = 5.5$

$p = <0.001$

Table II

The Ratio of Potassium Concentrations of (Sample 1) to the Potassium Concentration of (Sample 2)

Subjects	25
Mean Ratio	1.3
Range of Ratios	0.9 - 1.7
Std. Dev.	±0.2

CONCLUSIONS

The data in Table I indicates that the samples of parotid saliva collected during the first minute of stimulation are significantly differenct from the subsequent sample in regard to potasium concentration. The initial high value for potassium concentration is not dependent upon rate of flow, and since the rate of flow usually reflects the intensity of stimulation (13), it appears that this initially high value relates to an intrinsic mechanism of secretion. It might be hypothesized that the high potassium concentration in sample #1 relates to cellular extrusion of potassium which resembles the potassium transient in dogs reported by Burgen (7). Despite the above findings, the quesion of whether the concentration of tissue potassium is more accurately assessed by the serum values or parotid saliva values is unsettled. However, on the basis of the data, it is felt that any patient whose parotid saliva concentration obtained by the above methods is greater than 45 mEq/L or less than 10 mEq/L manifests an abnormal process. Furthermore, any patient with a ratio of concentration of potassium in sample #1 to sample #2, less than 0.8 or greater than 2.0, would also be considered to be manifesting an abnormal physiologic process.

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PRODUCTION OF ABNORMAL HAMSTER EMBRYOS WITH ULTRASOUND

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ABSTRACT

Fourteen pregnant hamsters of three different strains of golden hamsters (Hg, Mx, Cr) were irradiated with ultrasound on the sixth or ninth day of gestation. Doses which varied in intensity from 0.2 to 0.6 watts per square centimeter were applied for either two or three minutes. Embryos were examined grossly on the thirteenth or fourteenth day of gestation following sacrifice of the mother. The animal treated on the ninth day showed no living embryos. In the group which were irradiated on the sixth day, abnormalities were noted.

INTRODUCTION

Since ultrasound is a known destructive agent for cells and tissues, an attempt was made to determine if it has any effects upon developing hamster embryos. Hughes and Nyborg (1962) have shown that high frequency sound waves produced by a vibrating needle cause protoplasmic streaming, cavitation, and finally cell disruption. Ballantine, Huetner, Nauta, and Sosa (1956) demonstrated that leisons can be produced in nervous tissue with focused ultrasound. Defects in bone (Ardan, Janes, and Herrick, 1957) and liver (Curtis, 1962) have also been noted following ultrasonic irradiation. One of the few embryological investigations of the effects of ultrasound was carried out by Counce and Selman (1955). In this case shifting of cytoplasmic constituents and general distortion of spatial relationships similar to centrifugation occurred. Whereas these results are not directly applicable to mammalian embryology, they indicate some of the fundamental effects of ultrasound.

MATERIALS AND METHODS

In this investigation, three strains of hamsters (pregnant females) were used. The fur was removed from the abdominal areas of all animals to insure maximum transmission of the sound waves. Immediately prior to ultrasonic treatment, the animals were anesthetized by intraperitoneal injections of 1% seconal. Clinical ultrasonic equipment with a frequency of 1 megacycle per second was used. Mineral oil was applied to the skin as a coupling agent.

Of the Hg (Hathaway Gross) strain, three animals were irradiated with 0.3, 0.4, and 0.5 watts per square centimeter (w/cm^2). The hamster which received 0.5 w/cm^2 was treated on the ninth day of gestation, and the other two on day six. The duration of exposure was two minutes for each animal.

Five Mx (Marx) hamsters received the following intensities of ultrasound: 0.2, 0.3, 0.4, 0.5, and 0.6 w/cm^2. Again the time of exposure was two minutes.

In the final group, six Cr (Cream) hamsters were treated. The intensities are the same as those for the previous group, except that *two* animals received 0.4 w/cm^2 and in this case the treatment was given for three minutes. All the Mx and Cr animals were irradiated on the sixth day of gestation. Control animals were included with each group.

On either the thirteenth (Hg and Cr) or fourteenth (Mx) day of gestation, the hamsters were sacrificed, and the experimental and control embryos were removed for study. Slides of several of these embryos were prepared.

RESULTS

Although no *specific* malformations were identified, it is obvious that a number of the experimental embryos were affected by the ultrasonic waves. The normal thirteen-day embryos of the Hg strain measured 12 mm (crown-rump), while the corresponding experimental animals were approximately 9mm. Studies were made of comparisons of normal and abnormal embryos of the strains Cr and Mx. Irradiated and control embryos of the Hg strain were also examined in sagittal section. The gross outline of the body was peculiar in the treated embryos, and the fusion of the palate appeared less advanced than in the corresponding noramal embryos. Profuse hemorrhaging was apparent in several experimental embryos.

DISCUSSION

Since less than 10% of the 85 irradiated embryos revealed *gross* abnormalities, further work is necessary to determine the full potentialities of ultrasound as a teratogenic agent. The mechanism by which ultrasound affects tissues still remains obscure. It is certain that both physical and biological principles must be considered. Ultrasonic frequency, intensity, type of transmission, and duration of exposure, as well as the physiological characteristics of initial temperature, vascularity of area, and degree to which heat is carired away by blood flow play major roles. Perhaps further work will establish more definitely the mechanism of the teratogenic effects of ultrasound.

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THE INFLUENCE OF TRYPAN BLUE ON PRENATAL DEVELOPMENT OF THE GOLDEN HAMSTER

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ABSTRACT

A strain difference in teratogenic action of trypan blue has been observed in golden hamsters. In one strain death and resorption of embryos was the characteristic response to trypan blue injection during pregnancy. In the other strain, abnormalities such as exencephaly, cephalic bleb, and cleft palate were observed.

INTRODUCTION

The experiment was designed to compare the teratogenic effect of trypan blue in two strains of hamsters (Tawny, T, and Hathaway Gross, HG) and to determine the developmental stages at which teratogenisis is most marked, the critical period. Comparisons of critical periods in other rodents with X-irradiation are also made. Many similar experiments using trypan blue as the teratogen have been performed in hamsters and other rodents by other investigators.

METHODS AND MATERIALS

Animal Care. The forty-six female golden hamsters used in the experiment were provided with 60 grams/week of Purina Laboratory Chow Checkers or Labena, daily supplements of lettuce (10 gms) and a single yeast tablet treated with a drop of wheat germ oil. Tap water was provided *ad libitum.* The animals were kept either in small metal rack cages with newspaper bedding or in gallon glass jars with San-i-Cel bedding. To provide an accurate estimation of weight gain, animals were weighed each day at approximately 10 A.M.

Breeding Method. The hamsters were tested with mature males for four consecutive nights, at approximately 10 P.M., until mating occured. Breeding animals were paired for 30-45 minutes. Brother-sister crosses were made whenever possible. When brothers were not available, close relatives within the same strain were used.

Experimental Method. The experimental animals were distributed among four groups: Experimental Hathaway-Gross (1), Experimental Tawny (II), HG Injection Controls (III), and HG Stage Controls (IV). Groups I and II were given single intraperitoneal injections of 0.5 cc of a 1% solution of trypan blue between the second and tenth day of gestation. Group III received a single injection of 0.5 cc of ion exchange water at a comparable time.

All experimental and injection control animals were killed on the 13th day of gestation. The positions of embryos and implantation sites in the uteri were noted and then embryos were removed by uterine section. When embryos were placed in 0.9% NaCl solution, pulsation or bleeding of the umbilical vessels was considered indicative of life. Embryos were measured and weighed. Gross abnormalities were also recorded at this time.

Microscopic Study. A study was made of two abnormal embryos from the experimental HG group. One embryo, injected on the sixth day of gestation, showed exencephaly, while the other embryo, injected on day 7 of gestation, exhibited cephalic bleb. Both were embedded in paraffin and microtomed at 10μ and mounted serially on slides.

In order to determine the stage of development of the embryos at the time of injection, a group of seven female hamsters was used to provide embryonic stages on days 2-8 of gestation. One hamster was killed on each of the seven days and uteri containing the embryo removed and embedded in paraffin. These tissues were microtomed at 8μ and mounted on slides.

RESULTS

The action of trypan blue on thirty experimental T and HG hamsters is summarized in Table RI. Examination of this table indicates that the critical period for the HG strain may be day 7 of gestation, since that is the day when the greatest percentage of abnormalities was observed. In T strain animals the critical period appears to be on day four of gestation. Table RII presents results found in the nine HG animals injected with ion exchange water rather than trypan blue.

Eight different kinds of abnormalities observed in hamster embryos in this study are summarized in Table RIII in which T and HG experimental and injection control embryo percentage abnormalities are compared.

The microscopic study of the two abnormal embryos showed only central nervous system damage. One embryo exhibited distortion of the first, second and third ventricles together with a conical protruberance formed by the mesencephalon pushing upwards from the top of the head. The first and second ventricles were reduced in size while the third was collapsed with a small slit remaining. Hyperemia was evident in all ventricles. The second embryo showed herniation of the telencephalon and mesencephalon of the brain through the epithelial layer of tissue a "mushroom head." This exposed brain tissue extends around the outside upper portion of the head in a cup-like fashion just above the level of the eyes. The first, second, and third ventricles are slightly distorted. Hy-

Table RI. Results of injection of trypan blue on Experimental HG and T hamster embryos.

Strain	Day of Injection	2	3	4	5	6	7	8	9	10	Total
Hathaway Gross	Number of Litters	5	5	2	1	2	2	2	2	3	24
	Number of Implantations	52	54	24	13	22	26	22	16	27	256
	Number of Embryos	35	20	15	5	11	9	13	12	19	139
	% Abnormal Embryos	34.3	60	40	40	63.5	100	30.8	50	10.5	43.2
	% Resorbed Embryos	32.7	63	37.5	61.5	50	65.4	40.9	25	42.1	45.7
	% Resorbed and Dead Embryos	42.3	74.1	50	69.2	63.6	76.1	45.5	43.8	33.9	55.9
Tawny	Number of Litters	-	-	1	1	1	-	-	1	2	6
	Number of Implantations	-	-	13	15	12	-	-	16	24	80
	Number of Embryos	-	-	6	12	4	-	-	15	16	53
	% Abnormal Embryos	-	-	66.7	33.3	25	-	-	0	37.5	28.3
	% Resorbed Embryos	-	-	53.8	20	66.7	-	-	6.25	33.3	33.7
	% Resorbed and Dead Embryos	-	-	53.8	20	75	-	-	25	33.3	42.5

Table RII. Results of injection of ion exchange water on HG Injection Control hamster embryos.

Day of Injection	2	3	4	5	6	7	8	9	10	Total
Number of Litters	1	1	1	1	1	1	1	1	1	9
Number of Implanations	13	13	11	12	3	10	12	9	11	94
Number of Embryos	12	12	10	12	3	10	11	9	9	88
% Abnormal Embryos	0	0	10	0	0	30	9.1	11.1	0	6.8
% Resorbed Embryos	7.7	7.7	9.1	0	0	0	8.3	0	18.2	6.3
% Dead and Resorbed Embryos	23	7.7	9.1	8.3	0	0	16.6	11.1	18.2	11.7

peremia and excess connective tissue were found in all ventricles.

To understand a possible mechanism of the teratogenic action of trypan blue on hamster embryos, seven HG hamsters were used to determine embryonic stages from days two to eight of gestation. One pregnant hamster was killed on each of the days of gestation at the time of injection of an experimental HG hamster, and examination of the developmental stage of the embryo was made. Analysis of these stages was accomplished through the use of microscopic slides. A resumé of the developmental stages is presented in Table RIV.

DISCUSSION

This study was planned to expand a series begun by Hecht and Tucker (4) with animals of the same strain. The sizes of injection groups were planned so that the combined data resulted in groups of equal size for each day of gestation studied. Unfortunately with T strain, the number of animals was too small to provide groups of the same size (Table DI).

The data in Table RIII indicate a strain difference in susceptibility to trypan blue. However, the T strain results are of doubtful significance since the number of animals was small. Central nervous system damage is prevalent in the HG strain while in T strain animals cleft palate is more frequent. HG strain also shows a greater percentage of total abnormalities and resorptions than T strain. These differences may be due to genetic factors, but are not due to variations in developmental stages since embryos of both strains have similar average lengths and weights on the thirteenth day of gestation.

Table RIII. Summary of the teratogenic action of trypan blue on hamster embryos of Experimental and Injection Control groups.

Abnormalities	Percentage Abnormal		
	HG Experimental Group	T Experimental Group	HG Injection Control Group
Cephalic Bleb	24	5.5	0
Exencephaly	18	2	0
Back Blister	8	3.5	0
Hypermicrosomia	6.5	5.5	7
Cleft Palate	5.5	11	7
Coxitic Scoliosis	2	0	0
Micromelia	1.5	0	0
Blepharosynechia	.7	0	0
Microphthalmia	.7	2	0

Table RIV. Summary of embryonic stages of HG Stage Control animals.

Day	Developmental Stage
2	2 cells
3	3-5 cells.
4	7 cells, early blastocyst.
5	Late blastocyst, implantation established, inner cell mass and trophoblast.
7	Primitive streak, Reichert's membrane, yolk cavity, extraembryonic ectoderm; possible beginning formation of mesodermal tissue. Proximal and distal entoderm, Proamniotic cavity.
8	7 somites, neural tube open except in region of the 5th somite. Amniotic cavity closed. Yolk sac, extra- and intraembryonic coelom well shown. Notochord. Possible heart primordium.

Abnormalities in the control group may be due to several factors: 1) malformations characteristic of the strain itself, 2) result of injection with ion ex-

Table DII Measurements of embryos at 13 days

Type of Female		Average Weights mgm	Average Lengths mm
HG	Trypan Blue Injection Control	442.3	13.4
		471.0	13.2
T	Trypan Blue	455.8	13.2

Table DI: Combined results of action of trypan blue on hamster embryos.

Strain	Day Injected	2	3	4	5	6	7	8	9	10	Total
HG	Number of Litters	5	5	5	5	5	5	5	5	5	45
	Number of Embryos	35	20	26	14	21	16	33	29	28	222
	Number of Abnormals	12	12	16	10	15	14	17	6	2	104
	% Abnormal Embryos	34.3	60	61.5	71.4	71.4	87.5	51.5	20.7	7.1	46.8
T	Number of Litters	-	1	2	2	2	3	3	2	3	18
	Number of Embryos	-	7	16	14	7	20	18	28	25	136
	Number of Abnormals	-	2	8	4	1	6	3	0	6	30
	% Abnormal Embryos	-	28.6	50	28.6	14.3	30	17	0	24	21.6

change water (the solvent for trypan blue), 3) retarded or accelerated development of individuals of a single litter. Strauss (8) states that an ovum may be fertilized as many as twelve hours after ovulation or within two hours, resulting in embryos of the same litter differing in size by as much as a half a day. Some embryos actually having incomplete fusion of the palate may have been counted as "cleft palates" as is characteristic of the twelve day embryo. 4) injection of trypan blue causing a disturbance in maternal endocrine function or blood pressure which may lead to abnormal embryonic development. Czarnecki (9) shows that immediately following dye injection in dogs a sudden fall in arterial blood pressure and other symptoms of shock were observed.

Developmental stages observed in this study for the HG strain were compared with those described by Boyer (10). The only significant difference was found to be on day three with only 3-5 cells found while Boyer reports 5-12 cells.

Now, comparing hamster, mouse, and rat development (Table DIII), the mouse is slightly ahead of the other two in the early stages of development, but by the fifth day all have reached the implantation tage. At the four somite stage, however, the animals begin to show divergence in development, with mouse three-quarters of a day behind and rat three and three and three-quarter days behind the hamster. This difference is to be expected in light of the different gestation periods (hamster, 16 days; mouse, 19-23 days; rat, 21-23 days). As mentioned earlier the critical stage for HG hamsters seems to be between days 5.5 and 7. According to similar studies of the mouse (5, 6) sensitivity is marked from 6 to 12.5 days with days 6-7 being the critical period. Investigations of rate development (2, 3, 7) show that the critical period is from days 8 to 9. These periods correspond to approximately the same stage of development, that is, establishment of primitive streak and initial formation of somites.

Teratogenic studies with X-irradiation in rat, mouse, and hamster, (11) show the critical periods to be somewhat later, by .5 to 1.5, days than those observed with trypan blue. These results are summarized in Table DIV.

Table DIII. Comparison of early embryonic stages in common laboratory rodents.

Stage	Days of Gestation		
	Rat (60)	Mouse (59)	Hamster (67)
2 Cell	1		2
4 Cell	2		2.5
7-8 Cell	2.5-3	2	3
Morula	4	2.5-3	3
Blastocyst	4.5	4	3.5-4
Implantation	5-6	5-5.5	5-5.5
Placental Cone	6-7	5-5.5	6
Primitive Streak	9	6-6.5	7
First Somite	10		7.5
4 Somites	10.5	8	7.25

Table DIV. Critical periods of laboratory rodents.

Agent	Animal	Critical Period*
X-irradiation	Rat	9-10
	Mouse	7.5
	Hamster	7.5-8.5
Trypan Blue	Rat	8.9
	Mouse	6-7
	Hamster	5.5-7

* Days of gestation.

CONCLUSION

1. A single intraperitoneal injection of trypan blue administered in either the first or second trimester of pragnancy retarded growth of 13 day golden hamster embryos.

2. Under experimental conditions, trypan blue was found to have a teratogenic action on both strains of hamsters tested. Abnormalities observed in both strains were cephalic bleb, exencephaly, back blister, cleft palate, and microphthalmia, while coxitic scoliosis, micromelia and blepharosynechia were found only in HG strain animals.

3. A susceptibility difference to trypan blue was noted between HG and T strains (a) HG critical period, 5.5-7 days of gestation; T critical period, 4-5.7 days. (b) T strain showed 54% fewer abnormalities than HG animals. (c) central nervous system damage is most conspicuous in HG animals, while cleft palate is predominant in T animals.

4. Critical periods determined for trypan blue injections in hamsters, rats, and mice were shown to be from one-half to one and one-half days earlier than those determined for x-irradiation in these rodents. Critical periods in the different species occured at the same developmental stage, but on different days of gestation.

5. After the four somite stage, development in hamsters is more rapid than in either rats or mice. Critical periods for trypan blue injections in these rodents occur at similar developmental stages and not on the same days of gestation.

6. Examination of developmental stages of normal hamsters from the second to the eighth day of gestation confirms previous work with the exception of the third day when 3-5 cell cleavage stages were found rather than 5-12 cells reported by other investigators.

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HISTOLOGY OF DIGESTIVE ORGANS OF THE EASTERN CHIPMUNK, *TAMIAS STRIATUS*, IN RELATION TO REPRODUCTION AND HIBERNATION

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ABSTRACT

Microscopic analyses were made of the esophagus, stomach, small intestine, colon and liver from chipmunks captured during different stages of reproductive activity. Additional studies were made on hibernating and non-hibernating animals maintained at 0-2°C and 24°C. No cytological or histochemical changes were observed which could be related to reproductive activity, cold-exposure or hibernation. Liver mitochondrial respiration was unaffected by exposure to cold or hibernation.

INTRODUCTION

The reproductive cycle of annual breeding mammals has long been known to be associated with metabolic alterations which appear to be influenced by nutritional and climatic changes. This is especially apparent in hibernating animals exhibiting cyclic variations in food intake, body weight, body temperature, as well as reproductive function, which are related to periods of activity and dormancy of the animals. (Kayser, 1961).

Recently, Mayer *et al* (1957; 1958) reported that histological changes in digestive organs may also occur in some seasonally breeding hibernators. They describe marked changes in gastric glands and also in glycogen content of the liver of the hibernating, as contrasted to the active, arctic ground squirrel, *Spermophilus undulatus*. On the other hand, the liver glycogen content remains unchanged during hibernation in the hamster (Lyman and Leduc, 1953) and the 13-lined ground squirrel (Zimny and Tyrone, 1957). Information on the histology of the digestive tract of these species or other hibernating mammals is not available.

The present paper describes the normal histology and histochemistry of the digestive tract and liver of the eastern chipmunk, *Tamias striatus* as determined from studies of sexually active, sexually quiescent, hibernating, and active cold-exposed animals. During the course of this work measurements were also made on the respiration of liver mitochondria of warm and active, cold and active, and hibernating chipmunks.

MATERIALS AND METHODS

The chipmunks used in this study were trapped on the Campus of the Pennsylvania State University. Most of the animals were killed with ether; those used in studies of liver respiration were killed by a sharp blow on the head. The reproductive state of the animals was determined through histological studies of the gonads and accessories.

Sixteen adults (8 males and 8 females) of comparable size were selected for serial studies of the digestive tract. Of these, 4 were in a breeding condition (March capture), four in early sexual quiescence with gonads and accesories regressed (June and July), four in late sexual quiescence before the animals went into hibernation (October), and four in hibernation (January). The last 4 animals were trapped in November and maintained in a cold room (0-2°C) until they went into hibernation.

Selections of tissues were made from various regions of the digestive tract listed in figure 1. Junction samples were

longitudinal including several millimeters of tissue on either side of each junction. Tissues were fixed in Bouin's fluid, embedded in Tissuemat, sectioned at 6 micra, and stained with Harris hematoxylin and eosin or using the periodic acid-Schiff (P.A.S.) technique.

Liver samples from the above 16 animals were also subjected to the P.A.S. reaction to ascertain the content and distribution of glycogen. Additional information was obtained from studies of liver mitochondrial respiration of hibernating and active chipmunks. A separate group of 18 laboratory confined animals were used for these metabolic studies. Six control animals were maintained at ambient room temperatures (24 ± 2°C) and 12 were exposed to continuous cold (0-2°C) for 3-5 weeks. Six of the cold-exposed chipmunks were active and six were hibernating when they were killed and used for analyses. The average weights (gms ± S. E.) of animals used for liver analyses were as follows: controls, 89 ± 3; hibernating, 87 ± 7; cold but not hibernating, 91 ± 4. The rectal temperatures (± S. E.) of these three

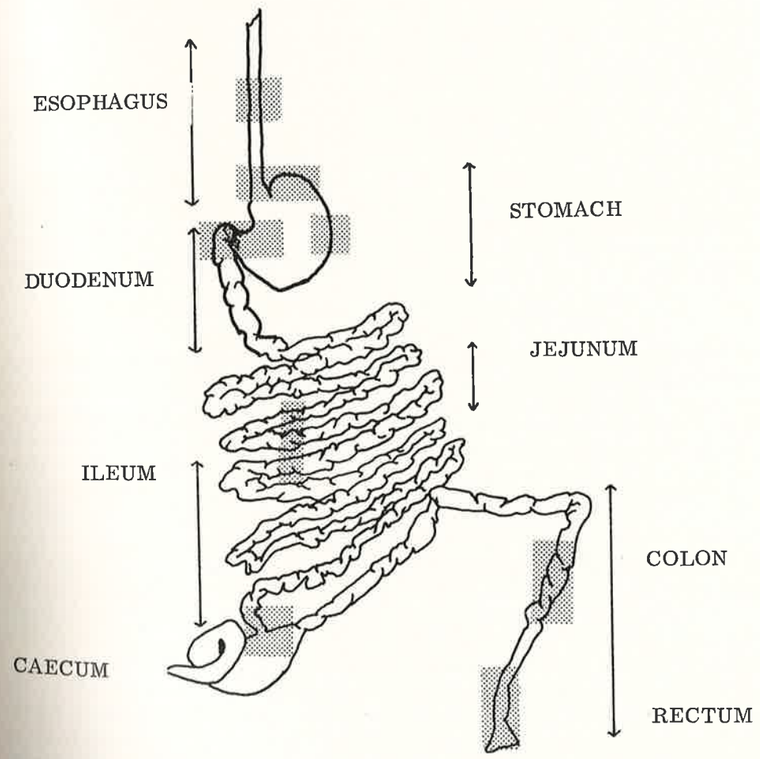


Fig. 1. Histology of the Digestive Tract of the Eastern Chipmunk, Tamias striatus, in Relation to Reproduction and Hibernation, by Adam Anthony, Nancy Bachman and John L. Frehn. Dept. of Zoology, The Pennsylvania State University.

groups were: controls, 38.0 ± .5° C; hibernating, 3.2 ± 1.0°C; cold-exposed but active, 36.3 ± .5°C. It is also noteworthy that cold-exposed active chipmunks maintained their average body weight after 30-80 days of exposure whereas the hibernating chipmunks lost an average of 29 ± 6% of their body weight over a comparable period of time. These latter individuals hibernated for 3-5 day intervals which were interrupted by similar intervals of activity and feeding. The procedures for preparing mitochondria and the oxygen electrode respirometer used in measuring mitochondrial respiration are described in earlier reports (Frehn and Anthony, 1962; Strickland, Ziegler and Anthony, 1961; Ziegler, Strickland and Anthony, 1963).

RESULTS

The histology of the gastrointestinal tract was found to be the same in all of the chipmunks examined. No cytological or histochemical changes were observed which could be related to sex, animal weight, state of reproductive activity or laboratory confinement at warm (24°C) or cold (0-2°C) temperatures. The normal histology of the major divisions of the chipmunk digestive tract and the data obtained from liver analyses of active and hibernating chipmunks are summarized separately below.

NORMAL HISTOLOGY OF THE DIGESTIVE TRACT

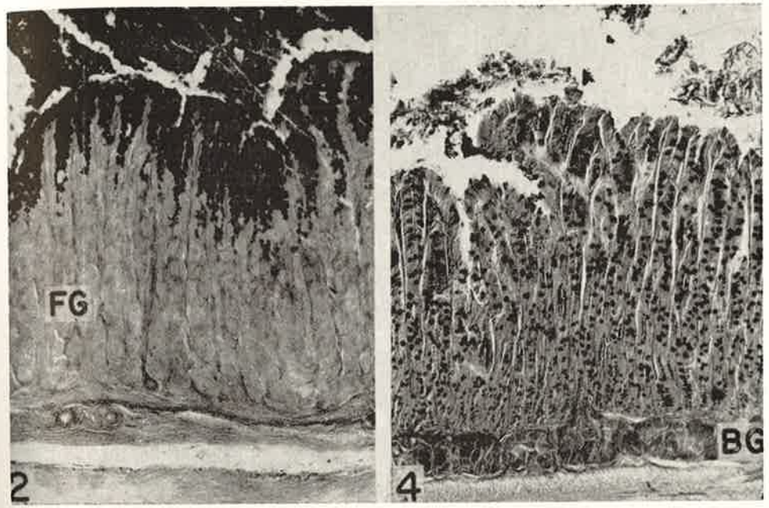
The esophagus of the chipmunk is lined by a thick layer of stratified squamous epithelium which is heavily cornified with keratohyaline. In some of the animals the keratinized layer made up as much as one half of the thickness of the epithelium. Other noteworthy features of the esophagus are the absence of any mucosal or submucosal glands and the lack of lymphatic nodules in the submucosa. At the esophageal-cardiac junction ,there is an abrupt change to columnar epithelium.

The stomach is lined with tall, simple columnar epithelium containing mucigen granules that stain intensely with P.A.S. Differences in the amount of mucus in the stomach were not observed even during hibernation. This is not surprising since the stomach was never found to be completely devoid of food in either hibernating or active chipmunks. As in all mammals there are four types of epithelial cells lining the stomach: surface mucous cells, neck mucous cells, chief cells and parietal (HCl secreting) cells. The first two stain intensely with P.A.S. and are found throughout the stomach. The chief cells and parietal cells are most numerous in gastric glands of the fundus and body. Parietal cells are fewer in number in the gastric glands bordering the pylorus and disappear completely in the pylorus proper.

Gastric glands are anatomically distinct in various regions of the stomach. The cardiac portion contains simple, slightly coiled, tubular glands which contain only mucous cells. Fundic and body glands contain parietal cells and chief cells in addition to the surface mucous cells and the glands are straight and long in comparison to either the cardiac or pyloric glands. Pyloric glands have a distinct pit or isthmus which occupies three-fourths of the depth of the gland which is completely lined with mucous cells. These differences are strikingly apparent in P.A.S. stained sections. Fundic glands reveal shallow pits with only the surface and neck cells staining with P.A.S. In contrast, pyloric glands have deep pits lined with P.A.S. positive mucous cells (figs. 2 and 3).

No differences were found in the P.A.S. staining of the stomach mucosa of hibernating or cold-exposed, active chipmunks. The submucosa of hibernating animals, however, was not as wide as that of cold active animals. This was due to the presence of collapsed lymphatics and presumably reduced amounts of chyme in hibernating chipmunks.

The *small intestine* is characterized by the presence of tall, closely packed villi in the duodenum, very tall villi in the jejunum where they also appear more slender since they are not as closely packed, and short and broad villi in the ileum. Villi appear to be taller on the mesenteric side of the intestine, especially in the jejunum. Crescent shaped folds



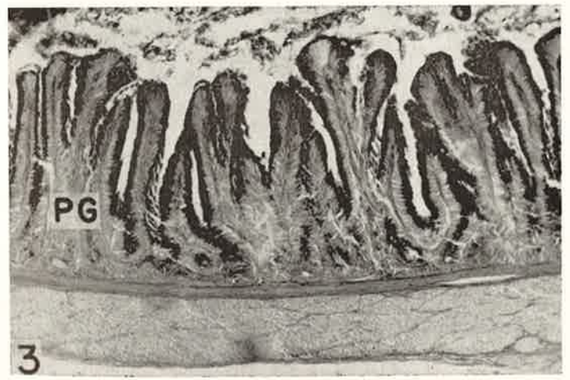


Plate I (Stained with P.A.S.)

Fig. 2. Gastric glands of the fundus (FG). Note that only the surface epithelium and neck cells show heavy deposition of mucin (x 200).

Fig. 3. Gastric glands of the pylorus (PG). These have deeper pits than the fundus and the demonstrate mucin extends to the base of each pit (x 200).

Fig. 4. Duodenal villi showing the presence of mucous epithelial cells as black spots. Note the compact layer of Brunner's glands in the submucosa (BG) (x 200).

of the mucosa and submucosa (valves of Kerkring) are present in the lower duodenum and the jejunum.

The epithelium of the small intestine is simple, striated columnar, mixed with goblet cells which stain darkly with P.A.S. (fig. 4). The columnar cells extend between the villi into the crypts of

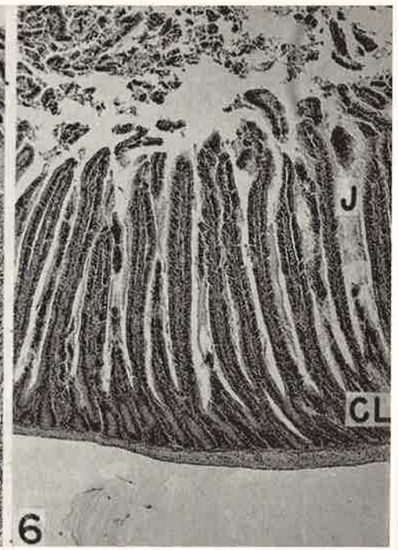


Plate II (Stained with Hematoxylin-eosin).

Fig. 5. Pyloric-duodenal junction showing the clear-cut transition between the pyloric glands (P) of the stomach and the duodenal villi (D) with Brunner's glands in the submucosa (x 100).

Fig. 6. Section of the jejunum showing characteristic long, slender villi (J) and the crypts of Lieberkuhn (CL) at the bottom of the villi (x 200).

Fig. 7. Ileo-colic valve showing typical short blunt villi of the ileum (I) and the absence of villi in the colon (C). Note presence of abundant goblet cells in the epithelium (x 100).

Lieberkühn which contain numerous Paneth cells containing coarse cytoplasmic granules. Submucosal, P.A.S. positive mucous glands (Brunner's glands) are found only in the duodenum whereas lymphatic nodules (Peyer's patches) are most numerous in the ileum.

The LARGE INTESTINE contains no villi but does possess prominent crypts of Lieberkühn that are deeper than those of the small intestine and become still deeper and wider in the lower colon and rectum before the epithelium becomes stratified squamous at the recto-anal junction.

LIVER ANALYSES

Glycogen stores of the liver were assessed by staining liver sections with P.A.S. and comparing these with control sections of the liver which were similarly stained after treatment with diastase to remove glycogen. Liver tissue not treated with diastase always revealed intense P.A.S. staining in the region of the large central hepatic vein. Diastase treated sections of the same tissue always proved P.A.S. negative. This indicated that the cytoplasmic material which took up the stain was glycogen.

No differences were found in the glycogen content of livers from sexually active as compared with sexually inactive chipmunks. Similarly neither cold exposure nor hibernation resulted in a depletion of liver glycogen. The distribution and intensity of staining of P.A.S. material in all of the laboratory confined chipmunks followed the same pattern as that observed in field captured animals.

Measurements of liver mitochondrial respiration provided additional support for the histochemical findings that the energy stores of the liver are not depleted by cold exposure or hibernation in the chipmunk. These data are summarized in table 1.

It is evident that the endogenous respiration of liver mitochondria from control animals is the same as that of hibernating and cold-exposed, non-hibernating chipmunks. Similarly, substrate respiration, that is, mitochondrial respiration in the presence of excess exogenous succinate or beta-hydroxybutyrate is unaffected by cold exposure or hibernation.

In addition to measurements of endogenous and substrate respiration, data were also obtained on the efficiency of oxidative phosphorylation as reflected in the ADP:O value. The ADP:O ratio represents the number of moles of ADP (adenosinediphosphate) which are phosphorylated per gram atom of oxygen consumed during accelerated mitochondrial respiration. The ADP:O ratio was determined by measuring the oxygen consumed by mitochondria during phosphorylation of a known amount of added ADP. With beta-hydroxybutyrate as a substrate, the ADP:O values were 2.26

			Substrate Respiration	
CHIPMUNKS	N	Endogenous Respiration	Beta-hydroxybutyrate	Succinate
Control	6	0.31 ± .03	0.31 ± .02	0.77 ± .04
Hibernating	6	0.29 ± .02	0.28 ± .02	0.83 ± .05
Cold-exposed	6	0.27 ± .03	0.31 ± .02	0.81 ± .07

Table 1. Effect of cold exposure (1 to 3 month at 0° to 2°C) on endogenous and substrate respiration in chipmunk liver mitochondria. Respiration values represent X ± S.E. in μM O_2/sec./mg. N.

± .06, 2.24 ± .04 and 2.14 ± .05 for tissue from 6 control, 6 cold exposed and 6 hibernating chipmunks, respectively. The ADP:O values with succinate as a substrate were 1.60 ± .05, 1.63 ± .04 and 1.57 ± .02, respectively for these same three groups, indicating that the efficiency of oxidative phosphorylation is unaltered in mitochondria from warm and active, cold and active, or from hibernating chipmunks.

DISCUSSION

The histological picture of the digestive tract of the eastern chipmunk closely resembles that of other mammals. Keratohyaline is found lining the chipmunk esophagus. This is characteristic of animals which eat rough, dry food (Hughes, 1955). The location of parietal cells in gastric glands may vary depending upon the species. In the chipmunk they were found in the fundus and body only, whereas they occur throughout the stomach in the human (Berger, 1934) and are reported to be limited to the cardia in the cotton rat (Blank, 1950). Except for such minor details, however, the histology of the entire chipmunk digestive tract typifies that found in any warm blooded mammal. No histological differences were found in the histology or histochemistry of digestive organs from chipmunks captured during sexual activity, sexual quiescence or in animals induced to hibernate in the laboratory.

Recently, Mayer and Bernick (1957, 1958) reported that changes in the digestive organs of the arctic ground squirrel are quite dramatic during hibernation. They observed a depletion of liver glycogen, an increase in stomach mucus and marked changes in the cytology of gastric glands. Our data showed that no reduction in liver glycogen occurs in the hibernating chipmunk. In this respect the chipmunk resembles the golden hamster, the 13-lined ground squirrel, the woodchuck and the hedgehog (Kayser, 1961). We also found that the endogenous and substrate respiration of liver mitochondria are unchanged in hibernating chipmunks. Others have reported that in the golden hamster the respiration of liver slices actually increases after cold exposure or hibernation (Denyes and Hasset, 1960). These findings add further support to the conclusion that, at least in the chipmunk and hamster, hepatic energy reserves are not depleted during hibernation.

In contrast to the arctic ground squirrel, the chipmunk also shows no changes in the content of stomach mucus or in the cytology and P.A.S. affinity of the gastric mucosa during hibernation. This is not surprising since the chipmunk has relatively short periods of uninterrupted hibernation (2-3 days) and eats food during intervals of arousal. Thus, the digestive tract is never completely devoid of food. Mayer, on the other hand, reports that his captive ground squirrels remained torpid for one to three week periods without awakening when exposed to 4°C. Moreover, his squirrels hibernated (with periodic spontaneous interruptions) for six weeks to three months without consuming any food during this entire period (Mayer and Bernick, 1958). It is possible that the liver and gastric changes described in captive arctic squirrels may have resulted from abnormally reduced food intake or starvation. Mayer himself reports that, in nature, arctic ground squirrels store food in hibernating nests and therefore presumably eat during periodic intervals of arousal. All of the presently available evidence indicates that such a pattern of sporadic replenishment of energy reserves is the general rule for all of the hibernating mammals thus far investigated.

ACKNOWLEDGMENTS

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SEASONAL CHANGES IN THE MALE REPRODUCTIVE TRACT OF THE EASTERN CHIPMUNK, *TAMIAS STRIATUS**

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ABSTRACT

Histological studies of gonads and accessories of male chipmunks were made during periods of sexual activity and sexual quiescence. The data indicate that the height of reproductive activity probably occurs in late February. Testicular involution commences in April and the reproductive tract remains completely regressed from July to October.

INTRODUCTION

Sexual periodicity in seasonally breeding mammals is characterized by relatively short periods of germ cell production during some particular season. In temperate regions, breeding is usually restricted to a few weeks in Spring so that the resulting offspring are reared under favorable environmental conditions. Few annual-breeding mammals have been studied with respect to the cyclic histological changes in the reproductive organs. Several species which have been described include the ground squirrel (Wells, 1935), the ferret (Bissonnette, 1935), the gray and fox squirrels (Mossman *et al,* 1955) and the prairie dog (Anthony and Foreman, 1951; Anthony, 1953; Foreman, 1962).

The present report deals with microscopic analyses of the male reproductive system of the eastern chipmunk, *Tamias striatus lysteri,* as it appears in the breeding condition and in the quiescent state. It was felt that this would lay the groundwork for future investigations on the physiology of reproduction in the seasonally breeding chipmunk.

MATERIALS AND METHODS

This study is part of a more comprehensive research program which includes investigations of cyclic changes in gastrointestinal organs (Bachman, 1959), in hemopoietic tissue (DeGraffenreidt, 1959) and in various aspects of tissue and cellular metabolism of the chipmunk (Frehn and Anthony, 1962). Thirty-four adult male chipmunks were used for histological analyses of reproductive organs in the functionally active and regressed states. The animals were trapped from the campus of the Pennsylvania State University during different months of the year as shown in Table 1. Chipmunks were normally confined in laboratory cages for 12 to 24 hours prior to autopsy unless otherwise specified. The procedure at autopsy consisted of weighing each animal, noting the extent of scrotal pigmentation and determining the position of the testis by palpation. The reproductive glands were than removed, weighed and fixed in Bouin's fluid or formalin before processing the tissues by the paraffin method. The tissues were sectioned at 7-10 micra and stained with Harris hematoxylin and eosin. In addition to the histological data, supplemental information was obtained from observation of animals in the field and from laboratory confined animals used in other research projects.

RESULTS

In this region chipmunks are first observed above ground in late February or early March. Animals trapped during this time are usually males. These chipmunks have enlarged testes found in highly pigmented scrotal sacs and greatly enlarged sexual accessories (Fig. 1). How long the males remain sexually active was not determined; however, some males trapped in late April proved to be in a reproductively active state. The testes of these April males were large although spermatogenesis had already ceased. The epididymis contained sperm and there was no histological evidence of regression in the sexual accessories.

Females trapped during March were either pregnant or in estrus with the uterus greatly enlarged and highly vascularized. Three pregnant females which were confined in the laboratory gave birth to their respective litters on March 31, April 3 and April 9. There were 5 young in each litter including 8 males and 7 females. In the field, young were observed above ground after the first week in May.

Animals trapped from June to October were in a sexually quiescent state. The testes were small, flabby and abdominal. The seminal vesicles, prostate and Cowper's glands were small and inactive. The entire reproductive tract of the female was also completely regressed. The ovaries were extremely small and the uterus and vagina were reduced to less than one-third of the diameter of these organs in the estral condition.

Seven males trapped in November and kept in the laboratory until the middle of December exhibited histologic signs of gonadal stimulation as evidenced by the

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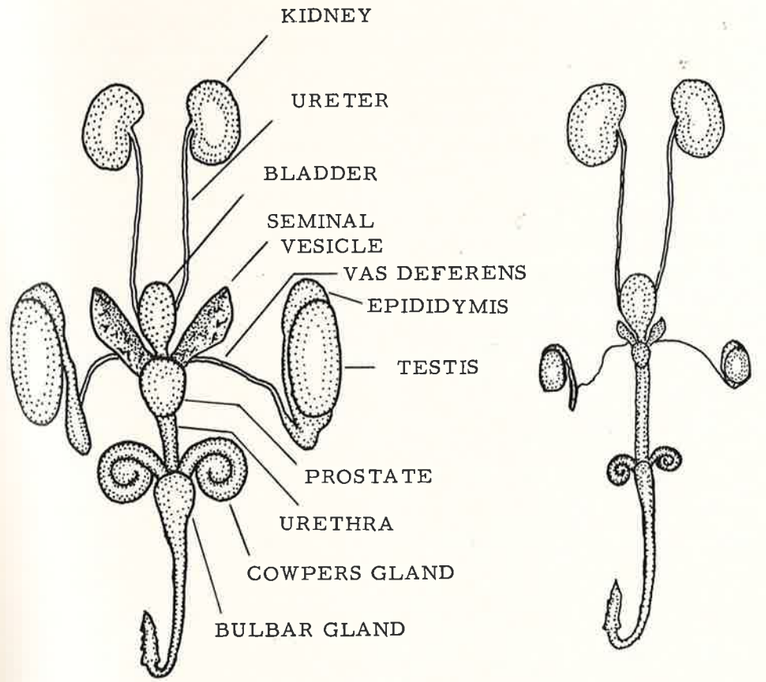

Fig. 1. Dorsal view of sexually active (A) and sexually inactive (B) reproductive tract of the male chipmunk.

presence of mitoses in some of the spermatocytes. There was no increase, however, in the weights of the testes or accessories. No gross or histological differences were observed in the reproductive organs of males kept at 27±1°C as compared to those in a cold room at 3±1°C.

The detailed histological features of the male reproductive organs are discussed below with the organ weights summarized in Table 1.

The testes were largest during March and April and ranged in weight from 0.58 to 1.37 gm. Seminiferous tubules were also maximal in size (140-182 micra) and exhibited wide lumina containing sperm. The basement membrane of the tubules is thin and supports a small number of widely spaced spermatogonia as seen in Fig. 2. In March males, all elements of the germinal line are present in the tubules. However, transformation from one generation to another does not simultaneously involve all tubules. Thus, in one tubule there is a preponderance of secondary spermatocytes while in an adjoining tubule some other stage may predominate. Male animals captured in April and May have large testes but no signs of spermatogenic activity. The seminiferous tubules contain sperm and degenerating spermatocytes.

The interstitial cells in March and April males occur in small groups between the seminiferous tubules. These cells are round in shape and contain vesicular, oval nuclei and clear cytoplasm.

In males captured from June to October the testes are completely regressed (0.05-0.11 gm.). The tunica albuginea appears thick relative to that of the functional gonad. The small seminiferous tubules (45-55 micra) show no apparent lumina and contain spermatogonia, Sertoli cells and degenerate spermatocytes (Fig. 3). The interstitial cells are spindle shaped and contain pycnotic nuclei.

The epididymis is greatly enlarged in Spring males and contains tremendous stores of spermatozoa (Fig. 4). The tall columnar epithelium is characterized

Table 1. Seasonal Variation in Sexual Organ Weights of the Male Chipmunk.

SEASON*	Number of Animals	Body Weight (gm ± σ)	Average organ weight (gm. ± σ)			
			Testes	Seminal vesicles	Prostate	Cowpers
Spring F(2); M(4); Ap(2); My(1)	9	86±12	1.00±.20	.410±.20	.120±.020	.330±.020
Summer J(1); Jy(7); Au(1)	9	81±15	.08±.03	.010±.003	.006±.003	.009±.003
Autumn S(1); O(8)	9	77±14	.06±.02	.008±.002	.004±.002	.007±.002
Winter** mid-December (7)	7	85±10	.05±.01	.007±.001	.003±.001	.007±.001

*The numbers of adult males captured are shown in parentheses next to the letters designating months.

**Winter animals were captured in mid-November and maintained in the laboratory until mid-December. Three of these were kept at a temperature of 27±2° C and did not hibernate; four were in a cold room at 3±1° C and went into hibernation.

by large basal nuclei and prominent stereocilia. Intertubular connective tissue is scant. In contrast, the epididymis of sexually inactive males contains large amounts of connective tissue relative to the amount of epithelial tissue. The tubules contain small circular lumina lined by pycnotic nuclei (Fig. 5).

Seminal vesicles of sexually active, Spring males are enlarged (0.30-0.52 gm.) and on cross section exhibit many follicles filled with secretion (Fig. 6). The epithelial height varies from tall to low columnar depending upon the amount of secretory material. In contrast, the seminal vesicles of sexually quiescent animals are small (.005-.01 gm.) and contain a disproportionate amount of connective tissue (Fig. 7). The epithelial lining is reduced to a layer of pycnotic nuclei which border irregularly shaped lumina that are devoid of any secretory substance.

The prostate gland in the sexually active animal is greatly enlarged (0.08-0.14 gm.) and contains a massive secretory area which is characterized by numerous closely packed acini (Fig. 8). The tall columnar epithelium has vesicular, basal nuclei and contains fine, secretory cytoplasmic granules. The secretory alveoli are separated by prominent, though thin, connective tissue. The regressed prostate, on the other hand, is small (0.003-0.006 gm.) and exhibits a marked increase in interlobular fibrous tissue. The epithelial tissue is confined to pycnotic nuclei lining sparsely scattered, irregular lumina (Fig. 9).

The Cowper's complex in the sexually active chipmunk ranges in weight from 0.31 to 0.37 gm. On cross section, the glands show compound tubular lobules separated by thin connective tissue septa. The peripheral alveoli have tall columnar epithelium while the central alveoli are lined with low columnar cells and are filled with secretory material. The regressed Cowper's glands are small (0.005-0.007 gm.) and consist largely of connective tissue which bounds the isolated lobules of small inactive tubules. The epithelial lining of the tubules, as in the other sex accessories, is reduced to the width of small pycnotic nuclei.

DISCUSSION

The state of sexual quiescence, which is marked by drastic regressive changes in the genital complex of the chipmunk, persists throughout the summer and fall and extends into the winter. Since histological studies were not made on animals captured during the latter part of hibernation, it was not precisely ascertained when sexual recrudescence is initiated. Allen (1938) has estimated that about two to three weeks are required for the gonads and accessories to become functionally active. Thus, January and early February represent the months when sexual augmentation probably occurs. In the prairie dog, whose reproductive apparatus is very similar to that of the chipmunk, testicular redevelopment is initiated four to six weeks prior to the time when sperm are first seen in the epididymis (Anthony, 1953). Since male chipmunks captured in late February are already in a breeding condition, and if one assumes they require a similar period of sexual development, then the onset of sexual augmentation would occur in late December or early January. This is in agreement with the finding that laboratory confined males exhibited initial signs of gonadal activity in mid-December.

It was observed that the height of testicular activity coincides with the period of estrus in the female. On the basis of this it was concluded that breeding occurs during late February or early March with a resultant birth peak in April. In the present study young were

first seen above ground early in May. This agrees with Allen's report (1938) that chipmunks have a 31 day gestation period and the young are approximately one month old at the time of their emergence, which would place the time of breeding in early March.

The microscopic appearance of the chipmunk reproductive organs, both in the breeding and non-breeding state, compares well with that described for other members of the *Sciuridae* and other seasonally breeding mammals in general. The growth and functional response of the genital complex at the approach of the breeding season are striking examples of the regulatory capacity of hormones. In some seasonal breeding mammals light and temperature have been implicated as important factors in the hormonal control of the seasonal reproductive cycle (Bullough, 1951). However, since the chipmunk comes into breeding underground, in the absence of light and at relatively constant den temperatures (Allen, 1938), it seems unlikely that either light or temperature is the major trigger which activates the endocrine system in this species.

SUMMARY

The seasonal changes in the reproductive organs of the male chipmunk, *Tamias striatus lysteri,* can be summarized as follows. During the last week of February and during March the testes are at the peak of spermatogenic activity. The fully active testis contains large seminiferous tubules with wide lumina and all stages of sperm production. The epididymis reaches maximum size in March as a result of the discharge of sperm into its tubules. The sexual accessories are also at their functional peak by the first week of March. Both the gonads and accessories are marked by great increases in weight over those of the sexually inactive animal.

It is probable that testicular regression is initiated in late April or early May although the gonads are still enlarged and the sexual accessories are full of secretory material. Testicular regression is completed by June and the gonads and accessories remain involuted through the summer and into the first two months of hibernation (November and December).

Sexual recrudescence is probably initiated during late December or January, while the chipmunks are in hibernation, and is completed toward the end of February. The period of breeding coincides with arousal from hibernation during late February or early March. Young are born in April and emerge from their burrows during May.

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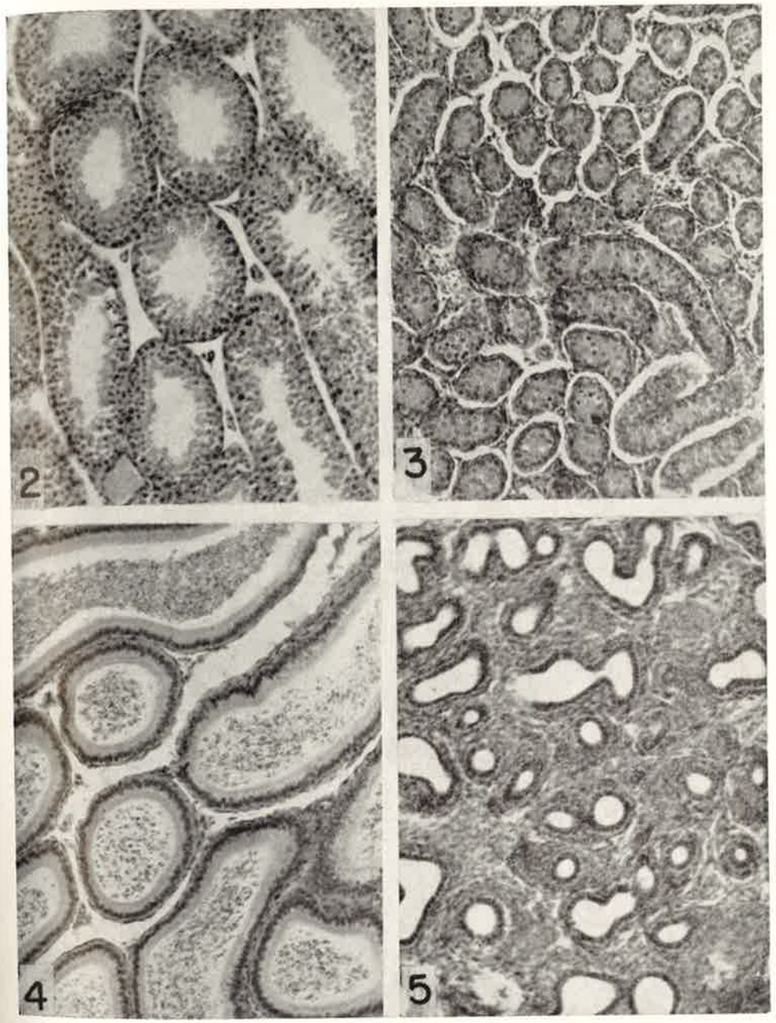

PLATE 1

Fig. 2. Testis from normal male killed during the period of sexual activity. Seminiferous tubules have prominent lumina and contain all elements of the germinal line (100 X).

Fig. 3. Testis from sexually quiescent male. Small tubules show no lumina and only resting spermatogonia (100 X).

Fig. 4. Typical section of epididymis of sexually active male. Lumina are filled with sperm and epithelium is tall columnar (100 X).

Fig. 5. Section of epididymis from sexually inactive male. There is a relative increase in connective tissue, the small lumina are bordered by low cuboidal epithelium (100 X).

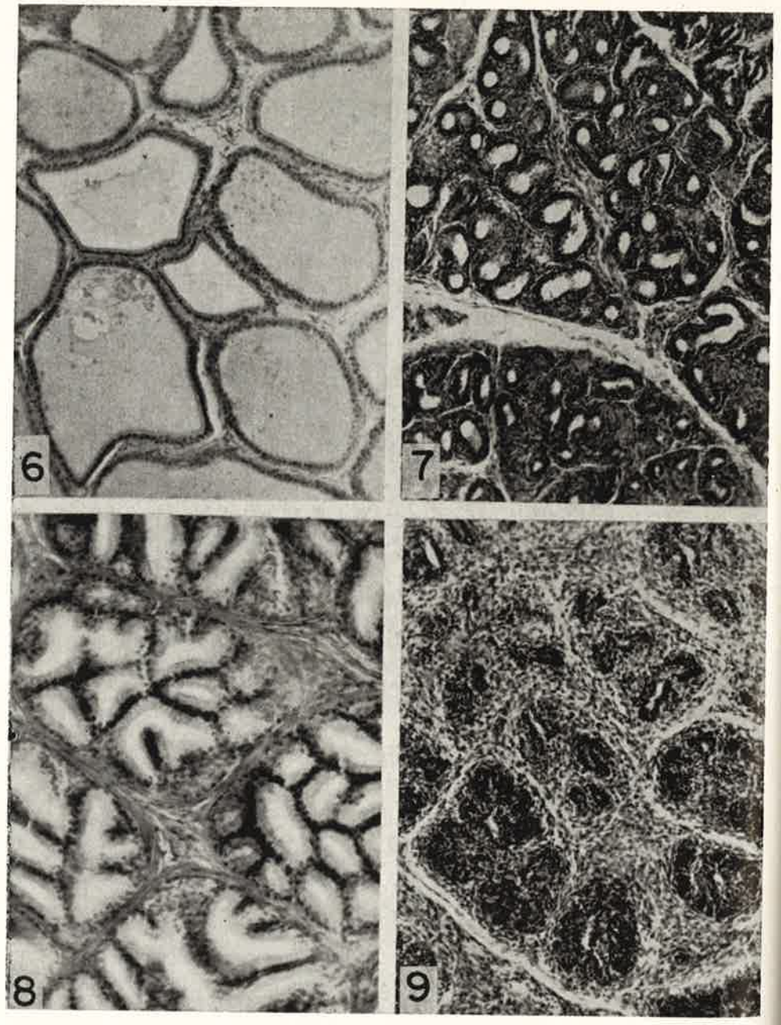

PLATE 2

Fig. 6. Seminal vesicle of sexually active male showing tubules lined with columnar epitheluim and distended with secretion (100 X).

Fig. 7. Seminal vesicle of sexually inactive male with small non-secretory tubules and abundance of connective tissue (100 X).

Fig. 8. Prostrate of sexually active male with typical secretory columnar epithelium (100 X).

Fig. 9. Prostrate of sexually inactive male showing complete absence of secretory components (100 X).

A STUDY OF THE INNERVATION RATIO OF THE ANTERIOR GRACILIS MUSCLE OF THE WHITE RAT

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ABSTRACT

Sections about 75 u thick of the anterior gracilis muscle of the albino rat were stained by a histochemical cholinesterase method modified by Koelle. The modified Koelle treatment results in selective staining of the motor end plates. The individual muscle pieces were then examined at a magnification of about 440X. for the presence of motor end plates. Muscles used for fiber counts were treated in their entirety in MacCallum's fluid for twelve hours at room temperature. Individual muscle fibers were dissected free and counted. Sections of the innervating nerve of the muscle were stained with H & E and the nerve fibers were counted. The innervation ratio of the muscle was determined.

INTRODUCTION

The purpose of the work to be described was to investigate the innervation ratio of the anterior gracilis muscle of the white rat and to compare the number of end plates in the muscle with the number of muscle fibers in the same muscle.

The anterior gracilis muscle was chosen for this study because previous investigations have made aavilable data concerning its innervation pattern (Jarcho et. al., '52). Schwarzacher ('56), studied the same muscle in the mouse and in the human ('59), and Christensen ('59), determined the innervation ratio in the gracilis muscle of still born infants.

MATERIALS AND METHODS

The animals used for this study were male white rats weighing about 200 g. Jarcho et. al. ('52) determined that the anterior gracilis muscle is innervated by two distinct bands of end plates: one near the origin of the muscle, the medial band, and the other near the insertion, the lateral band. The method used for the localization of the end plate bands in this study was similar to the one formulated by these workers.

The technique used to stain the motor end plates was the acetylcholinesterase localization method of Koelle and Friedenwald ('49), as modified by Koelle ('51) and further modified on personal suggestion by Dr. Koelle. This modification results in the selective staining of the motor end plates. Plate *A* shows a section of an end plate band stained by Koelle's method.

According to Couteaux ('58), the cholinesterase histochemical technique is restricted to the localization of acetylcholinesterase concentrations near the surface of a tissue preparation. End plates are readily stained since they contain a high concentration of the enzyme and are located on the surface of the muscle fibers. However, in its thickest part the anterior gracilis muscle has a depth of from ten to fifteen fibers. Therefore, in order to expose the end plates on the innermost fibers to the staining solution, the muscle biopsies were cut into twenty smaller pieces. These small bits of muscle were placed between two glass slides and crushed under considerable pressure. The effect of this procedure was to spread out the fibers over a large area, thus reducing the thickness of the pieces to three or four fibers. The endomysium was porous enough to permit the staining solution to reach the inner fibers at this depth.

After staining, the motor end plates on each side, i.e., those in each end plate

[a] This investigation was supported by a research grant from the National Science Foundation.

Plate A. Photomicrograph showing a section of an end plate band. Koelle's stain. 100x.

band, were enumerated with the aid of a microscope fitted with an ocular micrometer.

The muscles used for fiber counts were dissected from the animals and treated with macerating fluid in their entirety. The macerating fluid consisted of one part nitric acid, two parts glycerine and two parts water. Following this treatment the muscle was placed in 50 percent glycerine and teased under a dissecting microscope. The fibers were counted at the tendinous ends of the muscle.

Although gross observation of the gracilis under the dissecting microscope gives the appearance that the muscles run in a parallel fashion, from tendon to tendon, dissection of the muscles showed that most of the fibers were considerably shorter. Accordingly, the terminations of the fibers in two muscles were studied. One muscle after maceration measured 13 mm in length. Sections from 2 to 3 mm long were excised from the lateral end of the muscle beginning at the lateral end and continued to the medial end. Since the length of the muscle was distorted by the method of preparation the length of individual fibers reported here are relative ones. The fibers of lateral origin measured from 6 to 11 mm and terminated 2 to 6 mm from the medial tendon. The fibers of medial origin measured from 3 to 9 mm in length and terminated 3 to 9 mm from the lateral end.

The nerves of the muscle were dissected free, fixed in 10 percent formalin, embedded in paraffin, cut in transverse sections, affixed to slides, stained with hemotoxylin and eosin and mounted in balsam. The nerve fibrils in each branch were counted under oil with the aid of a microscope fitted with an ocular micrometer. In this way it was possible to count the total number of neurofibrils and to measure their diameter. Acording to the investigations of Feinstein, Lindegärd, Nyman and Wolfhart, ('55), 60 percent of the thick neurofibrils are considered as motor nerves, and by comparing this number with the total number of muscle fibers, the number of the motor units has been evaluated and the number

TABLE 1

Data from gracilis muscle

	End Plates	Muscle Fibers	Total End Plates	Total Muscle Fibers	Replicates
Proximal	1343	1373	3812	2859	20
Distal	1469	1486			20

The motor unit counts of the gracilis muscle are shown in Table (2)

TABLE 2

Muscle Measurements in mm	Average Number of Muscle Fibers	Number of Large Nerve Fibrils	Mean Diameter of Large Nerve Fibers u	Number of Small Nerve Fibers	Mean Diameter of Small Nerve Fibers u
35 x 5 x 1	2859	65	7.7	56	2.3

Calculated Number of Motor Units	Muscle Fibers per Motor Unit
39	74

of muscle fibers in each motor unit has been studied.

RESULTS

A total of 20 muscles were studied for end plate enumeration and muscle fiber counts. The results of the average counts are shown in Table 1.

The total number of nerve fibrils in the main twig of the obturator nerve averaged 328 while the posterior twig averaged 217, and the twig which innervates the anterior gracilis muscle averaged 121 nerve fibrils. These analyses are taken from 20 replicates.

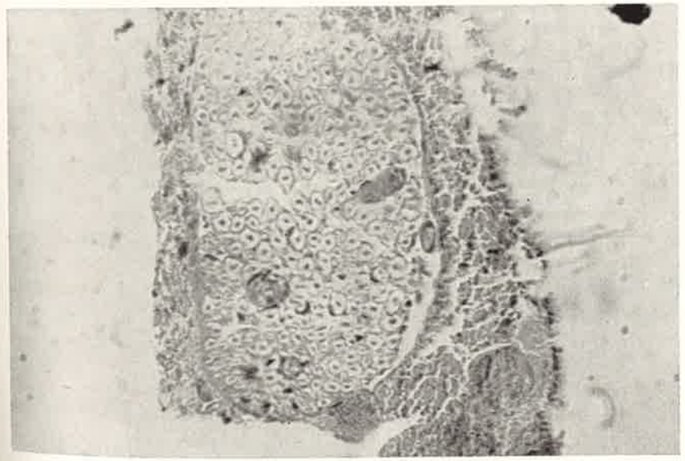

Plate B. Photomicrograph showing a section of obturator nerve. 950x. H. and E. stain.

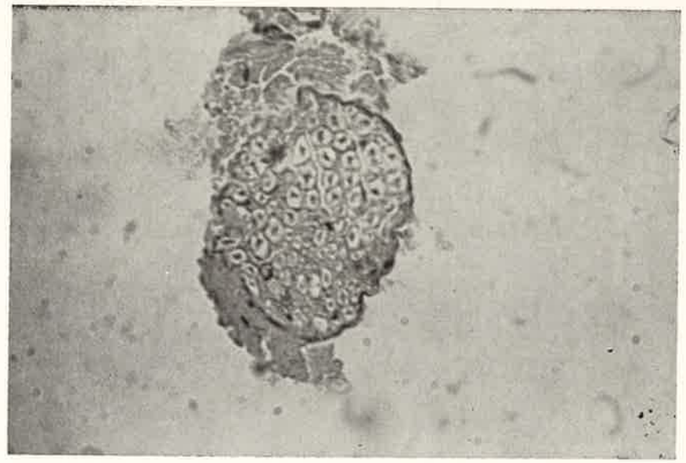

Plate C. Photomicrograph showing a section of posterior branch of obturator nerve. 440x. H. and E. stain.

Plates *B, C,* and *D* show photomicrographs of sections of twigs of the obturator nerve. Plate *E* shows a schematic drawing of a possible arrangement of fibers in the gracilis.

The results of the study of the terminations of fibers in the muscle were as follows: in a piece of muscle 2.4 mm from the lateral end of the muscle 1434 fibers all of lateral origin were enumerated. In a section 4.5 mm from the lateral end 1354 fibers were enumerated.

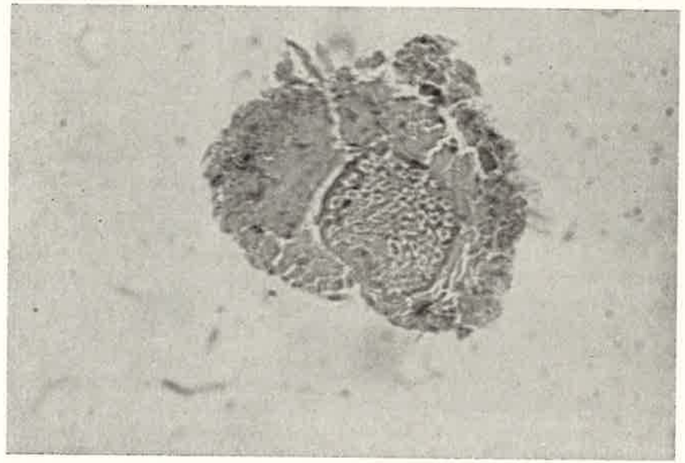

Plate D. Photomicrograph of twig of obturator nerve which innervates the gracilis muscle. 950x. H. and E. stain.

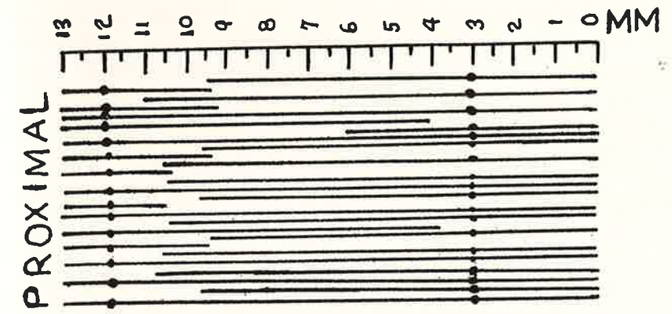

Plate E. Diagrammatic sketch of anterior gracilis muscle of the rat showing relative terminations of muscle fibers.

No terminal fibers were observed in this section. In a piece 6.8 mm from the lateral end 1412 fibers were counted. This number included 115 fibers of medial origin. In a section 9 mm from the lateral end 2553 fibers were enumerated. This number included 482 fibers from the medial end and terminate in this region. Also included were 218 fibers of lateral origin which terminate here. In a section 11 mm from the lateral tendon 2180 fibers were counted. This count included 494 fibers of medial origin and 250 from the lateral tendon which terminate here. The remaining medial piece of muscle 2 mm in length contained 1358 fibers all of medial origin.

DISCUSSION

Christensen ('59) and Coërs ('59), in interpreting the reason for multiple innervation bands in human muscles such as the gracilis, have concluded that these muscles arise from two or more metameres, each contributing an innervation band. According to this hypothesis, the majority of the muscle fibers in such a muscle would not extend its entire length. Rather, they would meet fibers which developed from the other metamere somewhere between their respective innervation bands. Because of the difference in counts at each end of the muscle, the study reported here appears to lend support to the hypothesis that the rat anterior gracilis develops from two metameres. Further, it has been observed that most of the fibers in this muscle did not extend the entire length.

The results of the counts of muscle fibers, and end plates reveals that there is a deficit of end plates to muscle fibers. These results perhaps rule out the possibility of double innervation in this muscle. Jarcho et. al., ('52), state that, "In the hundreds of individual fibers examined for double innervation only 2 or 3 were observed." It does however suggest that some muscle fibers extend from tendon to tendon in the muscle.

Because of the difficulties involved in making counts of both muscle fibers and end plates it was concluded that the values reported are accurate to within $\pm$ 100. This conclusion is based on replicate counts of the same specimen and taking the average of the counts. The nerve fibrils reported are considered to be correct to within $\pm$ 10 for the same reason.

The study of the distribution of fibers terminate in long tendrils which entwine

about the adjacent fibers. The majority of the fibers from the lateral end of the muscle terminate 5 to 6 mm from the medial tendon, while the majority of fibers originating from the medial tendon terminate within 4 mm from the medial end. Not all fibers terminate within the muscle; some pass from origin to insertion. A schematic drawing of our interpretation of the structure of this muscle is shown in Plate E.

SUMMARY

Using histological, histochemical and teasing techniques this study was undertaken to determine the number of end plates, and muscle fibers in the anterior gracilis muscle of the white rat. The number of nerve fibrils which innervate the gracilis muscle was also determined.

From these findings it was possible to study the number of motor units in the muscle and also the number of muscle fibers per motor unit.

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OBSERVATIONS ON BROMSULPHALEIN CLEARANCE AND HEPATIC BLOOD FLOW IN THE NORMAL DOG

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ABSTRACT

If a dye substance infused into the circulation is cleared exclusively by the liver, hepatic blood flow (HBF) may be estimated by the Fick principle from the rate of dye removal and the arterial-hepatic vein dye concentration difference. HBF was determined in 101 mongrel dogs (258 observations) using the dye bromsulphalein. The mean estimated HBF of this group was 696 ml/min, or 39.6 ml/kg.b.w./min. The mean cardiac output (CO) determined simultaneously in 43 dogs was 2.17 L/min and the hepatic fractional flow (HBF/CO x 100) 32.1. A significant correlation ($p < 0.01$) was found between HBF and CO. These results are compared to those of others using bromsulphalein and other methods and the significance of the above correlation is discussed.

INTRODUCTION

If a dye substance is infused into the systemic circulation and is cleared exclusively by the liver, hepatic blood flow (HBF) may be estimated by the Fick principle from the rate of removal of the dye from the circulation and the arterial-hepatic venous dye difference. If the infusion rate is adjusted so as to maintain a constant arterial dye level, the hepatic clearance of the dye is equal to the infusion rate. Over the past ten years bromsulphalein clearance by the liver has been employed by many investigators to estimate hepatic blood flow in the dog under many different forms of hemodynamic and metabolic stress.

Many estimates of hepatic blood flow have been made in the normal anesthetized dog. The number of animals employed in various studies, however, is small and in some cases the results show considerable variability. For this reason the results obtained over the last decade in the laboratories of one of us (SMH) have been compiled. The results contained in the present report represent 258 observations on 101 normal anethetized mongrel dogs.

METHODS

Details of the bromsulphalein method as well as the rationale for its use in the determination of hepatic blood flow have been previously discussed (Bender 1962; Werner and Horvath 1952; Bradley *et al* 1945). This method was employed to assess the behavior of the splanchnic circulation in a number of studies. During the course of these experiments 258 control observations were made on 101 normal mongrel dogs anesthetized with sodium pentobarbital. The average HBF for each dog was determined and this value used to compute the mean for the entire group. The methods for calculating splanchnic oxygen consumption, and splanchnic vascular resistance have been published elsewhere as well as the methods for determining blood oxygen and total oxygen consumption (Horvath and Bender 1961). Cardiac output was determined in 43 dogs by the Fick principle. In the course of the discussion of the results presented here, data from the literature have been cited for comparison. This data was taken from an extensive compilation of the results of previously published studies (Bender 1962).

TABLE I

Means and standard errors of various cardiovascular functions determined in normal anesthetized dogs.

Parameter	N	Mean	S.E.
Body weight	101	19.3	0.49
Hepatic blood flow, ml/min	101	696	26.41
ml/kg/min	101	39.6	1.56
$ml/m^2/min$	101	966	38.56
Cardiac output, L/min	43	2.17	0.17
HBF/CO x 100	43	32.12	2.03
Splanchnic O_2 uptake, ml/min	41	37.05	2.81
, % of total	41	38.15	2.45
Oxygen consumption, ml/min	48	93.73	4.95
Mean arterial blood pressure, mmHg	54	129	1.8
Splanchnic vascular resistance, units	54	0.21	0.02

RESULTS AND DISCUSSION

The data on hepatic blood flow and other cardiovascular and metabolic parameters are summarized in Table I. Significant correlations were found between the level HBF and cardiac output ($p<0.01$), splanchnic oxygen consumption ($p<0.01$) and body weight ($p<0.05$).

For purposes of comparison, the results of 22 studies performed by other investigators, employing the bromsulphalein technique, were averaged. The mean hepatic blood flow of these studies was 39.7 ml/kg/min. This compares extremely well with the value of 39.6 ml/kg/min for the present population. In addition, these results are in good agreement with those obtained using other techniques (See Table II).

TABLE II

Hepatic blood flow in the dog.

Method	Hepatic Blood Flow ml/kg/min	Percent of hepatic Flow by BSP*
Direct venous collection	27-44	94
Electromagnetic flow meter	39	93
Indocyanine clearance	43-56	113
Ethanol extraction		121
Colloidal Cr PO_4	38	95
Radiogold	33	84
Rose Bengal clearance	32, 33	101
Urea excretion	32	
Thermostromuhr	22-62	

* If determined in same study.

It is not the purpose of this communication to reiterate the sources of errors in the bromsulphalein methods or to discuss its limitations for these topics have been thoroughly outlined elsewhere (Bender, 1962). Nevertheless one important characteristic of clearance techniques used to measure HBF is that they estimate total liver perfusion even when one hepatic vein is catheterized to obtain venous blood samples for determination of dye content (Bender and Horvath, 1962). For this reason the relative contribution of the hepatic artery and portal vein cannot be assessed and therefore changes in total flow cannot be attributed to alterations in flow in one or the other inflow tracts.

However, with the use of non-cannulating electromagnetic flow meters the contributions of these two blood sources can be determined without the necessity of major surgical intervention. In such experiments the hepatic artery flow was found to be 20-30 percent of total liver flow.

The significant correlation found between HBF and cardiac output is not a surprising finding but one which deserves some discussion. Estimates of HBF without the simultaneous measurement of cardiac output do not allow a complete description of the splanchnic response to stress. For example, during hemorrhage and exercise hepatic blood flow is decreased. However, cardiac output increases during exercise and thus the splanchnic circulation is short-changed whereas during hemorrhage the splanchnic bed is spared. Because the various vascular beds are arranged in parallel, alterations in the resistances of these different areas may effect changes in splanchnic blood flow while producing either a marked change in cardiac output or little or no change in total systemic flow.

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THE RELATION OF HEPATIC BLOOD FLOW TO THE METABOLIC REQUIREMENT OF THE SPLANCHNIC BED

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ABSTRACT

It has been suggested that hepatic blood flow increases in some instances when an increased metabolic demand is placed on the liver. In the dog, hepatic blood flow (HBF) is increased 45% during the last half of a ten minute infusion of epinephrine, while splanchnic oxygen consumption (SO_2C is increased nearly 20 percent.

In dogs maintained 14 days after complete removal of the hepatic arterial supply to the liver, epinephrine infusion results in an increase in HBF of more than 80 percent while SO_2C is increased nearly 50%. In dogs maintained for 54 days the elevation in HBF and SO_2C induced by epinephrine is reduced below that exhibited by unoperated control animals, and after 294 days epinephrine has a negligible effect on the above parameters. Since epinephrine increases the rate of glycogenolysis in the liver, it was concluded that alterations in the response to infused epinephrine was due to changes in the glycogen content of the liver. The increase in flow therefore would follow the amount of available substrate. Supportive evidence from the literature concerning the effect of glucagon on the above parameters will be discussed.

INTRODUCTION

It appears that the rate at which blood passes through various tissues is dependent, at least in part, on the metabolic demand imposed upon these tissues. This is particularly true of skeletal and cardiac muscle and has been implied with respect to the hepatic circulation (Brandt *et al* 1955; Shoemaker *et al* 1959; Bender *et al* 1962). Epinephrine increases glycogenolysis in the liver (Sokal and Sarcione 1959) and increases oxygen upake of the splanchnic bed. In addition, splanchnic vascular resistance is decreased with a resultant elevation in hepatic blood flow (Farrand *et al* 1957; Bearn *et al* 1951; Bender and Horvath 1962). The results of the present work suggest that the metabolic and hemodynamic responses to epinephrine are related.

MATERIALS AND METHODS

Experiments were conducted on 14 mongrel dogs anesthetized with sodium pentobarbital (30 mg/kg). Each animal had undergone hepatic arterial ligation by a method previously described (Horvath *et al* 1957). Seven animals were used for experiments approximately 14 days after surgery, 10 animals at 54 days and five 294 days after ligation. Hepatic blood flow was estimated by the bromsulphalein method (Werner and Horvath 1952) and blood oxygen, splanchnic vascular resistance, and splanchnic oxygen consumption were determined by techniques previously described (Horvath and Bender 1961). Following control determinations, epinephrine was infused at a rate of one microgram/kg/min for ten minutes (Farrand *et al* 1957).

RESULTS

The results of these experiments are summarized in Table I. In unoperated animals (Farrand *et al* 1955) hepatic blood flow increases nearly 45 percent during epinephrine infusion. In hepatic arterial ligated animals the increase in hepatic blood flow induced by epinephrine is greater than that exhibited by control animals 14 days after surgery, but is reduced after 54 days. After 294 days hepatic blood flow is essentially unchanged during epinephrine infusion. The increase in oxygen uptake and the

TABLE I

Effects of hepatic arterial ligation on the splanchnic response to epinephrine

	Days after hepatic arterial ligation			
	0	14	54	294
Hepatic blood flow	+44.6	+82.1	+14.7	+ 3.0
Splanchnic O_2 uptake	+18.3	+41.9	+ 6.2	+11.0
Splanchnic vascular resistance	-28.6	-47.3	-13.0	+ 4.6

Alterations in the various parameters are expressed as percent change during the last 5 minutes of epinephrine infusion with respect to the control observations for each group.

decrease in the resistance of the splanchnic bed noted in control animals exhibited a similar pattern of response to arterial ligation as hepatic blood flow.

DISCUSSION

The alteration in the response to epinephrine as a result of hepatic arterial ligation may be explained in relation to the known effect of epinephrine on liver glycogen. However such an explanation depends on the assumption that the glycogen content of the liver is altered by hepatic artery ligation, which may be the result of chronic anoxia. Support for this conclusion may be found in the literature. Glucagon increases the breakdown of liver glycogen, as does epinephrine, by activating the phosphorylase system. Glucagon also increases splanchnic oxygen consumption as does epinephrine (Leevy *et al* 1961) and increases hepatic blood flow (Shoemaker *et al* 1959). Shoemaker and Van Itallie (1960) found that glucagon increased hepatic flow in dogs fasted for 24 hours. However, in one dog fasted for three days the increase in flow induced by glucagon was depressed, and in another dog fasted for five days no change in flow was observed. They concluded that glycogen stores were depleted by fasting, thus glycogenolysis induced by glucagon was modified or absent. Such an explanation may be used to explain the present findings. However, other explanations are possible such as a loss of enzymes as a result of chronic anoxia or an alteration in the sensitivity of various receptor sites to epinephrine. Nevertheless these results do suggest that the inability of epinephrine to increase splanchnic metabolism is responsible for the failure to demonstrate an increase in flow during epinephrine infusion, and thus imply a direct relationship.

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GROWTH INHIBITORS IN POTATO SPROUTS

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ABSTRACT

Ethanolic extracts of sprouts of three varieties of potatoes were evaporated to dryness and taken up with water. The aqueous extracts inhibited the growth of cucumber roots and the growth of a number of species of fruit-rotting fungi.

Some of the inhibitory action is apparently due to the presence of solanin.

INTRODUCTION

During the course of some preliminary investigations on growth-regulators it was observed that potato sprouts contain substances which inhibit growth of both fungi and of higher plants. It is quite obvious that a growing potato sprout must contain growth promoters, such as auxins, but the evidence obtained in this laboratory suggested the presence of more potent regulators. It therefore seemed advisable to conduct additional investigations.

REVIEW OF LITERATURE

A number of investigators have reported the occurrence of growth regulators in the potato (*Solanum tuberosum*) but, so far as the authors are aware, the investigations have been confined to the tubers rather than the potato sprouts. Blommaert[1] (1954) reported indole butyric acid and indolepyruvic acid in potato peelings. The so-called "growth-inhibitor beta," which commonly occurs on chromatograms of many extracts, is also found in potato peels. In 1958 Housley and Taylor,[4] in an attempt to identify inhibitor-beta (from potato peels), stated that the inhibitory activity could not be associated with any particular compound. Some growth promotion occurred at the position of 3-indoleacetic acid on the chromatogram but none of the characteristic color reactions of IAA was observed. Azelaic acid, coumarin and scopoletin were isolated, along with a new substance which was designated as "Acid A." The last mentioned substance was not completely identified but was believed to be an unsaturated, polyhydroxy fat acid.

Booth and Wareing[3] (1958) point out that growth activity in extracts of potato tubers has been ascribed to the presence of several indole compounds yet no investigator has demonstrated a correlation between color reaction and biological activity for the chromatograms. These authors believed that failure to identify the spot on the chromatogram as IAA, is attributable to the lack of sufficient quantities of the growth-regulator. They found that 5 micrograms were required to give a satisfactory color reaction for IAA. Booth and Wareing stated, as a result of continued experiments, that the only ether-soluble growth-promoter in potato tubers is indoleacetic acid.

Other investigations have been directed toward identifying the regulators which maintain dormancy in the tuber. Blumenthal-Goldschmidt, Hayashi and Rappaport[2] (1961) suggest that rest period in potatoes is regulated by many growth substances, such as auxins, gibberellins and others. They found that no single solvent system extracted complete activity of a class of compounds (auxins, gibberellins, or inhibitors) from potato peels. Succeeding solvent extractions usually provided additional substances with both inhibiting and stimulating activity. Rappaport and Blumenthal-Goldschmitt[5] (1961) noted that although the oat internode or wheat coleoptile are generally used to measure both growth and inhibition, too often growth substances which inhibit wheat coleoptiles, do not prolong the rest period of potatoes. They therefore developed a potato "eye" bioassay in which the effect of growth substances was studied on sprouting of buds on cylinders of potato tubers. Using this method, it was reported that exceedingly low doses of gibberellin A_1 and A_3 stimulated sprouting, whereas repeated treatment on the bud with comparatively high concentrations of coumarin did not affect the time of initial sprouting. The latter treatment *did* increase the time for 50% of the population to sprout.

MATERIALS AND METHODS

Three varieties of potatoes (*Solanum tuberosum*) were grown at Presque Isle, Maine, and shipped to the University of Pittsburgh. The tubers were held at room temperature until dormancy was broken and sprouts had grown to the length of from ¼ to 1 inch. The sprouts were removed and dropped into boiling 95% ethanol. The volume of alcohol was equal to twice the weight of sprouts. The samples were left to extract for a week at room temperature. The alcohol was then filtered off and evaporated to dryness on a water-bath. The residue was dissolved in hot distilled water, the volume being equal to half the amount of alcohol which was used for extraction. The varieties of potatoes employed in these studies were Katahdin, Green Mountain, and Russet Burbank.

The aqueous extracts were placed in small erlenmyer flasks and sterilized by autoclaving. Fungicidal tests were carried out as follows. One, five or ten ml. of the extract were combined with exactly 15 ml. of potato dextrose agar before pouring the plates. A 10 mm disc of mycelial mat of the test fungus was planted on the plate of agar which contained the extract. The cultures were grown at 20°C and the increases in diameter of the colonies were recorded at regular intervals.

Phytocidal activity was tested by observing the effect of the extract on the growth of cucumber roots. Preliminary work was begun by adding one ml of the extract to 9 ml of distilled water which, in turn, was poured over 25 cucumber seeds in a petri dish. The extracts were subsequently employed in graduated dilutions for the purpose of determining the minimum dosage required for inhibitory activity. The seeds were germinated at 20°C for 96 hours. At the end of this period the length of each root was measured and recorded.

RESULTS

Fungicidal activity was tested first on two species of fungi which are customarily employed for screening fungicides. These organisms are *Glomerella cingulata,* which causes bitter rot of apples, and *Monilinia fructicola,* the causal organism in brown rot of stone fruits. Figures 1 and 2 illustrate the method of testing the effects of the extracts on growth of the fungi. As a rule, 5 or 10 ml of extract per 15 ml of agar were required to produce significant inhibition of growth. Similar tests were conducted with other fruit-rotting fungi. The results of the tests with all of the fungi are presented in table 1. It will be noted that the degree of inhibition of growth varied with the species of fungus. Some of the fast-growing organisms were not retarded as much in their growth as were the slower-growing ones. Furthermore, the degree of retardation appeared to vary with the variety of potato from which the sprouts were taken. Green mountain and Russet Burbank, for example, showed greater retardation of fungal growth in all but one instance.

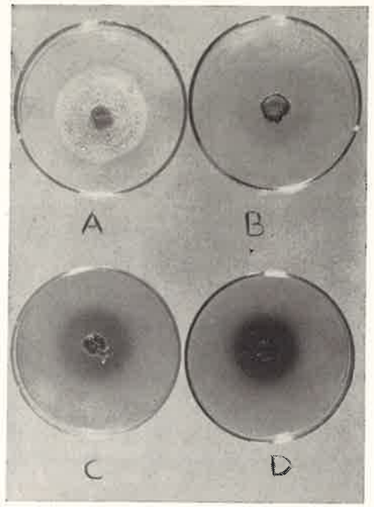

Figure 1. Effect of extracts of Katahdin potato sprouts on growth of **Glomerella cingulata.** A. Control; B. 1 ml. of extract; C. 5 ml. of extract; D. 10 ml. of extract.

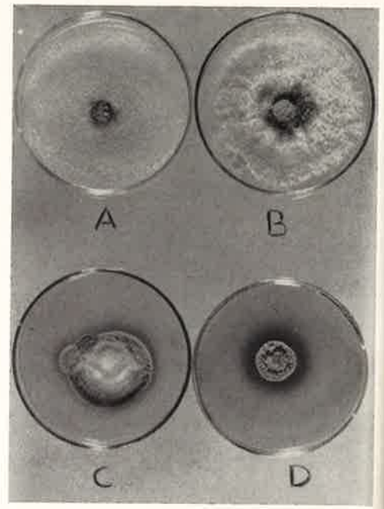

Figure 2. Effect of extracts of Katahdin potato sprouts on growth of **Monilinia fructicola.** A. Control; B. 1 ml. of extract; C. 5 ml. of extract; D. 10 ml. of extract.

PHYTOCIDAL ACTIVITY

One ml of sprout extract per 10 ml of water very significantly retarded growth of the cucumber roots. The results of these tests are presented in table 2. No significant varietal difference in the effect was noted. The length of roots at the end of 96 hours averaged less than 10 per cent of controls, irrespective of the variety of potato.

DISCUSSION

It has been definitely established that potato sprouts contain substances which inhibit growth of cucumber roots and of fungi. Although the terms "fungicidal" and "phytocidal" are customarily applied to the tests which are often used for screening growth inhibitors of this type, the effect of the extracts on fungi have been fungistatic rather than fungicidal. That the fungi were merely inhibited is shown by the fact that the disc of mycelium will resume growth when transplanted back to agar which contains no sprout extract. Cucumber seeds, on the other hand, seemed to have suffered considerable damage as a result of the 96 —hour exposure to the extract. They do not resume growth when transferred to distilled water, at least not after they have been treated with the maximum concentration which was employed in these investigations.

As mentioned previously, other investigators have reported the presence of indole compounds or other hormone-like substances in potato tubers. It was shown in our studies that indole compounds were not present in the extracts of potato sprouts. Spots on paper chromatograms did not coincide with indole compounds.

It occurred to us that the sprouts might contain the glyco-alkaloid solanine. Accordingly we analyzed the sprout extract and found as much as 2500 ppm of solanine in the extract. Solutions of pure solanine were tested on both fungi and cucumber roots, with the result that growth of both was inhibited. It i s interesting to note that we were unable to dissolve as much pure solanine in water as was found to be present in the sprout extracts, even with the use of 5% tween 20. Nevertheless, our concentrated extract of 500 ppm reduced growth in our tests.

We have received several inquiries regarding the possibility that sprouting potatoes might be poisonous to humans. Our reply has been to the effect that the sprouts might contain solanine, especially if the tubers had sprouted in the dark. There is the possibility too that some of the solanine could have been translocated from the sprouts to the tubers. Additional studies should be made on this aspect of the problem.

Another interesting point arises. Unharvested potato tubers, if exposed to light, will turn green and will also produce solanine along with the green pigment (chlorophyll). Instances have been reported in which pigs have been poisoned by eating potatoes of this type. The question that arises is why must the tubers have light for the production of solanine whereas the sprouts manufacture large quantities of this alkaloid only in the dark.

TABLE 1

EFFECT OF EXTRACTS OF POTATO SPROUTS ON GROWTH OF SEVERAL FUNGI

Fungus	Per Cent of Control		
	Katahdin	Green Mountain	Russet Burbank
Glomerella cingulata	20.3	10.2	13.1
Monilinia fructicola	39.9	11.6	5.6
Phomopsis citri	81.5	23.8	15.0
Diplodia natalensis	71.3	56.6	57.8
Botrytis cinerea	34.4	56.8	55.9
Alternaria tenuis	56.5	53.1	49.0

TABLE 2

Effect of Extracts of Potato Sprouts on growth of Cucumber Roots.

Variety of Potato	Growth of Roots after 96 hours at 20°C. (Per cent of Control)
Katahdin	7.5
Green Mountain	9.6
Russet Burbank	8.4

SUMMARY

Extracts of sprouts of three varieties of potatoes possessed growth-inhibiting properties. Phytocidal tests were conducted by determining the effect of the extract on elongation of roots of cucumber seedlings. The extracts also showed inhibitory action on the growth of *Glomerella cingulata, Monilinia fructicola,* and several other fruit-rotting fungi.

Evidence was presented which suggested that inhibitory action was caused by the glyco-alkaloid solanine.

ACKNOWLEDGMENT

The authors are indebted to Professor Hugh Murphy of the Maine Agricultural Experiment Station supplying the three varieties of potatoes which were used in these investigations.

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SIZE CHANGES DURING THE AGING OF YEAST CELLS

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ABSTRACT

Of the various alterations in the physiological and cytological aspects of aging yeast, the most striking is the diminution in size. Volume measurements on haploid and related diploid cells are made with the aid of a Coulter Counter for widely different age cultures. Implications of this study are offered.

INTRODUCTION

The age of a yeast cell population influences its sensitivity to various chemical and physical agents. Rosenberg and Wood (1957) have demonstrated that there is a dependence of the amount of heat inactivation on the age of the yeast used. From two weeks to two months the yeast tested appeared more and more sensitive. On the other hand in 1953 Wood has claimed that x-irradiation damage does not show an age correlation in older cultures. The all-or-none methylene blue destruction of yeast discovered by Passow et al. (1959) has been shown by Brosi and Rosenberg (1962) to involve an age parameter. It therefore seemed appropriate to look at morphological correlates of these physiological characteristics.

METHODS

A loop full of *Saccharomyces cerevisiae was streaked* on potato dextrose agar slants which had been prepared several weeks before. Aging was carried out in the dark at room temperature. Suspensions were prepared about a half hour prior to sizing. The concentration of yeast cells used was in the 10^5 cells/ml. range. The two haploid and the youngest diploid runs were made in M/15 KLCl. The three remaining diploid samples were made in Zeuthen's buffer consisting of 5 x 10^{-2}M NaCl, 10^{-3}M $MgSO_4$ and 10^{-2}M KH_2PO_4 at pH 6.5.

The determination of cell size employed the Coulter Particle Counter, Model A. In this instrument one half a cubic centimeter of suspension passed through a 100 micron aperture through which an electric current also flowed. When a cell came into the aperture, it caused a spike dip in the current which signal was counted and analysed for its pulse height. It has been established (Kubitschek, 1960) that this pulse height is proportional to the particle volume. By making repetative determinations of the number of cells with a given pulse height or greater, the population of cells was sized.

At the suspension concentrations used, the coincidence of two yeast passing through the aperture at the same time is less than two per cent. The strains of yeast were chosen so that cells did not adhere to one another. The occurance of clumping was very low.

RESULTS

A striking difference in size of yeast between different ploidy and from different age slants was immediately apparent. The pattern of size distribution may be seen in Table I. Young diploid cells are on the average almost double the volume of young haploid cells. Furthermore the diminution in the diploid was on a slower time scale than that of the haploid. This latter difference was also observed in the appearance of the colony growth on the respective slants. The haploid cultures appeared less moist and darkened well before the diploid.

The Coulter Counter was standardized

Ploidy	Age	Relative Volume Ranges 5	10	15	20	25	30	40	50	60	70	80
Haploid	2 weeks	13	19	21	17	12	10	8				
	3 months	47	25	18	6	4						
Diploid	2 weeks			12		23		21	16	15	6	7
	1 month			25		33		19	11	6	6	
	3 months			24		34		18	12	9	3	
	10 months			27	24	33		11	4	1		

Table I. Distribution of sizes of different haploid and diploid yeast.

with 2.1 micron spheres obtained from Dow Physical Research Laboratory. The relative volumes presented in Table I are about half the volumes in cubic microns.

DISCUSSION

The Coulter Counter has been used by others successfully for sizing red blood cells (Brecher et al., 1962) and bacterial populations (Lark and Lark, 1960). Whereas the error in measuring the linear dimention of a microorganism the size of a yeast cell is about five per cent, the corresponding error in volume of a spherical cell is three times this amount. In addition the ellipsoidal shape of the yeast presents difficulties for direct measurement.

It is interesting to note the pronounced size changes with age picked up by this sensitive electronic technique. The correlation of reduction in size with the variation in the heat and dye sensitivity of the yeast is suggestive. While the mechanism of heat inactivation may well be postulated to be nuclear, the destruction of the ionic interior by high concentrations of methylene blue most probably is mediated by attack on the membrane and binding sites in the cytoplasm. Thus the aging process is modifying all regions of the cell.

Correlations of the ultrastructure of yeast (Hirano, 1962) with its varying physiology and sensitivity to toxic agents should be obtained for each subclass of cells from an old culture. Ultimately one would want all this information about one individual cell in an aging population.

ACKNOWLEDGMENT

Related haploid and diploid cultures designated BH and BD were obtained from Dr. T. H. Wood, Physics Department, University of Pennsylvania.

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VIBRIO MULTIFORMIS IN RELATION TO MULTIPLE SCLEROSIS

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ABSTRACT

Steiner (1940) reported a spirochete-like structures in the brain tissue of multiple sclerotics. He believed them to be the etiologic agents of multiple sclerosis and named them **Spirochaeta myelophthora.** Ichelson (1958) confirmed these observations with rabbits injected with a spirochete isolated from the cerebrospinal fluid of patients with multiple sclerosis. A double blind study on the Ichelson organism by Kurtzke, Martin, Myerson, and Lewis (1962) demonstrated that no correlation exists between **S. myelopthora** and multiple sclerosis. Investigations by Martin (1962) demonstrated the Ichelson organism to be a species of **Vibrio,** named **V. multiformis,** a species readily isolated from fresh water. Histopathological studies on brain and spinal cord from rabbits injected with organisms from Ichelson's cultures and from normal rabbits, as well as from human multiple sclerosis and non-multiple sclerotics, fail to confirm the claims of Steiner and Ichelson. Many artifacts in the nervous tissue examined could be interpreted as being spirochete-like, but a thorough examination of over 1,000 sections of selected nervous tissue from the four categories studied failed to confirm the presence of bacteria, or of demyelinization in any of the injected rabbits. This study of nervous tissue leads us to conclude that the **Spirochaeta myelopthora** of Steiner and Iichelson, actually **Vibrio multiformis,** has no relationship to the disorder known as multiple sclerosis.

INTRODUCTION

Steiner (1940) reported spirochete-like structures in the brain tissues of multiple sclerosis patients. He believed them to be the etiologic agents of multiple sclerosis and named them *Spirochaeta myelophthora.* Ichelson (1958) confirmed these observations with rabbits injected with an alleged spirochete isolated from the cerebrospinal fluid of patients with multiple sclerosis. Rabbits injected with the Ichelson organism, *S. myelophthora,* were said to go blind and to exhibit the general overt signs of multiple sclerosis within 18-22 weeks after inoculation (Ichelson, 1958). Paraffin sections of brain and spinal cord from these animals were said to exhibit areas of demyelinization and the presence of bacteria, presumably the injected organism, *S. myelophthora.*

In an attempt to evaluate the Ichelson hypothesis, a double blind study on the Ichelson organism by Kurtzke, Martin, Myerson, and Lewis (1962) was conducted. This study demonstrated that no correlation exists between *S. myelophthora* and multiple sclerosis from a bacteriological point of view. Investigations by Martin (1962) demonstrated the Ichelson organism to be a species of *Vibrio,* an organism readily isolated from fresh water, and which Martin named *V. multiformis.*

With this information at hand, the present histopathological study was undertaken to evaluate the role of bacteria in the etiology of multiple sclerosis through an examination of selected nervous tissue from experimental animals and known cases of human multiple sclerosis.

