BULLETIN 60

Geologic Series

Short Geologic Papers

by

F. L. CUTHBERT
GLENN L. JEPSEN
HENRY HERPERS
WM. R. THURSTON
HORACE G. RICHARDS

STATE OF NEW JERSEY
DEPARTMENT OF CONSERVATION
AND ECONOMIC DEVELOPMENT

CHARLES R. ERDMAN, JR., *Commissioner*
DIVISION OF PLANNING AND DEVELOPMENT
WILLIAM T. VANDERLIPP, *Director*

TRENTON, N. J.
1951

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MEREDITH E. JOHNSON, *State Geologist*

TRENTON, N. J.
1951

COUNCIL OF THE
DIVISION OF PLANNING AND DEVELOPMENT

LETTER OF TRANSMITTAL

May 8, 1951

Mr. William T. Vanderlipp, *Director*
Division of Planning and Development

Sir:

I take pleasure in submitting copy for Bulletin 60, Geologic Series, entitled "Short Geologic Papers". Though short, each of these papers has merit, the first presenting fundamental data derived from an investigation of New Jersey clays; the second and third describing new species of extinct life not heretofore known to occur in New Jersey; the fourth giving the results of a detailed investigation of one of the limestone formations occurring in Sussex County; the fifth presenting a much-needed scientific investigation of the low-grade manganese deposits southeast of Clinton; and the sixth describing recent discoveries of fossil mammals that lived in New Jersey during the Ice Age, or immediately thereafter. It should be noted that the first three of these papers have already been printed, but their distribution has been limited pending incorporation in a bulletin of the Geologic Series.

Respectfully submitted,

MEREDITH E. JOHNSON,
State Geologist

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by F. L. CUTHBERT

STATE OF NEW JERSEY
DEPARTMENT OF CONSERVATION
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DIVISION OF FORESTRY, GEOLOGY, PARKS AND HISTORIC SITES

MISCELLANEOUS GEOLOGIC PAPER
TRENTON, N. J.

1946

LETTER OF TRANSMITTAL

Mr. Charles P. Wilber, *Director*
Division of Forestry, Geology,
Parks and Historic Sites,
Trenton, N. J.

Sir:

It gives me a great deal of pleasure to recommend for publication as a pamphlet the attached copy of a manuscript, "Differential Thermal Analyses of New Jersey Clays", by Dr. F. L. Cuthbert, which describes the results of an initial step in the reinvestigation of our clays which it is hoped will ultimately lead to their use on a scale broader than ever before. The clay industry is one of few showing a declining trend of production in the last 20 years, and it is felt that no line of investigation should be overlooked in order to reverse this trend.

It was only through the cooperation of Dr. Hans F. Winterkorn of the Soil Science Laboratory, Department of Civil Engineering, Princeton University, that the services of Dr. Cuthbert were made available for this work, and his office also provided the laboratory equipment, supplies and facilities which were needed. It is a pleasure to acknowledge this full measure of cooperation and to express the hope that the future will witness further cooperation of the State with the universities and colleges within its borders in the investigation of all our natural resources.

Yours sincerely,

MEREDITH E. JOHNSON,
State Geologist

FOREWORD

New Jersey's mineral production is an important factor in the economy of the State—more noteworthy than is generally appreciated. Iron ore has been mined here for more than 250 years. The quality of zinc ore at Franklin is unsurpassed in this country. Crushed stone, sand and gravel have been produced in enormous quantities. The annual value of our mineral production has reached