MATERIALS AND METHOD

In our laboratory, no adverse symptoms or effects have been observed over a period of four years in twelve rabbits given intravenous injections of descendants of an Ichelson culture (No. 473) of *Spirochaeta myelophthora.* Each injection consisted of one ml. of a living saline suspension of approximately 1,200,000,000 organisms per ml. every

1. This investigation was supported in part by Grant No. 261-2 from the National Multiple Sclerosis Society.

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other day for a period of five weeks. The injected rabbits appeared to be in good health four years after the last injection. Blood serum from the injected rabbits gave a strong four-plus antibody reaction ten days after the last injection when employed in slide agglutination tests with specific antigen (Martin, Youngue, Kost, 1959). Three of these rabbits were sacrificed for the preparation of tissue sections for this study.

Tissues were prepared by standard histological techniques. Paraffin blocks of brain and spinal cord from the rabbits described by Ichelson (1958) were processed in the same fashion as those from our experimental group. Likewise, tissue from patients diagnosed as having multiple sclerosis at autopsy and from patients without multiple sclerosis were processed in the same manner as the rabbit tissue. Since the Ichelson organism takes a silver stain, sections of brain and spinal cord were stained by the Steiner and Steiner (1944) silver method for spirochetes and Donovan bodies. Similar sections were stained with hematoxylin and eosin (Lillie, 1954) and with Erhart's modification of Pal-Weigert's stain for myelin sheaths (Erhart, 1951).

OBSERVATION AND DISCUSSION

In addition to the bacteriological studies performed by Ichelson (1957, 1958), from which she and other investigators concluded that a spirochete was the responsible etiological agent in multiple sclerosis, two histopathological criteria were also used by those investigators in corroborating and substantiating their findings. These were: 1) microscopic findings of demyelinization in the autopsy material from the brain and spinal cord of rabbits which had been injected 18-22 weeks previously with an alleged spirochete. These areas were considered to be typical of the areas of demyelinization seen in the autopsy material from the brain and spinal cord of patients in whom the diagnosis of multiple sclerosis had been confirmed clinically prior to death, and by microscopic studies after autopsy; and 2) microscopic identification of a spirochete-like organism in sections made from the brain and spinal cord of rabbits which had been injected with an organism that had been isolated and cultured from the cerebrospinal fluid of multiple sclerotics by Ichelson, and also identified by Steiner (1952) in brain sections from known multiple sclerosis patients.

In an effort to duplicate these findings, twelve rabbits were injected with the organism which had been sent to our laboratory by Ichelson. Multiple sections of various areas of the brain and spinal cord of three of these animals were made. As controls, similar animals were sacrificed which had not been injected with any organism. Additional controls consisted of studies of autopsy material from the brain and spinal cord of non-multiple sclerosis patients, as well as patients with known, long standing multiple sclerosis.

Careful microscopic examination of the brain and spinal cord of the injected animals failed to reveal any areas of demyelinization which could be considered in any way similar to those seen in the brain and spinal cord of patients with multiple sclerosis. Repeated myelin stains failed to reveal any areas of demyelinization. A few small artifacts could possibly be interpreted as focal demyelinization, but these could all be ruled out by repeated stains on tissue from the same paraffin blocks. Numerous other etiological agents; namely, emboli, anoxia, ischemia, toxins, viruses, vitamin deficiencies, abnormal enzymes, and allergic reactions have been incriminated as possible causes of demyelinization (Hurst, 1944). Thus, any actual small foci of demyelinization which had been seen on histopathological studies by Ichelson and others could possibly be ascribed to one of these other etiological agents.

The other histopathologic criterion used by Ichelson and Steiner, namely, the asserted identification of a spirochete within the brain and spinal cord of the injected animals, as well as in the brain and spinal cord of humans with the diagnosis of multiple sclerosis, presents an interesting and complex problem. Again, in an effort to duplicate these findings, the same categories of autopsy material were examined as have been described above in regard to the demyelinization aspect of this problem. Silver stains were employed to demonstrate the alleged spirochetes. It is apparent that numerous and varied structures in the sections might be identified as spirochetes. Careful microscopic study, however, reveals that these are not actually spirochetes but instead one or another of the following: 1) fragments of distorted cell walls of astrocytes and oligodendroglia; 2) fragments of distorted axis cylinders; 3) degradation products in areas of gliosis in the tissues of patients of long standing multiple sclerosis; or 4) artifacts produced by silver impregnation of the tissue substance. Possibly other structures which have been identified as spirochetes cannot be explained by any of the above. In no case, however, was a structure found which could unequivocally be classified histopathologically as a typical spirochete (Plates I and II).

Ayres (1958) suggested that the spirochete-like structures in the brain tissue of multiple sclerosis patients observed by Steiner (1952), and reported by him as *Spirochaeta myelophthora,* are spiral myelin forms producted by the interaction of lecithin and water. The lecithin in this case is split off from cerebral lipoproteins by a surface-active agent such as dioctyl sodium sulfosuccinate. Weil (1930) proposed that such a surface-active agent was produced in the liver of multiple sclerosis patients and was operative in the process of demyelinization. Weil and Luhan (1935) demonstrated a myelolytic agent in the urine of patients with multiple sclerosis. The occurrence of helical (spirochete-like) myelin forms implies that Steiner (1952) was actually staining spiraled myelin forms which simulate spirochetes, and that some surface-active substance is operative in multiple sclerosis, which promotes the development of spiraled myelin forms. Steiner (1952) described spirochetes with a knob on one end and entwined spirochetes similar to the helical and knobbed myelin described by Ayres (1958) and demonstrated to be present in the acute lesions of multiple sclerosis. A thorough review of Steiner's work (1940, 1944, 1952, 1954) indicates that the spirochete-like structures that he describes morphologically resemble members of the bacterial genera *Borrelia* or *Vibrio* more closely than any member of the genus *Spirochaeta.*

The literature records many instances of the occurrence of bacteria in nervous tissue. In reviewing the pathogenic action of *Vibrio cholera,* Greig (1929) reported the occurrence of this organism in the liver, kidneys, lungs, lymphatic glands, nervous system, spleen and urinary tract of man. Sanarelli (1922) in his experiments with dogs showed that *V. cholera* may leave the stomach and pass into the bloodstream, where it multiplies and ultimately reaches all parts of the body. Taking into account the filtrable nature of *V. multiformis* (Martin, 1962), it is logical to assume that it too may be distributed throughout the animal body with the same facility as are other members of the genus; and that with only morphology and staining reaction as guides, it could readily be described as a species of *Spirochaeta, Spirillum*

or of *Borrelia*. The masses of *Vibrio cholera* found in the brain and nervous system, for example, and described by Bechterew (1910), Scicluna (1912), and Utsumi (1922), are not unlike those found and described as a species of *Borrelia* by Steiner (1954) and those designated by Steiner (1952) and by Ichelson (1957, 1958) as *Spirochaeta myelophthora*.

In the light of these findings, it seems reasonable to assume that bacteria would be found in the brain and spinal cord of our injected animals and in some of our control human and rabbit tissue. However, our histopathological examination of the brain and spinal cord tissue from the four experimental categories selected for study fails to confirm the findings of Steiner and Ichelson, inasmuch as in no case was a structure found which could unequivocally be classified as a typical spirochete or a typical vibrio. Grinker (1960), in discussing the demyelinating disorders, points out that as yet no organisms have been isolated in culture or transmitted to experimental animals that are related in any way to multiple sclerosis, and that Steiner's spirochete, visualized only in silver impregnations, is undoubtedly a staining artifact. We found no typical areas of demyelinization in the rabbits injected with the Ichelson organism and conclude, therefore, that *Vibrio multiformis* plays no part in the process of myelin destruction. From our examination of over 1,000 sections of brain and spinal cord, it appears to us that the process of demyelinization as related to multiple sclerosis is not of bacterial origin.

SUMMARY

1. In our laboratory, no adverse symptoms or effects were observed in twelve rabbits injected with descendants of a bacterial species allegedly isolated by Ichelson from the cerebrospinal fluid of multiple sclerotics.

2. Histopathological studies on brain and spinal cord from injected and normal rabbits, and similar human tissue from multiple sclerotics and non-multiple sclerotics, fail to reveal the presence of any spirochete-like organism.

3. No areas of demyelinization were found in any of the experimental rabbit tissue that compared in any way with those areas present in human brain and spinal cord from a positive case of multiple sclerosis.

4. Many artifacts in the nervous tissue examined could be interpreted as being spirochete-like, but a thorough examination of over 1,000 sections of selected nervous tissue failed to confirm the presence of *Vibrio multiformis*.

5. This study of nervous tissue leads us to conclude that the *Spirochaeta myelophthora* of Ichelson and Steiner, actually *Vibrio multiformis,* has no relationship with the disorder known as multiple sclerosis.

6. The investigation of *Vibrio multiformis* and nervous tissue, even though it fails to suport the hypothesis that a bacterial species is the causative agent in the etiology of multiple sclerosis, does confirm the fact that this disorder is accompanied by a change in nervous tissue the causative agent of which is still unknown.

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EXPLANATION OF PLATE I

Fig. 1. **Vibrio Multiformis,** silver stain of broth culture showing typical wave-like morphology. Slide prepared from original Ichelson culture. X 3600.

Fig. 2. **Treponema pallidum,** silver stain showing typical corkscrew morphology. Slide prepared from infected rabbit testis. X 3600.

Fig. 3. Brain section of human known to have multiple sclerosis. Myelin stain showing classical differentiation between uninvolved tissue on the right and area of demyelinization on the left. X 720.

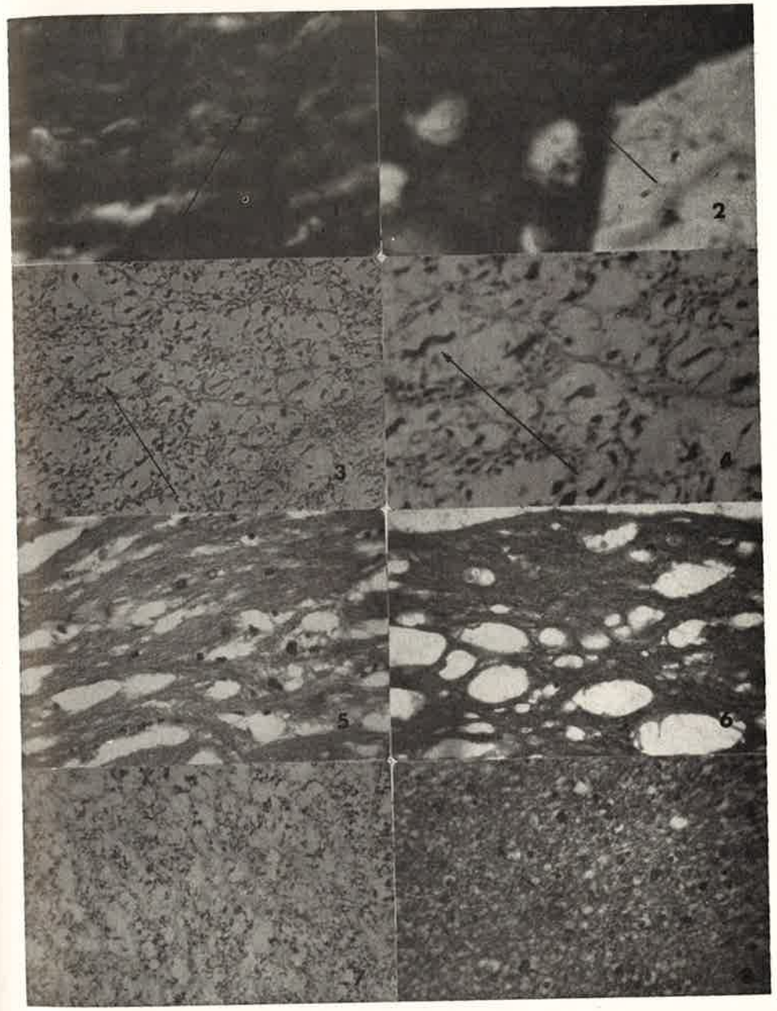
Fig. 4. Silver stain of brain section from same case of multiple sclerosis as Figure 3. Note area of demyelisization on left which is not as sharply defined as with a myelin stain. X 720.

Fig. 5. Section of rabbit brain from animal injected previously with Ichelson's organism. No areas of demyelinization are apparent with silver stain. X 720.

Fig. 6. Normal human brain section with silver stain. Myelin formation is complete as in Figure 5. Compare with demyelinization in Figure 4. X 720.

Fig. 7. Section of rabbit brain from animal injected previously with Ichelson's organism. Clear spaces between myelin stained tissue are artifacts produced by histopathological processing. The pattern of myelin formation can be readily distinguished from true demyelinization seen in Figure 3. X 1620.

Fig. 8. Section of rabbit brain prepared by Ichelson. Arrows indicate artifacts produced by silver impregnation which could be called spirochete-like. Note absence of corkscrew morphology present in **Treponema pallidum,** Figure 2. X 3600.



EXPLANATION OF PLATE II

Fig. 1. Section of rabbit brain prepared from tissue supplied by Ichelson. Arrow indicates artifact produced by silver impregnation which could be interpreted as a spirochete. X 3600.

Fig. 2. Section of rabbit brain from animal injected previously with Ichelson's organism. Arrow indicates similar artifact as shown is Figure 1. X 3600.

Fig. 3. Normal rabbit brain. Arrow indicates artifact produced by silver impregnation similar to those seen in animals injected with Ichelson's organism, Figures 1 and 2. X 1620.

Fig. 4. Normal rabbit brain. Oil immersion picture of Figure 3 showing artifact with typical morphology of **Vibrio multiformis.** X 3600.

Fig. 5. Spinal cord of rabbit injected previously with Ichelson's organism. Clear areas are artifacts produced by histopathological processing. Hematoxylin and eosin stain indicates normal tissue morphology. X 720.

Fig. 6. Spinal cord of rabbit injected previously with Ichelson's organism. Silver stain processing produces the same artifacts as seen in Figure 5. No areas of demyelinization are present. X 720.

Fig. 7. Section of rabbit brain prepared from tissue supplied by Ichelson. Myelin stain shows normal myelin formation. X 720.

Fig. 8. Section of rabbit brain prepared from tissue supplied by Ichelson. Silver stain shows normal tissue morphology. X 720.

IMMUNOCHEMICAL ANALYSES OF HEMAGGLUTINATING SUBSTANCES IN LEGUMINOSEAE SEEDS[1]

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ABSTRACT

The chemical composition of hemagglutinating substances obtained from 7 varieties of leguminoseae seeds were investigated and data concerning extraction and purification techniques, cellulose-actate electrophoretic studies, chromatographic studies, and inhibition tests with rabbit-anti-bean extract-sera are presented.

The studies indicated that two substances are involved in causing the agglutination of erythrocytes: A non-poteinaceous, non-specific, non-absorbable, unidentified portion; and a specific, absorbable, globulin protein portion. The cotyledons always have the hemagglutinating substance, and extracts of embryo and seed coat from certain varieties of beans contain such properties. However, extracts from roots, stems, and leaves do not possess hemagglutinating abilities.

INTRODUCTION

Plant agglutinins have been investigated for their ability to cause erythrocytes to agglutinate for a long period of time. With the finding that extracts from certain leguminoseae seeds exhibit specificity for certain erythrocytes, many investigators have examined such extracts in an attempt to obtain an inexpensive way to show intraspecific and interspecific differences among animal erythrocytes.

Many studies have demonstrated that the extracts from plant seeds are composed of proteins and are antigenic. The nature of the agglutinating substances has been investigated electrophoretically by Wong and Scheinberg (1960, 1963), Sanders (1962), and through classical techniques by other investigators. Studies by Sumner and Graham (1925), Boyd and Reguera (1949), and Bird (1959) have demonstrated that the portion of the plant extract causing the agglutination is proteinaceous. Studies of *Ricinus communis* extracts by Kabat, Heidelberger, and Bezer (1947) and by Krupe (1956) demonstrated that the extract was a globulin with an isoelectric point of 5.4-5.5, and a molecular weight of about 80,000. Boyd, Shapleigh, and McMaster (1955) also found that an extract from lima beans was a globulin. They further demonstrated that the purified material was electrophoretically heterogenous but nearly homogenous in the ultracentrifuge. They suggested the molecular weight of the agglutinin to be around 80,000.

Studies by Schertz, Jurgelsky, and Boyd (1960) demonstrated that agglutinins may occur in some varieties of a species and be absent in others. This difference existed when the varieties were grown in identical environments. Data showed that the differences were hereditary. Many investigators have found that the plant extracts are erratic in their reactions. Studies in our laboratories have demonstrated that two fractions (non-proteinaceous and proteinaceous) were involved in the agglutination reaction. A complete review of the literature on plant extracts has been contributed by Sanders (1962). Only literature pertinent to the problem will be considered in this paper.

The technical advancement of immunodiffusion (Oudin, 1946; Ouchterlony, 1949), performed in conjunction with absorptions, has made it possible to investigate the antigenic properties of the plant extract and to associate these factors with the agglutinating substance.

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The purpose of this paper is to present additional data on the use of plant extracts for immunogenetic studies and to investigate the nature of the agglutinating substance.

MATERIALS AND METHODS

Plant Extracts: Saline extracts from the following seeds or component parts of the plant were used in this experiment (Table1).

The method of preparation has been described by Sanders, (1962). Briefly, 2.5 gm of seed or component plant part was homogenized with 2.5 cc of 0.85% saline, and the resulting mixture was filtered and subsequently centrifuged. All extracts were frozen at -20°C until used.

Erythrocytes: For erythrocytes, whole blood was collected from the heart by cardiac puncture in tubes containing isotonic citrate-saline solution. The erythrocytes were washed in isotonic saline 4 times and reconstituted to a 2% suspension for testing. Erythrocytes were collected from the following animals: *Phasianus colchicus, Gallus domesticus, Meleagris gallopavo, Anas platyrhynchos,* and *Sylvilagus floridanus.*

Purification procedures: The method of isolating the agglutinating factor from seed extracts involved water precipitation and ammonium sulfate extraction. Both techniques were effective in yielding a relatively purified white proteinaceous material.

A water insoluble precipitate was formed by mixing 1 cc of extract with 14 cc of distilled water. Subsequent redissolving in 0.85% saline and reprecipitate. The precipitate was made soluble by reconcentrating it with saline to the original volume of liquid.

The process of isolating gamma globulin from serum proteins based on the differences in solubility of the various protein components when mixed with different concentrations of salt solutions was used to obtain purified protein from the plant extracts. The detailed procedure used in the studies can be found in

Table I

Leguminoseae varieties tested as a source of plant agglutinins

Species	Genus	Variety	Extract Number
Phaseolus	*vulgaris*	Red kidney soup or shell bean	1
		Sensation wax yellow bush bean	3
		Yellow pod bountiful yellow bush bean	4
		Lazy wife green pole bean	7
		White marrowfat bean	8
		Round pod kidney wax yellow bush bean	15
		White kidney bean	17
	lunatus	Wonder pole lima	2
		Fordhook U.S. 242	6
		Henderson bush baby lima	11
	multiflorus	Red scarlet runner	10
Glycine	*max*	Clark soy bean	9
		Wabash soy bean	12
		Madison soy bean	13
		Black wilson soy bean	14
		Shelby soy bean	16
Robinia	*pseudo-acadia*	Black locust	5

Cushing and Cambell (1957) or Kabat and Mayers (1961). Upon the gradual addition of ammonium sulfate, the globulin fraction of serum protein is the first to precipitate out of solution. Ammonium sulfate has the advantage in that it can be used at room temperatures as a precipitating agent with out denaturing the protein but has the disadvantage in that the precipitate must be dialyzed to remove the salts before using.

The procedure is to add slowly ½ volume of saturated ammonium sulfate solution to seed extract with constant stirring over a period of several minutes. The pH is adjusted to 7.8 with 1.0 N NaOH and allowed to stand at room temperature for about one hour. The precipitated protein is centrifuged and redissolved to the original volume in 0.85% saline and again precipitated with ammonium sulfate. The precipitate is washed twice with 1/3saturated ammonium sulfate, redissolved in 0.85% saline, and dialyzed against 0.85% saline under refrigeration until free of sulfate ions. Further separation of the protein fraction can be accomplished by dialyzing the salt-precipitated material against distilled water with the fractions separating into water-soluble (pseudoglobulin) and water insoluble (euglobulin) proteins. The fractions are then reconstituted with isotonic saline and frozen until used.

Diffusion plates: The detailed procedure used in the preparation of diffusion plates is described by Ridgway, Klontz, and Matsumoto (1962). The agar diffusion medium contained 1.5% Difco Bacto-Agar, 0.72% NaCl, 0.6% Sodium Citrate, 0.01% Merthiolate, and 0.01% Trypan Blue. The pH of the medium was adjusted to 6.7. One 8 ml layer of agar was poured into each petri dish, and stainless cylinders were positioned on top of this layer to give a hexagonal pattern with adjacent wells two cm apart. A second 8 ml layer was then poured around the cylinder. 0.25 ml of undiluted antisera was placed in the center well, and 0.2 ml of each plant extract to be tested, at a dilution of 1:3, was placed in the outer wells. Normal rabbit serum with plant extracts served as the control. The plates were sealed with rubber tape and incubated 7-8 days at 37°C. The plates were viewed and photographed utilizing dark field illumination. Photographs were taken on Plus-X film with a 35 mm camera mounted above the viewer.

Antisera: Rabbit anti-plant extract sera were prepared by intravenous injections of 0.5 ml unpurified and purified extract for a total of 9 injections. The rabbits were bled 6 days after the last injection, and the resulting antisera was stored under refrigeration until used.

Agglutination test: Agglutination tests were used to show intraspecific and interspecific differences. These tests were performed by micropipetting 1 drop of a 2% erythrocyte suspension into 1 drop of plant extract of appropriate dilution into disposable agglutination trays. After agitation on a shaker for 15 min. these trays were stored in the refrigerator, and readings were made after 1 hour. Final readings were recorded after overnight refrigeration. A scoring system of agglutination and grading down through 3, 2, 1 to – for a negative reading. A control, cells in saline, was always negative.

Qualitative test for chemical constituents of seeds: Purified and non-purified plant extracts were tested for carbohydrate, fats, and proteins by using the following qualitative tests: starch—iodine test, sugars—Benedicts test, fats—Sudan III, proteins—Biuret test and enzyme digestion. The procedure for each test will not be discussed since these tests are common procedure and can be found in most chemistry texts.

RESULTS

The unpurified extracts were tested against the erythrocytes of *Anas platyrhynchos, Gallus domesticus, Colinus virginanus,* and *Phasianus colchicus*. All the plant extracts reacted with *Anas, Colinus* and *Phasianus* erythrocytes; however, extracts 12 and 13 failed to react with *Gallus* erythrocytes. Thus, one was able to show interspecific differences. Differences in the degree of reactivity were noted with extracts 11, 13 and 14. Extract 11 exhibited a 1 plus reaction with *Gallus* erythrocytes while exhibiting a 4 plus reaction with the other three erythrocytes. Extract 13 failed to react with *Gallus* erythrocytes and exhibited a weaker reaction with *Colinus* and *Phasianus* than with *Anas* erythrocytes. Extract 14 exhibited a 1 plus reaction with *Anas* and *Gallus,* a three plus with *Colinus,* and a 4 plus with *Phasianus* erythrocytes.

Extracts from cotyledons, embryo, and seed coat were prepared in order to determine what portion of the seeds contained the agglutinating fraction. It was found that all three parts of the seed contained the agglutinating fraction in varying amounts. The extract from the cotyledons exhibited a stronger reaction than the seed coat or embryo. Extracts from root, stem, and leaves failed to exhibit a reaction in all cases. Extracts were prepared from seedlings at various stages of growth to determine if the agglutinating factor was metabolized or lost at a certain growth stage. The reaction occurred as long as the cotyledon was present. When the cotyledon withered away, the extract failed to exhibit a reaction. It was not possible to show a gradual decrease in the reactivity of the extract of the growing seedling.

The extracts were purified by precipitation in distilled water and ammonium sulfate treatment, and attempts were made to show that purified extracts would react differently than non-purified extracts when tested against erythrocytes of *Gallus, Meleagris* and *Sylvilagus*. Unpurified extracts, 4 and 7 embryo reacted with *Gallus* erythrocytes while the purified extracts failed to react. Purified extracts 1 embryo and 7 seed coat exhibited a weaker reaction with *Gallus* erythrocytes than the non-purified extract. Such results demonstrated that the degree of reactivity for non-purified and purified extracts differed.

Further tests were performed on the non-purified and purified extracts to determine if the differences in the degree of reactivity could be demonstrated with *Sylvilagus floridanus* erythrocytes. Table 2 shows the results when *Sylvilagus floridanus* erythrocytes were tested against unabsorbed and absorbed purified and non-purified extracts from the different components of the seeds.

Extracts 1 and 4 seed coats failed to agglutinate the erythrocytes when purified; however, the unpurified extracts agglutinated the erythrocytes. Absorption of the non-purified extract showed that only extracts 4 embryo, 7 embryo, 10 embryo, cotyledon, and seed coat could be absorbed. After repeated absorptions, it was impossible to remove the agglutinating factor from 5 of the extracts. However, after 3 absorptions, the purified extract failed to react with the erythrocytes. These studies demonstrated that some of the non-purified extracts contained an additional factor(s) that would cause erythrocytes to agglutinate.

Purified and non-purified seed agglutinins were tested for polysaccharides, lipids, and proteins with the iodine, Sudan III, and Biuret test. The non-purified extract exhibited a positive reaction to all three tests; whereas the purified extracts reacted with the Biuret test and failed to exhibit a test for carbohydrates and lipids.

Table II

Agglutination reaction of *Sylvilagus floridanus* erythrocytes with unabsorbed and absorbed seed agglutinins

Genus Species	Variety	Unabsorbed Extracts Non-purified	Unabsorbed Extracts Purified	Absorbed Extracts Non-purified	Absorbed Extracts Purified
Phaseolus vulgaris	Red kidney soup or shell bean (1)				
	Cotyledon	4	4	4	—
	Embryo	4	4	2	—
	Seed coat	3	—	—	—
	Yellow pod bountiful bean (4)				
	Cotyledon	4	4	4	—
	Embryo	4	4	—	—
	Seed coat	4	—	—	—
	Lazy wife green pole bean (7)				
	Cotyledon	4	4	3	—
	Embryo	4	3	—	—
	Seed coat	4	4	3	—
Phaseolus multiflorus	Red scarlet runner bean (10)				
	Cotyledon	2	2	—	—
	Embryo	2	2	—	—
	Seed coat	2	2	—	—

The purified and non-purified seed agglutinins were enzymatically treated with papain, diastase, and lipase and, after treatment, tested against *Sylvilagus floridanus* erythrocytes to determine if the agglutinating portion had been removed. Papain digestion removed the agglutinating fraction from purified extracts but failed to remove the agglutinating fraction from the non-purified extracts. However, such treatment reduced the speed and degree of reaction of non-purified extracts. Enzymatic digestion with diastase and lipase failed to alter the agglutinating reaction of purified and non-purified extracts.

Purification of the extracts demonstrated that the agglutinating fraction was soluble in salt solutions but not soluble in distilled water. Further purification with Ammonium Sulfate suggested that the precipate formed was a globulin protein.

Rabbit antisera were prepared against seed agglutinins 1, 7, 4, 10, and 3, attempts were made to inhibit the agglutinating ability of purified and non-purified seed agglutinins by combining equal amounts of seed agglutinins with anti-seed extract-sera. Tests with seed agglutinins 1, 7, 4, 10, and 3 demonstrated that the non-purified extract could not be inhibited. The purified extracts were inhibited and gave a negative reaction when tested against *Sylvilagus* erythrocytes.

The seed agglutinins were tested against the anti-seed extract-sera by the agar-plate diffusion method to determine if the agglutinating portion of the seed extracts was homogenous. Table 3 depicts the results from such a test.

The seed extracts were grouped into varieties on the basis of the pattern of precipitation bands formed. The agglutinins of *Glycine max, Robini pseudo acadi* and *Phaseolus lunatus* failed to exhibit a reaction with the antisera from

Table III

Comparative reactions in agar-plate diffusion method of precipitation analysis

Genus Species	Variety	Number of precipitation bands formed against Anti-1	Anti-7	Anti-4	Anti-10
Phaseolus vulgaris	Red kidney soup or shell bean (1)	3	2	1	—
	Yellow pod bountiful yellow bush bean (4)	2	2	2	2
	Lazy wife green pole bean (7)	2	3	2	2
	White marrowfat bean (8)	3	3	1	1
	Round pod kidney wax yellow mbush bean (15)	2	3	2	1
	White kidney bean (17)	2	3	2	1
Phaseolus lunatus	Wonder pole lima (2)	—	—	—	—
	Fordhook U.S. 242 (6)	—	—	—	—
	Henderson bush baby lima (11)	—	—	—	—
Phaseolus multiflorus	Red scarlet runner (10)	1	1	1	2
Glycine max	Clark soy bean (9)	—	—	—	—
	Wabash soy bean	—	—	—	—
	Madison soy bean (13)	—	—	—	—
	Black wilson soy bean (14)	—	—	—	—
	Shelby soy bean (16)	—	—	—	—
Robinia pseudo-acadia	Black locust (5)	—	—	—	—

the four varieties of the genus *Phaseolus*. Five of the seven varieties from *Phaseolus vulgaris* could be separated on the basis of the precipitation bands formed. Extracts 15 and 17 exhibited the same pattern of reaction and could not be differentiated. The one variety from *Phaseolus multiflorus* (red scarlet runner 10) exhibited a reaction with each of the antisera. The anti-multiflorus sera gave two precipitation bands.

DISCUSSION

Unpurified seed extracts from the Leguminoseae family failed to show intraspecific and interspecific differences with the one exception being *Gallus* erythrocytes. When tested with the erythrocytes from various animals, the agglutination reaction was very fast (20-60 seconds) with a 4-plus reaction. It was impossible to remove the agglutinating portion of many extracts with repeated absorptions. Another peculiar phenomenon with plant extracts was that when varieties had been grown in differnt localities they failed to exhibit the same agglutinating pattern when tested.

Extracts from the seed coat, embryo, and cotyledon are capable of causing erythrocytes to agglutinate. However, due to the stronger reaction exhibited by the cotyledon extract, it is suggested that most of the agglutinating substance is located in the cotyledons.

The agglutinating portion of seed extracts could not be demonstrated with germinating seedlings after the cotyledons disappeared. This suggested that the protein portion causing agglutination was utilized during growth. However, attempts to show a gradual decrease in the agglutinating ability of the growing plant failed to show such a reduction.

Unsuccessful attempts to absorb the unpurified seed extracts and successful

absorptions with the purified extracts clearly demonstrated that two or more factors were causing the erythrocytes to agglutinate.

Chemical analyses demonstrated that the plant agglutinins were proteinaceous, and data from the solubility test further suggested that it was a globulin. Our studies clearly showed that one of the agglutinating portions was an absorbable protein. The antigenicity of the seed agglutinins was demonstrated by producing rabbit anti-seed extract-sera. The positive inhibition test with purified extract demonstrated that the portion causing agglutination could be removed by combining the extract with anti-sera. Failure to remove the agglutinating fraction from non-purified plant extracts by the inhibition test further demonstrated that plant agglutinins contained a non- proteinaceous fraction that caused erythrocytes to agglutinate.

Immunochemical analyses of the plant extract with anti-plant extract-sera demonstrated that the agglutinating portion was heterogenous. Varieties within the same species contained different antigenic fractions. No attempt was made to determine which antigenic fraction or fractions were involved in the agglutination reaction by removing one or more of the antigens through differential absorptions.

The technique of agar gel diffusion along with differential agglutination of erythrocytes, electrophoretic patterns, etc., might prove useful in producing additional data on the identification of seeds.

CONCLUSIONS

1. Interspecific differences were demonstrated with the use of seed agglutinins against *Anas platyrhynchos, Gallus domesticus, Colinus virginanus,* and *Phasianus colchicus* erythrocytes.

2. Absorption tests demonstrated that most seed extracts contained an unabsorbable fraction; however, others were absorbable.

3. Extracts from seed coat, embryo, and cotyledon were capable of agglutinating erythrocytes.

4. Roots, stem, and leaf extracts failed to agglutinate erythrocytes.

5. Purification procedures with distilled water and ammonium sulfate demonstrated that the absorbable agglutinating fraction was a globulin.

6. Qualitative chemical analysis showed that purified seed extracts did not contain polysaccharides and lipids but were composed of proteins.

7. Enzymatic digestion of purified seed extracts showed that the agglutinating fraction could be removed with papain treatment. Treatment with diastase and lipase failed to alter the reaction pattern.

8. Rabbit anti-plant extract-sera inhibited purified extracts but failed to inhibit non-purified extracts.

9. Immuno-diffusion patterns demonstrated that the purified protein portion was heterogenous.

10. Immuno-diffusion patterns were utilized in identifying different varieties of seeds. The use of such techniques should be of value in seed identification.

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ANTIMETABOLITES IN LICHENS. A PRELIMINARY REPORT[1]

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ABSTRACT

Extracts of the lichen **Umbilicaria papulosa** have been found to inhibit growth of higher plants and of a number of species of fungi. By partitioning with various solvents, absorbing on charcoal columns and extracting with buffers, it is concluded that there are two substances, or possibly two groups of substances, present in this lichen. In other words, the principles which inhibit growth of higher plants are not necessarily the same ones that exhibit antifugal activity.

INTRODUCTION

More than a hundred compounds have been isolated from lichens by investigators in various parts of the world. Perhaps the best known of these compounds are the so called lichenic acids, a heterogeneous group of organic acids. It has now become established that antibiotic substances also may be obtained from certain species of lichens (1) (2) (3) (4) (5). In general, the term antibiotic has been employed to indicate antibacterial compounds and, less frequently, antifungal substances. In the investigations now being reported it was established that extracts of *Umbilicaria papulosa contain* substances which inhibit growth of both higher and lower plants.

MATERIALS AND METHODS

Specimens of the lichen *Umbilicaria papulosa* (Ack. and Tuck.) were ground to a fine powder in a mortar and extracted for 48 hours with ether. The residue was extracted with 80% ethanol, using soxhlet extractors. The alcoholic extract was evaporated to dryness and taken up with water. The aqueous extract of the lichen was tested for inhibition of growth of cucumber roots and of a number of species of fungi.

The cucumber root test was conducted as follows. Twenty-five cucumber seeds, were placed on a number one Whatman filter paper in a petri dish. One ml of the extract was combined with 9 ml of distilled water which was then added to the petri plate. Control lots were given distilled water only. These seeds were held at a constant temperature (20°C) for 96 hours. At the end of this time the seeds were removed and the length of each root was recorded in millimeters. Additional tests were conducted using varying dilutions of the lichen extract.

Antifungal activity was tested by mixing the lichen extract with melted potato dextrose agar and pouring into a sterile petri plate. When the agar had cooled a 10- millimeter disc of mycelial mat of fungus was cut from the stock culture by means of a sterile cork borer. The disc was then transferred to the center of the plate of agar which contained the lichen extract. These plates were incubated at 20°C for a week, at which time the rates of growth were recorded as increases in the diameter of each colony. One, five or ten ml of the lichen extract was added to 15 ml of the agar in preparing the test plate. Tests were begun with *Glomerella cingulata* and *Monilinia fructicola,* the two organisms customarily employed for screening fungicides. Subsequently a number of other fungi were tested also.

RESULTS

Preliminary experiments revealed that active substances were extracted from the lichen by either ethanol or methanol. Acetone was of no value despite the fact that other workers had employed this solvent for extracting some of the rather rare compounds from lichens. Additional studies indicated that 80% ethanol was more suited as an extractant than higher or lower concentrations. (Figure I). Studies were also inaugurated to determine the minimum time required for complete extraction of the active substances. In a series of 8-hr. sohxlet extractions it was found that 32 hours of extraction sufficed to remove all of the active substances. (Figure 2).

In figure 3 will be found the results of a typical experiment on the effect of lichen extract on growth of cucumber seeds. It will be observed that a slight amount of inhibition of root growth was produced by concentrations as low as 0.1 or 0.2 of a ml per 10 ml of solution. One ml of extract produced very definite inhibition, the rate of growth in this lot being about 25% of normal.

The results of tests on fungi are shown in figure 4. In this experiment 1, 5, and 10 ml of extract, respectively, were added to 15 ml of agar. It will be observed that little inhibition was produced by one

1. This research was supported by grant No. E-4743 from the National Institutes of Health.

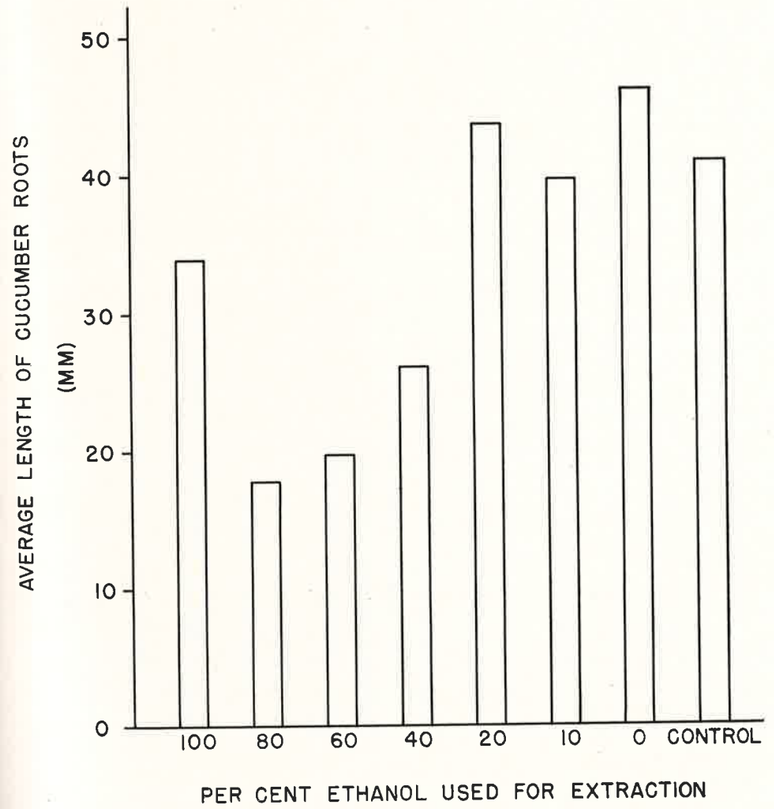

Figure 1. Effectiveness of different concentrations of ethanol in extracting antimetabolites of lichen.

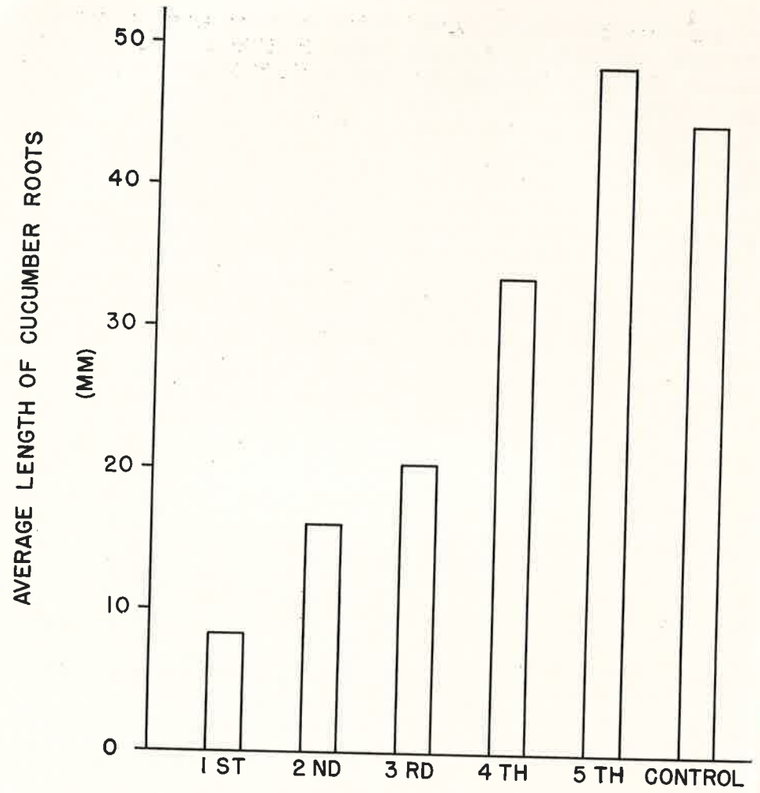

Figure 2. Minimum time required to completely extract antimetabolites from lichen.

Table 1. Fungi which have been inhibited in their growth by extracts of *Umbilicaria papulosa*:

Glomerella cingulata	(Bitter rot of apples)
Monilinia fructicola	(Brown rot of stone fruits)
Botrytis cinerea	(Gray mold of apples, etc.)
Alternaria tenuis	(Storage rot of tomatoes)
Lentizites trabea, Poria monticola, Lentinus lepideus	(wood-rotting)
Ceratocystis ulmi	(Dutch elm disease)
Trichophyton mentagrophytes	(Dermatitis)

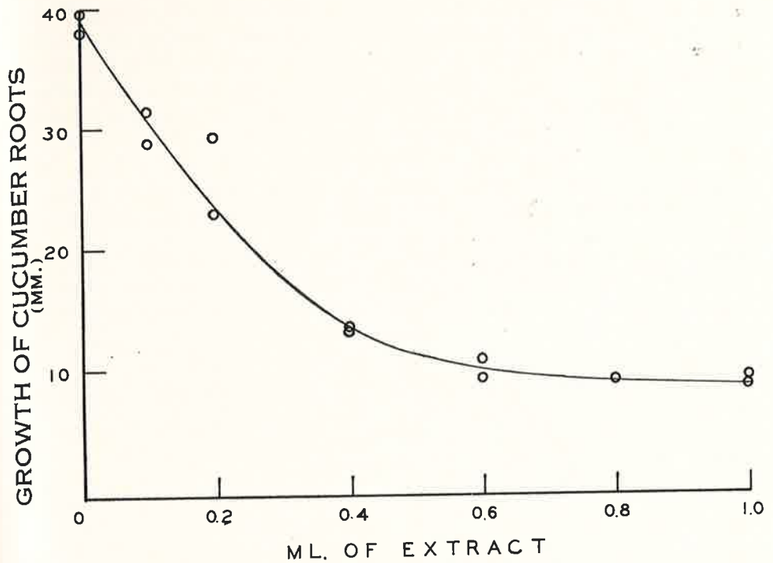

Figure 3. Effect of different concentrations of lichen extract on growth of cucumber roots.

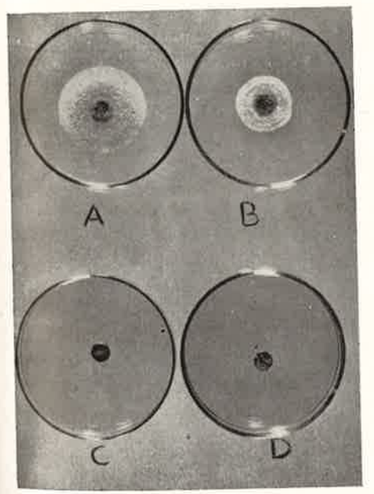

Figure 4. Antifugal effect of lichen extract. A. Control; B. 1 ml. extract; C. 5 ml. extract; D. 10 ml. extract. The fungus is **Glomerella cingulata.**

ml of extract, whereas both 5 and 10 ml of the extract completely stopped growth of the fungus.

As stated previously, the lichen extract was tested on other species of fungi. In all instances 10 ml of the extract either completely or greatly retarded the growth of the fungus. Table 1 lists the species of fungi which have been tested.

Evidence has been obtained which suggests that the lichen extract contains two separate inhibitory substances, or possibly two groups of substances. For example, a charcoal column (Norit A) completely adsorbs the active principles of the extract. Eluting with a mixture of acetone, water and ammonia removed only materials which inhibit growth of cucumber roots. No antifungal substances were present in the filtrate. It is apparent therefore that there are two different types of compounds responsible for the growth- inhibitory activity.

DISCUSSION

It is possible that we are extracting substances from *Umbilicaria papulosa* which have not previously been identified. Burkholder and Evans (3), in their investigations, showed that at least two of the lichenic acids were responsible for antibacterial activity of the lichens with which they were working. We do not feel that lichenic acids are involved because they are generally soluble in ether and we have been employing only aqueous solutions. This does not preclude the possibility that the active aqueous extracts contain water soluble acids. Recently some straw-colored crystals have settled out of our aqueous extracts after they had been stored for several weeks. These crystals were filtered off but the filtrate still showed antimetabolic activity.

One of the most widely distributed growth regulators in plants is indoleacetic acid. Although this compound is generally responsible for stimulating growth in meristematic tissues, relatively high concentrations can act as inhibitors. This possibility, however, was eliminated by conducting chromatographic analyses which gave negative tests for indole compounds.

As was mentioned previously, it is evident that two groups of substances are present—one inhibiting growth of the cucumber roots, the other showing antifungal activity. Additional studies are now in progress which are designed to aid in the characterization of the active principles. The methods being employed include paper chromatography and ultra violet and infra red spectroscopy.

SUMMARY

Extracts of the lichen *Umbilicaria papulosa.* (Ack. and Tuck.) inhibited the growth of cucumber roots and of several species of fungi.

Results are presented in regard to the most effective solvent and the optimal time for extraction of the active substances.

Apparently two types of compounds are present in the extracts because the "phytocidal" principles can be separated from the "fungicidal" compounds by the use of a Norit (charcoal) column.

ACKNOWLEDGMENTS

The authors are indebted to the following individuals for assistance in this research: Herbert G r a f f i u s, Thomas Schaefers, John Mete, William Popp, Rachel Goss, Wesley Brykailo and Alan Miller.

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OPTICAL MICROSCOPY INVESTIGATION OF PLANT CELL DESTRUCTION IN AN ELECTROSTATIC FIELD

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ABSTRACT

Orchard grass plants exposed continuously to sufficiently high electrostatic potential gradients have been observed to develop a leaf-tip burning. The severity of the burning has been noted to be a function of the potential gradient magnitude, and it has been possible to completely destroy plants by the initiation and propagation of the burning phenomenon. The present paper is an attempt to clarify the mechanisms of cell destruction in these plants by successive sectioning and optical microscopy investigations of the affected tissue.

INTRODUCTION

It had been shown as early as 1917 that plants or seeds exposed to short-period electrostatic fields produced better growth than unexposed plants (Jorgensen and Priestly, 1917). Blackman, Legg, and Gregory (1923) and Shibusawa and Shibata (1927) have also exposed various field crops and seeds to short-period electrostatic fields and have observed as high as 22% better growth (Shibusawa and Shibata, 1927) as compared with control plants.

In the comparison of electrostatic field phenomena with other physical phenomena associated with similar field and radiational properties such as the effects of x-radiation on plant growth, it became apparent to the author that perhaps if the electrostatic field were applied long enough to plants, the beneficial properties reported by others might vanish; and the plant would be affected detrimentally. It has been shown by Murr (1960) that bean seeds exposed to x-radiation tend to be benefitted in their ability to germinate if the duration of exposure is kept below a total intensity accumulation of 2000 roentgen units. As exposure time increases, however; the phenomenon is reversed, and germination is impeded.

Plants, and in fact all living matter, are continuously exposed to electric and magnetic field conditions just as they are continuously exposed to temperature, humidity, light, and other more common properties of the physical environment. Although a large volume of information exists concerning the effect on plant growth of extremes in moisture conditions and temperature, virtually no information is available concerning the effect on plant growth of extremes in the potential gradient (terrestrial electrostatic field). For the present, however, this factor does not change appreciably over the earth's surface, but there is ever increasing evidence taht continual contamination of the ionosphere by nuclear radiation may eventually alter the electro-environmental phenomena. In essence, then, plant growth studies in a continuous electrostatic field represent one of the last remaining unexplored frontiers in the investigation of the physical environment and its effects on plant physiology.

It is the purpose of this paper to show what happens to orchard grass plants when the yare exposed to a continuous electrostatic field. It is also the desire of the author to present a possible explanation for the observed phenomena as related to plant growth in general.

EXPERIMENTAL PROCEDURES

Seedling orchard grass plants were planted in two identical plots consisting of wooden frames with ventilated bottoms covered over with an aluminum

wire mesh, and filled with soil to a depth of approximately 7 inches. The environments measured 20 x 20 inches square and were fitted with identical movable aluminum wire mesh measuring 20 x 20 inches supported by polyethylene rods. Figure 1 illustrates schematically the arrangement of the environments.

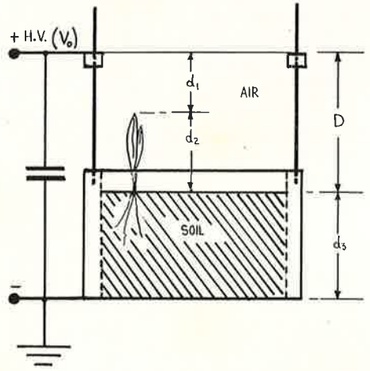


Fig. 1. Idealized Experimental Environment (schematic).

A d.c. high voltage, variable from zero to 15 kilovolts, was then applied to the top and bottom meshes of one environment. This environment was then designated the active environment. The second environment was not electrically active, and was called the control environment. Each environment was exposed to exactly the same temperature and light conditions, and the moisture content of the soil was adjusted to be the same in each environment to within plus or minus 1% of a selected level of available moisture by weight. The moisture level was manually maintained by a moisture monitoring network developed by the author. Details of this technique will be reported elsewhere in the literature.

The day lengt hof the environments was extended to 16 hours by artificial lighting. This allowed the plant growth to be accentuated in the vertical direction, thereby facilitating morphological observations, and speeding the progress of each experiment. The light intensity in each environment was maintained at approximately 90 foot candles by placing a hundred watt incandescent bulb over the plots at a predetermined height. This was just sufficient to maintain photosynthetic response (Withrew, 1936).

Soil pH readings were observed periodically in each environment, and every effort was made to ensure that variability which might arise during the course of the experimental work was due only to the electro-environmental conditions. The sand-lime-soil mixture employed throughout the experimental phase of this work was thoroughly steamed and compacted for equivalent soil permeabilities in each environment.

The electro-environmental factor involved in this study was measured as relative potential gradient or electric field intensity between the soil and the anode mesh in the manner described in previous work by Murr (1962). The moisture level of the environments was maintained at all times above 12% by weight since at this level or higher, it has been shown that a sand-lime-soil mixture exhibits high dielectric properties which allow the potential gradient to be described simply by (Murr, 1962):

$$E = \left(\frac{V_o}{D}\right) \qquad (1)$$

where V_o is the d.c. potential magnitude applied to the mesh electrodes of the active environment, and D is the distance from the soil surface to the anode mesh. This arrangement is analogous to the earth's surface and the ionosphere, for which the potential gradient normally measures approximately 140 volts per meter in the microclimate over most of Pennsylvania.

TABLE I
PLANT DRY-WEIGHT ANALYSIS—DATA

Relative Potential Gradient	#	Average Dry-Weight per Plant (mg.) (first harvest)		Average Dry-Weight per Plant (mg.) (second harvest)		Average Difference for Two Harvests (dry weight basis)
KV/m	plants	active	control	active	control	percent
15	35	1.3	1.5	2.1	2.5	14
30	35	2.4	2.8	8.0	10.0	17
50	40	1.0	1.5	5.3	6.8	28
75	35	.5	.9	destroyed		43

A number of experiments were conducted at various potential gradient magnitudes and under a variety of field configurations as shown in Table I. The plants in each experiment were clipped to a height of 1 inch after approximately two weeks of growth, and thereafter they were clipped to this same height at one week intervals. The clippings were then dried for 12 hours in air at 45°C and then weighed. The results of the first two dry-weight analyses of each experimental condition are indicated in Table I.

In the initial two-week growth period of all experiments, a leaf-tip burning phenomenon was observed to develop when the leaves attained a particular height. As the plants grew taller, the burning progressed down the leaf at a rate greater than the plant growth rate. Table II shows the height at which burning was detected in the leaf tips of the active environment plants for each experimental condition. This height will be referred to in this paper as the critical burning height. Several replications of the starred conditions were performed with the same results being observed each time as indicated.

The burning phenomenon was then investigated utilizing techniques involving

TABLE II
EXPERIMENTAL BOUNDARY CONDITIONS AND CRITICAL BURNING HEIGHT—DATA

Relative Potential Gradient	Air Distance (Fig. 1)	Soil Distance (Fig. 1)	Critical Burning Height*
KV/m	(D) - Meters	(d_3) - meters	(d_c*) - meters
15	.381	.165	.165
30**	.330	.165	.127
50**	.292	.165	.102
75	.178	.191	.025

* Average plant height at which burning of the tips was detected.
** Replicated.

optical microscopy. Initially, 10 micron transverse sections were prepared with a microtome after the clipped tips of a 40 kilovolts per meter experiment were killed and fixed in FAA, dehydrated in ethyl alcohol, and imbedded in commercial tissue mat. Following staining in safranin and fast green, the sections were mounted in Clarite (in toluol) and observed in a Unitron metallurgical microscope.

Three distinct leaf areas were observed to appear as the burning of the tips progressed. The most severely damaged tip portion turned pale brown, becoming almost transparent. Preceding the brown damage region was a dark green region which acted as a transformation region from the relatively undamaged leaf section down the plant. It was observed that after burning was initiated, the entire active plant became a darker green as compared with the control. In order to effectively study the damage mechanism, sections were cut from all three regions of the active plant. Several complete tips were also transversely sectioned to allow the transition of damage as evidenced by the color zones to be studied in greater detail.

Using a modification of a staining technique developed for studying wheat stem rust by Shipon and Brown (1962), whole leaf sections were cleared and

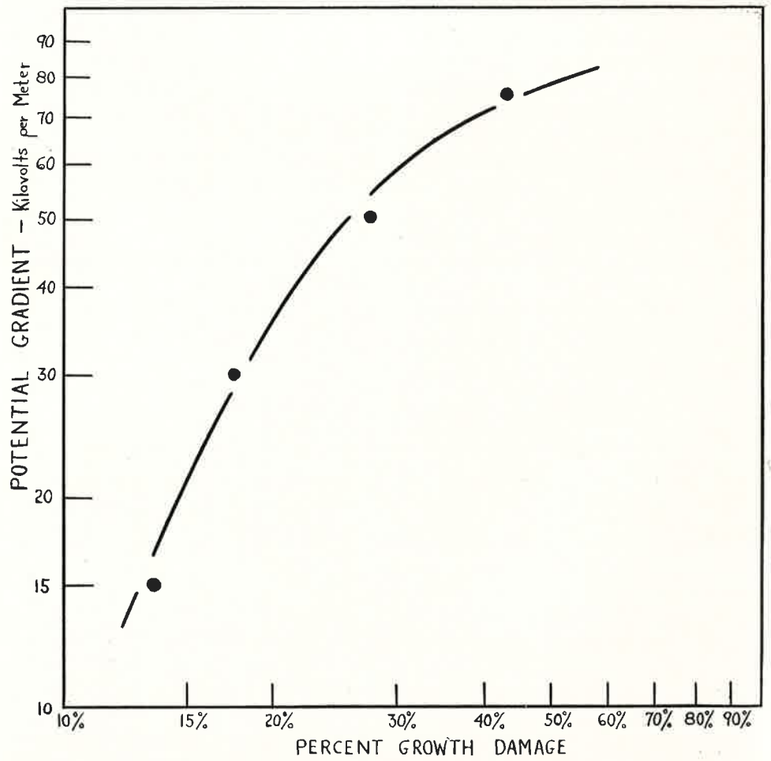


Fig. 2. Plant Damage of Seedling Orchard Grass in an Electric Field (dry-weight analysis).

stained. The method employed was to boil the clipped tips in an alcoholic solution of lactophenol cotton blue (4 parts ethyl alcohol (95%) to 1 part lactophenol cotton blue) for several minutes. The lactophenol cotton blue was prepared as follows:

phenol—10 gm
glycerine—10 cc
lactic acid—10 cc
aniline blue—.05 gm
distilled water—15 cc

Following boiling, the leaves were allowed to remain in the lactophenol cotton blue solution for approximately 24 hours after which time they were rinsed in

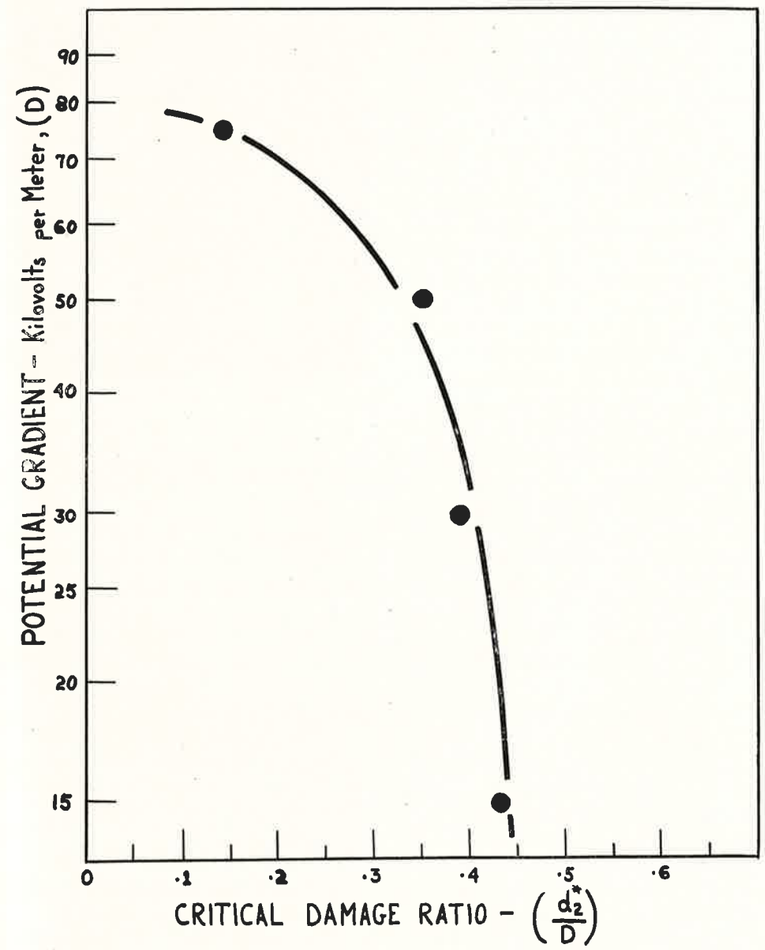


Fig. 3. Plant Damage as a Function of the Environmental Boundary Conditions and Electric Field Strength.

warm water and placed in a chloral hydrate solution (5 gm chloral hydrate to 2 cc distilled water) for approximately 1 hour, and destained to proper contrast. The stained leaf tips were then mounted using xylol and Clarite (in toluol), xylol being droped on the leaf tip before the final tacking with Clarite. Several whole leaves were also mounted directly. It should be pointed out here that both fresh tips and regrowth tips developed the burning, and histological samples were prepared from both tip types using the methods described.

DISCUSSION OF RESULTS

The graph of Fig. 2, constructed from the experimental data of Table I, shows the average plant damage as a function of the relative potential gradient of the experimental environment. It will be observed that if the curve is extrapolated at 100% plant damage, the relative potential gradient is approximately 85 KV/m. An interesting feature is also observed when the ratio of the plant height at which burning is detected (critical burning height) to the total distance between the soil and the anode screen is plotted against the relative potential gradient (Fig. 3). If the curve of Fig. 3 is now extrapolated to the zero point ratio, i.e.;

$$\left(\frac{d_2^*}{D}\right) \equiv 0 \qquad (2)$$

then the potential gradient wihch will initiate burning is found to be approximately 80 KV/m. The condition stipulated by equation 2 is identical or nearly identical to the case of the natural environment, since the distance from the ionosphere to the earth's surface is extremely large compared to the plant height on its surface. Thus, the ratio expressed in equation 2 would approach zero, and the natural-critical potential gradient would approximate 80 KV/m (relative). It will also be observed that the critical burning ratio is approximately the same as the potential gradient necessary to initiate total plant destruction as shown in the graph of Fig. 2. It would seem logical, then to state that potential gradients approaching this value in the natural environment would initiate the destruction of terrestrial plants.

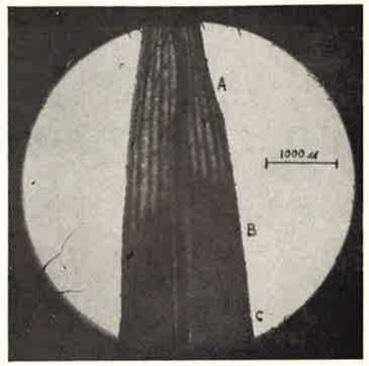
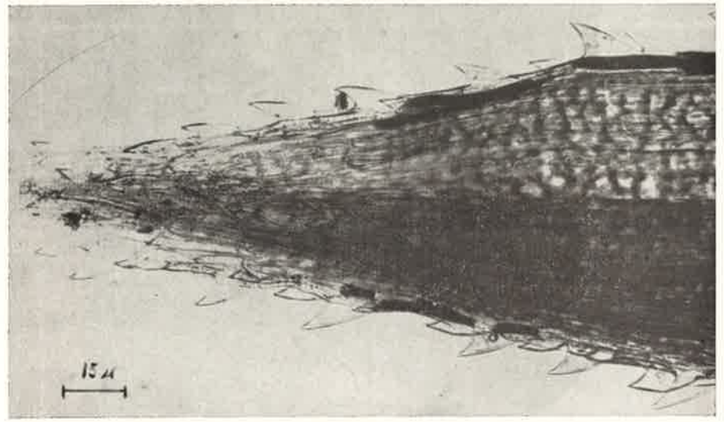


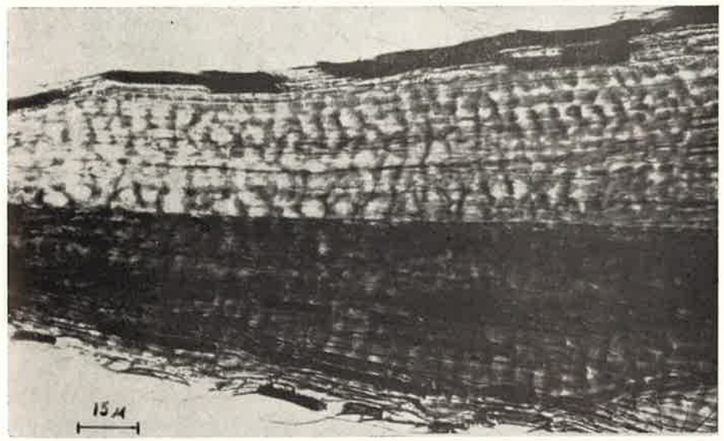
Fig. 4. Damages Zones in the Leaf Tip of Natural-Whole Orchard Grass:
(A) Brown, Severe Damage Zone.
(B) Dark Green, Transition Zone.
(C) Natural Active Tip Section.

Turning now to the optical microscopic investigations of the damaged plants, the transition zones in a typical active orchard grass leaf are shown in the photomicrograph of Fig. 4. Plate I also shows a lactophenol cotton blue stained whole-leaf section which has just begun to show burning. It will be observed that the tip appears to be torn out, and that definite cell structure is not apparent in the tip region; but becomes increasingly intact in the regions further from the damaged tip.

The sequence of transverse sections shown in the photomicrographs of Plate II and III display rather clearly the cell destruction involved. It will be observed that at the extreme tip regions, the secmediate surface area has been destroyed



A



B

PLATE I Lactophenol Cotton Blue Stained Whole Leaf of Orchard Grass

(A) Tip Area Showing "Tearing Out" of Material and Absence of Structure

(B) Continuation of Tip Area Progressing Into The Natural Tip Section. Structural Order is Apparent.

A

B

C

D

PLATE II Safranin-Fast Green Stained Sections (10 microns) Showing Damage Sequence in a Typical Orchard Grass Active Leaf.

(A) Control Section.

(B) Extreme Tip-Brown Damage Zone (complete epidermal absence).

(C) Brown Damage Zone Furher From The Tip (dead matter agglomerated).

(D) Boundary Section Near Dark Green Zone.

E

F

G

H

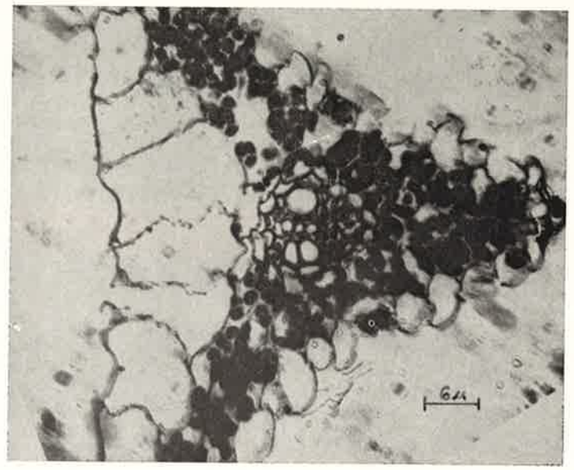
PLATE III Safranin-Fast Green Stained Sections (10 microns) Showing Damage Sequence in a Typical Orchard Grass Active Leaf. PLATE II, continued).

(E) Dark Green Zone Section.

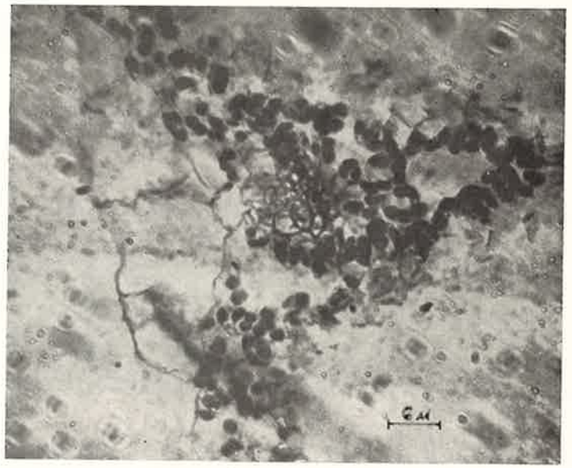
(F) Transition Zone Between Dark Green Area and Natural Leaf.

(G) Normal Active Leaf Section Below Dark Green Zone.

(H) Control Section.



A



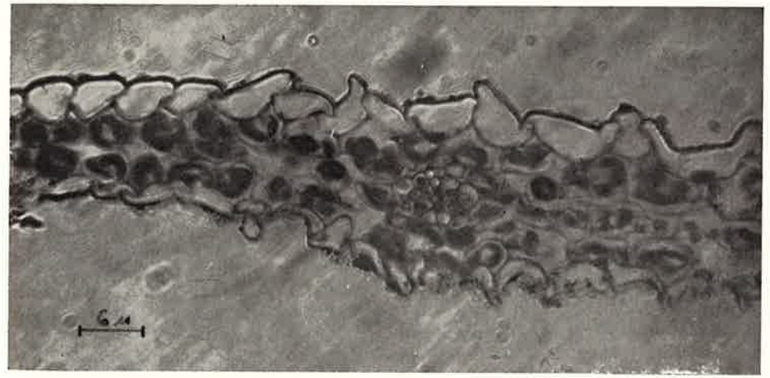
B

PLATE IV Comparison of Electric Potential Damage in Control and Active Orchard Grass Plants — Transverse Sections.

(A) Control Section.

(B) Active Section Showing Epidermal Destruction and Internal Damage.

A



B

PLATE V Comparison of Electric Potential Damage in Control and Active Orchard Grass Plants — Outer Section.

(A) Control Section.

(B) Active Section Showing Structural Voids and Epidermal Damage.

tions are completely devoid of the epidermis, and the internal cell structure has apparently agglomerated into masses of dead matter. As the sequence progresses away from the damaged areas, the epidermal cells appear, but not intact. Because of the apparent destruction of the epidermis about the entire periphery of many sections, the possibility of microtome damage may be eliminated. Another interesting feature displayed in the photomicrograph sequence in Plates II and III is that the sections in the vacinity of the dark green zone appear to have many void areas appear in these sections; especially where the epidermis in the imor disturbed appreciably.

In the high magnification photomicrographs of Plates IV and V, the destruction of the epidermal cells and the cuticle are most apparent. Large voids appear in the cell symmetry, and the chloroplasts appear to have been disturbed within the cellular configurations. Destruction of presence of destructive accumulations individual internal cell structures or the within the cell walls is not apparent from the photomicrographs.

It may certainly be stated from the dry-weight analysis and on the basis of the microscopic analysis presented that the plants of orchard grass are destroyed by a potential gradient of sufficient magnitude. The mechanism of destruction, considering the microscopic evidence, seems to be rooted in the destruction of the epidermal cells. Destruction of the epidermal cells would logically account for the appearance of the sections in Plate II in the severely damaged zone by allowing dehydration of the protoplasm to occur, and thereby cause destruction of cell structure and agglomeration of dead tissue matter.

Several possible theoretical approaches may be taken to explain the destructive action of the electric field on the epidermal cells, but the approach which seems most logical, and which will be proposed here, is an osmotic avalanche process. In this process, polarized salts present in the leaf are concentrated about the leaf periphery (in the epidermal cells) by the action of the potential field. As the critical burning potential is reached, and as the plant height corresponds to the critical burning ratio, large osmotic pressures created by the polarization action and the concentrated salts, force large quantities of water into the epidermal cells. Thus, as the intensity of polarization increases, the water in teh epidermis exerts an outward pressure on the cell walls until the elastic limit is exceeded, and the cell wall bursts. The appearance of the epidermal cells in practically all of the photomicrographs showing severe damage and the transition to this severe damage tend to suggest a bursting has indeed occurred. Once the cell wall has burst, polarized water would then stream to the anode plate aided by the electric field force and evaporational phenomena, and the leaf would soon dehydrate itself as the process is accelerated all around the tip periphery. Such a streaming of polarized water has been observed visually when the active plot was watered, and tiny water dropplets were created by splashing.

CONCLUSIONS

It has been definitely established in this paper that plants grown in sufficiently high potential gradient fields may be destroyed dcompletely, or greatly inhibited in growth by the initiation of a leaf-tip burning. Microscopic analysis of the disturbed leaf areas has revealed a very apparent destruction of the epidermis and consequent destruction of internal cell structure. The mechanism proposed for this epidermal destruction is based on a polarization phenomenon which initiates osmotic water migration to the epidermal cells in proportions which cause these cells to burst, and allowing subsequent dehydration of the internal protoplasmic material.

The proposed theory of leaf destruction will be further substantiated by subsequent investigations involving a chemical analysis of the defective tip regions, and studies involving the comparison of active and control plant-tip hydration levels. A detailed investigation involving the electronic and mathematical boundary properties relevant to an understanding of the physical properties of the system has been completed; and a detailed report of the results of this work will appear elsewhere in the literature.

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STREAM PLANKTON ABOVE AND BELOW GREEN LANE RESERVOIR*

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ABSTRACT

Stream plankton was studied above and below Green Lane Reservoir during the month of September 1691 when the impoundment was thermally stratified. Distinctly different plankton populations were found to exist above and below the impoundment, the former being predominantly diatoms and green algae while the latter was largely anaerobic bacteria derived from the hypolimnion and moribund diatoms and blue-green algae from the epilimnion. Simple enumeration of organisms suggests a richer plankton population below the reservoir than above it, both numerically and in terms of volume of protoplasm per unit of water volume, while a more critical analysis leads to the conclusion that most of the plankton below the dam is not a viable population but a contribution in the order of one part per million to the stream's load of decomposable organic debris.

Man's activities have resulted in many physical and biological changes in his environment, not the least of which are changes in rivers and streams. A number of published reports attest to the rising concern over this fact, and in 1960 a National Conference was held in Washington to discuss the problems of water pollution.

Creation of artificial impoundments in a river system is one activity which could change the ecology of downstream areas, for lentic environments with their high plankton production, thermal stratification and seasonal turnovers, heat storage and other distinctive biological and limnological characteristics are being interjected into lotic systems which have their own distinctive features. It has been recognized that lentic environments do alter certain aspects of downstream lotic environments, particularly the plankton. Kofoid (1903, 1908) stated that impoundments and backwater areas are important sources of Illinois River plankton. Blum (1956), who did an extensive literature survey, discusses the origin of river plankton in general, and considers impoundments to be one important supply. Hartman and Himes (1961) have studied the plankton of the Shenango River below Pymatuning Reservoir and have concluded that close to the dam the population structure is typical of the plankton of the impoundment. Several studies have been made of the fate of lake or reservoir plankton in the outlet stream (Chandler 1937, 1939; Reif 1939; Hartman and Himes 1961) with the general consensus that there is a decrease in numbers of organisms with distance below the outlet. No careful simultaneous studies have been made, however, of the lotic environments above and below artificial impoundments to determine to what extent the new body of water is altering the interrupted stream.

An additional aspect of the overall problem of impoundment effects upon stream systems is the construction of dams with deep-water releases. This is a type of discharge not found in naturally occurring lakes, and should attract the attention both of biologists and organizations concerned with water quality. Although not explicitly stated, the plankton studied by Hartman and his co-workers below Pymatuning Reservoir was apparently derived from surface waters as in the outlet of a natural lake.

This report is part of an extended survey of the effects of Green Lane Reservoir upon the microbiology of Perkiomen Creek, and presents a comparison of plankton populations above and below the reservoir for a representative date in September 1961 when the impoundment was in a state of thermal stratification. Green Lane Reservoir, built and operated by the Philadelphia Suburban Water Company, is located at the junction of the Main and Northwest Branches of Perkiomen Creek in Montgomery County, Pennsylvania. The impoundment occupies a total of 816 acres, with a shoreline of approximately 18 miles and a length of about 6 miles. The bottom topography is varied, with a maximum depth of 65 feet at the dam. Discharge, except for surface overflow in times of high water, is through controlled gates at a depth of 55 feet from the dam crest. In the period studied, discharge was in the range of 20 to 24 million gallons per day. The flow of the Northwest Branch was approximately 6 to 7 cubic feet per second, and of the Main Branch, 13 to 15 cubic feet per second. Unpublished reports of limnological surveys of the reservoir indicate that a thermocline generally exists throughout late summer and early fall.

* This paper was awarded the 1963 Darbaker Prize.

METHODS AND PROCEDURES

Collections were made at two stations, the first in the Northwest Branch one quarter mile above the reservoir and the second in the stream immediately below the dam. Water samples for plankton analysis were taken in glass jars and fixed in the field with a chromium trioxide-acetic acid-ethyl alcohol fixative (Lavdowsky's 1894c formula from Gray 1954). Upon return to the laboratory the organisms and other suspended solids were concentrated on a size HA Millipore membrane filter (pore diameter O.45 ± .02 microns). By adapting standard histological techniques to the filterpad with appropriate precautions against loss of organisms, permanent slide mounts were prepared. Plankters were tallied using a Leitz "Ortholux" microscope (magnification at the camera lucida drawing board of up to 4,000 diameters) and identified to species whenever possible using standard keys (Smith 1950, Tiffany and Britton 1952). Organisms not identifiable by this means were designated by reference to detailed camera lucida drawings made the first time they were encountered. The dimensions of a representative number of individuals of each species were measured and the average volume of each species calculated.

OBSERVATIONS AND DISCUSSION

Distinctly different plankton populations were observed above and below the reservoir (see Table 1). At the Northwest branch, diatoms (Bacillariophyceae) were the most conspicuous members of the population, accounting for 64% of the total volume. Five genera, *Cyclotella, Cocconeis, Navicula, Nitzschia* and *Acnanthes* occurred in numbers greater than ten per milliliter. Unicellular green algae (CHLOROPHYCEAE) were abundant and contributed 33% of the volume. Bacteria were the most numerous single group of organisms, but amounted to somewhat less than 4% of the total volume. A few amoeboid cells were found, either protozoans or amoeboid zoospores whose volume was insignificant. The total population was approximately 10,000 cells per milliliter and their volume totaled about 230,000 cubic microns.

Below the dam, the plankton was characterized by a bacterial population of greater than 300,000 cells per milliliter, apparently derived from the hypolimnion within the reservoir. Genera typical of anaerobic environments such as *Thiopedia, Thiothrix,* and *Methanobacterium* were recognized along with other forms whose morphologies resemble bacteria reported from lake hypolim-

PLANKTON IN THE PERKIOMEN CREEK, SEPT. 28, 1961

	ORGANISMS	NORTHWEST BRANCH				BELOW RESERVOIR			
		Number per ml.	Volume	% total Volume		Number per ml.	Volume	% total Volume	
CONSUMERS									
PROTOZOA	Ciliates								
	Amoeboid unicells	5	625	0.3		3	800	< 0.1	
						35	4,375	0.9	
BACTERIA	Bacteria (all)	8,846	8,846	3.8		317,480	500,580	62.2	
	Thiopedia					85,725	85,725	10.6	
	Methanobacterium					16,575	107,738	13.4	
	Bacterium A					2,646	79,380	9.9	
	Bacterium B					214	7,276	0.9	
	Thiothrix tenuis					277	5,540	0.7	
	Thiothrix nivea					39	3,120	0.4	
PRODUCERS									
BLUE-GREEN ALGAE	Coelosphaerium					18	212,400	26.6	
DIATOMS	Achnanthes minutissima	26	1,560	0.7		*			
	Cocconeis placentula	12	49,400	21.5					
	Cyclotella operculata	16	4,800	2.8					
	Cyclotella glomerulata					*			
	Cymbella tumida	3	3,000	1.4					
	Gomphonema sp.					*			
	Melosira italica					*			
	Navicula tuscula	66	52,800	22.9		*			
	Nitzschia palea	83	33,200	14.4					
	Nitzschia sp.					*			
	Stephanodiscus astraea var. minutula					80	8,800	1.9	
	Synedra Acus					26	78,000	9.7	
GREEN ALGAE	Algal Unicell #1	112	15,680	6.8					
	Algal Unicell #2	1,115	11,146	4.8					
	Closterium parvulum	54	49,500	21.5					
	TOTALS	10,339	230,557			317,680	805,160		

* Rare

nia. This group made up the majority of the volume of protoplasm in the water —62%. A relatively small number of diatoms, mainly *Stephanodiscus* and *Synedra* (12% of total volume) and the blue-green alga *Coelosphaerium* (27%), which were abundant in the epilimnion of the reservoir, were found. Although not occurring in great numbers, they contributed about three-eighths of the total volume of protoplasm per milliliter of water. It is perhaps possible that these organisms were drawn into the discharge openings by currents initiated by the force of the outflow. This explanation is suggested by temperature recordings made by the water company at the upstream side of the dam which indicate a lowering of the thermocline near the discharge. It is more likely, however, that the presence of these epilimnionic forms is the result of natural settling from the epilimnion into deeper water, since most of the diatom cells showed extensive cytoplasmic contraction indicating a moribund condition. Such a condition would result either from the settling of cells which were dying in the epilimnion or from the prolonged exposure of originally healthy cells to the adverse conditions of the hypolimnion. It probably would not be seen in the majority of cells drawn quickly from the surface waters.

Rare individuals of *Nitzschia, Navicula, Gomphonema, Melosira* and *Acanthes* were encountered below the dam. They were too few in number to enumerate other than collectively (38 cells per ml.) and they were most likely derived from the periphyton of the pool below the spillway from which the samples were taken. There were a total of 317,680 cells per milliliter of water below the reservoir discharge having 805,160 cubic microns of protoplasm.

Comparing the plankton populations of the two stream locations quantitatively, there was a greater number of individuals and a greater total volume of protoplasm per unit of water volume below the reservoir than above it. This simple enumeration of organisms agrees with the results of the studies cited above concerned with outlet water from lakes and reservoirs, but a more critical analysis in terms of the types of microorganisms present is required before any inference can be made regarding the significance of this agreement.

In the case of the Northwest Branch plankton we find organisms in their natural habitat and exhibiting no cytoplasmic contraction. Although there is some disagreement among investigators over the exact origin of stream plankton and over the ability of primarily attached forms to reproduce actively in a planktonic existence there is little doubt that the plankton is a metabolically active segment of the stream biota and that photosynthesis and respiration are undergone by the majority of the phytoplankters.

The situation is entirely different below the dam. Here we have found a large percentage of the plankton population, both in terms of numbers of organisms and volume of protoplasm, to be composed of anaerobic bacteria for which the stream environment is highly unsuitable. Therefore the bulk of the population can be considered to be so much organic detritus rather than functional organisms. Taking this into consideration, and recognizing that most of the diatoms counted were in a moribund condition and unlikely to resume life functions, the living plankton close to the dam is actually much less abundant than that found above the reservoir, being composed mostly of diatoms derived from the streambed below the discharge. In contrast to the results of Hartman and Himes, who found in their situation an abundant plankton population below the

dam and an overall decrease in plankton organisms with distance downstream, it appears that an increase in viable plankters should be found here. This increase would correspond to the increase in diatoms which they reported for the Shenango River. This possibility is presently being investigated.

The bacterial cells and moribund diatoms, although not existing below the dam as functional organisms, remain important as a source of organic enrichment for the stream, an enrichment of nearly one part per million. This is in addition to enrichment by other detritus and dissolved organic matter from the reservoir which was not studied. Decomposable organic debris from both of these sources is absent in the water of the stream above the reservoir. Its presence below is undoubtedly a significant factor affecting the ecology of downstream areas.

SUMMARY AND CONCLUSIONS

The plankton population in a stream one fourth mile above an impoundment was found to be distinctly different from that immediately below the dam, at a time when release of water was entirely from the hypolimnion of the reservoir.

The population collected at the upstream location is composed chiefly of diatoms and green algae, while the population below is largely anaerobic bacteria from the hypolimnion, with a few moribund plasmolysed individuals belonging to species typical of the epilimnion.

Both numbers and volumes of organisms are greater in the plankton below the dam than in the stream above the impoundment.

Most of the population encountered below the dam is unsuited to the lotic environment, and may therefore be considered as a contribution (in the order of one part per million) to the decomposable organic debris in the stream.

Normal diatoms and green algae have been virtually eliminated from the plankton in the vicinity of the discharge from the reservoir.

ACKNOWLEDGMENTS

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ISOLATION AND CHARACTERIZATION OF CERTAIN INSECT SECRETIONS

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ABSTRACT

Food insects, existent already in early ages, have found fertile breeding grounds in certain modern food industries. As a consequence, some of man's foodstuffs are contaminated with considerable amounts of insect debris. The problem has generally been recognized in terms of its aesthetic damage. This view is presently extended to include consideration of possible harmful effects of the beetle contaminants. Most insects of stored food secrete pungent fluids of benzoquinones, i.e., well-known toxic chemicals.

A method for the isolation of the quinones is described. It comprises freeze-killing and high-speed homogenizing of the beetles in cooled isopentane. The active material is recovered by controlled sublimation. Polarographic analysis shows that the method is quantitative and supplies substantially pure quinone.

Quinones thus obtained from flour beetles **Triboluim** have conspicious effects: (a) The growth of **Microsporum gypseum** accelerates in the presence of minute quantities (10^{-5} M) of the secretion; larger amounts of the material (10^{-3} M) block the development of the fungus; (b) Exploratory studies indicate that the beetle quinones provoke malignant lesions in rats; (c) Applied to immature stages of **Tribolium,** the fluids produce monstrous deformities in the emerging adult insects.

INTRODUCTION

In a recent survey on food pests in California (Strong and Okumura, 1958), beetles of the *Tribolium* spp. were found on: barley, corn, oats, rice, rye, wheat, flours, and breakfast cereals; beans, peas, potatoes; also: raisins, almonds, pecans, and walnuts; as well as powdered milk, candy, and beet pulp. The U. S. Department of Agriculture had somewhat earlier estimated that in one Midwestern State farmers were giving 380 billion insects (i.e.: 680 tons, or 1,900 cubic meters) "free board and lodging in their grain bins" (Haeussler, 1952). With an analytical procedure developed in 1952, these beetle remains were determined in: new wheat, 20 p.p.m.; cake flour, 45 p.p.m.; bakers' patent flour, 66 to 80 p.p.m.; and low grade flour, 129 p.p.m. The number of insect fragments ranged from 2 to 30 per 50-gram sample (Potter and Shellenberger, 1952). Current worldwide losses in stored food to insects are equivalent to the quantity required to feed 130 million people, and the true extent of these losses is often obscured by the retention of large quantities of insect remains and excrements by the infested commodities (Parkin, 1959).

In full recognition of the pest damage on foods, several casual remarks have been published as to the impropriety, but otherwise assumed innocuousness of insect fragments and secreta in consumer foods (Mills and Pepper, 1939; Kay, 1953; Hearings, 1953). However, the secreta which are discharged by the beetles as glandular liquids consist mainly of ethyl- and methyl-p-benzoquinone (Loconti and Roth, 1953). It may be well to recall that these chemicals have been reported to be bactericidal, fungistatic, spermicidal, acutely and subacutely toxic to animal and man, also: enzyme-inhibiting, antimitotic, mutagenic, and carcinogenic (Hoffmann-Ostenhof, 1947; Seifter, 1948). All these conclusions have been drawn from work with the synthetic compounds. Presently described test cases with the beetle secre-

tion indicate that the biological activity of the naturally derived quinones is just as impressive.

The scope of the problem is illuminated by the knowledge that has been rapidly accumulating on a great variety of quinonesecreting food-born insects, including certain common roaches (Moreau, 1932; Thomson, 1957; Roth and Stay, 1958; Schildknecht and Weis, 1960). Their secretions are almost identical. Conversely, the depth of the case comes into view from this study, which deals with the most familiar of the beetles, namely the *Tribolium* spp. These species have reached enormous population densities on cereals prior to World War II. They amounted to 97.1 percent of all the insects counted on infested flour which was taken from typical wheat processing mills (Good, 1937). Half-pound samples, collected from each individual milling stream, contained on the average 31.3 beetles, and some of them harbored up to 1,320 insects each. In comparison, 425 beetles were counted on the average in 1-pint samples of milled rice which came from four mills along the Gulf coast (Balzer and Cotton, 1947).

The secretion is rather difficult to isolate in quantity. An efficient method of isolation, that has made these investigations possible, will be described forthwith.

METHOD OF ISOLATION

Fifty thousand insects *Tribolium confusum* were raised, collected, and freeze-killed (Ladisch and McQue, 1953). After adding 100 ml. loose cellulose powder (Whatman, for chromatographic analysis) and 500 ml. pure-grade isopentane (Phillip's Petroleum Co.), the mixture was homogenized in an electrical blender at dry-ice temperature for two minutes. The sludge was allowed to settle. The supernatant and three subsequent isopentane extracts of the sediment were drawn, under suction, through a ¾ in. thick layer of anhydrous Na_2So_4 in a glass-fritted 500 ml. Buchner funnel. The filtrate was concentrated to a volume of 100 ml., *in vacuo* at 30°C. Cooled in an ethanolic dry-ice bath, the concentrate became a yellow paste into which 125 ml. cellulose powder were stirred. The remaining isopentane, except for a small quantity, could be removed from the paste under oil-pump vacuum, at a temperature not exceeding 10°C. The substantially dry and now loose powder was transferred to the sublimation apparatus shown in Fig. 1.

The apparatus consists of thermostated compartment (1) and condenser (2). The powder is placed into space (5), above glass wool filling space (4).

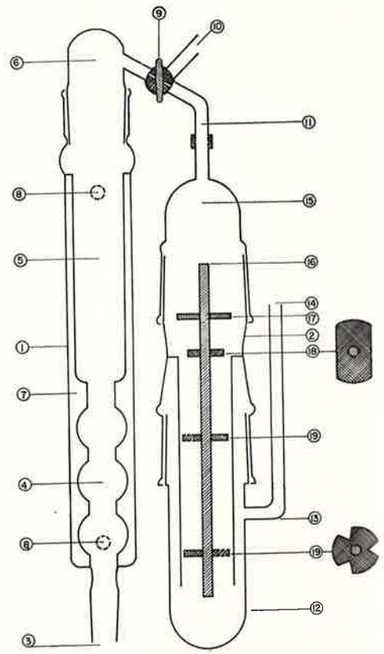

Fig. 1. Sublimation Apparatus. Drawn to scale. Overall height is 20 inch. nat. size.

Water circulates through jacket (7) with conectors (8), at 30°C for the first 18 hours of operation, and at 40°C for two additional hours, if necessary (*vide infra*). A gentle stream of air—having been passed through a column of anhydr. $CaCl_2$, a wash bottle containing conc. H_2SO_4, and a dry-ice cooled trap —enters at (3). The air carries volatile matter from the powder in space (5) to open space (6) and stopcock (9). Within the first half hour, residual isopentane is driven off from the powder. It is passed through outlet (10) and a cold trap (not shown), to be discarded. When the transfer of isopentane has ceased, stopcock (9) is turned to connect space (6) with tube (11).

Condenser (2) is positioned within a Dewar flask (not shown), whose open end coincides with the height level designated by numeral 15. Ethanolic dry-ice mixture fills the lower part of the flask to the height designated by numeral 13. At height (15), glass wool seals the open space between condenser (2) and the flask. Thus, a gradient is set up in the condenser bettween these temperatures: at the inlet (11) of the air, and the freezing mixture in the bottom of the flask. This feature combined with the device consisting of glass rod (16) and rubber baffles (17), (18), and (19) facilitates the isolation of the quinone in long yellow crystals. Rubber baffles (17) and (18) have identical size and shape, but they are turned perpendicular to each other. It will be noted that the stream of air entering through tube (11) is forced to flow through the bottom part of the condenser, leaving the latter at sidearm and opening (14).

In operation, the column of powder in space (5) becomes colorless, at its lower end within 2 hours, and over its entire length usually within 18 hours. Should the top of the column by that time have retained a trace of color, raising the temperature of the circulating water to 40°C will complete the sublimation of the quinone.

POLAROGRAPHIC EVALUATION OF THE ISOLATED MATERIAL

Polarographic analysis of the isolated quinone furnishes this information: (a) the half-wave potential as a qualitative index in comparison with the known half-wave potential of synth. ethyl-:methyl-p-benzoquinone; (b) the nature of the electrode process, i.e., a partially anodic current would disclose the presence of hydroquinone; (c) the height of the diffusion current as a measure of yield.

The present case can be fully interpreted with the data presented in Table I and Fig. 2. The results show: The half-wave potentials of all substances are identical within the limits of experimental error. None of the samples contains more than a trace of hydroquinone. The diffusion currents of the natural pro-

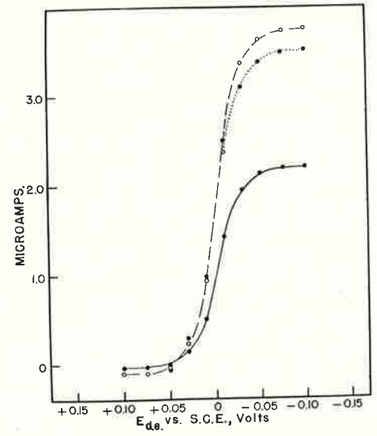

Fig. 2. Polarogram of Insect Quinone isolated from Flour Beetles **Tribolium confusum.** Full line: collected crystals, sample A. broken line: crystalline material recovered from walls of condenser, sample B; dots: isopentane extract, sample C. Consult text and Table 1.

Table 1. Method of Isolating Insect Quinone, Polarographic Evaluation

Synthetic ethylquinone prepared according to Ladisch, 1958. Methyl-p-benzoquinone: high-purity grade (Distillation Products). Sargent Model III Polarograph and Leeds and Northrup (or Fisher Scientific) Polarotron. Capillary: 4.55 sec., 1.47 mg./sec. Nitrogen: 99% pure, tank. Temp.: 25±0.05 °C. All samples in aqueous buffer contg. 0.05 M each NaH_2PO_4 and Na_2HPO_4. PH 6.65. All data corrected for iR. Internal cell resistance: 400 ohms.

Sample No.	Test substance	Dilution	Half-wave potential mv. vs. S.C.E.	Diffusion current μa	Yield mgs.
—	Synth. Quinone Mixture 80;20 ethyl:methyl-Quinone, by weight	133 mgs./1tr. (1 millimol.)	0	5.75	
A	Crystalline material collected in condenser	50 mgs./1tr.	1	2.14(1)	330
B	Crystalline material recovered from walls of condenser	Entire amount in 800 ml. test solution	1	3.86	72(2)
C	Original isopentane extract, 470 ml	50 ml. extract/ 500 ml. test solution	1	3.62	400(2,3)

(1) Equals 5.69 microamps. for 133 mgs./1tr. (2) Based on results from sample A. (3) Total yield from 20,000 beetles was 520 ml. extract, or 442 mgs. quinone; 50 ml. used for analysis (42 mgs. quinone). This amount does not appear in samples A and B.

duct, 5.69 microamps., and the synthetic quinones, 5.75 microamps., are in excellent agreement (133 mgs./1tr.) The amount of 400 mgs. quinone found in the original isopentane extract, sample C, is carried without loss through the entire described procedure, as 402 mgs. were recovered (samples A plus B). The yield from 20,000 beetles was 442 mgs. quinone, or 22 micrograms per insect.

BIOLOGICAL ACTIVITY OF BEETLE SECRETION

EFFECTS ON THE GROWTH OF MICROSPORUM GYPSEUM

Two quinonoid SH-conjugates were chosen to appraise their possible influence on the growth of *Microsporum gypseum*: (A) synth. ethylquinone (Ladisch, 1958): L-cysteine, free base (Nutritional Biochemicals Corp.), molar ratio 1:1; (B) insect-quinone: Cysteine, 1:1 M. Both are colorless, water-soluble crystals. The compounds were added to conventional growth media, in separate duplicate series at the concentrations shown in Fig. 3. Additional cysteine was introduced to make the total concentration of cysteine, free and bound, 1 millimolar in each medium. Inoculum *Microsporum gypseum* (PQMD 196) was: 200 spores, 9 days old, per microliter; 1 ml. per 40 ml. medium. Controls, otherwise of the same composition, did not contain conjugate. Culturing (30°C for 12 days on a reciprocal shaker), harvesting, and weighing were done as usual.

The results, Fig. 3, show a growth promoting effect on the fungus with 10^{-5} molar concentrations of both conjugates, but complete inhibition at 10^{-3} M. Concentration-dependent stimulatory and inhibitory effects of p-benzoquinone have been seen before in yeast, several bacteria, and the activity of desoxyribonucleinase (Hoffman-Ostenhof et al., 1949, 1952).

CARCINOGENIC EFFECTS

Certain observations on the carcinogenic activity of the insect quinones have been published (Ladisch, Dreizen, and Spies, 1953). For added detail, results are now reported relative to twelve Long-Evans rats, each of which received 7 subcutaneous injections of 5 mgs. insect quinone (total dose 35 mgs.) The injections, given in physiologic saline solution, were spaced two months apart. Necropsy findings: Numerous nodules, in diameter from 2 to 20 mm, were found in the abdominal cavity, i.e. in the mesenteries and greater and lesser omentums of the stomach and the substance of the liver (Fig. 4). Microscopically, the nodules were comprised of endotheloid cells with a very high degree of mitotic activity. The liver sinusoids were infiltrated with such cells (Fig. 5). Of the twelve animals, five developed these lesions. All rats either died before, or were sacrificed at the end of 110 weeks of age.

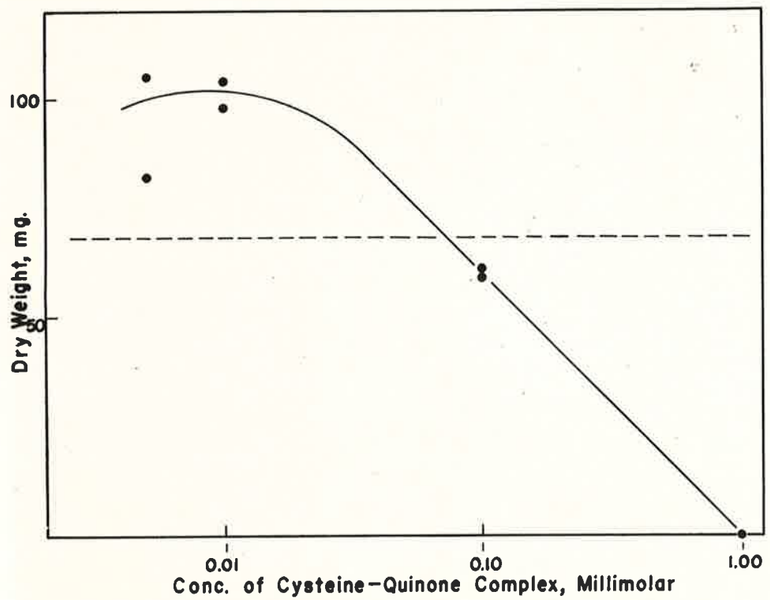

Fig. 3. Growth of **Microsporum gypseum** in the presence of quinone: cysteine conjugate. See text. Broken line: average growth in control media not containing conjugate.

In a further exploratory test (Druckrey, 1958), groups of four young rats each were given these conjugates in the laboratory diet during the initial 80 days:

A leukemia with extensive infiltrates of the liver and the spleen developed in group CN two years after the test was begun. In group AR I, a leukemia, likewise with infiltrates of the spleen, appeared after 860 days. Another animal in this group had a (probably spontaneous) fibro-adenoma. No tumors were observed in group AR II with the lowest dose of 320 mgs. conjugated insect quinone per animal. It seems noteworthy that 2 leukemias- generally of rare occurrence in rats—developed among the 8 animals which had ingested 700 and 1,100 mgs. respectively, of the insect quinone conjugates.

The possible carcinogenicity of these insect benzoquinones, as indicated, may

be viewed in the light of published data on: the carcinogenic action of synth. p-benzoquinone on mice (Takizawa, 1940; Takizawa and Sugischita, 1949; Sugischita, 1950; Hirai and Takizawa, 1951); p-benzoquinone as a potentially carcinogenic principle in the dye "butter yellow" (Potter, 1942; Kuhn and Bein-

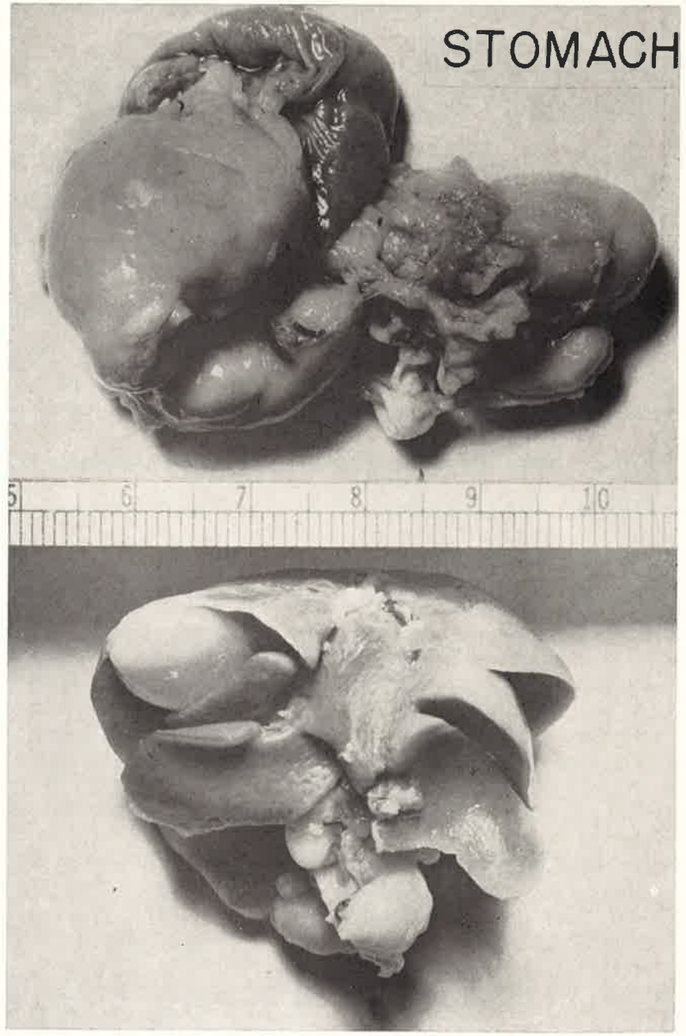

Fig. 4. Tumors in stomach and liver of rat injected with glandular quinones from flour beetles Tribolium. Rat died at 93 weeks of age. Scale, in cm, refers to size of liver.

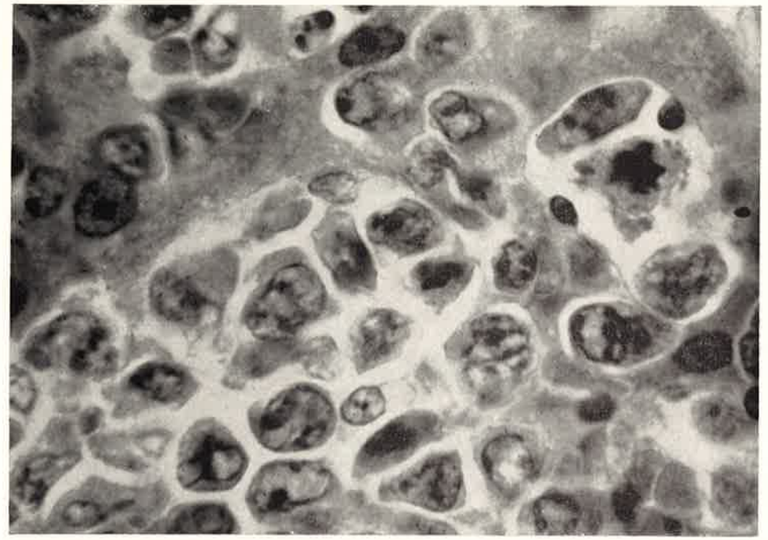

Fig. 5. Liver sinusoids infiltrated with endotheloid cells having high degree of mitotic activity. Liver is of rat injected with insect quinone.

ert, 1943); and the role of benzoquinones in allergy and carcinogenesis (Mayer, 1950). The concept of Quinone Cancer in relation to food insects has been discussed earlier (Ladisch, 1953).

MONSTROUS DEFORMITIES IN TRIBOLIUM

Twenty 6th instar larvae of *Tribolium confusum* were topically treated as described by Roth and Howland, 1941, but with insect-quinone: cysteine conjugate B (*vide intra*) in saturated aqueous solution. Only ten survived, and in three of the emerging adult beetles legs were malformed or missing (Fig. 6). Twenty control larvae, not having received the test compound, developed normally.

This result would further seem to implicate cysteine-bound insect secretion as a toxic substance with the power of producing interesting biological aberrations. The insect quinones *per se,* when applied to immature stages of *Tribolium,* have a very remarkable capability of provoking monstrous deformities in the emerging adults, e.g. beetles with duplicated and

		Molar ratio	Total Dose, gr. Conjugate	Quinone
CN	Cysteine: quinone	1:1	2.25	1.10
ARI	Arginine: quinone	1:1	1.75	0.70
ARII	Arginine: quinone	2:1	1.57	0.32

Quinone used in these conjugates was isolated from *Tribolium confusum.*

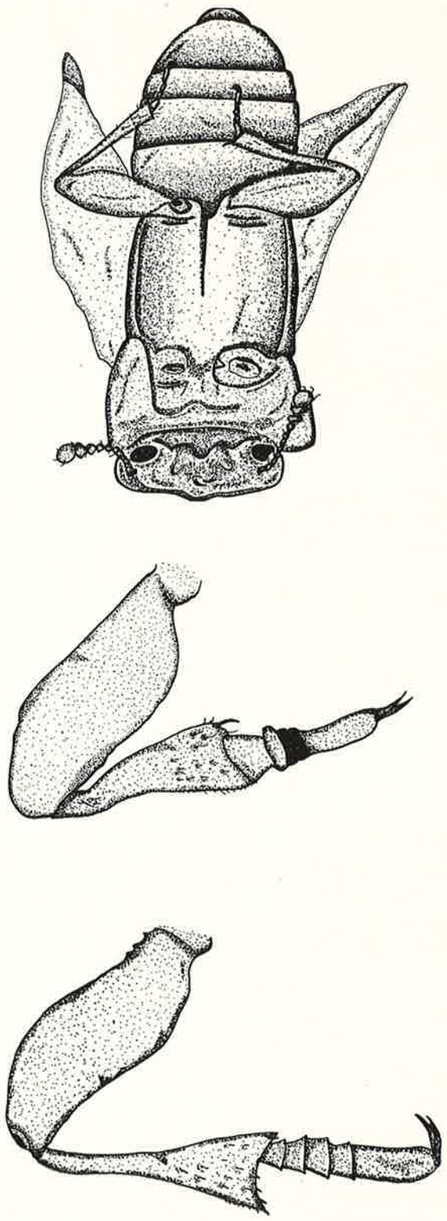

Fig. 6. Deformities in beetles **Tribolium confusum.** Left to right: Normally developed leg in untreated control animal. Leg with fused segments. Beetle lacking four legs. Deformed specimens emerged from larvae topically treated with insect-quinone: cysteine conjugate.

triplicated legs, branched antennae, or the omission of entire body parts (Roth and Howland, 1941). The p-benzoquinone- induced formation of viable monsters in *Paracentratus lividus* (Druckrey, 1953) at a 10^{-5} M concentration of the quinone is likewise impressive.

CONCLUSION

It would seem that quinone-secreting insect infestants are commonplace to a certain extent in the grain-milling machinery (Dyte, 1961; Cotton, 1962) and in many stored food items (Strong and Okumura, 1958). Heavy insect pest damage is known to occur during long-term storage (Grain Storage Newsletters, 1959 to 1962) and long-distance transport (Cotton 1960; Turtle, 1961) of bulk commodities. It has also been recognized that quinone-secreting beetles, wherever they are allowed to thrive on food, invariably deposit these reactive chemicals which are then absorbed by and firmly bound to the food proteins (Payne, 1925; Alexander and Barton, 1943; Ladisch, 1958). Ordinarily, the detection of this type of contamination is difficult. Wheat flour which has taken up the beetle quinones may still look normal, though its baking qualities are already impaired (Payne, 1925). These facts appear worth considering in view of the possible harmful effects that have been presently discussed in relation to the insect secreta and that have been well demonstrated years ago for chemically identical synthetic quinones.

ACKNOWLEDGMENT

I express my gratitude to Prof. Dr. Hermann Druckrey, Chirurgische Universitatetsklinik, Freiburg-Germany, for having undertaken the exploratory feeding test with insect-quinone conjugates. With special thanks, I remember the kind cooperation given in this project by the late Dr. Tom D. Spies, and Dr. Samuel Dreizen, both of the Northwestern University Medical School. Thanks are due to Mr. Bernard McQue for his valuable contributions to the development of the method for isolating insect quinones, and to Dr. G. Mandels, Miss Anne Norton, and Mr. P. Bernhardt of the U. S. Quartermaster Pioneering Research Division, for advice and assistance in certain phases of the work.

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TOXICITY OF INSECT QUINONES TO MICE

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ABSTRACT

Insects, **Tribolium,** common infestants of foods, secrete a glandular liquid mixture of p-ethyl:toluquinone. Commerial diet contaminated with 1000 p.p.m. of the quinone kills mice feeding on it within 4 to 8 days; food incorporating 500 p.p.m. of the substance is likewise lethal, within 1 to 13 weeks. Necrospy shows that most of the animals have dark-red lungs and black stained livers. Lung tissues taken from freshly killed control mice become deep red upon standing in 0.05 M aqueous solution of the quinone for 15 days. Liver tissues are black after the same treatment.

The insect secretion reacts avidly with animo acids forming intensely colored conjugates. The conjugates are related to coal tar dyes. They dye lamb's wool in a variety of colors. The quinones coupled to proline and glutamic acid respectively, are lethal to mice when administered at a level of 90 micrograms per gram of body weight.

Laboratory mice, painted on the dorsal skin with 5 mgs. of the quinones per animal per week, on the average succumb after the second or third application. The lungs and livers of these animals are deeply stained.

Of the 79 experimental mice treated with the quinones as specified, three have survived.

INTRODUCTION

The generally antibiotic and toxic qualities of simple p-benzoquinones, including ethyl- and toluquinone, are well known (Geiger, 1946; Hoffman-Ostenhof, 1947; Frimmer, 1960). These quinones may be more conveniently classified as Hydroquinone-Quinone-Systems, since administered *in vivo* they are quickly reduced in part to hydroquinones. The hydroquinones, in turn, are prone to re-oxidation to the quinones. (Seifter, 1948). *In vitro* reactions between the quinones and proteineous matter likewise produce in part hydroquinones (Fischer and Schrader, 1910). The acute LD_{50} of such hydroquinone-quinone-systems for animals covers the range from 50 to 300 mgs./kg. of body weight; sub-acute poisoning by these systems in man is characterized by jaundice, anemia, hemoglobinuria and cachexia (Seifter, 1948). Hydroquinone, formerly proposed as an antioxidant in foods, is no longer tolerated as a food additive as it is considered poisonous and deleterious.

Against this background, it appears noteworthy that many foodstuffs, particularly man's staple foods, are subject to natural contamination with small amounts of ethyl-and toluquinone (Loconti and Roth, 1953). The quinones are secreted by various food insect pests of which grain insects of the *Tribolium spp.* are the most prominent (Good, 1937). Such beetles, by their astronomical numbers, have become a worldwide problem in the storage and processing of foods (Dobrovsky, 1960).

We report in this paper on the acute toxicity of the insect quinones to laboratory mice. Data on the subcutaneous acute toxicity of p-benzoquinone have already been published some time ago (Marquardt, 1947). Owing to the nature of the present case, we have not only supplied the test substance as such, *via* skin-painting, but we have been more concerned with the feeding of the quinones to the animals as quinonoid adjuncts on the regular laboratory diet. For the same reason, the subcutaneous toxicity of two quinonoid amino acid conjugates, which are intimately related to the tissue, has been of interest to us.

MATERIALS AND METHODS

TEST SUBSTANCES

The basic test substance, Quinone Mixture, was 80% ethyl-p-benzoquinone (Ladisch, 1958) and 20% high-purity grade toluquinone (Distillation Products), by weight, melted together; MW 133. The mixture was kept refrigerated when not in use.

QUINONE-TREATED FOOD: 120 grams of Purina Chow pellets, cut to pieces ½ x ¼ x ¼ inch., were placed in a two-liter flask. A small glass vial, open at the top and charged with 120 mgs. of the quinone mixture, was rigidly suspended within the flask above the pellets. The flask was stoppered, shielded from light, and maintained at 40°C. for 10 days. It was rotated by hand at least four times a day to turn over the pellets, but the quinone was not allowed to contact the food at any time. The pellets absorbed the quinone entirely free from the vapor phase. Concentration of quinone on the food: 1000 p.p.m. Pellets containing 60 mgs., or 500 p.p.m. quinone, were also prepared in the same manner.

PROLINE CONJUGATE: 683 mgs. quinone mixture were dissolved in 100 ml. distilled water. 577 mgs. 1-proline, hydroxy-proline-free, M. A. (Mann Res. Labs.) were added with stirring. The clear solution was deep red within minutes. It was allowed to remain in a stoppered bottle for 36 hours, shielded from day-light and at room temperature, before injecting it subcutaneously. A water-clear solution of the same composition, but not containing the quinone, was used for injection into control mice.

GLUTAMIC ACID CONJUGATE: same as for proline, except that 755 mgs. 1-glutamic acid, M.A. (Mann Res. Labs.) were substituted for the proline in both, the experimental and control solution. The solution containing the quinone mixture was golden-yellow 5 minutes after the addition of the amino acid. Within hours, it became a dark red-brown.

ANIMALS

The test animals were young *dba/1* and *cba/Jax* (Jackson Memorial Lab.) and Haushka albino mice, all of which are being raised and propagated in this laboratory. The animals are kept on a diet of Purina Chow pellets and lettuce.

ADMINISTRATION OF TEST COMPOUND.

FEEDING TESTS: the mice received the quinone-treated food *ad libitum,* but no untreated pellets. For each animal, the individual amounts of pellets given were weighed accurately to 0.01 gr., or approximately 0.5 percent. It was ascertained that the quantities of food as recorded had been actually ingested by the mice. The animals accepted the quinone-treated pellets as readily as they had previously accepted the regular untreated pellets. Identical numbers of control animals were carried along with the test mice in each case. These animals received untreated pellets as usual.

SUBCUTANEOUS INJECTION OF CONJUGATES: animals with weights ranging from 14.5 to 26.5 grams were selected. After all-night fasting, each animal was weighed, anesthetized (ether), and aseptically injected with the respective conjugate solution under the skin of the dorsal area. A Hamilton microliter syringe was used to administer in each case an amount of conjugate containing 90 micrograms of the quinone mixture. An identical number of control animals were treated in the same manner, except that the solutions consisted of the amino acids without quinone (*vide intra*).

TOPICAL APPLICATION: the quinone mixture melts at approximately 30°C. Such liquified mixture was applied to the dorsal skin of the animals via a Hamilton microliter syringe, each animal receiving an amount of 5 mgs. quinone in one application each week. The control animals were not treated.

RESULTS AND DISCUSSION

With one exception (Ladisch, 1953; Ladisch, Dreizen and Spies, 1953), no one seems to have made any particular effort thus far to investigate possible harmful properties that may reside in the secretions of common insect pests thriving on food. The tabulated data are therefore of interest. They show that these quinones are lethally toxic to mice, and indeed at dose levels that have heretofore been recognized as applying to experimental mice, rats, cats and rabbits. (Gulland, 1932; Glock et al., 1945; Marquardt et al., 1947; Woodard, 1951).

The present findings, in addition, indicate that coupling the secretion to proteineous matter does not impair its toxicity. This fact may deserve attention. In explanation: glutamic acid and proline are main constitutents of wheat gluten, one of the most general human foods. In the present study, insect-quinonoid conjugates of these two amino acids, subcutaneously administered to mice at 90 micrograms per gram of body weight, have killed 17 of the 20 animals so treated. Twenty control mice that received the same injections, but not containing the quinone, survived without apparent ill effects.

Similarly significant are the results from the feeding tests. The described method of preparing the quinone-treated food would seem very much to simulate natural food contamination with the quinone of these insects, at least in principle. For it has been established beyond any doubt that the secretion exuding from the beetles is firmly absorbed by and bound to cereal proteins, such as wheat flour (Payne, 1925; Alexander and Barton, 1943). The chemistry of this general type of reaction has been investigated by various authors, with benzoquinone and numerous amino acids, peptides and proteins. In solution, very often intensely colored addition compounds are obtained along with split-off hydroquinone (Fischer and Schrader, 1910; Cooper et al., 1927; Woker and Antener, 1937). Wheat flour, infested with large number of insects Tribolium, becomes pink (Payne, 1925).

On autopsy, the majority of the quinone-treated deceased animals from all the tests exhibited stained organs, particularly deep-red lungs, black livers, and green to black colored intestines. None of these color phenomena were seen in control animals which were sacrificed and likewise autopsied. It is of great interest, that these normal lung tissues taken from the freshly killed controls acquired a deep red color when kept in a 0.05 M solution of the quinone mixture at room temperature for 15 hours. Concurrently, the lungs became solid to touch. Under the same treatment, the color of liver tissue turned to purplish-brown and black. *Vice Versa,* lung tissue disintegrated entirely when stored in a 0.05 M solution of 1:1 quinone mixture; 1-cysteine, free base (Nutritional Biochemicals) again at room temperature for a period of 15 hours. Liver tissue was stained black. In a control experiment, normal lung and liver tissues, submerged in distilled water for 15 hours, did not develop any of these marked color or physical changes. These observations seem significant as they demonstrate that insect quinones—and certain insect quinonoid conjugates—reveal a remarkable affinity to animal tissue. The same has been said before for p-benzoquinone, originating as well from p-dimethylaminoazobenzene (butter yellow) as a terminal oxidation product (Kuhn and Beinert, 1943), as from

TOXICITY OF QUINONES SECRETED BY INSECTS TRIBOLIUM

Route	Animal	Preparation and Dose	Number Dead	Animals Surviving	Time of Death	Total Dose per animal
In Food	13 dba/1 7 to 17 wks. old 4 cba/J 8 wks. old 3 Hauschka, 15 wks. old	Quinone (1) 1000 p.p.m. on commercial diet	20	None	4-8 days (3)	Av. 4.9 mg. (4)
	16 cba/J 8 wks. old 4 dba/1 10 wks. old	Quinone (1) 500 p.p.m. on commercial diet	20	None	7-22 days	Av. 9.8 mg. (5)
Subcutaneous	10 cba/J 10 to 14 wks. old	Glutamic Acid (2) Conjugate, one injection	9	1	1-2 days	90 micrograms per gram of body weight (6)
	10 cba/J 10 to 14 wks. old	Proline Conjugate, one injection (2)	8	2	2-3 days	
Tropically Dorsal Skin	19 dba/1 4 and 5 wks. old	Quinone (1) 5 mgs. weekly	1 6 8 4	None	1st wk. 2nd wk. 3rd wk. 2-4 mos.	5 mgs. 10 mgs. 15 mgs. >15 mgs.

(1) Mixture of 80% ethly-p-benzoquinone and 20% methyl-p-benzoquinone, by weight
(2) 1 Mol Amino Acid : 1 Mol Quinone Mixture (1)
(3) 1 animal died 12th day; 1 died 14th day
Average daily intake of quinone mixture per animal (4) 0.81 mg. (5) 0.62 mg.
(6) Conjugate-bound quinone mixture (1)

quinone-diimine during the latter's oxidation (Mayer, 1950). Salivary glands of *Drosophila robusta,* placed in an aqueous solution of the diimine ,were progressively stained purplish-brown to almost black at the site of the nucleoproteids (Mayer, 1948). It shall be further noted in this connection, that markedly stained livers have been observed in rats which were being fed butter yellow in the diet (Miller and Miller, 1947, 1950).

Of course, it is general knowledge that quinones of the presently discussed type have an outstanding power to dye and cross-link animal proteins. As a matter of fact, tanning of leather with quinone has been a most common practice. Relative to dyeing, it is therefore not particularly surprising that the present quinone mixture as such, in 0.2 percent aqueous solution, changes virgin wool at room temperature to a red rust-brown color within 15 hours. It is more conspicuous, though, that aqueous solutions containing 0.2 percent of the described glutamic acid or proline conjugate, i.e. bound quinones, dye wool red-violet and Magenta under the same conditions. The dyeing of wool with numerous such insect-quinonoid conjugates, even with water extracts from insect-infested whole wheat flour and from insect-contaminated wheat germ, has been previously reported (Ladisch, 1960). This part of the present case may be viewed from the broader basis of coal-tar dyes. Benzoquinonoid dyes, such as Helindone Yellow CG and CM, are commercial products.

In the light of the facts presented in this paper, questions would seem to arise as to possible chronic ill effects from, and to the general safety of insect-contaminated food.

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REGENERATION OF APPENDAGES IN THE ANGULAR-WINGED KATYDID (*MICROCENTRUM RHOMBIFOLIUM*, SAUSS.)

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ABSTRACT

Removal of a protibia and protarsus from nymphs of the angular-winged katydid is followed by regeneration of the excised segments. The size and degree of development of the regrown parts varies with the age of the nymph at the time of excision.

Chopard (1938) has called attention to the superior powers of regeneration possessed by most members of the orthopteran family, TETTIGONIIDAE. A preliminary attempt on my part to check the validity of this generalization for *Microcentrum rhombifolium* in 1958 produced evidence that considerable regenerative capability existed in the case of the legs and antennae, but that wings were regrown only with difficulty. The evidence at hand also indicated that regeneration occurred only during the nymphal stages and that adults showed no ability to replace excised appendanges.

Several years later a simple experiment was set up to determine whether variations noted in the amount of regenerated leg tissue could be correlated with the age of the nymph at the time of amputation. The present report is based on conclusions obtained from that study. This work was done in the autumn and winter. The insects, hatched indoors from eggs obtained the preceding summer, were reared in orange crates that were partially screened to convert them into two-compartment cages. Five nymphs were kept in each compartment (11 X 11.5 X 12 inches) and were fed on lettuce, English ivy (*Hedera helix*), and the buds and twigs of cultivated shrubs such as *Lonicera sp.* and *Cotoneaster sp.*. Under these conditions growth was slower than in summer, but in spite of the decreased exposure to light and the abnormal dietary regimen, the insects developed normally and attained a size closely comparable to that of normal, wild individuals. A total of 29 treated individuals and 11 controls were reared to the adult condition. The mortality that occurred during the course of the experiment (about 17%) was due to difficulties in molting under the crowded conditions in the cages and not to any direct effects of amputation.

The angular-winged katydid passes through six nymphal instars. These instars may be differentiated visually, not only by differences in overall size of the insects, but more specifically by certain peculiarities in the form and appearance of external features such as the wings and external genitalia. These are sufficiently distinct to prevent any uncertainty about the age of a particular nymph. Under laboratory conditions a nymph remains in a given instar about 10 days.

Amputations were performed on some nymphs in each of the six instars, the right prothoracic leg being partially removed from each treated individual. Incisions were made across the distal end of the femur, removing the tibia and tarsus of the leg. This operation was performed on a nymph within 3 days of its having attained the desired instar.

The greatest amount of regeneration took place in those insects that underwent limb amputation in the first instar (see Table). When these reached the adult condition, the right prothoracic leg in each was large and well-formed although the tibia and tarsus were shorter than their counterparts on the left side. Nymphs treated during the second instar showed somewhat less total regeneration ,but the new segments were also large and well-developed. In general, the same pattern held for all instars, each showing less regeneration than its predecessor. Sixth-instar nymphs showed no regrowth at all following amputation, while fifth-instar specimens regenerated only malformed stumps. Thus, early amputation and a consequent long growing period resulted in more regeneration than occurred with later amputation.

The following table shows the average lengths of the regenerated right prothoracic tibiae and tarsi as measured on preserved adult katydids. For comparison, average lengths of all the left (non-amputated) tibiae and tarsi are included.

In addition to the quantitative differences between normal and regenerated legs, there are certain qualitative differences. When amputation was performed on a first-instar nymph, the regenerated tibia and tarsus appeared normal in every respect except one—the failure of the new tibia to develop a chordotonal organ (Snodgress 1935). This so-called "ear" of the katydid, located at the proximal end of the tibia of each prothoracic leg, is always lacking in a regenerated segment. Thus the generalized functions of the foreleg (support and locomotion) are restored, but its specialized function (sound perception) is lost. In a similar manner, regrowth following second-instar amputation produced a leg that was well-proportioned and a replica of the original even to such details as spines and hairs, but, of course, with no indication of a tympanic membrane. Legs regrown on third-instar amputees were likewise well-proportioned, though smaller. Distortion, however, began to appear in legs regenerated following treatment in the fourth instar. In these the tibiae were bent and gnarled and the tarsal segments were unnaturally thick, with the terminal claws misshapen or, in some cases, lacking. Fifth-instar amputees showed considerable variation ranging from a complete but very short tibia and tarsus to a mere knoblike growth on the tip of the femur supporting a hooklike piece beneath it, the latter representing all of the lower part of the appendage. It appears from this evidence that regeneration of leg segments in this insect first produces a generalized growth that comes to resemble a normal appendage only if given sufficient time for development and which never duplicates structures of a highly refined and specialized sort.

CONCLUSION

Regeneration of appendages may be studied to advantage in the angular-winged katydid and probably in related species (Isely 1941). In the work re-

COMPARISON OF NORMAL AND REGENERATED PROTHORACIC LEGS

Instar of Amputation of Right Leg	Average Length of Right Tibiae	Average Length of Left Tibiae	Average Length of Right Tarsi	Average Length of Left Tarsi
I	6.5 mm.	7.8 mm.	3.6 mm.	4.0 mm.
II	5.8		2.9	
III	5.1		2.8	
IV	4.2		2.1	
V	1.5		0.6	
VI	0		0	

ported the size of the regrown section varied with the length of time available for growth following amputation, that is, the length of the remaining nymphal period. Regrown limbs lacked specialized structures, such as tympani. The next stage of investigation, now in progress, is the task of assessing the significance of the regenerative response following removal of varying amounts of appendage tissue from insects in the same instar.

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EFFECT OF SELECTION WITH IRRADIATION IN *DROSOPHILA MELANOGASTER*

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ABSTRACT

An inbred line of wild type **Drosophila melanogaster** derived at 26°C was chosen to examine responses to selection for thorax length. High and low response lines were developed, with and without irradiation. Data were obtained on body size as measured by the profile length of the thorax, and viability as measured by the number of adults eclosing per 24 hour period. The study included measurements taken each generation for six generations. Selection was found to be effective in both directions by the sixth generation, although somewhat greater in the high lines. Radiation exposure caused a reduction in body size. Significant interactions were seen between body size and small variations in population density. Selection pressure caused a sharp deline in viability in the low lines. The regression of density on length gave a 't' value of 2.45, a correlation of —0.847. The selected lines show a 4.1% increase in thorax length in females for the high non-irridiated line, a 2.2% decrease in the low irradiated line, when compared with the initial parents.

INTRODUCTION

The phenotypic expression of quantitative characters in populations of plants and animals is known to depend on a variety of environmental factors. In *Drosophila* variations in temperature, humidity, and light have been effective in altering the normal phenotypic variance of quantitative characters. Workers in this field have observed differences in the response to selection by populations with a large phenotypic variance, (Stalker '47; Buzzati-Traverso '55; Robertson '57; Beardmore '60; Mallah '61; and Parsons '61). De Fries and Touchberry ('61) reported a decline in fecundity in lines of *D. affinis* selected for body weight. Miller and Thomas ('58) demonstrated that larval crowding in *Drosophila melanogaster* produces a corresponding non-linear decrease in body weight.

This study was undertaken to determine how effective selection for thorax length would be in an inbred line of *Drosophila melanogaster* that was exposed to gamma irradiation. Various expressions of genotype-temperature interactions also were studied, but these aspects will be presented in a future paper. In this study the effects of small differences in population density were also investigated.

METHODS AND MATERIALS

The inbred line used in this experiment was derived from a wild population of *Drosophila melanogaster* collected near State College, Pa. in 1955. The line was maintained without selection for any trait during inbreeding, under constant temperature (26°C), for over 150 generations prior to this study. The line represents one of eight surviving temperature derived lines.

To initiate the experiment, single pair matings of 2-day old virgin flies were made and transferred daily to clean vials for 3 days. All matings were maintained in 25mm by 95mm shell vials containing about 20mm of standard corn meal media, seeded with dry active yeast. The thorax length of 220 adults emerging from these matings was measured (110 males—110 females). From the first random sample of 100, the 10 largest females and the 10 largest males were mated in single pairs, and they were designated the 'H' line. The second sample of 100 was treated in a like

manner and designated the 'HR' line. The 10 smallest males and females from each of these samples were also mated and called the 'L' and 'LR' lines, respectively. Just prior to mating the HR and LR lines were exposed to gamma irradiation from a cesium source of ca 1700r. A third sample of 20 flies was used to make 10 control matings, the 'C' line. All pairs were transferred daily to clean vials for three days and subsequently discarded. This same selection procedure was used within each line for six generations.

Thorax length was measured with a special device designed specifically for use with *Drosophila* by the Drummond Scientific Company of Philadelphia. Details of the apparatus are furnished by Mitchell ('58) and Keller ('59). In order to secure more repeatable measures the grooves provided in the device for placing the flies were not used. Instead, flies to be measured were placed on a circular disc to facilitate horizontal alignment while being measured. Measurements were take on etherized flies lying on their side. Thorax length was determined by the profile length between parallel lines at right angles to the body axis at the head-thorax juncture, and at the posterior tip of the thorax. All measurements were made to the nearest 0.005mm and were made by the same individual.

RESULTS

The mean thorax length for adults for each generation is given in Tables 1 and 2. These means are based on 50 measures, except where indicated. True differences are noted between the experimental lines and the controls. These differences are small for both males and females for the first three generations of selection, but become greater the last three. The means for the sixth generation place the control between the high and low non-irradiated lines for both sexes. The irradiated lines differ from one another in the selected direction, but are smaller than the non-irradiated lines. For females, the H line has a 2.4% increase, and the L line a 2.1% decrease, in thorax length when compared with the controls after six generations of selection. Although the HR and LR lines differ in the selected direction the HR line is 0.7% below the controls, and the LR is 4.0% below, in females. Selection for thorax length was possible in this inbred stock and irradiation caused a reduction in thorax size. It appears that selection for large thorax is more effective than selection for small thorax. The controls were not consistent, especially in the fifth generation. The standard error of the means range from 0.53 to 0.23.

In Figures 1 to 4 comparisons are made for male and female thorax lengths, among lines, between the first and the sixth generation of selection. In almost all cases the means are within one standard error of one another for the first generation, (Figs. 1 and 2). Within this first generation no consistent difference

Table 1. Mean thorax length of females of all lines for six generations. N=50. (Measurements in 0.01 mm)

	C	H	L	HR	LR
1	102.8	102.3	101.6	101.3	101.9
2	102.5	102.4	102.8	105.0	103.1
8	101.3	101.5	99.9	101.6	102.0
4	100.3	101.7	101.8	104.8	103.8
5	99.7	101.8	100.6	103.3	102.3
6	104.1	106.6	101.9	103.4	99.9

Table 2. Mean thorax length of males of all lines for six generations. N=50. (Measurements in 0.01 mm)

	C	H	L	HR	LR
1	89.5	88.7	90.2	90.4	90.5
2	89.2	89.2	89.7	91.7	91.7
3	87.4	87.9	87.3	88.1	88.8
4	87.5	90.7	90.1	91.9	90.8
5	88.8	90.0	88.6	91.2	91.2
6	91.0	94.5	90.5	89.2	87.5

is noted between irradiated and non-irradiated lines. Figures 3 and 4 compare thorax lengths after six generations of selection. Significant differences are observed between high and low lines for both sexes. The iradiated lines show a marked decrease in thorax length when compared with the non-irradiated lines. Although the control was not consistent during the six generations studied, the values for the first and sixth generation are not significantly different. The L line means for these two generations are also quite similar.

Very early in this study it became apparent that slight variations in the number of flies competing for food in each vial could alter the mean thorax value. The mean number of adults eclosing per vial is given in Table 3. Variation in fecundity was significant among lines, and within generations. The action of the controls could not be predicted from the data; the range in density was from 22.8 to 59.9. The selected lines were lower in viability values than the controls. This effect was greater in the irradiated lines. The mean number of adults eclosing for all irradiated lines was 27.0 per vial; for the selected non-irradiated lines it was 37.6. The mean number eclosing for all controls was 43.4, for the high-selected lines 36.7; and for the low-selected lines 27.8.

The correlation of the female thorax length on number of adults eclosing, the regression line of length (y) on density (x), the 't' value for linear regression, and the 'F' value for density comparisons are as follows:

$r = -0.847 \quad y = -0.1203x + 107.39$

$t = 2.45 \quad F = 12.61^{***}$

In Figures 5 to 8 comparisons are made between lines when thorax length is adjusted to a constant density. When these graphs are compared with Figures 1 to 4 differences are noted the first generation between high and low lines, and between irradiated and non-irradiated lines.

Table 3. Mean number of adults eclosing per vial for each line for six generations.

	C	H	L	HR	LR
1	39.8	42.6	25.9	28.3	18.7
2	41.4	43.1	37.4	12.9	14.4
3	51.6	51.3	45.2	42.3	32.3
4	59.9	41.4	40.0	20.1	15.0
5	49.6	44.8	28.1	23.3	9.8
6	22.8	26.7	21.8	46.9	23.3

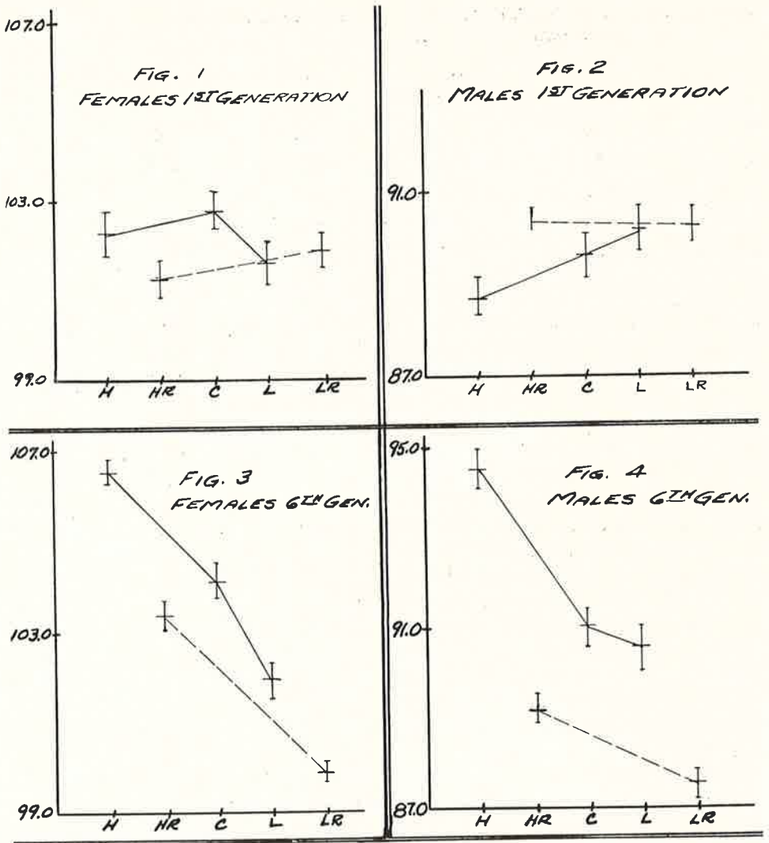

FIG. 1-4 COMPARISONS OF MEAN THORAX LENGTH FOR MALES AND FEMALES THE FIRST AND THE SIXTH GENERATION. BROKEN LINE CONNECTS IRRADIATED LINES. SOLID VERTICAL LINE SHOWS STANDARD ERROR OF MEAN.

DISCUSSION

This study was undertaken to determine the nature of response to selection for thorax length in an inbred stock. The results, in some cases, are in agreement with those of other investigators concerned with quantitative morphological characters. The females were consistently larger than the males for thorax length. Treatment with radiation caused a decline in body size. Selection pressure was effective in decreasing fecundity.

The particular line of flies used in this experiment had been inbred at 26°C ± 0.5° for over 100 generations. Of particular concern of this study was to determine the extent of homozygosity realized through this inbreeding program. The

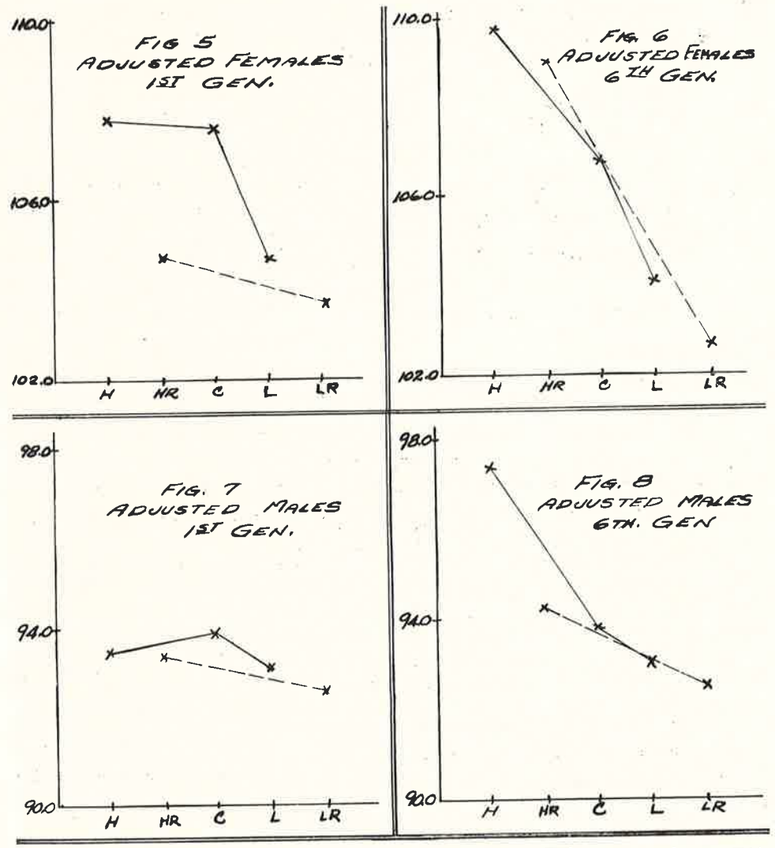

FIG. 5-8 COMPARISON OF MEAN THORAX LENGTH OF MALES AND FEMALES THE FIRST AND SIXTH GENERATION ADJUSTED TO CONSTANT DENSITY. BROKEN LINE CONNECTS IRRADIATED LINES

possibility that small mutations, induced by radiation, may produce a variance in thorax length was also examined. From the responses of the experimental lines it is evident that some genetic variability for thorax length was present. Further, the factors concerned with size are, at least in part, epistatic to viability.

The results indicate that at least three factors are determiners of adult thorax length, and that interaction is present between some of these factors (see Figure 9). 1) Radiation can cause a reduction in body size and in viability. 2) Population density will also effect body size, with or without irradiation. 3) Selection pressure reduces fecundity; this reduction is greater in the low-selected

lines. It is not possible to determine if radiation has effected the response to selection.

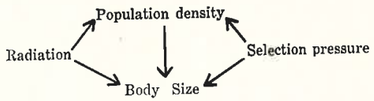

Figure 9. A schematic representation of the path relations among three determiners of body size.

The high correlation between thorax length and mean vial density suggests that some of the fluctuation in the controls may be due to competition. Miller and Thomas ('58) and Prabhu and Robertson ('61) have shown this to be effective for body weight. In contrast to the work of Miller and Thomas for weight, there is a linear relation between size and density. Of particular concern here is that even small variations in density may be effective in altering some morophological characters. Further studies, with larval competition held constant indicate a higher correlation with thorax length than number of adults eclosing. Variations in number of larvae surviving may then account for some of the discrepancies in Table 1, lines C5 and C6.

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COMPARISON OF THE RATE OF DEVELOPMENT OF *BRACHYLECITHUM ORFI* (*TREMATODA*: *DICROCOELIIDAE*) IN THE LAND SNAILS, *ZONITOIDES ARBOREUS* AND *CIONELLA LUBRICA*

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ABSTRACT

Limited data on experimental infections of **Brachylecithum orfi** Kingston and Freeman, 1959 in laboratory reared specimens of the terrestral snails **Zonitoides arboreus** and **Cionella lubrica** show a differential rate of development of the parasite in the different host species maintained at the same temperatures. Within a single species of host the rate of development is temperature dependent.

INTRODUCTION

Brachylectithum orfi Kingston and Freeman, 1959, is a species of trematode belonging to the family DICROCOELIIDAE which is found as an adult in the biliary ducts of the ruffed grouse. Eggs of the parasite are fully developed at oviposition and infect terrestrial molluscs only when ingested. Development of the larval stages of *B. orfi* occurs in the terrestrial snails, *Zonitoides arboreus, Z. nitidus,* and *Cionella lubrica,* and in the slugs *Deroceras laeve* and *D. reticulatum* (Kingston and Freeman, 1959). Following development the cercariae of *B. orfi* escape from the daughter sporocysts by way of a birth canal and pass out of the respiratory pore of the mollusc bathed in slime; they aggregate on the dorsum of the mollusc in some numbers forming, what has been termed, a slimeball (Krull and Mapes, 1952). This paper is concerned with an examination of differences in the development of the larval stages of *B. orfi* in different species of snails maintained at the same and at different temperatures. Development was studied in all species of molluscs listed above but the data in this paper are primarily derived from a study of development in *Z. arboreus* and *C. lubrica.*

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2. Part of a Thesis submitted to the Graduate School, University of Toronto in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Zoology.

MATERIALS AND METHODS

Snails and slugs used in infection experiments were individually exposed to eggs of *Brachylecithum orfi* on lettuce in shell vials and their feces were examined microscopically after feeding to verify the presence of hatched and empty eggshells. The snails and slugs were then segregated by species and feeding group in 10 cm. crystallizing dishes which were lined with moistened filter paper; the molluscs were fed oatmeal dusted with calcium carbonate, lettuce, leached maple leaves, and leaves of *Ailanthus* sp. in season. Groups of exposed molluscs were maintained over the next three to four months at temperatures averaging 59°, 63°, and 75°F. at the end of which time they were again individually segregated, and observed daily thereafter. The date of the appearance of the first cercariae produced in a slimeball by each mollusc was recorded and records were kept of the frequency of slimeball production by each mollusc thereafter for periods in some cases in excess of three months. Counts were made on a limited basis of the number of cercariae found in the slimeballs produced by the different species of molluscs. Where feasible the accumulated data were compared statistically using Student's "t" test for the comparison of mean values of small samples.

RESULTS

SLIMEBALL PRODUCTION IN *Zonitoides arboreus* AND *Cionella lubrica* MAINTAINED AT 63°F.

Twelve of sixteen *Zonitoides arboreus* belonging to three feeding groups maintained at an average temperature of 63°F. survived to produce cercariae in slimeballs (Table I). Initiation of slimeball production in these snails ranged between one hundred and forty-seven days and one hundred and seventy-two days after exposure to the eggs of *B. orfi* with a mean of one hundred and fifty-six days (Table II). Thirteen of fifteen *Cionella lubrica* belonging to two feeding groups maintained at this temperature survived to pass slimeballs containing cercariae. Initiation of slimeball production in these snails ranged between one hundred and

TABLE I

Summary of Protocols of Feeding Experiments of Molluscs Serving as First Intermediate Hosts of *B. orfi.*

Species of Mollusc	No. of Molluscs exposed/No. inf.	No. of Molluscs passing slimeballs	No. of days of development	Av. Temp. °F	No. of slimeballs initial 30 days	Total no. of slimeballs	Total no. of days observed
Zonitoides arboreus	6/6	2	89	75°	17, 15	40, 39	110
do.	5/5	4	147-149	63°	11, 11 15, 17	28, 13, 36, 33	93-95
do.	5/2	2	156, 172	63°	15, 17	18, 17	32-44
do.	6/6	6	158-162	63°	12, 16, 8, 12, 1, 2	12, 16 10, 12, 3, 3	24-42
do.	14/5	0	85-108	63°			
Z. nitidus	12/8	1	196	59°	9	9	27
Deroceras laeve	4/2	2	205	59°	7, 8	7, 8 (53) combined after initial 8 days	8 (37)
Deroceras reticulatum	76/13	0	39-109	59-63°			
Cionella lubrica	6/5	5	181-201	63°	15, 11, 9, 10, 12	15, 11, 9, 12, 14	34-54
do.	18/9	9	221-278	59°	3, 3, 13, 6, 6, 2, 1, 10, 5	4, 4, 15, 6, 6, 2, 1, 12, 7	8-65
do.	4/4	4	132-147	70°	1, 7, 3, 1	do.	1-37
do.	17/7	6	219-267	59°	4, 14, 13, 9, 7, 9	6, 15, 21, 16, 13, 13	40-88
do.	9/9	8	180-226	63°	4, 4, 6, 9, 6, 5, 10, 4	4, 7, 10, 15, 6, 5, 14, 4	15-61
do.	13/7	4	116-126	75°	5, 5, 4, 2	5, 5, 4, 2	16-26
do.	3/3	0	71-82	63°			

eighty days and two hundred and twenty-six days after exposure to infective eggs (Table I) with a mean of one hundred and ninety-seven days (Table II). The difference between the means obtained for cercarial development in *Zonitoides arboreus* and *Cionella lubrica* was found to be significant at the 0.1% level ($t = 9.36$, 23 degrees of freedom).

SLIMEBALL PRODUCTION IN *Cionella lubrica* MAINTAINED AT 59°F.

Fifteen of thirty-five specimens of *Cionella lubrica* belonging to two feeding groups maintained at an average temperature of 59°F. survived to produce carcariae in slimeballs. Initiation of slimeball production in individuals of this species ranged betwen two hundred and nineteen and two hundred and seventy-eight days after ingestion of infective eggs of *B. orfi* (Table I), with a mean of two hundred and forty days (Table II). The difference between the mean values for cercarial development at 59°F. and at 63°F. in this species of snail was found to be significant at 0.1% level ($t = 7.3$, 26 degrees of freedom).

SLIMEBALL PRODUCTION IN SNAILS MAINTAINED AT 75°F.

Two of six specimens of Z. *arboreus,* maintained at 75°F., produced slimeballs containing cercariae, each beginning slimeball production eighty-nine days after infection was established. Four of thirteen specimens of *C. lubrica* maintained at this temperature produced slimeballs containing cercariae, slimeball initiation ranging between one hundred and sixteen days and one hundred and twenty-six days after infection was established (Table I).

DEVELOPMENT OF CERCARIAE OF *Brachylecithum orfi* IN OTHER SPECIES OF MOLLUSCS:

Cercariae of *B. orfi* developed in specimens of *Zonitoides nitidus, Deroceras laeve,* and *D. reticulatum* in addition to the above mentioned species. One specimen of Z. *nitidus* of eight infected, maintained at 59°F., produced slimeballs beginning one hundred and ninety-six days after infection was established. Two specimens of *D. laeve* maintained at this temperature produced cercariae in slimeballs beginning two hundred and five days after infection was established. None of the infected speciments of *D. reticulatum* produced slimeballs during a period of observation ranging between thirty-nine and one hundred and nine days (Table I).

COMPARISONS OF THE NUMBERS OF SLIMEBALLS AND THE NUMBERS OF CERCARIAE PRODUCED BY *Zonitoides arboreus* AND *Cionella lubrica.*

The fourteen specimens of *Zonitoides arboreus* produced between one and seventeen slimeballs in the thirty day period following initiation of slimeball production with a mean of approximately twelve slimeballs per snail. The twenty-eight specimens of *Cionella lubrica* produced between one and fifteen slimeballs in the same period following initiation of slimeball production with a mean of approximately seven slimeballs per snail. The difference between the means of numbers of slimeballs produced by Z. *arboreus* and *C. lubrica* was found to be significant at the 1% level ($t = 3.21$, 40 degrees of freedom). Data on total number of slimeballs produced by individual snails were collected over varying periods of time (Table I). They tend to corroborate the findings expressed above but, owing to the differences in the periods of time during which slimeball production was observed in snails, these data are not easily comparable (Table I).

The numbers of cercariae in slimeballs produced by Z. *arboreus* and *C. lubrica* were recorded and compared. Eleven slimeballs produced by Z. *arboreus* con-

tained an average of one hundred and forty-one cercariae compared with an average of one hundred cercariae found in twenty-one slimeballs produced by *C. lubrica;* these differences were found to be significant between the 1 and 2% level (t = 2.61, 30 degrees of freedom).

DISCUSSION

The development of *Brachylecithum orfi* in *Zonitoides arboreus* and *Cionella lubrica* maintained at different temperatures is graphically compared in the figures in Table II. The lengths of the heavey bars in the upper figure indicate the range of the number of days in which development took place before slimeball production was initiated. At all temperatures development progressed at a slower rate in *C. lubrica* than in Z. *arboreus,* the slopes of the lines are distinctly separated and almost parallel. Z. *nitidus* is extrapolated into the chart to indicate the rate of development of *B. orfi* in this genus at 59°F. The mean number of days of development in each species at each temperature is indicated. The histogram shows development of cercariae as determined by the initial date of slimeball production in Z. *arboreus* and *C. lubrica.* The developmental times of *B. orfi* in these groups of snails of

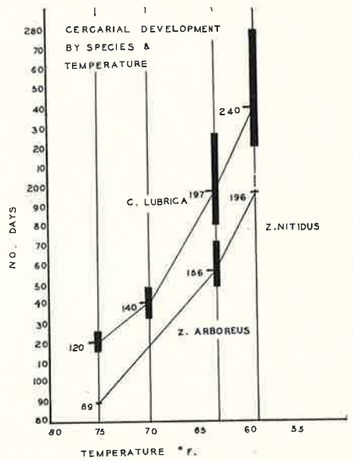

TABLE II, Fig. 1

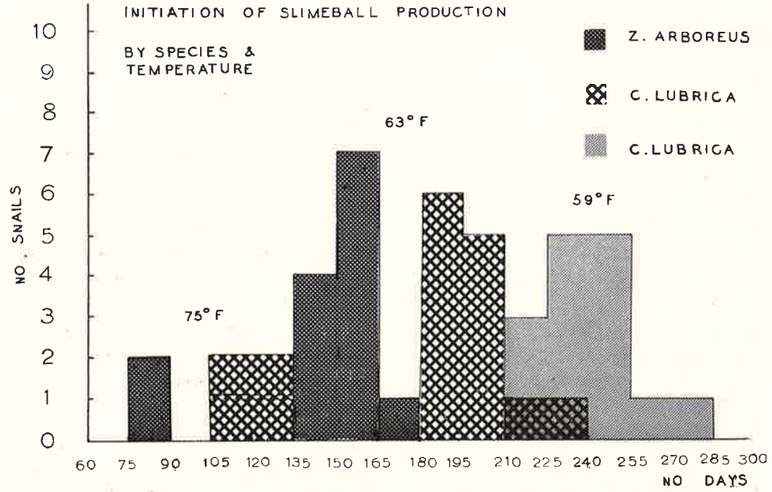

TABLE II, Fig. 2

different species kept at the same temperature show the same marked differences between the two species of snails as indicated above. Likewise, the developmental rate of the parasite in snails of the same species kept at different temperatures shows a marked divergence except for a slight overlap in specimens of *C. lubrica* kept at 59° and 63°F. Temperatures are expressed in both figures as accumulated mean monthly temperatures.

From the data obtained in these experiments it is clear that the rate of development of *Brachylecithum orfi* varies directly with the temperature. This finding is in accord with our general understanding of developmental rates of ectothermic animals and the speed of chemical reactions in protoplasm (Prosser and Brown, 1961) and needs no further discussion here. Also clearly suggested, however, is a significant difference in the rate of development of *B. orfi* in different molluscan hosts maintained at the same temperature, and further significant differences are apparent in the numbers of cercariae produced by these hosts in the same period of time. While these differences are not clearly understood at present, they may reflect the greater likelihood of involvement of Z. *arboreus* in the life cycle of *B. orfi* in its natural habitat. Z. *arboreus* is found within the range of distribution (Kingston, 1962) of this parasite in ruffed grouse while *C. lubrica* is not present (Oughton, 1948) in at least one area where *B. orfi* is found. Other differences, behavioral and physiological, between these two species of hosts have not been studied.

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NEWLY RECOGNIZED FOLDING IN THE TRIASSIC OF PENNSYLVANIA*

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ABSTRACT

One to two miles south of Fritztown, Berks County, an eastward plunging syncline and complementary northeastward plunging anticline north of it occur in the Gettysburg formation about Camp Indiandale. A branching fault cuts the common limb. Exposed folded rocks are three conglomerate members and interbedded sandstones, aggregating 1200 feet thick.

Folding on a broad scale has been known in the Triassic rocks of Pennsylvania for many years. Lyman (1895) mapped Bucks and Montgomery Counties late in the past century and recognized the open synclinal structure of the Quakertown basin, the Pennsburg syncline, and the deep basin between Boyertown and Zieglerville. Farther west, d'Invilliers (1883) mapped the Jacksonwald syncline north of the Schuylkill in Berks County. All these structures have dimensions of the order of ten miles. Folding on a smaller scale has been found mainly in local reversals of dip probably due to drag near some of the major faults.

In the area south of Fritztown in Berks County, the outcrops seen along the public roads give little indication of deviation from the well known northerly- to northwesterly-dipping homocline. However, during detailed mapping of the Sinking Spring quadrangle, large numbers of outcrops away from the roads were found to show discordant dips. Most of these are within a radius of about half a mile east, south, and west of Camp Indiandale, near Vinemont. While some of the discordances could be explained by faulting, most of them fell into a pattern that suggested an eastward-plunging syncline with a complementary anticline north of it. Unfortunately, large parts of the area contained no outcrops and other parts were difficult of access, so that the picture remained incomplete for a long time.

Relief in the area is about 500 feet. The highest point is the hill summit southeast of Camp Indiandale, elevation about 1060 feet. The hills are densely wooded, and in some places thick underbrush is almost impassable in the summer months. The most difficult areas were finally mapped in the spring of 1962.

Mapping and location of outcrops were done by compass-and-pace traverses adjusted on features that could be identified on the topographic map or on the aerial photographs. Figure 1 is a map of the area reduced from an original plotted on a scale of 1 cm. to 250 feet. The dips and strikes shown are only a representative sample in the areas where outcrops are most numerous.

The rocks of the area are sandstones and conglomerates of the Gettysburg formation. A minor diabase dike occurs in the ravine near the southern edge of the map area. The sandstones are thick-bedded, fine- to coarse-grained, gray, brown, and reddish brown. They are composed almost wholly of quartz grains with more or less hematite. A very uniform medium-grained brown sandstone that is quite similar to the Hummelstown "brownstone" has been quarried locally on a small scale. Occasional pebbly bands and fine conglomerate are interbedded with the sandstone.

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The conglomerates range from small pebble to coarse cobble conglomerate. The smaller pebbles are mainly of subrounded vein quartz, usually white but often pinkish. These seldom exceed an inch in diameter. The larger pebbles and cobbles are subangular to subround and are chiefly of fine-to medium-grained light gray quartzite lithologically similar to the Shawangunk quartzite now exposed in the ridge of Blue Mountain 18 miles to the north. Pebbles 2 to 3 inches in diameter are very common, and occasional quartzite cobbles 6 to 8 inches in diameter were found. A small percentage of pebbles are of hard fine-grained brown sandstone or quartzite. No pebbles or chips of shale or limestone were found in this immediate area, though in one place some angular cavities from which limestone pebbles may have been dissolved were noted. Limestone conglomerate does occur locally in dominantly quartzite conglomerate along U. S. Highway 222 near Gouglersville, only two miles distant. The matrix of the conglomerate is composed of coarse to very coarse quartz grains and tiny chips of quartzite.

Table 1
Composite Section of Folded Strata near Camp Indiandale.

Member	Thickness feet
Upper Conglomerate (III)	225
Sandstone	170
Middle Conglomerate (II)	300
Sandstone	250
Lower Conglomerate (I)	310
Total	1255

A number of outcrops show torrential crossbedding. The dips of the foreset beds show that the depositing streams flowed variously from the north, east, and west, but the greatest number of individual outcrops indicate a source to the northeast. All of the conglomerate members finger out westward beyond the map border and grade into sandstone within two or three miles.

The exposed strata involved in the folding are three thick conglomerate members (designated I, II, and III in ascending order) and the intervening sandstones. A composite section is given in Table 1. Members II and III with the intervening sandstone were measured in the deep ravine east of Vinemont Road (Fig. 1, Section location A-B). Members I and II with the sandstone between them were measured on the south slope of the steep hill where the south limb of the syncline occurs (Fig. 1, Section location C-D). The tabulated thickness for the middle conglomerate (II) is the mean of the two measurements. Beneath the tabulated section is a considerable thickness of sandstone containing two thinner conglomerate members that finger out westward into sandstone. The equivalent of the upper of these two thinner conglomerates is believed to be the rock that is exposed in the hill west of Indiandale Road.

The most prominent structural feature is the eastward-plunging syncline already mentioned. Its axis trends nearly east-west along the crest of the highest hill southeast of Camp Indiandale. Dips on the south limb average about 25°. On the north limb they are slightly less near the nose of the fold, but apparently become gentler toward the northeast, as shown by the dips of scarce outcrops and by the apparent fanning out of alternating and poorly defined conglomerate and sandstone sub-members. The conglomerates appear to finger out eastward here and grade into sandstones. Along the eastern edge of the map area there are no outcrops on which dips can be measured, but the trends of traceable bands of conglomerate indicate that dips probably become quite gentle there.

The complementary anticline to the north of the syncline is indicated by a dome-like structure west of Indiandale Road and by the abruptly curved and cuspate outcrop of conglomerate members east of Vinemont Road. The anticlinal axis trends northeastward and plunges in that direction. No exposures on which dips could be measured were found toward the eastern end. Between the two areas just mentioned, the anticline contains a saddle formed by a transverse northward-striking syncline south of the lake at Camp Indiandale.

The common limb of anticline and syncline is traversed by a fault which strikes northeasterly. Downthrow is on the north side. Near the northeastern corner of the map area the calculated displacement is about 600 feet, if the sandstone and conglomerate members are assumed to maintain uniform thicknesses.

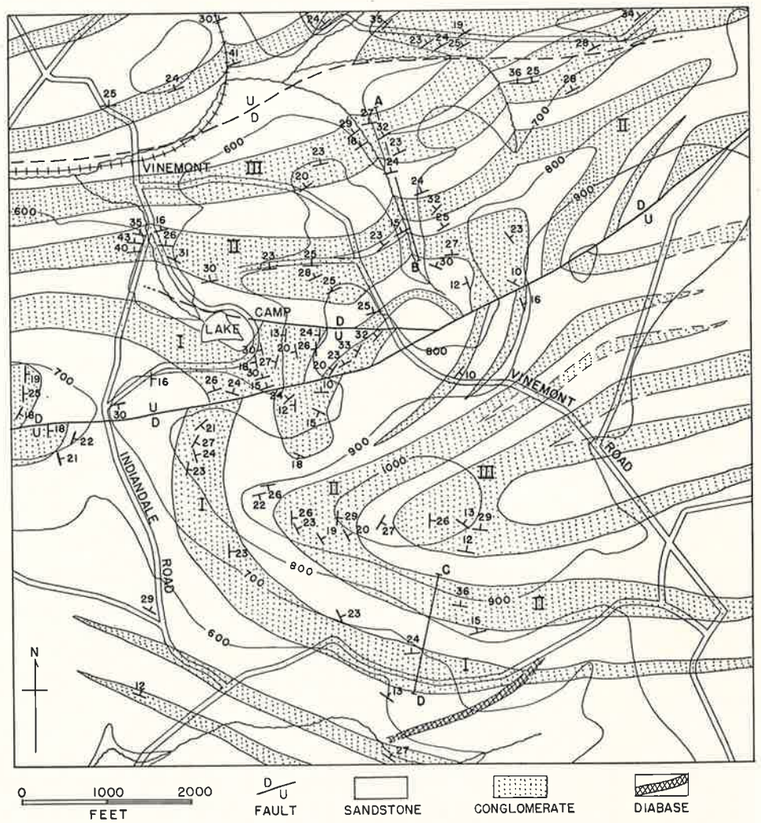

Figure 1. Geologic map of an area one to two miles south of Fritztown, in Sinking Spring quadrangle, Berks County, Pennsylvania. Contour interval 100 feet. Mapped in 1957, 1958, and 1962. Conglomerate members are designated by Roman numerals I, II, and III. Locations of sections measured are indicated by the lines A-B and C-D.

The displacement decreases toward the southwest, and in the ravine east of Vinemont Road it is only about 100 feet. At this place the fault branches. One branch trends slightly north of west, with downthrow still on the north side. It dies out near Indiandale Road. The other branch extends south of west, with downthrow at first on the *south* side, but this reverses near Indiandale Road, and west of there the downthrow is on the north. The branch dies out several hundred feet beyond the western border of the map area. The calculated displacement is about 150 feet on the hill west of Indiandale Road. The greatest displacement is at the point of the wedge where the fault branches. Here the rocks in the wedge are raised 450 feet relative to those south of them and 550 feet relative to those north of them.

In the horst-like wedge between the faults, strata of the lower conglomerate member (I) dip westward 20° or more over a distance of several hundred feet, conspicuously discordant with the northward dip of the middle conglomerate (II) only a few hundred feet to the north. This discordance is the clearest evidence for the northern branch of the fault, which traverses an area that is covered with brush and is without exposures.

Along the trace of the main fault, slickensided rock was found at several places, though not as abundantly as might be expected. The principal evidence for this fault is the truncation of conglomerate members that have been traced out. Where the fault branches, several springs in the deep ravine are sources of the stream that flows northward from there. Along the southern branch of the fault, in a ravine about midway between Vinemont and Indiandale Roads, there is a possible exposure of the fault surface itself. More likely it represents a minor northward branch fault, for the slickensided face strikes N 60° W and dips 42° SW.

Another fault crosses the northern part of the area shown in Fig. 1. It has downthrow on the south, about 200 feet, causing repetition of nearly the entire thickness of the upper conglomerate. Slickensides and springs occur along its trace.

The cause of the folding in this area is not clearly evident. The larger synclines mentioned in the first paragraph are all located not far from large bodies of diabase, and they may have originated through subsidence following removal of magma from beneath. The syncline near Camp Indiandale may have had a similar origin, for a large body of diabase occurs immediately east of the map area.

Another posibility is that large-scale crumpling of the strata may have occurred incidentally to down-faulting at the north border of the Triassic basin. The great border fault is less than two miles north of Camp Indiandale and it has a displacement of several thousand feet several miles west of this area (McLaughlin 1958). The displacement decreases eastward, but may still be as great as 2000 feet due north of the map area.

The author does not consider the folding to be evidence of regional compression.

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EVIDENCE ON THE ORIGIN OF THE "PINITE" OF THE READING HILLS, PENNSYLVANIA

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ABSTRACT

"Pinite" is a phyllitic rock occurring at a few localities at the base of the lower Cambrian Hardyston quartzite of the Reading Hills. Petrographic and field study of some exposures in Lehigh and Berks Counties suggests that some "pinite" is a cataclastic rock derived from intense shearing of the Precambrian crystalline rocks.

INTRODUCTION

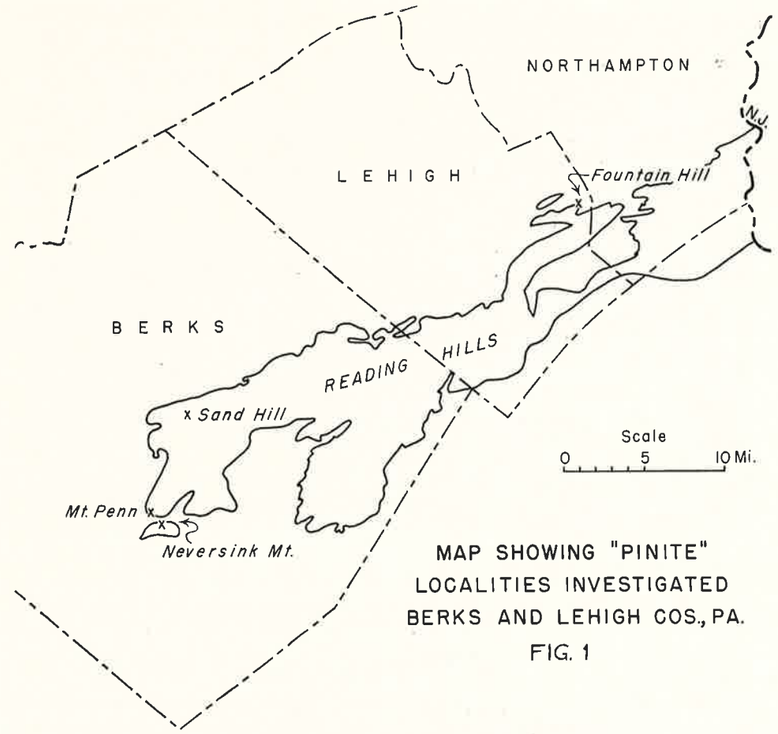
At several localities in the Reading Hills of southeastern Pennsylvania a varied-colored phyllitic rock sometimes referred to as "pinite" occurs at or near the base of the Hardyston formation of lower Cambrian age, approximately at the contact with the underlying Precambrian crystalline rocks. Occurrences in Lehigh and Northampton Counties were briefly described by Miller and Myers (1939, p. 213, 1941, p. 171) who believed it to represent a residual soil cover on the old crystallines which was preserved from erosion by the invading Cambrian seas and later metamorphosed to its present state. Stose and Jonas (1935, p. 760) and Stose (1931, p. 16) refer briefly to its occurrence in the Reading Highlands and consider it to be of similar origin. Hans Wilkens (1955, p. 194) mentions its occurrence in Berks County in the western part of the Reading Hills. The writer referred to it in a report on the Reading quadrangle (1962, p. 25) and suggested it to be in part of cataclastic origin, an idea further developed in this paper. Virgin (1956) discussed in considerable detail four occurrences in Lehigh, Northampton and Bucks Counties, presenting evidence suggesting the pinitic rock is a metamorphosed soil cover. He also discussed the status of the name "pinite" and its significance mineralogically and petrographically.

According to several authorities cited by Virgin (Dana's System of Mineralogy (1895, p. 621), Wahlstrom (1955, p. 188), Clarke (1924, p. 398, 410) pinite is not properly a mineral, but rather an aggregate of predominantly sericite and some chlorite. Wahlstrom (1955, p. 188) and Harker (1939, p. 340, 346) refer to its formation by alteration of cordierite. The petrographic and x-ray analyses mentioned below indicate that it is chiefly an aggregate of sericite and a little very fine-grained quartz. Virgin (1956, p. 152) also writes "A rock primarily composed of the mineral pinite is also commonly referred to by the name pinite." He uses the term "pinitic schist" to refer to the foliated rocks which he describes in the Reading Hills. The writer will use the term "pinite" for the rocks which resemble those described by Virgin, but not as a mineral name, which is inappropriate since pinite is an aggregate. This name seems preferable to "pinitic schist" as the rocks are not everywhere schistose and are locally poorly foliated.

DESCRIPTION AND INTERPRETATION OF PINITE AT FIELD LOCALITIES

Pinite, occurring at four localities, three in Berks County and one in Lehigh County (fig. 1), is described and interpreted below. Those in Berks County are the only outcrops known to the writer, although pinite occurs sparingly in float at a few places.

Sand (Wagoner) Hill locality. Pinite at this locality is exposed in a pit at the extreme west end of Sand Hill, accessible from the old black top road between Breezy Corners and Blandon. The field

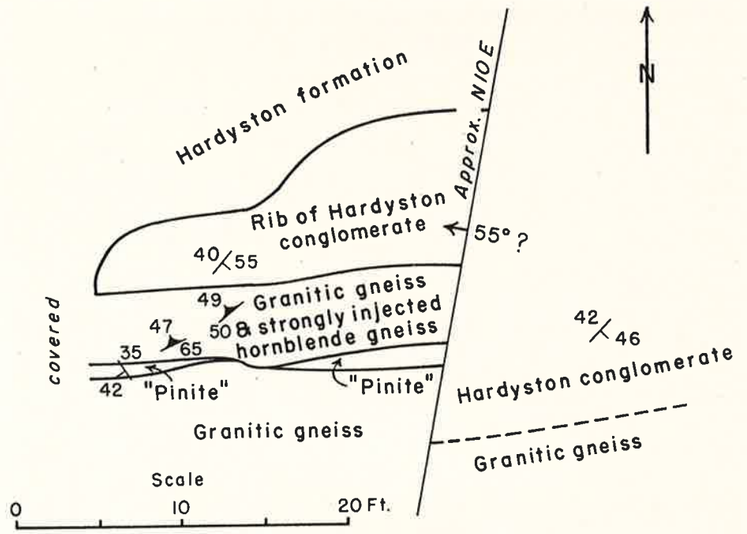


MAP SHOWING "PINITE" LOCALITIES INVESTIGATED BERKS AND LEHIGH COS., PA.
FIG. 1

relations are shown in the sketch (fig. 2). Pinite occurs in a band approximately 6 inches thick and about 4 feet below the base of the Hardyston basal conglomerate. In the west part of the band the pinite is dark gray, very fine-grained and exhibits only fairly well-defined foliate structure. An exact reading of the strike and dip of the foliate structure is difficult to measure, but the strike is apparently at great variance with the strike of the Hardyston beds. A few clastic grains are visible in the dense matrix. Thin section and x-ray diffraction examination indicate it is composed of about 90 per cent sericite, about 5 per cent very fine-grained hematite and perhaps 5 per cent quartz. Hematite occurs in thin streaks parallel to each other. Very rare angular feldspar is present.

Nearer to the cross fault, the pinitic rock contains only about 50 per cent matrix of which approximately 35 per cent is sericite and about 15 per cent opaque material, largely hematite, a little very fine-grained magnetite and possibly leucoxene. The coarser fraction consists of very angular clastic grains of quartz, potash feldspar and plagioclase, some of which are ground out into long stringers roughly parallel to the schistose structure.

The occurrence of the band of pinite within granitic gneiss and the presence of abundant, very angular quartz and feldspar in part of the pinite strongly suggest, if not prove, that here at least pinite is of cataclastic origin and may appropriately



SKETCH SHOWING FIELD RELATIONS OF "PINITE" AT SAND HILL LOCALITY, BERKS CO., PA.

FIG. 2

be termed a phyllonite. It is most unlikely here that it could be a metamorphosed soil as granitic gneiss occurs above as well as below it. The near absence of visible clastic particles in the west part of the band suggests that the crystalline rock was here almost completely mylonitized. The abundant sericite in this rock presents no major problem as it is well-known as a major constituent of phyllonites formed by cataclastic metamorphism. (Moorhouse, 1959, p. 413; Harker, 1939, p. 173; Heinrich, 1956, p. 186; Williams, Turner and Gilbert, 1954, p. 206).

Neversink Mountain—Nearly 8 feet of "pinite" is unusually well-exposed in the west end of a large quarry on the north slope of Neversink Mountain. The quarry is accessible by a paved road leading to the settlement on top of the mountain. Unlike at Sand Hill the pinite occurs directly below the basal Hardyston conglomerate. Most of it is a very fine-grained, dark gray, well-foliated phyllite. Its foliation nearly parallels that in the Hardyston beds. Occurring very sparingly throughout it are thin, discontinuous bands, about one-eighth to one-quarter inch thick of angular, broken and somewhat elongated quartz and minor feldspar grains. (Fig. 3) Under the microscope, much of the rock consists of about 90 per cent sericite, and about 10 per cent very angular, very fine to very coarse-grained elongate quartz.

Near the west end of the quarry where the outcrops are less well-exposed, a very minor part of the pinite exhibits abundant sheared-out microscopic grains of pink feldspar and quartz in a greenish-gray very fine-grained matrix, giving the rock

Fig. 3. Pinite showing foliation caused by sericite and thin clastic quartz band. Crossed nicols. Approximately X40. Neversink Mountain locality.

an appearance somewhat like augen gneiss. Under the microscope, quartz and microcline, which comprise about 50 per cent of the rock, show extreme cataclastic deformation. Both are locally milled and granulated, extremely angular, and drawn out into long streaks. Some quartz is very strongly sutured. The parallelism of the elongated grains and granulated sheared-out streaks is striking. About 40 per cent of the rock consists of sericite and a few per cent is hematite.

Megascopicaly, the bulk of the pinite of Neversink Mountain somewhat resembles typical phyllite, like the Harpers phyllite of southern Pennsylvania and Maryland, which are derived from bedded sediments. However, the conspicuous microscopic cataclastic textures in the thin quartz and minor feldspar bands and those of the minor zone in the west end of the quarry suggest that this pinite may also be a phyllonite, that is a phyllite formed by dynamic metamorphism. It is noteworthy in this connection also that the lower few inches of the basal Hardyston conglomerate which overlies the pinite is also dynamically metamorphosed. It consists of about 50 per cent very angular, fractured quartz some of which shows lamellae characteristic of intensely cataclastically deformed rocks. Some is also finely granulated. The remainder of the rock consists of well-foliated sericite identical to that in the underlying pinite.

Mt. Penn locality—About 8 feet of pinite is poorly exposed on the steep southwest slope of Mt. Penn at approximate elevation 570 feet about 60 feet below the first sharp turn to the east of the Skyline Drive. Both top and base of the exposed pinite are covered and much of the exposure is slumped. Small exposures of the Hardyston lower conglomerate which appear to be in place occur within a very few feet of the top of

the pinite, but the exact contact is covered.

Much of the pinite here is a reddish to greenish, fairly well-foliated to weakly foliated phyllitic rock. About 75 per cent of the rock is sericite exhibiting weak parallelism, 15 per cent is exceedingly fine-grained angular quartz and feldspar embedded in the sericitic matrix, and about 10 per cent is hematite and magnetite. Hematite partly replaces the angular, irregularly shaped grains of magnetite.

In about the middle of the exposure a slumped bed apparently about a foot thick is much redder than the rest of the pinite and shows much poorer foliation. It is composed of about 70 per cent sericite, 20 per cent hematite and about 10 per cent magnetite. Hematite occurs commonly in groups of short parallel linear aggregates which exhibit a few microfolds. Magnetite occurs as larger very angular grains which are fractured and many of them are elongate.

The pinite of Mt. Penn shows less clear evidence of strong dynamic metamorphic origin than that at the other three localities. Cataclastic textures are indicated mainly by the very fine angular quartz and feldspar and more notably by the angular, broken, drawn-out stringers of magnetite and hematite in the reddish variety. Much of the pinite here resembles the bulk of that at Neversink Mountain and that in the west end of the band at Sand Hill.

Fountain Hill—Pinite is exposed in at least three places along the north side of Fountain Hill and on the south side of the Lehigh River. One where pinite is well-exposed and lithologically fairly representative of all is an old pit about 80 feet long and 40 feet wide, approximately 1000 feet north of St. Luke's Hospital in Fountain Hill Borough. It is accessible by an unimproved road which parallels the river.

In the east side of the pit about 6 feet of reddish, slaty, apparently slumped pinite is exposed which grades below into an exceedingly sheared migmatite formed by injection of hornblende gneiss by granite. The shearing and alteration of the gneiss are so intense that it is difficult to ascribe precise boundaries between the pinite zone and the gneiss. The pinite is overlain by strongly sheared Hardyston conglomerate, of which the lower one to two feet are almost identical with the lowest conglomerate at Neversink Mountain. The contact between pinite and conglomerate is not well defined for not only is the lower conglomerate strongly sheared and contains abundant dark, pinitic-like matrix, but also within some of the pinite are a few macroscopic, subrounded quartz grains like those in the conglomerate. Microscopically, the slaty pinite consists very largely of exceedingly fine-grained sericite, about 2 to 3 per cent of similar-sized quartz and feldspar and about 5 per cent of limonite which occurs largely in streaks parallel to the foliation. Foliate structure is caused by frequent parallelism of the sericite.

On the west side of the quarry a band of well-foliated pinite varying in width from 6 inches to about 1½ feet occurs within the granitic gneiss migmatite. Here also the differentiation between pinite and sheared gneiss is difficult to make. The band is located from about 2 to 4 feet below the contact of gneiss and the Hardyston basal conglomerate. Microscopically, the pinite here consists of about 75 per cent very fine to exceedingly fine-grained, fairly well-lineated sericite and an estimated 20 per cent angular quartz and feldspar. The latter two minerals both occur as infrequent fine- to medium sized angular grains and as exceedingly fine fragments in the sericitic matrix.

The occurrence of some of the pinite on the west side of the pit within the gneiss, as at Sand Hill, renders probable a cataclastic origin for at least this part of the exposure. The angular, very fine-grained quartz and feldspar as well as the strongly sheared appearance of the underlying gneiss also lends support to this hypothesis of origin. The lower foot or so of the Hardyston conglomerate, particularly on the east side of the pit, contains abundant sericitic, pinitic matrix, which Virgin (1956, p. 155) suggests represents soil from the decomposed crystallines which has been reworked and deposited within the lower Hardyston. Inasmuch as the lower conglomerate locally grades insensibly into the pinite, this explanation here appears tenable. Pinite, the lower Hardyston conglomerate, and the underlying gneiss all show some cataclastic textures, suggesting that here dynamic metamorphism accompanied or folowed the low grade, greenschist facies, regional metamorphism which formed much of the slaty pinite.

SUMMARY

The occurrence of pinite within the Precambrian gneiss at Sand Hill and in the west part of the exposure at Fountain Hill strongly suggests that it was formed there by strong local cataclastic metamorphism of the gneiss. Conspicuous cataclastic textures support this interpretation. At Neversink Mountain and Mt. Penn, where the pinite directly underlies the Hardyston conglomerate, the evidence is less convincing, though cataclastic textures are locally present. In the east part of the Fountain Hill exposure the Hardyston conglomerate with an abundant sericitic matrix seemingly grades into pinite, suggesting the matrix of the conglomerate was derived from the pinite and possibly represents reworked soil as Virgin (1955, p. 155) earlier hypothesized. Cataclastic metamorphism later strongly deformed conglomerate, pinite and gneiss.

The writer has suggested in another paper (1962, p. 41) that the Hardyston in the western part of the Reading Hills has been folded into tight synclines in which one or even both limbs have been sheared out. The intense shearing at the base of the Hardyston which locally, at least, formed the pinite may be a manifestation of this larger scale tight folding and indicate differential movement of the Hardyston over the underlying crystallines.

ACKNOWLEDGMENTS

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CONDITIONS OF FORMATION OF PREHNITE AND ASSOCIATED VEIN MINERALS IN DIABASE NEAR COOPERSBURG, PENNSYLVANIA

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ABSTRACT

Prehnite, α quartz, and calcite occur as vein minerals in diabase near Coopersburg, Pennsylvania. Textural relations indicate that these minerals cocrystallized. Therefore the mineral assemblage must have formed below the $\alpha - \beta$ quartz inversion temperature and also below the temperature of raction of quartz + calcite $\rightleftarrows$ wollastonite + CO_2. Experimentally prehnite is found to decompose to wollastonie + anorthite + vapor at temperatures lower than 375°C and 380°C at a water vapor presure 14.700 and of 22,500 psi.

INTRODUCTION

Although prehnite is well known to the mineralogists of Pennsylvania and New Jersey, there are but few reports giving the paragenetic relation of this mineral to other secondary minerals. It is the purpose of this paper to briefly describe the occurrence of prehnite in the diabase near Coopersburg, Pennsylvania, and from the coexistence of the associated minerals estimate the pressure-temperature conditions of formations of the prehnite.

The writer is indebted to the late Professor H. R. Gault for a well cataloged collection of prehnite-bearing rocks from the diabase near Coopersburg. When the quarry was last studied the prehnite vein could not be found.

GEOLOGICAL SETTING

The form of the diabase sheet around Quakertown is an elliptical body whose long axis strikes northeast. Hersey (1944) suggests on the basis of gravity data that the diabase thickens toward the central axis of the structure. Hersey states (1944), "the gravity anomaly could be caused by an intrusive roughly 100 feet thick near its edges and about 1,800 feet thick along its axis." The prehnite was collected near the northern edge of the diabase intrusive, and consequently in an area where the sheet is probably thin.

In hand specimens the diabase is dark gray to black. Layering, streaks, or schlieren are not found in the rock.

Under the microscope the rock is found to be predominantly pyroxene and labradorite. The pyroxene, forming about one-half of the rock, is about 50 per cent hypersthene and 50 per cent augite. Most of the hypersthene and augite occur as discrete crystals anhedral to subhedral in form. However, some hypersthene contains oriented inclusions of augite, and some augite contains lamella giving the crystals a herringbone structure. Labradorite, also forming about one-half of the rock, is twinned and zoned. Composition determinations by the method of Michel Lévy show this mineral to be about An_{65-70}.

Apatite, biotite, chlorite, potassium feldspar, quartz, and an opaque mineral with a silvery-white reflection were found in trace amounts in the rock.

Labradorite crystals occur as laths 1-2 mm long, and the augite and hypersthene is present as anhedral crystals 1-2 mm in diameter. Thus the rock is hypidiomorphic-granular with a subophitic texture. With this texture the rock should be called a medium-grained gabbro; but in keeping with prior usage, the name diabase is retained in this report.

Overlying the diabase is the Brunswick lithofacies of Triassic age. This rock is described by McLaughlin (1959, p. 93)

as "a weak, bright-red argillaceous shale that readily crumbles into thin flakes or ragged fragments." He further states (p. 93), "near the north border a number of beds of very fine-grained, micaceous red sandstone are interbedded with with weaker red shale." The thickness of the shale cover at the time of intrusion of the diabase is unknown, but it probably was not great because basic rock genetically related to the diabase occur as flows in nearby areas.

PREHNITE VEINS

The complex mineralogy of the veins will be described in a subsequent publication. It is the purpose of this paper to describe only the minerals associated with prehnite.

Prehnite and calcite vein and fill interstices in an albitite rock. Composition determinations indicate that the feldspar host of this rock is nearly pure albite. Rarely is prehnite and calcite found in the same vein; in fact some veins of calcite are found to offset veins of prehnite. This relationship of veins suggests that the prehnite predates the calcite.

In another specimen prehnite and quartz occur as euhedral crystals and fan-shaped aggregates partially filling a vein. The euhedral quartz crystals have faces characteristic of the α or low temperature form. Under the microscope it is found that large prehnite crystals contain small equant and flamboyant crystals of calcite and elongate crystals of quartz. The crystals of calcite are not concentrated along prehnite grain boundaries nor is the long dimension of the flamboyant aggregate parallel to grain boundaries or cleavage directions. Flamboyant aggregates of calcite occur as overgrowths on prehnite crystals. If the calcite and quartz had formed in the prehnite by some replacement process, it seems likely that they would be concentrated along grain boundaries or cleavage planes. The lack of such evidence suggests that the calcite, quartz, and prehnite cocrystallized. Calcite occurring as overgrowths on prehnite and the veining relations previously described indicates that calcite continued to crystallize after cessation of crystallization of prehnite.

CONDITIONS FOR PREHNITE FORMATION

The limiting conditions under which prehnite forms can be estimated by four methods.

1. Quartz coexisting with the prehnite has the α or low temperature form. This form indicates a temperature of formation of less than 573°C at 1 atmosphere pressure. At higher pressures, about 1000 Kg/cm², the temperature of formation could be about 598°C.

2. Quartz and calcite coexist with prehnite. At high temperature quartz and calcite react yielding wollastonite and CO_2. Harker and Tuttle (1956) show that this reaction proceeds at 600 to 620°C at a pressure of 5000 psi, just under 690°C at 15,000 psi, and just under 750°C at 30,000 psi. Extrapolation of these data to one atmosphere pressure indicates a reaction temperature under this pressure of 375°C to 400°C. Because prehnite coexists with quartz and calcite it also must have formed below the temperature of formation of wollastonite. It should be remembered that in the experimental study the pressure was largely CO_2 pressure, whereas in the prehnite veins the pressure was probably in a large part the partial pressure of water.

3. At pressures under 1000 bars, Kennedy (1950) shows that at a constant water pressure the solubility of quartz reaches a maximum and then decreases with increasing temperature. For a silica-water system at constant volume and pressure, the first effect of cooling from a high temperature will be a solution of pre-existing quartz until the maxi-

mum of the solubility curve is reached, after which with lowering temperature there will be precipitation of quartz. The fact that quartz precipitated in the prehnite veins and does not show any indication of corrosion or solution indicates that it formed below the temperature that corresponds to the maximum of the isobaric solubility curves.

In applying the quartz solubility data there are the following assumptions:

1. That the prehnite veins are a constant volume system.

2. That the pressure of the system was constant.

3. That the presence of CO_2 or other ions in water has little or no effect on the position of the maximum of the solubility curves.

The constant volume-pressure conditions of the natural system are probably satisfied; because deposition was in open veins most likely with a relatively constant volume, and pressure is probably a function of the lithostatic load. The greatest uncertainty is the effect of CO_2 and other ions on the solubility of quartz. This uncertainty cannot be evaluated with the present knowledge of the system. It is hoped that experimental work on the stability of prehnite will contribute to a gross understanding of the problem.

4. The stability of prehnite in hydrothermal solutions is currently being investigated by the author. At present it is known that prehnite decomposes to wollastonite + anorthite + vapor at a temperature less than 375°C at a water vapor pressure of 14,700 psi and less than 380°C at a pressure of 22,500 psi.

CONCLUSION

It is dififcult to estimate both the pressure and the temperature of a natural system. For some problems the pressure can be estimated by assuming that the fluid pressure is equal to the rock pressure or lithostatic load. Unfortunately, the lithostatic load during the intrusion of the diabase is not known, but it probably was not great because equivalents of the diabase occur as flows in nearby areas. On this basis an estimate of 1000 meters of cover is probably in excess of the actual thickness of the cover. Using this estimate of 1000 meters of cover, the temperature of formation of the prehnite could not have been in excess of 375°C, and it was probably much less. The precipitation of quartz suggests a temperature lower than 380°C. The estimated temperature is consistent with the occurrence of α quartz and calcite. The precise determination of the stability of prehnite will further elucidate the problem.

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CORDIERITE ALTERATION

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ABSTRACT

Detailed study by X-ray diffraction, thin-section, and oil-immersion, of altered cordierites (pinites, et al) from various localities in Europe and New England has corroborated and amplified the essential results of nineteenth century petrographic investigations. Muscovite and chlorite are the chief pseudomorphosing constituents, although paragonite or a halloysite-like phase dominates in certain cases.

INTRODUCTION

The mineral cordierite, $(Mg, Fe)_2Al_3Si_5AlO_{18}$, occurs largely in metamorphic rocks. It may be found in rocks that have been subjected to high grade regional metamorphism (schists, gneisses, granulites) or in rocks resulting from thermal metamorphism of aluminous (argillaceous) sediments. It is found less commonly in igneous rocks, both of mafic and granitic types. There are a few occurrences of cordierite in pegmatites and quartz veins. The igneous origin of the mineral is probably dependent, in many cases, upon aluminum- and magnesium-enrichment due to magmatic assimilation of sediments rich in these elements.

Cordierite is frequently found in an altered condition, the alteration being partial or complete. The common replacing products are muscovite, chlorite, and a halloysite-like material, (septechlorite). The latter herein will be referred to as "7A material," in reference to its X-ray basal spacing of ca. 7 Angstrom units. Paragonite is an important replacing constituent in certain localities. Quartz and hydrous iron oxide are minor phases in many altered cordierites; other products are relatively rare and of only local occurrence. Commonly the texture of the pseudomorphs is very fine-grained, although there are significant exceptions to this. In most specimens one or two replacing minerals predominate, while other replacing minerals are present in small amount or are absent. The major alteration has presumably taken place under retrogressive conditions: retrograde metamorphism, cooling of an igneous body, etc.

In order to present a general picture of the textural and mineralogical aspects of cordierite alteration, descriptions of several examples are given below with accompanying photomicrographs. The specimens selected represent most of the important types of occurrence of cordierite, with the notable exception of the fine-grained hornfelses of contact metamorphism. Only the more salient features of alteration are included in this article; a more comprehensive presentation will appear in a forthcoming paper. For convenience in the petrographic descriptions of the alteration mineralogy, the following terms are provisionally employed as prefixes for grain-size: mega ($> 100\ \mu$); micro ($< 100 > 10\ \mu$); proto ($< 10\ \mu$) [e.g., micro-muscovite]. Locality names head the separate descriptions.

HELSINKI, FINLAND

Specimen 1 is an inequigranular gneiss (?) consisting largely of quartz and altered cordierite in approximately equal amounts. The grain size ranges from 1 to 8 $^{m}/_{m}$. Minor constituents are: biotite in small, scattered aggregates; sillimanite as fibrous knots in biotite, and as minute laths bordering and within some of the pods of altered cordierite; a few chunky grains of andalusite in al-

tered cordierite; local oligoclase grains; a trace of chlorite. Megascopically the masses (pods) of altered cordierite are of dark brown to black color, soft, dense, with dull luster.

In thin-section the alteration is seen to be complete, many pods consisting chiefly of material which is apparently septechlorite, according to optical, X-ray, and D.T.A. data. This "7A material" is largely pale buff-tan to colorless, with slightly variable refractive index, close to 1.540. Birefringence is weak to nil. Much of the material has a columnar or lineated structure. Local areas are light brownish yellow to orange-brown, with index of refraction ranging up to 1.580. Many of the pods consist in part of very fine-grained muscovite (micro- and proto-muscovite). Amongst various pods all stages may be seen in the progressive sericitization of the 7A material:

(1) a thin irregular border, and a few hair-veinlets of proto-muscovite projecting into the 7A pod (Fig. 1); proto-muscovite lamellae range in size from $<$ 1 to ca. 10 μ; preferred orientation of lamellae is already initiated.

Fig. 1. A virtually isotropic, 1 $^{m}/_{m}$ pod of altered cordierite (center), entirely surrounded by quartz. A smaller pod appears at lower left. Crossed polars.

(2) border becomes wider but quite irregular, the veinlets larger and more numerous; the muscovite is somewhat coarser (micro-muscovite) with marked preferred orientation.

(3) only a few patches of 7A material remain.

(4) a solid aggregate of micro-muscovite; the lamellae range in size from ca. 20 to 40 μ, most of them in alignment.

Thus, the alteration represented in specimen 1 appears to be:

$$\text{cordierite} \xrightarrow{\text{complete}} \text{7A material}$$

$$\xrightarrow{\text{partial}} \text{proto- and micro-muscovite.}$$

ABO (TURKU), FINLAND

Specimen 2 is a flesh-colored granite of medium grain size, 2 to 6 $^{m}/_{m}$. A rough mode is as follows: 50% microcline, perthite, and microperthite; 15-20% oligoclase (An_{10-12}); 25% quartz; 5% altered cordierite; minor garnet and biotite; a trace of andalusite and zircon. As with speciment 1, the pods of altered cordierite are, in megascopic view, dark brown, soft, and of dull luster. Most pods have an elongate, irregular shape, a few are essentially rectangular.

Petrographically the pods are composed mostly of yellowish tan 7A material, although the color ranges from pale beige to deep orange. Nearly all the 7A material is isotropic, the remainder being very weakly birefringent. Index of refraction is slightly variable, less than to greater than that of balsam, the more deeply colored material having the higher index. Structures and patterns are diverse and complex. The 7A material is transected by numerous fuzzy veinlets of proto-muscovite (Fig. 2), the lamellae of which are oriented nearly perpendicular to trend of veinlet. A few lamellae of leaf-green chlorite are present which are optically (-) with mean index of 1.626. Some grains of andalusite and biotite are arranged preferentially around borders of the pods, and minor biotite

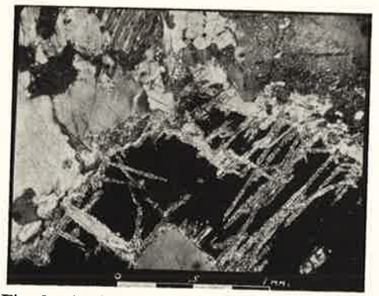

Fig. 2. An irregular shaped pod of isotropic, altered cordierite cut by veinlets of proto-muscovite. Quartz, feldspar, and biotite are the chief constituents outside the pod. Crossed polars.

laths are found within; these constituents were probably formed more or less contemporaneously with the original cordierite. Alteration in this specimen would thus seem to be:

$$\text{cordierite} \xrightarrow{\text{complete}} \text{7A material}$$

$$\xrightarrow{\text{incipient}} \text{proto-muscovite and minor micro-chlorite.}$$

FALUN, SWEDEN

Specimen 3 is a talc schist from the Falun mines of south-central Sweden. The schist is silvery gray, very fine-grained and compact, and encloses several irregular pods or chunky nodules of altered cordierite ranging in length from $<$ 1 $^{m}/_{m}$ to 15 $^{m}/_{m}$. In hand specimen the pods are generally dark brown, locally dark greenish and dark brownish red, translucent, dense, soft, with dull luster.

Thin-section examination (supported by X-ray work) reveals that the cordierite is almost completely altered. Again, 7A material predominates, exhibiting extreme diversity of structure, pattern, and shade of color (colorless, pale beige, pale to deep yellow). Birefringence ranges from nil to weak, some of the latter areas yielding very diffuse interference figures, apparently biaxial (-). Index of refraction, although slightly variable, is close to 1.570. One of the most distinctive patterns is a delicate anastomosing structure (Fig. 3), with complex arrange-

Fig. 3. Part of a large pod of altered cordierite, exhibiting anastomosing structure. Pod lies in pure, fine-grained talc. Crossed polars.

ments of concentric banding and "ring structure"; this is well shown only in crossed polars. Elsewhere within the altered cordierite pods there are extensive areas and numerous veinlets of proto- and micro-muscovite. Another constituent, in addition to local remnants of cordierite itself, is pale green chlorite, both optically (+) and (-), with β indices of 1.584 and 1.586, respectively.

The alteration of the Falun cordierite can be represented as:

$$\text{cordierite} \xrightarrow{\text{extensive}} \text{7A material}$$

$$\xrightarrow{\text{partial}} \text{proto- and micro-muscovite, and micro-chlorite.}$$

In some specimens from Falun part of the alteration material appears to be bowlingite.

STURBRIDGE, MASSACHUSETTS

Specimen 4 is a coarse-grained gneiss, the constitution of which is approximately: 35% microcline, 15% oligoclase, 25% quartz, 10 to 15% cordierite, with minor muscovite, biotite, sillimanite, andalusite, kyanite (?) and zircon.

Thin-section examination shows that the cordierite has sustained considerably more sericitization than the feldspars. One large cordierite grain, ca. 8 $^{m}/_{m}$ in diameter, is entirely bordered by a narrow zone of micro-muscovite; an extensive area within the grain is also composed of micro-muscovite, and numerous veinlets of the same material extend into the fresh cordierite (Fig. 4), the largest

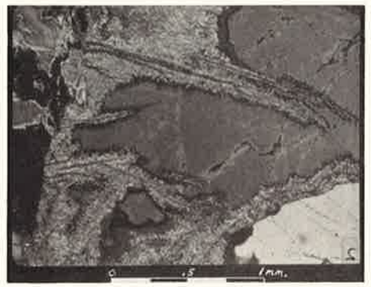

Fig. 4. Fresh cordierite (center and upper right), cut by small veinlets of micro-muscovite. Crossed polars.

veinlet being 5 $^{m}/_{m}$ long and .5 $^{m}/_{m}$ wide. Some veinlets follow cleavage or parting cracks, others are oblique thereto. Within the region of virtually solid micro-muscovite, small irregular patches show a high degree of preferred orientation of micro-lamellae. Alteration in specimen 4 appears to be simply:

$$\text{cordierite} \xrightarrow{\text{partial}} \text{micro-muscovite.}$$

UNITY, NEW HAMPSHIRE

Specimen 5 derives from a vein occurrence or from the margin of a pegmatite. It is a rough, tabular, light greenish mass measuring 4 cm. in thickness, 10 by 7 cm. in area, part of what was originally a large single crystal of cordierite. Basal parting surfaces are coated with colorless mica and light green chlorite. Minute stellate groups of kyanite needles are embedded in the mica and chlorite. Edges of the specimen exhibit small local masses of fresh, pale blue cordierite and light green, altered cordierite. An irregular seam of quartz approximately parallel to the basal surfaces lies medially within the specimen.

A thin-section cut perpendicular to the basal surfaces of the tabular specimen and ca. perpendicular to Z (= b) of the cordierite shows a striking 90° grid or replacement network (Fig. 5).

Fig. 5. Fresh cordierite transected by replacement grid-work. The (001) layers, seen edge-on, trend ca. N 10° W in this view. Crossed polars.

Thin bands (layers) parallel (001) of the cordierite are made up of relatively large lamellae of paragonite and subordinate pale green chlorite and laths and fibers of kyanite. All of these minerals participate also in diverging bunches branching off from the (001) layers. The (100) direction of the grid is expressed by a host of veinlets composed of buff-colored, very fine-grained paragonite; the veinlets originate at (001) layers, some pinching out, others connecting with a neighboring (001) layer. Each veinlet has a central channel a few μ wide composed of proto-paragonite, bordered on both sides by paragonite lamellae 10 to 50 μ long, oriented oblique to veinlet. Most of the (001) layers are bounded by narrow zones of micro-paragonite; where the layers are quite close together, coalescence of border zones has produced local masses of essentially pure micro-paragonite (the soft, light green portions of hand-specimen view). A few small veinlets cut obliquely across the grid structure. Occasional trains of stubby andalusite crystals more or less follow the grid directions. Formation of the andalusite and kyanite is here considered to have been essentially concurrent with that of the cordierite. 40 to 50% of the regions dominated by cordierite is occupied by replacing material. There is no evidence of 7A substance. Alteration in specimen 5 may be stated:

$$\text{cordierite} \xrightarrow{\text{partial}} \text{mega-chlorite, mega-paragonite and micro- and proto-paragonite.}$$

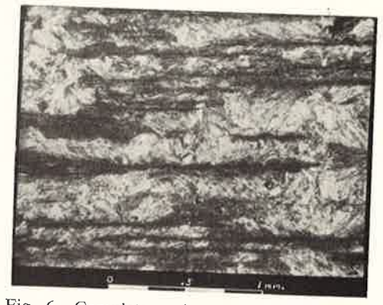

Fig. 6. Complete replacement of cordierite by phyllosilicates; some lamellae are arranged in thin layers, seen edge-on, parallel to (001) of the parent cordierite, others are in diverse orientations between the layers. Crossed polars.

PLYMOUTH, CONNECTICUT

Specimen 6 is a portion of a large, tabular crystal of altered cordierite measuring 5 cm. thick, with an original diameter of 15 cm. The occurrence is evidently similar to that of specimen 5. Basal surfaces of the specimen are coated with relatively large lamellae of buff to colorless mica and a lesser amount of emerald-green chlorite. Numerous parting surfaces parallel to the base exhibit similar development of mica and chlorite. Many lamellae of these minerals are oriented perpendicular to the base, others in oblique position. Most of the interparting material consists of relatively fine-grained intergrowths of colorless mica and light green chlorite lamellae in diverse orientations.

A thin-section cut perpendicular to (001) of the parent cordierite reveals that no cordierite is present, alteration being complete. Relatively little material of extremely fine grain size is present. The section is dominated by numerous parallel narrow layers (seen edge-on) of aligned paragonite and subordinate chlorite lamellae developed parallel to (001) of the parent cordierite (Fig. 6). The layers pinch and swell slightly, some diverging sheaflike at their ends. These layers comprise 25 to 30% of the thin-section. Between the aligned layers, more or less randomly oriented lamellae and stellate groups are present; these lamellae of paragonite, chlorite, and minor muscovite (confirmed by X-ray) are of considerably smaller size than those developed along (001). Some short layers of aligned lamellae are arranged perpendicular to the (001) system, yielding local semblances of a 90° grid-work. A few elongate lenticles of quartz up to .3 $^{m}/_{m}$ long are enclosed within the aligned bunches of mica-chlorite. This alteration can be summarized:

$$\text{cordierite} \xrightarrow{\text{complete}} \text{paragonite, chlorite, minor muscovite (and quartz?).}$$

CONCLUSIONS

Alteration of cordierite in several localities is characterized by initial development of a soft 7A material (septechlorite). This alteration is effected by a significant gain of water and loss of magnesium. With introduction of potassium the apparently metastable 7A sub-

stance is rather readily replaced by fine-grained aggregates of the stable phyllosilicates, white mica and chlorite. In some localities 7A material is not involved in the cordierite alteration. In such cases the direct replacement by white mica and chlorite is, in part, controlled by directions of parting and cleavage in the cordierite, the basal parting developing as a consequence of alteration.

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PALEOECOLOGY OF UPPER CRETACEOUS (NAVESINK) BEDS AT PORICY BROOK, MONMOUTH COUNTY, NEW JERSEY

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ABSTRACT

Preliminary study of an exposure of shell beds in the Navesink Member, Monmouth Formation demonstrates the interrelation of sampling methods, selective preservation, and ecological factors in production of the fossil sample. The occurrence of articulated *Exogyra* and *Gryphaea* valves in life position demonstrates that the sample was derived from a single biocoenosis. The rarity of species other than of these two heavy shelled pelecypods may represent a valid aspect of the biocoenosis produced perhaps by soft substrate and salinity variations, but evidence of shell solution prior to or during burial and the traces of poorly preserved echinoids, worm tube, and bryozoans demonstrate selective modification of the biocoenosis to produce a chemical lag deposit. Sampling bias induced by selective collecting from contemporary stream bar deposits has reinforced the effects of selective preservation.

INTRODUCTION

The Navesink member of the Monmouth formation, Upper Cretaceous of New Jersey, contains several distinctive shell beds (Spangler and Peterson, 1950, p. 41). We report here a preliminary study designed 1) to determine if these beds are biotic or sedimentary accumulations 2) to define the possible factors controlling their accumulation, and 3) to examine their suitability for a large scale paleoecologic study.

The northernmost outcrop of the Navesink at Atlantic Highlands lacks any trace of shell beds (Spangler and Peterson, 1950, p. 41), but five miles to the southwest in central Monmouth County three distinct shell beds appear, the lower, *Belemnitella,* bed, the middle, *Exogyra,* bed, and the upper, *Gryphaea,* bed. (ibid, p. 42-43). Twenty-five miles further south, near New Egypt and Mullica Hill, the Navesink contains a single shell bed including *Belemitella, Exogyra,* and *Gryphaea* in abundance as well as many other species (ibid, p. 44).

The senior author undertook the study of the Navesink shell beds as an undergraduate research project, did most of the field work and collecting, made preliminary identifications and descriptions, and prepared a tentative interpretation of the data. The junior author directed the project, provided further identifications, and made a partial reinterpretation for this paper.

DESIGN OF STUDY

We decided after initial reconnaissance to limit this preliminary study to a small area in central Monmouth County, to examine only the beds that contained an abundant benthic fauna, the *Exogyra* and *Gryphaea* units, and to concentrate upon a single, easily accessible outcrop where both of these beds were well exposed. The selected locality was along Poricy Brook described by Spangler and Peterson (1950, p. 42) as:

> "Locality 654, ¼ mile south of Oak Hill and about 1¾ miles south of Middletown, 500 feet east of road in south bluff of Poricy Brook."

The geographic coordinates are approximately 74°07′ W. Long. -40°22′ N. Lat., and the shell beds are exposed in both banks and in the creek bed. Table 1. reports the section measured here by Spangler and Peterson (ibid, p. 42).

The larger number of specimens were located from sand bars in Poricy Brook;

TABLE 1

Stratigraphic Section of Navesink Member, Monmouth Formation, Poricy Brook, Monmouth County (from Spangler and Peterson, 1950, p. 42).

Thickness	Description
5-6'	Soft, sticky, plastic, black glauconitic clay
8	Gray-black, calcareous, micaceous, argillaceous glauconite. Abundant fragile, small white shells in upper part
5	Greenish black glauconite. Top of this bed formed by layer of *Gryphaea convexa,* with numerous *Ostrea mesenterica* and *Belemnitella americana.* This upper layer is *Gryphaea* bed and is 3-4 inches thick.
3-4	Layer of *Exogyra costata,* and *E. cancellata.* This bed is at, and in places below, brook level. It also contains scattered *Belemnitella americana.* This is *Exogyra* bed. Base covered

a somewhate smaller sample was obtained *in situ;* and a small number of specimens were obtained by washing and screening bulk samples from each bed.

In addition, collections were made at Nut Swamp Brook one mile to the southwest and along Big Brook six miles to the southwest (Spangler and Peterson's Locality 651, p. 43), for comparative purposes. We report here only on the samples from Poricy Brook.

SAMPLE DESCRIPTION

The fossils of the lower, *Exogyra,* bed are dominated numerically by *E. costata* and *E. cancellata. Belemnitella americana* occurs infrequently; a few indeterminable fish bones were recognized. Two *Exogyra* shells bear calcareous tubes, presumably of some annelid, and two other shells show evidence of attachment to echinoid tests. Some of the shells are extensively bored, presumably by sulphur sponges.

The fossils of the upper, *Gryphaea,* bed consist, as implied by the name, principally of *Gryphaea convexa. Ostrea mesenterica, Terebratella plicata* and *Belemnitella americana* occur in some abundance, however. The majority of the *Gryphaea* shells are extensively bored, and about 5% retain traces of calcareous worm tubes. Three unidentified bryozoan species, two encrusting *Gryphaea* and *Ostrea* shells and a ramose type represented by a single specimen, have been recognized. A small pecten, also unidentified, and indeterminable fish bones, were also collected from this unit.

In the layers between the shell beds, *Gryphaea, Ostrea, Terebratella,* and *Belemnitella* are common; *Exogyra* is extremely rare except in the *Exogyra* shell bed.

Because of difficulties in measurement, no precise data on size variation can be given yet. In general, the *Exogyra* specimens range from 7.5 to 15 cm in length; the *Gryphaea* from 7.5 to 16 cm; the *Ostrea,* including specimens encrusting other shells, from about 4 to 30 mm. A single *Exogyra* about 1 mm long was found buried in the attachment area of a much larger individual. A count of the number of articulated *Gryphaea* and *Exogyra* valves and of the separated right and left valves is reported in Table 2.

Of the *Exogyra* and *Gryphaea* specimens collected in place the majority had the valves articulated and in life position, convex valve down. About 5% of the matrix in the shell beds consists of shell fragments, but few identifiable specimens, even the delicate *Ostrea,* show evidence of breakage. Many of the *Gryphae* shells were leached before burial or during diagensis as demonstrated by undisturbed matrix in solution cavities penetrating the shell structure. None of the other molluscan species show such clear evidence of solution prior to recent weathering though a few of the *Exogyra* and *Belemnitella* may be so interpreted. The calcareous worm tubes, the bryozoans, and the echinoids are poorly preserved; in particular, the fragments of the latter identified in an *Exogyra* attachment area were scarcely distinguishable from the matrix and would not have been recognized except for the impression of spine bases retained in the *Exogyra* shell material. As already noted, many *Exogyra* and *Gryphaea* shells were bored by worms; about 10% of the former and 60% of the latter display extensive boring, penetrating to the inner surface of the shell. Very few of the other types of shells are bored; none extensively. Many of the *Exogyra* (over 50%), a few of *Gryphaea,* and a few *Ostrea* show evidence of attachment during life to other shells.

TABLE 2

Frequency of Articulated and Separate Valves in Sample of *Exogyra* and *Gryphaea* from Poricy Brook Outcrop of the Navesink.

Position of Sample	Valves	*Exogyra*	*Gyphaea*
Collected in situ	Articulated	3	13
	Right	0	0
	Left	3	3
Collected from stream bars	Articulated	0	0
	Right	80	18
	Left	80	98

The Navesink in central Monmouth County consists of marl or calcareous clay. Glauconite is abundant, constituting in some samples over 50% of the sediment, and ranges in size from silt to coarse sand. Mica (1-2%), well-rounded quartz grains (1-2%), and shell fragments (1-5%), constitute the remainder of the sediment. Except for the shell beds themselves, the marl is apparently structureless and forms a plastic clay in outcrop.

INTERPRETATION

The characteristics of the sample just described are attributible in part to sampling difficulties, in part to selective preservation, and in part to ecologic controls of the living population. Since we picked a large portion of the sample from modern streams bears, the rarity of small individuals and of delicate species as well as differences in the number of right and left valves of *Gryphaea* can be attributed in part to differential solution, to mechanical destruction, and to selective removal by stream action since exposure of the bed in the current erosion cycle. Collecting bias would presumably produce similar effects and reinforce the overall bias of the sample. The rarity of these fossil elements (with the exception of the ratio of right to left valves) among the specimens collected *in situ* suggests strongly, however, that whatever the effects of sampling bias they did no more than exaggerate a prior feature.

The evidence of pre-burial or diagenetic solution implies a considerable modification of the sample by selective chemical action during preservation. The al-

teration of the echinoid tests and the apparent solution of the encrusting bryozoans and worm tubes indicate rather significant losses of skeletal material with calcium ion turnover at the substrate-water interface, or within the substrate. The abundant *Gryphaea* and *Exogyra* shells would thus represent a chemical lag deposit buffered by size, thickness, and chemical stability for a rather long period of time; the less frequent forms would, in turn, represent brief episodes of unusually rapid burial or other circumstances that favored preservation of delicate and unstable skeletons.

The fragmentation of some shell material suggests a moderate amount of mechanical action and possible selective destruction and transport. However, the frequency of articulated valves in life position and the preservation of delicate *Ostrea* shells demonstrates clearly that the shell beds, in central Monmouth County at least, are not shell pavements reworked by storm waves. The selective effects of burrowing and mud feeding organisms on the sample cannot be evaluated yet—the abundance of glauconite pellets and the absence of bedding structure suggests though it does not prove the activities of such ogranisms. The worm borings almost certainly effected the survival of the shells bored since they would increase both the rate of chemical solution and the probabilities of mechanical fragmentation.

Inasmuch as the shell beds are not pavements produced by wave or current sorting of a thick sedimentary sequence, the concentration of shells in these beds must represent a change in the ratio between sedimentation and biologic population density. The abundance of heavily bored, encrusted, and leached shells in the *Gryphaea* bed suggests long post-mortem exposure on the substrate before burial and thus a slow rate of deposition. The *Exogyra* beds display little evidence of such exposure and must consequently indicate only a brief episode of rapid shell growth and slow sedimentation.

From this consideration of preservational factors, we conclude that the Navesink shell beds are portions of biocoenoses *in situ,* but that the taxonomic content and the characteristics of the species populations reflect rather extensive selection in preservation.

The demonstration of selective preservation requires that paleoecologic interpretations be made with great caution. Until more extensive sampling permits us to analyse the effects of this selection in greater detail, we can only suggest that turbidity and soft substrate may have limited bottom colonization to specially adapted forms such as *Gryphaea* and *Exogyra* and to those species that could grow attached to them. The paucispecific character of the samples, if not entirely the result of selective preservation, implies exposure, at least periodically, to abnormally low salinities. Speculation on temperature, turbulence, pH, gas concentrations, etc. would be entirely premature.

We conclude from our initial study that further investigation of the Navesink could provide a useful demonstration of the interrelation of sampling methods, preservational factors, and ecologic controls in the production of a fossil sample. Such investigation would properly employ statistical studies of the species populations and their associations and quantitative analyses of both the organic and inorganic components of the shells and sediment as well as the classical techniques of paleontology and sedimentary petrography.

REFERENCES CITED

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LITHOSTRATIGRAPHIC NOMENCLATURE OF THE TRIASSIC NEWARK-GETTYSBURG BASIN*

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ABSTRACT

A review of the lithostratigraphic elements which comprise the Newark Group in the Newark-Gettysburg Basin brings out regional relationships between the Brunswick and Gettysburg Formations and the Brunswick and Lockatong Formations which can be understood more clearly via nomenclatural modifications. Coarse sediments exposed in the narrow neck of the outcrop belt in Pennsylvania are proposed as the Hammer Creek Formation. Formalization of this coarse clastic body avoids overextending Brunswick and Gettysburg formational terminology to include rocks typical of neither unit. Hammer Creek Formation is delimited laterally by two arbitrary cut-offs (one at the Schuylkill River, the other just northeast and parallel to the Susquehanna River). Its base is the Stockton and New Oxford Formations; its top, the north margin of the Newark-Gettysburg Basin. The proposed Hammer Creek Formation is typified by coarse sandstones and conglomerates in which individual units pinch out laterally. The type section is along Hammer Creek in the Richland (Pa.) 7½ minute Quadrangle.

The Lockatong and Brunswick Formations, characterized by lateral intertonguing and vertical alternation may be treated in two alternative ways. (1) The entire red and gray Brunswick-Lockatong complex can be considered a single formation or group and individual, isolated gray and red horizons assigned names. (2) The assumption can be made that the isolated gray Lockatong horizons and red Brunswick horizons join their respective main bodies down dip or were parts of these bodies during deposition. Indirect evidence suggests that this assumption is reasonable and application of the term *lithosome*[1] connotes the implied three-dimensional relationships between these two lithic bodies. In this paper, they are called the Lockatong lithosome and the Brunswick lithosome.

INTRODUCTION

The Newark-Gettysburg Basin is the sinuous outcrop belt of Triassic rocks extending from southeastern New York through New Jersey, Pennsylvania, and into Maryland (Figure 1). Sedimentary rocks contained within the Newark-Gettysburg Basin constitute the Newark Group[2].

Lithologic descriptions, thickness, and locations of types and reference sections of formal sedimentary rock units are listed in Table IA and IB. In summary, the lowermost strata in this generally north-dipping homoclinal sequence are conglomerate, arkose, red sandstone, siltstone, and shale which rest unconformably upon Lower Paleozoic and Precambrian rocks. In the eastern portion of the basin (Figure 1), these rocks are called Stockton Formation (maximum thickness—5,000 feet); in the western portion, New Oxford Formation (maximum thickness—6,900 feet). Uppermost contacts are gradational with overlying units. Above most of the Stockton are dark gray shale and argillite, with siltstone and very fine sandstone near the base, designated the Lockatong Formation (maximum thickness—3,800). The Lockatong is traceable but a few miles west of the Schuylkill River in Pennsylvania and in northeastern New Jersey its outcrop limits are terminated by faulting, fingering out, and overstepping

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1 The term "lithosome" is not recognized formally by the Pennsylvania Topographic & Geologic Survey.

2 The term "Newark" was introduced by Redfield (1856) and later was used by Kummel (1896). Although both authors utilized the terms "Newark System," Kummel (p. 29) noted: "It (Newark) is the oldest title which makes no implication of geologic age." Klein (1960), in his study of the Canadian Maritime Triassic, substituted for the term "Newark" one which he felt had purely rock-stratigraphic connotations. However, in view of Kummel's statement and of later general usage of Newark Group, the term does not appear to conflict with the Code of Stratigraphic Nomenclature (American Commission on Stratigraphic Nomenclature, 1961). In this paper, Newark is retained and used to designate the group of sedimentary rocks in the Newark-Gettysburg Basin.

TABLE IA

NEW OXFORD FORMATION	STOCKTON FORMATION
Defined by Stose and Bascom, 1929. Type section is composite of measured sections in and around New Oxford, just east of Gettysburg, Pennsylvania.	Defined by Kummel, 1896. Type section along east bank of Delaware River at Stockton, New Jersey.
TYPE SECTION Top **arbitrarily defined where light gray mic hard ss no longer predominant, and red ss and sh of overlying Gettysburg Formation prevail.**	REFERENCE SECTION (Composite of measured sections after McLaughlin *in* Willard et al, 1959) Top of Stockton Formation gradational with overlying Lockatong
2,200'—Red sh with red ss; light gray to white mic ss and thin fine calc cgl. 500 —Many thick-bedded light gray to white coarse mic ss, with some cgl interbedded with red sh. 1,300 —Red and white sandy sh with few beds of light gray to white mic ss. 20-50 —Light gray to green thick-bedded granular mic ss with some fine cgl. 210 —Red sh; some dark red ss. 1-5 —Gray to white mic ss. 420 —Red sh. 1-5 —Coarse white ss and and cgl (qtz pebbles up to 2"). 980 —Red sh and gray to red mic ss. 1-25 —Gray mic ss; some qtz cgl. 460 —Red sh with beds of red mic ss. 660 —Red sh. 1-5 —Cgl containing 1" - 3" rounded white qtz pebbles. 20 —Sh (not well exposed). 1-5 —Thin greenish - gray to reddish mic ss. 40 —Red and yellow conglomeratic calc mud stone. 15 —Black carbonaceous fissile sh crowded with small bivalve shells (Estheria ovata (Lea); some inter-bedded yellow earthy calc sh toward top. 35 —Red sh and mic ss containing beds of limestone cgl and calc sh. 6,900'	202'—Reddish-brown and gray, tough, fine-grained, miscaceous sandstone[a] and red shale 129 —Covered; largely red, fine-grained sandstone and shale 167 —Shaly, reddish-brown, fine-grained sandstone and red shale 30 —Massive, medium-grained, gray arkose 196 —Thin- and thick-bedded, red and brown, fine-grained sandstone 143 —Massive, white and gray, medium- and coarse-grained arkose 150 —Covered; fragments of fine- and coarse-grained arkose 350 —Covered; fragments of red and gray, very fine-grained sandstone 130 —Red shale and red, weak, fine-grained sandstone 2 —Greenish-gray shale 60 —Thick-bedded, gray medium-grained arkose and red sandstone 40 —Thin-bedded, brown, very fine-grained sandstone and red shale 5 —Massive, gray, coarse-grained arkose 52 —Covered; upper part medium-grained arkose; lower, red sandstone 148 —Red, weak, fine-grained sandstone and red shale 160—Massive, gray, medium-and coarse-grained arkose, with a few beds of brown, tough, fine-grained sandstone 42 —Thick-bedded, reddish-brown, very fine-grained sandstone 30 —Massive, light-gray, coarse-grained arkose 47 —Thick-bedded, reddish-brown, very fine-grained sandstone 15 —Red shale and red, weak sandstone 25 —Massive, gray, medium-grained arkose 70 —Covered; chiefly red sandstone and red shale 157 —Thin- and thick-bedded, red, fine-grained sandstone and red shale 59 —Covered; red, fine-grained sandstone above; arkose below 40 —White, coarse-grained arkose, poorly exposed 28 —Thick-bedded, reddish-brown, fine-grained sandstone 137 —Thick-bedded, gray, medium- to coarse-grained arkose with some quartz conglomerate and interbedded red, fine-grained sandstone 110 —Red, fine-grained sandstone, poorly exposed 26 —Red and brown, very fine-grained sandstone and red shale 243 —Thick-bedded, white and gray, coarse-grained arkose, with some conglomerate and much red, fine-grained sandstone and red shale 15 —Yellow, coarse-grained arkose and quartz conglomerate 216—Thick-bedded, gray arkose with interbedded brown, fine-grained sandstone 447 —Red, weak, fine-grained sandstone with some arkose, poorly exposed 30 —Thick-bedded, gray, medium-grained arkose 136 —Thick-bedded, white and gray arkose and quartz conglomerate 58 —Covered 20 —Thick-bedded, gray, coarse-grained, quartz conglomerate 58 —Red shale and red, weak sandstone 136 —Covered 173 —Massive white and gray, very coarse-grained, quartz-arkose conglomerate 720 —Interbedded gray and white, coarse-grained arkose, quartz conglomerate, red, fine-grained sandstone, red shale, intermittently exposed Paleozoic limestone 5,002' TOTAL
	Primary structures Cross-beds Channels
	[a]Sandstone is here used to designate silicarenite as distinguished from arkose.
	Rests unconformably upon Paleozoic crystalline limestone and sandy calc argillite.

TABLE IB

GETTYSBURG FORMATION	BRUNSWICK AND LOCKATONG FORMATIONS
Defined by Stose and Bascom, 1929. Type section is composite of measured sections in and around Gettysburg, Pennsylvania.	Defined by Kummel, 1896. Brunswick type section along Raritan River, New Brunswick, N. J. Lockatong type section along Lockatong Creek, tributary on east bank of Delaware River, north of Stockton, N. J.
TYPE SECTION Total thickness: 15,500'	Composite of sections along Delaware River, after McLaughlin, 1946 (1); 1943 (2); 1944 (3); 1945 (4). Total thickness: 10,002' REFERENCE SECTION
Upper member: 3,200'—Fanglomerate lentiles (containing limestone, qtz, qtzite, ss and rhyolite). Soft red sh and cgl (ridgeformer). Fine black carbonaceous sh, gray to rusty shaly, earthy ss with stem markings (2,000' below top). Heidlersberg Member (4,800' thick): 600'—Dull red and green sh and ss with numerous hard gray, green, yellow and white ss beds. 900'—Hard red and light gray to green sh, fissile in part, with some thin slabby ss and few blue calc beds. 2-5 —Hard white ss. 1,200 —Red and dark gray hackly sh. 2-5 —Hard light gray ss. 600 —Thin-bedded red sh with some black sh. 2-5 —Hard white ss. 300 —Red, green and bluish sh and compact argillite (with mud cracks) with a little black sh and ss. 2-5 —Hard red ss. 900 —Red sh. 2-5 —Hard gray to white ss. 300 —Red sh. 2-5 —Hard gray to white granular ss. Lower member (7,500' thick): Thickness of individual units not given. —Red and yellow sh with few red ss. —Thin bed of fine qtz cgl. —Dense black carbonaceous argillite and thin dark gray to red impure limestone. —Soft red sh. —Red sh with few beds of calc red ss, with small pebbles and fragments of limestone. —Red sh and ss with hard gray to white ss.	Brunswick: (1) 200'—Limestone cgl with red sandy argillaceous matrix. 2,400 —Red sh and ss. 15 —Gray-green sh. 500 —Red sh and ss. 30 —Qtz cgl. 50 —Dark gray sh. 56 —Red sh. 38 —Dark gray sh. 440 —Red sh. (2) 15 —Blue sh. 63 —Brown ss. 6 —Black slate and blue sh. 227 —Red and brown ss. 41 —Gray mic ss. 100 —Red-brown ss. 10 —Blue and black sh. 415 —Red and brown ss and sh. 15 —Gray and blue sh. 10 —Hard black slate. 225 —Pink and red-brown sh and ss. 90 —Red ss. (3) 42 —Black and gray sh. 42 —Red sh. 50 —Black and gray sh. 220 —Red sh. 33 —Green-gray sh with interbedded red. 60 —Red sh. 60 —Gray and green sh. 250 —Red sh. 80 —Black and gray argillite. 394 —Red sh. 25 —Black and gray argillite. 38 —Red argillite. 70 —Black and gray argillite. 227 —Red sh and argillite. Lockatong: 160 —Black and gray argillite. 36 —Red argillite. 36 —Black argillite. 27 —Red argillite. 266 —Black hard argillite. 50 —Red argillite. 238 —Black hard argillite. 25 —Red-brown argillite. 25 —Black argillite. 50 —Red argillite. 9 —Black argillite. 40 —Red argillite. 247 —Black hard argillite. 110 —Red hard argillite. 276 —Black hard argillite. 15 —Red hard argillite. 1,000 —Black hard argillite (metamorphosed). (4) 210 —Diabase. 60 —Massive, black very hard argillite (meta.) 300 —Black hard argillite (intermittently exp.) 265 —Massive black argillite with much interbedded light gray hard calc argillite and impure limestone. 155 —Thick-bedded black argillite (intermit. exp.) 75—Thick-bedded black hard sh with interbedded brown hard argillite. 110 —Interbedded red, purplish and black hard argillite. 100 —Purplish gray, red-brown and red argillite. 20 —Brown-red hard sandy argillite. 10,002'

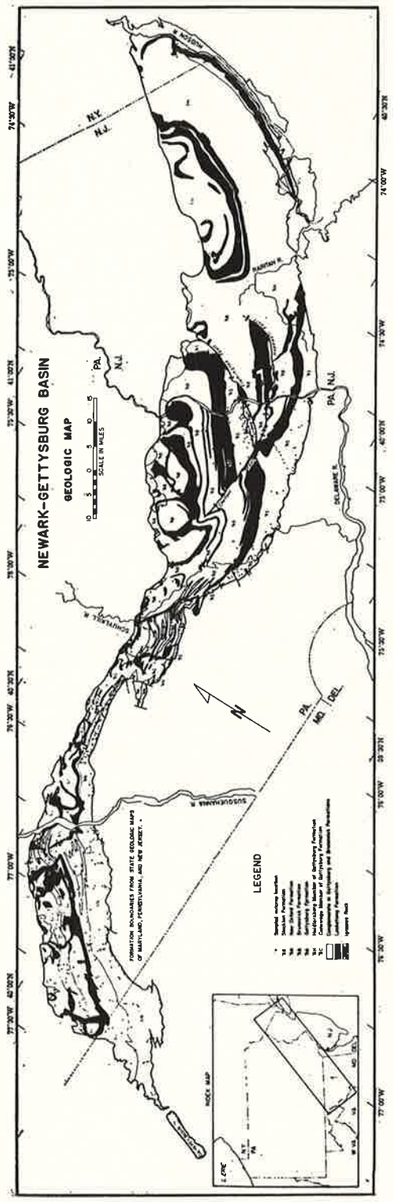

Figure 1. Geologic Map of the Triassic Newark-Gettysburg Basin.

by Atlantic Coastal Plain sediments. Above lower Lockatong, this gray lithology is arranged in alternating succession with red shale, argillite, siltstone, and fine sandstone called Brunswick Formation (maximum thickness at least 7,000 feet). Conglomerate and coarse sandstone crop out locally at the north margin of the Brunswick belt.

The commonly arkosic New Oxford Formation in the western portion of the outcrop belt (Figure 1) is overlain by the Gettysburg Formation (maximum thickness—15,500 feet), an assemblage of red medium to fine grained sandstone, siltstone, and shale capped by locally exposed conglomerate at the north edge of the outcrop belt. The middle member of the Gettysburg Formation is the Heidlersberg Member, characterized by red, green, and gray shale and argillite with minor thin beds of gray to white sandstone. The over-all lithology of the Heidlersberg is remarkably similar to that of the Lockatong.

In the narrow neck of the Newark-Gettysburg Basin, generally between the Susquehanna and Schuylkill Rivers and stratigraphically above the arkosic New Oxford and Stockton, occur coarse clastic sediments to which the terms Gettysburg and Brunswick apply. The eastward termination of the Gettysburg Formation lies in this narrow neck and is demarcated by an irregularly shaped, northwest-trending diabase body (Figure 2). To the east of this diabase body lies the western boundary of the Brunswick Formation.

In the remainder of this discussion are examined other methods of characterizing (1) the coarse clastics in the narrow portion of the outcrop belt to which the terms "Brunswick" and "Gettysburg" both apply and (2) the complex interfingering exhibited between Lockatong and Brunswick.

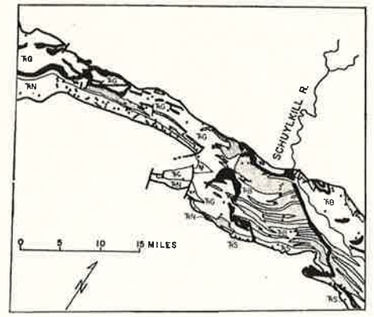

Figure 2. Close-up of Figure 1 in narrow portion of Newark-Gtetysburg Basin in Pennsylvania. Stippled areas are conglomerates in the Gettysburg and Brunswick. Note division between Gettysburg and Brunswick is placed arbitrarily at the irregularly and regularly shaped diabase body (solid black).

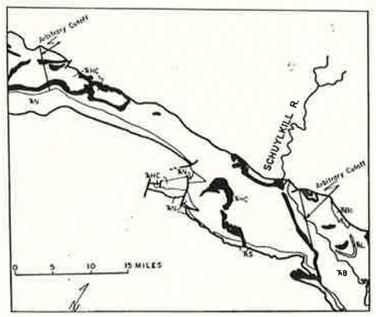

Figure 3. Arbitrary cut-offs delimit the area of coarse clastic sediments here designated Hammer Creek Formation. Same area of narrow portion of Newark-Gettysburg Basin as shown in Figure 2 minus the designation of conglomerate units. Solid black areas are diabase.

GETTYSBURG-BRUNSWICK RELATIONSHIPS

The coarse clastics which prevail in the narrow neck of the outcrop belt above the Stockton and New Oxford Formations is a lithology typical of neither Brunswick nor Gettysburg. Application of the terms "Brunswick" and "Gettysburg" to these coarse clastic sediments is an extension of lithostratigraphic nomenclature beyond the areas of recognition of the dominant red sandstone, siltstone, and shale which typify the Gettysburg and Brunswick (Table IB).

There is an alternative means of separating Gettysburg from Brunswick which focuses attention upon the fact that this coarse clastic lithology is distinctive and can be treated logically as a discrete lithic entity. Two arbitrary cut-offs (Wheeler and Mallory, 1953) shown in Figure 3 represent useful lateral limits of the coarse detrital sediments. The easternmost cut-off is so placed that it restricts the term "Brunswick," as originally defined (Table IB), to the red fine sandstone, siltstone, and shale along with the locally exposed uppermost conglomerate bodies at the north margin of the outcrop belt. These typical Brunswick lithologies occur principally east of the region of extensive lateral interfingering with coarse sandstone and conglomerate in the vicinity of the Schuylkill River (Figure 2). Thus, the easternmost cut-off here defines the western termination of the Brunswick (Figure 3).

Likewise, the Gettysburg Formation here is limited to rocks exposed west of the westernmost arbitrary cut-off (Figure 3). There occur the typical sandstone, siltstone, and shale (which overlie the New Oxford), the Heidlersberg Member, and the lobate conglomerate bodies exposed locally along the north margin of the belt in topmost Gettysburg strata[3].

3 That part of the Gettysburg designated Conewago Conglomerate Member named by Stose and Jonas (1929) was examined at seven exposures by the writer and did not reveal distinctive traits which made it separable from typical Gettysburg lithologies. Therefore, the name, Conewago Member, is not recognized in this paper and rocks in the area designated Conewago Member in Figure 1 are part of the undifferentiated lower unnamed member of the Gettysburg Formation.

PROPOSED HAMMER CREEK FORMATION

The coarse detrital sediments which occur between the two arbitrary cutoffs (Figure 3) comprise an operationally defined lithostratigraphic unit. The cut-offs define facies boundaries between laterally intergrading and intertonguing rock units and separate this coarse facies from its equivalents, the Brunswick, to the east and, the Gettysburg, to the west and southwest. The rocks which comprise this newly defined lithostratigraphic unit are here named the Hammer Creek Formation. The proposed name, Hammer Creek Formation, is applied to all sedimentary rocks which are part of the Newark Group bounded laterally by the two arbitrary cut-offs shown in Figure 3. The Hammer Creek Formation lies above the Stockton and New Oxford Formations and extends to the north edge of the Newark-Gettysburg Basin. The Hammer Creek Formation includes rocks of the Robeson and Furnace Ridge (also called Elizabeth Furnace in Reeside, et al, 1957) of McLaughlin (1939). Such subdivisions, however, are not utilized further in this paper.

The Hammer Creek Formation is named for discontinuously exposed strata above the New Oxford Formation along Hammer Creek in the Richland (Pa.) 7½-minute Quadrangle (the SE ¼ of the Lebanon 15-minute Quadrangle). The type section was described by McLaughlin (Lebanon County Report, manuscript on file, Pennsylvania Geological Survey) and a summary of the measured sections was published by McLaughlin and Gerhard (1953). The detailed measurements and descriptions by McLaughlin of these sections are given in Table II.

The Hammer Creek is characterized by its lateral and vertical heterogeneity. Individual beds in the type section pinch out laterally as shown in map patterns (Gray, et al., 1958). Nonetheless, the exposures along Hammer Creek are representative of the heterogeneous textural and compositional characteristics of these coarse clastic sediments. The type section along Hammer Creek is one of the most complete sequences of exposures available in the coarse clastic sediments of this narrow neck of the Newark-Gettysburg Basin.

The cut-offs (Figure 3) which segregate the Hammer Creek from its lateral, finer grained equivalents, Brunswick and Gettysburg, were selected on the basis of outcrop-sample properties in such a way that coarse sandstones and conglomerates dominate in the belt called Hammer Creek Formation and finer sandstone, siltstone, and shale dominate east and west of that area. As additional data on the nature of the intertonguing become available, more refined statistical limits or natural intertongued boundaries might be established. Detailed mapping by McLaughlin (in Gray, et al, 1958, Geyer, et al, 1958 and 1963) is available in parts of the proposed Hammer Creek Formation and McLaughlin (personal communication) is continuing work on these coarse sediments. The present proposal to give formational status to these coarse clastic sediments is aimed at formally recognizing this distinctive rock body (many parts of which have been mapped in extensive detail by McLaughlin) rather than applying to this essentially coarse lithic body terminology of the finer grained Brunswick and Gettysburg, which merely obscures the over-all regional relationships.

LOCKATONG-BRUNSWICK RELATIONSHIPS

A complex stratigraphic relationship is exhibited in the laterally interfingering and vertically alternating lithologies of the Lockatong and Brunswick (Figures 1 and 4). Three methods have been em-

TABLE II

HAMMER CREEK TYPE SECTION*
(Measured by Dean B. McLaughlin)

Thickness in Feet	Description
200	"Shale conglomerate" with interbeds of quartz conglomerate containing cobbles of Hardyston quartzite; band of limestone conglomerate at north border.
140	Red quartzose sandstone and red shale with interbeds of "shale conglomerate."
200	Coarse conglomerate with cobbles of Hardyston quartzite and interbeds of "shale conglomerate."
190	Medium-grained, red, quartzose sandstone, poorly exposed.
100	Coarse conglomerate with Hardyston quartzite cobbles.
170	Red, quartzose sandstone, poorly exposed.
100	Coarse conglomerate with Hardyston quartzite cobbles.
190	Red and brown quartzose sandstone with interbeds of coarse, quartz conglomerate
120	Coarse, quartz conglomerate with cobbles of gray granular (Tuscarora?) quartzite.
240	Medium grained, red sandstone, overlain by much red shale.
260	Thick-bedded, very coarse conglomerate with cobbles of gray quartzite.
900	Red and brown, fine-grained, quartzose sandstone with some coarse sandstone and thin, pebbly bands.
70	Thick bedded, very coarse conglomerate with quartzite cobbles.
420	Thick-bedded, medium-grained, red sandstone with a few interbeds of quartz-pebble conglomerate thin-bedded, fine-grained red sandstone and red shale near base of the unit.
70	Thick-bedded, coarse conglomerate with quartzite cobbles.
140	Red sandstone, poorly exposed.
160	Massive, very coarse conglomerate with quartzite cobbles.
190	Thick-bedded, medium- to coarse-grained, red quartzose sandstone, pebbly sandstone, and fine conglomerate.
190	Thick-bedded, coarse, quartz-pebble conglomerate with scattered large quartzite cobbles and interbeds of quartzose sandstone.
780	Fine- to medium-grained, red and brown, quartzose sandstone with red shale and a few pebbly bands.
110	Coarse, quartz-pebble conglomerate.
500	Fine- to coarse-grained, red sandstone with red shale and some pebbly interbeds.
110	Thick-bedded, very coarse conglomerate with quartzite cobbles.
480	Medium- to coarse-grained, red, quartzose sandstone.
300	Quartz-pebble conglomerate with much interbedded red sandstone.
540	Medium- to coarse-grained, red, quartzose sandstone with some pebbly bands.
280	Thick-bedded, coarse conglomerate with quartzite cobbles and minor interbeds of coarse, red sandstone.
350	Fine- to medium-grained, red, quartzose sandstone.
260	Thick-bedded, very coarse conglomerate with cobbles of gray (Tuscarora?) quartzite interbeds of sandstone and red shale.
250	Fine- to medium-grained, red sandstone with pebbly bands and some interbeds of red shale.
50?	Quartz-pebble conglomerate with sandstone interbeds.
1300	Thick-bedded, fine- to medium-grained, red, quartzose sandstone with a few pebbly bands.
	NEW OXFORD FORMATION: interbedded arkose, red sandstone, and red shale.
9360	TOTAL

*Along Hammer Creek, Richland (Pa.) 7½-minute quadrangle (SE ¼ of Lebanon 15-minute quadrangle).

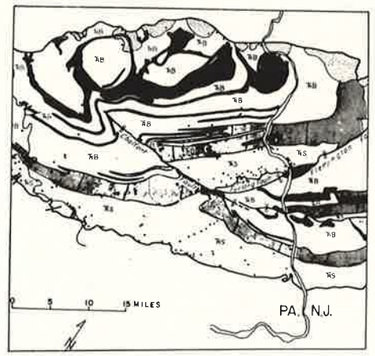

Figure 4. Close-up view of Figure 1. Lockatong-Brunswick laterally interfingering and vertical alterations in the Delaware River area. Lockatong is gray lined pattern; conglomerates in the topmost Brunswick stippled; diabase, solid black.

ployed to describe these two formal units. (1) Arbitrary assignment to the Brunswick of all rocks above the stratigraphic horizon at which red argillite and shale predominate. Rocks below that horizon are arbitrarily called Lockatong (McLaughlin, 1944, 1946). This method does not portray adequately the lateral and vertical complexities existing between Lockatong and Brunswick. (2) Willard, et al, (1959) utilized the terms "Lockatong Lithofacies" and "Brunswick Lithofacies" to supplant the use of formational terms and showed these units on a map as intertongued lithofacies. However, lithofacies means the sum total of the lithologic character of sedimentary rocks (Krumbein, 1948, p. 1909). Wheeler and Mallory (1956, p. 2718) pointed out that lithofacies are "laterally segregated, statistical, lithic variants of a stratigraphic interval." Thus, the manner in which the term "lithofacies" was used by Willard, et al, is not consistent with its intended meaning. (3) The current use of Lockatong Formation and Brunswick Formation (Pa. State Geologic Map, 1960) results in repetition of formal stratigraphic names in a normal stratigraphic succession (Figure 4). Such an arrangement of recurring, superposed formation names in alternating succession renders the Law of Superposition somewhat ambiguous.

There are two alternative ways to treat the laterally intertongued and vertically alternating sequence of gray and red argillite, shale, siltstone, and fine sandstone. The first alternative is to consider the entire Brunswick-Lockatong gray and red complex as a single, major lithic unit; i.e., a formation or group. This method would be quite objective and consistent with current stratigraphic practice but would result in a multiplicity of new member or formation names. There is a second alternative which may be adequate not only descriptively but also in suggesting the possible nature of the interrelationships between Lockatong and Brunswick lithologies. Wheeler and Mallory (1956) proposed the term "lithosome" for rock bodies in which the vertico-lateral distribution is known, and interfingering relationships with another rock body are established. They defined lithosome as a lithostratigraphic body (three-dimensional lithic unit) which mutually intertongues with one or more rock bodies of differing lithic constitution. Parts of a lithosome, unlike a formation, can be repeated in a vertical succession of strata.

In order to call the Lockatong and Brunswick lithosomes an assumption must be made that the isolated outcrop units (Figure 4) of Lockatong surrounded entirely by Brunswick ,and vice versa, join with the main portion of their respective lithic bodies down dip or were part of these bodies during deposition. Because of the homoclinal nature of the north-dipping sequence of strata in the Newark-Gettysburg Basin, the down dip relations of these isolated Brunswick and

Lockatong horizons cannot be observed. If these isolated units joined up dip, such evidence has been lost to erosion.

No direct evidence exists, on the other hand, to rule out the possibility that the isolated Lockatong and Brunswick horizons are, in fact, discrete, repeated lithic types recurring in alternating fashion. If such is the case, the first alternative is the more reasonable; i.e., to name the entire red and gray Lockatong-Brunswick sedimentary complex a formation or group and designate the individual, isolated horizons as formal subunits.

However, the second alternative of calling Brunswick and Lockatong lithosomes[4], rather than formations, is favored by the writer despite the present incompleteness of data concerning the three-dimensional relationships between isolated Brunswick and Lockatong horizons to their respective main sedimentary bodies. Three lines of reasoning lead the writer to this view. (1) The general lithic similarities among recurring discrete Lockatong horizons and among recurring discrete Brunswick horizons with respect to their main sedimentary units suggest origins common to all parts of the Lockatong and to all parts of the Brunswick. Thus, the two distinctive lithic types are thought to be parts of the main lithic bodies in the third dimension. (2) The extensive tongues which project in outcrop from the main Lockatong and Brunswick bodies (Figure 4) have general lithic similarities to isolated units of Lockatong and of Brunswick, respectively, in outcrop. This suggests that isolated horizons differ only in degree of isolation and not in kind. (3) That the discrete parts of the Lockatong were developed as part of a single event seems implicit in Van Houten's (1962) interpretations of the Lockatong. His work does not suggest that conditions of Lockatong accumulation started from "scratch" at various times during the filling of the basin.

Thus, it is proposed here that the Lockatong and the Brunswick are intertonguing, mutually exclusive, lithostratigraphic bodies. Isolated Lockatong and Brunswick horizons, physically separated from the main bodies of Lockatong and Brunswick, respectively, in outcrop (Figure 4) are thought to join down dip with their respective main bodies or were originally part of the main sedimentary bodies. Based on this assumption, the writer proposes that these units can be designated the *Lockatong lithosome* and the *Brunswick lithosome*.

In Table III is listed the stratigraphic terminology for sedimentary rocks in the Newark-Gettysburg Basin which the writer thinks most adequately describes the stratigraphic relationships as they are presently known or interpreted.

4 The term "lithosome" is not used formally by the Pennsylvania Topographic & Geologic Survey. Both the Lockatong and Brunswick retain their formational status and the use of this term here does not reflect adoption by the Pennsylvania Geological Survey of lithosome in place of formation.

TABLE III
LITHOSTRATIGRAPHIC NOMENCLATURE

Md.-Pa. (area SW of arbitrary cutoff near Susquehanna River)	Area between arbitrary cutoffs shown in Modified Geologic Map (Fig. 2)	E. Pennsylvania & W. New Jersey	N.E. New Jersey and New York
Gettysburg Formation	Hammer Creek Formation	Brunswick lithosome	Brunswick lithosome
upper unnamed member Heidlersberg Member lower unnamed member		Lockatong lithosome	
New Oxford Formation	New Oxford Formation (to west) Stockton Formation (to east)	Stockton Formation	Stockton Formation

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A NEW STUDY OF TERTIARY AND CRETACEOUS SEDIMENTS FROM THE 2306-FOOT 1901 ATLANTIC CITY, NEW JERSEY, WELL

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ABSTRACT

A 2306-foot Atlantic City well was first described by Woolman in 1901, and later used as a key deep well in Coastal Plain paleontologic and stratigraphic studies. 141 Tertiary and Cretaceous samples were recently examined in the light of modern knowledge of sedimentation. This new log is used in discussing certain stratigraphic relationships of the Coastal Plain.

GEOLOGICAL BACKGROUND

The Coastal Plain of New Jersey is underlain by a series of unconsolidated sedimentary rocks, dipping gently eastward and forming a wedge, thinnest at its iner edge at the Piedmont and thickening to about 6000 feet at the mouth of Delaware Bay (Richards, Olmsted and Ruhle, 1962). The marine and nonmarine sediments, of Upper Cretaceous to Recent age, are evidence of alternating transgression and regression of the sea over the Coastal Plain area, and of considerable uplift and erosion in the source areas to the north and west.

Beneath the Coastal Plain sediments lies a pre-Upper Cretaceous erosion surface on rocks similar to those exposed on the Piedmont and Triassic Lowland. Maps and cross-sections of the "basement" beneath the Coastal Plain (Anderson, 1948, Richards, 1945, 1948, Richards, Olmsted and Ruhle, 1962) show a large embayment extending from Long Island to Norfolk, Virginia. Relatively little known subsidiary structures trend normal to the regional strike of the Fall Line. First called the "Salisbury Embayment" by Richards (1948) for the trough which extends from near Washington, D. C. eastward across the Eastern Shore of Maryland, the larger embayment has been called the Chesapeake-Delaware Embayment by Murray (1962). Considering the extent of the embayment to include New Jersey, it will be called the "Middle Atlantic Embayment" in this paper.

Although the New Jersey Coastal Plain sediments are typical of a stable shelf environment, changes in facies and thickness along the regional strike, as well as changes in direction of formational strike, show that the underlying basement has been a differentially warping platform. Among the factors influencing sedimentation was the position of the mouths of Cretaceous and Tertiary to Recent rivers in relation to the growing wedge of sediment. Recently the pre-Upper Cretaceous courses of the ancestral Delaware and Schuylkill have been discovered under the inner edge of the Pennsylvania Coastal Plain near Trenton and Philadelphia (Greenman, *et al,* 1961). This leads to the consideration of the ancient courses of such rivers as the Hudson and Susquehanna, and their relationship to Coastal Plain sedimentation. Events in the source area to the west are reflected also in the successive changes in types of Coastal Plain sediments.

INTRODUCTION

Between 1887 and 1902 the Annual Reports of the State Geologist of New Jersey contained reports (including logs and discussions of fossils and correlations) by Lewis Woolman on the numerous wells drilled for water in the Coastal Plain of New Jersey. In the Annual Report for 1901, Woolman com-

mented on the drilling of a 2306-foot well at Young's Pier, Atlantic City. A short log was included. Since this well has so often been used in cross-sections of the Coastal Plain, Dr. Horace Richards suggested that a detailed lithologic study of the well be made, and provided the samples from the Woolman Collection of the Academy of Natural Sciences of Philadelphia. Richards and Harbison (1942) have generally described the Cohansey and Kirkwood formations, as well as the Miocene invertebrate fauna.

One hundred and forty-one small samples were examined by binocular microscope and notes were made on the following: (1) color name and number according to the color chart of the Geological Society of America (Goddard, *et al,* 1948); (2) estimates of grain size and texture, including sorting and roundness; and (3) composition. Several heavy mineral separations were made. Included in this paper is a log which gives names and ages and the general (due to lack of space) details of the information gathered in the microscopic examination of the samples. The complete log will be on file at the Geological Surveys of New Jersey and Delaware, the Academy of Natural Science of Philadelphia, and with the author. Samples from other Atlantic City wells may have been included in this group by Woolman, since there are duplicate samples, and some overlap others. Many samples are missing.

DISCUSSION

CAPE MAY AND PENNSAUKEN FORMATIONS

The Pleistocene period is represented in the well by 90′ of sands and clay (Cape May) and 36′ of Pennsauken (Richards and Harbison, 1942), which consists of heavy gravel with some thin seams of yellow clay (Woolman, 1901). The three samples available from the Cape May formation showed traces of lignite, but no other fossils. No samples were available from the Pennsauken.

COHANSEY FORMATION

Due to the almost complete lack of fossils, the age of the Cohansey formation is dificult to ascertain. Richards, Olmsted, and Ruhle (1962) suggest that because of its relationship to the underlying Kirkwood, it is probably Miocene in age and equivalent to the Yorktown formation of Virginia. Non-marine in outcrops, the Cohansey covers more than two-thirds of the New Jersey Coastal Plain. Samples from the upper part of the formation (126′-270′) show: light yellowish brown sandy gravel (to 9 mm.) from 167′ to 180′; 40′ of light orange, well-sorted fine-to-medium quartz sand with a trace of feldspar; and 20′ of light yellowish brown very fine quartz sand. Non-opaque heavy-minerals from 210′-225′ show a "limited suite" (Dryden and Dryden, 1956), mostly a flood of zircons. This association of minerals (all of the common heavy-minerals of the nearby crystalline rocks, except garnet, epidote, chloritoid and hornblende) is found in non-marine Coastal Plain sediments from Virginia north. Woolman (1901) characterizes the section as "alternations of light yellow and bright orange-colored and grayish sands and gravels without fossils."

The lower section of the Cohansey consists of light yellowish brown fine-to-coarse quartz sands, frequently granular. Several samples are slightly clayey. Opaque heavy-minerals (ilmenite and magnetite) are conspicuous in their abundance throughout the section, and there are traces of feldspar and lignite. No fossils of any kind were observed in the Cohansey, but a full suite of non-opaque minerals (the "limited suite" plus garnet, epidote, chloritoid and hornblende) was seen in the 340′-350′ sample. This material may have been reworked from older marine sands, or they may represent a marine environment, transitional from the fully marine Kirkwood.

KIRKWOOK FORMATION

In outcrop, the Kirkwood formation consists of a fine quartz sand and beds of dark silty clay, usually near the base. The Shiloh marl, a highly fossiliferous clayey or silty sand, is found at the top of the formation in southern New Jersey. Ilmenite deposits (non-opaque heavy minerals) have been located in sugary sands in the vicinity of Lakewood, Lakehurst, and Colliers Mills (Johnson, Markewicz, and Parillo, 1958). On the basis of fossils, the Kirkwood has been correlated with the Chesapeake group of Maryland; on a lithologic basis, correlation with individual formations is difficult.

In the deep Atlantic City well, the Kirkwood extends from 390′ to below 950′ (975′, Woolman, 1901) in contrast to the less than 100′ of outcrop. Over 560 feet of Kirkwood may be divided into several sections: (1) the Great Diatom Bed; (2) the 700 and 800 Foot Sands; and (3) the Lesser Diatom Bed (Woolman, 1901). The sediments from 390′ to 700′ Woolman characterized as the "Great Diatom Bed, mainly bluish (when wet) brownish clays richly diatomaceous (20%) throughout: Miocene mollusks at 560′-580′ and 680′-690′." This bed of diatomaceous sediments has been found in New Jersey deep wells as ar north as Beach Haven and as far south as Cape May (diatomaceous sediments of Miocene age continue to Virginia). Westward, toward the outcrop, it pinches out near Hammonton, 28 miles west of Atlantic City (Richards and Harbison, 1942, p. 239). This pinching out appears to be due to pre-Cohansey erosion and overlap by the Cohansey formation. Generally speaking, only the lower part of the formation is visible in outcrop, which helps to account for the difference in thickness between the outcrop and this Atlantic City well. The outcropping basal clays probably represent the Lesser Diatom Bed, and the sands a facies of the sands from 700′ to 860′.

Fossils of St. Mary's age (upper Chesapeake of Maryland) have been found in the upper part of the Great Diatom Bed in wells at Wildwood, Millville, Cape May, and Lewes, Delaware (Richards and Harbison, 1942), but no farther north. Richards and Harbison took this to mean tha tthe shoreline probably crossed New Jersey from somewhere near Atlantic City westward near Millville. At Atlantic City, there are no fossils (except marine diatoms) in the uppermost part of the Great Diatom Bed (390′-520′, sample missing from 520′ to 540′). The sediments consist of light yellowish brown generally fine quartz sand and sandy clay. A full suite of non-opaque heavy-minerals was found in the 400′-410′ sample, adding to the evidence of the diatoms as to the marine environment of deposition. These sediments, pinching out to the north and west under the overlapping Cohansey, probably represent an inner neritic environment either hostile to animal life or to the preservation of fossils. The east-west strike of the fossiliferous sediments containing neritic St. Mary's fauna, may represent the north shore of a Delaware embayment. Further evidence of the trend of sediments of this age is missing.

The lower part of the Great Diatom Bed (520′ to 700′) is marked by an upper bed of light olive gray clayey sand (40 feet) and a lower section of light yellowish brown sandy clays (30 feet). Abundant shell fragments are found from 540′ to 580′, as well as rare sponge spicules and Foraminifera. At 560′-580′ there is scarce glauconite, the only occurrence above 931′; at 540′-560′, a full

suite of non-opaque heavy minerals is found. In the sandy clays, shell fragments are common to abundant. Fossils found at the top of the outcropping formation at Shiloh, near Delaware Bay, are found near the base of the Great Diatom Bed or in the sands beneath (Richards and Harbison, 1942). Most of the Kirkwood fossils of the Great Diatom Bed correlate with the Calvert formation of Maryland (diagnostic Choptank fossils are generally lacking).

The richly diatomaceous clays of the Chesapeake group and the Kirkwood are peculiar to this particular time in the geologic history of the Middle Atlantic Embayment. Bramlette (1946), discussing conditions necessary for the deposition of the thick diatomaceous Monterey formation of California, suggests that they must have included extremely favorable circumstances as to nutrients and silica for the rapid multiplication of the diatoms and preservation of their easily dissolved skeletons in such quantities. The drifting of microplankton by currents from open ocean into catchment areas of deeper water or cul-de-sacs along the coast may have been involved. The thickness of the sediments implies rapid subsidence and the maintenance of shallow water conditions by rapid deposition. In the diatomaceous sediments of the Miocene of New Jersey, glauconite is conspicuous by its absence, although it occurs in great quantity in older sediments in which diatoms are not particularly abundant.

Below the Great Diatom Bed lies 160′ of light yellowish brown quartz sands, with beds of medium olive gray tough clay and 20 feet of quartz pebbles and sand at 740′-760′. The sands from 780′ to 860′ are well known as an aquifer (the 800 Foot Sands of Woolman, 1901). Fine-to-coarse shell fragments are scarce to abundant. Foraminifera are scarce in the upper part; sponge spicules are rare throughout the section. Woolman (1889) observed in another Atlantic City well the association of marine diatoms with spicules from marine sponges. In the sample from 790′-800′ there is a full suite of non-opaque heavy minerals.

The Lesser Diatom Bed (860′-950′ plus) lies beneath the 800 Foot Sands. It includes 90 feet of olive gray to medium yellow brown (excepting dark greenish gray glauconitic clay at 931′) sandy fossiliferous clay, which may be correlated with the Calvert formation of Maryland. One diatom, *Actinoptychus heliopelta,* serves to mark the base of the Calvert Miocene, wherever found in the Middle Atlantic Embayment, whether in outcrops or in wells (Woolman, 1890). However, the same author (1901) comments that this diagnostic diatom was not found at Atlantic City.

PINEY POINT FORMATION

Richards and Harbison (1942) described the glauconitic sands beneath the known Calvert Miocene Lesser Diatom Bed as Miocene in age, but in 1948 Richards noted, "The presence of the Jackson coral *Trochocyathus lunulitiformis* at 950 feet, as well as numerous microfossils, suggest the presence of the Jackson Eocene between 950 and 1240 feet, instead of the basal Miocene as previously reported (Richards, 1945, p. 896)." Atlantic City well samples from 950′ plus to 1155′ are a glauconite and quartz sand, with varying amounts of clay and mica. Shell fragments are common to abundant; Foraminifera are scarce at 990′ only, and sponge spicules are rare in almost every sample. Below 1155′ are 45 feet of medium olive gray clay (with abundant fine quartz sand and common to abundant glauconite, scarce shell fragments, rare sponge spicules and scarce Foraminifera at 1200′). Woolman (1901) mentions 5 feet of yellow sand, 10 feet of clay, and 25 feet of greensand to 1240′; the samples are missing.

Richards, Olmsted, and Ruhle (1962) mention a written communication from W. C. Rasmussen (1957) giving the name Piney Point to sediments of Jackson age pentrated by a deep well at Atlantic City, New Jersey. The Piney Point glauconitic sands were named by Otton (1955) from the location of a well at Piney Point, St. Mary's County, Maryland. The name has been extended to similar units, in the subsurface only, on the Eastern Shore of Maryland (Rasmussen and others, 1957) and northward into Delaware (Rasmussen, Groot, and Depman, 1958, and Jordan, 1962). Parker and others (in press) have used the name in a report on water resources of the Delaware River Basin and adjacent coastal New Jersey.

In summarizing the history of the Piney Point, Richards, Olmsted, and Ruhle (1962) define the formation as comprising all the sediments of late Eocene (Jackson) age in New Jersey (it has not been found north of Atlantic City). Since a formation is defined by lithologic character and extent, rather than age alone, the Manasquan and Shark River should be separated from the Piney Point on that basis. Samples from the Atlantic City well are missing, from 1200′ to 1430′. This includes the entire section (from 1240′ to 1430′) described by Woolman (1901) as "very hard and tough light and dark slate or ash-colored clays with Coccoliths plentiful throughout, and with a few *Textularia, Nodosaria,* and other Foraminifera. (Lower layer of the Upper Marl Bed)." The Shark River, known in outcrop only from Monmouth County, consists of glauconitic clay and silt; the fauna is correlated with the Wilcox (lower Eocene) Group of the Gulf Coast. The Manasquan outcrops consist of an upper fine-grained sand and greenish-white clay, and a lower glauconite sand (middle Eocene Claiborne). Richards, Olmsted and Ruhle (1962) consider the Manasquan and Shark River as one lithologic unit, although they are faunally distinct.

VINCENTOWN FORMATION

In contrast to a thickness (in wells near the outcrop) of from 10 feet in the southwest to 130 feet in the northeast, the Vincentown consists of 466 feet of sediment. Greacen (1941) discussed the stratigraphy and paleontology of the formation. She mentions several interfingering facies: (1) a gray greensand near the basal contact with the Hornerstown; (2) a glauconitic limesand with sparse fossils; (3) glauconitic quartz sand with rare fossils; and (4) "type" Vincentown, limesand with abundant Bryozoa, echinoids and other neritic fauna, as well as abundant Foraminifera of Eocene and/or Paleocene age. The calcareous beds become more conspicuous to the southwest, essentially replacing the yellow sand beds of the northeast. Greacen suggests a relationship of facies to the location of river mouths, since Bryozoa require clear water. The Vincentown Bryozoa are large erect branching forms, which probably grew in a water depth of 200-300 feet.

In the Atlantic City well, the Vincentown is a fine sand (abundant carbonate, usually common glaucnite and quartz, often abundant Foraminifera) and clay (abundant carbonate and scarce clay mineral). The clay mineral has been termed montmorillonite by Owens and Minard (1960). Although the carbonate in the samples is now so friable that any estimation of the true proportions of the grain sizes is difficult, Woolman (1901) reported that the rock was consolidated when drilled.

Except in two samples, the color does not vary from yellowish gray. Above 1527′, there are shell fragments; below

that sample none were found, but Foraminifera are common to abundant. No Bryozoa were found, nor any echinoid spines. Scarce to rare pyrite was found in many samples. The Vincentown in this well may be defined as an allochthonous, or detrital, limestone. Pettijohn (1949, p. 304) defines a calcarenite as a detrital carbonate rock of sand grain size, with or without calcite cement, and composed mainly (over 50 per cent) of carbonate detritus (a spergenite has less than 10 per cent quartz). The sediment where Foraminifera are especially abundant may be termed a microcoquina. Pettijohn (p. 304) emphasizes the fact that clastic quartz and clastic carbonate may be mingled in all proportions. The facies of the Vincentown represented in the well samples suggests that debris from the shoreward biostrome, best developed around Vincentown, was swept into the area of Atlantic City, as was quartz sand and silt and glauconite from the other outcrop facies. The thickness of the deposit suggest optimum conditions for the fauna, which supplied the debris, and a nice ablance of subsidence and deposition. Post Eocene erosion thinned the shoreward deposits considerably.

HORNERSTOWN FORMATION

The 3 feet of sediment at 1906′-1909′ shows a distinct change from the Vincentown. The light olive gray clay is slightly sandy and silty (scarce quartz, glauconite and Foraminifera. Succeeding samples to 1940′ and 2070′ to 2080′ range from olive gray to greenish gray in color, and vary as to proportions of clay and sand. All have common Foraminifera. This material has been recognized as Hornerstown (Woolman, 1901), now considered to be of Paleocene age.

MONMOUTH AND MATAWAN GROUPS

The Red Bank and Navesink (Upper Cretaceous) Formations are undifferentiated from the Hornerstown in the Woolman logs below 2,150′ were found the dark micaceous clays of the Mt. Laurel and Wenonah Formations. At 2306′ (samples are missing from 1940′ to 2070′ and from 2088′ to 2306′) the sample contains medium olive gray clay and fine sands and silt (abundant quartz and glauconite, scarce Foraminifera, rare sponge spicules and lignite).

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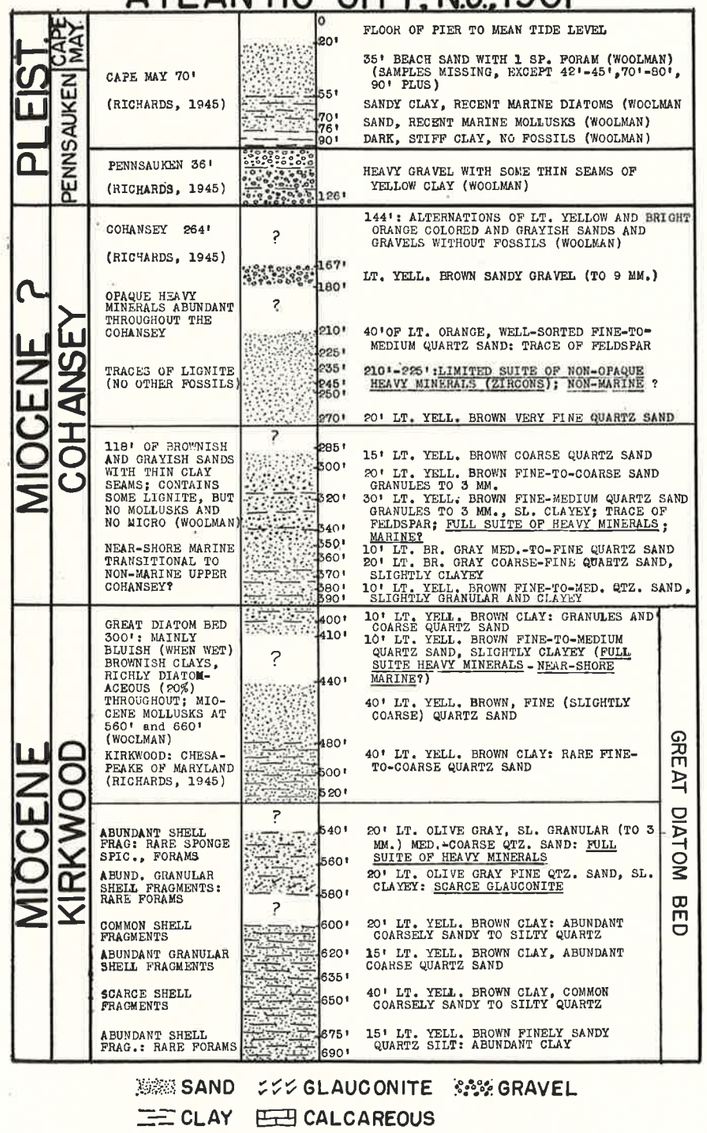
LOG, YOUNGS PIER WELL, ATLANTIC CITY, N.J., 1901



MIOCENE	KIRKWOOD	ABUNDANT TO SCARCE FINE-TO-COARSE SHELL FRAGMENTS: SCARCE FORAMS;. RARE SPONGE SPIC. (700-727'); RARE LIGNITE	700' 716' 727' 750' 760' 780'	90' FINE-TO-COARSE QUARTZ SAND WITH VARYING AMOUNTS OF CLAY AND SILT; LIGHT YELL. BROWN ABOVE 727': FULL SUITE OF HEAVY MINERALS 716-750', 757-759', AND 765-778': TOUGH MEDIUM OLIVE GRAY CLAY (SANDY) 750-760': YELLOW GRAY, 2/3 QUARTZ PEBBLES, COARSE TO FINE SAND	700 FOOT SAND
		760-790', 800-810': SCARCE SHELL FRAGMENTS 790-810':ABUNDANT COARSE SHELL FRAGMENTS; RARE SPONGE SPICULES	790' 800' 810' 815' 818' 850'	38' COARSE-TO-FINE QUARTZ SAND, SLIGHTLY CLAYEY LT. YELLOWISH BROWN, EXCEPT 790-810', LIGHT OLIVE GRAY 790-800' and 800-818': FULL SUITE OF HEAVY MINERALS 850': PALE YELL. BROWN, FINE-MEDIUM QUARTZ SAND; MICACEOUS	800 FOOT SAND
		RARE LIGNITE, 860-873' DIATOMS (WOOLMAN) ABUNDANT SHELL FRAGMENTS BELOW 873' 939-941': ABUNDANT THICK SHELL FRAGMENTS (TO 8 MM.)	860' 873' 895' 931' 939' 941' 950'	90' CLAY WITH VARYING AMOUNTS OF FINE-TO-GRANULAR QUARTZ OLIVE-GRAY, EXCEPT 873-931'(MEDIUM YELLOWISH BROWN QUARTZ MORE ABUNDANT ABOVE 931' MICA COMMON, 895-931' DARK GREENISH GRAY: ABUNDANT GLAUCONITE IN SANDY CLAY	LESSER DIATOM BED
EOCENE	JACKSON (PINEY POINT?)	COMMON TO ABUNDANT SHELL FRAGMENTS; RARE SPONGE SPICULES THROUGHOUT SCARCE FORAMS AT 990' "PINEY POINT" (JACKSON): RICHARDS, OLMSTED AND RUHLE, 1962; RASMUSSEN, 1957 FOSSILS OF JACKSON AGE, 990'-1240' (RICHARDS, 1945) 1200': RARE LIGNITE	950' plus 974' 990' 1012' 1033' 1055' 1075' 1096' 1116' 1134' 1155' 1171' 1188' 1200' 1205' 1215'	950' plus-1155': -205' GLAUCONITE AND QUARTZ SAND WITH VARYING AMOUNTS OF CLAY AND MICA (974', GREENSAND, WOOLMAN) MEDIUM OLIVE GRAY EXCEPT 1018-1033' (MEDIUM YELLOWISH BROWN), 1054-1075' (LIGHT OLIVE BROWN) AND 1075-1097' (DARK YELLOWISH BROWN) UPPER MARL BED (WOOLMAN) 1155-1200': 45' OF MEDIUM OLIVE GRAY CLAY WITH ABUNDANT FINE QUARTZ SAND AND COMMON TO ABUNDANT GLAUCONITE 1200-1205': DULL YELLOW SAND WITH BARNACLES, FORAMS SMALL MOLLUSKS (WOOLMAN) 1205-1215': CLAY WITH MOLLUSKS (WOOLMAN) 1215-1240': 25'GREENSAND MARL (WOOLMAN)	
EOCENE	SHARK RIVER-MANASQUAN	MANASQUAN: 1240-1440' (RICHARDS, 1945)	1240' 1430'	VERY HARD AND TOUGH LIGHT AND DARK SLATE OR ASH-COLORED CLAYS WITH COCCOLITHS PLENTIFUL THROUGHOUT, AND WITH A FEW TEXTULARIA, NODOSARIA AND OTHER FORAMS--LOWER LAYER OF UPPER MARL BED? (WOOLMAN) SAMPLES MISSING: 1200'-1430' 1430-1450': PALE YELL. BROWN GRAVEL (TO 1 CM.) OF VERY FINE QUARTZ SAND, GLAUCONITE AND FINE CARBONATE, LIGHTLY CEMENTED; SCARCE PYRITE REWORKED VINCENTOWN?	

PALEOCENE OR EOCENE	VINCENTOWN	COMMON LARGE FORAMS, GRANULE-SIZE SHELL FRAGMENTS ABUNDANT FINE FORAMS AND SHELL FRAGMENTS SCARCE SHELL FRAGMENTS FORAMS COMMON: 1527'-1578' YELLOWISH GRAY COLOR, 1527' to 1906', EXCEPT 1740' (YELL. OLIVE GRAY) AND 1886' TO 1896' (DUSKY YELL. GRAY) SMALL FORAMS ABUNDANT: 1578' TO 1906' VINCENTOWN, 1440' TO 1900' (460'): RICHARDS, 1945	1440' 1450' 1478' 1527' 1545' 1570' 1572' 1609' 1620' 1638' 1665' 1683' 1722' 1746' 1766' 1786' 1806' 1826' 1846' 1866' 1886' 1896'	(TRANSITION, SAME AS 1430-1440']: PALE YELLOW BROWN GRAVEL (TO 1 CM.) OF VERY FINE QTZ. SAND, GLAUC., AND FINE CARBONATE, LIGHTLY CEMENTED; SCARCE PYRITE MED. YELL. BROWN VERY FINE QTZ. SAND TO SILT, AND CLAY (CARBONATE AND ? CLAY)[; ABUNDANT MICA YELL. GRAY FINE SAND TO SILT (2/3 QTZ., 1/3 CARBONATE), SLIGHTLY CLAYEY; SCARCE PYRITE YELL. GRAY 1/2 CLAY AND 1/2 FINE SAND TO SILT (QTZ., GLAUC., AND CARBONATE) 1572-1609': SL. CLAYEY FINE SAND (ABUNDANT CARBONATE, ABUNDANT OR COMMON QUARTZ, COMMON GLAUCONITE; SCARCE PYRITE AND MICA (11 SAMPLES) 1609-1638': SLIGHTLY CLAYEY AND SILTY VERY FINE SAND (ABUNDANT CARBONATE, COMMON QTZ. AND GLAUCONITE);SCARCE PYRITE (8 SAMPLES) 1638-1722': FINE TO VERY FINE SAND AND SILT (ABUNDANT CARBONATE, COMMON GLAUCONITE AND QUARTZ) AND CLAY, VARYING FROM "MODERATELY CLAYEY" TO ONE HALF THE SAMPLE (1686', 1705', 1710', 1715') (14 SAMPLES) 1722-1746': 1/2 TO 2/3 CLAY, AND FINE SAND TO SILT (ABUNDANT CARBONATE, SCARCE GLAUCONITE, COMMON QUARTZ 16 SAMPLES) 1746-1806': FINE SAND (ABUNDANT CARBONATE, COMMON TO SCARCE QUARTZ, SCARCE GLAUCONITE) (3 SAMPLES: 1746-1766'; 1766-1786'; 1786-1806') 1806-1906': 2/3 FINE SAND (ABUNDANT CARBONATE, SCARCE GLAUCONITE, AND SCARCE TO RARE QUARTZ) AND 1/3 CLAY (EXCEPT 1886-1896', FINE SAND AND COMMON CLAY); RARE PYRITE, 1826-1866' (7 SAMPLES: 1806-1826'; 1826-1846'; 1846-1866'; 1866-1886'; 1886-1896'; 1896-1906')
CRETACEOUS-PALEOCENE	WENONAH TO HORNERSTOWN	1906-1909': SCARCE FORAMS 1909-1940': COMMON FORAMS 1923-1926': RARE SPONGE SPICULES HORNERSTOWN, RED BANK AND NAVESINK UNDIFFERENTIATED, 1900-2180'; MT. LAUREL AND WENONAH, 2180' TO BASE OF WELL AT 2306 (WOOLMAN,1902 and RICHARDS,1945)	1906' 1926' 1940' 2070' 2088' 2300' 2306'	1906-1909': CLAY (CLAY AND SOME CARBONATE BY HCL TEST); SLIGHTLY SANDY AND SILTY (SCARCE QUARTZ, GLAUCONITE, FORAMS) 1909-1913': LT. OLIVE GRAY, 1/2 CLAY (CARBONATE?) AND 1/2 FINE SAND AND SILT 1916-1919': OLIVE GRAY, SAME AS 1909-1913' EXCEPT THAT GLAUCONITE IS COMMON 1923-1926': GREENISH GRAY FINE SAND (1/2 GLAUCONITE AND 1/2 QUARTZ); 1/3 CLAY (CARBONATE?); SOME CLAY PELLETS APPEAR ROLLED 1937-1940': GREENISH GRAY, 2/3 CLAY (CARBONATE?), 1/3 FINE SAND (ABUNDANT GLAUCONITE, SCARCE QUARTZ, COMMON FORAMS MISSING SAMPLES: 1940'-2070' 2070-2088': GREENISH GRAY CLAY (CARBONATE?) AND 1/3 FINE QUARTZ SAND AND SILT (COMMON FORAMS AND GLAUCONITE, SCARCE QUARTZ) SAMPLES MISSING, 2088'-2300' 2300-2306': MED. OLIVE GRAY CLAY AND FINE SAND AND SILT (ABUNDANT QUARTZ AND GLAUCONITE, SCARCE FORAMS, RARE SPONGE SPICULES, SCARCE LIGNITE)

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A PROVISIONAL SILURIAN TO MISSISSIPPIAN ROCK-STRATIGRAPHIC COLUMN FOR CENTRAL PENNSYLVANIA*

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ABSTRACT

Silurian to Mississippian rock-stratigraphic nomenclature in use by the Pennsylvania Geological Survey in central Pennsylvania includes established, redefined, or recently proposed names for mappable rock units. Some terms, previously used in central Pennsylvania, are poorly defined or lack priority and are discarded or not used at the present time. Well-exposed sections of the mappable units, where available, are listed.

INTRODUCTION

The purpose of this paper is to present the sequence of rock-stratigraphic units (formations, members) used in central Pennsylvania by the Pennsylvania Geological Survey. The present sequence of units is the result of mapping in a seven quadrangle area, part of which is published and part of which is now in progress (Fig. 1). It is a provisional sequence which should be applied only in the area being mapped. Some or all of the accepted units may be valid outside this area, but before they are used elsewhere, they should be tested to determine if they are applicable and utilitarian.

The U. S. Geological Survey, in the adjoining anthracite region to the east, is using many of the same rock units in their mapping and originated some of the new unit names. In most cases, but not all, the same unit names are used by the two Surveys.

The unit names in the composite geologic column are provisional because, as mapping proceeds, changes may have to be made in the rank or validity of a particular name. Since the program of mapping began, many changes in names occurred in order to bring the terminology in line with the observable lithologic units. It is likely that this process of evolution of names will continue.

Rock unit names are an overgeneralization that may sometimes confuse the geologist rather than help him. Thus, an overemphasis on nomenclature is unwarranted and improper. The lithologic features of the various mappable units are the important and proper considerations. Within this framework, the rock unit names for central Pennsylvania are presented.

It is pertinent to point out that the units originally based primarily on lithology have stood the test of time and, for the most part, are useful in mapping. Those units based on fossils, genesis or geologic time, as an integral part of their recognition, create many problems because they usually do not agree with the visible lithologic units. Most of these units and their names are redefined or abandoned.

COMPOSITE GEOLOGIC COLUMN

The column presented here is divided into three sections. At the left brackets are drawn to indicate the extent of exposure one may expect on visiting the localities indicated by number. Directions to these localities are listed later under the same heading. The middle section of the column lists the formation and member names plus the range of thickness encountered in the mapped area. At the right the characteristic lithology of the formation or member is briefly presented.

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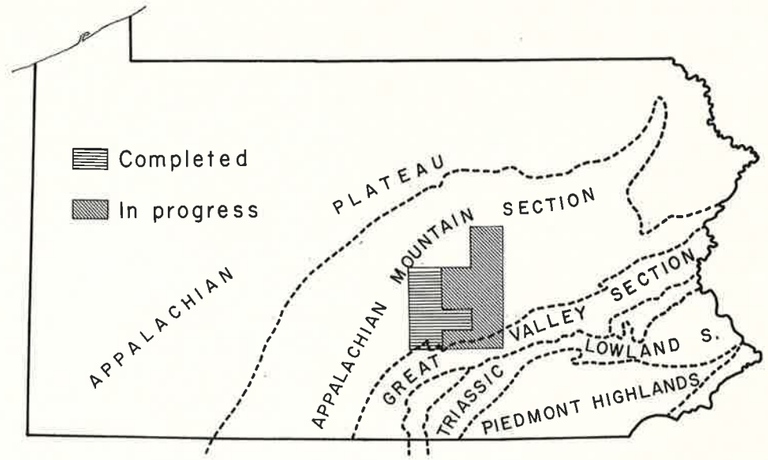

Figure 1. Area of mapping in central Pennsylvania.

ABANDONED OR NON-APPLICABLE STRATIGRAPHIC NAMES

A group of previously used stratigraphic names are judged to be not applicable or invalid in the area mapped. These are listed below with the reasons for their present status.

COVE MOUNTAIN, PETERS MOUNTAIN, AND SECOND MOUNTAIN MEMBERS:

These names were originated by Willard and Cleaves (1938, p. 18) for a threefold subdivision of the Pocono Formation. Described sections were not given and the proposed members were not mapped. The existing description of the units precludes their use until mapping in the type area tests their validity. Present mapping in the Pocono Formation indicates that, if these units are mappable they will be valid in only a small area.

DAMASCUS, HONESDALE, AND CHERRY RIDGE MEMBERS:

Willard (1936, p. 581-585) applied these names to units in the Catskill Formation of the Susquehanna-Juniata Rivers region. They are accepted by the U. S. Geological Survey (Arndt and others, 1962 ,p. C32). The Pennsylvania Geological Survey, however, does not acept these names for the Susquehanna River region at the present time. This is because the Cherry Ridge, Honesdale, and Damascus Members have not been mapped from their type areas to the Susquehanna. Until mapping establishes the actual continuity of these members, they should not be used outside their type areas.

FORT LITTLETON AND RUSH FORMATIONS:

The terms Fort Littleton and Rush are abandoned in favor of Trimmers Rock Formation, Brallier Formation and Harrell Formation because the latter terms adequately describe the lithologic sequence encountered. These units, when

(Footnotes to Geologic Column)

1. In the Millersburg, Millerstown, and New Bloomfield (north 1/3) 15-minute quadrangles the middle portion of the Catskill is mapped as one unit, the Buddys Run Member. In the New Bloomfield (south 2/3) and Harrisburg 15-minute quadrangles the name Buddys Run is dropped and four member units are mapped in its place.
2. In the Loysville and New Bloomfield 15-minute quadrangles the lower 2/3 of the Mahantango Formation is mostly sandstone and is mapped as one member. In the Millersburg and Millerstown 15-minute quadrangles the lower portion of the Mahantango is mostly shale and separately mappable as a third member.

Composite Geologic Column

Well-exposed sections	Formations and members			Lithology
1	Mauch Chunk	Upper M. 200'-500'		red & gray sh., ss., & cgl.
		Middle M. 2000'-6000'		red sh. & ss.
		Lower M. 100'-500'		red & gray sh., ss., & sandy cgl.
2	Pocono	Mount Carbon M. 500'-1000'		gray ss. with prominent cgl. at base
		Beckville M. 500'-800'		gray ss. & cgl. with prominent cgl. at base
3	Catskill	Spechty Kopf M. 0-2400'		gray sh., ss., & cgl. with some red sh. & ss.
4		Buddys[1] Run M. ca. 4500'	Upper ss. M. ca. 700'	gray ss. & cgl. with some red sh. & ss.
5			Upper Redbed M. ca. 600'	dominantly red sh. & ss.
6			Clark's Ferry M. 0-700'	gray to red, resistant cgl., ss. & sh.
			Lower Redbed M. ca. 2700'	dominantly red sh. & ss.
		Irish Valley M. 200'-2300'		red (<50%) & gray sh. & ss. Unit base is lowest red bed.
7	Trimmers Rock	1500'-2000'		gray, fine-grained ss. & siltst. with some sh.
8	Brallier	250-500'		gray sh. & siltst. with some ss.
9	Harrell	40'-100'		light-gray sh.
		Burket M. 0-200'		grayish-black fissile sh.
		Tully M. 0-20'		gray calcareous sh. & argillaceous ls.
	Mahantango	Sherman Ridge M. 475'-600'		gray sh. & siltst. with some ss.
		Montebello M.[2] 350'-1000'		gray ss.
			unnamed M. 0-400'	gray sh., siltst. & ss.

Red sh. & ss. with some gray sh. & ss.

Composite geologic column contd.

10	Marcellus	Mahanoy M. 0-120'	dark-gray, laminated silty sh.
11		Turkey Ridge M. 100'-150'	gray ss.
		Shamokin M. 75'-110'	grayish-black, fissile, carbonaceous sh.
12 13	Onondaga	Selinsgrove M. 50'-75'	gray argillaceous ls. & calcareous sh.
		Needmore M. 25'-140'	gray calcareous sh.
14	Old Port	Ridgeley M 0'-40'	light-gray ss. & conglomeratic ss.
15		100-175'	gray chert, cherty ls. & calcareous sh.
16	Keyser	150'-180'	gray, nodular, fossiliferous ls.
17	Tonoloway	225'-600'	gray, laminated, non fossiliferous ls.
18	Wills Creek	Upper M. 170'-200'	gray sh., siltst., ss.; argillaceous red sh. & ss. unit at top
19		Lower M. 400'-450'	gray, green, & red sh., siltst. & argillaceous ls.
20	Bloomsburg	350'-500'	dominantly red sh., siltst. & ss
21	Mifflintown	McKenzie M. 100'-225'	gray ls. & sh.
		Rochester M. 20'-40'	gray sh. & ls.
		Keefer M. 0-50'	gray, quartzitic ss. with some sh.
22 23 24 25 26	Rose Hill	Upper M. 100'-150'	gray sh., siltst. & argillaceous ls.
		Centre M. 10'-40'	grayish-red, ferruginous ss.
		Middle M. 250'-400'	gray sh., siltst. & ss.
		Cabin Hill M. 0-45'	grayish-red, ferruginous ss.
		Lower M. 200'-375'	gray sh., siltst. & ss.
27	Tuscarora	350'-700	gray, cross-bedded, quartzitic ss.

originally described, were given defined type sections or exposures. Neither Fort Littleton nor Rush have defined type sections. The Brallier and Harrell were named by Butts (1918, p. 523-524) and have priority over Rush and Fort Littleton as defined by Willard (1935, p. 1199-1200). The Trimmers Rock, originally a member of the Fort Littleton, (Willard, 1935), is raised to formational rank because of its mappability.

The rocks called Tully are included as the basal member of the Harrell at the present time.

PARKHEAD MEMBER:

Willard (1935, p. 1199) included this member at the top of his Fort Littleton Formation, but noted that it was not lithologically distinct in the Juniata River region where he recognized it by its fauna. The Parkhead is thus not used as a rock unit in this region.

LOSH RUN MEMBER:

The ten-foot shale unit between the Brallier and Trimmers Rock Members of Willard's Fort Littleton Formation was named the Losh Run (Willard, 1935, p. 1206). It contains a characteristic fauna. This member is abandoned as a rock unit (Dyson, 1963) because mapping in the type area shows that it differs in no way from other thin shale units in the Trimmers Rock and Brallier Formations except in its fauna.

MEXICO MEMBER:

The Mexico Member of the Marcellus Formation (Willard, 1935a, p. 203) was abandoned as a mappable rock unit by Conlin and Hoskins (1962, p. 27-28) and Miller (1961, p. 27). Mapping in the type area of the member has shown that it cannot be separated from, and is identical to, the Turkey Ridge Member.

NEWTON HAMILTON FORMATION:

Swain (1958, p. 2867) proposed the Newton Hamilton Formation, and its included members — Hares Valley and Beaverdam Run—to supplant the Onondaga Group and its included formations—Selinsgrove and Needmore—of Willard and others (1939, p. 146-149). These new names are not accepted at present because it is felt they are not necessary. Willard's establishment of Selinsgrove and Needmore is acceptable and the two units are mapped together as members of one formation, the Onondaga Formation.

ORISKANY AND HELDERBERG GROUPS:

The rocks formerly called the Oriskany and Helderberg Groups are assigned to a new formation, the Old Port (Conlin and Hoskins, 1962, p. 20-21). These groups and their included formations are, with one exception (the Ridgeley), not mappable in the stated area. The formations are downgraded to member status and the terms Oriskany and Helderberg, as rock units, are abandoned.

The members — Ridgeley, Shriver, Mandata, New Scotland, and Coeymans- are lithologically definable. The Ridgeley can be mapped separately in some areas. The remaining four members, in these areas, are combined and mapped as a single unit.

CASTANEA SANDSTONE:

The Castanea Sandstone (Swartz, 1934, p. 109) is not a mappable unit in the area examined. Rocks similar to the described type lithology are present in the Mifflintown quadrangle (Conlin and Hoskins, 1962, p. 11). This unit, if mappable elsewhere, should probably be considered a member of the Tuscarora.

APPENDIX

Well Exposed Sections. Numbers Refer to Those on Geologic Column:

1. Mauch Chunk. Partial and intermittent exposures of lower two members on road leading south from Pillow to Loyalton. Millersburg 15-minute quadrangle.

2. Pocono. Type section of Mount Carbon and Beckville Members, (Trexler and others, 1962). East side of Schuylkill River gap in Second Mountain 1 mile north of Beckville on paved road to Mount Carbon. Pottsville 7½-minute quadrangle.

3. Pocono and Catskill. East side of Susquehanna River gap in Berry Mountain 1 mile south of Millersburg (Hoskins and Conlin, in preparation). Millersburg 7½-minute quadrangle.

4. Pocono and Catskill including type section of Clark's Ferry Member (Dyson, 1963, in press). East side of Susquehanna River gap in Peter's Mountain on U. S. Route 22-322, 3/5 miles south of Clark's Ferry Bridge. Duncannon 7½-minute quadrangle.

5. Type section of Buddys Run and Irish Valley Members, Catskill Formation (Arndt and others, 1962). West side of Shamokin Creek along Reading Railroad cuts 1½ to 3¼ miles north of Shamokin. Shamokin 15-minute quadrangle.

6. Catskill. East side of Juniata River along U. S. Route 22-322, 100 yards south of Newport Bridge north to Buffalo-Berry Mountain (Dyson, 1963, in press). Newport 7½-minute quadrangle.

7. Trimmers Rock and Brallier. East side of Susquehanna River along Pennsylvania Railroad cuts ¼ mile south of Fidler Run and ½ mile south of Herndon (White, 1883, p. 366). Pillow 7½-minute quadrangle.

8. Catskill to Mahantango. East side of Juniata River along U. S. Route 22-322, ½ to 2½ miles north of Amity Hall (Willard and others, 1939, p. 353). Duncannon 7½-minute quadrangle.

9. Catskill to Mahantango. West side of Susquehanna River along U. S. Route 11-15, 1½ to 3 miles north of New Buffalo. Halifax 7½-minute quadrangle.

10. Mahantango. East side of Susquehanna River in abandoned quarries along Pennsylvania Railroad 2½ miles south of Dalmatia (Hoskins and Conlin, in preparation). Exposures are in southern two of four quarries. Dalmatia 7½-minute quadrangle.

11. Marcellus. South of Tuscarora Creek in bed of intermittent tributary 800 feet east of boundary of Spruce Hill and Turbett Townships (Conlin and Hoskins, 1962, p. 27). Mifflintown 7½-minute quadrangle.

12. Marcellus to Old Port. East side of Susquehanna River along Pennsylvania Railroad 1 to 1½ miles south of Dalmatia 7½-minute quadrangle.

13. Type section of Selinsgrove Member. East side of Susquehanna River along Pennsylvania Railroad ½ mile south of Selinsgrove Junction (White, 1883, p. 359). Sunbury 15-minute quadrangle.

14. Type section of Old Port Formation. In stream bed and road cut 1½ miles west of Old Port (Conlin and Hoskins 1962, p. 23). Mifflintown 7½-minute quadrangle.

15. Old Port. East side Pa. Route 225, ¼ mile south of Bull Run (Swartz, 1939, p. 80). Pillow 7½-minute quadrangle.

16. Keyser-Tonoloway. East side of county road ¼ mile south of Pine Grove. Spruce Hill 7½-minute quadrangle.

17. Keyser-Tonoloway. Cuts along Pennsylvania Railroad ¼ mile south of Mexico. Mexico 7½-minute quadrangle.

18. Wills Creek. Cuts along Pa. Route 274 and dirt road leading south at Cisna Run (Arndt and others, 1959, p. 30). Andersonburg 7½-minute quadrangle.

19. Wills Creek. On dirt road leading north off Pa. Route 274 at Center (Arndt and others, 1959, p. 31). Andersonburg 7½-minute quadrangle.

20. Bloomsburg. On U. S. Route 22-322, 150 yards north of Mifflintown (Hoskins, 1961, p. 31-35). Mifflintown 7½-minute quadrangle.

21. Type section of Mifflintown Formation. On U. S. Route 22-322, ¼ mile north of Mifflintown (Miller, 1961, p. 12). Mifflintown 7½-minute quadrangle.

22. Mifflintown and Rose Hill. On county road bordering Tuscarora Creek 1¾ miles west of Port Royal. Mifflintown 7½-minute quadrangle.

23. Rose Hill. East side of Sherman Creek 1 mile south of Cisna Run (Arndt and others, 1959, p. 29). Andersonburg 7½-minute quadrangle.

24. Rose Hill and Tuscarora. West side of Susquehanna River on U. S. Route 11-15 in gap in Blue Mountain 1½ miles south of Marysville (Swartz and Swartz, 1931, p. 631-634). Harrisburg West 7½-minute quadrangle.

25. Type section of the Cabin Hill Member. On Pa. Route 850, 1½ miles north of Kistler (Miller, 1961, p. 10). Spruce Hill 7½-minute quadrangle.

26. Rose Hill. Along dirt road at the west end of Shaeffer Valley where the road turns south along the south Branch of Laurel Run. Exposure is one mile northeast of the southwest corner of the Andersonburg 7½-minute quadrangle.

27. Tuscarora. Along road and stream through Run Gap, 2 miles northwest of Ickesburg. Spruce Hill 7½-minute quadrangle.

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A DEVONIAN FAUNULE FROM LEHIGHTON, PENNSYLVANIA

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ABSTRACT

A new road cut at Lehighton, Pennsylvania, has revealed an exposure containing fossils of Middle Devonian age. The fauna is especially noteworthy because of the unusual number of pelecypods including the following genera: *Nuculites, Nuculoidea, Phthonia, Modiomorpha* and *Pseudaviculopecten*. Gastropods, Cephalopods, Brachiopods and Trilobites are also present.

During the past three years fairly extensive collecting has been carried out at a hitherto unrecorded Devonian locality on Route 209, about half a mile east of Lehighton, Carbon County, Pennsylvania. The locality consists of a road cut and small quarry and is locally known as Mennonite Hill. Part of the area is now occupied by a filling station, but it is still possible to obtain fossils behind the station.

The fossils mentioned in this report were collected by various groups from the Academy of Natural Sciences and the University of Pennsylvania under the leadership of the senior author. The most extensive collection was made by Richard Weiss, then a student at the University of Pennsylvania, who also wrote a preliminary report on the locality as part of a senior problem course. Among others who contributed material discussed in this report are William Gallagher, David Govoni, Michael Gibson, Maxwell and Kenneth Stepanuk. We also want to express our appreciation to Dr. Bradford Willard who gave advice in the identification of some of the specimens.

FAUNA

Most of the fossils were poorly preserved, making specific identification very difficult. In most cases, therefore, we have only attempted to record the genus.

The characteristic which makes this fauna worthy of note is its abundance of pelecypods which are generally not too common in Devonian fossil localities in Pennsylvania. The pelecypods comprise the largest part of the fauna, both in regard to individuals and to genera. Nine genera are recorded, and one species of *Phthonia* is described as new. The most abundant genera are *Nuculites, Nuculoidea, Palaeonilo* and *Modiomorpha*.

Only slightly fewer than the Pelecypods in number of individuals, but not in number of genera, are the Brachiopoda with the spirifers probably the most abundant.

Gastropoda are represented by only one genus (*Loxonema*) and this is rare. The cephalopods are relatively common, the most abundant being assigned (in a broad sense) to the genus *"Orthoceras."* Other members of the faunule include some corals (not here identified), two genera of trilobites (*Phacops* and *Greenops*) as well as a few specimens of *Hyolithes* and *Conularia*. The complete list of genera is given below:

COELENTERATA (CONULARIDA): *Conularia* sp.

COELENTERATA (ANTHOZOA): Corals (not studied)

PELECYPODA: *Nuculoidea* (probably three species), *Nuculites* sp. *Phthonia pennsylvanica* n. sp. (see below), *Palaeonilo* sp. *Paracyclas* sp. *Modiomorpha* sp., *Cypricardella* sp., *Grammysia* sp. *Pseudaviculopecten* sp.

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GASTROPODA: *Loxonema* sp.

CEPHALOPODA: *Spiroceras* sp., *Bactrites* sp., *"Orthoceras"* sp.

PTEROPODA (?): *Hyolithes* sp.

BRACHIOPODA: *"Spirifer"* spp., *Stropheodonta* sp., *Rhipidomella* sp., *Orbiculoidea* sp., *Athyris* sp. *Lingula* sp.

ARTHROPODA (TRILOBITA): *Phacops* sp. *Greenops* sp.

One of the pelecypods is believed to be new, and is here described.

Phthonia pennsylvanica n. sp.

Shell of medium size; elongate as shown in figure. Basal margin almost straight, curving to both anterior and posterior margins. Valve slightly convex; faint indications of growth lines; radial straie not visable.

Differs from *P. cylindrica* Hall from the Hamilton of New York in general shape, especially in being more elongate. The absence of radial striae could be due to poor preservation. This species does not have the conspicuous sculpture of *P. nodicostata* Hall or *P. sectifrons* Hall, both of which are known from the Hamilton of New York.

Length of holotype (ANSP 31181): 29 mm; Width 13 mm

Collected by Kenneth Stepanuk.

Figure 1. *Phthonia pennsylvanica* Richards and Shapiro n. sp.

STRATIGRAPHY AND AGE OF FAUNULE

The faunule is of late Devonian age and is referred to the Hamilton Group. This group is divided into formations as follows:

HAMILTON GROUP

Moscow Formation

Ludlowville Formation
(including Centerfield Coral Reef)

Skaneateless Formation

Marcellus Formation

The two formations of the Hamilton Group known to contain a relative abundance of pelecypods at some localities are the Moscow and Ludlowville formations. The absence at the Lehighton locality of the brachiopod *Vitulina postulosa* Hall, an index fossil of the Moscow Formation, casts some doubt on the correlation of the Lehighton beds with that formation. Therefore, the faunule is tentatively correlated with the Ludlowville Formation, although more intensive collecting and a more detailed study of the fauna may alter this interpretation.

SAW CUT BONES IN AN APPARENT FOSSIL

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ABSTRACT

Several well defined saw cut surfaces prove that a mass of cemented bones, found on a New Jersey beach, are not fossils. It is proposed that the severe storm of March 1962 destroyed a bone midden of a country abbatoir. Cementation was due to iron discarded with the bones.

Last October I was loaned a mass of mammalian bones cemented in beach sand by iron oxide. The specimen, owned by Mrs. Theodore M. Smith of Northampton, R. D. 2, Pennsylvania, and brought to my attention by Mr. Karl L. Werkheiser of Lehigh University, was collected from shallow water on the beach at Ship Bottom, New Jersey, the day after a heavy September storm. At first glance it looked like fossil material from some of the famous bone-beds of the Tertiary, but close examination proved that it could not be a fossil for there was a very pronounced saw cut steak bone in the mass. The specimen and its probable history seem worthy of being recorded.

In over-all dimensions the specimen is approximately eighteen inches long and six inches in height and thickness. The most prominent of the exposed bones are a mandible with well preserved teeth, obviously belonging to a cow or steer, and part of the skull of a sheep or lamb showing the left maxillary with the included teeth and part of the rise to the zygomatic arch. (Fig. 1) Above the mandible and standing free of the matrix, is a triangular bone, three-quarters of an inch thick, which was obviously cut by a saw in producing a steak. Closer study revealed a neural spine, presumably from a steer, which shows a saw cut along its entire length, the posterior part of a small skull which could not be identified, part of a rib of either a large sheep or a hog and numerous other unidentified bones. Altogether, there are eight places where it is possible to see saw cut surfaces.

The matrix is impure quartz sand which included an oyster shell and several small gastropods. At one place a piece of hide, about the size of a leather shoe lace and a half inch in length stuck out from the cemented matrix. Even with careful handling this soon broke off.

Running the length of the specimen on one side is a circular cavity approximately fifteen inches in length and seven-eighths of an inch in diameter. At places the outer surface has broken away, and at others it is complete. Where visible, this tubular cavity has linear markings similar to those seen where iron pipes or bolts have rusted out of old timbers. This portion of the specimen is most highly cemented by iron oxide and is reddish brown in color.

Since it is obvious that any mass of bones which show saw cuts must be of very recent age, they cannot be fossils. However, this conclusion does not remove the desirability of interpreting the conditions that produced the lithification and the eventual finding of the bones.

It is a known fact that fishing draggers working the banks off the New Jersey coast have from time to time brought up collections of mammalian remains. (Widmer, 1962) Some of these specimens are fossils for they are the bones and teeth of the extinct musk-ox, moose and mastodon that lived in this region during the cooler Pleistocene when a large belt of the present continental shelf was exposed due to the lowered sea level. (Dyson, 1962) There are others which probably are not fossils for it is known that in addition to the garbage from coastal ships, New York City for many years disposed of much of its garbage and refuse by towing it to sea to be dumped from scows off of the New Jersey coast. However, there does not seem to be any record of the bones retrieved by draggers having been cemented or having such a variety of bones in a single mass.

The presence of the skull bones and the variety of animals suggests the debris from a slaughterhouse rather than ordinary garbage. Therefore, it is suggested that these bones represent part of the debris from a small abattoir or country bucher shop from which the bones and refuse were buried in the sand of the New Jersey coast. At some time a section of iron pipe or an iron rod was also thrown into the pit. Subsequent years allowed the iron to rust way, leaving the cavity, and at the same time cementing the bones that lay directly beneath it. That such cementation of sand, by the weathering of scrap iron can occur, is attested to by the fact that cemented Bermuda sands adjacent to a piece of iron chain have been reported. (Willard, 1962)

In March of 1962, sections of the New Jersey coast were devastated by a severe northeast storm which caused millions of dollars worth of damage to property and which drastically modified the shore line in places. The dunes and the buildings upon them were removed, the waves went completely across the barrier beaches, and new channels were cut into Barnegat Bay.

Therefore, it seems logical to believe that this March storm might well have eroded and scattered this old bone midden, with only those bones that had been cemented by the iron pipe remaining as a discrete mass which was carried out to sea. Six months later a strong September storm washed it up on the beach at Ship Bottom where it was discovered. Presumably, some of the other bones were also washed out to sea and then returned to the beaches, but as single bones they would go unnoticed.

The only alternate hypothesis is that these bones are from garbage dumped at sea. It is known that submarines weight their garbage bags with scraps iron to prevent their being recovered, but submarines do not carry live animals to be slaughtered as needed, and this piece has parts of three skulls which would never

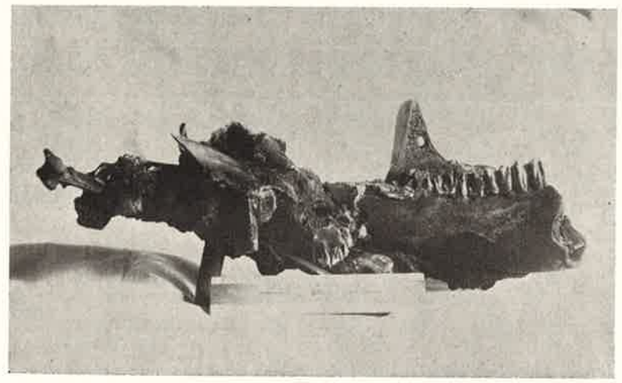

Fig. 1. Cemented bones from beach at Ship Bottom, N. J.

be found on sides of meat carried by a submarine. In the days of sail, coasting vessels did sometimes carry live animals as a source of fresh meat, but three animals would not be slaughtered at one time when there was no refrigeration. Municipal garbage dumped from scows would presumably be more varied.

Therefore, this specimen is interesting for two reasons: first, the presence of the many saw cut surfaces proves that it is of very recent origin, hence, not a fossil; and, secondly, it presents a problem which can be adequately solved by following known facts to logical deductions.

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ONTOGENY OF THE JURASSIC AMMONITE ARIETITES FROM PERU

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ABSTRACT

The Bassler collection of Peruvian fossils at Lehigh University includes many examples of the Jurassic ammonite *Arietites*. These show growth stages from 3 to at least 200 mm. in diameter. Besides the ammonites, only benthonic animals are preserved. Absence of aptychi and the condition of the fossils implies an allochthonous origin relative to place of burial of the ammonites.

INTRODUCTION

In the 1961 *Proceedings* and elsewhere (Willard, 1961, 1962) I reported on the Harvey Bassler collection of Peruvian fossils which was left to Lehigh University and which I am currently studying under grants from the National Science Foundation. In 1962 I discussed the paleoecology of some of the vertebrate fossils in the collection (Willard, 1962b). My 1961 paper touched briefly upon the presence among the Jurassic fossils of the ammonite *Arietites* which shows growth stages. Also I commented on the paleoenvironment. It is the purpose of the present article to amplify those themes.

DISTRIBUTION OF JURASSIC FORMATIONS IN PERU

Because Bassler collected from the Jurassic in the Central and Eastern Cordillera, a summary of the distribution of Jurassic sedimentary rocks in Peru is relevant. The geologic maps of South America (Stose, 1950) and of Peru (Bellido *et al,* 1956) show the distribution of the Jurassic. The 1956 map indicates some areas as "Jurasico-Triasico." In Peru, the system is restricted areally. There is a small patch on the Alto Marañon River below its confluence with the Rio Utcubamba, lat. 5°S.; long. 78° 30′ W., approximately. A long, narrow band stretches south-southeast from Chachapoyas on the Utcubamba River to the valley of the Pachitea River north of Oxapampa, from near lat. 6°S.; long. 78° W. to about lat. 10° 10′ S.; long. 76° W. There are areas in the vicinity of the towns of Moyabamba and Tarapota, lat. 6° S.; long. 77° W., south-southeast from which small patches are mapped into the Ucayali Valley. The foregoing areas embrace most of the places in eastern Peru from which Bassler collected Jurassic fossils. Also, he found some in the Marañon Valley in Pongo Manseriche where no Jurassic is shown on the 1956 map, nor likewise so indicated on the 1950 map. Other Jurassic patches are strung out along the Alto Marañon River southeastward past Cerro de Pasco to the Bolivian border. They are shown in Steinmann's incomplete geologic map of Peru (1929). All these lie west of the region where Bassler worked.

AGE AND LITHOLGY

Much of the Peruvian Jurassic was long ago assigned to the lower part of the system, the Liassic (*Cf.* Hyatt, 1875), albeit there is younger Jurassic in the country. From published descriptions it seems the lithology of the Peruvian Jurassic is quite diverse. The paleontologic and rock specimens at hand are mostly blackish to chocolate-colored siltstone. There is one faunule in lithographic limestone, but its fossils are somewhat aberrant and identification is incomplete. The siltstone is slabby and often too coarse-grained to preserve the finest details of the fossils. The ammonites are represented by at least 200 individuals which range in diameters from 3 to more than 200 mm.

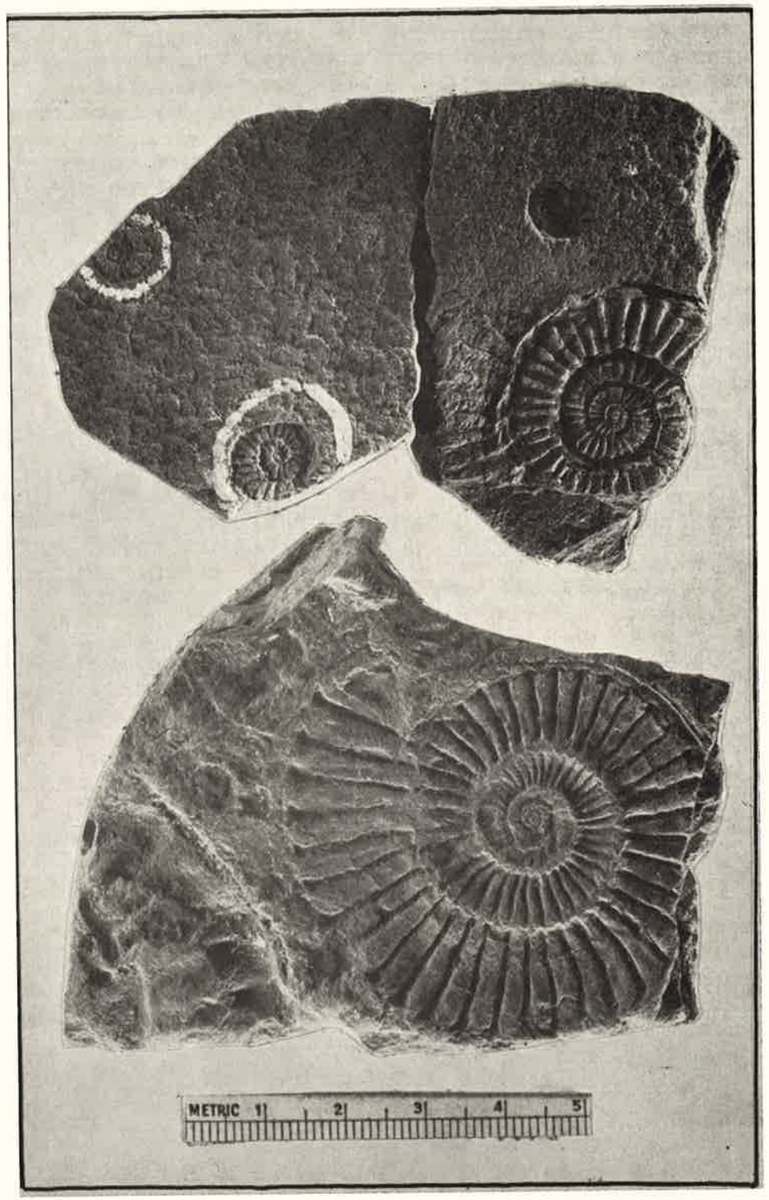

Fig. 1. Slabs of Jurassic siltstone from upper valley of Pasqui River. Impressions of *Arietites*.

THE FAUNA

The complete list of Jurassic fossils identified from the collection follows:

Lingula sp.
Terebratula domeykana Bayle and Coquand
T. ovatissima Quenstedt
Scurria (?)
Ampullella peruviana Cox
Potingensis Tilmann
Lucina liasina Steinmann
L. cf. atacamensis Möricke
Schlotheimia angustisulcata Geyer
Arietites coregonensis Sowerby
A. stübeli Tilmann
A. ceratitoides Quanstedt
Microderoceras sp.

Arietites coregonensis is represented by a few inferior individuals, but the other two species of this genus are plentiful and fairly well-preserved. Evamples of *Schlotheimia* are small, but good. Arkell *et al* (1957, p. L238) characterize the genus *Arietites* as follows:

"*Arietites* Waagen, 1869 . . . Giant, massive, evolute, planulate with subquadrate whorls and tricarinate-bisulcate venter. L. Sinem. [Sinemarian or Lower Jurassic]. Eu.-Anatolia-Himalayas-? Japan,-? Philip.-Indo.-N. Alaska-Nev.-Chile-Peru-Arg. . . ."

Trauth (1935) in his studies of the anaptychus figures this organ from European species of *Arietites*. Although no aptychi or anaptychi have turned up in the Bassler representatives, certainly these South American species possessed them.

The two commoner species of *Arietites* are much alike, so that distinction among the material is not always clear, especially as identification must be made on exteriors alone. No speciman preserves enough of the interior to be diagnostic; none has siphuncle or septa, and one only retains a tiny fragment of characteristic suture. The adult *A. stübeli* has arcuate to nearly straight ribs, but on *A. ceratitoides* the ribs are slightly curved or hooked peripherally. Among the immature examples it is quite difficult or impossible to make specific distinctions, but since the two species mingled, the growth stages of both have been plotted together indiscriminately.

The shells of the brachiopods, pelecypods and gastropods are little worn or entire. Some of the larger ammonites have been broken and may be fragmental; the smaller ones show erosion at the periphery, but ribs and umbilicus distinct. The graph, Fig. 2, shows growth stages by volutions (whorls) plotted against diameters in millimeters. There is a gradational series from smallest to largest. Size increase and addition of whorls are uniformly rapid up to about the six or seventh volution. Thereafter, few (two or three) whorls are added. Because the breadth of the last whorls increases rapidly, the diameter of the conch expands proportionally.

PALEOENVIRONMENT

Akell and co-authors (*op. cit.* p. L22) in discussing the environment of ammonites state:

". . . Presumably, assemblages containing various growth stages of the same species accumulated *in situ*. Those that consist exclusively of mature individuals probably indicate that the animals had changed their habitat during ontogenic development. Concentrations of small individuals resulted from mechanical sorting by waves and currents. Concentrations of aptychi are believed to have resulted from the drifting away of the shells after separation from the decaying bodies."

I am not in full agreement with all of these statements because some appear to be incompatible with my deductions. I do not think the specimens that I am studying accumulated in the place where the animals lived.

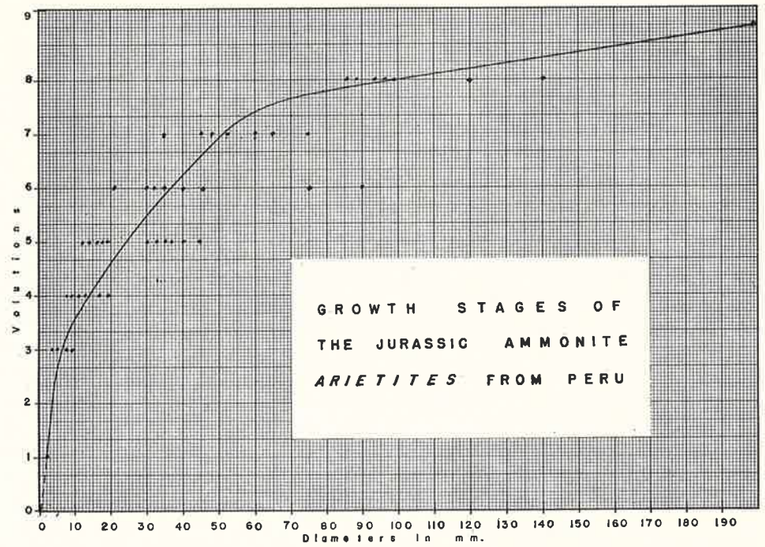

Fig. 2. Graph showing growth stages of *Arietites* (two species) constructed by plotting number of whorls against diameter in millimeters; based on about 75 examples.

The absence of aptychi or anaptychi implies that the cephalopods are thanatocoenose assemblages. It is axiomatic from the deduced conditions of life and death of ammonites that defunct individuals float, the soft parts decay, and the aptychi drop off, sink to the bottom and become fossils. The empty shells may be borne far before they come to rest. They could accumulate as scattered individuals of various sizes.

Were the ammonites benthonic, one would expect to find aptychi buried with the shells. Because none was recovered, I believe *Arietites* was planktonic. Ammonites may have crawled on the bottom, but they may have been "jet propelled" nekton or floating plankton. Somewhere *Arietites* was reproducing as attested by the many growth stages. The shells finally accumulated among remains of benthonic invertebrates already lodged on or in the bottom sediments. Currents and waves caused the imbricating or piling up of individual ammonite shells.

The foregoing suggestions attempt to explain:

1. The association of slightly worn ammonite shells with little worn or entire remains of benthomic invertebrates.
2. The mixing of sizes of *Arietites*.
3. The absence of aptychi.
4. The distribution of the ammonite shells on the sea bottom.

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TOCKS ISLAND PROJECT

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ABSTRACT

The largest water-control project planned for the Delaware River Basin will be located near the Water Gap.

Development will require much alteration of the landscape and radical changes in the settlement pattern.

The project will have a major impact on the area's economy. Seven million visitors are expected annually.

The proposed Tocks Island Dam with its thirty-seven mile long reservoir and extensive recreation areas is the largest of all projects planned for the Delaware River Basin. And when completed, it will provide recreational facilities for an estimated seven million annual visitors. Functions of this multiple-purpose project include flood damage reduction, supplies of water, and hydroelectric power.

The Army Engineers were authorized to make a study of the water control needs of the entire Delaware River Basin. It was undertaken in 1956. The study covered projected needs of the river basin for the fifty year period, 1960-2010. All aspects of water use were taken into account and plans were drawn for the construction of dams and other facilities as found necessary to meet the anticipated needs and demands of the region. A number of special studies were made by various Federal and State Agencies. The National Park Service made estimates of future recreational needs of the Basin. And the U. S. Office of Business Economics studied population, industrial production, and employment trends.

Estimates of growth in the basin indicate a need for a much more efficient use of the waters of the Delaware system. About half of the potential water use now is being wasted. In the fifty year period, 1960-2010, the population of the region is expected to rise from 21 to 42 million. Industrial employment should double and industrial production quadrupple in that time. Outdoor recreation resources will need to be expanded six fold. Electric power demands of the basin will triple by 1980 and will increase to nine times by the end of the period. The Army Engineers expect to reduce flood damage by 45% in reaches that are affected by major impoundment sites. They expect to increase surface water flows on the Delaware and its tributaries by 2100 cubic feet per second. This amounts to an increase of more than one and one third billion gallons of water per day.

The over-all plan for the Delaware River Basin includes 58 control projects that will cost approximately $591 million dollars. Eleven of these will be multiple-purpose projects of which eight will receive large financial grants from the Federal Government. The Tocks Island project is the largest one in terms of costs of development and of services to be rendered. Its location will be in an area already noted for recreation and one that is accessible from the two largest urban centers in the eastern United States. Tocks Island Dam near the Water Gap on the eastern edge of the Poconos will have a great impact on the economy of the area. Also, it will pose serious problems of resettlement for some communities, cause changes in the tax ratables, and will require extensions of local public services, such as roads, fire protection, police protection and sewage disposal.

The Delaware River runs from the Water Gap to Port Jervis, N. Y., a distance of 42 miles. Here in the Ridge and Valley country, the Delaware flows along the western side of Kittatiny Mountain until it can break through at the famous Delaware Water Gap. The dam is to be built across the upper end of the small Tocks Island. The Delaware River, in its course above the water gap contains several islands, such as Tocks. Rolling uplands parallel the river on the west. These are the Eastern Poconos which merge northwestward into the Pocono Plateau whose elevation exceeds 2000 feet in places. Note the dam's proximity to East Stroudsburg and the borough of Stroudsburg lies one mile farther west across Brodhead Creek. The Stroudsburgs are the largest towns in the area and together have about 15,000 people. Northwestward from Stroudsburg Route 611 leads to the Poconos and on to Scranton and Wilkes-Barre in the anthracite region. Also, to the northwest a section of the Keystone Shortway is under construction. When completed, the Shortway will provide the most direct route between Chicago and New York City. Heavy traffic along this highway will pass through the Stroudsburgs and the southern ends of the Tocks Island Project at the Delaware Water Gap. The stretch of the river with the proposed dam and reservoir lies approximately 75 miles from New York. Allentown and Bethlehem are about 40 miles from Stroudsburg by road going westward on highway 209 and down Route 12 through Wind Gap. This road connects with the Northeast Turnpike to Philadelphia and with Route 22 to Harrisburg. South of the project area, through the Water Gap, highways lead to Philadelphia on both sides of the Delaware . . . a distance of about 85 miles. Tocks Island Dam will be two and a half hours of driving time from the two major cities on our Eastern Seaboard. Highways now providing access to both centers will need improvements to handle future traffic requirements. It is expected that New Jersey will widen Route 206 giving better access to the northern part of the area. Plans include extending Route 80 in New Jersey westward from Netcong to the Delaware River. The new road will be several miles shorter than the present Route 46 from New York and will carry more than twice the traffic. All these routes will provide approaches to the general region of the Tocks Island project area.

Tocks Island is the site chosen for the dam. This small island lies 5 miles upstream from the Delaware Water Gap. It is 2½ miles above Shawnee Village and about 7 miles northeast of Stroudsburg. To the east, Kittatiny Mountain rises almost a quarter of a mile above the river to an elevation of 1600 feet. Highlands to the west go to about 900 feet elevation. The valley is narrow at this point and offers a good location for a dam emplacement. The small island here in the river presents an added advantage for dam construction. The dam will span the valley for 3200 feet. It is to be made of earth and rock and will rise 160 feet above the river to an elevation of 456 feet.

A spillway and power plant will be located on the left (NEW JERSEY) side of the stream. The spillway cut into the left abutment will have a concrete crest at an elevation of 395 feet. Above the crest will be mounted 10 radial gates, each 40 feet long and 35 feet high. The conventional power plant will have two turbine driven generators of 23,000 kilowatt capacity each. In addition, a pumped-storage power plant located a short distance upstream will have a much greater capacity. Included in construction costs are facilities for passing fish

over the dam, in case studies indicate the need for such an arrangement.

The normal pool level at the 410 foot elevation will provide more than 400,000 acre feet of active long-term water storage. At flood level water will reach an elevation of 428 feet. The reservoir shore line at flood level will be about 100 miles in length and water will extend approximately 9 miles up Flat Brook. Inundation of the Valley will necessitate relocation of 27 miles of U. S. Highway 209, a number of county and local roads, many homes, and two communities. Protection for the town of Matamoras will be probided by building a dike 12,000 feet long.

Acquisition of more than 62,000 acres of land will be necessary to provide the 14,800 acres needed for construction and the additional space for recreational facilities. The total cost will exceed $177,000,000. About half of the amount will be financed by the Federal Goverment. The non-Federal interests involved with development and financing are the states of New York, New Jersey, and Pennsylvania and a private utilities company.

Considering the great effort and expense involved in such a proposal as Tocks Island, we are intereted in benefits that it can provide. And, also, how these may fit into the changing needs of the region.

An expanding water supply is a growing need in the service area with its rapid increase in population and industry. Philadelphia may face a shortage of water by 1970. New Jersey, also in the service area, has growing needs for water. Tocks Island's long-term water storage will provide a net yield of 980 cubic feet per second. This will assure downstream metropolitan areas an adequate supply for fifty years. It will, also, provide for additional water needed in the Passaic Basin and the Raritan areas of New Jersey.

Reduction of flood damage is an important function of the Tocks Island Project. The reservoir will substantially reduce flood damage on the main stem of the Delaware as far south as Burlington, New Jersey. It is estimated that the flood control storage provided by this and other projects in the comprehensive plan will reduce the stage of the 1955 flood at Trenton by about 6 feet.

The conventional power plant will deliver a dependable capacity of 20,000 kilowatts of electrical power. This is a small power production. However, the pumped-storage plant will yield a dependable 342,000 kilowatts with an average annual production of 732 million kilowatt hours. Pumped-storage power is consumptive power, but it is valued as a most flexible source to meet peak demands. The New Jersey Power and Light Company has offered to develop this facility.

The greatest asset of Tocks Island development for the immediate area and probably for the whole region is its great potential for outdoor recreation. The National Park Service believes that Tocks Island Project has both regional and national significance. It has proposed to establish a National Recreation Area here. Bills are before Congress now to authorize this proposal. There are only three such areas in the United States and all are located west of the Mississippi River. Even though authorized, such a development can be accomplished only through the united efforts of the people and governments in the Basin. Thirty million people live within 100 miles of Tocks Island and, at present, non-urban recreational facilities are quite inadequate. The Park Service expects that facilities can be developed to accommodate 100,000 persons daily. Hunting and fishing would be permitted in season.

150 camp sites would be developed. Ten recreation sub-areas are planned to provide a variety of outdoor activities. For example, the Delaware Water Gap Scenic Area would be set aside for scenic enjoyment and the use of foot and briddle paths. At Bushkill, an area would be developed for all water-based sports, picknicking, and camping facilities. Near Milford, another area would provide 7 miles of water frontage for beaches, boat launching, and marine facilities.

Advantages of the Tocks Island Project are many. However, serious problems will arise during the years of land acquisition and construction.

The relocation of inundated villages has been a subject of discussion among residents along the Delaware. The villages of Bushkill and Flatbrookville will be under water, as well as part of Dingman's Ferry. Hundreds of homes and many hotels, motels, churches, and business buildings will be destroyed. Financial reimbursements can be made, but provision for relocation present many problems yet to be solved. Taxable lands will be lost to communities, but in time increased property values should off set immediate losses. But will lieu payments be made for tax ratables taken for the project? And if so, for how long? Many problems will arise that will call for inter-agency cooperation.

Some form of an organization will be needed to facilitate an exchange of information between the various agencies of the Federal Government, the Delaware River Commission, and the state and local governments. A Regional Council with representatives of all units of government could be formed, so that the people of the region could play an important role in shaping the future of the development.

The Tocks Island Project has been authorized by Congress and the President of the United States. A bill is now in Congress to provide funds for preconstruction planning. If passed this year, construction could begin by 1966 and the project could be in operation by 1973.

The Water Resources Association of the Delaware Basin is encouraging regional planing by the five counties of the area. The purpose is to permit the communities to guide the type of developments desired. The Association is, also, stressing the need of research by individuals and organizations interested in conservation, and various kinds of resource use. Geographers and students of Science have a unique opportunity to contribute to regional planning of the largest public recreational project in the Eastern States.

RECENT POPULATION CHANGES IN THE ANTHRACITE BELT

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ABSTRACT

Between 1950 and 1960, the population of the five counties of the Anthracite Belt declined by 113,330 persons. Within the region, however, over one-third of the minor civil divisions gained population. This paper examines the nature and distribution of these population changes with particular emphasis on the role of migration.

INTRODUCTION

The relationship between declining employment in anthracite mining and continuing loss in the population of the anthracite counties of Pennsylvania is well-known and needs but brief recapitulation here. After a period of sustained growth through the latter part of the 19th century, employment in the anthracite industry broke downward after World War I, with the tempo of decline sharply accelerating after the late 1920's. Except for a temporary reversal during World War II, the rapid decline in anthracite employment has continued to the present. By the late 1950's, the average annual employment in anthracite had declined to fewer than 24,000 persons—less than one-fifth of the numbers employed in 1930.

The population response to declining employment in mining was neither immediate nor direct. While every county during the 1900-1960 period registered its most rapid population gain in the 1900-1910 decade, the population continued to grow, despite employment losses, until 1930, at which date each county reached its maximum population. Thereafter, every county has exhibited a continuing population loss. These losses, slight during the 1930 decade, sharpened appreciably in the next decade, and continued unabated during the 1950's. In both the 1940 and the 1950 decade, the population of the anthracite area declined by a little more than 10 per cent. By 1960, the population of the five counties combined was only three-fourths that of their 1930 population.

REGIONAL DIFFERENCES IN RECENT POPULATION CHANGE

There has been, however, a marked variation in the timing and magnitude of population change among the counties and minor civil divisions of the Anthracite Belt. Generally, large population losses were first felt in the northern areas, notably in Lackawanna County, reflecting the earlier drop in anthracite production and employment in this region. In the most recent decade, 1950-1960, the greatest population losses shifted to the western portion of the anthracite producing area. Schuylkill County, for example, lost a greater proportion of its population during the 1950 decade (14 per cent) than did any other anthracite county. This loss of population accompanied a very sharp reduction in anthracite employment. During the 1945-1954 period, anthracite mining employed, on the average, more than 18,000 persons in Schuylkill county. During the last five years of the 1950 decade, however, average employment had declined to 5,000 persons, a reduction of over 70 per cent.

Among the counties of the anthracite area during the 1950's, there was a direct association between the proportion of employed persons engaged in mining and the degree of population loss. Carbon and Lackawanna counties, having rather low proportions of employed persons in mining, experienced population losses of less than 10 per cent between 1950 and 1960. Schuylkill county, having the largest relative employment in mining, lost 14 per cent of its 1950 population during the same period.

The minor civil divisions in which dependence on anthracite mining would seem to be great likewise show sizeable population declines between 1950 and 1960. Lacking employment data by minor civil divisions which would permit the testing of the generalization, a map was constructed which superimposed the 1950-1960 population changes by minor civil divisions on a map of the areas underlain by coal. In the latter areas almost not minor civil divisions increased in population between 1950 and 1960. In the area of the Northern Field, all or the greater part of 51 minor civil divisions are underlain by coal. Of these 51 townships and boroughs, all but three lost population between 1950 and 1960. Elsewhere in the anthracite producing areas, only 2 of the 60 minor civil divisions included gained population in this period. The minor civil divisions located outside the anthracite producing area, on the contrary, more often gained than lost population during the 1950's. Of the 128 townships and boroughs so located, 85 gained and 43 lost population. Moreover, most of the latter divisions losing population were marginal to or partly included within the areas underlain by coal.

Nearly all of the townships and boroughs having comparatively large populations lie within the anthracite area and owe their large size and recent decline to the changing fortunes of the anthracite industry. The loss in anthracite employment, concentrated in the larger cities of the region, has brought about an anomalous growth pattern of divisions ranked by population size. Contrary to general experience, there is an inverse relationship between the population size of the minor civil divisions and the population change between 1950 and 1960. Divisions with fewer than 500 persons gained, on the average, by 15 per cent during the 1950-1960 interval, while the largest divisions, those having populations of more than 10,000, declined by about 15 per cent. Intermediate-sized communities generally declined by somewhat smaller percentages. Regrouping the data by rural and urban components indicates that the rural population of the anthracite area gained slightly in numbers between 1950 and 1960, whereas the urban population ranged from 11 per cent in Lackawanna county to nearly 22 per cent in Northumberland county. Only seven of the 64 urban places of the anthracite region gained in population during the 1950 decade.

NET MIGRATION IN THE ANTHRACITE AREA, 1950-1960

The loss of population in the anthracite counties since 1930 implies a rather large and continuing out-migration. Unfortunately, there are no data which permit the direct determination of the magnitude nor the changing tempo and sources of that out-migration. It is possible, however, to obtain some indication of the magnitude of the net migration indirectly. One such indirect approach is the vital statistics method of estimating net migration. As here employed, the number of deaths occurring to residents of the anthracite counties between 1950 and 1960 are subtracted from the number of births, and the resulting natural increase is added to the 1950 population. Had there been no migration in the interval, the 1950 population together with the natural increase between 1950 and 1960 would yield the 1960 population. The difference between this *"expected"* population and that actually enumerated

TABLE 1

Components of Population Change
by County, 1950 - 1960

County	Population 1950	Natural Increase 1950-1960	Expected Population 1960	Actual Pop. 1960	Net Migration 1950-1960	Migra. as % of 1950 Pop.
Carbon	57,558	4,213	61,771	52,889	- 8,882	15.4
Lackawanna	257,396	15,894	273,290	234,531	- 38,759	15.1
Luzerne	392,241	23,942	416,183	346,972	- 69,211	17.6
Northumberland	117,115	8,521	125,636	104,138	- 21,498	18.4
Schuylkill	200,577	11,048	211,625	173,027	- 38,598	19.2
TOTAL	1,024,887	63,618	1,088,505	911,557	-176,948	17.3

in 1960, therefore, gives an indication of the net migration. This method of migration estimation suggests that the anthracite counties lost approximately 177,000 persons by net migration during the 1950 decade, a number equivalent to 17 per cent of the 1950 population. Net migration totals by county are shown in Table 1.

Unfortunately, the same type of analysis cannot be carried out for all of the minor civil divisions of the anthracite area; vital events by place of residence are recorded for only the communities having populations in excess of 10,000. The indicated net migration betwen 1950 and 1960 for these communities is shown in Table 2.

In an attempt to determine the migration patterns for the divisions having fewer than 10,000 persons, the natural increase for the large communities was subtracted from the county total, and the remainder distributed among the other minor civil divisions proportionately to their population. The resulting differences between the *"expected"* and the enumerated population in 1960 indicate that while 90 of the total 239 divisions of the anthracite area gained population between 1950 and 1960, only 44 experienced a positive net migration. All but

TABLE 2

Net Migration in the Larger Communities of the Anthracite Area
1950 - 1960

City	Net migration 1950-1960	as a % of 1950 pop.	City	Net migration 1950-1960	as a % of 1950 pop.
Kingston	- 2,129	10.1	Carbondale	- 3,446	21.1
Dunmore	- 2,731	13.4	Wilkes-Barre	-17,325	22.6
Pottsville	- 3,504	14.8	Mahoney City	- 2,503	22.9
Old Forge	- 1,515	15.5	Plymouth	- 3,145	24.2
Hazleton	- 5,760	16.2	Nanticoke	- 5,228	25.9
Tamaqua	- 1,886	16.4	Pittston	- 4,021	26.6
Scranton	-21,896	17.4	Mt. Carmel	- 3,984	28.0
Sunbury	- 2,726	17.5	Shenandoah	- 4,705	30.0
Dickson City	- 1,769	19.8	Shamokin	- 5,782	34.3

13 of these divisions of gain were located in Lackawanna and Luzerne counties in a nearly continuous belt on either side of the anthracite valley. The area of greatest relative gain was the townships south of Wilkes-Barre. The four townships included had an indicated positive net migration between 1950-1960 equivalent to 50 per cent of their 1950 population. Other areas of sizeable positive net migration were located north and south of Scranton. The location of these areas of migration gain strongly suggests suburbanization.

In the western portion of the anthracite area, the minor civil divisions which had an indicated positive net migration were few and largely restricted to northern Northumberland county.

EFFECT OF MIGRATION ON AGE STRUCTURE

Out-migration streams in the United States generally are composed of young adults, with greater numbers of males than females involved in the movement. Out-migration from the anthracite area would seem to be no exception to this generalization. It is difficult, however, to determine directly the age structure of the out-migrants. Were data available on the number of deaths by age for the residents of the various divisions of the anthracite area, it would be possible, using the method employed previously to estimate net migration, to determine the indicated movement of persons by age. Lacking these data, the various age groups were reduced according to the mortality expectations of the 1950 Pennsylvania life table. The *"expected"* size of the various age cohorts was then compared to the enumerated cohorts, and the difference assumed to be net migration. Admitting the probability of a wide-margin of error, there is, nevertheless, an impressive indication of large-scale out-migration concentrated in the cohort aged 20-29 years in 1960. This cohort was reduced by more than one-third greater than what was expected from mortality alone.

A similar conclusion is suggested by the comparison of the differences between the anthracite counties and the state in the degree to which various age cohorts were reduced during the 1950 decade. The great difference between the state and the anthracite counties in the decline of the 1950 cohort aged 10-19 years, as shown in TABLE 3, could only have been produced by a large-scale out-migration of young people from the latter region.

The concentration of young adults in the out-migration stream has had a number of important consequences. The median age of the population, for exam-

TABLE 3

Reduction in size of selected age cohorts, 1950 - 1960

County	Decline in cohort aged 10-19 (1950) between 1950-1960	Decline in cohort aged 45-54 (1950) between 1950-1960
Carbon	41.6%	15.6%
Lackawanna	36.9	18.8
Luzerne	41.4	14.8
Northumberland	42.1	19.8
Schuylkill	46.7	19.6
State	14.8	14.2

ple, has increased as young people continue to move from the area. In 1960, the median age of the population of Pennsylvania was 32 years. Among the anthracite counties, the median age ranged from 34.5 years in Northumberland county to 36.2 years in Schuylkill county, the latter having the second-highest median age of any county in Pennsylvania. The large cities of the anthracite areas likewise had median ages well above the average for communities of comparable size in the state. In a ranking of Pennsylvania cities of more than 10,000 population by median age, the six highest-ranked cities were located in the anthracite counties. Further, since these out-migrants are chiefly in the ages when families are commonly formed, their removal, and the consequent relative growth of the older population, has resulted in unusually low crude birth rates and relatively few children in the anthracite counties as compared to the other counties of the state. The effect on the age of the labor force needs no elaboration.

SUMMARY

In summary, the counties of the anthracite area have all consistently lost population since 1930. This loss has been concentrated in the regions most dependent on anthracite employment. The area of greatest loss, which in 1940 was the northeastern part of the region, shifted to the west during the 1950 decade. Despite the loss of nearly 177,000 people by net migration during the 1950-1960 period, there were a fairly large number of minor civil divisions peripheral to the Northern Anthracite Field which registered sizeable net migration gains. These gains, together with other evidence, lend some support to the arguments of those who suggest that the balance between economic opportunity and population in the Northern Field is about to be reached, and that the long-continued population decline may be shortly halted.

CENTRAL PLACE RELATIONSHIPS OF THE TOWNS IN THE SOUTHERN AND MIDDLE ANTHRACITE REGION OF PENNSYLVANIA

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ABSTRACT

This paper presents results from an investigation of the trade characteristics of towns in the Southern and Middle Anthracite Region of Pennsylvania. . These findings were part of a study which had as its objective to account for the size, number, location and spacing of towns in the region. Among others, a major hypothesis investigated was that one of the primary factors influencing the distribution of mining towns was the role of these towns as a market center for a tributary area. The trading or central place characteristics of the mining towns are reported in this paper and attention is directed to their comparability with characteristics described by theory.

THEORETICAL BACKGROUND

Geographers have long been concerned with an explanation for the distribution of towns. Their most recent efforts have noted that one of the major factors influencing the pattern of towns in a region is the role of these towns as a market center for the surrounding countryside. Interplay between demand for goods and services by consumers in the region and supplying of these goods and services by towns is felt to be a primary force in determining the distribution of the towns. The set of relationships between the size, number, location, and spacing of towns, the number and kinds of goods supplied from these towns or central places, and the size of the tributary or market areas of the towns have been summarized in a body of theory called central place theory. First postulated by Walter Christaller in 1933 (Christaller, 1933), the theory noted that some goods and services like grocery stores and churches have a large and frequent demand and are found in most towns in a region. Other kinds of goods and services like shoes and banks have a smaller and less frequent demand and are found in fewer towns. The theory also noted that there would be many small towns which supply only the more ubiquitous goods and services, and fewer, larger towns which supply the scarce goods and services in addition to the ubiquitous goods. Further, the theory postulated that the places and goods could be ordered and grouped such that places of each higher rank or class would supply all the goods that lower rank places provided plus a group of activities which were not performed by the lower order places. Ideally, these relationships can be illustrated by the incidence matrix shown in TABLE 1. The central places are ranked by size group from A to N in descending order, and the goods are ranked by a measure of their demand from **1** to **n**, in descending order. The A centers supply all goods and services; the B centers supply all goods and services except the highest order good, say good **1**; the C centers supply all goods except good 1 and good 2; etc. This reasoning can be extended to show the expected relationships between the sizes of the central places, the numbers of goods and services supplied by the places, the numbers of central places by size classes, the spacing of central places, the location of central places, and the sizes of the tributary areas of the central places.

EMPIRICAL INVESTIGATIONS

These theoretical relationships have been investigated in a number of diverse regions—the state of Iowa, southwestern Iowa, northeastern and southwestern

TABLE 1

The Supply of n Classes of Goods from N Classes of Central Places, Theoretical

Central Places	Goods 1	2	3	4	...	n
A	X	X	X	X	...	X
B		X	X	X	...	X
C			X	X	...	X
D				X	...	X
⋮					...	⋮
N						X

South Dakota, southwestern Wisconsin, Snohomish County Washington, southern Germany, southern England, northern India and Korea (Berry and Pred, 1961; Berry and Mayer, 1962). Table 2 shows results from three of these studies (Berry and Mayer, 1962). As suggested by theory, the high correlation coefficients in Table 2 denote a strong relationship between the variables of size of place (P), number (F) and diversity of central place activities (CF), and number of business districts (BD). Comparable results were found in all of the regions noted.

MINING TOWNS AS CENTRAL PLACES

One implicit assumption in the theoretical model is that population and resources be evenly distributed over a large region. Since all previous studies were conducted in predominantly agricultural regions where resources were areally distributed, a question was raised as to the nature of the central place relationships in a mining region where the utilization of resources is punctiform. It can be observed that settlement in the Southern and Middle Anthracite Region is clustered around mining facilities with few dispersed or isolated houses.

TABLE 2

Correlation Coefficients of Selected Central Place Relationships, Three Selected Areas

Southwestern Iowa

		P	LP	F	LF	CF	BD
P	Polulation of Center	X	—	0.979	—	0.890	0.872
LP	Log. of Population		X	—	0.958	0.953	—
F	No. of Functional Units			X	—	0.929	0.881
LF	Log. of Functional Units				X	0.976	—
CF	No. of Central Functions					X	—
BD	No. of Business Districts						X

Northeastern South Dakota

	P	LP	F	LF	CF	BD
P	X	—	0.986	—	0.790	0.968
LP		X	—	0.978	0.931	—
F			X	—	0.978	0.931
LF				X	0.864	—
CF					X	0.870
BD						X

Southwestern South Dakota

	P	LP	F	LF	CF	BD
P	X	—	0.981	—	0.746	0.813
LP		X	—	0.923	0.908	—
F			X	—	0.858	0.886
LF				X	0.975	—
CF					X	0.935
BD						X

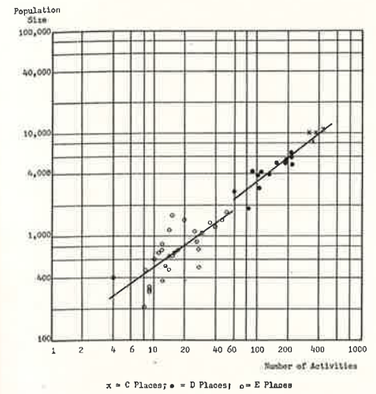


Figure 1. Relation between population-size and number of activities.

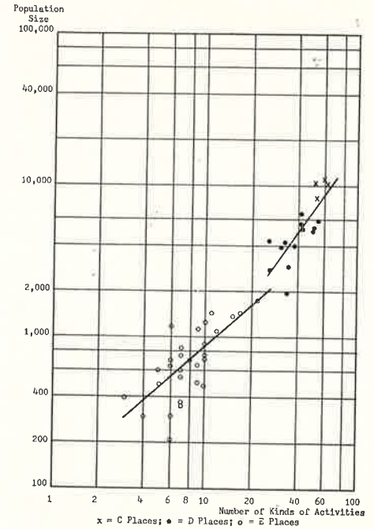


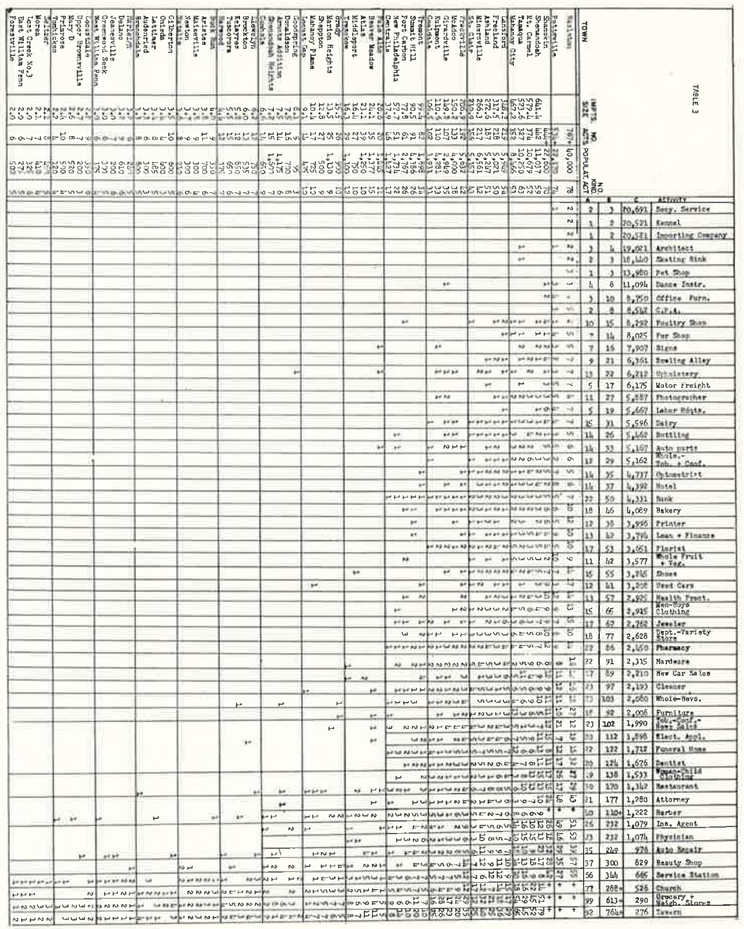
Figure 2. Relation between population-size and number of kinds of activities.

An investigation was made of the central place attributes of this mining region. The thesis offered is that although the location and existence of the towns were primarily influenced by the locations of mines and collieries, and by historical developments in the anthracite industry, these towns nevertheless served as central places providing goods and services to surrounding tributary areas. Because of certain factors, a few towns grew in size and today provide a great number and wide variety of goods and services to a large, widespread hinterland. Most towns, however, remained as small central places providing limited services to a small market area. It is hypothesized that differences in demand for certain goods and the necessity of supplying this wide range of goods gave rise to a system of central places described by theory.

The results of this investigation showed that the mining towns in the Southern and Middle Anthracite Region generally conformed with the relationships predicted by theory and found in other parts of the world. High correlation coefficients were found between population-size and number of activities, and population size and number of kinds of activities, 0.96 and 0.94 respectively. Figures 1 and 2 illustrate the nature of these relationships. These figures also show these same relationships for third, fourth and fifth-order groups. Similar central place characteristics for groups of towns can be seen in these figures, especially for the higher order places.

Finally, these results are summarized in TABLE 3 which shows the places ranked by size, and the goods and services ordered by a measure of their demand. In general, this table conforms with the theoretical incidence matrix of TABLE 1. More specifically, TABLE 3 shows the numbers and kinds of central place activities in the towns. Taverns, grocery stores and churches are the most numerous and ubiquitous activities, and secretarial services, kennels and importing companies are the scarce functions found only in the highest order places.

TABLE 3



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THE RISE AND DECLINE OF THE CONNELLSVILLE BEEHIVE COKE REGION

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ABSTRACT

The Connellsville Beehive Coke Region is an elongated 137 square mile tract almost completely underlain originally by a portion of the Pittsburgh coal seam which here was unsurpassed for beehive coking. The coal outcrop formed the boundaries of this Region which extends as two synclines, arranged *en echelon,* through Westmoreland and Fayette Counties, Pennsylvania, and within 50 miles of Pittsburgh.

Downfolding of the coal within the syncline saved it from the erosion which stripped it from the peripheral outcrops to 500 feet below the surface along the synclinal axes. The earliest, simplest operations were along the outcrop; later, more sophisticated operations were along the axes.

The development of the Coke Region, based upon hitherto unused Frick Coke Company data, is divided into three periods, the Pr-Coke Era (to 1860), the Beehive Coke Era (1860-1920) and By-product Coke Era (1920-).

This paper treats of the chronological development of the old Connellsville Beehive Coke Region from its beginning about 1860 to its end about 1960. Most of the information is from hitherto unused H. C. Frick Coke Company data although such other sources as state and federal reports, county histories, and periodicals have been used. Because the Frick Coke Company finally controlled three-fourths of the beehive coke plants in the Coke Region and meticulously maintained records pertaining to them, its data actually made this study possible.

The Coke Region is an elongated 137 square mile tract almost completely underlain originally by a portion of the Pittsburgh coal seam which here was unsurpassed for beehive coking. The coal outcrop formed the boundaries of this Region which extends as two synclines, the Latrobe and Uniontown, arranged *en echelon,* through Westmoreland and Fayette Counties, Pennsylvania, and within 50 miles of Pittsburgh. (The Coke Region proper extends only as far north as Loyalhanna Creek). Pittsburgh's supremacy in iron manufacturing was founded upon and sustained by Connellsville coke.

Downfolding of the coal within the synclines saved it from the erosion which stripped it from the flanking western Fayette and eastern Chestnut Ridge anticlines and the cross-anticline. The latter, in the vicinity of Jacob's Creek, enabled erosion to separate the coal into the two distinct units. And it left the coal remaining near it almost horizontal and close to the surface. Elsewhere the coal of the synclines plunged from peripheral outcrops to depths of 500 feet below the surface along the synclinal axes. In cross-section the coal seam is somewhat U-shaped; in profile it resembles a hammock. The attitude and elevation of the coal played significant roles in the manner of the Region's development.

Three types of mine entry were used in the Coke Region; these were the *drift, slope* (including rock slope), and the *shaft*.

The drift entry was comparatively simple to open and maintain and was used where the coal was horizontal or where it dipped toward the outcrop. Coal, waste, and water were easily *"drifted"* out of the mine. These outcrop entries were the most popular type in the early days of primitive skills and little capital.

In 1875, 61 per cent of the mine entries were drift.

The slope entry was a common though less popular type of entry. It was opened where the coal dipped or *"sloped"* from the outcrop toward the synclinal axes. It was more expensive to drive and maintain and required greater power to haul materials from the mine.

The rock slope entry was a variant of the slope type and was used where the outcrop was controlled by another party. In 1875, 35 per cent of the mines employed slope and rock slope entries.

The shaft entry was the costliest to open and maintain because of the depth to which manway, haulage, and ventilation shafts had to be sunk and the greater need for power to vertically lift materials from the mine. In 1875, only 4 per cent of the entries were shaft.

Drift and slope mines were located only around the peripheries where coal was exposed at outcrop. These comparatively simple entries were generally based upon small acreages (100 or less) so that entries were commonly closely spaced.

Once the peripheral areas were taken, only that coal obtainable through shaft mining was left. Shaft mines required large acreages of inexpensive coal to operate profitably and such acreages were unavailable except in the deeper coal areas avoided by the small operators. Shaft mining had to await the day of the heavily capitalized company, about 1880.

The location of mine entry types influenced the pattern of the coal and coke settlements. The numerous drift and slope mines (and their coke works) with their accompanying and generally small settlements festooned the earliest used outcrops. The company towns in places appeared as a single elongated settlement. The fewer but larger settlements associated with shaft mines were sprinkled through the interior.

Had the mining techniques of the middle nineteenth century been more advanced, had development occurred later, or had Frick controlled the Coke Region from the beginning, it seems certain the number of mines and coke works and their settlements might have been fewer, greater economies in the use of the Region's natural and human resources might have resulted, and the present depressed economic condition of the Coke Region might have been lessened.

Coal had been mined, at least for local markets, for many years before the manufacture of commercial beehive coke. Washington wrote in his journal of seeing a coal-bank at Gist's Plantation, along the eastern outcrop of the Uniontown syncline.

The use of coke as a furnace fuel in the Region began in the 1830's and was established at all Regional furnaces before 1860. However, Connellsville coke was not much used outside the Region until 1860 when it was successfully used at Pittsburgh's Clinton Furnace.

Despite its early discovery, coal from the Coke Region was economically unimportant outside it until 1860. Pittsburgh coal was available at or near Pittsburgh. The Connellsville portion of the Pittsburgh seam was too friable to be delivered in useful condition after a trip over the railroad bed of a century ago. And, importantly, there was no market for the by-products produced in coking, by-products which constituted about 35 per cent of the coal by weight.

Coke was important within the Region prior to 1860. Between Connellsville and Uniontown relatively high grade iron ores, limestone, and hardwoods were used from the late 1700's to make iron that sold cheaper than that brought from eastern furnaces. Coke was used when charcoal became uneconomical and it helped this iron-making section maintain its lead as western Pennsylvania's foremost iron producer until the period of the Civil War.

By 1861, a railroad line had been constructed from Pittsburgh to Connellsville and Uniontown. On or near this railroad 14 coke works were operating by 1869, all in Fayette County. Coke produced downstream from Connellsville was exported by railroad because the Youghiogheny River was unreliable and there were no furnaces in this area. But the railroad did not serve those coke works located betwen Connellsville and Uniontown as these works served the local furnaces. In this latter section, therefore, railroads and coke works used the same valleys but operated independently of each other.

The greatest absolute expansion in numbers of coke works occurred in the decade 1870-1879. During this time iron furnaces in Pittsburgh expanded in number and size. Coke Region furnaces, using ores now inferior to those of the Great Lakes and operating antiquated equipment, became less significant. Much of the coke manufactured in the Region was for Pittsburgh furnaces which had whole or partial interest in some of the new works. The former independence of railroads and coke works became interdependence.

Coke works appeared for the first time in the shallow drift and shaft coal sectors of the southern Latrobe syncline. In this decade a branch of the Pennsylvania Railroad was built through the southwestern part of the Latrobe syncline from the main line at Greensburg. A spur of this branch served the southcentral portion. The southeastern section was served by a branch of the Baltimore and Ohio Railroad that connected Broadford, on the main line, to Mount Pleasant.

Most of the drift coal areas were under development by 1879. And the Baltimore and Ohio and the Pennsylvania Railroads were joined in battle over control of the lucrative coke-hauling trade.

In the 1880-1889 decade, 32 new coke works were opened. Although the number was less than that of the previous decade, the size of the individual works increased. Most of these plants were located north and south of the earlier established drift mines and were by necessity situated in the shaft sector. In the northcentral Uniontown syncline an 8,500 acre tract, the largest contiguous tract ever in the Region, was the site of the Leisenrings, three of the largest and longest operated works in the Region.

A new railroad, the forerunner of the present Pittsburgh and Lake Erie line, enabled coke works to operate profitably on the southern bank of the Youghioheny across the river from, and within sight of, beehive ovens built 40 years earlier.

In this decade some of the older, smaller drift mines were consolidated into fewer but more economical mines by Henry Clay Frick who entered the coke business in 1871.

The number of new coke works built in the 1890-1899 decade dropped to 24. Some of these were built in already established areas to increase a given tract's coke production. Two new areas for coke works in the Uniontown syncline were in the Uniontown shaft area, and near or at the western outcrop where coal peripheral to the Leisenring tract was taken up. Railroad branches made these developments feasible.

The western outcrop coke works were the first ever to appear on the west side of the Uniontown syncline in a half-century of coke making. The reasons for such late development appear to have been several. Among them were a belief by early operators that this coal was somewhat inferior to that of the eastern outcrop (a belief substantiated by some experienced operators of the present), the

lack of a local market (the iron furnaces were on the eastern outcrop), and no railroads until 1890 (the eastern outcrop had two lines by 1861).

Few works and settlements were ever located along the western outcrop of the Uniontown Syncline. By the time such works were economically possible, the coal was already under development by the shaft mines to the east.

The northern part of the Latrobe syncline began coke production with the extension of branches from the main lines of the Pennsylvania Railroad. These were principally slope and shaft operations.

The last period of development was from 1900-1908 during which time 23 new plants were built. In the Latrobe syncline scattered small works were established along the northwestern outcrop in the peripheral drift coal section. The development in the central shaft sector resulted from an additional works at the Hecla complex and the first use of the undeveloped Thaw tract.

The greatest concentration of new plants in this decade was in the previously untouched southern Uniontown syncline. Although this area of drift coal was located but a short distance from works that had been operating for 50 years, it defied development until 1900. Its lack of development apparently stemmed from two factors; greater distance from the Pittsburgh market, and a belief that arose about 1880 that only deep coal made good metallurgical coke. Assuming that unpopularity depreciated its market value, this coal presumably sold cheaper than that elsewhere in the Region. By 1900, when Connellsville coal was approaching exhaustion, the numerous small tracts of this area had been consolidated by a few astute individuals into a few large tracts suitable for large scale development. Most of the works built by the Frick Coke Company were erected here at this time.

The most productive period in the Coke Region's history was the 1910-1919 decade during which time the largest number of coke works and ovens were in operation, the largest tonnages of coal and coke were produced, and the greatest number of people lived in the hundred-plus coal and coke communities throughout the Region. In this period of peak activity technological changes occasioned by World War I were shaping the future of the coke industry—a future that was to exclude the Connellsville Coke Region.

By 1918, the biggest by-product coke plant in the world was operating at Clairton on the Monongahela River upstream from Pittsburgh and less than 20 airline miles from the Connellsville Coke Region.

Coke Region operators recognized the by-product oven's potential but were economicaly unable to change their now obsolescent equipment. Three years after the first by-product ovens were built in the United States, 50 Semet-Solvay ovens were erected at the Dunbar Iron Furnace, near Connellsville. This was the only place in the entire Region where such an operation was practical, because the economics of by-product operation demand that such ovens be located at the furnace and the by-product market, not at the mine. Dunbar was the largest furnace in the Coke Region and an adjacent glass factory used the gas.

In 1898, a by-product oven cost 5 to 7 times as much to build as a beehive oven and required a huge coal reserve. By 1900, only one-third to one-half of the original Coke Region reserves remained. These reserves were insufficient to justify scrapping beehive ovens and building by-product ovens in their stead. Such reserves were an insufficient base for a plant as large as Clairton. Located along the river it was able to draw its coal supplies cheaply from numerous parts of the Monongahela Basin.

In the 1910-1919 decade the only operator controlling sufficient coal to justify the erection of a by-product plant in the Coke Region was the Frick Coke Company, but Frick was a component of U. S. Steel, operator of Clairton. In the peacetime years of the 1920's, Clairton was able to meet metallurgical coke needs. Because a ton of coal now yielded as many dollars from the sale of its by-products as from that of its coke, beehive ovens owned by steel companies became too expensive to operate and they were permanently or temporarily closed.

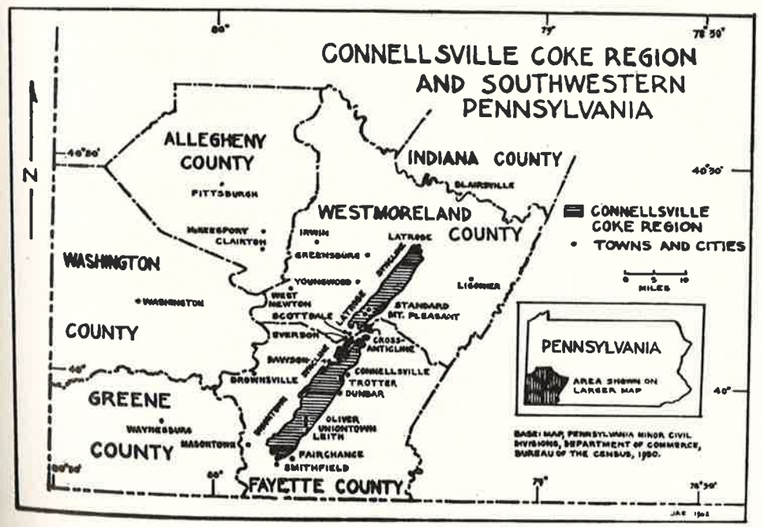
Closures, of course, had occurred throughout the history of the Coke Region. In the years 1880-1889, 11 plants are known to have closed through exhaustion or consolidation. All were in the earliest developed portion of the Coke Region.

Thirty-nine works closed in the 1900-1919 period, chiefly in the latter years. With some exceptions, these were located in the oldest developed areas and resulted from exhaustion brought about by the industrially active years of World War I. Closures occurring beyond the original developed areas were at drift mines that had exhausted small peripheral coal pockets.

The greatest period of closures came in the 1920-1929 decade when 39 works shut down. The large number and their amorphous pattern indicate that closure was externally caused, not internally caused as heretofore. The external cause was the Clairton by-product plant.

Some of the Frick beehive plants had been leased to small operators as a small demand for foundry and domestic coke, ignored by the by-product plants, existed. During the years of World War II and Korea, those plants still operable were reclaimed by U. S. Steel. But it was only during such times that the Region resembled the Coke Region of old.

In the 1930's the economic depression brought the closing of more works. Futhermore, unrestricted flooding brought an end to deep mining in the Coke Region part of the Latrobe syncline. A combination of careless tech-



niques apparently allowed the breaching of safety walls and flood waters inundated deep mines from Latrobe to Mount Pleasant. Only drift and slope operations remained in the small acreages of peripheral coal.

In the 1940's and 1950's most of the remaining plants closed in the Uniontown syncline. These mines, spared the flooding, were worked to exhaustion. In 1960, the last two significant shaft mines of the Uniontown syncline, Collier and Leisenring, were worked out and the Coke Region's activity was essentially over.

Some small drift, slope, and strip mines still operate and some beehive ovens still make coke, but the production is meager and well below that of any period since sometime before 1875.

In the past 100 years beehive coke producing in the Connellsville Beehive Coke Region has swung full circle. Begun as a business comprised of small units owned and operated by individuals or partners, it has ended in similar fashion. Perhaps the major difference between these developmental stages is that a century ago the industry had a future; today it has only a past.

HISTORICAL GEOGRAPHY OF MAJOR PENNSYLVANIA ANTHRACITE MINE ACCIDENTS CAUSED BY GAS EXPLOSIONS*

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ABSTRACT

The virtual cessation of accidental deaths in Pennsylvania's declining anthracite industry makes the present an appropriate time to analyze the historical geography of such deaths in this hazardous industry. In this study, geographical differences in the number of accidental deaths caused by major gas explosions that have occurred within various parts of the anthracite fields are demonstrated, and a variety of possible causes for such geographical differences are proposed and investigated.

The annual number of accidental deaths in Pennsylvania's anthracite mining industry has diminished in recent years to a very small figure (Fig. 1). In 1870, almost a century ago, more than 200 anthracite miners lost their lives through mine-connected accidents, and by 1907 this figure had risen to some 700. A gradual decline in the annual number of such deaths was experienced between 1907 and 1930, and drastic reduction occurred during the three decades, 1930 to 1960. In that latter year, fewer than 50 miners died from work-associated accidents.

In part, the above trend in annual number of accidental deaths reflects the manyfold increase in annual anthracite employment between 1870 (fewer than 40,000 employees) and 1914 (more than 180,000 employees), and the subsequent major decline in employment during later decades (20,000 employees in 1960). But also of considerable significance in accounting for the reduction in annual accidental deaths has been the gradual improvement in safety conditions in the mines, which resulted in a decline in number of accidental deaths per million tons of coal production per year from 15 in 1870 to less than 2.5 in 1960 (Fig. 1, inset).

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In view of the current small number of accidental deaths in Pennsylvania's anthracite industry, and of the near term prospect that the number of such deaths will continue to be limited, the present would appear to be an appropriate time to make an historical survey of the geographic aspects of the subject. Of particular significance would be an analysis of the areal distribution of past accidental deaths throughout the anthracite fields, and an evaluation of possible causes for concentrations of specific types of accidents, with a view toward reducing or preventing such accidents if in the future the anthracite industry should experience major rejuvenation. In addition, the findings of this study might be applicable to other currently more active coal fields in the United States or elsewhere in the world.

Both the severity and types of accidents causing death in anthracite mines are diverse. One accident resulted in a loss of life of over 100 persons; many others have brought death to but a single individual. Types of accidents range from those intimately related to mining, such as roof falls, gas explosions, and those associated with mine shafts, to a host of others that could occur in any occupation involving physical labor and the use of heavy mechanical equipment. Adequate treatment of such a diverse subject in its entirety obviously is beyond

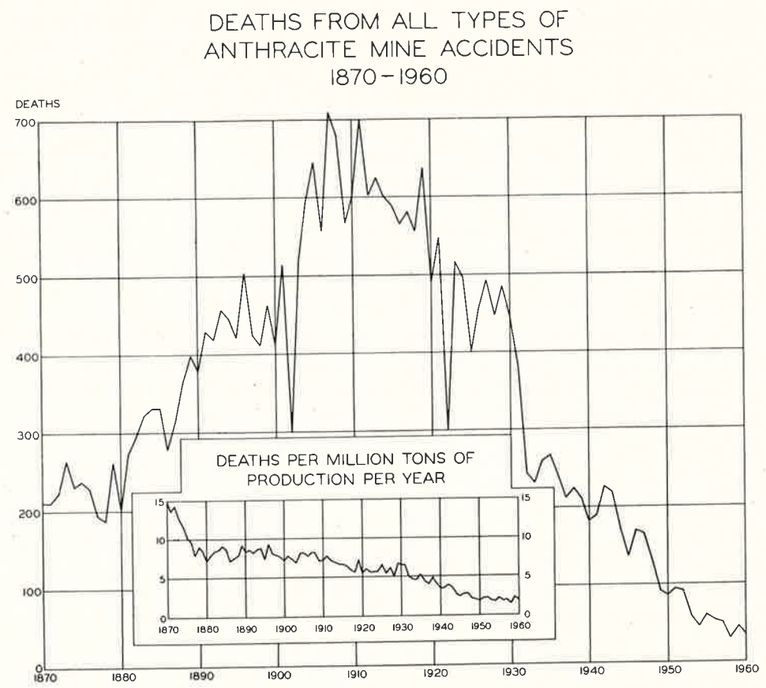

Fig. 1. Deaths From All Types of Anthracite Mine Accidents in Pennsylvania, 1870-1960. Source: Anthracite Division, Pennsylvania Department of Mines and Mineral Industries.

the capabilities of this brief study. Instead, attention is concentrated on only a single type of accident, that resulting from methane gas (marsh gas; fire damp; carburetted hydrogen; CH_4) explosion, which is both extremely important as a cause of accidental death and very intimately associated with the mining occupation. Moreover, even this limited phase of the total potential subject matter has been further restricted so as to include only those gas explosions that have resulted in the death of five or more persons. Less destructive explosions are not treated because of the lack of comprehensive or accurate data concerning some of them. The theme of this brief study, therefore, is restricted to an analysis of the historical geography of major accidents resulting from gas explosions in the anthracite fields of Pennsylvania. The time period covered extends from 1847 through 1959.

NUMBER AND RELATIVE IMPORTANCE OF MAJOR GAS EXPLOSION ACCIDENTS

During the 113-year period between 1847 and 1959 there occurred in the anthracite mines of Pennsylvania a total of 117 major accidents, each involving the death of five or more persons (1). Of these accidents, 62 were caused by explosion of gas, and the remaining 55 were the result of all other causes combined. In the 117 major accidents, a total of 1241 miners were killed. Of these, 509 died from explosion of gas, with lesser numbers being killed by mine fires (234), explosion of powder and dynamite (134), roof falls (111), objects falling down mine shafts (86), drowning (46), suffocation by gas (40), inrush of quicksand (26), and other miscellaneous causes (55). Obviously, the most frequently occurring and disastrous cause of major mine accidents over the years has been exploding gas.

The relative significance of accidents resulting from explosion of gas, however, has not remained the same during past years. In the period, 1847-1869, only two major accidents occurred, one being caused by explosion of gas. During the decennium, 1870-1879, the six major accidents caused by explosion of gas exceeded in number the four resulting from all other causes. However, during each decennium between 1880 and 1909, the situation was reversed and major accidents from other causes outnumbered those due to explosion of gas (7 others to 6 gas in 1880-1889; 15 to 11 in 1890-1899; and 14 to 8 in 1900-1909). Again conditions changed, and each decade between 1910 and 1950 was characterized by more major accidents due to explosion of gas than from all other causes combined (11 gas to 6 others in 1910-1919; 10 to 3 in 1920-1929; 5 to 2 in 1930-1939; and 4 to 0 in 1940-1949). In the decade, 1950-1959, there were two major accidents due to other causes and one resulting from explosion of gas, but these numbers are so small that ratios are of little significance.

On the basis of the above figures, and in the light of related knowledge concerning mining conditions and facilities, one may presume that, in general, mechanical equipment and mine control standards were relatively incapable of coping with accident-generating conditions unrelated to gas during the 1880 to 1909 period, and consequently major accidents due to explosion of gas were out-numbered by combined aceidents from other causes. Since 1910, better equipment and more adequate control measures have tended to lessen the accident hazards due to these other causes, and the as yet incompletely mastered problem of gas explosions has again become relatively more significant as a cause of accidental death.

GEOGRAPHIC DISTRIBUTION OF MAJOR GAS EXPLOSION ACCIDENTS

Major gas explosion accidents are a widely distributed phenomenon of Pennsylvania's 484 square miles of anthracite lands. They have occurred in all four of the fields (Fig. 2)—Northern (38 accidents), Eastern Middle (1), Western Middle (12), and Southern (11), and in or near 33 towns and cities of five counties (Fig. 3). The vicinity of Wilkes-Barre has experienced 11 such accidents. Other towns with neighboring territories that have been subject to two or more major explosion accidents include Ply-

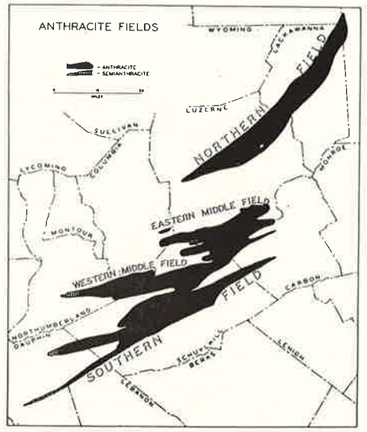

Fig. 2. Anthracite Fields of Pennsylvania. Individual coal field names, as well as county names and boundaries, are shown for identification purposes.

mouth (7), Nanticoke (6), Shamokin (4), Edwardsville (2), Lansford (2), Mount Carmel (2), Pittston (2), and Pottsville (2). Single major explosion accidents have occurred at the remaining 24 towns, including such widely separated sites as Priceburg in the northern portion of the Northern Field, and Tower City in the southwestern arm of the Southern Field (Fig. 3).

During the 33-year period, 1847-1879, five of the seven major gas explosion accidents occurred in the Southern and Western Middle Fields, and there was only one each in the Northern and Eastern Middle Fields. In the decade, 1880-

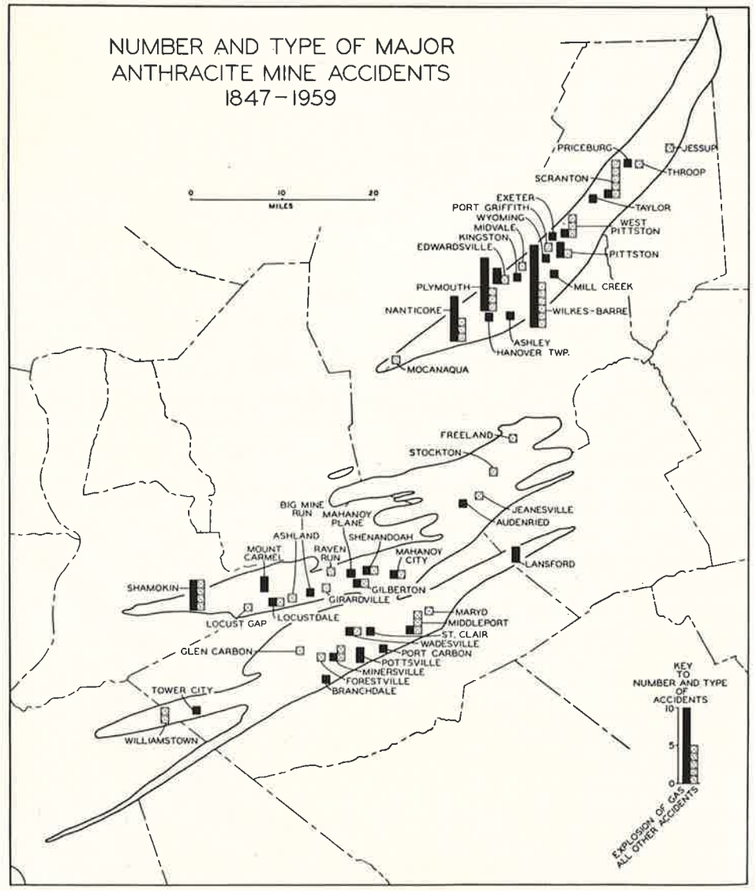

Fig. 3. Number and Type of Major Anthracite Mine Accidents in Pennsylvania, 1847-1959. Only those accidents are included in which five or more persons were killed. Town names are shown for general orientation purposes, and not necessarily to indicate the specific site of each accident. The locations of two accidents could not be determined. Source: Anthracite Division, Pennsylvania Department of Mines and Mineral Industries.

1889, there were three major gas explosions each in the Northern and Western Middle Fields, and none in the other fields. During each decennium since 1890 except one, the number of such accidents in the Northern Field exceeded the total number occurring in all other fields combined (9 Northern to 2 others in 1890-1899; 6 to 2 in 1900-1909; 7 to 4 in 1910-1919; 6 to 4 in 1920-1929; 2 to 3 in 1930-1939; 3 to 1 in 1940-1949; and 1 to 0 in 1950-1959). It is evident from these figures that, over the past century and more, the general locale for the occurrence of major gas explosion accidents has shifted among the various anthracite fields, but during the last 70 years has most commonly tended to be the Northern Field.

An inspection of the map in Figure 3 reveals, however, that not all portions of each field have been equally susceptible to major gas explosion accidents over the years. In the Northern Field, for example, 35 such explosions have occurred in the southwestern, or Luzerne County, half of the field, and only three have happened in the northeastern, or Lackawanna County, portion. Similarly, eight explosions were concentrated in the southeastern part of the middle segment of the Southern Field, between Middleport and Branchdale, and only three took place in the remaining four-fifths of the field. Likewise, even though individual major gas explosion accidents are widely disseminated throughout much of the Western Middle Field, there are significant centers of concentration apparent in the vicinity of Shamokin and Mount Carmel. Finally, the Eastern Middle Field has been almost completely free of such accidents. In other words, what the map in Figure 3 indicates is that, although major gas explosion accidents are in general a characteristic of the anthracite region as a whole, nevertheless their occurrence in significant numbers is limited to restricted segments of the region. The major portion of the anthracite region, in contrast, has for more than a century of intensive exploitation been relatively or completely free from such disasters.

Such a distributional pattern, of course, fairly begs for explanation; and it, as well as equivalent patterns in other coal fields throughout the world, has not gone unnoticed by earlier researchers. A summary of some of the previously advanced explanations for geographical variations in gas-caused accidents, as well as a graphical analysis of what the present authors believe to be the most significant causes for the anthracite accident pattern, form the themes of the following sections of the study.

POSSIBLE CAUSES FOR THE ANTHRACITE ACCIDENT PATTERN

Any analysis of possible causes for geographical variations in the distribution of major accidents resulting from the explosion of methane and air mixtures must be prefaced by a statement calling attention to the present meager knowledge concerning methane. It is not yet certain as to the precise source materials for the gas; nor how and when it was formed; nor in what quantities it may have originally existed in coal; nor how it is held by, or included within, coal; nor through what mechanisms, at what rate, and for how long it is released by coal (2). Hence, all theories concerning the possible causes for geographical variations in methane-generated accidents must be based on spatial correlations between probable or possible accident-inducing causes and the known distribution of such accidents.

The several suggested geological causes for the greater than normal presence of methane in coal in certain geographical localities, and hence the presumably above average susceptibility of such areas

to fatal gas explosions, may all be grouped into two categories, as follows: (a) variations from place to place in the the original methane content of coal and (b) variations from place to place in the degree of retention of an originally rather uniform methane content in all coal. In the first case it has been argued by some that the differing nature of the original vegetal material forming coal, and of bacteriological action on that material, would cause geographical differences in the original methane contest of coal and hence in its present-day abundance. However, many analyses of coal show no relationship between methane content and rate of release on the one hand, and nature and composition of coal on the other. Lignite, bituminous coal, and anthracite are all generally closely alike as to their methane component. Hence, it is reasoned by others that geographical differences in the present methane content of coal must be due to such factors as depth of burial of the seams, permeability of the overburden, the amount of interstitial moisture in the pore spaces of the overburden, and the presence or absence of faulting in the vicinity of the seams. Deep burial, lack of permeability in the overlying strata, and an abnormally large amount of interstitial moisture in the overburden, all favor a high degree of retention of the original methane content, it is argued, because of retardation of the upward seepage and escape of the gas. On the other hand, proximity of coal seams to the relatively permeable crushed rock zones associated with faulting would facilitate the escape of coal-associated methane into the atmosphere.

Strong arguments have been presented, and numerous specific case studies cited, in support of both of the above hypotheses. But equally valid refutations have been made by opponents, and many specific exceptions to document the refutations have been reported (2). It appears to the authors of this paper, therefore, that both hypotheses are probably to an extent, and under certain circumstances, correct; but that they are not necessarily of the same degree of significance, nor operative with equal intensity in all localities, nor do they have the same quality of essentiality.

The authors take the position, and will attempt to support it by means of graphic correlations based on multivarient mapping, that the two geological factors of primary importance in rendering a coal mining district more than normally susceptible to major gas explosion accidents are (a) thickness of overburden and (b) absence of faulting. Given such a favorable set of geological circumstances for methane retention, then local variations in the original methane content of the involved coal seams, as well as local differences in the permeability and interstitial moisture content of the overburden, become operative as secondary factors in determining the occurrence or absence of major gas explosion accidents at specific sites. It is maintained, moreover, that the reverse ordering of conditions will not precondition a district to experience an above normal number of such accidents; i.e., no matter how high the original methane content of coal, or the degree of impermeability and moisture saturation of the overlying strata, shallowness of burial and/or the presence of extensive nearby faulting will have permitted previous escape of much of the methane and so have rendered the district relatively free of gas explosion hazards.

The entire geologically-based argument, above, must be modified by a third spatially variable factor, namely, the extent to which mining has been carried on in a region over the decades. Comparatively fewer explosion accidents are likely to happen in areas that have been subject to less than average amounts of mining, and of course no mining accidents of any kind whatsoever can occur in portions of a coal field that have never been mined.

Finally, consideration must be given to the intangible human element, insofar as it may affect the distribution of major gas explosion accidents. To the extent that carelessness and poor judgment, and lack of provision for proper equipment for gas detection and mine ventilation, come into play, they will alter such correlations as would otherwise be achieved, for almost any subterranean coal mining operation becomes subject to the hazard of serious gas explosion if improperly conducted. Thus, because of the human propensity to relax precautions somewhat when danger appears to be remote, one must expect to find occasional major explosion accidents occurring in areas where conditions would indicate that the gas situation should not be serious.

GEOGRAPHIC DISTRIBUTION OF APPARENT CAUSAL FACTORS

The map and cross-sections in Figure 4 represent the geographical distribution of the two geological factors that have been suggested above as having primary causal relationship to the areal pattern of major gas explosion accidents. Shown on the map are all major faults of the anthracite area. The accompanying generalized stratigraphic cross-sections indicate, for each of the four coal fields, the average elevation of the ground surface, the average maximum depth of all coal-bearing strata, and the average maximum depth and thickness of the zone containing most major coal seams. An examination of the map and cross-sections reveals widespread differences in these presumably critical geological conditions from one part of the anthracite area to another.

The northeastern one-quarter of the Northern Field, from Forest City to Jermyn, for example, is characterized by the extremely shallow depths of its major coal seams and the absence of major faults. Farther southwestward, from Jermyn to Old Forge, the major coal seams lie at somewhat greater depths, and again there are essentially no faults of significance. For a short distance beyond, between Old Forge and Pittston, the major coal seams once more rise close to the surface; but immediately to the southwest, and continuing almost to the end of the Northern Field, the major coal bearing zone descends to its greatest depths in the entire anthracite area. This latter segment, like the more northerly portions of the field, also has almost no faulting of significance.

The Eastern Middle Field, as represented on Figure 4, is everywhere an area of relatively shallow coal seams, with faulting limited to parts of its margins. The Western Middle Coal Field, in contrast, is characterized by coal seams of intermediate depths, and the widespread occurrence of faulting. Attention should be especially directed in this field to the thicker than average overburden atop the major coal seams in the Shamokin to Mt. Carmel area; to the greater than average depth of the base of the major coal bearing zone in the Shenandoah area; to the breaks in the otherwise continuous line of faults along the northern margin of the field in the general vicinity of both Shamokin and Mt. Carmel; and to the broad fault-free medial strip extending through the western portion of the long axis of the field.

The Southern Field, as shown in Figure 4, has the greatest over-all depth of major coal seams of any of the four fields, and much of it is shattered by extensive faulting. It should be noted, however, that a large area in the south-central portion of the field is completely free from faults, and that this section is coincidentally characterized by the great-

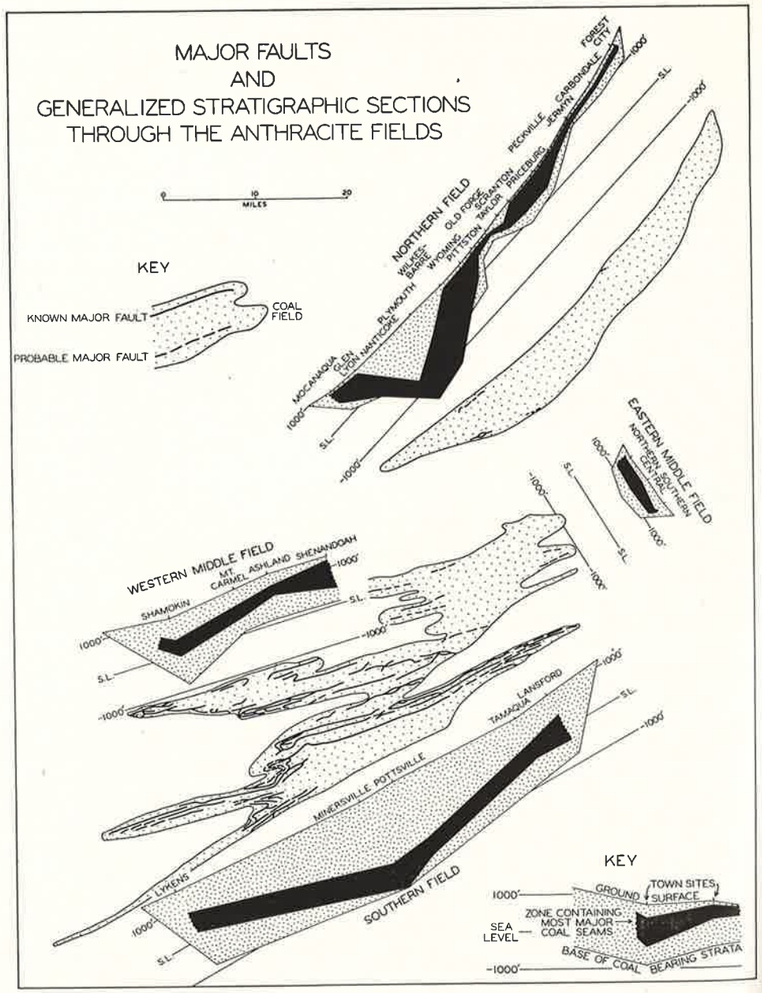

Fig. 4. Major Faults and Generalized Stratigraphic Sections Through the Anthracite Fields of Pennsylvania. The cross-sections are highly generalized and represent specific conditions only at the sites of towns named; conditions in intervening areas are interpolated. The cross-sections indicate, for each of the four coal fields, the average elevation of the ground surface, the average maximum depth of all coal-bearing strata, and the average maximum depth and thickness of the zone containing most major coal seams. The left-hand portion of the cross-section for the Southern Field represents conditions in the northern of the two western arms of that field. Sources: U. S. Bureau of Mines, Bulletin 245, 1927, Figures 3 and 4; Pennsylvania Topographic and Geologic Survey, Geologic Map of Pennsylvania, 1960.

est depth of major coal seams. Also to be observed is the relative absence of faulting along the southern margins of both the northeastern and northwestern fingers of the field, and the fault-free condition of the long narrow southwestern finger.

Referring now to Figure 5, one finds presented the geographical distribution of the third factor suggested by the authors

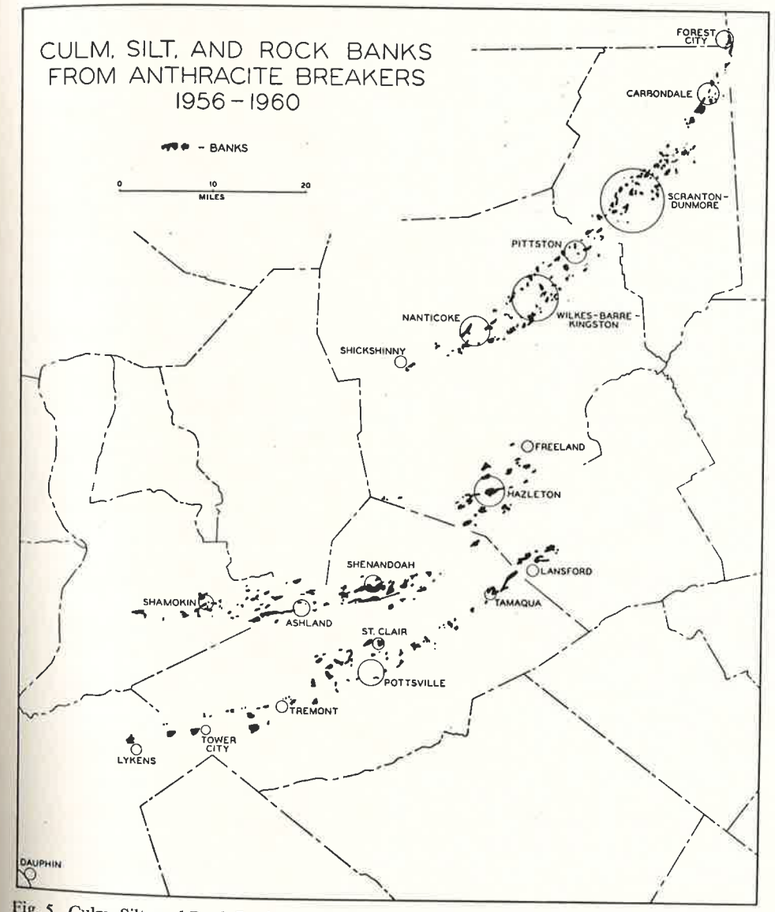

Fig. 5. Culm, Silt, and Rock Banks from Anthracite Breakers in Pennsylvania, 1956-1960. Black areas represent cumulative deposits of waste materials from anthracite preparation plants from the beginning of mining operations to the dates given. County boundaries and selected town names are shown for orientation; coal field boundaries can be determined from previous maps. Source: compiled from aerial photographs taken at various dates between 1956 and 1960, and available from the U. S. Department of Agriculture. Compilation performed by Mr. John Viletto, Jr., graduate assistant, The Pennsylvania State University.

in the previous section as having significant causal relationship to the areal pattern of gas explosion accidents—namely, the degree to which the various portions of the anthracite fields have been subject to mining over the past century or more. Represented on the map are the accumulations of waste materials (termed culm, silt, and rock banks) that have been discharged from anthracite processing plants (breakers) throughout the history of mining in the anthracite region. Such accumulations provide a relatively reliable index as to regional variations in the intensity of mining, since virtually all raw anthracite is processed before being placed on the market.

Perfect correlation between the amount of waste material existing in an area and the local intensity of mining, of course, is not to be expected. Some of the old waste accumulations have been reduced in areal extent by later reprocessing to recover fine-sized coal particles that were originally discarded. Moreover, the quantity of waste materials per ton of raw anthracite differs from place to place, and hence total accumulations of waste are not necessarily correlative with the intensity of mining. Then, too, raw coal is sometimes shipped to distant rather than local breakers, so that the distributional characteristic of the mining source is not always reflected by its waste. Finally, strip mined as well as deep mined coal is processed by the breakers, and waste from the former type of coal is not indicative of the presence of gas-generating underground mining. Despite such limitations, the map in Figure 5 provides a useable indication of those general areas in the total anthracite region that have been intensively mined underground over the years, as contrasted with others that have been utilized only moderately or remain unmined.

Most of the Northern Field, for instance, obviously has been intensively mined, for waste banks are numerous and in close proximity over most of its extent. But attention should be directed to a relative dearth of such accumulations in the section located a short distance southwest of Carbondale, and to the area between Nanticoke and Shickshinny.

In the Eastern Middle Field, it appears probable from the distribution of waste banks that mining has been largely restricted to the interior area, centering on Hazleton, and has been little practiced in the peripheral portions of the field. In the Western Middle Field, mining apparently has been extensively conducted from a site about five miles east of Shenandoah, westward to a short distance beyond Shamokin. The westernmost portion of the field, however, would seem to have been utilized to a lesser degree.

Much of the Southern Field is characterized by a fairly dense pattern of waste banks, which would suggest a generally widespread distribution of well developed mining activity. However, the complete absence of waste accumulations in the southwestern arm of the field is strikingly apparent.

SPATIAL CORRELATIONS BETWEEN APPARENT CAUSAL FACTORS AND MAJOR GAS EXPLOSION ACCIDENTS

If the three factors of primary importance in determining areas of highest and lowest frequency of major gas explosion accidents are those described above, then one would expect to find a high degree of correspondence between their areal variations and the occurrence of above and below average numbers of disastrous explosions. Comparison of the distributional patterns on Figures 3, 4, and 5 should confirm or deny the existence of significant spatial correlation.

In the Northern Field, the heavily mined but very shallow coal seams of the Forest City-Jermyn section, as might be predicted, have never experienced a major gas explosion accident in over a century of intensive utilization. The equally intensively exploited structural basin of the Jermyn to Old Forge section, with its moderately deep and unfaulted coal seams, logically has had a number of such accidents, including one each in the vicinity of Priceburg, Scranton, and Taylor. Several major gas explosion accidents—near West Pittston, Exeter, and Pittston—have occurred, anomalously, in the shallow-coal section between Old Forge and Pittston; their causes, obviously, were not related to the general geological characteristics of the region, nor to a lack of mining operations in the vicinity, but must be attributed to the intangible human factor. Finally, in the intensively mined southwestern part of the Northern Field, the extremely deep and essentially unfaulted basin complex between Pittston and Mocanaqua has been, as could be expected, the scene of the greatest concentration of methane-induced major accidents in the entire anthracite area, including 11 near Wilkes-Barre, seven near Plymouth, six in the vicinity of Nanticoke, two near Edwardsville, and one each in the neighborhood of Ashley, Hanover Township, Kingston, Mill Creek, and Wyoming. Unexplained by major geological considerations is the absence of such accidents in the southwestern portion of this deep basin, between Nanticoke and Mocanaqua. However, the lack of extensive accumulations of waste in this area suggests that there has been only a limited amount of mining here, and hence only a limited exposure of miners to the danger of methane explosion.

The shallow coal seams of the intensively mined interior portion of the Eastern Middle Field, as anticipated, have produced almost no major gas explosion accidents in the past century, the only exception being that near Audenried. The equally shallow, in places badly faulted, and almost unmined coal seams in the peripheral parts of the field, of course, have been free of all such disasters.

The greatest concentrations of methane-induced accidents in the Western Middle Field have occurred in the Shamokin and Mt. Carmel areas, where are found coal seams at greater than average depths, a local absence of faults both along the northern periphery and in the medial strip, and large-scale mining operations. Equally intensive exploitation has taken place elsewhere in much of the field, but, because of the prevalence of faults and the lesser amounts of overburden atop the major coal seams, accidents have been limited to single occurrences at scattered localities (Locustdale, Big Mine Run, Mahanoy Plane, Gilberton, Shenandoah, and Mahanoy City). It should be noted, moreover, that a number of these accidents are concentrated in and about the Shenandoah area, where the base of the major coal bearing zone has a greater than average depth and mining is extremely well developed. The absence of major gas explosion accidents in the westernmost portion of the field is probably a result of the lesser degree of exploitation in that area and the greater than average concentration of faults.

Most of the major gas-caused accidents in the Southern Field are logically concentrated in its south-central portion, where intensive mining of very deeply buried, fault-free coal seams has produced disastrous explosions at Branchville, Minersville, Pottsville (two), Wadesville, St. Clair, Port Carbon, and Middleport. Despite the great depths of major coal seams elsewhere in the Southern Field, there logically have been few major gas explosion accidents because of either the presence of extensive faulting

and/or the absence of mining. The outstanding example of the latter situation in this field, and indeed in the entire anthracite region, is the long, narrow southwestern arm which has remained essentially unexploited to this day. It is significant to note that the two isolated sites of major gas explosions in the Southern Field, one near Tower City in the northwestern arm and the other near Lansford in the northeastern arm, are both situated, as one might expect, along the southern, relatively fault-free margins of those extremities.

CONCLUSION

In resume, and in light of what is stated above, it would appear to the authors that a discerning individual cannot but arrive at the conclusion that there is a close relationship between the geographic pattern of major gas explosion accidents in the anthracite region, and the complex of distributional variations in what are believed to be the three major causative factors producing the accident pattern, namely (1) relative depth of coal seams, (2) relative prevalence of faulting, and (3) degree of intensity of mining. Minor aberrations in the accident pattern that are unexplainable in terms of these three factors must be ascribed to the elements of human carelessness and imprudence.

One obviously cannot employ the above factors to pinpoint the precise time and place of occurence of major gas explosion accidents. The triggering of such accidents, and their specific locale, undoubtedly are a result of minor differences in geological conditions, small variations from place to place in the nature of the coal seams being mined, abrupt changes in atmospheric pressure, contrasting procedures in mining, differences in mining equipment, and the ever present but unpredictable human factor. Nevertheless, proper application of the three factors analyzed in this paper apparently does permit one to determine those areas that are preconditioned to experience more than their proportionate share of disastrous explosions over a period of decades. Such certainly proves to be the case in the anthracite region of Pennsylvania.

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SOME GEOGRAPHIC ASPECTS OF A NEW TOURIST FACILITY IN THE ANTHRACITE REGION*

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ABSTRACT

Previous studies by the authors have advocated the desirability of strengthening and diversifying the ailing economy of the anthracite region of Pennsylvania by the establishment of a large scale tourist industry. The present study describes the development and current status of the new tourist facility initiated in 1962 at Ashland in Schuylkill County, and analyzes some of the significant geographic aspects of that development.

A previous study by the authors advocated the desirability of strengthening and diversifying the ailing economy of the anthracite region of Pennsylvania by the establishment of a large-scale tourist industry in the area (1). A subsequent paper suggested two specific sites in the anthracite region for possible initial development, and appraised the potentialities of these sites for the attraction and servicing of tourists (2). This present study describes the development and current status of the first of what is hoped will be a large number of tourist facilities in the anthracite area—that at the Borough of Ashland in Schuylkill County (Fig. 1), and analyzes some of the significant geographic aspects of that facility.

It has been the good fortune of the authors to have been in communication with the developers of the Ashland project (3) almost since its initial opening to the public in September, 1962, and to have been given full access to all of the records and files pertaining to that project. Hence, a relatively rare opportunity has been granted to a group of geographers to be present at the birth of a tourist facility, and to analyze at first hand some of the geographic aspects of its early infancy. Results of the analysis should have significance as a type study in the over-all framework of academic knowledge relative to the geography of tourism. It is to be hoped, additionally, that this paper will prove to be of some immediate and practical value to the developers of the Ashland facility, as well as having more widespread applicability in governmental agencies at the state and Federal levels that are charged with the promotion of tourism both within and outside of the anthracite region.

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SITE CHARACTERISTICS AND FACILITIES AT THE ASHLAND PROJECT

Ashland, a borough of slightly more than 5,000 population, is situated in the Western Middle Anthracite Field at a distance of approximately 85 miles northwest of Philadelphia. The nearest major town is Pottsville, located about 10 miles to the southeast (Fig. 1).

Like many other anthracite towns, Ashland was once the center of a prosperous mining industry, but in recent decades the local mines have closed and the town has become economically depressed. The usual reaction among residents of anthracite towns in such a situation has been to attempt resuscitation of their local economies by appealing to manufacturing concerns to establish plants in their vicinity (1). The civic leaders of Ashland, however, are utilizing a new and unique approach; they are striving to develop the abandoned remnants of

the former coal mining industry as a tourist attraction, and thereby bring their local economy into mesh with one of the fastest growing large-scale industries in Pennsylvania—tourism.

The raw materials for a tourist attraction at Ashland's disposal are impressive. Immediately south of the town is Mahanoy Mountain (Fig. 2), whose surface is cut lengthwise by two abandoned open-trench coal mines (Fig. 2, map and cross-section). These deep gashes in the mountain side, with their sheer rock walls and great piles of mine waste, are imposing reminders of the efforts exerted by man in his search for energy sources, and, if properly and imaginatively developed, could serve as major tourist attractions. Neither of the open-trench mines is visible from Ashland, for they are hidden behind the wooded slopes of the mountain, nor are they accessible by automobile road. Fortunately, however, an abandoned roadbed of a former narrow-gauge mining railroad extends from the southwestern edge of Ashland, along the northern slope of Mahanoy Mountain, to the eastern terminus of the farthest trench (Fig. 2, map and cross-section). This roadbed is eminently suitable for development as an access route with a minimum of grading expense, and its termination point overlooking Mahanoy Creek valley provides a high-altitude observation site from which the countryside to the north and northeast can be viewed for many miles (Fig. 2). Furthermore, if utilized for the construction of a steam-powered narrow-gauge mining railroad rather than an automobile road, the roadbed could be converted into a potent lure for railroad buffs as well as a

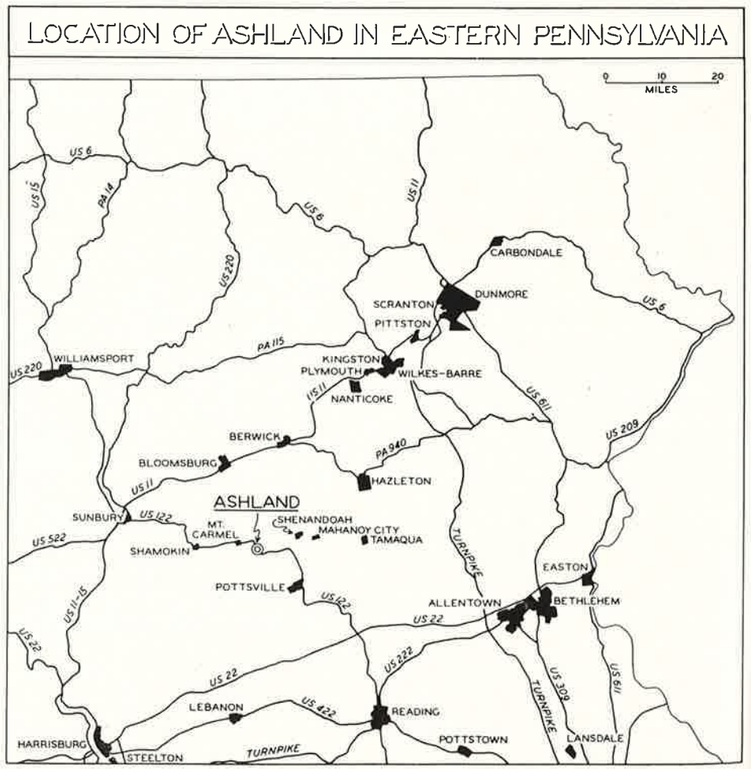

Fig. 1. Location of Ashland in Eastern Pennsylvania. Only selected major highways and towns of over 10,000 population are shown, except for Ashland.

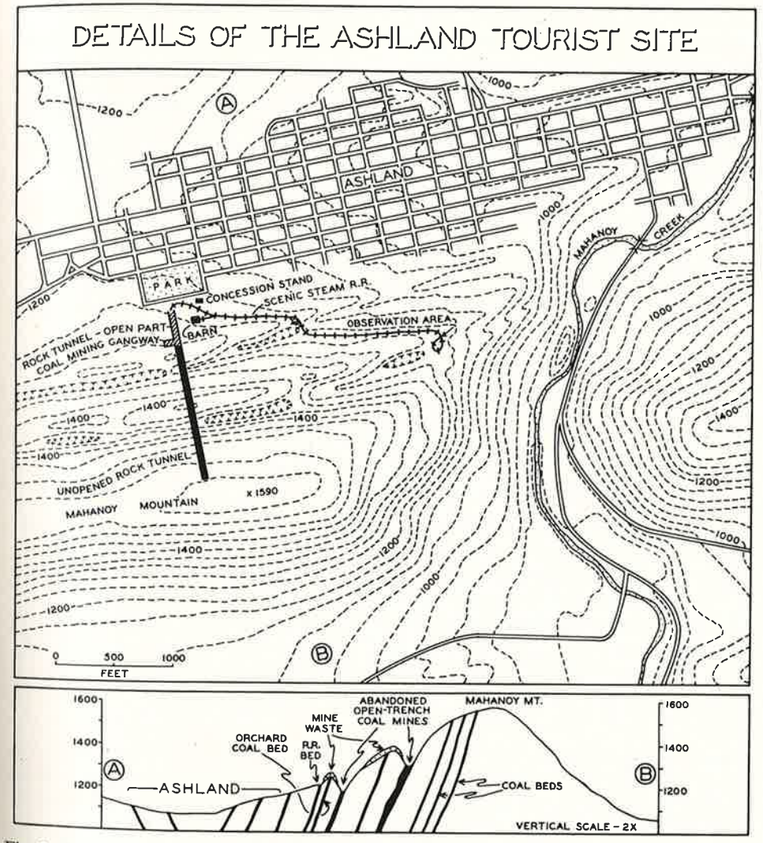

Fig. 2. Details of the Ashland Tourist Site. The letters A and B on the map represent the termini of the cross-section, which is drawn at the same horizontal scale as the map. The two abandoned open-trench coal mines on the map extend from the left-hand margin eastward, and terminate approximately at the railroad line. Their axes are indicated by a series of closed contour lines with in-facing tick-marks, which represent basins without outlets. Sources: topography and geology based on Coal Investigations Map C13, Sheets 1 and 2, U. S. Geological Survey, 1953; tourist site data from Ashland Community Enterprises.

ride that would provide revenue. The absence of appreciable gradient along the roadbed (Fig. 2) eliminates the risk of accidents to tourists should defects occur in the locomotive-braking or car-coupling mechanisms. At the western terminus of the railway roadbed is the entrance to an abandoned tunnel, closed since about 1931, which extends southward beneath Mahanoy Mountain for some 1,250 feet and pierces more than a half-dozen steeply dipping coal beds (Fig. 2, map and cross-section). The tunnel is driven through hard rock and hence is in an excellent state of preservation; it can be reopened with a minimum of reexcavation costs and maintained with a minimum of timbering. Because the tunnel is horizontal, it can be utilized on a *"walk-in"* basis for tourist purposes in contrast to vertical shafts which might be feared and avoided by many visitors. Since the tunnel penetrates a series of steeply inclined coal beds, only a few of which have been previously exploited via lateral tunnels (gangways) by the former mining company, there are available near at hand coal resources which can be utilized to demonstrate authentic underground mining techniques to interested tourists. Both the entrance to the tunnel and the beginning of the railway roadbed are located only a few tens of feet from Ashland's network of paved roads (Fig. 2), so that tourist access to them via automobile is possible without construction of supplementary roads. Moreover, an attractive park with picnic and playground equipment already exists at the tunnel entrance site; and borough water, electricity, and sewage facilities are immediately at hand. Then, too, Ashland has among the best overnight accommodations and dining facilities for tourists to be found among the smaller boroughs and towns within the anthracite fields; its hotel (Fig. 3, upper left) and several motels, while by no stretch of the imagination in the luxury class, are surpassed only by those of a few large cities in the region such as Scranton, Wilkes-Barre, and Pottsville (Fig. 1). Finally, the tourist potential of Ashland is enhanced by its location on route US 122, one of a network of main highways in southeastern Pennsylvania (Fig. 1) which feeds a large stream of tourist prospects through the borough.

Such an imposing array of physical assets as that enumerated above is probably not unique in the entire anthracite region, but the list certainly cannot be matched or exceeded at more than a very few other potential tourist sites. If one adds to this list a highly propitious human element, in the form of a far-sighted and energetic group of civic leaders who have envisioned the opportunity at hand and vigorously developed it, then one is tempted to assert that the Ashland site is presently unequaled in its tourist potential throughout the anthracite area.

The full story of the development of the Ashland tourist potential has been told elsewhere (4), and only the highlights need be briefly recapitulated here. The initial idea was conceived by a number of local citizens in late 1961, and a non-profit operating group, Ashland Community Enterprises (3), was incorporated with the approval of borough officials. Permission to construct a railroad on the old roadbed was graciously granted by the Reading Anthracite Company, owner of the surface rights at the projected tourist site; and permission to reopen the abandoned tunnel and engage in demonstration coal mining was given by the Borough of Ashland, owner of the mineral rights beneath the site. Authority for reopening the tunnel was obtained from the Pennsylvania Department of Mines and Mineral Industries provided all applicable safety rules and regulations were followed. Local capital

was raised from private sources and the borough, and a loan by the Area Redevelopment Administration in Washington, as well as a grant of State funds by the Travel and Vacation Bureau in Harrisburg, supplemented local monies. These funds, together with large amounts of gratuitous material and labor, were used to purchase and refurbish an old steam mine locomotive and a group of abandoned mine cars, grade the old roadbed and lay track, reopen part of the tunnel, build a concession stand and a barn for the locomotive, and provide publicity for the project. On September 1, 1962 the 3,000-feet scenic narrow-gauge steam railroad was opened for business; it operated every week-end of September and October plus several week days. The tunnel portion of the project was not completed during the 1962 operating season and remained unopened to the public, but clearing was accomplished for a distance of some 275 feet from the entrance, to slightly beyond the Orchard coal vein (Fig. 2, cross-section), and a coal mining gangway in this seam was in process of being driven west from the main tunnel (Fig. 2, map).

Descriptions and specifications of the major facilities at the Ashland tourist project give some conception of the type and magnitude of tourist appeal they can be expected to exert. The completely overhauled and newly painted and polished locomotive (Fig. 3, middle left), named the Henry Clay, is of the 0-4-0 type with 33-inch drivers, and is about 23 feet long, 8 feet across the cab, and 12 feet high to the top of the stack. It was built in 1927, retired from service about 1957, and is believed to be one of the last of its kind in existence. Its piercing whistle, chugging exhaust, and accompanying clouds of steam and acrid smoke are guaranteed to bring nostalgic memories to oldsters and to quicken the pulse of today's youngsters. The six open passenger cars (Fig. 3, lower left) are rebuilt from old local mine cars, are painted various bright colors, and are individually named. They have no springs or shock absorbers and no buffers at the couplings, so that they ride like nothing modern on wheels and produce a real sense of "roughing it" for the passengers. Total capacity of the six cars, with a mix of adults and children, is about 100 riders and the cars are typically completely filled (Fig. 3, lower left). The narrow-gauge (42 inch) track runs through both wooded and open countryside (Fig. 3, middle right), and provides a number of scenic panoramic overviews of the town and valley lands below. Switching arrangements at approximately the mid-point and terminus of the track (Fig. 2, map) permit the locomotive to be changed from pushing to pulling positions, and enable the passengers to observe the "loki" in action while it is temporarily disconnected from the cars and maneuvering about. At the termination of the rail line is the larger of the two abandoned open-trench coal mines, termed the Mammoth Stripping after the name of the exceptionally thick Mammoth Vein that was mined there (Fig. 2, cross-section). The south side of this trench is an imposing 250-foot-high man-carved wall of solid rock that rises at an angle of 70 degrees and extends as far westward as the eye can see. The trench was started in 1918 and was dug with steam shovels of the Panama Canal type mounted on railroad trucks and driven by hugh chains. Like its companion trenches elsewhere in the anthracite region, it was considered one of the engineering wonders of its day. Innumerable fragments of waste slate on the floor of the trench contain fossils and fossil imprints, and could provide a natural history bonanza for school child and adult alike (Fig. 3, lower right). The tunnel portion of the Ashland proj-

Fig. 3. Upper left—Marko Towne House, Ashland's hotel; upper right—entrance to Pioneer Tunnel; middle left—the Henry Clay returning from a trip; middle right—a section of the scenic railroad line; lower left—trainload of tourists at the end of the ride; lower right—tourist-hunting fossils among slate fragments on the floor of Mammoth Stripping.

ect (Fig. 3, upper right), termed Pioneer Tunnel from the name of a late 19th century mine in the vicinity, was a main branch of a connected group of exploratory and mining tunnels cut into Mahanoy Mountain, beginning in 1918, by the Philadelphia and Reading Coal and Iron Company, predecessor of the present-day Reading Anthracite Company. The tunnel is approximately 10 feet wide and 7 feet high. Water seeps from the walls, the air is dank, and the floor is wet, but a raised walk will permit visitors to remain dry of foot. When the tunnel is opened to the public, tourists will experience all of the fascinating sensations of a trip into a cave, plus finding at the end of their 275-foot walk an authentic underground mining operation in full swing and an experienced miner to explain the process. Finally, the concession stand provides refreshments for the visitor and a number of types of mementos of his visit, including such items as polished coal jewelry, coal fossil specimens, literature on anthracite and the anthracite region, "coal" candy, and for the youngsters wooden whistles with a piercing sound that resembles that of the locomotive. Such is the fascinating array of experiences, sensations, and products that the Ashland tourist project offers the visitor—an assortment that should appeal to young and old, stranger and local resident.

IMPACT OF THE ASHLAND PROJECT ON THE LOCAL AREA

Data are limited concerning the impact of the Ashland tourist project on the economy of the local area and the morale of its inhabitants during the first partial season of operation. However, based upon available information and some reasonable projections, the effect appears to have been of significant magnitude.

During the week-ends and two weekdays of September and October, 1962, a total of 14,621 visitors were paying passengers on the project's scenic railroad (Table 1), of which some ten per cent are estimated to have been residents of the borough. Hence, there converged on Ashland during a two-month period some two and one-half times as many people as the normal population of the borough—people who would otherwise in large measure have had no occasion to have visited the area. The mere presence of these visitors, in itself, gave a tremendous lift to the moral of the local inhabitants of the long depressed town, for it indicated that the area had something of interest and value to offer to others.

The tourists paid more than $7,600 for railroad fares and for food and souvenirs sold on the grounds. One can

TABLE 1

Passengers on the Scenic Railroad of the Ashland Tourist Project, September 1 to October 28, 1962

Date	Number of Passengers	Percentage of Passengers Registering
Sat., Sun., Mon., Sept. 1, 2, 3	4,258	no registry
Sat., Sept. 8	555	31
Sun., Sept. 9	1,096	19
Sat., Sept. 15	310	24
Sun., Sept. 16	1,204	26
Sat., Sept. 22	155	52
Sun., Sept. 23	951	25
Sat., Sept. 29	173	47
Sun., Sept. 30	1,167	18
Sat., Oct. 6	315	33
Sun., Oct. 7	944	26
Mon., Oct. 8	216	no registry
Fri., Oct. 12	202	no registry
Sat., Oct. 13	266	41
Sun., Oct. 14	1,113	38
Sat., Oct. 20	368	31
Sun., Oct. 21	735	28
Sat., Oct. 27	65	46
Sun., Oct. 28	528	26
TOTAL	14,621	

conservatively estimate that they spent elsewhere in Ashland and vicinity an average of perhaps one dollar more per person for such items as gasoline, food, and drug store products, which would add another $14,600 to that spent directly at the project. Hence, some $22,000 of new money probably was injected into the Ashland economy by the operational phase of the tourist project (5). Since each dollar of new money is estimated to turn over four times in the normal course of exchange in an area, the Ashland region probably has benefitted in the amount of some $88,000, a by no means small sum during a two-months period in a depressed town of some 5,000 population.

In projecting the impact of the tourist facility on the Ashland economy during coming years, it must be kept in mind that the 1962 figures form a most conservative base. In the first place, only a portion of the total contemplated facilities was in operation during the first season, for the tunnel and underground mining operation had not yet been opened to the public. Then, too, the project admitted its first customers during the Labor Day week-end, the traditional close of the tourist season in northeastern United States, and hence was not exposed to the full flow of summertime tourists. Moreover, the project was in operation only on week-ends during the past year, whereas in 1963 the plans call for full-time operation during June, July, and August, and week-end operation during May, September, and October. Finally, any first season operation of a tourist facility lacks the cumulative benefits of past promotional activities that will accrue to it during subsequent years. Because of these circumstances, therefore, one can look forward with a fair degree of optimism to increasingly beneficial effects of the Ashland tourist project upon the future economy of the town.

IMPACT OF THE ASHLAND PROJECT ON OUTSIDE AREAS

The impact of a tourist facility on outside areas is apparent solely in terms of the visitors which it attracts from such areas, for, unlike other forms of industry which ship their products to the customers, the tourist industry must draw its customers to its products. Fortunately, detailed sampling data are available on the sources of tourists that visited the Ashland project during 1962, for a guest registry was maintained during each week-end of September and October except the initial Labor Day week-end. This registry contains the names and addresses of between 18 and 52 per cent of the total estimated attendance on each day during which the registry was open (Table 1), and forms the basis for the accompanying maps showing sources of visitors. The patterns on the maps present, at least to the authors, some rather unexpected results with regard to the impact of the Ashland project on outside areas.

The map in Figure 4 represents the number of days that residents of individual states visited the Ashland tourist site during the 16 week-end days that the registry was open. As might be anticipated, residents of Pennsylvania were present on all 16 days. Strangely enough, however, New Jerseyites and New Yorkers appeared on almost as many days (15 and 12, respectively), although of course they were not nearly so numerous individually as Pennsylvanians. Other states in the vicinity of Pennsylvania that contributed visitors on three or more of the 16 days included Maryland (10 days), Delaware (5 days), and Connecticut, District of Columbia, Massachusetts, Virginia, and West Virginia (all 3 days, each). Thus, attendance from nearby states to the north, east, and south of Pennsylvania was relatively frequent, but that from the west was

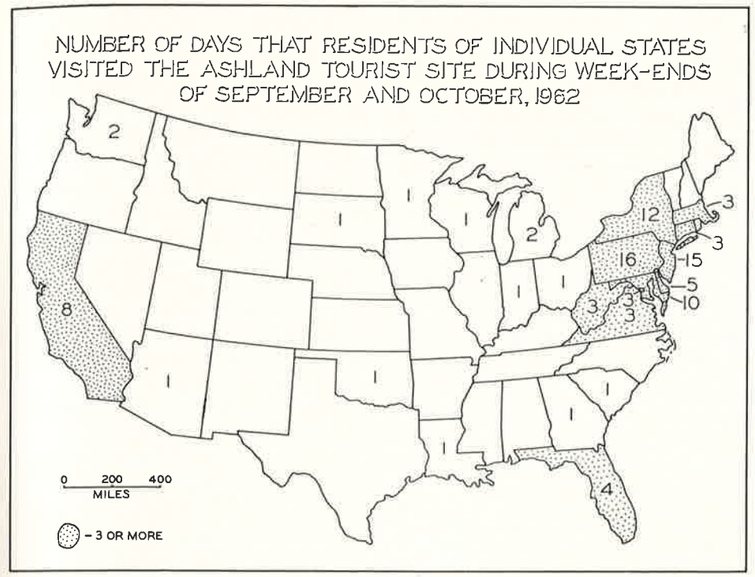

Fig. 4. Number of Days That Residents of Individual States Visited the Ashland Tourist Site During Week-Ends of September and October, 1962. Data are based on a random sampling of tourists for eight week-ends of the two-month period, exclusive of the Labor Day week-end. The figures indicate the number of week-end days out of a possible total of 16 that tourists from a particular state visited the tourist site. States represented on three or more days are stippled. See text for details. Data from Ashland Community Enterprises.

rare (Ohio, for instance, 1 day). Most of the southern, midwestern, and western states were unrepresented, or almost so, but Californians and Floridians appeared with surprising frequency (8 and 4 days, respectively) even though their total numbers were small. In view of these facts, one is perhaps justified in questioning the commonly expressed adage that, barring the existence of major obstacles, the impact area of a tourist facility expands over the years in an ever-widening series of concentric circles centered on the facility until the boundary of the area reaches its outermost practical limits. Certainly, the impact area of the infant Ashland project is not a contiguous one. Nor does the most local of the several fragments of the impact area have the configuration of a circle centered on the tourist project; instead, it is of eccentric shape and is offset, with the bulk of the territory apparently lying to the north, east, and south of the project.

The explanation for the fragmented character of the impact area is unknown to the authors. They can only surmise that Californians and Floridians are among the most numerous and widely travelled of American tourists, and hence because of sheer numbers found their way to the Ashland tourist site on a large number of days. Or, perhaps they represent emigrant residents of Ashland returning to their former homes for a visit.

Regardless of the explanation, the fact remains that California and Florida are definitely within the first-year impact area of the Ashland project.

The explanation for the eccentric shape and off-center location of that portion of the impact area located in northeastern United States is best prefaced with an examination of more detailed data concerning the source of tourists from that area. Figure 5 represents the number of days that residents of individual eastern and central Pennsylvania towns visited the Ashland tourist site during the 16 week-end days that the registry was open in September and October of 1962. As is apparent from the map, residents of Ashland were present on all 16 days; those from Philadelphia on 15 days; those from a half-dozen small towns in the vicinity of Ashland on from 10 to 13 days; those from Reading on 12 days;

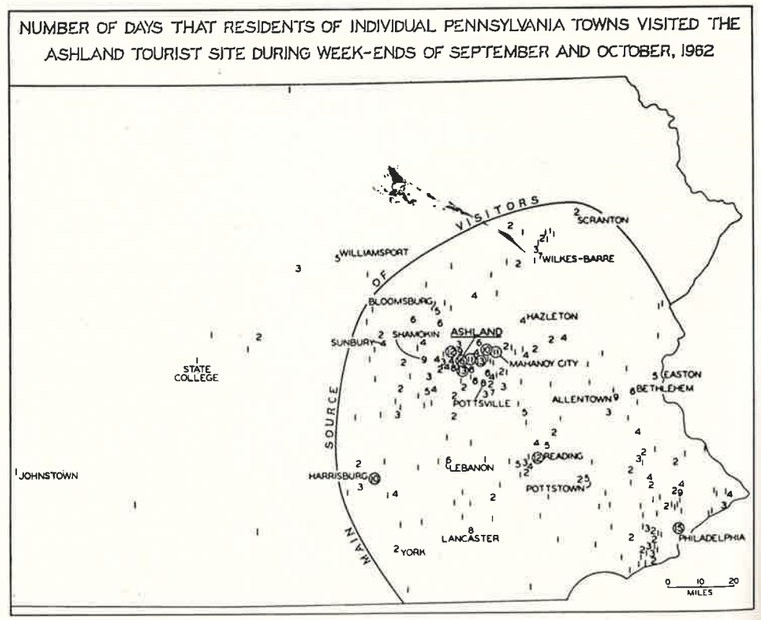

Fig. 5. Number of Days That Residents of Individual Pennsylvania Towns Visited the Ashland Tourist Site During Week-Ends of September and October, 1962. Data are based on a random sampling of tourists for eight week-ends of the two-month period, exclusive of the Labor Day week-end. The figures indicate the number of week-end days out of a possible total of 16 that tourists from a particular town visited the Ashland project. Two-digit figures are circled, and figures for some of the larger towns are identified by name for orientation purposes. The western third of Pennsylvania is omitted from this map, but is included on the following one. The boundary line encircles the main source of visitors. In about three-quarters of the cases, the number of individual visitors from a town can be estimated by multiplying the figure on the map by a factor of 2 or 3; less frequently by factors of 4, 5, or 6; and in rare instances by factors of 7 (for Danville, Nanticoke, and Shamokin), 8 (Dallas and Frackville), 9 (Pottsville), or 11 (Reading). Data from Ashland Community Enterprises.

and those from Harrisburg 10 days. Other sizeable towns in eastern and southeastern Pennsylvania contributed visitors on a considerable number of days, and many intervening small boroughs and suburban sites supplied tourists on one or more days. The most surprising fact brought out by this map is the concentration of visitor sources in areas largely to the east and south of Ashland, and the almost complete absence of such visitor sources at any great distance to the north and west. The line on the map encloses what is termed the "main source of visitors." Figure 6 is an extension of the previous map and shows similar information for the remaining significant portions of the northeastern states. It indicates that additional major sources of visitors to the Ashland tourist site were New York City—Newark and vicinity, Camden and vicinity, Wilmington and vicinity, Baltimore, and Washington, D. C. and vicinity. When these and related areas are encircled by a continuation of the boundary line drawn on Figure 5, there is enclosed a very circumscribed territory which supplied by far the great majority of the first-year tourists visiting the Ashland

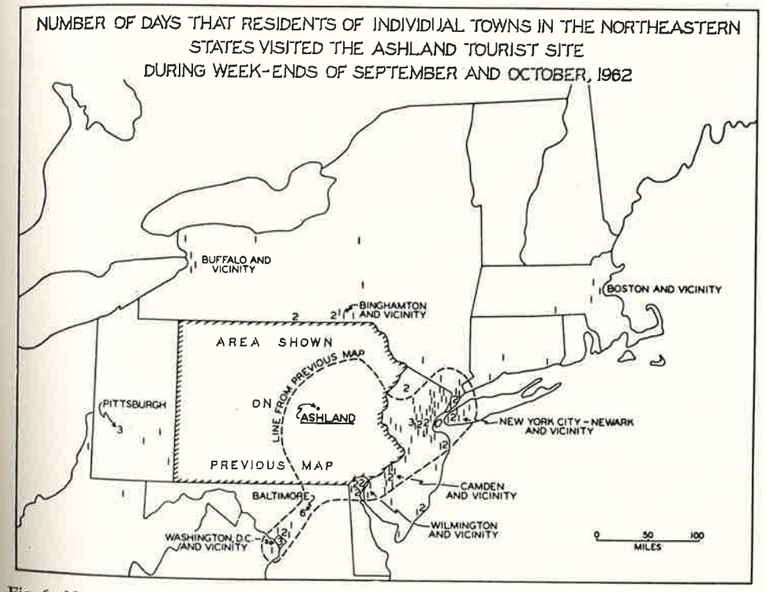

Fig. 6. Number of Days That Residents of Individual Towns in the Northeastern States Visited the Ashland Tourist Site During Week-Ends of September and October, 1962. Data are based on a random sampling of tourists for eight week-ends of the two-month period, exclusive of the Labor Day week-end. The figures indicate the number of week-end days out of a possible total of 16 that tourists from a particular town visited the Ashland project. Two towns in Virginia, and one in West Virginia, cannot be shown on the map. Some clusters of figures are identified by town names. The dashed boundary line encircles the main source of visitors to the Ashland project. Figures for eastern and central Pennsylvania are shown on the previous map. Data from Ashland Community Enterprises.

project. The area thus enclosed consists of two parts: (1) east-central and southeastern Pennsylvania, and (2) the almost continuous line of large cities and associated suburbia (megalopolis) extending from Washington, D. C. northeastward to New York City. With such a detailed picture in mind, it is now possible to attempt an explanation of the position and configuration of the main impact area during the first year of operation at the Ashland tourist facility.

Immediately to be ruled out is the assumption that the registry does not reflect the true distribution pattern of visitors to the Ashland site, for the percentages of guests registered on the various days is far too large to permit bias to develop. One potentially significant causative factor that comes to mind is publicity, for one would assume that the greatest number of visitors would come from areas in which a tourist site is most intensively publicized. To test this theory, a map (Fig. 7) was constructed showing all known sites and types of publicity in Pennsylvania given to the Ashland tourist project between January and October of 1962. Non-Pennsylvania areas are omitted from the map because there are very few known publicity sites outside of the state (6). News stories about the project are known to have been carried in 34 Pennsylvania newspapers. Interestingly enough, by far the greater number of such newspapers was located in the western and central parts of the state, from which very few visitors originated. In contrast, there was an almost total absence of such publicity in the southeastern corner of the state, which contributed a large proportion of the visitors (Fig. 5).

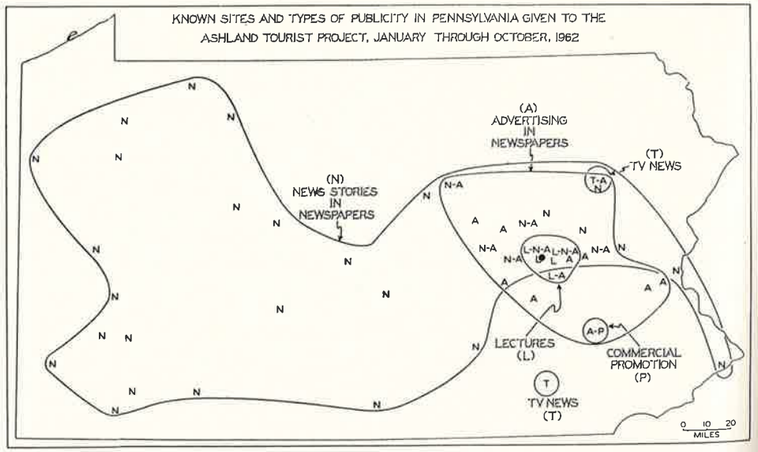

Fig. 7. Known Sites and Types of Publicity in Pennsylvania Given to the Ashland Tourist Project, January Through October, 1962. The letters N represent the locations of towns with newspapers known to have published news stories about the Ashland project, and the letters A indicate the locations of towns with newspapers carrying paid advertisements concerning the project. Similarly, T refers to television news stories, L to lectures, and P to commercial promotion relative to the tourist site. Towns represented by a hyphenated series of letters received multiple types of publicity. Boundary lines encircle all letters of a similar category. The large black dot represents Ashland. Data from Ashland Community Enterprises.

Advertising concerning the tourist facility was placed by its operators in the newspapers of 18 towns, and, from the distribution of these towns on the map in Figure 7, it is evident that the advertising campaign was as intensive and far-reaching to the north and west of Ashland as it was to the south and east. Obviously, there is no areal correlation between the line bounding the advertising sites in Figure 7, and the line delimiting the main source of tourists in Figure 5. Television news stories about the Ashland project were carried on two stations, one in Wilkes-Barre and the other in Lancaster, neither of which towns was a particularly prolific source of visitors to the project. One of the officers of the operating corporation presented a series of lectures on the subject before service organizations in Ashland and four other towns in the immediate vicinity (Fig. 7), which, together with other types of publicity in the local area, certainly proved effective in bringing out nearby visitors (Fig. 5); but such lectures could not have played a significant role in attracting more distant tourists from elsewhere in the eastern and southern parts of the state. Another type of publicity, intensive commercial promotion by a former Ashland resident who is now the president of a bus-tour company in Reading, was very effective in bringing residents of that city to the tourist site but could have been of no significance elsewhere in the state. No data are available concerning radio news coverage, automobile bumper sign dissemination, or word of mouth information, but there is no reason to believe that such forms of publicity would have been restricted only to areas east and south of Ashland. In resume, therefore, and after comparing *in toto* the patterns of data shown on the maps in Figures 5 and 7, it can be stated that, insofar as can be determined, publicity was not a primary factor in determining the eccentric shape and off-center location of the main impact area of the Ashland tourist project during its first season of operation.

Another factor that quite conceivably could explain such conditions is the contrast in population density, and in number of cities and towns, between counties within the impact area and those beyond it. Most counties within the encircled territory shown in Figures 5 and 6 have a very high average population density and a considerable number of medium- to large-sized cities. In contrast, average population densities, and the number and size of cities and towns, tend to be smaller in counties situated outside the encircled area. One might suspect that such a population differential would be a significant causative factor in determining the configuration and orientation of the main impact area. But that it is not the sole factor, nor even the main factor, is evidenced by the absence of all but a very few tourist sources beyond the bounds of the impact area. On Figure 5, for instance, central and northeastern Pennsylvania are by no means the population voids that are implied by the lack of tourist sources. Instead, as indicated on Figure 8, they are liberally sprinkled with hundreds of small settlements and have a considerable number of medium-sized towns (among them Altoona, Carlisle, Chambersburg, Hanover, Lewistown, Lock Haven, and Waynesboro), the equivalent of which in southeastern Pennsylvania and adjacent portions of neighboring states have all contributed their quota to the flow of tourists to the Ashland site. On the basis of such evidence, therefore, one must conclude that the population density factor does not explain the configuration and orientation of the main impact area of the Ashland tourist project.

After careful study, it appears to the authors that the factor of greatest signifi-

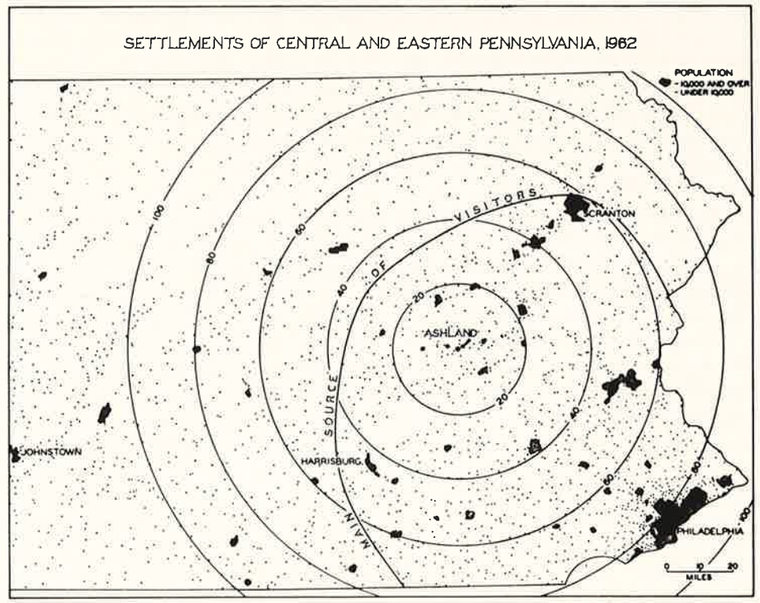

Fig. 8. Settlements of Eastern and Central Pennsylvania, 1962. Urban centers of 10,000 or more population are represented by large black symbols; smaller settlements are indicated by means of dots. Concentric circles are centered on Ashland and spaced at 20-mile intervals. The heavy boundary line encircles the main source area of visitors to the Ashland tourist facility.

cance in establishing the location and boundary of such an area is the relative familiarity of various people with anthracite. It is assumed that among those who have used in the past or now use the fuel for domestic purposes, or who know through family history of its use, there is a real interest in and a willingness to visit a tourist project featuring the anthracite theme. It is further assumed that to most other people the term anthracite is meaningless or almost so, and thus there would be little incentive to investigate a related tourist site. If such presumptions are correct, then there should exist close correspondence between the boundaries of the market area for domestic sizes of anthracite and the outer limits of the major source area for Ashland's tourists. Figure 9 represents the distribution of anthracite sales, by states, in 1959-1960. Greatest sales were made in Pennsylvania, major amounts were sold in New York and New Jersey, and significant quantities were purchased in the New England states and the Maryland-Delaware, District of Columbia region. Much of this coal was for domestic use. In contrast, the anthracite sales made in Ohio and westward were almost entirely for industrial purposes, and only the rare individual had contact with the fuel. When one compares the pattern of coal sales (excluding those from Ohio westward) in Figure 9 with the pattern of Ashland visitors represent-

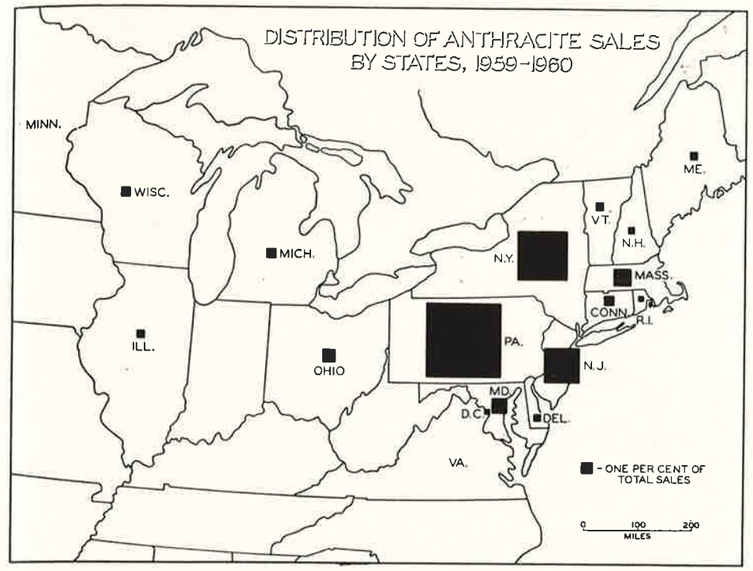

Fig. 9. Distribution of Anthracite Sales, by States, 1959-1960. Sales to foreign countries are not shown, but are included in the term total sales. Source of data: U. S. Bureau of Mines

ed in Figure 4, the resemblance is apparent. A refinement of the comparison would further reveal that virtually all anthracite sold in Pennsylvania is marketed in the eastern and southeastern parts of the state (7), and that the major market area for the domestic sizes of anthracite in nearby Atlantic seaboard states extends in a line from Washington, D. C., northeastward through Baltimore, Wilmington, Philadelphia, Camden, Trenton, New York City, and on to Boston. Except for the more distant northeastern arm of the Atlantic seaboard line, these areas almost duplicate the primary impact area for the Ashland tourist site as outlined on the map in Figure 6. One can only conclude that, since the domestic-sized anthracite sales area and the anthracite tourist source area are essentially coextensive, prior knowledge about the fuel must have been a significant factor in inducing tourists to visit the Ashland project. It is further concluded that, in order to attract any considerable numbers of tourists from outside the domestic-sized anthracite sales area in the future, it will be necessary to educate such potential tourists as to the nature of anthracite and the significant role it has played in the American economy. Promotional activities directed toward such tourists, therefore, should be designed with a different approach than those employed with persons already familiar with anthracite.

SUMMARY

This study has examined in detail some geographic aspects of the first significant effort made to develop a commerical tourist site in the anthracite region of Pennsylvania. The Ashland lo-

cale, it is pointed out, is well endowed geographically for such a purpose, and is being skillfully developed by a group of dedicated citizens who are installing facilities calculated to appeal to a wide range of visitor interests. Response of the touring public to the new attraction during the first partial season of operation has far exceeded earlier expectations, with consequent beneficial impact on the economy and morale of the local community. The only problem apparent to date is the inability of the tourist site to attract major numbers of visitors from areas beyond the traditional sales territory for domestic sizes of anthracite, thereby presently relegating the facility to the status of a strictly regional attraction rather than one with a more widespread geographical appeal.

REFERENCES AND NOTES

1. Deasy, G. F. and Griess, P. R. 1961. Tourism for the Anthracite Region—An Alternative for Unemployment. Min. Industries 30 (7):1-8.
2. Griess, P. R. and Deasy, G. F. 1961. Some Specific Potential Tourist Sites in the Anthracite Region. Proc. Pa. Acad. Sci. 35:212-220.
3. The Ashland tourist facility was conceived and developed by Ashland Community Enterprises, a non-profit corporation. The purpose of the corporation, as stated in its charter, is "to maintain and operate facilities demonstrating the mining of anthracite coal, to exhibit tools and equipment used in the anthracite industry, to preserve the lore and traditions of mining in the area, to stimulate the production and distribution of handicraft articles, to provide means of recreation for the residents of the Borough of Ashland, and to foster and promote the health, education and welfare of the residents of the Borough of Ashland." Should the Ashland tourist project operated by the corporation prove to be profitable over the years, such profits will be used for public works in the Borough of Ashland and no profits will inure to the benefit of any individual.
4. The Ashland Daily News. Sept. 1, 1962.
5. Excluded from this figure are thousands of dollars of ARA loan money, which were used in part to purchase local supplies and hire local labor during the initial developmental phase of the tourist project prior to September, 1962. These monies are excluded because they do not represent an annually recurring addition to the economy of Ashland.
6. Newspapers in Baltimore, Md., Nashville, Tenn., New York City, and Olean, N. Y. are known to have carried news stories of the Ashland project.
7. Jaworek, W. G. and Schanz, J. J., Jr. 1961. The Use and Interchangeability of Fuels in Pennsylvania. Min. Conserv. Ser. Bul. 74. Pa. State Univ.

SOME ASPECTS OF THE DISTRIBUTION OF POPULATION IN PENNSYLVANIA*

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ABSTRACT

The purpose of this study is to present some of the main characteristics of the distribution of population in the Commonwealth of Pennsylvaina, as of 1960. The following ten maps were prepared using census data by counties:

1. Density of Population;
2. Urban Population;
3. Rural Farm Population;
4. Persons of 65 years of age and over;
5. Nonwhites;
6. Net gain or loss by civil migration; (1950-60);
7. Change in Population; (1950-60);
8. Families with an annual income of under $3,000;
9. Families with an annual income of $10,000 and over; and
10. Unemployment.

The preliminary analysis of each of these maps brings out interesting distributional patterns. Their correlation affords some insight into the recent trends and focuses attention on the problem areas.

After analyzing the patterns of distribution an attempt is made to delineate a certain number of homogeneous sub-regions within the Commonwealth. Two broad regions stand out: one representing conditions of general growth; and the other of general stagnation. These have been further subdivided depending on the degree of differences shown by them.

The Megalopolitan area of Pennsylvania, along with some of the counties in the western and central parts of the state can be called the region of promise. The rest of the state shows stagnation and needs deeper study to understand its problems.

INTRODUCTION

The Commonwealth of Pennsylvania is striving to adjust to the forces that are at present reshaping the population patterns of the United States. Whether the future of this state is bright or not depends upon a thorough understanding of the ills and assets of the region. Man is the pivot of all activities and his distribution and movements should reflect a deeper meaning than is superficially seen and casually understood. Such a picture can prove to be a meaningful index of the existing conditions in a region. The present study endeavours to present an integrated view of some of the population attributes in their spatial interaction, in Pennsylvania.

* Author is greatly indebted to Dr. Jean Gottmann, for his valuable guidance throught the work. Presentation of this paper has been possible through the constant and active encouragement from Dr. H. V. B. Kline, Jr., and Dr. John E. Rickert, Dept. of Geography, University of Pittsburgh. Author deeply appreciates their help.

METHOD

The basic unit of study for the purpose is the county. It is admitted that the unit is, in itself, a large area, but for the present undertaking it is deemed significantly revealing. All the data are from the City and County Data Handbook, 1960.

Countywise census data for the following population attributes were plotted on a simple graph to group the counties by using the significant breaks: Density of a) population, b) urban population, c) rural farm population; Net gain or loss by civil migration, change in population (1950-60); per cent of a) persons of 65 years and over, b) edu-

cated, c) unemployed, and d) families in two income categories: below $3,000, and $10,000 and over, per annum.

Each of these groupings was assigned a factor depending on its position in the set of groupings of a particular attribute. For example, the higher the density, the higher the factor assigned. But, for the attributes like old age group, unemployed, low income families, etc., the higher the percentage figures, the lesser are the assigned factors. Civil migration, being the single most important attribute, is weighed doubly. All these factors are added up for each county in the state. These figures are used to compute the standard deviation. The counties are then grouped on the basis of their departures from the mean value measured in terms of the standard deviation. Thus the following five categories were recognized:

1. counties with values between minus and plus 0.5 standard deviation are grouped as the subregion showing little change;

2. those with values beyond 0.5 but below 1.5 standard deviations are grouped as the subregion showing moderate growth;

3. those beyond plus 1.5 standard deviations are regarded as showing intense growth;

4. those between minus 0.5 and minus one standard deviations are regarded as showing moderate decline; and

5. those beyond -1.0 standard deviations are regarded as showing significant decline.

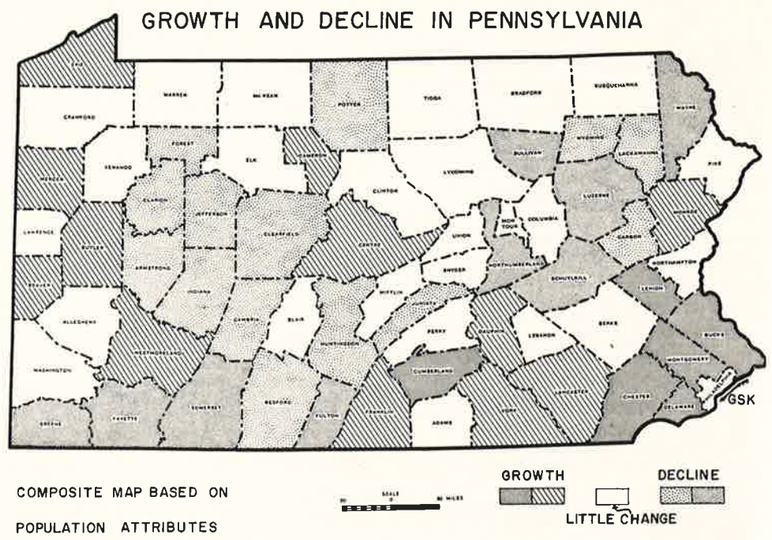
These five subregions are mapped (refer the map). It gives a generalized picture of the existing condition of the state's population. It poses many problems whose solution would need a detailed study of the related aspects.

CONCLUSIONS

The composite map shows that the megalopolitan area within the state, along with some of the counties in the western and central parts of the state, can be called the region of promise. A major part of central and southern western Pennsylvania and the northeastern region show a definite sign of decline. It is here that a further detailed study of all aspects of the economy is warranted. It would be worthwhile, too, to base this study on a thorough understanding of the causes of growth in the more fortunate parts of the state.

It has to be remembered that Pennsylvania is a heterogenous region and has its population concentrations oriented outside the state. Possible exception may be of the Pittsburgh region which itself acts as the focal point for the surrounding tristate area.

To study the whole state as one unit is to forget its diversity. Hence such a division into significant and meaningful subregions is the first important step. This division is tentative but highly revealing.



POPULATION GROWTH AND EMPLOYMENT TRENDS IN BUCKS COUNTY, PENNSYLVANIA, 1950 TO 1960

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ABSTRACT

Bucks County, Pennsylvania, experienced a large increase in population numbers in the 1950 decade. Accompanying this population growth was an upsurge in industrial facilities and employment within the county. Utilizing census data covering number of inhabitants and place of work of the resident labor force, an attempt is made to measure the influence which a growing economy has had upon population change.

The areal association between population growth or decline and economic health is rather clear in some cases. For instance, a high proportion of the loss of population in the anthracite areas of Pennsylvania over the past few decades can be attributed to the decline of such primary economic activities as coal mining and railroad repair, as well as the inability of these places to attract industries which would provide employment suitable for heads of households. Conversely, the vigor displayed by California and Arizona in attracting thousands of new residents annually has been identified with the search for amenities, or a "nice" place in which to reside. Even though the inhabitants of this country have become increasingly mobile since World War Two, it is difficult to conceive of regional shifts in population of so great a magnitude without a certain degree of economic attraction being involved. That is, greater job opportunities in the place of destination as compared with lesser opportunities in the place of origin.

While recognizing the role of fundamental changes in the realm of economic advantages—such as increased employment in foot-loose or tertiary job opportunities and a relative decrease in primary and secondary occupations; increased importance of market as a factor in location of industries; and, a greater frequency of early, paid retirement—Edward Ullman upholds the strength of amenities as an important factor in regional population shifts. He groups these amenities into a set of pulls toward comfort such as pleasant climate and easy access to recreation. Ullman also asserts that amenities are noteworthy in the growth of suburbs.[1]

The purpose of this paper is to explore the merits of amenities as opposed to economic attraction in an attempt to account for the recent expansion of population in Bucks County, Pennsylvania. Located in southeastern Pennsylvania, this county has undergone considerable change since 1950. Population more than doubled and important additions were made to the industrial complex of the County.

Foremost among the industrial accessions was the opening of the Fairless Works of United States Steel. Lower Bucks County, the site of the steel plant, possessed several advantages for the location of such an industry. Of prime importance was the location of the site with respect to the Philadelphia area and a broad market extending throughout the Eastern Seaboard and New England.[2] Moreover, the expected depletion of high grade domestic ores prompted the development of foreign ores in Venezuela, Liberia, and Labrador. Thus, Eastern Seaboard locations became important in raw material assembly.[3]

The beginning of industrial growth in Bucks County in this period was thus heralded by the announcement, in December, 1950, by United States Steel to build an integrated steel mill. A second development was announced in August, 1951. Kaiser Fleetwing proposed a changeover from household appliances to aircraft parts in their Bristol plant. An anticipated tenfold increase in number employed, from 700 to 7,000, accompanied this latter proposal.[4]

Following the land assembly by United States Steel for its proposed plant, a Columbus, Ohio builder was encouraged by that company to seek land for a steelworkers housing project. Shortly thereafter, William Levitt announced that a new Levittown would be built near the steel plant, provided Lower Bucks County was declared a Critical Defense Housing Area. Favorable credit restrictions to home buyers and reduced risks to builders via additional mortgage supports by the government were forthcoming with this designation. After a short period of lobbying, Lower Bucks received such a designation in October, 1951.[5]

Since population growth and noteworthy additions to the industrial structure of the County were concurrent, it seems logical to assume that economic attraction would have fostered much of the growth. Furthermore, the association in area between high rates of population growth and new industrial enterprises seems to strengthen this assumption. If job opportunities were the major factor in attracting migrants, one would expect a relatively large proportion of the newcomers to be employed within the County. On the other hand, if little or no differences exist in terms of work-residence separation between the areas of rapid expansion and those of lesser growth rates, perhaps the notion of amenities could be looked upon as a significant factor in attracting migrants to Bucks County.

Transposed into other terms, an examination of the regional variation in population growth as compared to changes in job opportunities should shed some light on the question of whether Bucks County has experienced suburbanization or growth more nearly urban in nature. Amenities as a factor in such a situation do not seem illogical when one is reminded of the suburban trend in mature, urban places such as Philadelphia.

Duncan investigated the factors involved in work-residence separation and found that frequency and distance varied directly with socioeconomic level of workers and centralization of workplace.[6] From this statement one could infer that such separation is sought by individuals who can afford to reside in less urban circumstances and commute to work. Levittown and Fairless Hills (the community originally built to house steelworkers) offer such condtiions at relatively small costs. In fact, the general terms outlined for those interested in moving into these communities were so reasonable that houses built specifically for rental eventually had to be sold because of their inability to compete with a nominal down payment and small carrying charges.[7] Thus, the new communities, Levittown and Fairless Hills along with smaller subdivisions, provided inexpensive housing for those desiring a suburban mode of life.

The actual distribution of the new increment of population in Bucks County is very uneven. Lower Bucks County received almost 90 per cent of the total between 1950 and 1960 (Fig. 1[8] and Table I). Furthermore, three of the four minor civil divisions within which Levittown and Fairless Hills are located —Bristol Township, Falls Township, and Middletown Township—account for over 57 per cent of the total difference in number over the same period. The bulk of the remaining increment of growth in

Lower Bucks County occurred in Bensalem, Lower Southampton, Upper Southampton, Lower Makefield, and Warminster Townships, all of which border Philadelphia, Trenton, or Montgomery County (Fig. 1).

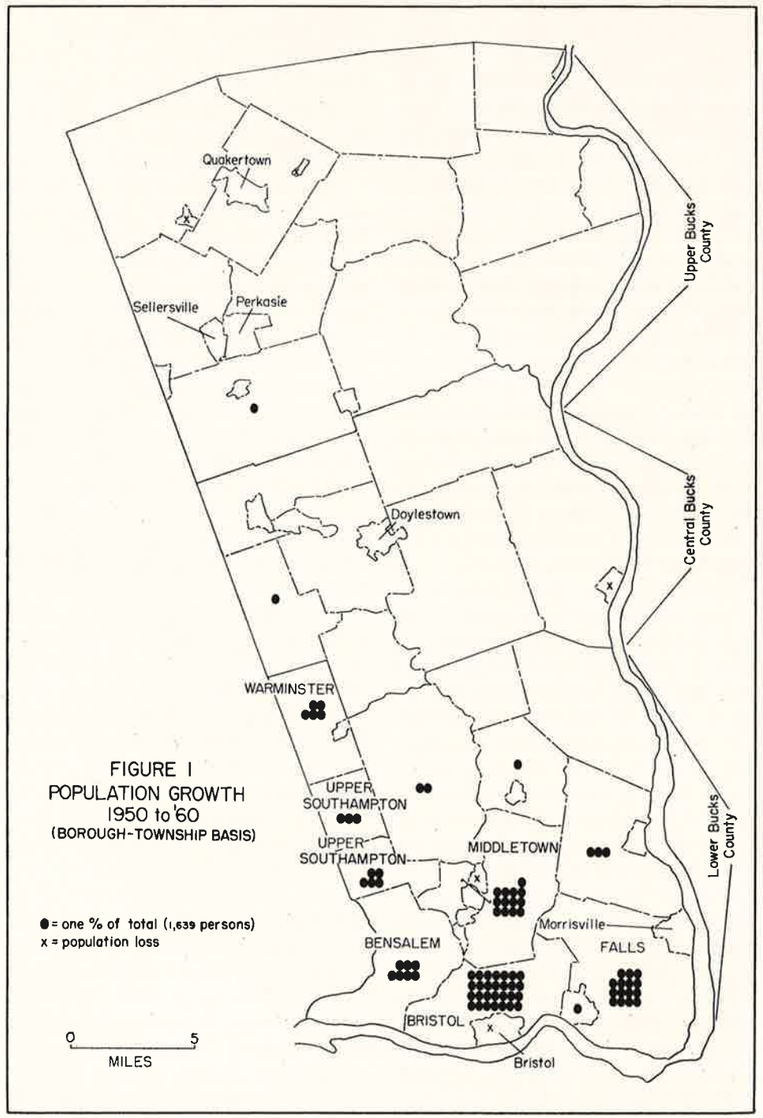

FIGURE 1
POPULATION GROWTH
1950 to '60
(BOROUGH-TOWNSHIP BASIS)

As compared to growth in Lower Bucks County, Central and Upper Bucks experienced only a slight increase in population in 1950 decade (Fig. 1 and Table I). Of the five places that actually lost population, all were boroughs, and the decrease was small, averaging less than 6 per cent.[9] Although undocumented, much of this loss may have been due to the movement out of the incorportated places into the new subdivisions located in the surrounding townships.

Concerning the question of whether or not any degree of areal accordance exists between population growth and increases in the industrial complex of Bucks County, Figure 2 portrays the ratio of resident workers in manufacturing to job opportunities in 1950 and 1960. It is rather significant that of the rapidly expanding civil divisions in terms of population, only Falls Township, home of Fairless Steel, experienced more rapid gains in industrial employement opportunities than in number of resident laborers. All of the other places occupying a high rank demographically lost ground or the ratio remained essentially the same.

The remaining civil divisions of the County indicate similar trends with the exception of Sellersville, where an increase in production of a rather large firm created an appreciable number of new jobs while the resident population remained almost stable.[10] In every other case, where job opportunities were expanded at a relatively greater rate than population, the absolute change in industry was small and could have been made by a slight expansion of existing manufactural facilities or additions of small operations (see Fig. 2).

The summary measures for all of Bucks and its three major divisions (Lower, Central and Upper Bucks) indicate that, on the whole, the resident labor force in manufacturing increased considerably more than job opportunities. Among the divisions, both Lower and Central Bucks reflect the general county trends, whereas Upper Bucks, the slowest growing area demographically, actually gained relatively more industrial job opportunities than resident workers (see Fig. 2).

This ratio, measuring potential job opportunities in manufacturing as compared to the number of resident laborers, indicates that Bucks County has become increasingly dormitory in nature. This is especially true of Lower Bucks, within which population gains seemingly outstripped industrial growth by a considerable margin.

Turning from potential in job opportunities as shown on Figure 2 to the ac-

TABLE I

Population Growth, 1950-1960
Bucks County and Major Divisions

	Population 1950	Population 1960	Rate of Change	Absolute Change	Percentage of Total Growth
Lower Bucks	82,417	228,827	2.78	146,410	89.3
Central Bucks	22,278	32,581	1.46	10,303	6.3
Upper Bucks	39,925	47,159	1.18	7,234	4.4
Total Bucks	144,620	308,567	2.13	163,947	100.0

Source: U S. Dept. of Commerce, Bureau of The Census.
Census of Population, 1960.

tual proportion of the resident labor force in manufacturing employed in their home borough or township, the comparison is roughly the same. The greatest percentage of workers engaged in local industries is not found in the rapidly growing places

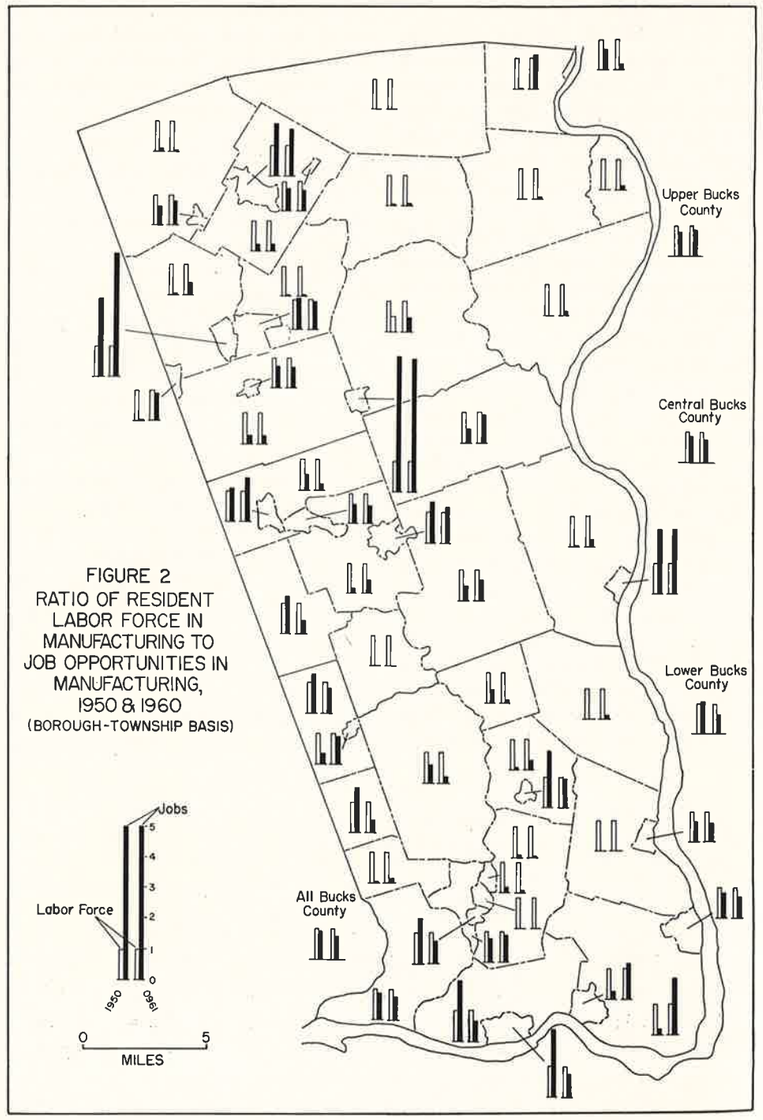

FIGURE 2
RATIO OF RESIDENT LABOR FORCE IN MANUFACTURING TO JOB OPPORTUNITIES IN MANUFACTURING, 1950 & 1960
(BOROUGH-TOWNSHIP BASIS)

but in the boroughs which grew only slightly or lost population. For example, the greatest proportions of those employed in their civil division of residence exist in Quakertown, Perkasie, Doylestown, Morrisville, and Bristol (Fig. 3).

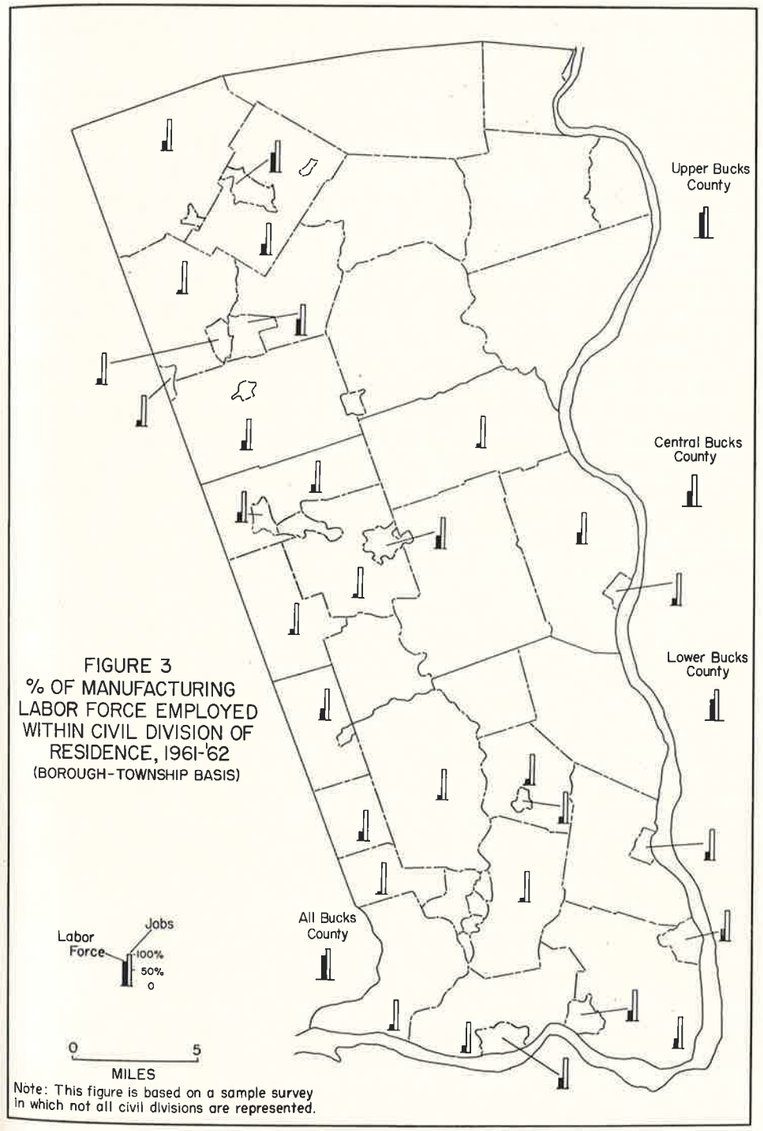

FIGURE 3
% OF MANUFACTURING LABOR FORCE EMPLOYED WITHIN CIVIL DIVISION OF RESIDENCE, 1961-62
(BOROUGH-TOWNSHIP BASIS)

Note: This figure is based on a sample survey in which not all civil divisions are represented.

TABLE II

Jobs in Manufacturing by Selected Categories, 1960
Bucks County and Major Divisions*

	Chemicals		Metals		Paper and Printing		Textiles and Apparel		All Industries	
	No.	%	No.	%	No.	%	No.	%	No.	%
Lower Bucks	3,347	14.4	14,793	63.8	2,001	8.6	746	3.2	23,192	100.0
Central Bucks	134	5.4	943	38.1	472	19.1	463	18.7	2,475	100.0
Upper Bucks	241	2.9	2,749	33.6	291	3.6	3,766	46.0	8,193	100.0
Total Bucks	3,722	11.0	18,485	54.6	2,764	8.2	4,975	14.7	33,860	100.0

*Compiled From Bucks County Industrial Development Corporation, *Directory of Manufacturing Plants in Bucks County, Pennsylvania,* 1961.

The summary bars shown in Figure 3 indicate once again that Upper Bucks ranks highest in this respect (i.e., proportion of people living and working in Upper Bucks County). Perhaps the combination of far fewer new residents, less access to large employment fields, and the type of industry prevalent in these divisions influences the variations. Textiles dominates the industrial scene in Upper Bucks County, whereas the metals industry and chemicals prevail in Lower Bucks (Table II). The former industry suffers from a significantly lower wage scale than either of the latter two and could not hope to draw upon as wide an area for labor. Therefore, a high percentage of employees live relatively close to their place of work in Upper Bucks County.

TABLE III

Place of Work of The Total Labor Force, 1960
Bucks County and Major Divisions

Place of Work	Place of Residence							
	Lower Bucks		Central Bucks		Upper Bucks		Total Bucks	
	No.	%	No.	%	No.	%	No.	%
Bucks County	37,156	48.0	7,691	60.6	12,908	67.0	57,755	52.8
Philadelphia	19,016	24.6	1,447	11.4	640	3.3	21,103	19.3
Montgomery County	4,282	5.5	2,067	16.3	2,513	13.0	8,862	8.1
Burlington County	1,934	2.5	41	0.4	4	—	1,979	1.8
Camden City	408	0.5	13	0.1	12	0.1	433	0.4
Balance, Camden Co.	247	0.3	12	0.1	3	—	262	0.2
Trenton	6,572	8.5	135	1.1	8	—	6,715	6.1
Balance, Mercer Co.	2,365	3.1	70	0.5	30	0.2	2,465	2.3
Lehigh County	80	0.1	25	0.2	634	3.2	739	0.7
Northampton Co.	20	—	10	0.1	897	4.7	927	0.9
All Others and Not Reported	5,230	6.9	1,177	9.2	1,628	8.5	8,044	7.4
TOTAL	77,319	100.0	12,688	100.0	19,277	100.0	109,284	100.0

Cource: Computed From Tabulated Tract Data, U. S. Dept. of Commerce, Bureau of the Census, *Census of Population,* 1960.

The relationship between a high incidence of commutation and rapid gains in population seems to hold true for the total resident labor force. Figure 4 illustrates the percentage of the labor force of each civil division employed within

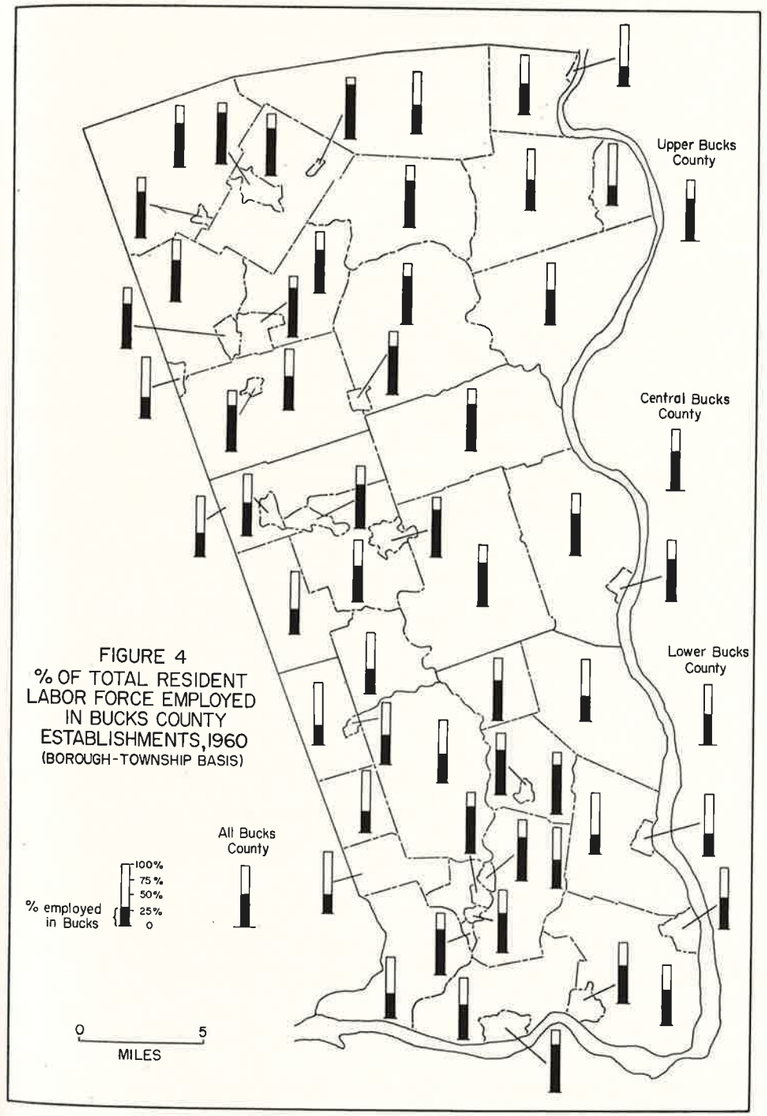

FIGURE 4
% OF TOTAL RESIDENT LABOR FORCE EMPLOYED IN BUCKS COUNTY ESTABLISHMENTS, 1960
(BOROUGH-TOWNSHIP BASIS)

Bucks County. (This includes all gainfully employed persons.) The places which experienced relatively little population growth appear as having a high proportion of their workers engaged within the county of residence. The summary bars for the major divisions indicate that Upper Bucks has the highest rank in this respect with 67.0 per cent of the labor force engaged within Bucks County, Central Bucks is second with 60.6 per cent, and Lower Bucks is last with only 48.0 per cent. It is significant that almost one-quarter of the labor force of Lower Bucks is employed in Philadelphia, and an additional 8.5 per cent in Trenton (Table III). This may reflect the suburban nature of the growth of Lower Bucks County; that is, a large share of people moving only a short distance and maintaining jobs in their former place of residence (see Table III).

From the materials presented certain inferences can be drawn. The importance of the locational decision of United States Steel cannot be overlooked as the original stimulant to much of this development, for without the presence of such a primary industrial undertaking, the interest of builders such as Levitt might have waned. This is of particular importance since Levitt stipulated that he would build only after Lower Bucks was declared a Critical Defense Housing Area. However, when the data have been reviewed, it is equally valid to assert that, in general, the areas of relatively little change reflect a strong association between places of work and residence. On the other hand, the centers of rapid growth seem to have become more dormitory in nature, exhibiting a higher degree of work-residence separation imposed by the differential between population growth and industrial expansion. Thus, it appears as if amenities, or the desire for suburban residence, are important in accounting for the recent population gains of Bucks County.

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THE RECREATION POTENTIAL OF THE UPPER SUSQUEHANNA (WEST BRANCH) BASIN: A GEOGRAPHIC ANALYSIS

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ABSTRACT

As leisure time increases and the population of the nation becomes more highly urbanized, there is a growing demand for outdoor recreational facilities. The purpose of this study is to investigate the recreational potential of the Upper Susquehanna Basin, West Branch. The study involves first a survey of the physicial environment and secondly the way man can utilize this area as a permanent recreational region.

There is a growing demand for new recreational areas in eastern United States. This is a response to such factors as longer vacations, the general high level of economic prosperity, the desire of an expanding urban population to spend a vacation in rural, natural areas, and the overcrowding of park areas near the large urban centers. In northeastern United States there remain relatively few areas of low densities of population, which could be called "wilderness areas." It is the purpose of this study to analyze the recreational potential of one remaining "wilderness area"—the Upper Susquehanna West Branch Basin of central Pennsylvania. This study is limited to the four counties of Lycoming, Clinton, Centre, and Clearfield. Although portions of this region are isolated today, the completion of the Keystone Shortway by 1970 through the heart of the area will make it readily accessible to millions of city dwellers in the Midwest and the Atlantic Coast. This wilderness area will be only about four hours from New York City by automobile.

PHYSICAL SETTING

The Upper Susquehanna West Branch Basin has about three-quarters of its area in the Allegheny Mountains of the Appalachian Plateau and about one-quarter in the Ridge and Valley Province. A large portion of the area in the Allegheny Mountains is truly a "wilderness" area. It is a part of the most primitive, undeveloped area in Pennsylvania, and one of the least populated areas in eastern United States (Figure 1). Many people do not realize that such a rugged, inaccessible forested area could exist in such a well-developed, densely populated state as Pennsylvania.

This mountainous region is a broad, deeply dissected plateau. Local relief frequently exceeds 1,000 feet and occasionally approaches 1,800 feet. With local relief of such magnitude scenic views are numerous. Regrettably, the major highways through the region are often confined to the valley bottoms while only occasionally rising to the top of the plateau. However, many small access roads lead away from the valley highways and wind their way to the top of overlooking crests. Maximum elevations seldom exceed 2,500 feet above sea level, but consistently high elevations give this region one of the highest average elevations of any area in the state.

These high elevations, together with the greater continentality resulting from its inland position, give this mountainous area a more rigorous climate than any other region in Pennsylvania. The summers are characterized by cool nights, and few excessively hot summer days. The snowfall in the area is heavy so that the region has the most reliable snow cover in Pennsylvania.

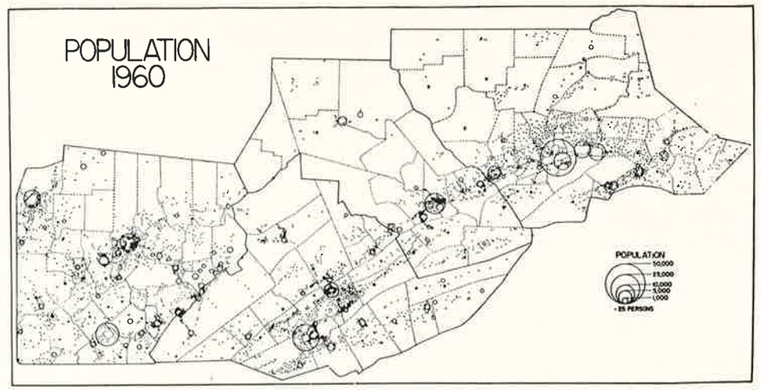

Figure 1. Population distribution of the Upper Susquehanna Basin West Branch in 1960.

The Ridge and Valley area located in the southeastern portion of the Upper Susquehanna Basin is one of the most scenic regions in Pennsylvania. The ridges attain an elevation of about 2,000 feet and relief is frequently between 1,000 and 1,200 feet. The long, almost unbroken ridges of nearly uniform height curving gently from southwest to northeast are the most prominent physiographic features of the region. Since these ridges lie athwart the main east-west highways, thousands of people see the scenic views, possibly more from necessity than as a primary objective.

The rugged, ridge areas are still primarily forested making it possible by showing forest lands to trace the parallel ridges. Most of the valleys have been cleared for agricultural use and are densely populated. With the forest lands located on the higher, steeper slopes, most recreational attractions are restricted to these same slopes.

RECREATIONAL FACILITIES

Because 75 per cent of the area is forested, the present recreational facilities are largely based on these natural resources. The most popular recreational pursuits of the area are hunting and fishing. When the conservation movement became active more than 35 years ago, it was easy for the state to acquire large tracts of land in the abandoned forest lands in the sparsely inhabited areas (Figure 2). As a result State Forests and Game Lands now total 779,310 acres, or 36.9 per cent of the total forested area of the four counties. In Clinton County 51.0 per cent of the forest land is controlled by the state.

In the sparsely settled, heavily wooded area, the state has developed outdoor recreational facilities. There are ten state parks in the region varying from 25 to 23,000 acres in size. Bucktail State Park is the largest, located in Clinton and adjacent Cameron County. The purpose of the state park system according to law is "to promote healthful outdoor recreation and education and make available for such use natural areas of unusual scenic beauty, especially such as impressive views, gorges, creeks, caves, and other unique and interesting features." In 1962 the Department of Forests and Waters reported 892,754 persons visited the state parks of the area.

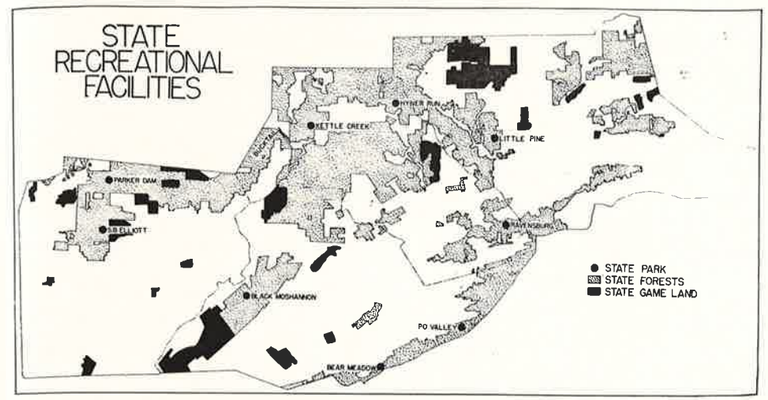

Figure 2. State Recreational Features.

Within the state forests 10 picnic areas have been established varying from 3 to 75 acres in size. Of these, Centre and Clinton each has four, and there is one each in Clearfield and Lycoming counties. According to records of the Department of Forests and Waters over 100,000 people registered in the picnic areas in 1962.

The four counties have 119,702 acres in State Game Lands. The game lands of Centre County are second in area in the state exceeded only by Elk County. As a result of the large amount of forest land and the low density of population over large areas, both small and large game hunting has become a major sport. In 1961, 75 bears were killed in the four counties. This was 31.6 per cent of the total state kill. Lycoming and Clinton rank among the best bear hunting counties in the state. The area is also noted for its deer hunting. In 1961, 5,853 antlered deer were killed or 15.1 per cent of the state's total. During the same year 2,085 antlerless deer were killed or 12.0 per cent of the state's total. Based upon the rate of annual deer kill to acres of forest land, Centre and Lycoming counties rank among the highest in the state.

The swift streams originating in dense forest lands and flowing for scores of miles under a cool, shaded canopy, provide one of the best environments for trout and bass fishing to be found anywhere in Pennsylvania. Except for stretches along the major Susquehanna River, which is too warm for trout, much of the area is a vast, trout fishing region. Nevertheless this region is not as important to the non-resident and local tourist fishermen as is northeastern Pennslvania. This is largely due to the more rugged landscape, and consequently poorer accesibility. There also seems to be a preference by the non-resident and local tourist fishermen for the less strenuous lake fishing, which is so popular in northwestern and northeastern Pennsylvania.

A unique trout fishing area has been developed by the state on Spring Creek near Bellefonte in Centre County. This is known as Fisherman's Paradise. The stream has been improved by placing small dams in it. An associated fish hatchery has kept the area well-stocked

with trout. Special rules apply to fishing. However, because of expense, the program was curtailed in 1962.

Recreational facilities developed by private capital are not of great importance to the tourist trade of the area. Summer homes and hunting lodges, built exclusively for recreation, are no doubt most important. Because few lakes are found in the region, the streams influence the location of many of the summer homes. They are concentrated primarily along the rivers and major tributaries. Hunting lodges are normally situated along wooded ridges and divides. There are more than 200 summer homes and lodges in the area.

Although the region has a long winter and a heavy snowfall, few winter recreational facilities have been developed. A new ski lodge with two ski slopes was placed in operation in 1963 near State College. Black Moshannon State Park also has ski facilities.

PROBLEMS AND RECOMMENDATIONS

The tourist industry in the Upper Susquehanna region is relatively undeveloped. There are a number of reasons for the limited growth of a recreational economy. Of the retarding factors none is of greater importance than the isolation and resulting inaccessibility of the area (Figure 3). The two major highways within the region, routes 322 and 220, are peripheral to the vast forest areas. Large areas, particularly in the northern portion of the counties are served primarily by unpaved timber roads. In addition, many of the paved roads are narrow, and frequently in poor repair. The completion of the Keystone Shortway will provide a major four-lane highway through the heart of this region. However, unless access roads are provided, the Shortway will provide only a passageway through the region with few people stopping to enjoy this wilderness area. The development of transportation facilities to provide adequate accessibility is a primary prerequisite to the expansion of the recreational economy.

If a recreational economy is to be an effective economic stimulator, services must also be provided for the tourist. The facilities in the state parks at present are only for outdoor recreation and are quite limited. The state parks in the four

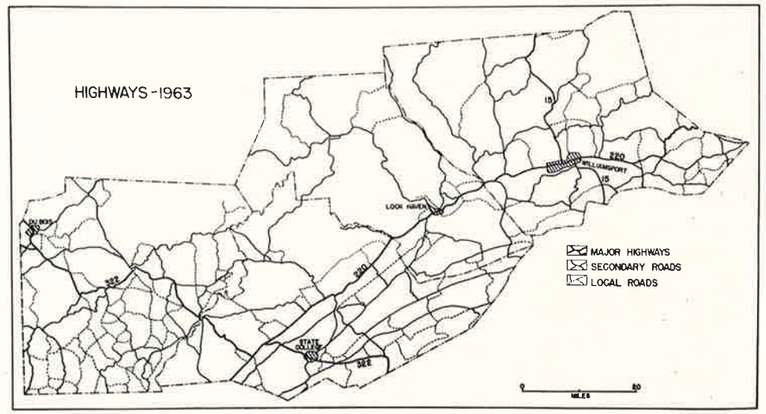

Figure 3. Highways 1963.

counties have only 190 tent and 83 trailer campsites. The S. B. Elliott Park has 21 cabins, Parker Dam 16, and Black Moshannon 14 cabins. Within the state parks and picnic areas, there are 2,340 tables, 437 stoves and fireplaces, and 50 picnic shelters.

With the growing demands for out-

Figure 4. Strip Mined areas of southeastern Clearfield County.

door recreational facilities by individuals from all economic classes and from every age group, the present facilities are inadequate. Fundamental to the development of a modern tourist region is the establishment of food and shelter facilities ranging from the camping ground and the general store to the modern lodge with its excellent dining room and other amenities.

The establishment of food and shelter in a potential recreation area, however, is not sufficient to develop the tourist industry. Other facilities must be provided in order that the tourist may enjoy his vacation. For example, trails must be developed and clearly marked for hiking and horseback riding. Riding stables need to be established. The golf courses in the Upper Susquehanna region are private and therefore not readily accessible to the tourist. Public golf courses are needed in the area. There are no natural lakes in the region and few man-made water bodies. The development of new man-made lakes is another essential to the growth of the tourist industry.

In the United States today there is a growing awareness of past cultures and economies. Because this region was a part of the great coniferous forest belt of the Appalachians, it developed many communities based on lumber in the nineteenth century. The restoration of a lumber town with an associated museum would attract a large number of tourists.

As urban population increases there is a growing demand for information about nature. Facts about nature which were once commonplace to the rural dweller now elude the city dweller because of his environmental surroundings. A portion of this wilderness area should be preserved in as near a primeval state as possible. It could then be utilized as a great outdoor laboratory for nature study. The development of such an area could include instruction for both students and adults.

Although much of this region is one of the most scenic in Pennsylvania, the strip mined area of southern Clearfield County presently detracts from the tourist potential (Figure 4). About 20 per cent of this area is in spoil banks. In this area acid water from the abandoned spoil banks has adversely affected the fishing. A conservation policy is needed to restore the strip mined areas. With a minimum of effort many of the strip banks could be converted into small lakes which could then be utilized for fishing, boating and swimming. Thus a debit factor could be changed to an asset.

CONCLUSIONS

Under legislation now proposed in Pennsylvania's 1963 General Assembly new recreational areas will be created in the state. This legislation, known as Project 70, will authorize the Commonwealth to create a $70,000,000 bond issue for the acquisition of land for parks, reservoirs, and historical sites. Within this proposal Centre, Clearfield and Clinton counties are designated as tourist destination areas and Lycoming County as one of 43 critical urban counties which are in need of more recreational facilities.

The acquisition of additional state forest land is of limited importance in the development of the tourist industry of the Upper Susquehanna West Branch Basin. The development of new tourist facilities through governmental and private interests is essential however, to fulfill the future tourist potential. The present state lands should be maintained as "wilderness" areas with the expansion of basically the same types of outdoor facilities as now exist in the state parks and picnic areas. At the same time private interests should develop needed housing and food facilities and other tourist attractions.

Planning is needed when a new tourist region develops. Because of the seasonal nature of the tourist industry, buildings are frequently constructed that soon become shoddy, and in certain instances create recreational slums. State and local planning is necessary to prevent the deterioration of a natural region.

The tourist industry could stabilize the economy of a large portion of the Upper Susquehanna Basin that is now in a decline. Developmental recreational groups, such as the Otactin group in Clearfield County, are presently being formed in the area. State and local governmental plans should be coordinated in order to develop the region as a unified tourist area. The future is promising for there are few areas in eastern United States that remain as undeveloped in their tourist potential as the Upper Susquehanna West Branch Basin.

EMPLOYMENT IN SELECTED MANUFACTURING INDUSTRIES IN PENNSYLVANIA

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ABSTRACT

This paper examines employment in four manufacturing industries in Pennsylvania (two each in durable and non-durable categories) with the specific purpose of determining their distributional patterns and drawing correlative conclusions in regard to their distribution. The industries selected for study are: (1) textile mill products, (2) apparel and related products, (3) primary metal products, and (4) fabricated metal products.

Analysis first proceeds with an investigation of the distributional pattern of the four industries. The distributional patterns show several dstinct regions within the state where durable (metal and fabricated metal products) and non-durable (textile and apparel products) industries predominate. An attempt is then made to ascertain what correlative patterns of durable and non-durable industries exist. Analysis suggests a certain degree of correlation for the western part of the state, while the east has a large degree of homogeniety. This latter feature may be partially explained by that region's proximity to the large metropolitan areas of Philadelphia and New York.

The purport of this study is to examine the distribution of employment in four manufacturing industries in Pennsylvania, and to suggest some reasons for the observed pattern of distribution of the four industries. The industries selected for study are: Textile Mill Products, Apparel and Related Products, Primary Metals Products, and Fabricated Metals Products.

The largest manufacturing employer in the state is the primary metals industry. Its associative industry, i.e., the industry which uses its end products, is the fabricated metals industry. As of 1961 the two industries accounted for 316,795 employes out of a total of 1,370,000 in all manufacturing. The second largest industry is apparel which employed 169,634 workers for the same period; and, the textile mill products industry employed 75,032 production personnel during the same period. Together, the four industries had a total of 561,461 employes, or 41% of all manufacturing employes in the state.[1]

Figure I indicates that the distribution of the four industries is fairly uniform throughout the state. Exceptions to this, however, appear in the northern tier of counties and in several of the west-central counties. However, Figure I does not indicate the level of employment of the industries. The quantitative distribution is shown in Figures 2, 3, 4, and 5.

As shown in Figure 2 distribution of employment is fairly uniform in fabricated metals with a somewhat heavier concentration in the southeastern and western parts of the state. Perhaps the best explanation for concentration in the southeast is the area's proximity to the large urbanized markets of Megalopolis[2] which has within its boundaries some 38 million ultimate consumers.

The two counties with the greatest fabricated metals employment, Philadelphia and Allegheny, lie at opposite ends of the state. Concentration in Allegheny is due to the very great degree of primary metals production in and around that county (Figure 3.). The counties of Beaver, Allegheny, Westmoreland, and Cambria average 21,500 persons in primary metals. The only other county that approached this level in 1961 was Northampton at the eastern end of the state with an employment level of 14,025.

Northampton's proximity to the counties of Philadelphia and Montgomery, which are an integral part of Megalopolis, suggests that primary metals flowing from Northampton move into the fabricated metals industry of these two counties and other parts of the industrial East.

It will also be noted that where primary metals employment is low, as in the northern and southern tier of counties and in the greater portion of the central part of the state, employment in fabricated metals is equally low. The reverse is also true, i.e., in those counties where there is a great deal of primary metals activity one will find high fabricated metals employment.

Since the fabricated metals industry uses the end products of primary metals, locationally we may consider fabricated metals to be more versatile than primary metals. This, of course, implies adequate transportation facilities. A good transportation network is an important reason why fabricated metals are able to locate in counties that do not have a base of primary metals. But for the seven counties where this is actually a fact, it must be mentioned that fabricated metals employment is low. (Compare Figures 2 and 3.)

The distributional pattern of textile and apparel employment is markedly different than that of the metals industry. Figures 4 and 5, however, show a striking coincidence of textile and apparel employment. In both industries, the eastern part of the state clearly predominates over the rest of Pennsylvania.

The leading textile counties are Philadelphia, 21,000, and Berks, 10,000. Both are near the large Megalopolitan apparel markets. Montgomery and Lehigh counties, important in textiles, are also close to Megalopolis. Three other principle textile counties, Lackawana, Luzerne, and York, are in economically depressed areas, suggesting the parasitic nature of the textiles industry.

Until 1947, textiles accounted for more employment than apparel. However, in keeping with the movement of industry to the South and West, and increasing automation, textile employment has seen its ranks dwindle from the 1930 high of 185,000 to the 1961 low of 75,000, whereas the apparel industry has grown from a 1930 figure of 30,000 to a 1961 high of 170,000 with less automation.[3]

The movement of the textile industry is a familiar one to many. Changing technology and rising labor costs resulted in the movement of plants from sources of inefficient power to the location of raw materials and cheap labor. Consequently, with this movement, the newly built plants were in a better competitive position due to their more up-to-date and efficient production facilities, their proximity to raw materials, and the availability of cheap labor.

The apparel industry has two important characteristics: it is a low wage industry characterized by female employment and it is most ideally located in close proximity to its own markets.[4]

The leading apparel counties as seen in Figure 5, are Philadelphia, Luzerne, Northampton, Lackawana, and Schuylkill. In 1961 their average employment was 18,450. With the exception of Philadelphia and Northampton, there has been much unemployment in these counties due to the decline in anthracite coal mining. It would seem, then, that the distribution of apparel employment is, in part, the result of parasitic influences.

Figure 5 highlights the relation of low wage counties, i.e., especially those counties located in some of the anthracite and bituminous coal regions, to apparel concentration. This relationship is even more strikingly brought out by Figure 6 which shows the concentration of textile apparel

DISTRIBUTION OF SELECTED INDUSTRIES IN PENNSYLVANIA
(BY COUNTY)

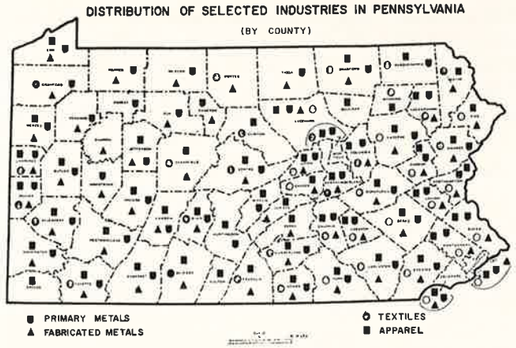


FIGURE 1

FABRICATED METALS EMPLOYMENT IN PENNSYLVANIA
(BY COUNTY)

FIGURE 2

PRIMARY METALS EMPLOYMENT IN PENNSYLVANIA
(BY COUNTY)

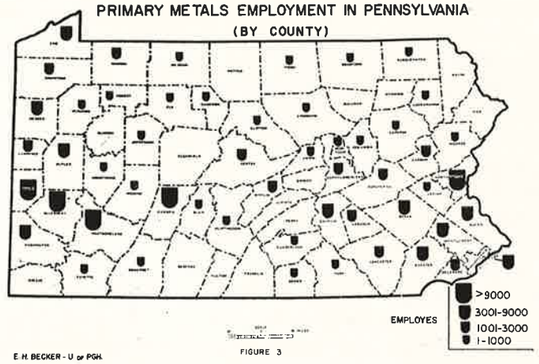


FIGURE 3

E.H. BECKER - U. OF PGH.

TEXTILE EMPLOYMENT IN PENNSYLVANIA
(BY COUNTY)

FIGURE 4

APPAREL EMPLOYMENT IN PENNSYLVANIA
(BY COUNTY)

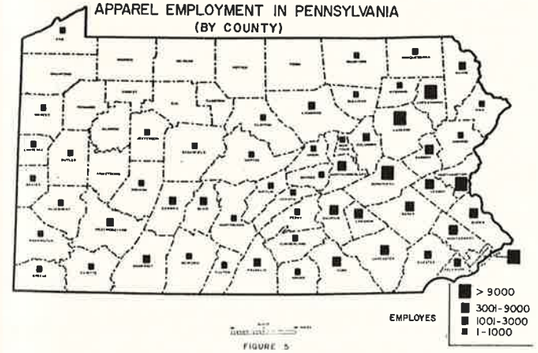
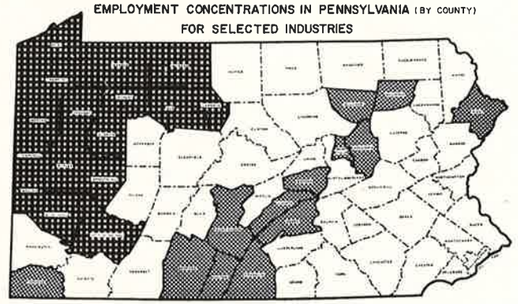


FIGURE 5

EMPLOYMENT CONCENTRATIONS IN PENNSYLVANIA (BY COUNTY)
FOR SELECTED INDUSTRIES



MORE THAN 90%
PRIMARY & FABRICATED METALS

MORE THAN 90%
TEXTILES & APPAREL

FIGURE 6

employment as a percent of total employment of the four selected industries. It will be noted that in the low wage counties more than 90% of the total employment of the four industries is in textiles and apparel. Too, Figure 6 shows an associative pattern of primary to fabricated metals. The northwestern section of the state does not have textile and apparel concentrations mainly because of its distance from the major markets and its lack of incipient textile/apparel settlement. On the other hand, this area is well serviced by primary and fabricated metals production due to its location and the fact, that once constructed, the mills of primary metals represent major capital investment and, therefore, are difficult to relocate.

Figure 6 shows sixteen counties with concentrations of primary metals and fabricated metals production. Total manufacturing in these counties for 1961 was 367,539, averaging 22,971 per county. The thirteen counties with textile/apparel concentrations accounted for only 33,613 employees in all manufacturing with a county average of 2,585. It is apparent, then, that counties with high total manufacturing employment have, as well, high concentrations of metals employment. Similarly, counties with low total manufacturing employment have high concentrations of textile and apparel employment. This relationship appears to hold for at least two-thirds of the counties in Pennsylvania, although concentrations in these cases are not at the 90% level.

The factors which favor concentration and which play a role in the location of the four selected industries are clearly discernable. The large markets of Megalopolis, the attraction of associative industries, the availability of labor, the state of the local economy, and the availability of first-class transportation facilities all play their part in the distributive pattern of each of the industries considered.

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EIGHTEENTH CENTURY INDUSTRIAL BETHLEHEM A STUDY IN HISTORICAL GEOGRAPHY

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When most people from Bethlehem are traveling, and are asked where they come from, the imemdiate response to their answer is, "Oh yes, Bethlehem. That's where the Bethlehem Steel Company is located." The modern Bethlehem is so identified, yet few people realize that two centuries ago, when it was only a small frontier community on the fringe of settlement, three days at least from tidewater, the community was even then an industrial center in every sense of the term industrial. By actual count there were 38 industries in full swing along the banks of the Monocacy Creek just above its junction with the Lehigh River, in 1748. Bethlehem had been founded in 1742, and six years later its population stood at 395. It is safe to assume that at least one quarter of these people were engaged in the extraction of raw materials or the manufacture of finished goods. The value added to the finished goods by manufacture was certainly close to 100%. By 1760 the total number of industries had increased to fifty. This industrial development was phenomenal to say the least. How do we account for it?

First it might be well to look at the industries represented. We list them herewith, in their respective categories. Note that only industries of production are included. Extractive industries such as quarrying, lumbering, etc., are not considered. The productivity of these early industries can be seen in the stock list of Bethlehem's first general store, which was opened for business in 1753. Over one hunderd commodities offered for sale were the products of the industries opeating in the community.

METAL WORKING
Bell foundry
Blacksmith
Cooper
Copper smith
Foundry
Nail works
Pewter works
Silver smith
Tin smith

BUILDING
Brick making
Joiner and glaziery
Tile works

CLOTHING
Breeches maker
Glove maker
Hatter
Shoe maker
Stocking weaver
Woolen clothes

FOOD AND BEVERAGES
Bakery
Brewery
Buckwheat mill
Grist mill

TEXTILES
Blanket weaver
Carpet weaver
Linen weaver
Silkworm culture

CHEMICAL
Apothecary
Dyer
Glue works
Oil mill
Salt Peter works
Soap mill
Tar works

LEATHER GOODS
Harness maker
Tannery

WOOD WORKING
Box & spindle works
Cabinet maker
Chair maker
Gunstock maker
Wagoner

MISC.
Agricultural tools
Book bindery
Clock maker
Furrier
Fuller
Millwright
Organ building
Pottery
Rope walk
Wheelwright

In order to understand this industrial development it is first necessary to examine the economic organization of the village itself. From 1754 to 1762 Bethlehem was operated under a system known as the General Economy. This was set up as a temporary economic arrangement by which the labor of the community was geared to fullfil the purpose for which Bethlehem was founded by the Moravians.

This purpoes was twofold. First the Moravians aimed to Christianize the Indians of eastern Pennsylvania and adjacent areas. Second they hoped to provide spiritual leadership for the many German settlers of southeastern Pennsylvania who were without pastors. Bethlehem was founded to be the administrative center of this work. It was also to serve as a supply base for the missions. Included in the Economy was the village of Nazareth, eight miles to the north, and a number of smaller villages known collectively as "the upper places." These settlements were thoroughly organized. The resources they deevloped on the land they controlled provided the wealth that financed much of the Moravian's work in America.

The people of these settlements were divided into two groups; one, the Pilgergemein, composed of those who went out as missionaries or evangelists or stayed home as teachers; the other, the Hausgemein, or local congregation, whose members did the work to maintain the Economy. No one was paid for his toil. All were fed, clothed, and housed from a common fund. Private property, however, was not forbidden. All property such as real estate, tools of production, etc., was owned by the congregation. There was no compulsion. Anyone who did not like the way of life under the economy was free to leave.

Although Bethlehem's function in this system was primarily administrative, because of its position as a supply center the village quickly became involved with the business of manufacturing the commodities needed, not only to maintain itself, but also the mission work to which its people were committed. The outlying villages of the Economy furnished raw materials from their land. Some items, unobtainable from Moravian land, were secured nearby. Bar iron from Durham Furnace on the Delaware River is a case in point. In a few instances raw materials such as cotton and a few metals, were hauled to Bethlehem from the ports of Philadelphia or New York.

Grain raised on the Economy's farms was milled, distilled, and brewed along the Monocacy Creek whose water furnished both the power to turn wheels and to be boiled for other purposes. Flax for linen was raised nearby and processed in the mills. Local clay furnished raw material for bricks and tiles as well as pottery. The surrounding woodlands furnished charcoal for fuel and lumber for many uses. Wool was raised locally, as was leather, and tannin came from the forests as well as dyes. An herb garden contributed to the apothecary's stock of medicines. Silk worms and mulberry trees were introduced, but without much success.

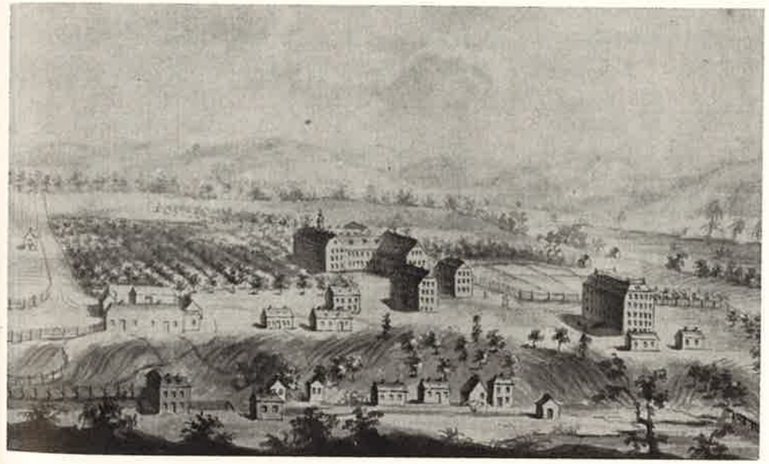
Bethlehem's infant industrial establishments were for the most part built along the Monocacy Creek and on the slopes of that stream's deep valley. Above them lived the townsfolk in their great houses on Church Street, the single men in one house, the single women in another, and the married people in a third. This communal living was a part of the Economy's plan. Work was distributed accordingly.

What about technical skills and labor? The members of the community were recruited from the old world, chiefly Germany, and brought to America in ships owned by the Moravians. Each shipload was known as a sea congregation. They were made up of men and women selected or the skills and abilities. Thus, if a tanner was needed, a tanner was recruited and brought to Bethlehem. In this way the population became a highly specialized group, trained in the production of things most needed for modifying frontier living.

An example of how well this recruitment worked is seen in the establishment in Bethlehem of America's first municipal water works. One of the factors that played a major role in the location of the town's first house was the presence of a large spring nearby. This spring immediately became the water supply for the infant community. We might add that it furnished Bethlehem with its water until 1912 when pollution forced its closing.

The first method of supplying the town with water consisted of carrying it from the spring up the hill to the big houses on Church Street. This was slow, inefficient, and hard work. In 1751, Hans Christopher Christiansen, a Danish mechanic arrived in Bethlehem. He designed a pump which forced the water to a reservoir above the houses to which it was fed by gravity. This was placed in operation in 1754. The pipes used to carry the water were hollowed tree trunks. Several have been preserved and can be seen today.

The Economy was abolished in 1762. Individuals then purchased or rented from the Church most of the land, stock, and fixtures of the industrial establishments and operated them as private ventures. Some were abandoned within a few years. Others survived into the nineteenth century to depart from the Monocacy valley as industry was located in other areas. Today none survive although a flour mill operated in the valley well into the present century.



Credit for Photo: Historic Bethlehem, Inc.

The view above represents Bethlehem in 1755 as seen from the west. In the foreground are the mills and workshops which lined the Monocacy Creek. On the hill are the imposing multi-storied structures which contained living quarters for upward of five hundred villagers. Many of these fine buildings, now in their third century of continuous use, may be seen on what today is Church Street in Bethlehem.

The Monocacy area that was occupied by these early industries gradually declined into slums and dumps. Prior to the building of Bethlehem's "Hill to Hill" bridge, 1922-1925, considerable traffic passed through the area but much of this ceased when the bridge was opened. Decline gained momentum. By 1950 the area was not only an eye-sore but a menace to public health.

In March 1959 the Redevelopment Authority of the City of Bethlehem submitted a Project Eligibility and Relocation Report on the Monocacy Creek Urban Renewal Area. The result of this report was a grant of $112,595.00 for use in the advance planning of the area. Included in these plans are the restoration of the eighteenth century industrial sites. A number of structures are still identifiable. Among these are the old waterworks, the tannery, the grist, and the fulling mill. Foundations of the oil mill, the locksmith shop, the smithy, and nailshop have been located. Recently, through demolition of more recent structures the foundations and a wall of the pottery have been identified.

The restoration of the Monocacy industrial area is now under way. Historic Bethlehem, Inc., is in charge of the work. This organization was established in 1957 for "the charitable and educational purpose of improving, preserving, and restoring historical areas, sites, momuments, buildings, and objects located in Bethlehem, Pennsylvania, and its vicinity." The Monocacy restoration when completed will take its place among such restorations as Williamsburg in Virginia, Old Salem in North Carolina, or Old Sturbridge in Massachusetts. Like them, it will bring into focus a way of life that has vanished from America but which should be remembered and understood by generations yet to come.

DOCUMENTATION

A number of secondary sources give excellent lists of the early Bethlehem industries. Chief among these are:

Levering, J. M., A History of Bethlehem, Pennsylvania, published by the Times Publishing Company, 1903.

Leibert, A. H., A Chronicle of The First Century of Bethlehem, Pennsylvania, 1741-1841, published privately in 1921.

Schwarze, W. N., Early Moravian Settlements in America, a presidential address of the American Church History Society, delivered in 1922.

All these authors had at their disposal the original Bethlehem Diary, a day by day account of everything that happened in Bethlehem. These papers are on file in the Provincial Archives of the Moravian Church in Bethlehem.

Considerable help in the preparation of this paper was given by Mr. Stuart Bolger, Executive Director of Historic Bethlehem, under whose direction the work of restoration is being done.

THE BIMODAL DISTRIBUTION OF HOARDING SCORES IN THE GOLDEN HAMSTER

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ABSTRACT

Hoarding scores of 16 golden hamsters are shown to have a bimodal distribution. The two curves of the distribution may be separated into one for "non-hoarders" with a maximum frequency between 0 and 5 and with little variance, and one for "hoarders" with a maximum frequency between 50 and 60 and a large variance. The presence of such distributions in data presented elsewhere is demonstrated. The implications of such distributions for a genetic interpretation of hoarding are discussed.

INTRODUCTION

The genetic basis of hoarding behavior has been implicit in the data which have been gathered on this activity since Wolfe first applied the laboratory method to its study. The implications rested in differences between strains in hoarding intensity (3, 4), and in differences observed within the same strain (1, 2, 6). Working with a strain of brown rats, Morgan *et. al.* (2) had to discard 16 of their 30 experimental animals (44%) because after 20 trials they still would not hoard to the criterion of 5 pellets during a 30-minute period, even under deprivation conditions. Marx (1) encountered a similar difficulty when 17 of his 40 Ss (43%) failed to reach the same criterion on the first day of testing. An explanation of these and similar findings may be suggested on the basis of Stamm's paper on the genetics of hoarding (5). Stamm has demonstrated that in crosses between high- and low-hoarding strains of rats, the scores of the F_1 and backcross generations outline curves very much like those observed in experiments on physical traits involving a single dominant gene. He suggests that the simplest interpretation of his data is "that a single dominant factor is primarily responsible for the obtained differences in hoarding performance among the strains of rats investigated." A major implication of this suggestion is that if hoarding is due to a single dominant genetic factor, then measurements of the activity in a random population of animals should reveal a bimodal distribution of scores with some of the animals showing a scatter of scores on the positive axis of a graph and others with scores about the zero point. Futhermore, the distribution of animals in the high-low groups could be an indication of the frequency of the gene in the population. In the present investigation the distribution of hoarding scores for a group of 16 golden hamsters is analyzed and interpreted in light of these expectations.

METHOD

Animals

The experimental animals were drawn from two strains of golden hamsters maintained in the Bucknell colony, designated by coat color as banded amber gold (Ag) and banded cream (BCr). The distribution was 10 amber golds (5 males, 5 females), and 6 banded creams (4 males, 2 females). The age of the group was about six months.

Procedure

The 16 Ss were individually maintained in gallon jars placed on their sides with the openings screened with wire mesh. Each jar was provided with a water bottle and 75 g. of bedding. The bedding was partially changed (about

half replaced) once during the experiment.

The animals were given at least a week to acclimate to their new jars and the conditions in the experimental room. The experiment started after this time and continued for 16 days. Hoarding trials were conducted every night between 9 and 10 P.M. for a period of 20 minutes. At the start of each trial period the screen was raised from the openings of the jars, giving each animal access to an alley 12″ x 3″ x 3″, at the end of which was a bin the size of a coffee can containing 150 Purina Lab Chow pellets. Each pellet weighted about 3 g. At the termination of the 20 minutes the alleys were closed and the number of pellets in the home jars counted. The hoarded pellets were replaced in the bins, and each animal was given a standard food ration to last until the next trial.

The 16 trials were evenly distributed between two conditions—satiation and deprivation. After each of the first seven trials 5 pellets (15 g.) were placed in the home jars as a food ration. Since this ration was never completely consumed it is reasonable to assume that the first 8 trials were run under satiation conditions. After trial 8 the ration was reduced to 1½ pellets (5 g.) per day.

	I		II		III	
S	MEAN	SD	MEAN	SD	MEAN	SD
1	15.2	13.5	63.2	31.0	39.2	34.2
2	58.4	19.8	26.7	16.8	42.5	24.4
3	.1	.3	.4	.7	.2	.5
4	.4	.7	0	0	.2	.5
5	99.9	20.5	43.2	37.1	71.5	41.3
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	13.8	20.7	42.4	36.1	28.0	32.7
9	0	0	9.6	15.3	4.8	11.4
10	.5	.7	1.2	3.3	.9	2.4
11	31.2	26.0	53.5	32.7	42.3	32.3
12	0	0	.6	1.1	.3	.8
13	0	0	6.8	15.6	3.4	11.6
14	0	0	.5	.9	.2	.2
15	43.8	35.9	11.6	18.8	27.7	32.9
16	5.6	6.9	.2	.7	2.9	5.2

Table 1. Mean hoarding scores for 16 hamsters (Ss) I. During satiation conditions, II. During deprivation conditions, and III. For entire test period.

Since no portion of this ration was ever left over and the mean loss of weight for the group was 2 g. per day, the last 8 trials may be regarded as deprivation runs.

RESULTS

The results of the 16 day hoarding period are summarized in table 1. There was no significant difference in hoarding between the two strains. A slight sex difference appears in the amber golds in which a greater percentage of the males hoarded than did the females. This is probably a result of the sample size since 1) the females which did hoard did as well as the males, and 2) in a preivous investigation using the same strain the females showed no inferiority. There was no significant difference in hoarding between the satiation and deprivation conditions.

Two striking trends are observed in the data of table 1:1) the means are grouped in two widely separated clusters, one group ranged very close to zero and the other spread more widely between 11 and 99, and 2) the high means have extremely large deviations. Figure 1 is a graph of the mean hoarding scores for a breakdown into four-day intervals of the 16 day test period. The breakdown was carried out in order to secure a representative number of points for the graph. 61% of the scores fall within the interval of 0-10. (59% fall below 5.0.) The remaining 39% are distributed from 10-120. The graph is suggestive of a bimodal distribution for the hoarding scores with a steep curve about the 1-5 interval with very little variance, and a low curve from 10-120 with a large variance. Such a distribution may be the result of two separable sub-populations in the major grouping.

DISCUSSION

Bimodal distributions of hoarding scores may be seen in data other than that reported here. The Morgan, Stellar and Johnson data on the effects of food deprivation on hoarding in the rat (2)

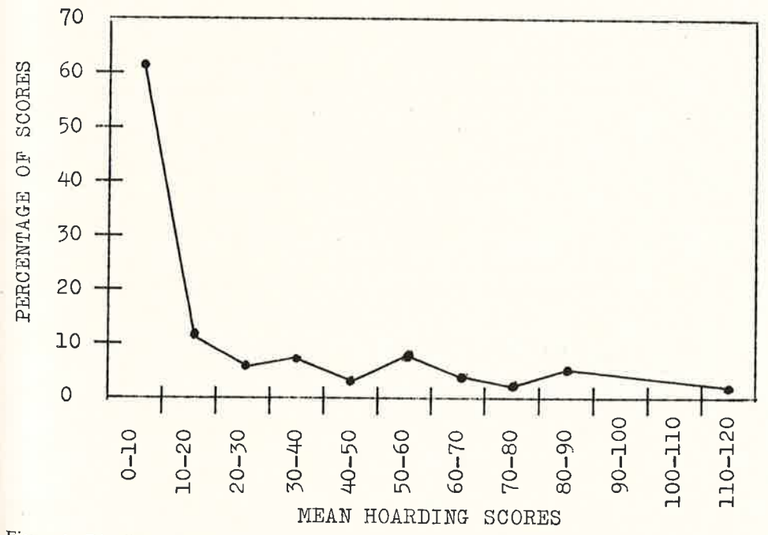

Figure 1. Distribution of mean hoarding scores for four-day intervals of the 16-day test period.

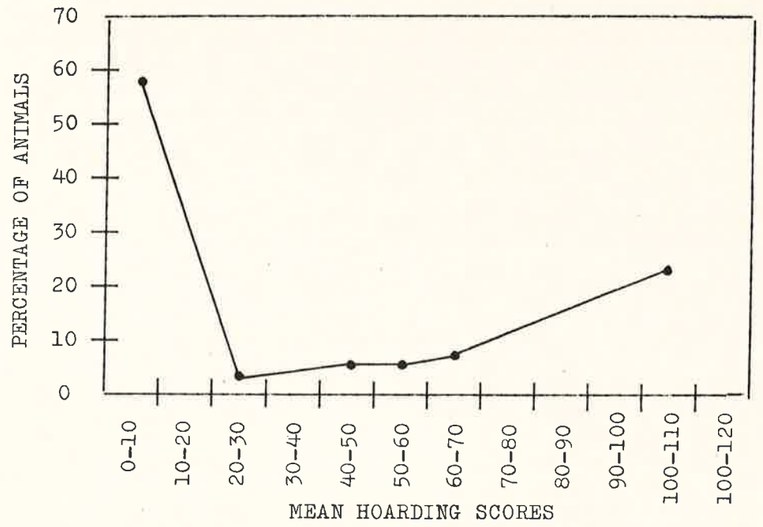

Figure 2. Distribution of mean hoarding scores for 36 rats as reported by Morgan, Stellar and Johnson, 1943.

are treated in figure 2 in the same manner as the hamster data in figure 1. The similarity of the two distributions is evident. A similar treatment of the scores obtained by Marx (1) on his first day of testing (before he discared the non-hoarders) reveals the same bimodal trend.

Measurements within a population of a trait controlled by a number of different genes usually conform to a normal distribution. If, however, a trait is controlled by a single gene the measurements will form a bimodal distribution with some of the population lacking the trait and others possessing it to a varying degree, depending upon whether the gene exhibits total dominance and whether or not it interacts with other genes. The bimodal distributions of hoarding data suggest that a single factor may exert primary influence upon the activity. Further study is necessary if we are to interpret the wide rage of scores and the great variance as interaction with other genetic factors, with organism factors, with environmental factors, or a combination of these.

ACKNOWLEDGMENT

I would like to thank Dr. Hulda Magalhaes of the Bucknell Biology Department for her aid and encouragement in this work. Both were invaluable.

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PROGRESS OF U. S. GEOLOGICAL SURVEY INVESTIGATIONS IN THE ANTHRACITE REGION OF PENNSYLVANIA[1]

J. Peter Trexler[2], Gordon H. Wood, Jr.[3], and Harold H. Arndt[3]

ABSTRACT

More than half of the structurally complex Anthracite region of eastern Pennsylvania has been mapped during a period of more than 10 years. Subdivision of previously recognized formations and members into map units has resulted in the recognition of facies changes, an angular unconformity, and numerous folded and nonfolded thrust faults. Detailed mapping has revealed that geologic relations and history are far more complex than had been thought previously.

INTRODUCTION

SUMMARY OF PREVIOUS WORK

The Anthracite region of eastern Pennsylvania is a classic region in American geology. Because of its economic importance it was studied extensively during the 19th century, particularly by the Second Pennsylvania Geological Survey. Much information was obtained concerning the stratigraphy and structural geology of eastern Pennsylvania that contributed materially to the general understanding of Appalachian geology.

The Anthracite region historically has been considered a comparatively simple area geologically, with the coal-bearing beds of Pennsylvanian age preserved in four deeply downfolded synclines which form the anthracite fields. The geologic history, also, was throught to be comparatively simple, commencing with a long episode of deposition of marine beds, followed by an almost equally long episode of continental deposition which culminated in coal swamps that developed during the Pennsylvania Period throughout most of the eastern part of the United States. This was followed by the Appalachian Revolution when the thick sequence of strata was tightly folded and subsequently subjected to erosion and epeirogenic uplift which led to the present topography.

PRESENT INVESTIGATIONS

The last comprehensive study of the entire region was that done by the Second Pennsylvania Geological Survey, although some geologic work has been done by individuals and small groups. Therefore, at the request of the anthracite industry and after consultation with the Pennsylvania Topographic and Geologic Survey, the U. S. Geological Survey inaugurated a research project in the Anthracite region. Work was begun in the Western Middle anthracite field in 1947 and in the Southern anthracite field in 1953. These projects are still active. The Western Middle Field has been completely mapped, and a series of detailed coal maps, with accompanying cross sections, contour maps, stratigraphic sections, and descriptive texts has been published. Except the southern "fishtail," the western half of the Southern anthracite field has been mapped in detail, and several reports and papers have been published concerning this area. The reports published by geologists working on both projects are listed in the selected references at the end of this paper.

Although the original emphasis was on mapping the geology of the anthracite fields, it was felt that much additional information essential to sound interpretations and conclusions could be obtained from areas of older rocks adjacent to the anthracite fields. Study of these older rocks has resulted in a better understanding of the structure, stratigraphy, regional

1 Publication authorized by the Director, U. S. Geological Survey.

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geologic setting ,and geologic history of the Anthracite region as a whole.

In addition, work done by U. S. Geological Survey geologists on projects concerned with mine drainage and subsidence, and the radio-active mineral deposits in the vicinity of Jim Thorpe (Klemic and Baker, 1954), has contributed detailed information on several areas other than those covered by the Western Middle field and Southern field projects. More than a thousand square miles of the Anthracite region has been mapped in the course of these various projects.

METHODS OF MAPPING

Field mapping was by conventional methods. Parts of the mined areas were mapped by plane table. Many stratigraphic sections were measured. In addition, the extensive use of aerial photographs by means of a pocket stereoscope enabled project geologists in the field to extrapolate information from the limited number of outcrops and to interpret to the greatest possible extent topographic features which reflect the bedrock geology. Despite the dense forest, widespread talus, stream alluvium, and soil deposits, all of which obscure the bedrock, detailed mapping on aerial photographs was accomplished in the ridge and valley region of the Appalachians (Trexler, 1960).

The major formations previously recognized in the region were subdivided into members (Arndt, Wood, and Trexler, 1962; Trexler, Wood, and Arndt, 1962; Wood et al., 1956), which were in turn subdivided into numerous mappable units. The mapping of multiple units on aerial photographs resulted in the discovery of many geologic structures and made possible the interpretations of stratigraphic relationships that would otherwise have been overlooked. Field work done within the anthracite fields was then correlated with the wealth of mine data furnished by local mining companies and a well-documented three-dimensional picture of the geologic relations has resulted.

RESULTS

Detailed work in the Anthracite region has revealed that many of the classic conclusions concerning the geology of the folded Central Appalachians are inadequate. The geology and geologic history of the region are much more complex than had previously been thought. These results in the Anthracite region lead to the obvious conclusion that the geology of the Appalachians as a whole is far from understood. Some of the specific discoveries, concepts, and conclusions arrived at by geologists on the anthracite projects can be outlined under the following headings:

1. *Abundance of faults.*—Faults are common in the Anthracite region. Low-angle, high-angle, and bedding-plane thrust faults are abundant. Small tear faults are common, and several large tear faults, with movements of about half a mile, are present along the southern margin of the Southern field (Wood and Kehn, 1961). Many of the low-angle thrust faults are folded, which adds to the difficulty of recognition and mapping. A study of many mine maps and sections, however, plus detailed surface mapping, established unquestionably the presence of folded thrust faults in the anthracite fields; similar faults have been found in the older rocks surrounding the anthracite fields. As much as a mile of movement has occurred along the larger folded faults (Wood et al., 1958), and collectively the cumulative movement has been several miles. In addition, at least one nonfolded low-angle thrust fault, the Sweet Arrow, has a displacement which may be as great as 2 or 3 miles.

The large, low-angle thrust faults are similar in many respects to the large overthrusts in the Southern Appalachians, although not as large in stratigraphic displacement. However, some of these faults in the Anthracite region have been more intensely folded. Thus, the Anthracite region appears to have been more severely deformed than the Southern Appalachians. For example, after the low-angle thrust faulting typical of both areas, beds in the Anthracite region were subsequently folded into tight anticlines and synclines and then deformed by high-angle thrust faults and tear faults.

2. *Presence of unconformities.*—An angular unconformity exists between the Catskill and Pocono Formations (Trexler, Wood, and Arndt, 1961). This unconformity is exposed at only a few places but has been mapped throughout the western part of the Anthracite region. Bedding is parallel on opposite sides of the unconformity at many localities, but approximately 1,700 to 2,400 feet of gray and red sandstone and shale beds in the upper part of the Catskill Formation in the vicinity of Lykens is gradually truncated by the overlying Pocono Formation and is generally missing elsewhere in the western part of the Anthracite region. Plan fossils of Mississippian age have been found in these beds, and consequently the upper part of the Catskill Formation in this locality has been dated as Mississippian in age. Beds on opposite sides of the unconformity are in angular contact at other localities, although the angularity is not as pronounced. This unconformity is thought to have been caused by the Acadian orogeny and is dated as Early Mississippian in age.

Another unconformity probably exists between the Schuylkill and Sharp Mountain Members of the Pottsville Formation (Wood, Trexler, Yelenosky, and Soren, 1962, p. 194), and it is possible that a local hiatus occurs between the Pottsville and Llewellyn Formations in the western part of the Southern Anthracite field (Wood, Trexler, Yelenosky, and Soren, 1962, p. 195). Other unconformities are present in the area, but most are of minor stratigraphic importance.

The unconformities show that the tectonic history of the Appalachian geosyncline in Pennsylvania was complex and was interrupted by several breaks in sedimentation. They also indicate that several periods of uplift accompanied by gentle warping or folding preceded the Acadian orogeny and Appalachian Revolution.

3. *Presence of facies changes.*—A number of coarse gravels in the sedimentary sequence indicate that the highland area to the southeast, which contributed sediments to the Appalachian geosyncline during most of the Paleozoic Era, underwent almost constant crustal unrest which culminated in the Appalachian Revolution. The sedimentary history of the Anthracite region was the direct result of this crustal unrest in the source area. Periods of comparative tectonic calm in the source area are represented by siltstone, shale, coal, and limestone in the Anthracite region, whereas influxes of sand and gravel followed sporadic periods of uplift in the source area.

In Late Mississippian time an influx of gravel began along the southern margin of the Southern anthracite field. The first deposits of gravel are interbedded with red sandstone and shale, and have been assigned to the Mauch Chunk Formation of Mississippian age at Pottsville and along the southern margin of the Southern field (Wood et al., 1956). Succeeding deposits of conglomerate and sandstone followed, which are assigned to the Pottsville Formation of Pennsylvanian age. However, while conglom-

erates of the Pottsville were being deposited along the southern boundary of the Southern anthracite field, red-bed deposition of the Mauch Chunk continued to the north (Wood, Trexler, and Arndt, 1962, p. C40, C41). Therefore, the upper part of the Mauch Chunk Formation is of Pennsylvanian age in the region north of the southern boundary of the Southern anthracite field (Wood, Trexler, and Arndt, 1962, p. C41).

4. *Stages of structural deformation.* The influx of gravel which resulted in the deposition of the rocks of the upper part of the Mauch Chunk Formation and the Pottsville Formation recorded a major uplift in the source area to the southeast. The gravel represents detritus eroded during the first orogenic episode of the Appalachian Revolution, which during later episodes destroyed the Appalachian geosyncline. The conglomerates of Late Mississippian and Early Pennsylvanian age in the Pottsville and the upper part of the Mauch Chunk probably record a disturbance in the Central Appalachians that is partly equivalent in age to the Early Pennsylvanian Coosa disturbance of the Warrior coal basin of Alabama, which resulted in the accumulation of thousands of feet of sand and gravel.

The deformation which resulted from the Appalachian Revolution has been divided into five stages in the Anthracite region (Arndt and Wood, 1960): (1) gentle folding; (2) low-angle thrusting, the formation of imbricate thrust sheets, formation of subsidiary folds on developing anticlinoria and synclinoria, followed by additional low-angle and high-angle thrusting; (3) folding of low and high-angle thrusts and the further development of high-angle thrusts; (4) overturning; high-angle thrusting, and tear faulting; and (5) the probable formation of recumbent folds and nappe structures, and recurrent low-angle thrusting. Areas of approximately equal structural complexity, indicative of the various stages outlined above, have been plotted (Arndt and Wood, 1960, p. B183, fig. 181), showing variations in the intensity of deformation which they have undergone. The southeastern part of the Anthracite region is more complexly deformed than the northern part, which suggests that deformation proceeded from the southeast toward the northwest.

CONCLUSIONS

These discoveries and conclusions, along with others made during the course of geologic research in the region, indicate that the history of the Appalachian Revolution was long and involved. The area southeast of the Anthracite region was uplifted by the initial phase of the revolution during Late Mississippian time, with the result that gravel and coarse sand deposits spread northward across the Anthracite region. As uplift advanced northwestward, the beds in the Anthracite region first were warped, later broken by low-angle thrusts, and then strongly deformed by recurrent episodes of folding, low- to high-angle thrusting, and tear faulting. Intensive folding accompanied by low- to high-angle thrusting and tear faulting was the last stage of deformation in the southern part of the Anthracite region, but in the northern part the intensity of deformation reached only the stage of gentle folding and initial faulting. It is apparent from the preceding discussion that the geology and the geologic history of the Anthracite region are extremely complex. Many problems remain, and recognition of the fact that much detailed mapping and research are needed in the Appalachians should stimulate renewed interest in this area. Additional geologic work will undoubtedly modify many of the classic concepts concerning the geology of the folded Appalachians.

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PARTIAL SECTION OF WISSAHICKON SCHIST, WISSAHICKON CREEK

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ABSTRACT

Major units near Cresheim Creek are quartzite, quartzite and schist interbedded, and schist. Facies change rapidly. Minor units are differentiated by lithology, grain size and gradation, mica types, and mineral (garnet, staurolite, kyanite, tourmaline) size and abundance. The homocline between two anthophllite sills may be a fold overturned eastward, cut by thrusts.

INTRODUCTION

The type section of the Wissahickon Schist is along Wissahickon Creek (Bascomb, 1909). A detailed stratigraphic section has never been measured. The beds are highly contorted, facies changes are rapid, and interpretations have been based on secondary structural features alone.

The beds dip nearly uniformly to the northwest except near the Rosemont fault (Weiss, 1949), which separates the Wissahickon Schist and Baltimore Gneiss. The majority of lineations plunge northeast, and minor folds are usually overturned toward the southeast.

At the junction of Wissahickon and Cresheim Creeks (Figures 1, 2), a repetition in stratigraphic sequence; the curvature of a quartzite, Unit 4; drag folds, lineation, and a 4 inch chlorite zone all combine to suggest an overturned anticlinal fold cut by nappe thrusts.

STRATIGRAPHIC UNITS

Unit 1. This unit is a series of interbedded quartzites and schists, and the axis of the postulated anticline was arbitrarily placed in its center (Figures 1, 2). The beds have many minor folds overturned toward the southeast.

The quartzite is light gray, weathering light to dark orange-gray or brownish-gray; fine to medium grained; and schistose in part (mainly biotite). The beds contain thin layers and lenses of recrystallized quartz, with feldspar and mica. Garnets are relatively rare and small except in schistose layers.

The schists are greenish-black to white on fresh surfaces and weather to yellow or reddish brown. If rich in garnets they weather to a deep, dusky red. They contain common to abundant garnets from 0.5 mm up to 5 mm in diameter, and crystals of kyanite and occasional staurolite and tourmaline. Staurolite crystals are commonly broken and appear partly re-absorbed.

Quartzites and schists in other units are similar to unit one except where noted. All intergradations between schistose quartzite and quartzitic schist are present.

Unit 2. This unit is dominantly muscovite schist, with larger garnets up to 5 mm in diameter, and staurolite crystals up to 2 cm long. It contains thin layers of quartzite. On the south flank of the anticline it is more quartzose and weathers into dusky red and yellow-brown. Here it contains isoclinal folds and drag folds indicating overturning (Figure 1). On the north flank the unit contains prominent garnet and staurolite crystals and has a shiny unweathered appearance; small drag folds indicate a normal sequence.

Unit 3. This unit is a series of alternating schists and quartzites like Unit 1, but not as highly folded. Lateral changes in color and composition are very rapid below Cresheim Creek bridge (Figure 1). Near the Shakespeare plaque, drag folds, and cleavage steeper than bedding indicate a normal sequence, although a minor cleavage dips less than bedding.

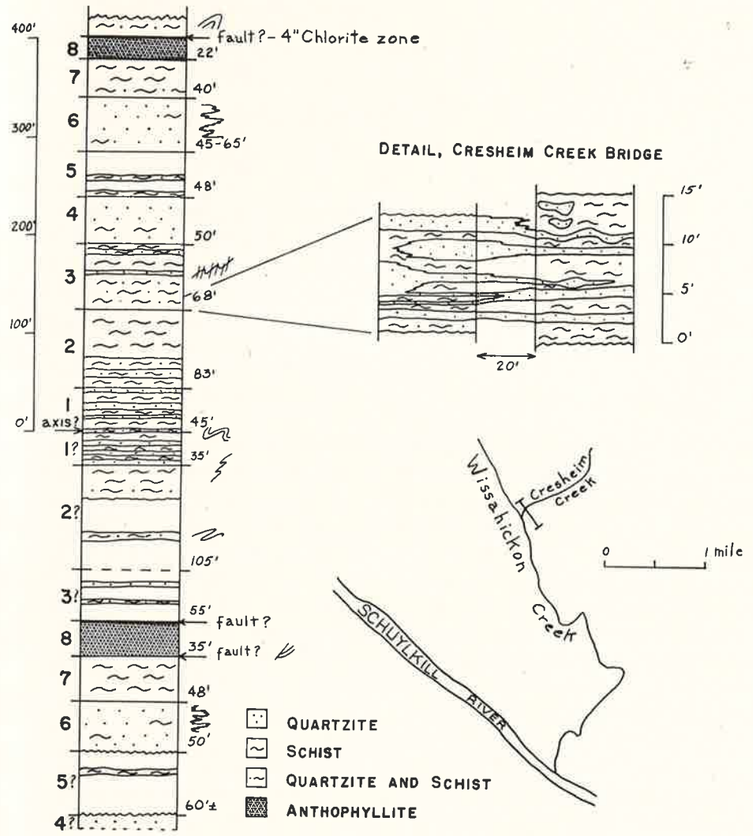

FIGURE 1. CRESHEIM CREEK SECTION

Unit 4. A resistant quartzite, unit 4, occurs below the aqueduct north of Cresheim Creek. The quartzite bends southward as it crosses the creek (Figure 2), and continues as a ridge up the hill to the southeast where it is lost in alluvium.

The quartzite contains little garnet, is fine to medium grained, schistose in part, and has recrystallized quartz layers and thin interbeds of schist. Small tourmaline crystals up to 1cm long occur occasionally. The unit is more contorted and recrystallized in its upper part, with some large quartz-feldspar pods and thin quartz-feldspar layers folded ptygmatically.

Unit 5. Unit 5 is largely brown quartzose schist with small garnets. Most of it is soil covered.

Unit 6. This is a distinctive, perhaps unique layer of schistose quartzite (dominantly biotite) containing very

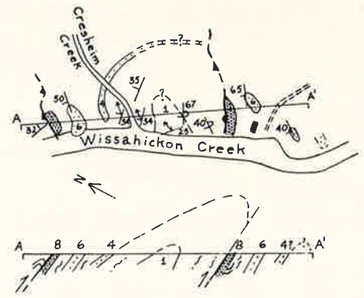

FIGURE 2. MAP AND CROSS SECTION
0 ¼ mile

rare, small (lmm) garnets. It has many thin recrystallized layers containing quartz, feldspar and mica that are folded ptygmatically. Fold axes parallel bedding.

The unit is prominent north of Cresheim Creek as a thick rib jutting out into Wissahickon Creek. Here it seems to have been squeezed or flowed into a thick mass, for it decreases in thickness and contortions up the hill to the east, and across the creek to the west.

A similar if not identical bed occurs south of Cresheim Creek, northeast of the Canoe Club boathouse (Figure 2). Proximity of ptygmatic folding to the anthophyllite (unit 8) indicates a genetic relationship is possible, perhaps intrusion of the anthophyllite while the beds were plastic.

Unit 7. This is a series of soft, crumbly, brown, quartzose schists that grade into harder schists containing relatively large garnets, staurolite, and tourmaline. The quartz grains are highly fractured, and the rock is a crushed zone behind the Canoe Club. Here the beds contain pods and lenses of recrystallized quartz, and pegmatite up to 24″ thick occurs 100′ up the ridge. The angle of dip decreases toward Unit 8, indicating drag along the *base* of the anthophyllite.

Unit 8. Unit 8 is greenish-grey anthophyllite that weathers reddish-brown. North of the Canoe Club it contains thick reddish-brown layers, evidently formed by superficial alteration by groundwater. The two separate beds near Cresheim Creek are unique along this section of Wissahickon Creek and perhaps along its entire length.

This suggestion of repetition is supported by the following analysis:

Normal variation among anthophyllites may be as much as .054 (Rodgers and Kerr, 1942). Between these two it is .008.

A "chilled zone" of finer crystalline, more dense anthophyllite 18 inches thick exists along the north edge of the unit north of Cresheim Creek, and the topmost wedge of the unit south of Cresheim Creek. This zone, plus apparently conformable relations with adjacent schists, suggests the anthophyllite is an injected sill. North of Cresheim Creek near the path a 4″ thick zone of chlorite occurs between the "chilled zone" and adjacent schists, which are isoclinally folded or "dragged" along the chlorite contact.

TABLE I

Wissahickon Creek anthophyllite:

Fine anthophyllite (radial)	*Coarse anthophyllite* (diverging)
A = 1.613 ± .002	A = 1.621 (?)
B = 1.621 "	B = 1.629 (?)
G = 1.632 "	G = 1.640 ± .002
A & G from approximate measurement; B estimated from literature.	G from approximate measurement, A and B estimated from literature.
North of Cresheim Creek	South of Cresheim Creek

Such retrogressive metamorphism generally indicates a fault zone. This evidence plus the drag below the anthophyllite behind the Canoe Club indicates that movement occurred along the anthophyllite boundaries.

STRUCTURE

Fold intensity increases near the anthophyllte (Unit 8) and also on the postulated south limb of the anticline. A brief reconaissance along Wissahickon Creek suggests several repetitions of gentle stretches followed by highly crushed zones.

Repetition of Units 4 through 8 suggests folding or faulting. The curvature of Unit 4, lineations plunging northeast, drag folds and cleavage, and the chlorite zone combine to suggest the interpretation shown in the bottom of Figure 2, an overturned nappe. Another interpretation might be a series of parallel imbricate slices, with little major folding.

ACKNOWLEDGMENTS

The study was supported by funds from the Committee for the Advancement of Research, University of Pennsylvania. Petrographic examination of anthophyllites and x-ray determination of chlorites were made by Fred Layman of the Department of Geology, University of Pennsylvania. Bruce K. Goodwin offered much helpful advice. Richard Custer and Edwin Jefferis assisted briefly in the field.

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STRUCTURAL CONTROL OF WISSAHICKON CREEK IN PHILADELPHIA, PENNSYLVANIA

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ABSTRACT

The path of Wissahickon Creek is strongly controlled by the underlying geologic structures and lithology. Major joint sets at right angles to the regional strike are a primary control. The effects of lithologic composition on joint development are responsible for deviations in the stream's path. Where flowing on competent, well joined rocks, the stream follows joint sets and cuts across the regional strike of bedding and schistosity at right angles. Where encountering sequences composed primarily of incompetent rocks which lack joints, the stream follows along the strike of bedding and schistosity.

INTRODUCTION

The valley of Wissahickon Creek has long been a subject of interest to students of the geology of the Philadelphia area. The excellent exposures of bedrock along the course of this creek caused Bascom (1909) to choose it as the type locality of the Wissahickon formation. More recently some of the structural and lithologic details of this section have been described by Postel and Adelhelm (1943), Weiss (1949), Ch'ih (1950), and Wyckoff (1952).

For the past few years the author has become increasingly interested in the minor structures of the Wissahickon formation. A study of these structures inevitably led to the extensive exposures along Wissahickon Creek. During the course of these investigations it became evident that the path of the creek bore a prevailing relationship to the structural features of the bedrock over which it flowed.

The present paper deals with this relationship between the structure of the Wissahickon formation and the path of Wissahickon Creek.

CHARACTERISTICS OF THE CREEK PATH

That portion of Wissahickon Creek studied in the present paper lies within the limits of the City of Philadelphia. It extends along the course of Wissahickon Creek from its confluence with the Schuylkill River northward along its path for approximately six and a half miles (Fig. 1), to where the Wissahickon formation lies in faulted contact with the Baltimore gneiss (Weiss, 1949). The entire section of the present study is underlain by the Wissahickon formation.

From north to south the creek flows along a trend of approximately S25E. About 1.3 miles from its junction with the Schuylkill River it makes a sharp bend and flows to the southwest. The features described in this paper can be best illustrated between this sharp bend and the boundary to the north with the Baltimore gneiss.

This section is characterized by long, rather straight reaches trending S25E. However, at three localities the stream path makes right angle turns and flows for short distances on a bearing of about S45W (Fig. 1). The question arises as to why the stream should deviate from its predominant southeasterly trend to make these short traverses to the southwest and then return sharply to its original course.

LITHOLOGIC AND STRUCTURAL SETTING

The Wissahickon formation exposed along Wissahickon Creek is composed primarily of mica schist and quartzite. All gradations from coarse mica schist to quartzose schist to schistose quartzite to quartzite are present. Over much of the section quartzite and schist are interbedded with individual beds ranging in thickness from an inch to several feet. Schists usually predominate and at times occur in thick sequences with an almost total exclusion of quartzites. However, at other localities quartzites may be dominant.

Within the Wissahickon formation, and exposed along the creek, are local and relatively thin occurrences of amphibolite, serpentine, and anthophyllite. Numerous pegmatite sills and one granite mass are also encountered.

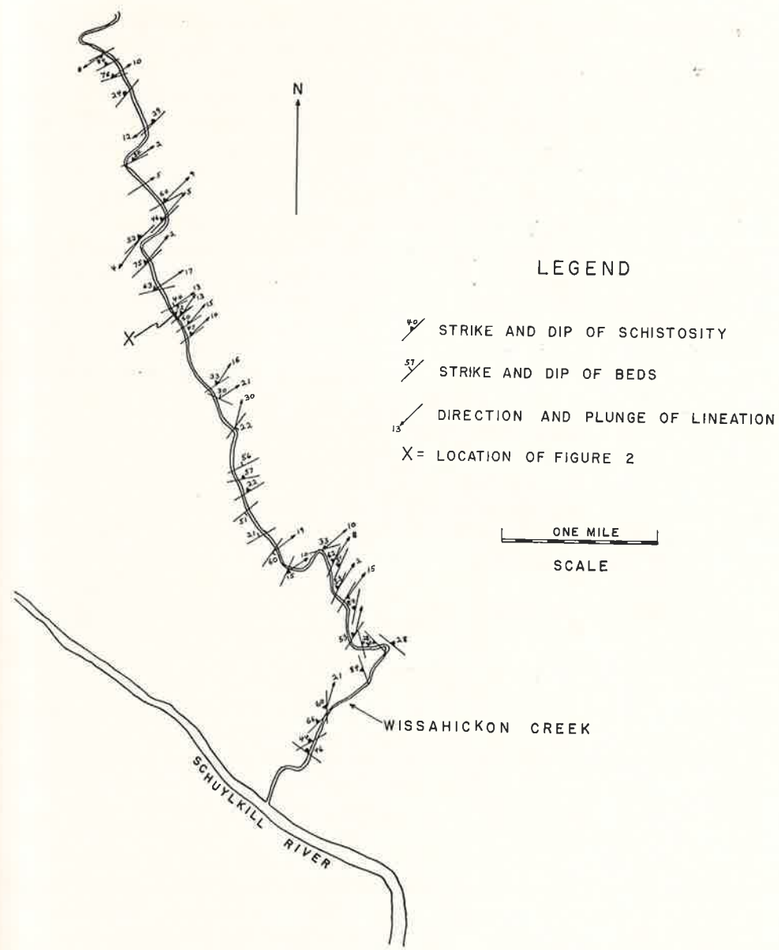

Figure 1. The path of Wissahickon Creek and structural details of the bedrock over which it flows.

The major structural features are summarized in Figure 1. Bedding and schistosity strike rather consistently to the northeast and fold axes also plunge gently to the northeast. The entire section is highly folded and repetition of units by folding undoubtedly occurs. Bedding and schistosity have a predominant dip to the northwest. Deviations from the dominant trends mentioned above occur and some of these are indicated on Figure 1. These are particularly prevalent along the northeasterly trending section adjacent to the Schuylkill River where the rocks have been extremely contorted.

The quartzites and igneous rocks are highly jointed although joints are not indicated on Figure 1. In general, the schists are almost entirely free of joints or are poorly jointed. 100 joints were measured from a series of exposures approximately 150 feet in length found on the east side of the creek just south of the water fall to the north of Valley Green (Fig. 1). The poles of these joints were plotted on the lower hemisphere of an equal area projection, and the plot contoured (Fig. 2). The path of the stream, strike of the beds, and direction of fold axes at this locality are also indicated on

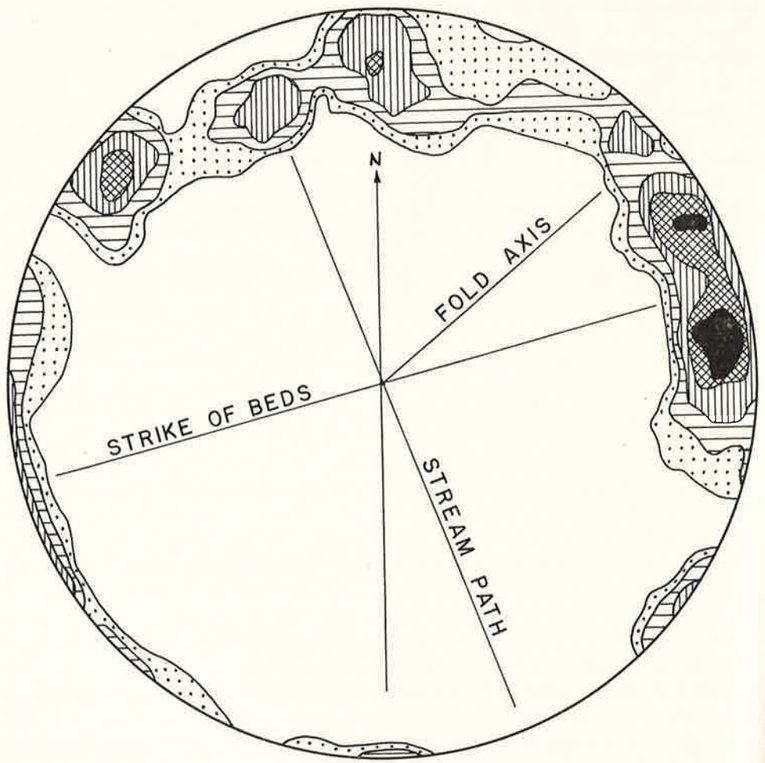

Figure 2. Equal area projection of poles of 100 joints from the Wissahickon formation. Location indicated on Fig. 1. Strike of beds, stream path, and fold axis are indicated. 1 — 2 — 4 — 8 — 12%.

the diagram (Fig. 2). From this it can be clearly seen that concentrations of joints occur nearly at right angles to the strike of the beds. This same joint concentration strikes parallel to the path of the stream.

STRUCTURAL CONTROL OF STREAM PATH

The long straight southeast trending stretches of the stream, cutting directly, across the regional strike of bedding and trend of fold axes, indicate that neither of these features is responsible for the control of the major portion of the stream's course.

An obvious explanation for this cross-cutting relationship of the stream to the structure would be the presence of a fault, the line of which is being followed by the stream. At first this concept may appear to have merit. For example, a large anthophyllite sill exposed on the east side of the creek north of its intersection with Creshiem Creek can not be found on the west side of the creek. However, just to the south of the water fall north of Valley Green a pegmatite sill nearly fifty feet wide continues across the creek with no deviation. A short distance south of the contact with the Baltimore gneiss a granite mass about fifty feet in thickness can be seen to extend across the creek, and some 1,000 feet further south a serpentine mass also extends on both sides of the creek. These continuous features would indicate that at least over much of its course a fault can not serve to account for the trend of the stream.

Figure 2 indicates that a major joint set at right angles to the regional strike parallels the stream path. Work elsewhere along the creek indicates that this same relationship holds true. Such cross joints normal to fold axes appear to be the dominant joint set developed over much of the Wissahickon formation in the Philadelphia area (Ch'ih, 1950) (Goodwin, 1961). Therefore, it appears likely that the southeasterly trending portions of the stream's path are following this major joint set. It is further suggested that where slight deviations occur in the direction of fold axes, this joint set makes a corresponding change in orientation and minor curves in the stream path result.

Figure 1 illustrates that the short southwesterly trending portions of the stream's course are parallel to the strike of bedding. This becomes evident in the field where individual beds can be followed for some distance paralleling the sides of the creek. It is especially obvious on the east side of the creek along the northernmost of these short stretches where the beds can be seen to parallel the stream in almost continuous exposures several hundred feet in length.

LITHOLOGIC CONTROL OF STRUCTURES

It has been determined that over much of its course the stream follows joint sets, but locally forsakes this preferred trend to follow bedding planes. The reason for this deviation lies within the lithology.

At first it appears logical to assume that the stream was forced to follow along bedding planes because some resistant rock strata lay in its path forcing it to take a route of easier erosion parallel to bedding. However, field investigation soon revealed that this was not true. Both the thick pegmatite and granite sills mentioned above cut across the center of southeasterly trending portions of the stream. Furthermore, these portions of the stream path are generally underlain by alternating schist and quartzite sequences. Where the stream does make the sharp turns to the southwest no prominent masses of resistant rock occur. On the contrary, the southwesterly trending portions of the stream occur in areas

which are underlain predominantly by mica schist.

The stream, therefore, appears to behave in an opposite manner than would be predicted. Where encountering hard, resistant units the stream cuts across their strike, but when flowing over soft schists the stream's path parallels bedding and schistosity. This is due to the different behavior of these two contrasting lithologies to deformation. During deformation the competent quartzites were fractured, and the well developed joints have served as controls over the stream's course. The thick schists were incompetent members during deformation, no joints were developed, and the stream lacking these fractures of access, was forced to follow along planes of bedding or schistosity.

CONCLUSIONS

The upper two thirds of Wissahickon Creek in the area of the present study appears to have its path controlled by a dominant joint set, which in turn is restricted in its development by the type of rock which underwent deformation. Sections containing an abundance of competent rocks are highly jointed. Here the stream follows the joint set and flows at right angles to the regional strike of bedding and schistosity. Sections underlain by an incompetent schistose sequence lack joints and the stream flows parallel to bedding. This is contrary to what might at first be expected.

It is suggested that this control of Wissahickon Creek on a small scale may find application to the control of streams on a larger scale. For example, if similar conditions prevail between the competent and incompetent units in the vicinity of Kittatinny Mountain, then the paths of the larger rivers such as the Delaware, Lehigh, and Susquehanna through their watergaps would be exactly as expected.

ACKNOWLEDGMENTS

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TRACE OF CONCEALED BED AND APPARENT DIP IN CROSS SECTION BY RAPID STEREOGRAPHIC TECHNIQUES

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ABSTRACT

Stereographic techniques for determination of apparent dips using a simple overlay, and map trend of concealed dipping strata on slopes using supplementary curves for slope angle expedite construction of geologic maps and cross sections. A little known method of plotting with revised stereonet calibration reduces potential error and speeds procedure.

INTRODUCTION

In the process of compiling geologic maps and structure sections, accurate work frequently requires construction of the traces of concealed beds on covered slopes and many determinations of apparent dips in the plane of cross section. Methods for expediting these procedures are presented here. Most workers in deformed strata are familiar with polar stereographic plotting for summary and statistical analysis of aggregates of orientation data; but, in many cases, it appears that they have not appreciated the convenience of this method for treatment of problems involving only two planes. The polar technique is here applied to the problem of the trace of a concealed bed, in conjunction with a graph for determination of slope angle from topographic maps. A simple scaling device is described for the determination of apparent dips which provides a solution that is actually cyclographic but is comparable to polar plotting in application and speed. Readers who wish to review general stereographic procedure or terminology will find Phillips (1954) the most complete general reference.

RAPID STEREOGRAM PLOTTING

Many workers making structural fabric studies have found it much more convenient to record the amount and direction of dip rather than the more conventional dip and strike. This not only has the advantage of greater compactness and less potential ambiguity of notation; but also lends itself to a very simple technique of stereogram plotting which is surprisingly little known.

The conventional orientation of the stereonet is shown on the outer portion of Figure 1. If, however, the net is calibrated counterclockwise with north at the right end of the horizontal diameter, east at the top, south at the left, and west at the bottom, plotting is facilitated. Such calibration for use with the quadrant Brunton is shown inside the circle on Figure 1 and for the 360° Brunton, which I prefer, just outside the circle. With this calibration it is only necessary to rotate the north reference mark on the overlay to the dip direction. The pole of a plane will then always lie on the left side of the horizontal diameter and its great circle may be drawn on the right. The pole of a lineation or intersection of

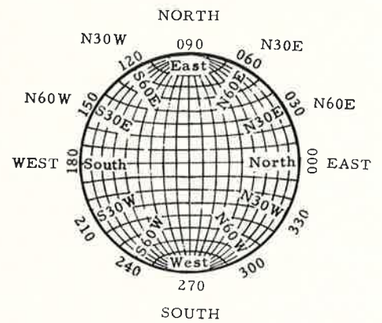

Figure 1. Alternative calibration of stereonet.

planes is always on the right. In this paper attitudes are referred to 360° azimuth, and plotting is discussed with respect to this rapid method. The relation of this procedure to the conventional one is apparent by consideration of Figure 1. I believe its advantages will become self-evident with very little use.

PROJECTING TRACE OF A CONCEALED BED

The establishment of the trace of a concealed bed is merely one case of the general problem of the orientation of the intersection of two surfaces; in this case an inclined stratum and the land surface. In Figure 2 this is simultaneously solved by the polar method and the more usual cyclographic method. The pole and great circle of bed dipping 64° to azimuth 204° (condensed notation, S_o 204/64) are plotted (Fig. 2A) by rotating the reference mark to 204 and marking the pole 64° to the left of the center and drawing the circle on the right side 64° from the edge. In like manner (Fig. 2B) the pole and circle of a land surface with slope 079/17 are plotted. The required trace (Fig. 2C) is determined cyclographically by rotating the plotting paper so that the intersection of the great circles falls on the right half of the horizontal diameter and reading the azimuth (126°) from the reference mark. The polar solution yields the same result when the plotting paper is rotated so that both poles lie on the same great circle on the left side of the net. It is obvious that the two solutions are exactly equivalent; but the polar method eliminates the need for tracing circles with its attendent errors.

DETERMINING SLOPE ANGLE

In constructing the trace of a bed on a sloping surface, it is usually necessary to determine the slope angle ($\bar{o}$) from a

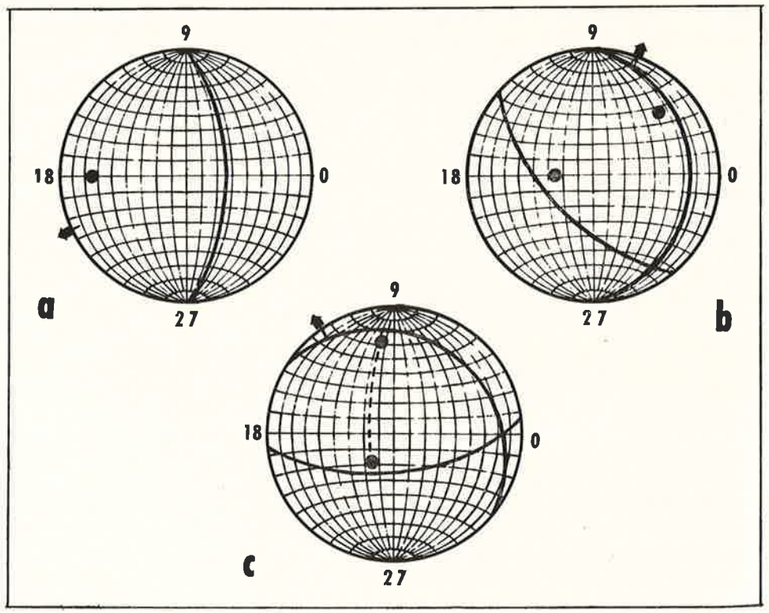

Figure 2. Polar and cyclographic solutions of the trace of a dipping bed on a slope.

topographic map. This may be computed trigonometrically from the equation $d=AHS \cot \bar{o}$, where d= the absolute map distance between adjacent contours in any convenient units; H= the contour interval; S= the map scale ratio; and A= constant equating the units of d and H (i.e. if d is in inches and H in feet, A=12; d in mm. and H in meters, A=1000, etc.). If many such determinations are made, however, it is convenient to graph the function as in figure 3 which has curves corresponding to the spacing between 1, 5, and 10 contours. It is then possible to take the contour spacing from the map with dividers and, holding them parallel to the abscissa, find that spacing inside the curve and read the slope angle on the ordinate.

The burden of plotting such curves is the principle objection to their use. However, as each curve is in fact the plot of a constant term x cot $\bar{o}$, if the plotted curve is enlarged or reduced to an appropriate size for any values of H and S, it may be used without replotting. Figure 3 is adapted to this use by the reference line 50 AHS. If the appropriate values of A, H, and S are substituted in this term, the resulting number is the length, in units of d, that the reference line should have on the copy. Thus, for example, a contour interval of 100 ft. on a map a 1/24,000 scale gives 50 AHS= 2.5 inches. The same map with 20 ft. contours yields 50 AHS=0.5 inches, which is inconveniently small and illustrates the limits of the graphical method. These limits may be extended by scaling the distance with proportional dividers. With the dividers set a a 5:1 ratio the spacing is spread so that the 2.5-inch reference line is appropriate for the 20-foot interval. It should be apparent that 50 AHS=2.5 inches is also correct for 200 ft. contours at 1/48,000, and scaling with proportional dividers at 2:1 ratio will give spacings for 100 ft. contours, while a 10:1 ratio is effective for 20 ft. Enlargement and the use of proportional dividers thus make these curves more flexible than at first apparent.

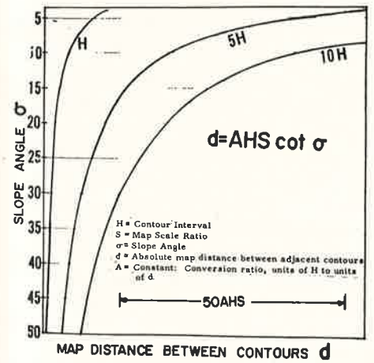

Figure 3. Graph for determination of slope angle from contour spacing.

RAPID DETERMINATION OF APPARENT DIP

The determination of apparent dip is actually another special case of the intersection of two planes. The fact that the plane of apparent dip is vertical, however, permits the simplified cyclographic solution illustrated in Figure 4A and B. The figure is set up for a bed S_o 174/66 on a section oriented 030°. This method is quite adequate for occasional use, but a simple scaling device will eliminate the need for all plotting or constructing great circles.

This scaling device consists of nothing more than a copy on a transparent overlay of the horizontal diameter of the stereonet calibrated from 0° at the primitive to 90° at the center. In effect this performs as the essential element of the rather elaborate stereographic calculator described by Wallace (1948), but is much easier to prepare. I have found that placing the scale on the under surface of a mylar sheet, so that reference marks may be erased without hazard,

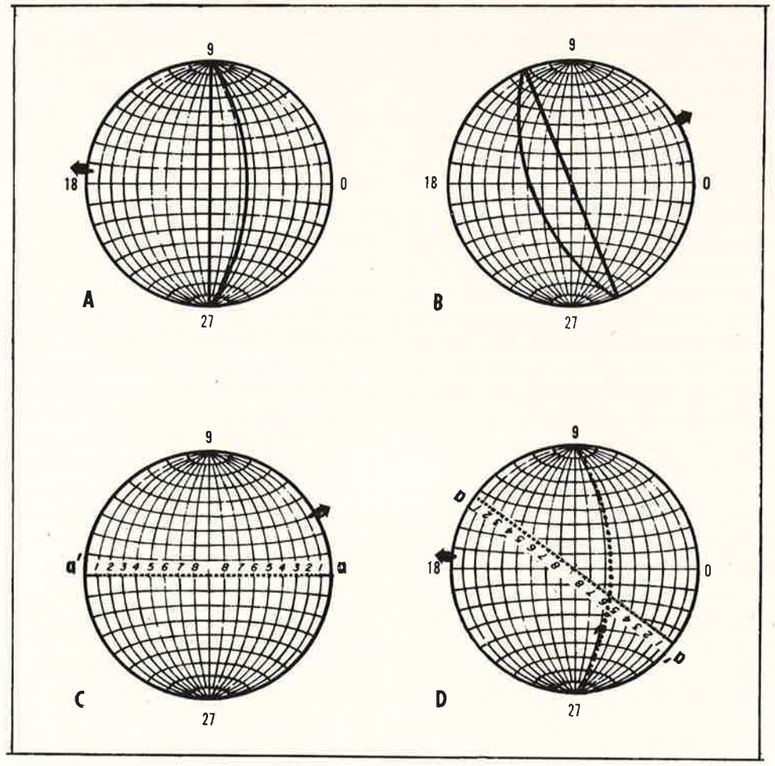

Figure 4. Determination of Apparent dip in cross sections.

makes the most durable scaler; but tracing paper will serve.

Determination of apparent dip by the scaler is shown in Figure 4C and D. The overlay is placed on the net with the scale on the horizontal diameter. The north reference mark is then placed at the azimuth of the section line (030°). The reference mark is then rotated to the dip azimuth of the bed (S_0 174/66). The overlay is now in the position where the trace of the bed was plotted in Figure 4A; the apparent dip (60° to the SW or a' direction) may now be read directly on the scale. It is only necessary to pick the point where the great circle plotted in Figure 4A would cross the scale. This method is particularly advantageous in the construction of cross sections where it is usually necessary to determine a number of apparent dips in one direction. Once the section direction is established by the position of the reference mark with respect to the scale, each may be determined successively by a single rotation to its dip direction.

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PRINCIPLES OF DICHOTOMY

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Almost everybody is familiar with the term "dichotomy" and many investigators become confronted in the pursuit of biological tasks with its various, often intricate systems. However, few are aquainted or recognize the principles involved, which lead to this important growth structure. Yet, it is based on the timeworn structural components of aggregation, division and separation, which have an early history in microscopic cell patterns. As we actually can trace them back to physical processes of atoms and molecules, they become more clear and convincing in biological applications, particularly in the plants (fig. 1) and to a lesser degree but just as important in the animals (fig. 2).

Fig. 2

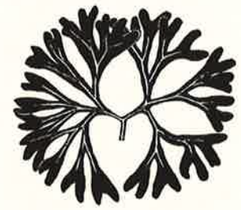

Fig. 1

1. Dichotomous *Fucus* species.
2. Marginal dichotomous Crinoid *Hallocrinus*. Goldring 1923.

To understand the ontogenetic development of dichotomous growth, we have to transfer our thoughts to the world of cells, on which the most important beginning of dichotomy rests. When a single cell unit divides, it builds a partition wall, which creates two cells, we may consider to be branches, expanding from the partition, which becomes the dichotomous base. We may say, as a general principle ,a dichotomous pattern originates from a single member or base of any shape, which develops a pair of terminal branches. Strange enough,

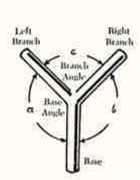

Fig. 3

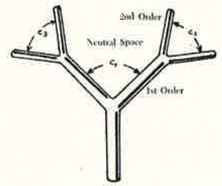

Fig. 4

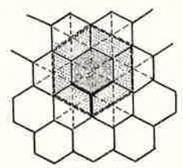

Fig. 4A

3. Basic DICHOTOM, consisting of base, two branches, branch and base angle.
4. DICHOTOMY of two orders, forming neutral space.
4A. HEXAGONAL DICHOTOMY, explaining concentric pattern repetition.

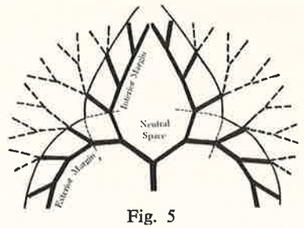

Fig. 5

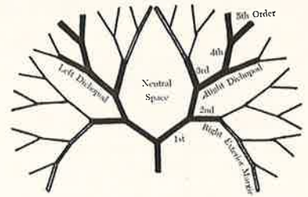

Fig. 6

5. Dichotomy pattern, showing MARGINAL DICHOTOMY development.
6. Dichotomy pattern, showing DICHOPODIAL development.

there exists no definite mathematical term for it, but it actually represents only the intersection of three lines, or the edges of a triangular pyramid (fig. 3). Occasionally, such a structure is called a triad, depending on the group of science, in which it is employed. Biologically, the term "dichotom" appears to be the most suitable one.

The pattern of "dichotomy" (fig. 4) is reserved for continuous dichotomous branching, in which each branch of a dichotom develops into a new dichotom. The number of consecutive sets of dichotoms establishes the succession of dichotomous orders. The branches never close or touch each other. Their number depends on this open pattern and they will increase according to the law of geometrical progression. Therefore, a system of the loth order would have a total of 2046 branches. As will be seen later the branching angle of the different orders becomes usually smaller, otherwise the branches may close or overlap.

On this open base pattern (fig. 4) a number of sub-species of dichotomy rest. "Marginal dichotomy," one of the later adopted types, is shown in fig. 5 as a part of the open dichotomous pattern, in which only the branches of the marginal orders develop. We can distinguish exterior marginal dichotomy (fig. 7), which is represented by the crinoid *Hallocrinus* (fig. 2) and interior marginal dichotomy (fig. 8) seen in the umbrella-

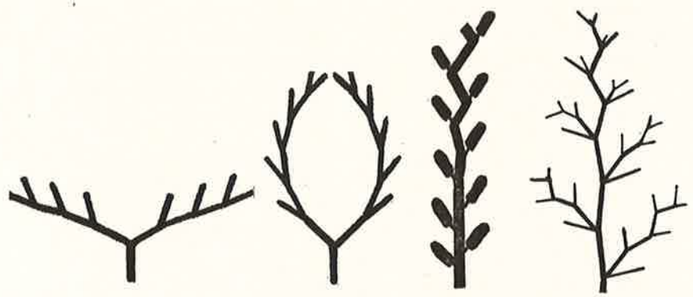

Fig. 7 Fig. 8 Fig. 9 Fig. 10

7. EXTERIOR MARGINAL DICHOTOMY.
8. INTERIOR MARGINAL DICHOTOMY.
9. Single, left DICHOPODIUM, developing from a zigzag line into straight axis.
10. Main DICHOPODIUM with axillary branch dichopodia of 8 orders.

like fern *Adiantum pedatum* (fig. 11). This type of application is not very frequently used and appeared at the beginning of the Mesozoic period.

The second dichotomous base pattern (fig. 6) known as "dichopodium"; or "dichopod", is mainly characterized by alternate suppression of branches, yielding a zigzag or undulating axis. It is eminently important because it succeeded in converting the cumbersome two-axial system of open dichotomy into an one-axial dependency (fig. 9, 10). All bilateral or pinnated leaves such as in the ferns and angiosperms are based on this system. When the various components are disposed around the axis a three-dimensional or spiral dichopodium is achieved. This design has been already practiced by Devonian plants.

The last step of dichopodial development was taken, when branching became initiated within the axil of leaf dichopods (fig. 10) such as in lycopods (fig. 12), conifers and finally in the angiosperms. Here, the usual main stem dichopodium develops sub-orders of axillary branch dichopodia. This system is found today in almost all angiospermous trees (fig. 10). Thus, in plant life the open dichotomy became vastly superseded by the open dichopodial system.

So far these dichotomous patterns are of two-dimensional origin; however, a large mass of dichotomous branching architecture invades the space, getting twisted out of the single plane and penetrating practically into all directions. Particularly "closed dichotomy" indulges in three-dimensional structures (fig. 4A, 13-15), which includes the radiolarias, diatoms and many other plants. In the invertebrate groups it may form a carapace of a space lattice pattern (fig. 14), sensory and vision (facet eye) structures and cellular arrangements. The dichopodium may also enter space by the stairway-like design of certain crinoidal appendages (fig. 18).

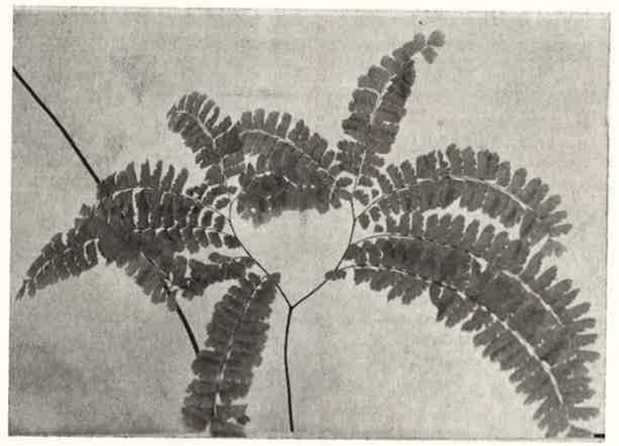

Fig. 11

11. ADIANTUM PEDATUM. Natural growth, youngest leaves directed upwards, forming marginal dichotomy. The two main branches resemble a lyre. (Montgomery Cty., Pennsylvania).

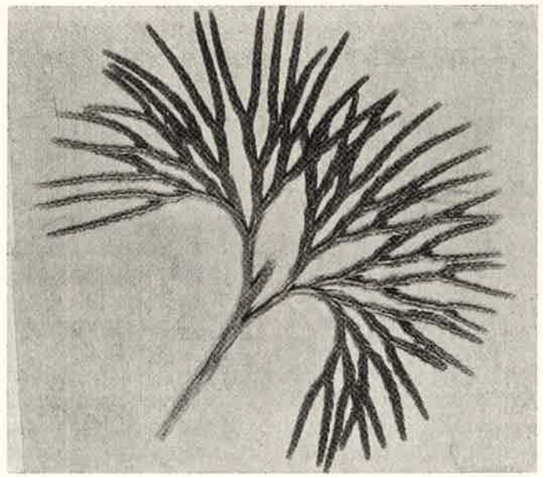

Fig. 12

12. *Lycopodium flabelliforme,* showing dichotomous branches.

Another group, "functional dichotomy," is a space agency, which is able to accomplish kinetic motions. It comprises all species of dichotomy, which are flexible or locomotive. Its first expression is found in the flagella of algae, protozoans, crustacean limbs, including the respiratory paddle of trilobites (16-17). Single, functional dichotoms developed into chela, claws and pinchers, particularly in the ancient limuloids or Chelicerata, where the cutting or movable knife grows on the posterior side. In the crustaceans it is usually attached to the anterior side, an important phylogenetic difference. Paired, locomotive organs

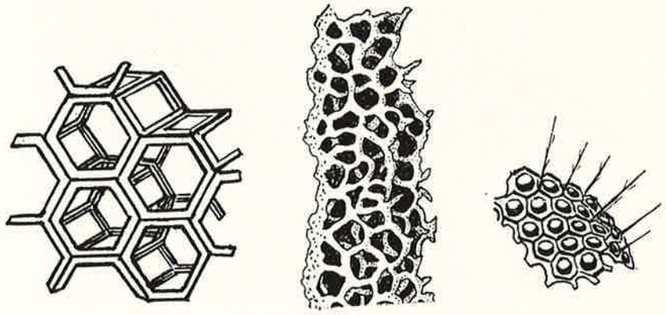

Fig. 13 Fig. 14 Fig. 15

13. HEXAGONAL SPACE DICHOTOMY.
14. POLYGONAL LATTICE DICHOTOMY. Caster and Eaton, 1956, text, fig. 2B.
15. HEXAGONAL DICHOTOMY of radiolarian.

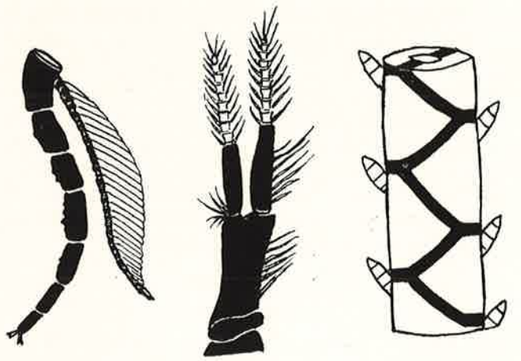

Fig. 16 Fig 17 Fig. 18

16. *Dichotomous* appendage of trilobite.
17. Typical *dichotomous* limb of crustacean.
18. HEXAGONAL BISERIAL DICHOPOD displayed by crinoidal arm.

should also fall largely into this category of functional dichotomy.

"Segmental dichotomy" is based on the segmentation of biological units, which in its simplest form may be represented by the single cell chain of oscillatory algae such as *Rivularia* species. The ontogenetic growth of worms is not fully known in all details, but it is considered to represent successive segmentation, where such a division is present. Segments developing paired symmetrical appendages such as in trilobites, or later on in vertebrates, should be at least, functionally, considered to represent dichotomous units, even, if their origin is still obscured. The detailed structure of the vertebrate limb is doubtless dicho-

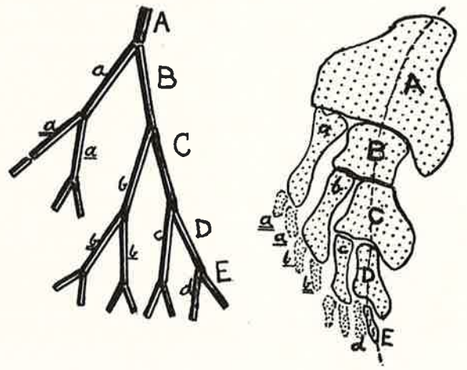

Fig. 19 Fig. 20

19. Dichotomous diagram of fin skeleton shown by the Devonian rhipidistian *Eusthenopteron.*
20. Pectoral fin skeleton of *Eusthenopteron foordi.* (All figures are after Bock, 1962, unless stated otherwise).

tomous, which is clearly shown in the perfect design of the Devonian *Eusthenopteron fin* (fig. 19, 20).

A new development in the field of biological branching is the discovery of open dichotomy in the venation of the primitive angiosperm *Kingdonia uniflora* from the highlands of China (Foster, 1959.) This author points out the perfect open vein dichotomy in the lamina and petiole of this plant, displaying about 8-9 dichotomous orders, similar to that of ginkgos and ferns. Although there is at the base a single order of closed dichotomy, or w-dichotomy, intercalated, the pattern of the venation is considered to be primitive and a retention of ancient open dichotomy. It easily may become a milestone in tracing the origin of the angiosperms.

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SOME SPECIAL ADDER FUNCTIONS

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University of Scranton

ABSTRACT

Symmetric functions constitute a large and important class of Boolean switching functions. Their simplification by conventional methods is difficult and yields only moderately successful results. However, when using the vacuum tube or transistor switching model, certain highly effective simplifications become possible through the use of specialized Boolean operators and the corresponding circuit analogs. These include the "exclusive or" element and its complement, and also the stroke and double stroke (Sheffer Stroke) elements. The use of these elements allows a substantial reduction in the number of components required in a wide range of symmetric circuits, including the full and half adder circuits.

INTRODUCTION

The half adder and full adder constitute the basic components for binary addition within the digital computer. Ordinarily these circuits are constructed using ordinary "and", "or" and "not" gates. However, by the use of special Boolean operations applicable to symmetric functions a substantial reduction may be made in the number of components required for these adders.

DEFINITION OF SYMBOLS

In this paper, switching variables x, y etc. will represent inputs to the circuit. "+" will denote the operation of union, and "." will denote the operation of intersection. "′" will denote the unary operation of complementation.

THEORY

The first step in the development of these specialized functions is to consider two operation "(+)" and "(X)" which are defined as follows:

$x\ (+)\ y = xy' + x'y = (x + y)\ (x' + y')$

$x\ (x)\ y = xy + x'y' = (x + y')\ (x' + y)$

The first operation "(+)" is the "exclusive or" operation, that is "x or y, but not both." The second operation "(x)" will be referred to as the coincidence operation, that is "x and y, or not x and not y." Both of these operations may be shown to obey the Laws of a binary Boolean Algebra. They obey both the Commutative and Associative Laws in addition. Two further properties should also be noted, namely that

$(x\ (+)\ y) = x\ (x)\ y$

and also that

$x\ (+)\ (y\ (+)\ z) = x\ (x)\ (y\ (x)\ z)$

These relations may be proved by considering the functional definitions as minterm expressions. There are many other relations existing between these operators which could be proved if desired.

If these functions are to be of any use in the simplification of switching functions, it must be shown that they are capable of economical electronic realization. In practice it is possible to construct relatively simple transistor circuits for both of these operations. The "exclusive or" gate is shown in Fig. 1. In the interest of simplicity capactitative inputs and biasing circuits have been omitted. Two PNP transistors are connected in parallel, sharing a common load resistor. It will be assumed that positive logic is being used, although the circuit would function equally well for negative logic. Spe-

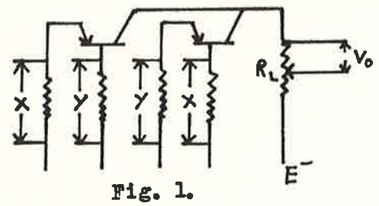

Fig. 1.

cific values of the circuit parameters depend upon the transistor being used. The output is taken with a potentiometer R_L so that the output pulse size may be adjusted to the same size as the input pulse. The principle of operation of the circuit is relatively simple. If there is a positive input at x, transistor 1 conducts since it is forward biased. This produces an output pulse V_0.Transistor 2 remains cut off with a positive voltage on its base. If there is an input on y, transistor 2 conducts etc. If x and y are both low, then obviously there is no output. If x and y are both high at 1, then the effective emitter bias on each transistor is O, so that there is no output. Thus it can be seen that this circuit realizes the "exclusive or" operation.

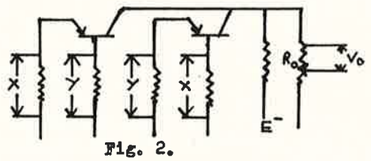

Fig. 2.

The coincidence gate is constructed in a somewhat similar fashion. This is shown in Fig. 2 for a PNP transistor. R_0 must be large and of the order of ½ megohm. The connection is between the collector point and ground. A potentiometer is used to allow adjustment of the output pulse size. Inputs etc are as before. If x and y are both O neither transistor conducts and there is a voltage at V_0. The same is true if x and y are both 1. If there is an input at x, transistor 1 conducts, and almost all of the voltage E appears across R_L, so that V_0 is effectively O. The same is true if the input is on y. Therefore this circuit realizes the coincidence operation. These two circuits posses several advantages. First, in their normal state, that is quiescent state, neither circuit draws any power beyond that used for the leakage current. Second, these circuits may be realized either with PNP or NPN transistors, with the same circuit functioning equally well for positive or negative signals. Third, by combining these circuits, it becomes possible to realize the "exclusive or" and coincidence operations simultaneously with a single gate. This is shown in Fig. 3. V_1 gives the "exclusive or" output and V_2 gives the coincidence output. In this way two outputs normally requiring four transistors may be obtained with only two transistors.

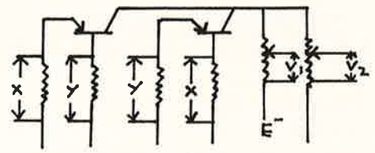

Fig. 3.

Now that the existence of circuit analogs to these two operations has been established, we may consider the application of these operators to a class of Boolean functions known as symmetric functions. By definition, a function of n variables $x_1, x_2, \ldots x_n$ is symmetric in these n variables if the interchange of these variables leaves the function identically the same.[1] If a function is symmetric the permutation of variables will not alter the function as long as the primes are not permuted. Symmetric functions possess three important properties. First, the sum of symmetric functions of n-variables is symmetric.[2] Second, the product of symmetric functions of n variables is symmetric. Third, the complement of a symmetric function is symmetric. It should be noted that it is possible for one or more of the variables of symmetry to be a primed variable.

The type of symmetric Boolean function which will be considered here is the k out of n type. This function represents a circuit which is to have an output if and only if k out of the n inputs are activated. Symmetric functions of this type are often added together. For example, the switching function of n variables which is to have an output if k or all of the n inputs are activated is a symmetric function.

ADDER FUNCTIONS

The half adder is the basic computer adder. Its truth matrix is shown in Table 1[3]. x and y represent the inputs

Table 1.

Input		Output	
x	y	S_0	C_0
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

to be added. S_0 gives the value of the output sum where $S_0=xy'+x'y$. The output carry C_0 is given by $C_0=xy$. Both the sum and the carry are symmetric functions. The sum is a one of two function. The carry is a two of two. The sum function may be expressed as x (+) y, or by adding a "not" gate as (x (x) y)′. The block diagram is shown in Fig. 4. This configuration requires only four elements, as compared with the seven to ten elements required for conventional circuits. This configuration has another advantage in that it reduces the number of stages from two to one. This will improve the switching time.

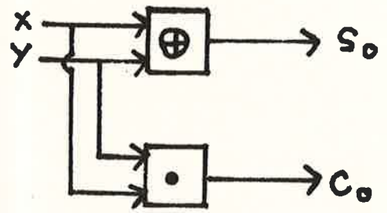

Fig. 4

The full adder is a somewhat more complex case. There can be a large amount of flexibility in its construction. In constructing the full adder, three criteria may be considered. They are, first, minimization of the number of stages, second, minimization of the number of components, and third, maximum uniformity in the type of gates used. Emphasis on different combinations of these will produce different circuits.

In the full adder provision must be made for x and y inputs, and also for c the carry from the previous stage. The full adder itself will generate a sum or carry, or both. There will be a carry when any two of the inputs or all three inputs are activated. The carry function is a two of three added to a three of three. There will be a sum output when one of the

Table 2.

Input			Output	
x	y	c	S_0	C_0
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

three inputs, or all three inputs are activated. This is a one of three added to a three out of three symmetric function. In minterm form these functions would be expressed as

$C_0 = x'yc + xy'c + xyc' + xyc$

$S_0 = x'y'c + x'yc' + xy'c' + xyc.$

or in strict minterm notation

$S_0 = p_1 + p_2 + p_4 + p_7$

$C_0 = p_3 + p_5 + p_6 + p_7$

where p_i is the i th minterm. These functions show the utility of applying the concept of a symmetric function to the setting up of a switching function. Whenever the closure conditions are expressed in terms of the number of inputs which must be activated, rather than specific inputs, the function will generally be symmetric. This indeterminacy of closure conditions is usually the first indication that a symmetric function may be present. The full adder switching functions could also have been synthesized in minterm form from a truth matrix. Table 2 shows the form of the matrix.[4] In either case the result is identical.

The first full adder configuration uses two half adders in cascade. This is shown in Fig. 5. The sum from the first half adder is gated into the second half adder with the input carry. The carries from both half adders are sent through an "exclusive or" gate. This gives the output carry. The operation of the circuit is best understood in terms of specific examples. If x=1, and y=c=O, a sum, but no carry is formed in the first half adder. The 1 sum is gated with the O input carry to produce a 1 output sum and a O output carry. If x=O and y=c=1, half adder 1 forms a sum, but no carry. A 1 carry and a O sum is formed in the second half adder, making S_0=O and C_0=1. If x=y=c=1, a O sum and a 1 carry is formed in the first half adder. The O sum is gated with the 1 carry to produce an output sum of 1. In this way, by considering all eight possible cases, it can be shown that the circuit satisfies the truth matrix for the full adder. The "exclusive or" gate is used rather than an "or" gate for the output carry for the sake of uniformity. This is allowable since both carries cannot simultaneously be 1. This circut requires a total of ten transistors and has a maximum signal path of three stages.

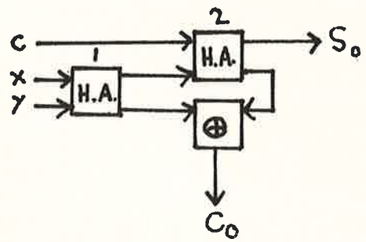

Fig. 5.

Another full adder may be synthesized directly from the truth matrix and closure conditions. For the sum function we have

$S_0 = x'y'c + x'yc' + xy'c' + xyc$

$x'(y'c + yc') + x(yc + y'c')$

$x'(y(+)c) + x(y(+)c)'$

$x(+)(y(+)c)$

The carry function does not lend itself to such an elementary analysis.

$C_0 = x'yc + xy'c + xyc' + xyc$

$x(y'c + yc') + yc\ (x + x')$

$x(y(+)c) + yc.$

Alternate simplifications are possible. This simplification was performed in such a way as to allow the subfunction y(+)c to be shared by both functions. The block diagram for this full adder is shown in Fig. 6. There does not appear to

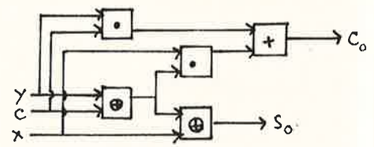

Fig. 6.

be any way to realize the carry function completely in terms of specialized operators. This adder circuit would require ten transistors. The maximum signal path is three stages. The chief disadvantage of this circuit is the lack of uniformity, since three different types of gates are used. Since we are dealing with symmetric switching functions, we may interchange variables in performing the simplifications. The sum could also be defined in terms of coincidence operators, that is

$S_0 = x(x)\ (y(x)z)$

This is valid since it can be shown that $x(+)\ (y(+)z) = x(x)\ (y(x)z)$. The carry function is best defined with an "exclusive or" arrangement. This does not require extra components since we may obtain y(+)c and y(x)c from a single tow transistor circuit, as shown previously. If one transistor is added for a "not" gate we could use $(x(+)y)'$ or $(x(x)y)'$ in setting up the function. This would give us several additional configurations.

SUMMARY

The chief advantage of these adders using special operators is that they reduce the number of components required. In certain cases they increase uniformity. The three basic full adder configurations each require ten transistors, with variations which may need eleven or twelve. This is in contrast to conventional circuits which may require twenty or more components. At present more work is being done on the applications of these and other specialized operators to symmetric functions, including adder functions. This includes a study of the operators themselves and also the construction and testing of the actual gate circuits.

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A FURTHER REPORT ON RADIOACTIVE FALLOUT AT UNIVERSITY PARK, PENNSYLVANIA

E. C. Keller, Jr.,[1] Rodger Granlund[2] and Edward S. Kenney[3]

ABSTRACT

Daily radioactive fallout counts (estimated by gross β-ray counts) were recorded over a five and one-half year interval beginning in May of 1957 at University Park, Pennsylvania. In general, the fallout levels between the summer of 1957 and the spring of 1959 were relatively high, with a decreased level recorded for the rest of 1959. This low level was maintaiend (with the exception of fallout from the French nuclear bomb test in February 1960) through the fall of 1961 when a large increase was recorded upon the resumption of nuclear bomb testing. These recent nuclear tests yielded increased fallout levels even above those of 1957-58 from the U. S. Nevada and U.S.S.R. nuclear bomb test series.

Previous data have been reported (1) concerning the general levels of radioactive fallout in central Pennsylvania for 1957, 1958 and 1959. These data were obtained at the Health Physics Office of the Pennsylvania State University starting in May 1957. The fallout was collected in an oiled tray with an area of 1280 cm^2. The tray was exposed for a 24-hour period except for the Monday sample which was for the 72 hour weekend. The fallout collected, including any precipitation, was transferred to an aluminum planchet, ashed at 300°C and counted inside a two-pi proportional counter. Only the beta counts are recorded here. The alpha counts were negligible. A geometry factor of 50% was used to compute beta disintegrations per minute, but no corrections were applied for self-absorption or backscattering. However, estimates of the backscatter and self-absorption corrections indicate that the product of these correction factors is approximately unity.

The data in Figure 1 represents the average daily fallout for a given week. The first samples in 1957 were obtained just prior to the start of the U. S. Plumbbob series and just after completion of a U.S.S.R. series. During the period from the summer of 1957 to the fall of 1958 there was extensive testing by both the U. S. and the U.S.S.R. Although testing was suspended in November 1958, fallout levels were still relatively high in the spring of 1959. The decrease in fallout level from the cessation of testing in 1958 to the low levels of the fall of 1959 is very apparent from the figure. While a decay equation might be fitted to this interval, the situation is complicated by the seasonal variation which tends to increase fallout levels in the winter and spring months of the year (2).

The small peak in late February 1960 is probably the result of the first French test in the Sahara Desert on February 13, 1960. Approximately twelve days elapsed between the test and the increase in activity at this station. No significant increases were recorded following the French tests in April and December of 1960. This is no doubt due to the fact that only the debris cloud from the February test passed over this station, since it has been shown that the path of the debris cloud must pass fairly close to the recording station to be detected.

The relatively low fallout levels of 1960 and 1961 reflect the cessation of general atmospheric nuclear weapons testing. The resumption of testing by the U.S.S.R. on September 1, 1961 was

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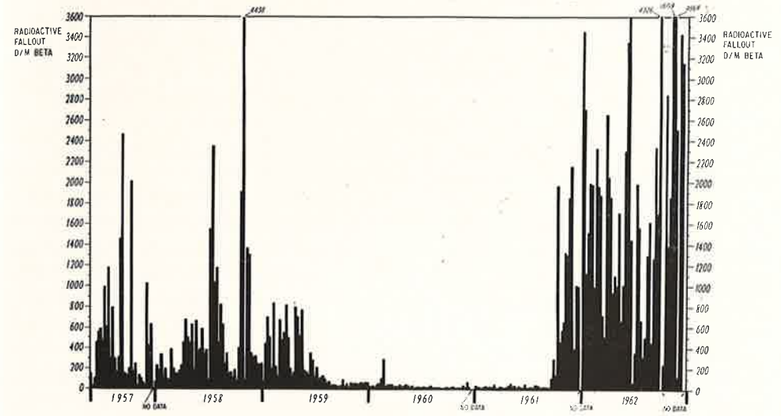
FIGURE 1. MEAN DAILY RADIOACTIVE FALLOUT AT UNIVERSITY PARK, PENNSYLVANIA WEEKLY INTERVALS



detected 13 days later at this station. With the extensive atmospheric testing which has been conducted since that time, the fallout level has remained high, even exceeding the levels of 1957-58.

SUMMARY

Daily radioactive fallout counts (estimated by gross beta-ray counts) were recorded over a five and one-half year interval beginning in May of 1957 at University Park, Pennsylvania. In general, the fallout levels between the summer of 1957 and the spring of 1959 were relatively high, with a decreased level recorded for the rest of 1959. This low level was maintained (with the exception of fallout from the French nuclear bomb test in February 1960) through the fall of 1961 when a large increase was recorded upon the resumption of nuclear bomb testing. These recent nuclear tests yielded increased fallout levels even above those of 1957-58 from the U. S. Nevada and U.S.S.R. nuclear bomb test series.

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TEACHING OF CHEMISTRY IN THE SECONDARY SCHOOLS OF THE SOVIET UNION FROM 1917 TO 1931

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ABSTRACT

The paper discusses the changes in teaching chemistry in the secondary schools of the Soviet Union from the October Revolution to 1931.

This paper discusses the teaching of chemistry in the secondary schools of the Soviet Union from 1917 to 1931. It is a sequence to my three other papers discussing teaching of chemistry in Russia at secondary school level at various periods[1,2,3]. As the original sources are almost unavailable in this country my paper is based on a set of articles published by the historian of Russian chemical education Parmenov in the magazine "Khimia v Shkole" (Chemistry in School)[4,5,6]. It is also based on a book that discusses Soviet secondary school in the period 1926-1930[7] published in the Soviet Union, and on the book of the President of the Second State University of Moscow Albert P. Pinkevitch[8] published in this country. Albert P. Pinkevitch was one of the reformers of the Soviet schools in the twenties and with many others he disappeared in the purges of the late thirties.

After the October revolution in 1917 the Communist Government hastily introduced a lot of changes into the Russian school system. Many of them were preparded before the revolution, others, as for example, abolition of home works were abandoned later.

Among these changes the teaching of religion, classical languages (Latin in most schools) and the second foreign language were abandoned, and the number of hours for sciences was increased.

At the same time chemistry was introduced as a separate subject in all secondary schools. This was certainly a premature step. On the First All-Russian Congress of Science Teachers in Petrograd in August 1923 the known Russian educator professor V. N. Verkhovskii stated: "Chemistry is included in the curriculum of the labor school, but in reality is not yet taught in many schools, and if it is taught the teaching in the enormous majority of cases is unsatisfactory because of lack of laboratories, equipment, and means for the organization of experiments. All talk about methods of teaching chemistry are meaningless as long as the main method, the method of the experiment, can not be widely used." This point of view was supported by many other speakers. Even in 1929 the deputy director of the Division of Social Education M. M. Pistrak complained that the majority of schools do not have chemical laboratories.

Till the year 1920 the chemistry syllabus was the responsibility of local school authorities and even individual teachers.

In the curricula of 1920 3 hours per week were devoted to chemistry in the seventh and eighth years of study. The total number of hours was 306. The Commissariat of Education organized two committees to prepare a syllabus of chemistry. One was headed by professor V. N. Verkhovskii and is known under the name of the "Petrograd" Committee. The other was headed by professor P. P. Lebedev and is known as the "Moscow" Committee. Both syllabi were approved at the plenar meeting of all science committees and the Secondary School Division of the Commissariat for

Education sent them both to the schools as sample syllabi. The idea was that on basis of these two syllabi the local school administration and chemistry teachers can work out their own syllabi taking into account local conditions. Here are the main topics of the "Petrograd" syllabus: Introductory information, Mixture and a chemical compound. Law of conservation of mass. Water. Hydrogen. Hydrogen perovide. Law of multiple proportions. Law of equivalents. Oxygen. Combustion and oxidation. Solutions. Chlorine and other halogens. Atomic theory, ozone. Sulfur Nitrogen. Phosphorus and its analogues. Carbon (with inclusion of organic substances). Silicon. Periodic system. General properties of metals. Alkali metals. Alkaline-earth metals. Magnesium, zinc, mercury. Aluminum. Lead, tin. Iron. Copper. Alloys. Each of these topics was worked out in details on six pages of a "Methodic Elaboration of the Syllabus." It was a forerunner of the present syllabus in which the teaching of chemistry is based on the atomic-molecular theory and periodic system. Much time was devoted to correlation with everyday's life and nature. The experiment and the inductive method were the basis of teaching chemistry. The chemical language and chemical calculations were considered important and their knowledge should be acquired by practice and not by memorization. The Soviet historian of chemical education criticizes the syllabus for overstressing the inductive method and recommending to the teachers among others two books of Wilhelm Ostwald and the "Elements of Inorganic Chemistry" by Alexander Smith which he considers idealistic, besides this his appraisal of this syllabus is rather positive.

The "Moscow" syllabus starts with a defence of necessity of teaching chemistry in secondary schools that was apparently necessary in those times. This syllabus is much more general and does not give even a sample syllabus that may be used by a teacher. It also does not recommendany textbooks or manuals for teachers. The syllabus is subdivided into the following sections: 1) Laws, 2) General concepts, 3) Elements and their compounds, 4) Organic compounds, 5) Some information about chemical technology. It was recommended to acquaint the students with technology of water, sulfuric acid, metallurgy, production of fertilizers, lime, cement, gypsum, glass, ceramics, soap, processing of petroleum, coal, and wood, and production of organic dyes. The syllabus does not introduce the periodic law as the authors think that not enough factual material is introduced to deduce this law. All teaching was based on laboratory. All laws where possible were deduced from experiments. Lectures are given only for introduction or explanation of the gathered material.

As the result of vagueness of the "Moscow" syllabus most teachers, many of them inexperienced, either used the "Petrograd" syllabus completely or followed closely the widespread textbooks. Those were the "Elementary Course of Chemistry" by I. M. Kukulesko, the "Short Course of Chemistry" by G. M. Grigor'ev, and most often "The Elementary Course of Chemistry" by S. I. Sozonov and V. N. Verkhovskii.

In 1921 the Division o Social Education of the Commissariat of Education published a new syllabus for the seven year school. Several pages of this syllabus were devoted to the elements of chemistry that should be introduced in the first four grades, the syllabus for the senior grades was a repetition of the "Moscow" syllabus.

The above mentioned All-Russian Congress adopted a resolution stressing the importance of laboratory work, re-

quiring an increase of funds for equipment, introduction of organic chemistry, and teaching of chemistry during three years—six hour per week. It also stressed the importance of preparation of chemistry teachers.

For the Soviet schools the twenties were a period of extensive experimentation. The Dalton plan and the project method were borrowed from this country, and the Soviet educators worked out themselves the complex method, that was defined by Pinkevitch as "the study in the school of some problem, theme, or complex manifestation which from the standpoint of our educational aims is significant." In connection with this in the year 1923 the "Sketches of Programs" of the State Scientific Council were published that abolished separate subjects. Those programs stated: "There is no special course of chemistry, it is amalgamated with the courses of physics and nature, mainly in the form of experiments from the field of chemistry of everyday's life and agriculture. This is an introduction into chemistry without formulas through practical problems." This change hit chemistry much harder than the subjects that had been in the secondary school curriculum for a long time. All study material was subdivided into nature, man's exploitation of nature, and social life. No systematic course in chemistry was supposed to be given. For example, in the sixth grade following knowledge in chemistry should be acquired in this order: certain metals, their technical properties, and changes in the moist air, and by ignition; properties and composition of air and water; solutions; colloids; sulfur, silicon, phosphorus, carbon and their simplest compounds; combustion and composition of candle; breathing; composition of organic fuel; nitrogen and its simplest compounds; elementary analysis of organic substances; determination of carbohydrates, fats and proteins in an organic substance (flour); laws of conservation of mass, and definite composition; element and compound; types of chemical reactions; acids, bases, and salts (general concepts); some methods of soil analysis.

Pinkevitch in his book states that in the fifth grade the students got "physics and chemistry in so far as they are needed for clear understanding of climate, life of soil, life of plants," and in the sixth "physics and chemistry in so far as they are necessary for an understanding of (1) life of animals and man and (2) application of these sciences to industry (machine construction, locomotives, electricity)."

At a later time the complex themes were for the fifth grade, for example; 1. Peasant economy, forms of agriculture. 2. Manufacturing industry; city as an industrial center. 3. Relations between the city and the village.

In 1925 and 1926 the sketches were replaced by actual programs. The complex method in those was still stronger. The authors of the "Programs" were firm believers in the inductive method.

There was a strong opposition among teachers to these changes. Even the school administration of certain provinces kept separate subjects in their schools. Many schools paid lip service to the complex method but actually were teaching separate subjects. In the experimental school of the Pedagogical Institute of Tver a committee on chemistry discussed the new syllabus and the results were published in the local educational magazine. The committee considered that the material is badly correlated with other subjects, the syllabus is not systematic, material is wrongly distributed between grades, and the abilities of the pupils are overestimated. The syllabus calls forth the impression of a chaotic pile of material with frequent

repetition of the same theme, and intrusions in the field of other subjects, and all this with the purpose to adjust the work in chemistry to corresponding complex themes" . . . "Why, for example, water, solutions, and alloys come under heading "Types of Manufacturing Industry," and air and metals under the heading "Types of Agricultural Industry," why bleaching of fabrics with chlorine belongs to "Exchange between city and village," production of aluminum—to "Organization of Basic Branches of Industry," and production of alcohol—to "Development of Peaceful Economy." I think these two quotations from the report of the committee make any further commentaries unnecessary.

The local authorities were allowed to make some adjustments in the syllabi. For example, the Moscow Division of Public Education published in 1927 a minimum syllabus in chemistry. One hundred and ten hours were assigned to chemistry in the sixth and seventh grades subdivided in the following way: Combustion and oxidation—10 hrs.; Reduction 5 hrs.; Water 12 hrs.; Alkalis, acids, and salts 18 hrs.; Review 10 hrs. (grade six). Sulfur 20 hrs.; Nitrogen 6 hrs.; Phosphorus 3 hrs.; Chlorine and its analogues 5 hrs.; Carbon 5 hrs.; Basic chemical industry 4 hrs.; chemistry and defence 4 hrs.; Review 8 hrs. (grade seven). The syllabus gives a list of recommended experiments and demonstrations and of necessary equipment and reagents for a school laboratory. It also advises that students should work in laboratories in threes.

Since the school year 1927/28 curricula and sylabi became obligatory for the whole Russian Federative Republic. According to the curriculum of the secondary school, chemistry was taught in the fifth, sixth, seventh, eighth and ninth grades, one hour per week in the fifth, and two hours per week in all other grades. A syllabus for the eighth and ninth grades was published. Its main topics were for grade eight: Avogadro's law and the molecular theory. Petroleum, coal, hydrocarbons. Fermentation and alcohols. Carbohydrates. Products of destructive distillation of wood. For the ninth grade they were: Chemistry in peace and war (continuation of inorganic chemistry). Summary of course of chemistry and deductions (a short review o the history of chemistry, the periodic system, radioactivity, atomic number and atomic weight, elements of spectral analysis). The stress on organic chemistry was motivated, among other reasons, by the necessity f;or the military training of the students.

The textbooks used at this time were of the so called "work book" type. The most typical of them; according to Parmenov, is the Work Book in Chemistry by P. P. Lebedev. This book cooresponds to the syllabus of the State Scientific Council. Chapters I and II of this book discuss the basic concepts of chemistry correlated with the complex theme "Handicraft." Chapter III is devoted to the combustible substances and their use and is correlated with the theme "Handicraft and Factory." Chapter IV discusses study of soil and is correlated with the theme "Agriculture." Chapters V and VI discuss poisonous and preserving substances and fertilizers and are correlated with the themes "Relations between the city an dthe village" and "Exchange between the city and village." Instead of a systematic exposition of the course of chemistry the book uses the concentric method. The main part of the book consisted of research problems in which the students should answer questions on basis of their observations of everyday's life or laboratory experiments. The students are supposed to work in small groups called "brigades." This was the dominant method of teaching at these

times. It was called the "laboratory—brigade method."

In 1929 the Government of the Russian Federative Republic decided to reorganize the 9 year school into a 10 year school. The number of hours of chemistry in the new curriculum was two per week in the five senior grades.

The new syllabi of 1929 were stressing the complex method still more. The experimentation reached its peak. V. N. Shul'gin, director of the Institute of school Methods, talked about "withering away of the school." The school was declared a part of a factory or a collective farm. There were talks about abolishing lessons, textbooks, and so on.

The syllabus in chemistry conformed to the general trend. Here are two quotations: "The basic content of the teaching process in the proposed syllabus is the study of the chemical processes. Therefore the study material is exposed not by elements or compounds, but by processes. This is called "change from chemical statics to chemical dynamics." This is done out of Weltanschaung (world outlook) considerations, as the study mainly of properties of the substances and the enthusiasm for classification (according to the periodic system or in any other way) results in a static study of nature" . . . "The industrial material must be introduced into the teaching process . . . as the basic core of the teaching process, that gives to the study of chemistry its purpose."

But very soon the period of experimentation was over. Three decrees of the Central Committee of the Communist Party of September 5, 1931 "On the Primary and Secondary School," of August 25, 1932 "On School Programs and Administration in Primary and Secondary Schools," and of February 12, 1933 "On Textbooks for the Elementary School" opened a new period in the history of the Soviet schools and with it in the history of chemical education there. The scope of this work does not permit me to discuss the reasons for these changes.

More information about the state of the Soviet schools in this period may be obtained from many books on Soviet education, for example, from the two mentioned in the literature cited[9,10].

In conclusion it is my pleasant duty to thank the College Research Fund of Lafayette College for the support of the research that lead to this paper.

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SOME TEMPERATURE-VISCOSITY RELATIONSHIPS FOR CERTAIN ESTERS OF NAPHTHENIC ACID: III.

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ABSTRACT

The low temperature-viscosity relationships of fractionated ethyl ester and fractionated n-propyl ester of naphthenic acid of boiling range 0°-250°C. were investigated. In addition the temperature-viscosity relationships of the low boiling fraction of the naphthenyl ester of naphthenic acid and of the naphthane hydrocarbon were determined. These data are illustrated in Figures 1-4 of this paper. Gas chromatographic analysis of the low boiling components of the ethyl ester and of the n-propyl ester of naphthenic acid, boiling range of 0°-250°C., was employed to illustrate the complexity and heterogenieity of these substances. X-ray diffraction patterns of the low boiling cut of napthenic ester were obtained to illustrate the non-crystalline character of this fraction at specific low temperatures. The results reported herein indicate more favorable temperature-viscosity relationships than those previously reported (Appleton, Haab, et. al., 1962; Brennan and Appleton, 1961).

INTRODUCTION

Brennan and Appleton, (1961), reported that the ethyl ester of naphthenic acid exhibited superior low temperature-viscosity phenomena when compared to dioctyl sebacate. This latter ester is a dicarboxylic acid ester of comparable molecular weight. Appleton, Haab, et. al. (1962) reported that the low boiling fraction of the ethyl ester of naphthenic acid possessed better low temperature-viscosity relationships than those obtained previously in this laboratory.

OBJECT AND PLAN OF INVESTIGATION

It was felt that fractionation of the ethyl ester and of the n-propyl ester of previously cut naphthenic acid might result in components exibiting better temperature-viscosity relationships than those reported above. In addition the low boiling fractions of the naphthenyl ester of refined naphthenic acid and of the naphthane hydrocarbon were investigated regarding low temperature-viscosity relationships. Gas chromatographic fractionation was employed to illustrate the complexity and heterogenieity of the substances studied. X-ray diffraction analysis was also utilized to establish the non-crystallinity of the low boiling portion of the ethyl ester of refined naphthenic acid at specific low temperatures. The gas chromatographic and the X-ray diffraction data are related to the temperature-viscosity manifestations evaluated.

METHODS

The naphthenic acid used in this investigation had the specifications reported by Appleton, Haab, et. al., (1962) and Brennan and Appleton (1961).

Naphthenic acid was distilled at atmospheric pressure and the portion having a boiling range of 0°-250°C. was collected. One mole of this substance was reacted with 1.5 moles of thionyl chloride for 3 hours to produce the naphthenoyl chloride. The excess thionyl chloride was removed by distillation.

The ethyl and n-propyl esters of fractionated naphthenic acid were prepared by the quantitative reaction of the acid chloride and the sodium alkoxide (Brennan and Appleton 1961).

The ester fractions were characterized with respect to saponification number, acid number, specific gravity, refractive

*National Science Foundation Undergraduate Research Participants.

TABLE I

CHARACTERISTICS OF ESTER FRACTIONS AND HYDROCARBON STUDIED

	Ethyl Naphthenate			n-Propyl Naphthenate		
	A	B	C	A	B	C
Acid No.	0.53	0.42	0.94	1.61	1.43	1.43
Saponification No.	140.0	158.1	176.0	104.4	115.6	161.9
Specific Gravity	0.959	0.964	0.972	0.961	0.972	0.975
Refractive Index[1]	1.472	1.476	1.477	1.468	1.471	1.472
Boiling Range (°C)[2]	31-54	54-74	74-102	34-74	74-91	91-110

	Naphthenyl Naphthenate A		Naphthane Hydrocarbon
Acid No.	3.35	Acid No.	0.981
Saponification No.	203.0	Per Cent Hydroxyl Group[3]	0.03
Specific Gravity	0.962	Refractive Index[1]	1.464
Refractive Index[1]	1.480	Specific Gravity	0.939
Boiling Range (°C)[2]	25-137	Per Cent Iodine[3]	1.86

[1] Sodium "D" line at 25°C.
[2] 1 mm Hg
[3] Per Cent by weight

index, and boiling range at reduced pressure. These data are delineated in Table I. The low boiling fractions are designated by A, the intermediate boiling fractions by B, and the high boiling fractions by C.

Naphthenyl naphthenate was prepared by refluxing a mixture of 0.45 moles of naphthenoyl chloride with 0.40 moles of naphthenic alcohol in 200 ml benzene for 6 hours. The naphthenoyl chloride employed was prepared from undistilled naphthenic acid according to the method of Appleton, Haab, et. al., (1962) and Brennan and Appleton, (1961). After refluxing, 200 ml distilled water were added to hydrolyze the excess acid chloride. The reaction gave 98% yield. This ester was purified and fractionated in the same manner as the ethyl and n-propyl esters. The characteristics of the low boiling naphthenyl ester fraction also appear in Table I. The temperature-viscosity data obtained using the intermediate and high boiling fractions of this ester were found to be substantially higher than those of the control, dioctyl sebacate. For this reason these data are not presented.

Naphthenyl alcohol was prepared by the quantitative reaction of naphthenic acid and of lithium aluminium hydride, according to the method of Nystrom and Brown, (1947):

A solution of 0.684 moles lithium aluminium hydride in 500 ml of absolute ether was placed into a 1 liter ground glass 3 necked flask. The flask was fitted with a dropping funnel, a reflux condenser, and a mechanical stirrer and was protected from moisture at the openings of the apparatus by means of calcium chloride tubes. The lithium aluminium hydride was mechanically ground in a dry nitrogen atmosphere. The reaction flask was flushed with dry nitrogen gas for 10 minutes prior to the introduction of the lithium aluminium hydride dissolved in 200 ml of absolute ether. 0.82 moles of refined naphthenic acid were added by means of a dropping funnel at a rate conducive to gentle reflux. Ten minutes after the last addition and with continuous stirring, 50 ml distilled water were added, through the dropping funnel, to hydrolyze the excess reducing agent. The reaction mixture was poured into 1 liter of cold 15% sulfuric acid solution. The oily layer which separated was collected, washed successively with sodium bicarbonate and with distilled water, and dried over anhydrous sodium sulfate.

The hydroxyl content of this alcohol was determined according to the method of Smith and Bryant (1935), and was found to be 99.8% of the theoretical amount based on the molecular weight as determined from the acid number.

Naphthane hydrocarbon was prepared by a modification of the method of Marwel, Hager, and Caudle (1932):

Into a 1 liter flask was placed 250 ml of glacial acetic acid, 0.12 moles red phosphorous, and 0.02 moles iodine. After 15-20 minutse, 5 ml distilled water and 0.40 moles naphthenyl alcohol were added. A reflux condenser was attached and the mixture was allowed to reflux for 6 hours. At the completion of this period, the hot reaction mixture was filtered to remove excess red phosphorous. The hot filtrate was slowly poured into a cooled, well stirred, filtered solution of 20-25 grams sodium bisulfite in 1 liter distilled water. The oily layer which separated was removed and washed with distilled water. The reaction gave 97% theoretical yield.

The hydroxyl content of this hydrocarbon was determined by the aforementioned method. Because of a possible alkyl iodide by-product of the above reaction, the iodine content was determined according to Volhard's Method, (1962). The iodine content was confirmed by neutron activation analysis, (McGinnis and Zimmer, 1963). These data and other physical constants characterizing the hydrocarbon are presented in Table I.

Viscosity measurements were obtained using a Brookfield model LVF Synchro-lectric viscometer (Minard, 1934). Temperature control was effected by means of various freezing mixtures such as: ethyl alcohol and solid carbon dioxide, ethyl ether and solid carbon dioxide, and ice water. A Dewar flask was employed to maintain constant temperature. Temperatures were determined using a copper-constantan thermocouple (Bernard, 1956).

The gas chromatograms of the low boiling fractions of the ethyl esters of fractionated naphthenic acid and of various simple esters were obtained employing a Fisher-Gulf model 300 Partitioner.

Two columns were employed in the gas chromatographic analysis:

a. a six foot column, consisting of a solid packing Johns Manville Chromosorb and of a liquid phase of High Vacuum Silicone Grease (Dow-Corning) in a ratio of 4 to 1 grams respectively by weight.

b. an eight foot column consisting of a solid packing of Johns Manville Chromosorb and of a liquid phase—the aforementioned silicone grease—in a ratio of 5 to 1 grams respectively by weight.

Dry helium gas was used as the carrier gas. The chart speed of the recording unit was 0.25 inches per minute for all determinations.

The samples of the low boiling fractions of the ethyl and n-propyl esters of naphthenic acid of boiling range 0°-250°C. utilized in this gas chromatographic analysis were obtained by distilling the aforementioned esters at atmospheric pressure and collecting the distillates having a maximum boiling point of 250°C.

X-ray diffraction patterns of the low boiling fraction of the ethyl ester of undistilled naphthenic acid reported by

Appleton, Haab, et. al., (1962) were obtained using a Molybdenum x-ray tube and a Buerger Precession Camera. Exposures were of 20 minute duration at 18 microamps and 50 kilovolts. The coolant used was liquid nitrogen. The precession angle was 6°.

PRESENTATION AND DISCUSSION OF DATA

The temperature-viscosity relationships of the low boiling, the intermediate boiling, and the high boiling fractions of the ethyl and n-propyl esters of naphthenic acid of boiling range 0°-250°C were determined. These data appear in Tables II and III and are illustrated in Figures 1 and 2 respectively. In addition, the temperature-viscosity variabilities of the low boiling fraction of the naphthenyl ester of undistilled naphthenic acid, of the naphthane hydrocrabon, and of dioctyl sebacate were resolved. These data are presented in Table IV and are depicted in Figures 3 and 4 respectively. The viscosity data in these tables are given in centipoise units. The temperatures are in degrees Centigrade.

TABLE II

TEMPERATURE-VISCOSITY DATA FOR ETHYL ESTER FRACTIONS

Low Boiling Fraction		Intermediate Boiling Fraction		High Boiling Fraction	
Temp.	Visc.	Temp.	Visc.	Temp.	Visc.
-63.0	79.80	-60.5	194.1	-59.0	195.8
-60.2	59.30	-59.0	134.2	-55.0	127.8
-54.0	31.90	-53.8	73.2	-39.0	87.6
-51.0	29.70	-49.8	56.0	-36.2	78.6
-45.0	22.15	-43.2	33.2	-24.1	51.3
-40.5	18.25	-33.8	21.0	- 6.0	13.7
-31.5	12.31	-22.4	18.3		
-20.8	12.31	-17.5	13.7		
-13.8	11.40	- 9.0	11.4		

TABLE III

TEMPERATURE-VISCOSITY DATA FOR N-PROPYL ESTER FRACTIONS

Low Boiling Fraction		Intermediate Boiling Fraction		High Boiling Fraction	
Temp.	Visc.	Temp.	Visc.	Temp.	Visc.
-60.8	52.1	-58.2	153.4	-57.0	371.0
-58.2	38.0	-54.5	96.4	-53.0	236.2
-50.5	27.4	-50.8	82.0	-45.8	97.3
-46.8	16.5	-44.2	46.8	-36.2	46.8
-40.5	15.6	-38.0	30.2	-24.2	19.2
-33.0	11.9	-21.8	14.8	-13.5	14.8
-24.2	11.0	-12.8	14.8		
-12.8	11.0				

TABLE IV

TEMPERATURE-VISCOSITY DATA OF LOW BOILING NAPHTHENYL ESTER FRACTION, FOR NAPHTHANE HYDROCARBON, AND FOR DIOCTYL SEBACATE

Ester Fraction		Hydrocarbon		Dioctyl Sebacate	
Temp.	Visc.	Temp.	Visc.	Temp.	Visc.
-35.0	280.0	-41.0	290.0	-17.0	223.8
-30.0	171.0	-32.0	161.0	-14.0	177.7
-21.0	99.9	-26.0	87.0	-13.0	161.1
- 9.5	48.4	-17.0	48.5	-11.0	145.5
- 1.5	36.3	- 9.0	35.5	- 9.0	108.7
		- 1.0	32.3	- 8.0	100.1
				- 5.0	75.6

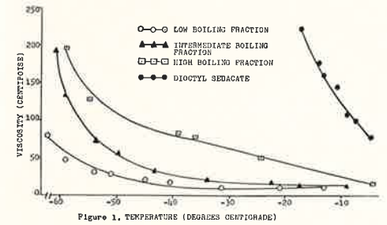

Figure 1. TEMPERATURE (DEGREES CENTIGRADE)

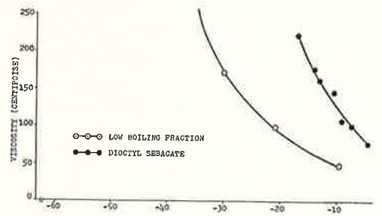

Figure 3. TEMPERATURE (DEGREES CENTIGRADE)

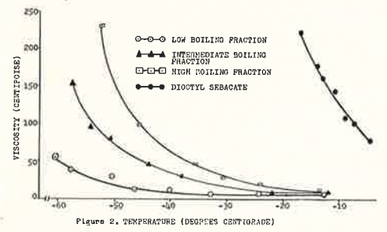

Figure 2. TEMPERATURE (DEGREES CENTIGRADE)

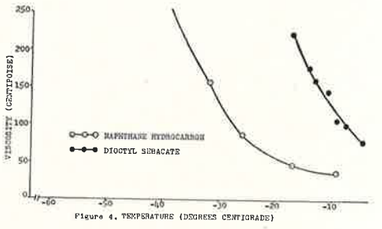

Figure 4. TEMPERATURE (DEGREES CENTIGRADE)

Figure 1. Temperature-Viscosity Relationships of Fractionated Ethyl Esters of Naphthenic Acid of Boiling Range 0°-250°C and of Dioctyl Sebacate.

Figure 2. Temperature-Viscosity Relationships of Fractionated n-Propyl Esters of Naphthenic Acid of Boiling Range 0°-250°C and of Dioctyl Sebacate.

Figure 3. Temperature-Viscosity Relationships of the Low Boiling Fraction of Naphthenyl Ester of Undistilled Naphthenic Acid and Dioctyl Sebacate.

Figure 4. Temperature-Viscosity Relationships of the Naphthane Hydrocarbon and of Dioctyl Sebacate.

It can be seen from the above figures that fractionation of the naphthenic acid prior to esterification and also subsequent fractionation resulted in cuts possessing superior temperature-viscosity relationships than those previously reported. Concerning the various fractions of the ethyl and n-propyl esters, it can be noted that the viscosity increased as the boiling range of the ester fraction increased. Also, the viscosity increased as the molecular weight of the ester increased. It would seem that as the carbon content of the alcohol portion of the ester increased, the temperature-viscosity correspondence approached those of the control, dioctyl sebacate. All substances evaluated exhibit superior temperature-viscosity phenomena than those heretofore reported.

The gas chromatograms of the low boiling fractions of the ethyl and n-propyl esters appear in Figures 5, 6, 7, 8, 9, and 10. Gas chromatographic separation of a mixture of simple esters appears in Figure 11. Figures 5, 6, 9, 10, and

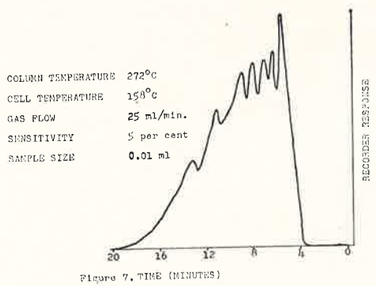

Figure 7. TIME (MINUTES)

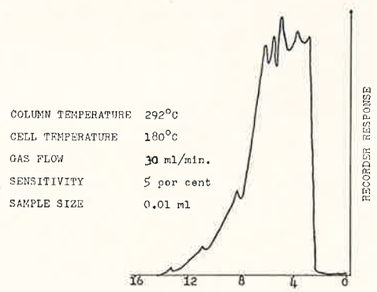

Figure 5. TIME (MINUTES)

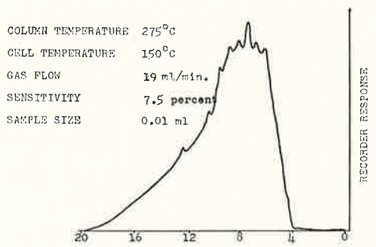

Figure 6. TIME (MINUTES)

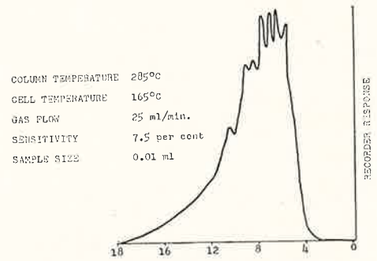

Figure 8. TIME (MINUTES)

Figure 5. Gas Chromatographic Separation of the Low Boiling Fraction of the Ethyl Ester of Naphthenic Acid with the Six Foot Column at 292°C.

Figure 6. Gas Chromatographic Separation of the Low Boiling Fraction of the Ethyl Ester of Naphthenic Acid with the Six Foot Column at 275°C.

Figure 7. Gas Chromatographic Separation of the Low Boiling Fraction of the Ethyl Ester of Naphthenic Acid with the Eight Foot Column at 272°C.

Figure 8. Gas Chromatographic Separation of the Low Boiling Fraction of the Ethyl Ester of Naphthenic Acid with the Eight Foot Column at 285°C.

11 were obtained using a six foot column consisting of a solid packing of Johns Manville Chromosorb and of a liquid phase of High Vacuum Silicone Grease (Dow-Corning) in a ratio of 4 to 1 grams respectively by weight. Figures 7 and 8 were obtained using an eight foot column consisting of a solid packing of Chromosorb and of a liquid phase—the aforementioned silicone grease—in a ratio of 5 to 1 grams respectively by weight.

It is evident from the above chromatograms that improved resolution was obtained for the low boiling fractions of the ethyl and n-propyl esters of distilled naphthenic acid than was previously reported from this laboratory. The low boiling ethyl ester fraction was partially resolved into 7 and 8 peaks; the low boiling n-propyl ester component was partially resolved into 9 and 10 peaks. With respect to the ethyl ester fraction, better resolution was obtained using the eight foot column than with the six foot column. Separation of the simple esters resulted in one clearly defined peak for each ester. The gas chromatograms of the low boiling fractions of the ethyl and n-propyl esters, with reference to the simple esters evaluated, illustrate the heterogenieity and complexity of the naphthenic acid esters.

X-ray diffraction patterns of the low boiling fraction of the ethyl ester of undistilled naphthenic acid are presented in Figures 12 and 13. Figure 14 illustrates the x-ray diffraction pattern of benzene, the standard employed, at a temperature of -131°C. Figure 12 represents the x-ray diffraction pattern of the ester at a temperature of -152°C. Figure 13 is the pattern of the same ester, taken in a different part of the capillary utilized to

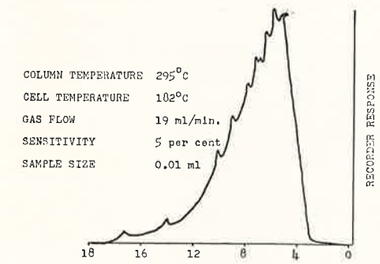

Figure 9. TIME (MINUTES)

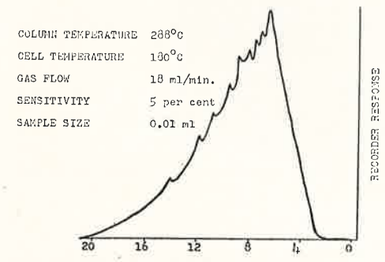

Figure 10. TIME (MINUTES)

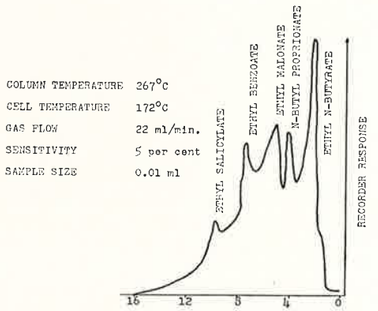

Figure 11. TIME (MINUTES)

Figure 9. Gas Chromatographic Separation of the Low Boiling Fraction of the n-Propyl Ester of Naphthenic Acid with the Six Foot Column at 295°C.

Figure 10. Gas Chromatographic Separation of the Low Boiling Fraction of the n-Propyl Ester of Naphthenic Acid with the Six Foot Column at 288°C.

Figure 11. Gas Chromatographic Separation of a Mixture of Simple Esters with the Six Foot Column at 267°C.

Figure 12. X-ray Diffraction Pattern of the Low Boiling Fraction of the Ethyl Ester of Undistilled Naphthenic Acid at —152°C.

Figure 13. X-ray Diffraction Pattern of the Low Boiling Fraction of the Ethyl Ester of Undistilled Naphthenic Acid at —132.5°C.

hold the sample and at a temperature of -132.5°C. In each case, it is evident that, under the conditions specified, no pattern indicative of a pure crystalline compound was found with the low boiling fraction of the ethyl ester of naphthenic acid. The benzene control illustartes a diffraction pattern indicative of crystalline form.

SUMMARY AND CONCLUSIONS

1. The low temperature-viscosity relationships of fractionated ethyl and n-propyl esters of distilled naphthenic aicd (boiling range 0°-250°C); of the low boiling fraction of the naphthenyl ester of undistilled naphthenic acid; and of the naphthane hydrocarbon were investigated.

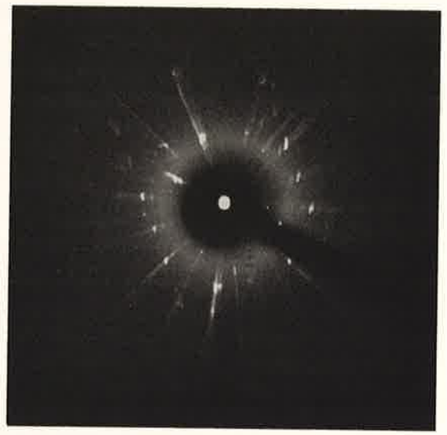

Figure 14. X-ray Diffraction Pattern of Benzene at —131°C.

2. Gas chromatographic preparations of the low boiling fractions of the ethyl and n-propyl esters of distilled naphthenic acid (boiling range 0°-250°C) and of a mixture of simple esters were determined.

3. X-ray diffraction patterns were obtained for the low boiling ethyl ester fraction of undistilled naphthenic acid.

4. It has been demonstrated that fractionation of naphthenic acid prior to esterification and subsequent additional fractionation of the ester yields components which posses superior temperature-viscosity relationships than formerly reported. Improved resolution regarding the heterogenieity of these naphthenic acid esters can be perceived from the gas chromatographic data presented.

5. The low boiling fraction of the ethyl ester of distilled naphthenic acid possesses the best low temperature-viscosity manifestations of those reported herein or formerly reported from this laboratory.

6. X-ray diffraction analysis illustrates the non-crystalline character of the low boiling fraction of the ethyl ester of undistilled naphthenic acid at specific low temperatures.

ACKNOWLEDGMENT

The authors acknowledge the services of Mr. Sanford Ostroy, Case Institute of Technology, who contributed the x-ray diffraction data utilized in this paper.

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A MODIFICATION OF THE GUTHRIE TEST FOR PHENLYKETONURIA[1]

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ABSTRACT

Guthrie's test (1960) was designed to screen phenylketonurics within a few days of birth. A modification of this procedure has been devised incorporating a new gel-forming agent as a replacement for agar-agar in the bacteriological medium utilized. This new medium, containing spores of **B subtilis** was lyophilized, stored, and then rehydrated at room temperature to evaluate blood samples for the determination of the approximate phenylalanine content.

INTRODUCTION

In 1934, A. Folling (1934) called attention to the fact that phenylpyruvic acid was found in the urine of some mental retardates. This condition has since been referred to as phenylketonuria. The condition of phenylketonuria has been observed by Hsia (1958) to be associated with severe mental retardation and a light coloration of the skin and hair. Because it has been actually shown to be a cause of mental retardation, it has been the object of much intensive study.

Knox (1960) has shown that treatment of phenylketonurics at an early stage with a phenylalanine-low diet reduces the occurrence of the objective symptoms and such treatment can be a preventive of mental deficiency. To detect this disease in infants, Guthrie and Tieckelmann (1960) devised a test which operated on the principle of the microbiological inhibition assay. The growth of a bacterium, *Bacillus subtilis,* is inhibited by b-2-thienylalanine and this inhibition is overcome by L-phenylalanine. In this test, blood is obtained from the infants to be tested and spotted on absorbent filter paper. Discs of known diameter are punched from these spots and steamed under pressure to affix the blood pigments firmly. The discs are then placed on an agar medium containing the bacteria spores, the inhibitor, and the nutrients required by *Bacillus subtilis* (buffered to optimum p^H). After incubation, the size of the growth area, as compared to that of controls, gives a semi-quantitative estimation of the phenylalanine in each blood disc.

OBJECT AND PLAN OF INVESTIGATION

The problem was to establish the composition of and to prepare a bacteriological medium containing spores of *Bacillus subtilis,* its inhibitor, the nutrients and buffers required for the growth of this organism, and a suitable gel-forming agent, all of which could be lyophilized and rehydrated to be used in performing the test contrived by Guthrie and Tieckelmann (1960). One requirement of the lyophilized medium was that it should be acapable of being reconstituted with water at room temperature. Furthermore, it must form a gel which would be rigid enough to support paper blood discs after rehydration and also be free of air bubbles throughout. The reconstituted medium should also be capable of maintaining a definite pH, and be non-toxic to the organism present. Such a medium could be prepackaged and would lend itself to rapid and convenient utilization.

METHODS

Since the composition of the medium used for cultivating *Bacillus subtilis* was known from the work of Demain (1958)

1 This research was supported by grants from the Pennsylvania Academy of Science, The Scranton Foundation, and U. S. Public Health Service Grant No. 07421-01A1.

* National Science Foundation Undergraduate Research Participant.

and Guthrie and Susi (to be published), most of the work reported here involved the search for a gel-forming agent other than agar which could be lyophilized and then reconstituted at room temperature. Agar was unsuitable since it does not disperse in water until a temperature of approximately 100°C. is attained. This temperature may adversely affect the organism contained in the lyophilized culture upon rehydration.

Guthrie's medium consists of the following ingredients:

K_2HPO_4	30.0 gm.
KH_2PO_4	10.0 gm.
NH_4Cl	5.0 gm.
NH_4NO_3	1.0 gm.
NA_2SO_3	1.0 gm.
L-Glutamic acid	1.0 gm.
L-Asparagine	1.0 gm.
L-Alanine	0.5 gm.
Dextrose	10.0 gm.
Agar	30.0 gm.
$MgSO_4.7H_2O$	0.1 gm.
$MnCl_2.4H_2O$	0.01 gm.
$FeCl_3.6H_2O$	0.01 gm.
$CaCl_2$	0.005 gm.
b-2-Thienylalanine	0.00171 gm.

These ingredients were diluted to 2 liters with distilled water and 2 ml. of spore suspension of optical density of 0.9 were added to complete the culture.

The medium designed as a substitute for the above in this work consisted of the following ingredients:

K_2HPO_4	30.0 gm.
KH_2PO_4	10.0 gm.
NH_4Cl	5.0 gm.
NH_4NO_3	1.0 gm.
Na_2SO_3	1.0 gm.
L-Glutamic acid	1.0 gm.
L-Asparagine	1.0 gm.
L-Alanine	0.5 gm.
Dextrose	10.0 gm.
Hydroxyethyl cellulose	140.0 gm.
$MgSO_4.7H_2O$	O.1 gm.
$MnCl_2.4H_2O$	0.01 gm.
$FeCl_3.6H_2O$	0.01 gm.
$CaCl_2$	0.005 gm.
b-2-Thienylalanine	0.000855 gm.

The above ingredients were diluted to 1 liter with distilled water.

It should be noted that this medium is not a "minimal" one. All nutrients with the exception of the inhibitor, b-2-thienylalanine, exist in twice the concentration of that found in Guthrie's medium.

Inoculations were 1 ml. of spore suspension having an optical density of 0.9 to the above quantity of cooled medium. Before inoculation was made the medium, materials, and equipment used were sterilized by autoclaving at 15 p. s. i. for 20 minutes. The paper blood discs, mentioned previously, were also steamed under these conditions. The b-2-thienylalanine was kept frozen until needed and was added to the medium after sterilization. Doubly distilled water was used in all preparations.

Lyophilization was carried out with a VirTis freeze-dryer utilizing flasks which could be dismantled for the convenient removal of material. Pressure, less than 1 mm. of mercury, was indicated by a manometer. Lyophilization was continued for from 60 to 80 hours. Since, as known from preliminary tests, there was no danger of contamination from the air, the suction holding the flasks to the manifold of the freeze-dryer was broken by admitting air from the atmosphere to the evacuated system. This was done with ease since the flasks used provided for the admission of air by having intake holes which could be opened if desired. The dehydrated medium was then mechanically ground in an apparatus which had been previously sterilized in an autoclave. After rehydration with sterile distillied water the pH of the medium was checked at 6.8.

After 0.2 hours of hydration, the samples to be tested and a set of control blood spots (to which phenylalanine had been added in the concentrations of 2, 4,

6, 8, 10, 12 mg. %) were placed on the solidified medium, which was then allowed to stand undisturbed overnight at room temperature. The bacterial growth was observed after 20-24 hours of incubation at 30° C.

DATA

A 250-ml. quantity of medium with hydroxyethyl cellulose substituted for agar was used to test 20 blood samples obtained from Selinsgrove State School at Selinsgrove, Pennsylvania. Of these samples eight showed noticeable growth after incubation. Inquiry verified that these eight samples were taken from phenylketonurics.

Three additional portions of the lyophilized culture were kept in Petri dishes for thirty days at room temperature and then rehydrated. Three blood spots were placed on each gel. The blood spots contained 2, 10 and 20 mg. % of phenylalanine. These samples indicated growth proportional to the phenylalanine concentration against controls. These results show that the procedure used here does not adversely affect the spores and that the hydroxyethyl cellulose has no inhibitory effect.

A 250-ml. portion of this lyophilized culture was hydrated and used to test an assortment of control, normal, and phenylketonuric blood samples. Each of the phenylketonuric samples stimulated growth and proportionate growth response was obtained from the controls.

Normal blood spots prepared by utilizing excessive concentrations of blood also gave a growth response. Care should be taken not to apply excessive amounts of blood to any of the filter papers from which discs are obtained. This prevents unduly high accumulation of phenylalanine and proline normally present in blood.

CONCLUSION

This "instant" culture offers promise for the detection of phenylketonuria and offers a procedure that is relatively simple, and convenient. The culture or medium would be very useful for the screening of large numbers of infants and it can be prepackaged to be made available to physicians and others who would perform the test. The convenience with which blood samples can be tested by this revised procedure is especially notable. The person performing the test need only reconstitute the medium with sterile distilled water, add the blood spots and incubate the culture prior to checking for growth response.

Validation and reliability studies of this new verision of Guthrie's test as applied to the blood of 5-day old infants are in progress in this laboratory at present.

ACKNOWLEDGMENTS

For supplying hydroxyethyl cellulose gratitude is expressed to Glenn I. Stelzer, Manager, Wilmington District, Hercules Powder Company, Wilmington, Delaware. For furnishing spores of *Bacillus subtilis* ATCC 6051 thanks are due to Robert Guthrie, Ph. D., M. D., Department of Pediatrics, University of Buffalo Children's Hospital, Buffalo, New York. Acknowledgment is also made to Lewis Gerhart, M. D., and Mr. Jack Brause, M. T., at Selinsgrive State School, Selinsgrove, Pennsylvania, for supplying blood samples.

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PROGRAM and ABSTRACTS of the 39th ANNUAL SESSION

THE PENNSYLVANIA ACADEMY OF SCIENCE

39th Annual Meeting

EAST STROUDSBURG STATE COLLEGE
East Stroudsburg, Pa.

FRIDAY, APRIL 12, 1963

Registration—9:00-4:00 P.M.—Reception Room, Laurel Hall

Registration fee — $2.00

Executive Committee Meeting — 9:00 A.M. - 12:00 Noon
Reception Room, Laurel Hall

A. GEOLOGY: SESSION I.

Friday 1:30 - 4:30 P.M. Science Building 203

Chairman: Arthur H. Socolow, State Geologist, Dept. of Internal Affairs, Harrisburg, Pa.

McLAUGHLIN, D. B. (University of Michigan). Newly recognized folding in the Triassic of Pennsylvania ..... 12 Minutes

BUCKWATER, T. V. (University of Pittsburgh). Evidence on the origin of the "pinite" of the Reading Hills, Pennsylvania ..... 15 Minutes

SIMPSON, D. R. (Lehigh University). Conditions of formation of Prehnite and associated vein minerals in diabase near Coopersburg Pennsylvania ..... 15 Minutes

LAYMAN, F. D. (University of Pennsylvania). Cordierite alteration. ..... 15 Minutes

HUELSENBECK, P., and J. R. BEERBOWER (Lafayette College). Paleoecology of late cretaceous shell-beds at Poricy Brook, Manmouth County, New Jersey ..... 15 Minutes

GLAESER, J. D. (Department Internal Affairs, Harrisburg). Lithostratigraphic nomenclature of the Triassic Newark-Gettysburg Basin ..... 15 Minutes

REED, J. C. (Wayne, Pennsylvania). A new study of Tertiary and Cretaceous sediments from the 2306-foot, 1961 Atlantic City, New Jersey, well ..... 15 Minutes

MYERS, P. B. and J. D. Ryan (Lehigh University). Uraniferous black shales in the Triassic of Pennsylvania ..... 10 Minutes

HOSKINS, D. M. (Pa. Geological Survey, Harrisburg). A provisional Silurian-Devonian rock-statigraphic column for central Pennsylvania ..... 15 Minutes

RICHARDS, H. G., and E. SHAPIRO (Academy Natural Sciences, Philadelphia). A Devonian faunule from Lehighton, Pennsylvania ..... 10 Minutes

WHITCOMB, L. (Lehigh University). Saw cut bones in an apparent fossil. .... 10 Minutes

WILLARD, BRADFORD (Lehigh University). Ontogeny of the Jurassic ammonite Arietites from Peru ..... 10 Minutes

B. GEOGRAPHY SESSION I.

Friday 1:30 - 4:30 P.M. Science Building 204

Chairman: E. Willard Miller, Pennsylvania State University

CREVELING, R. F. (State College, E. Stroudsburg). Tocks Island project. .... 15 Minutes

SIMKINS, P. D. (Pennsylvania State University). Recent population changes in the anthracite belt of Pennsylvania, 1950-1960 ..... 15 Minutes

KARASKA, G. J. (University of Pennsylvania). Central place relationships in the distribution of mining towns in the Southern and Middle anthracite region of Pennsylvania ..... 15 Minutes

ENMAN, J. (State College, Bloomsburg). The rise and decline of the Connellsville Beehive Coke region ..... 15 Minutes

DEASY, G. F., and GRIESS, P. R. (Penna. State University). Historical geography of major Pennsylvania anthracite mine accidents caused by gas explosions ..... 15 Minutes

GRIESS, P. R., and G. F. DEASY (Pennsylvania State University). The geography of a new tourist facility in the anthracite region of Pennsylvania ..... 15 Minutes

C. SYMPOSIUM: FACTORS GOVERNING MORPHOGENESIS OF PARASITIC ANIMALS

Friday 1:00 - 5:00 P.M. Science Building 303

Chairman: Thomas C. Cheng, Lafayette College, Easton

CHENG, T. C. (Lafayette College). The development of form and parasitism: Introduction.

STABLEFORD, LOUIS T. (Lafayette College, Easton). Some general considerations in morphogenetic studies.

KATZ, FRANK F. (Seton Hall University, South Orange, N. J.). Endocrinological factors in the life histories of parasitic helminths.

OGREN, R. E. (Dickinson College). Morphogenesis of the tapeworm hexacanth embryo.

GRAHAM, GEORGE L. (Univ. of Pennsylvania). Heterogenesis and the biology of *Strongyloides.*

MEINKOTH, NORMAN A. (Swarthmore College, Swarthmore, Pa.). The present status of our knowledge of development in the Mesozoa.

SILLMAN, EMMANUEL I. (Duquesne University, Pittsburgh). The ecology of trematode development: A review.

CHENG, THOMAS C. (Lafayette College). One aspect of the biochemical basis for development: The source and utilization of amino acids in intramolluscan larval trematodes.

D. VERTEBRATE ZOOLOGY SESSIONS

Friday 1:00 - 5:15 P.M. Science Building 104

Chairman: James H. Leathem, Rutgers University, New Brunswick, N. J.

Session I.

CORSO, JOHN F. (St. Louis Univ.) and MURRAY LEVINE (Penna. State Univ.). The pitch of ultra-sonic frequencies heard by bone conduction .... 15 Minutes

KOSKI, JAMES (Bucknell University, Lewisburg). Hoarding differences in different strains of golden hamsters ..... 15 Minutes

HOULIHAN, R. T. (Pennsylvania State University). Correlation of blood-clotting time and population density in the vole *Microtus californicus* ..... 10 Minutes

YATVIN, M. B., and J. H. LEATHEM (Rutgers University, New Brunswick, N. J.). Ovarian fixation of I-131 containing compounds ..... 15 Minutes

NELSON, B. DEAN, and ADAM ANTHONY (Pennsylvania State University). Electrophoretic analysis of serum proteins and blood hematocrit determinations in rats exposed to reduced barometric pressures ..... 15 Minutes

PAUL, P. K., and J. H. LEATHEM (Rutgers University). Influence of steroid hypertension on electrolytes and serum proteins ..... 15 Minutes

WEINSTEIN, JAMES D., and J. MARMER (Univ. Pennsylvania School of Medicine). The determination of salivary electroyte levels in man ..... 15 Minutes

BRIEF INTERMISSION 2:45 - 3:00

D. VERTEBRATE ZOOLOGY SESSIONS — cont.

Chairman: James H. Leathem

Session II. Room 104, 3:00 - 5:15 P.M.

WEINLAND, LINDA (Bucknell University). Production of abnormal hamster embryos with ultrasound ..... 15 Minutes

EVOY, MARTHA and HULDA MAGALHAES (Bucknell University). Teratogenic action of trypan blue in two strains of golden hamsters ..... 15 Minutes

FRIEDMAN, M. H. F. (Jefferson Medical College, Phila.). Total body irradiation. 15 Minutes

ANTHONY, ADAM, and NANCY BACHMAN (Pennsylvania State University). Histology of gastro intestinal organs as influenced by season reproductive activity and hibernation in the eastern chipmunk, *Tamias striatus* ..... 15 Minutes

NEFF, W. H., and ADAM ANTHONY (Pennsylvania State Univ.). Microanatomy of the male reproductive organs of the eastern chipmunk, *Tamias striatus* .... 15 Minutes

BARTONE, JOHN C. (George Washington University, Washington, D. C.). Histochemical distribution of the non-specific alkaline phosphatase in the organs and tissues of the 10 mm pig embryo (*Sus scrofa*) ..... 10 Minutes

BALLANTYNE, ROBERT L. (Marine Corps Air Facility, Jacksonville, N. C.). Basic considerations in teaching aerospace biology ..... 10 Minutes

SHENK, WILBUR D. (Franklin and Marshall College, Lancaster, Pa.). The innervation ratio of the anterior gracilis muscle of the albino rat ..... 10 Minutes

BENDER, A. DOUGLAS, and S. M. HORVATH (Smith, Kline and French, Phila.). Observations on bromosulphalein clearance and hepatic blood flow in the dog ..... 10 Minutes

BENDER, A. D. and S. M. Horvath (Smith, Kline & French, Phila.). On the relation of hepatic blood flow to the metabolic requirements of the spanchnic bed ..... 10 Minutes

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ACADEMY BANQUET

6:00 P.M. Reception — Academy Members and Friends, Reception Room, Stroud Hall.

6:30 P.M. Academy Banquet — Dining Hall, East Stroudsburg State College.

8:30-10:00 P.M. Lecture — Dining Hall, East Stroudsburg State College.
"The Universe as Revealed by Radio." Professor Fletcher G. Watson, Director of Science Teacher Education, Harvard Univ. Graduate School.

10:00-12:00 P.M. Continuation of the Executive Committee business meeting, if necessary. Reception Room, Stroud Hall.

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SATURDAY, APRIL 13, 1963

9:00-10:00 A.M. Annual Academy Business Meeting. Science Building 104.
President Georeg F. Deasy, Presiding.
Report of Executive Committee, Election of Officers.
Discussion and vote on proposed changes to constitution.

E. BIOLOGY SESSION: I BOTANICAL STUDIES

Saturday 10:00 - 12:00 A.M. Science Building 303

Chairman: Paul R. Wagner, Ursinus College, Collegeville, Pa.

Co-chairman: Albert Martin, Jr., Veterans Hospital, Pittsburgh, Pa.

MILLER, ERSTON V., M. FRY and V. MAZEKE (University of Pittsburgh). Growth inhibitors in sprouts of the potato *Solanum tuberosum* ..... 15 Minutes

ROSENBERG, ALBURT M. (Swarthmore College, Swarthmore, Pa.). Size changes during the aging of yeast cells ..... 15 Minutes

MARTIN, ALBERT JR. (V. A. Hospital, Pittsburgh, Pa.). *Virbrio multiformis* and nervous tissue ..... 15 Minutes

GEWANT, WARREN C. and HARRY K. LANE (Franklin and Marshall College). The biological availability of riboflavin solubilized with sodium salicylate .... 10 Minutes

SANDERS, BOB G. and A. ROTHBART (Lafayette College, Easton, Pa.). Immunochemical analyses of hemagglutinating substances in leguminoseae seeds. 15 Minutes

MILLER, ERSTON V., R. GREENE, C. CURRY and A. S. CANCILLA (Univ. of Pittsburgh). Antimetabolics in the lichen *Umbilicaria papulosa*. I: A preliminary report ..... 10 Minutes

GROSSMAN, HERBERT H. (Pennsylvania State University). Proliferation in moss leaves under various experimental conditions ..... 15 Minutes

MURR, LARRY E. (Pennsylvania State University). Optical microscopy investigation of plant cell destruction in an electrostatic field ..... 15 Minutes

F. GENERAL SCIENCE, REVIEW AND INVERTEBRATE ZOOLOGY SESSION

Saturday 10:00 - 12:20 P.M. Science Building 306

Chairman: Elmer C. Herber, Dickinson College, Carlisle, Pa.

MARTIN, PHYLLIS C. (Chatham College, Pittsburgh, Pa.). Including scientists in science courses ..... 15 Minutes

EISS, ALBERT F. (Dept. of Public Instruction, Harrisburg). The role of the Pennsylvania Academy of Science in education ..... 15 Minutes

LOUGHRY, F. G. (Soil Conservation, U. S. Dept. of Agriculture, Harrisburg). Soil science serves all of Pennsylvania ..... 15 Minutes

COUTANT, C. C. (Lehigh University, Bethlehem). Stream plankton above and below Green Lane Reservoir ..... 15 Minutes

KNEPP, T. H. (Stroud Union High School, Stroudsburg). The 1962 appearance of brood II of the 17 year cicada in Monroe Co., Pa. ..... 15 Minutes

KINGSTON, NEWTON (Geneva College, Beaver Falls, Pa.). Comparison of the rate of development of *Brachylecithum orfi* (Trematoda: Dicrocoeliidae) in the land snails, *Zonitoides arboreus* and *Cionella lubrica* ..... 10 Minutes

LADISCH, R. K. (255 Windermere Ave., Lansdowne, Pa.). Isolation and characterization of certain insect secreta ..... 15 Minutes

AGATHA, SISTER M. ST. (Immaculata College, Immaculata, Pa.) Insect-quinone treated food; Toxicity to mice ..... 10 Minutes

GROVE, DAVISON G. (Wilson College, Chambersburg). Regeneration of appendages in the angular-winged katydid, *Microcentrum rhombifolium* Sauss .. 10 Minutes

COME, T. V. (Edinboro State College, Edinboro, Pa. and D. J. NASH (Rutgers University New Brunswick, N. J.). Effect of population density on thorax length in *Drosophila melanogaster* ..... 15 Minutes

G-1. GEOGRAPHY II.

Saturday 10:00 - 11:15 A.M. Science Buliding 203

Chairman: Phyllis R. Griess, Pennsylvania State University

KULKARNI, GOPAL S. (University of Pittsburgh). Some aspects of the distribution of population in Pennsylvania ..... 15 Minutes

SCHNELL, GEORGE A. (State University College, New Paltz, N. Y.). Population growth and employment trends in Bucks County, Penna. 1950-1960 .... 15 Minutes

MILLER, E. WILLARD (Pennsylvania State University). The recreation potential of the Upper Susquehanna (West Branch) Basin: A geographic analysis ..... 15 Minutes

BECKER, EUGENE H. (University of Pittsburgh). Employment in selected manufacturing industries in Pennsylvania ..... 15 Minutes

MYERS, RICHMOND (Moravian College, Bethlehem). Colonial industrial Bethlehem ..... 15 Minutes

WHITNEY, HERBERT A. (Pennsylvania State University). Densities of population in the colonies of Rhode Island and Plymouth in 1689 ..... 15 Minutes

G-2. GEOLOGY II.

Saturday 11:30 - 12:20 P.M. Science Building 203

Chairman: Richmond Myers, Moravian College, Bethlehem, Pa.

TREXLER, J. P., G. H. WOOD, JR. and H. H. ARNDT (Juniata College and U. S. Geological Survey, Washington, D. C.). Progress of U. S. Geological Survey investigations in the anthracite regions of Pennsylvania ..... 15 Minutes

GOODWIN, BRUCE K. (University of Pennsylvania). Structural control of Wissahickon Creek in Philadelphia, Pa. ..... 15 Minutes

KELLER, ALLEN (University of Pennsylvania). Partial section of Wissahickon Schist, Wissahickon Creek ..... 12 Minutes

MACLACHLAN, DAVID B. (Bur. Topographic & Geological Survey, Harrisburg). Stereographic methods for rapid determination of apparent dip and map trace of intersecting surfaces ..... 15 Minutes

BOCK, WILHELM (Geological Center, North Wales, Pa.). Principles of dichotomy ..... 10 Minutes

H. CHEMISTRY SESSION

Saturday 10:00 - 12:00 Noon. Science Building 204

Co-Chairmen: Paul C. Casey and M. D. Appleton, University of Scranton, Scranton, Pa.

FEELEY, R. and E. A. McGINNIS (University of Scranton, Scranton). Symmetric switching functions ..... 15 Minutes

KELLER, E. C. (Univ. N. Carolina) R. GRANLUND and E. S. KENNEY (Penna. State Univ.). A further report on radioactive fallout at University Park ..... 10 Minutes

BANTZ, W. and J. P. HARPER (University of Scranton). Measurement of beta-ray spectra ..... 10 Minutes

SIEMIENCOW, G. (Lafayette College). The teaching of chemistry in the secondary schools of the Soviet Union from 1917 to 1945 ..... 15 Minutes

BURTI, U. H., P. J. CASEY, R. C. MELUCCI and J. F. IMBALZANO (University of Scranton). Some temperature — viscosity relationships for certain esters of naphthenic acid: III. ..... 15 Minutes

HAAB, W., M. D. APPLETON and R. J. FANUCCI (University of Scranton). A modification of the Guthrie test for phenylketonuria ..... 15 Minutes

FIELD TRIP

2:00 - 5:00 P.M. Saturday, April 13

Mr. Thomas Knepp, Head, Dept. of Science, Stroud Union High School; GUIDE.

The tour will leave the parking lot, Shanee Hall, promptly at 2:00 P.M.

It will visit the following places of interest:

1. The Cranberry Bog Preserve—Rich in unique plant life and ecological material.
2. The Big Pocono State Park—This is a new State Park atop the Big Pocono Mountain and overlooking a vast area of the Pocono Mountains.
3. A Preview of the Keystone Shortway.

The tour includes some 40 miles of travel round trip and is so arranged that members may drop out as they desire.

ABSTRACTS

BANTZ, W. AND HARPER, J. P., MEASUREMENT OF BETA-RAY-SPECTRA.

The object of this study is to evaluate the effectiveness of a scintillation detector, used with a single channel differential pulse height selector, to measure energy distributions and maximum energies of pure beta-ray spectra. Methods are presented for minimizing the effects of the scattering of beta-rays from the scintillator and its surroundings and the effects of the absorption of the rays in the sample, in its mounting and in the air between the source and the scintillator. Calibration of the system for a certain equivalence between energy and pulse height presented some difficulty but has been accomplished by use of gamma ray sources.

BARTONE, J. C., HISTOCHEMICAL DISTRIBUTION OF THE NON-SPECIFIC ALKALINE PHOSPHATE IN THE ORGANS AND TISSUES OF THE 10mm PIG EMBRYO.

Alkaline phosphatase was localized histochemically in an important stage of development of embryos wherein cells begin to specialize into tissues and organs. The enzyme activity throughout a 10 mm pig embryo was tabulated into the first tables of the histochemistry of development.

Alkaline phosphatase activity may serve as a growth indicator. Structures with rapid growth also reveal strong enzyme metabolism. Thus, primordia continue to reflect chemical differences preceding histologic differentiation.

GEWANT, W. C., AND LANE, H. K. THE BIOLOGICAL AVAILABILITY OF RIBOFLAVIN SOLUBILIZED WITH SODIUM SALICYLATE.

The biological availability of riboflayin solubilized with sodium salicylate is being determined with *Lactobacillus casei* and with chicks as the test organisms. The vitamin was fully available to *Lactobacillus casei* since the solubilizing agent exerted no determinable effect. The tests with the chicks are not completed.

Tests on solutions stored at room temperature showed, further, that the vitamin solubilized with sodium salicylate was stable to storage as this temperature.

GROSSMAN, H. H., PROLIFERATION IN MOSS LEAVES UNDER VARIOUS EXPERIMENTAL CONDITIONS.

Three species of moss were subjected to four experimental conditions to observe the regenerative capacity of the leaves. Leaves attached to stems and leaves separated from stems were used. The type, amount and place of regenerative proliferation were recorded along with observations of cellular details.

KNEPP, T. H., THE 1962 APPEARANCE OF BROOD II OF THE SEVENTEENTH YEAR CICADA IN MONROE CO., PA.

Brood II of th seventeen-year cicada, *Magicicada spetendecim,* caused extensive damage in various parts of Monroe County, Pennsylvania, during June and July, 1962. Kodachrome slides will be used to show emergence from the ground, the adult forms, copulation, and extensive damage done to a young peach tree. Control measures and orchard damage will be discussed.

MYERS, P. B. AND RYAN, J. D. URANIFEROUS BLACK SHALES IN THE TRIASSIC OF PENNSYLVANIA.

The central portion of the Triassic basin in eastern Pennsylvania is occupied by a black argillits, the Lockatong formation. A thin zone of Radioactive black shales which average about 0.02% U^3O^8 is found in the upper part of this formation. The occurrence of these black shales, exposed in stream valleys and road cuts in an arcuate belt between Rushland and Gwynedd Valley, Pennsylvania, is described.

WHITNEY, H. A., DENSITIES OF POPULATION IN THE COLONIES OF RHODE ISLAND AND PLYMOUTH IN 1689.

The degree of population growth at which certain economic activities and service functions appear and can be supported is of increasing interest to geographers, economists, town planners, and others. Unfortunately, initial experiences in this country are largely unknown and unused, primarily for lack of sufficiently detailed information about population densities. The present study attempts to supply information about population densities in one particular region at one particular time. The region is the part of southern New England which formed the early hinterland of Newport, one of the five important cities of the English North American colonies. The time is a half century after the initial settling of the region, a century before the first Federal Census, and the beginning of a period of notable increasing economic activity throughout New England. The sources for estimating population densities by minor civil divisions are several little known records of the region, found to complement each other.

ACADEMY BUSINESS

1963

ACADEMY BUSINESS
1963

A. MINUTES OF THE EXECUTIVE MEETING includes the following items and reports:

B. MINUTES OF THE ANNUAL GENERAL BUSINESS MEETING includes the following reports and appointments:

A. MINUTES OF THE THIRTY-NINTH ANNUAL MEETING OF THE EXECUTIVE COMMITTEE

The Executive Committee met April 12, 1963, at 9:00 a.m. in the Hotel Penn Stroud, Stroudsburg, Pa., with President George F. Deasy presiding.

I. The following minutes of the Executive Officers were read and approved.

August 24, 1962

The Executive Officers met with Dr. Albert Eiss and Charles Bikle during the summer meeting at California State College.

It was decided to participate as co-sponsors with the State Department of Education in the Conferences on science education. These conferences are planned for October, 1962. Dr. Eiss will serve as coordinator and program planner.

It was decided to approve the sponsorship of two members of the Junior Academy to present papers at the National Junior Academy meeting in December, 1962, at Philadelphia. The Junior Academy members chosen shall finance their own way or secure assistance from outside of regular Academy funds.

It was decided to make a payment of $200.00 from the Junior Academy N. S. F. grant to care for sponsorship costs to the Senior Academy.

Approval was given for Dr. Eiss to prepare a proposal for an N. S. F. grant for regional conferences on science teaching in Pennsylvania.

K. B. Hoover
Secretary

II. Old Business

The incorporation of the Academy was postponed until after a new Secretary takes office in order to avoid complications in change of address during the incorporation procedure.

III. Reports

The following reports were presented and approved.

1. REPORT OF THE SECRETARY — Kenneth B. Hoover

a. Membership

Regular	615	
Affiliated	6	
Emeritus	16	
		637
New Members		55
Members Lost		
Deceased	9	
Resigned	13	
Dropped, 2 yrs in arrears	40	
		62
Net Loss		7
*New members for 1963 to April 10		29

b. Distribution of Proceedings

Sale to Libraries	33
Sale to Societies	8
Sale to Individuals	6
Gratis	3
	50

c. N. S. F. Grants

Grant No. GE 1597 for the Junior Academy in the amount of $7990.00 has been approved for 1963-64.

Grant No. GE 1673 for the Senior Academy in the amount of $4505.00 has been approved for 1963-64 for the "Improvement of Undergraduate Science Education." The program will be under the director of Dr. Albert Eiss.

2. REPORT OF THE TREASURER, December 31, 1962 — Kenneth B. Hoover

(A) SUMMARY REPORT

Balances on hand, January 1, 1962		
General	$ 1,843.09	
Darbaker	802.17	
NSF (Jr. Academy)	0.00	
Total		$ 2,645.26
Receipts		
General	$ 6,860.79	
Darbaker	628.06	
NSF (G 22635)	9,005.00	
Total		$16,493.85
Total Balance and Receipts		$19,139.11
Expenditures		
General	$ 7,205.45	
Darbaker	542.94	
NSF (G 22635)	8,500.00	
Total		$16,248.39
Balance on hand, December 31, 1962		
General	$ 1,498.43	
Darbaker	887.29	
NSF	505.00	
Total		$ 2,890.72
Total Expenditures and Balance		$19,139.11

(B) GENERAL FUND

Balance on hand, January 1, 1962		$ 1,843.09
Receipts		
Membership dues (old)	$ 2,536.10	
Membership dues (new)	298.00	
Sale of Proceedings	281.00	
Excess printing in Proceedings	644.00	
Advertising in News Letter	576.67	
A.A.A.S. Research Grants	250.00	
Meetings	65.02	
Clerical services for Jr. Academy	10.00	
Gifts	2,200.00	
Total Receipts		$ 6,860.79
Total Balance plus receipts		$ 8,703.88

Expenditures

News Letter		
Printing	$ 485.71	
Bulk mailing and postage	83.20	
Addressing	46.51	
Envelopes	21.65	
Total		$ 637.07
Proceedings		
Volume 35, 1961		
Printing and mailing	$ 2,547.42	
Editor's expense	1.03	
Volume 36, 1962		
Printing	$ 2,880.00	
Editor's expense	86.30	
Total		$ 5,514.75
Secretary's Expense		
General postage and telephone	$ 66.15	
Clerical help	268.31	
Printing and supplies	59.88	
Total		$ 394.34
Academy Conference dues		$ 12.50
President's expense		0.00
Delegate to Academy Conference		39.56
A.A.A.S. Research Grant		250.00
Membership Committee (printing and postage)		75.00
Library Subscription Committee (printing and postage)		69.75
Bonding of Treasurer		12.50
Science Talent Search		100.00
Science Writing Project		100.00
Total		$ 7,205.45
Balance on hand, December 31, 1962		$ 1,498.43
		$ 8,703.88

(C) DARBAKER FUND

Balance on hand, January 1, 1962		$ 802.17
Receipts		
January 17, Darbaker Trust (Jr. Academy)	$ 286.43	
January 17, Darbaker Trust (Sr. Academy)	286.43	
Interest on "K" Bonds	55.20	
Total		$ 628.06
Total Balance plus receipts		$ 1,430.23
Expenditures		
Junior Academy Biology prizes	$ 266.94	
Printing prize papers	276.00	
Total		$ 542.94
Balance on hand, December 31, 1962		887.29
Total		$ 1,430.23

(D) N. S. F. GRANT TO JUNIOR ACADEMY

1962-63 Grant No. G22635

Receipts

U. S. Treasurer, April 6	$ 5,400.00	
U. S. Treasurer, September 17	3,505.00	
Total		$ 9,005.00

Disbursements

Transfer to Jr. Academy Treasurer, April 16	$ 5,500.00	
Transfer to Jr. Academy Treasurer, Nov. 7	3,000.00	
Total		$ 8,500.00
Balance on hand, December 31, 1962		$ 505.00
Total		$ 9,005.00

(E) SPECIAL ACCOUNT

Balance on hand, January 1, 1962		$ 58.73

Expenditures

Administrative expense, secretary-treasurer	$ 8.40	
Supplies	13.57	
Writing Conference	36.76	
Total		$ 58.73
Balance on hand, December 31, 1962		0.00

3. REPORT OF THE AUDITING COMMITTEE — Elmer C. Herbert, William B. Jeffries

We have examined the books and supporting records of the Secretary-Treasurer of the Pennsylvania Academy of Science for the year ending December 31, 1962 and in our opinion, the records of the Academy are properly maintained and in excellent order.

The Auditing Committee

4. REPORT OF THE EDITOR OF THE *NEWSLETTER* — George E. Grube

PAS members continued to receive six issues of the *Newsletter* since the last annual meeting at Pittsburgh. Numbers were mailed in May, July, October, December, 1962, February and March, 1963.

Several changes were initiated including: (1) expansion to eight pages, (2) increase in charges for advertising to total $655.00 as compared with $400.00 last year. (This rate became effective with new advertisers in 1962 and with our old friends in 1963.), (3) increased size by changing to 10 point type instead of 12 point as formerly used, (4) several changes in format including itemizing of news, modernization of the heading, inclusion of informative articles, editorials, letters to the editor, etc., and (5) addition of Keystone Microscope Company to our list of advertisers.

Burrell Corporation; Welch Scientific Co.; Williams, Brown and Earle; and Carolina Biological Supply Co. continue to support the *Newsletter* through paid advertisements. The academy commends these advertisers to all members and friends.

5. REPORT OF THE EDITOR OF THE *PROCEEDINGS* — Robert E. Ogren

Volume 36, 1962 was somewhat different than previous volumes in that two columns of type were used and a quarter inch larger page: 10 inches by 6¾ inch. The format of the cover was changed, the emblem of the state was improved and the color of the cover was changed, to light blue. Some revisions were made under suggestions to authors. This volume contained a new page devoted to Pennsylvania Junior Academy of Science winners and the first

List of Members for several years. Members making use of this list must remember, however, that at the time of its distribution it was already out of date. Nevertheless, it may help in regard to our more stable membership. Editorial advertisement was solicited and pages may be set aside as they are needd for this purpose. As requested at the Executive Meeting, a list of Academy Meeting Places was prepared since 1943 and page 319 which may be of some interest to the membership. In addition to the above the volume included the list of officers, minutes of executive committee and annual meetings, index of 96 authors, abbreviated title index, instructions to authors, 49 complete papers, abstracts and program of the annual meeting.

The bill from Chuch Center Press to the Academy showed the following breakdown of expenses: Time, $2,870.40; material $355.07; cuts, $583.36; mailing and delivery, $134.81, with a total cost of $3,943.64. Editorial expenses were $111.77 but included secretarial help and mailing for the Proceedings manuscripts and proof, as well as phone calls and help for the 1962 and 1963 annual program.

The manuscripts were edited during June and July, most were taken to the printer between July 6-18, 1962. Unfortunate delay in the print shop resulted in suitable galley proof February 8, 1963. Corrected proof was returned February 23, 1963, the last of the page proof was mailed May 9, 1963. My copy was received in completed form on June 24, 1963. By August 13, all reprint orders had been filled.

6. REPORT OF THE HISTORIAN AND LIBRARIAN — Richmond E. Myers

No report at this time.

7. REPORT OF THE PRESS SECRETARY — Dixon, Johnson

President Deasy reported that the Press Secretary had released Academy publicity in state-wide press releases as well as releases in local papers concerning Academy members in their respective areas.

8. REPORT OF THE DIRECTOR OF THE SCIENCE TALENT SEARCH—
William A. Uricchio

The Science Talent Search competition is held in cooperation with the Westinghouse Educational Foundation to determine the most promising scientists in American high schools. Awards were made to the 40 winners and 359 honorable mention placements. The 40 winners received an all-expense trip to Washington, D. C. to attend the Science Talent Institute where further critical judging is conducted to determine the recipients of the 5 highest awards. This year 204 students from the state of Pennsylvania completed entries in the National Science Talent Search. Of this number there was one winner and four honorable mention awards. This represents a decrease of two national winners and a decrease of seven honorable mention awards. Over the past 22 years Pennsylvania has had a total of 42 national winners and 359 honorable mention awards to place us fourth in the country following New York, Illinois, and California. Also this year a student from Pennsylvania received one of the five highest awards. All winners in the national competition are considered automatic winners in the 16th Annual Pennsylvania Science Talent Search. To enter the National Science Talent Search, the student must be in his senior year in public, private, or parochial school; take the science aptitude examination conducted by SCIENCE CLUBS OF AMERICA, and write a report describing his own science project.

The School Science Committee of the Pennsylvania Academy of Science, under the direction of Charles L. Bikle, is responsible for arranging regional meetings throughout the state to further determine additional winners in the State Science Talent Search. To participate in this, a student must have taken the science aptitude examination, he must present a research paper at one of the regional meetings and be interviewed by a committee selected by the Pennsylvania Academy of Science or the regional chairman. The names of the winners will be publishd in the forthcoming issue of the NEWSLETTER of the Pennsylvania Academy of Science. In addition, these students will receive a certificate from the Pennsylvania Academy of Science, and usually they receive scholarships and financial assistance to local and national colleges and universities.

9. REPORT OF THE PENNSYLVANIA JUNIOR ACADEMY OF SCIENCE—

Charles L. Bikle

1. The director was requested to look into the advisability of insurance for participants in Junior Academy meetings.

2. ANNUAL REPORT

The Pennsylvania Junior Academy of Science has shown its greatest growth during the past year. The Regional Directors have reported both an increase from 20 to 400% in numbers of students participating in the regional meeting and an encouraging improvement in quality of work done by the participants. The state meeting at State College at Kutztown was the largest ever held with 225 papers presened and over 550 in attendance from throughout the state. Although the support funds for regional meetings were eliminated this year for the participants, the enthusiasm has continued to increase as more and more students found the satisfaction of presenting an oral report was more inspiring than the science fair type of exhibit.

The increased status of the Pennsylvania Junior Academy was reflected by its being chosen as the selection agency for the two participants to attend the National Science Camp to be held in conjunction with West Virginia's Centennial Celebration with 100 boys from all the United States being given an all expense five week camping experience near the Raido telescope. The Junior Academy will be represented at the National Science Seminars held in Albuquerque, May 7-11 participating in panels led by the top scientists of the United States with Glenn Scaborg, Werner Von Braun, Edward Teller as representative speakers and leaders.

We also had two representatives present their first award papers at the meeting of Junior Academy representatives at the Academic Conference of the AAAS in Philadelphia during the Christmas recess. Your State Director was honored by being appointed Chairman of the Junior Academies Conference for the Cleveland AAAS meeting in 1963 when again the Junior Academies will be asked to send one or two of their top students.

News has also been received that NSF will support our program through the Pennsylvania Academy of Science by a grant of $7990 for the coming year. Under terms of the grant—only senior high school student expense will be supported to the state meeting—so funds will have to be found for the junior high school section as we feel that it is most important to encourage the junior high school student during the formative years when he is deciding whether he will continue in a science career or select some other field.

The junior high students will attend this year's state meeting at Milton Hershey School on April 26-27 at their own expense, but already many have indicated their desire to appear on the program.

Most generous support of our program has again been given by the Pennsylvania Dental Association which gave $250 to our general prize fund. They also gave $125 to help print the summaries of the prize winning papers of the 1962 state meeting. The Pennsylvania Science Teachers Association also assisted in this project by a grant of $100 and the papers were sent to all schools of the state by the Department of Public Instruction at no expense to the Academy.

If sufficient funds are available we hope to see that each science teacher of the state will receive a copy of the 1963 papers.

Copy of N. S. F. Report May 1, 1961 — May 1, 1962

Grant No. 17033 — Total	$ 9,760.00
A. Participation Support (Meals and Lodging)	$ 2,153.00
Travel	2,988.45
Sub Total	$ 5,141.45
Total Direct Costs	$ 8,491.45
Indirect Costs	1,098.44
Total Expenditures	$ 9,589.89
Returned to N. S. F., June 8, 1962	$ 170.11
	$ 9,760.00

B. Operational Costs

State Director	$ 653.83
Regional Directors	1,114.54
Judges	470.00
Secretarial and clerical	402.63
Supplies and postage	381.12
Printing	327.88
Sub Total	$ 3,350.00

PRIZE FUND ACCOUNT

April 1, 1962 — April 1, 1963

Income

Balance brought forward	$ 260.00
Darbaker fund	266.94
Dues & contributions from regions	146.50
Transferred from Jr. Acad. Saving Acct.	150.00
Pa. Dental Association	250.00
Pa. Dental Association (for summary booklet and poster)	125.00
1963 Club dues to date	64.50
Total	$ 1,262.94

Expenses

Prizes awarded at Kutztown State Meeting (68 prize winners)	$ 554.00
First AAAS Academy Conference at Phila., Dec. 26, 2 students, 1 sponsor @ $13	39.00
Brochure Printing	45.00
Total Expenses	$ 638.00
Balance on hand	$ 624.94

J. Lee McConnell, Treasurer

10. REPORT OF THE MEMBERSHIP COMMITTEE — E. Willard Miller

The membership committee for 1962-63 was composed of eleven members selected from the different scientific fields. The committee members undertook the contacting of prospective members in their individual fields. The desirability of membership in the Pennsylvania Academy was stressed as to (1) the stimulus that could result from interdisciplinary contacts outside the field of specialization of the new members and (2) the desirability of furthering contacts between research-oriented faculty members of the large universities of the State and those of the more numberous colleges and other smaller educational institutions of the Commonwealth.

The committee consisted of the following:

Bertil G. Anderson—Zoology and Entomology
Alvin R. Grove—Botany
Benjamin F. Howell, Jr.—Geophysics and Geochemistry
Edward S. Kenney—Engineering and Architecture
Laurence H. Lattman—Geology
Donald J. Nash—Genetics
William L. Pervin—Mathematics
Gordon H. Pritham—Physiological Chemistry
James W. Shigley—Agricultural and Biological Chemistry
E. Willard Miller—Geography, Chairman

A number of suggestions for increasing membership were presented.

Academy members were encouraged to write to the chairman of the new membership committee and give their suggestions.

11. REPORT OF THE RESEARCH GRANTS COMMITEE—Paul R. Wagner

The chairman wishes to make the following report for his committee.

Three requests for grants from the Academy funds were received during the past year. The committee reviewed each of these and unanimously agreed to make dispersals to two of them; one to Dr. Kenneth B. Hoover, Messiah College, Grantham, Pennsylvania, in the amount of $250.00 to partially subsidize a study pertaining to Chemical Mutagen Tests in the Determination of Genetic Structure in *Salmonella typhimurium*. A second grant was given to Dr. George S. Shortess, Department of Biology, Lycoming College, in the amount of $200.00 to help defray the costs of research pertaining to the Extraction and Testing of a Bacterial Inhibitant in Maple Leaves.

The Committee began its work with a total of $487.00, representing an unused carry-over balance from the years 1961-62. Subsequently, a contribution from the AAAS in the amount of $365.—for disbursement in 1963 only was received. The total of $843.00 less the $450.00 recently distributed leaves a current balance on hand of $393.00.

The chairman wishes to express his gratitude to his committee colleagues, Dr. George R. Jenkins, Institute of Research, Lehigh University, Bethlehem, Pennsylvania; and Dr. David E. Davis, Professor of Zoology, College of Agriculture, The Pennsylvania State University, University Park, Pennsylvania, for their counsel and assistance during the past year. Grateful acknowledgment is also given to our Secretary-Treasurer, Dr. Kenneth B. Hoover, for his advice and guidance in several matters.

12. REPORT OF THE LIBRARY SUBSCRIPTION COMMITTEE—Phyllis R. Griess

The Subscription Committee, consisting of T. C. Cheng, Christopher Crowe, and Phyllis R. Griess, was established by President George F. Deasy for two purposes: to solicit library subscriptions to the PROCEEDINGS of the Pennsylvania Academy of Science and to mail the annual billings to subscribers to the PROCEEDINGS.

Letters (about 300 to date, 4-6-63) describing the PROCEEDINGS together with two enclosures consisting of a subscription blank and a sample page of the publication are being sent to a selected list of libraries in the United States and Canada. The list of libraries was compiled from the twenty-third edition (1962) of the *American Library Directory*, and includes primarily public, college and university, state and Federal government, industrial, medical, and military libraries.

Subscriptions also have been solicited from libraries that had received free or exchange copies of the PROCEEDINGS prior to the discontinuance of this type of distribution.

Expenditures to date (4-6-63) amount to $47.73 for printing charges and supplies, and $21.97 for postage.

Twenty-two new subscriptions have been received to date (4-6-63).

13. REPORT OF THE MEETINGS COMMITTEE — E. G. Williams, Chairman

The following approvals and arrangements were made for future meetings on the basis of invitations submitted to the meetings committee.

Summer 1963 (action to be reported later)
Spring 1964 The Pennsylvania State University
Summer 1964 Clarion State College
Spring 1965 Villanova College

The Executive Officers were authorized to accept if an invitation is received from either of two institutions with whom negotiations are in progress for the spring of 1966.

14. REPORT OF THE SUMMER MEETING 1962 — Albert F. Eiss

The summer meeting of the Pennsylvania Academy of Science was held jointly with the Pennsylvania Science Teachers Association August 23-24, 1962. The session was preceded by the annual meeting of the State Science Curriculum Committee, at which time the status of the science curriculum was presented, and future curriculum plans were discussed.

The theme for the meeting, which was held at the California State College, was "Progress in Science Education." The program was oriented towards new developments in science as well as in science education.

The Thursday meetings were divided into elementary, junior high, senior high, and college groups, each of which discussed various aspects of the science curriculum. At the senior high school meeting, Dr. Paul Brandwein presented the BSCS Biology program, Mr. Joseph Schmuckler discussed the CHEM Study program, and Dr. John J. O'Neill, consultant for the Atomic Energy Commisssion, discussed "Modern Physics and its impact upon classroom Teaching."

The college group heard a report of research on "Short Term Visual Memory" by Dr. Emanual Averback, of Bell Telephone Laboratories.

In the afternoon, the senior high school and the college groups were combined. Dr. Richard Holroyd, of the Mellon Institute, presented a paper on "Research Chemistry and the Use of Isotopes in Research." Dr. H. A. Neidig discussed "Implications of Research for College Science Teachers."

The evening meeting was combined with the PSTA Annual Banquet, with the theme "Looking Ahead 25 Years in Science." Members of a discussion panel included Dr. H. R. Kiehl, of Corning Glass, Dr. Dana W. Smith, of the research Department of U. S. Steel, Mr. E. A. Sack, Manager of the Westinghouse Solid State Devices Department, Dr. Gilbert Thiessen, of the Koppers Company Research Department, and the Director of the Bituminous Coal Research Laboratories.

Field trips were scheduled Saturday to the Monesson Pittsburgh Steel Plant and to the Harmon Creek Coal Conservation strip mining operation.

The meeting was very well received, and several people suggested the desirability of holding other joint meetings. Since the PSTA is planning to place greater emphasis on new developments and research in science, the common interests of the two groups appear to be increasing. I would like to suggest that the Academy seriously consider inviting the PSTA to hold another joint summer meeting at some future time.

Respectfully submitted,
Albert F. Eiss

15. NEW BUSINESS CONSIDERED BY EXECUTIVE COMMITTEE

A. Affiliation with the National Association of Biology Teachers
The following action were taken:
1. At this time the Academy is not ready to affiliate with the NABT.
2. The president was instructed to appoint a committee on affiliations.

B. Publications Endowment Fund
A motion was passed that an effort be made to establish an endowment fund for Academy publications.

C. A letter from Dr. George F. Carter called attention to the need for study and action in the area of conservation in Pennsylvania.
Action was taken to reactivate the Conservation Committee.

D. Revised Constitution
Time was given to the discussion of the proposed revised constitution.
The Executive Committee made the following recommendations:
1. That category of life membership be deleted.
2. That the following be inserted at the end of Article II, Section 4 of the Constitution. "as well as for outstanding contributions to the Pennsylvania Academy of Science."

B. MINUTES OF THE ANNUAL BUSINESS MEETING

April 13, 1963

The general business meeting was held in the Hotel Penn Stroud, Stroudsburg, Pa. The session convened at 9:00 with President George F. Deasy presiding.

The minutes of the executive committee were presented and approved.

16. REPORT OF CONSTITUTIONAL COMMITTEE

The Committee presented the revised Constitution. A motion was passed with the required three-quarters affirmative vote of all members present accepting the Constitution as presented with the following revisions:

1. Deletion of the category of life members.
2. Expand the category of honorary members by inserting in the Constitution Article II, Section 4, the following: "as well as for outstanding contributions to the Pennsylvania Academy of Science."
3. A motion was passed designating all present Emeritus Members as Honorary Members.
4. The name Publication Committee be changed to Editorial Committee.
5. A nominating committee shall be named among the standing committees.
6. In case of the inability of the President to perform the functions of the office, the President-elect shall assume the responsibility of the office of the President.
7. The category of non-resident members was eliminated and such members shall be included in the active category.
8. An article shall be inserted to designate the AAAS as the recipient of assets in case of the discontinuance of the Academy.
9. The Constitutional Committee was instructed to make the necessary editorial changes to make the Constitution conform to the above changes. The revised Constitution will be published in the *Newsletter*.

Action was taken instructing the officers to put each of the various provisions of the new Constitution into effect at the most appropriate time within the next year.

17. REPORT OF RESOLUTIONS COMMITTEE

Be it resolved that the P.A.S. express their thanks to the local committee for the excellent job they did under trying circumstances.

To the management of the Penn Stroud Hotel for their magnificent cooperation under similar difficulties.

To the outgoing officers of the Academy for their valuable and untiring services during their respective terms in office.

To the various committees for their contributions to the success of the Academy's business.

To the commercial exhibitors for their instructive displays.

Be it also resolved that the Academy notes with sorrow the passing of the following members:

Warren U. C. Baton	Harrison S. Hires
Norris D. Blackburn	Rose R. Ichelson
R. Adams Dutcher	Alexander Silverman
G. B. Farris	Charles A. Thomas
H. Richard Gault	George H. Young

18. REPORT OF THE NOMINATING COMMITTEE

President—Phyllis C. Martin
President Elect—K. B. Hoover
Vice-President (East)—Albert F. Eiss
Vice-President (West)—Natalie Barish
Secretary-Treasurer—Thomas C. Cheng
Editor of Newsletter—George E. Grube
Editor of Proceedings—William A. Uricchio
Junior Academy Sponsor—Charles L. Bikle

The above slate of officers was presented and a motion was passed declaring the slate elected.

The retiring President, Dr. Deasy, presented the new President, Dr. Martin. After some remarks announcements were made concerning the appointment of committees.

19. COMMITTEE APPOINTMENTS FOR 1963-64 — P. C. Martin, President

See Pages 3 and 4

Pennsylvania Junior Academy of Science State Meeting Winners

Milton Hershey School, April 26-27, 1963

SELECTEES FOR THE NATIONAL SCIENCE YOUTH CAMP, CAMP POCOHANTOS, WEST VIRGINIA, JUNE 30 to JULY 20, 1963.

John Rehr, Carlisle High School, Carlisle, Pennsylvania
Howard Glaven, North Hills Catholic High School, Pittsburgh, Pennsylvania

TO REPRESENT PENNSYLVANIA JUNIOR ACADEMY AT ACADEMIES CONFERENCE OF AAAS IN CLEVELAND, DECEMBER 26, 1963.

Marguerite Yevitz, St. Nicholas High School, Wilkes-Barre, Pennsylvania
Joseph Serene, Indiana Joint High School, Indiana, Pennsylvania

GRAND CHAMPION JUNIOR HIGH SCHOOL AWARD (WORLD BOOK ENCYCLOPEDIA)

Mark Feinberg, Susquehanna Jr. High School, Harrisburg, Pennsylvania

ADVANCED BIOLOGY

1st Award	Natalie Manley, Selinsgrove Area High School, Selinsgrove
2nd Award	Magdalena L. Morris, Gateway Senior High School, Monroeville
2nd Award	Carol A. Becker, North Hills High School, Pittsburgh
Hon. Mention	Thomas R. Shick, West Mifflin South High School, Dravosburg
Hon. Mention	Emery M. Froelich, St. Peter High School, McKeesport
Hon. Mention	Chester Kessler, Lebanon High School, Lebanon
Hon. Mention	Patricia Waldron, Fox Chapel High School, Pittsburgh

SENIOR HIGH SCHOOL BIOLOGY

1st Award	Arthur Shapiro, Central High School, Philadelphia
1st Award	Robert Litman, Overbrook High School, Philadelphia
1st Award	Stefan Goslowski, Central Catholic High School, Allentown
1st Award	Boyer Westover, Garfield Junior High School, Johnstown
1st Award	Jack Spayd, Lebanon High School, Lebanon
1st Award	Mary Repasky, Greensburg Central Catholic High School, Greensburg
2nd Award	Robert R. Jacobs, Shippensburg Area Sr. High School, Shippensburg
2nd Award	Joan Kolic, St. Peter High School, McKeesport
2nd Award	Paul Meiers, South Hills Catholic High School, Pittsburgh
2nd Award	Linda Myers, St. Francis Academy, Pittsburgh
2nd Award	Carol Hinderliter, DuBois High School, DuBois
2nd Award	David Long, Manheim Township High School, Neffsville
2nd Award	Anne Marie Zosak, Central Catholic High School, Allentown
2nd Award	Paula Buskey, Reading Central Catholic High School, Reading
Hon. Mention	Christine Kislo, West Side Catholic High School, Kingston
Hon. Mention	Chris Dinsmore, Clarion Area High School, Clarion
Hon. Mention	Donald F. Roberts, Camp Hill High School, Camp Hill
Hon. Mention	Jack Anderson, South Hills High School, Pittsburgh
Hon. Mention	Douglas Lavery, North Allegheny Jr.-Sr. High School, Marion Center
Hon. Mention	Bernadette Jordan, St. Canice High School, Pittsburgh

Hon. Mention	Tim Silvester, South Hills Catholic High School
Hon. Mention	Carolyn Waszczak, Elizabeth-Forward High School, Elizabeth
Hon. Mention	Elizabeth McCaffrey, Reading Central Catholic High School, Reading
Hon. Mention	James Bechtel, Lewisburg Joint High School
Hon. Mention	Martha Sterniuk, Cumberland Valley High School, Mechanicsburg
Hon. Mention	John Starfuric, Bishop McDevitt High School, Harrisburg
Hon. Mention	William Thieman, South Hills Catholic High School

PHYSICS

1st Award	John Rehr, Carlisle High School, Carlisle
1st Award	David Gillingham, Knoch High School, Saxonburg
1st Award	Howard Glavin, North Catholic High School, Pittsburgh
1st Award	Joe Serene, Indiana Joint High School, Indiana
1st Award	John Stofko, Reading Central High School, Reading
2nd Award	Thomas Hunter, North Allegheny High School, Pittsburgh
2nd Award	David Purnell, Camp Hill High School, Camp Hill
2nd Award	David Stahle II, Lock Haven High School, Lock Haven
2nd Award	Fred Peiffer, Lebanon High School, Lebanon
Hon. Mention	George Bedrin, St. Nicholas High School, Wilkes-Barre
Hon. Mention	Thomas Streever, St. Elizabeth High School, Pittsburgh
Hon. Mention	Louis Mayer, Indiana Joint High School, Indiana
Hon. Mention	John Marsden, Tyrone High School, Tyrone
Hon. Mention	Ronald Lemonelli, Archbald High School
Hon. Mention	Dave Carlson, Fort LeBocuf High School, Waterford
Hon. Mention	David Wilson, Kutztown Area High School, Kutztown

ENGINEERING

1st Award	George Halloran, Cathedral High School, Scranton
2nd Award	Carl J. Spitz, North Catholic High School, Pittsburgh
2nd Award	David D. Pettigrew, Jr., Fox Chapel High School, Pittsburgh
2nd Award	George Albright, Central Catholic High School, Allentown
Hon. Mention	William E. Kauffman, Tyrone Area High School, Tyrone
Hon. Mention	Charles Croskey, Reynolds Area Joint High School, Greenville
Hon. Mention	Mike Markowski, Central Dauphin East, Harrisburg

SENIOR HIGH SCHOOL CHEMISTRY

1st Award	Marguerite Yevitz, St. Nicholas High School, Wilkes-Barre
1st Award	Larry Graham, Susquehanna High School, Harrisburg
1st Award	Margaret Flemming, Reading Central Catholic, Reading
2nd Award	Dorothy Barrett, Archbald High School, Archbald
2nd Award	Edward Tokarsky, Elizabeth Forward High School, Elizabeth
2nd Award	Gregory Blosick, Selinsgrove Area High School, Selinsgrove
2nd Award	William Kovchak, General McLane High School, Edinboro
2nd Award	John Kelly, Northwestern High School, Albion
2nd Award	Harry Graack, Nazareth High School
2nd Award	Barbara Descoteaux, Mt. St. Michael High School, Hyde Park, Reading

Hon. Mention	Edward Hunter, Marple-Newtown High School, Newton Square
Hon. Mention	Robert Barchi, St. Joseph's Prep. School, Philadelphia
Hon. Mention	Barbara Bougher, Dormont High School, Pittsburgh
Hon. Mention	Lynn Willis, Rice Ave., Union High, Girard
Hon. Mention	John Grabish, Nativity BVM High School, Pottsville

MATHEMATICS

1st Award	Mrak Feinberg, Susquehanna Junior High School, Harrisburg
2nd Award	Richard Fink, Saint Wendelin High School, Pittsburgh
2nd Award	Darlene Trageser, Saint George High School, Pittsburgh
2nd Award	Kathleen Raley, Our Lady of the Sacred Heart High School, Coraopolis
2nd Award	David Shahian, Camp Hill High School, Camp Hill
2nd Award	Carol Smith, Swatara Junior High, Oberlin
Hon. Mention	Susan McDonald, Vincentian High School, Pittsburgh

EARTH-SPACE SCIENCE SENIOR HIGH

2nd Award	William F. Neal, Elizabeth-Forward High School, Elizabeth
2nd Award	Joyce Lewis, Lawrence Park High School, Lawrence
Hon. Mention	Glenn H. Thompson, Elizabeth-Forward High School, Elizabeth
Hon. Mention	Carl Winklevoss, Lakeview High School, Stoneboro

EARTH-SPACE SCIENCE JUNIOR HIGH

1st Award	Richard Guidin, Kutztown Area Junior High School, Kutztown
1st Award	Joseph Schulter, Central Catholic Junior High School, Kutztown
2nd Award	Margery Meltzer, Westmont Hilltop Junior High School, Johnstown
2nd Award	Lewis Biddle, College Area Junior High, State College
2nd Award	Paul Fessler, Edison Junior High School, Harrisburg
2nd Award	Maynard Cressman, Brandywine Heights Junior High School, Topton
Hon. Mention	Dominick Lorenzetti, Archbald High School, Archbald
Hon. Mention	Lawrence Emmer, St. Elizabeth High School, Pittsburgh

JUNIOR HIGH SCHOOL BIOLOGY

1st Award	David Dublin, Camp Curtin Junior High School, Harrisburg
1st Award	Frank Rudy, Susquehanna Junior High School, Harrisburg
1st Award	Joanne Ritz, Kutztown Area Junior High School, Kutztown
2nd Award	John W. Beers, North Pocono Joint School, Moscow
2nd Award	Thomas Hartz, South Hills Catholic High School, Pittsburgh
2nd Award	Cheryl Biever, Raub Junior High School, Allentown
Hon. Mention	Stubican Miroslav, College Area Junior High School, State College
Hon. Mention	Louise M. Grube, Lock Haven Junior High School
Hon. Mention	Margaret Simon, Elizabeth-Forward Junior High School, Elizabeth
Hon. Mention	Judie Heck, St. Nicholas High School, Wilkes-Barre
Hon. Mention	Charles Mallory, Rice Ave., Union High School, Girard
Hon. Mention	Carol Ann Moll, Fleetwood Junior High School, Fleetwood

JUNIOR PHYSICAL SCIENCE

1st Award	Ned Mountain, Cochran Junior High, Johnstown
1st Award	William Phillips, Camp Hill High School
1st Award	Elizabeth Stahler, Kutztown Area Junior High School, Kutztown
1st Award	Paula McDermitt, Central Catholic Junior High School, Allentown
1st Award	Janine Philips, Schuylkill Valley, Leesport
2nd Award	Delbert J. Umholtz, Tyrone Area Junior High School, Tyrone
2nd Award	William A. Jenkins, Benjamin Franklin Junior High, New Castle
2nd Award	Orville Kelley, Lower Paxton Junior High, Harrisburg
2nd Award	Steve Briggs, Union City High, Union City
2nd Award	Don Hiltzinger, Raub Junior High School, Allentown
2nd Award	Karen Dicks, Raub Junior High School, Allentown
2nd Award	Richard Frey, Kutztown Area Junior High School, Kutztown
Hon. Mention	John Haneiko, St. Elizabeth High School, Pittsburgh
Hon. Mention	Richard Irving, Danville Junior High School, Danville
Hon. Mention	Mary Hoffman, North East High, North East
Hon. Mention	Russell Ober, South Hills Catholic High School, Pittsburgh
Hon. Mention	Kathleen Meckes, Kutztown Area Junior High School, Kutztown
Hon. Mention	Deanne Chirillo, Joseph Johns Junior High School, Johnstown
Hon. Mention	David Scott, Indiana Junior High School, Indiana

ACADEMY MEMBERSHIP 1963

HONORARY MEMBERS

Bardy, Joseph, 338 S. 16th St., Phila. 2, Pa.
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Meeting	Volume	Year	Location
19	17	1943	State Capitol Building, Harrisburg, Pa.
20	18	1944	Yorktowne Hotel, York, Pa.
21	19	1945	Academy of Natural Sciences, Philadelphia, Pa.
22	20	1946	Lehigh University, Bethlehem, Pa.
23	21	1947	Johnstown Central High School, Johnstown, Pa.
24	22	1948	Grove City College, Grove City, Pa.
25	23	1949	Franklin and Marshall College, Lancaster, Pa.
26	24	1950	Waynesburg College, Waynesburg, Pa.
27	25	1951	Muhlenburg College, Allentown, Pa.
28	26	1952	Dickinson College, Carlisle, Pa.
29	27	1953	Lebanon Valley College, Annville, Pa.
30	28	1954	Pennsylvania College for Women, Pittsburgh, Pa.
31	29	1955	Academy of Natural Sciences, Philadelphia, Pa.
32	30	1956	Indiana State Teachers College, Indiana, Pa.
33	31	1957	Waynesburg College, Waynesburg, Pa.
34	32	1958	Lafayette College, Easton, Pa.
35	33	1959	Spring Mountain House, Schwenksville, Pa.
36	34	1960	Lycoming College, Williamsport, Pa.
37	35	1961	Gettysburg College, Gettysburg, Pa.
38	36	1962	Carnegie Museum, Pittsburgh, Pa.
39	37	1963	Penn-Stroud Hotel, Stroudsburg, Pa.
40	38	1964	The Pennsylvania State Univ., University Park, Pa.

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ABBREVIATED TITLE INDEX

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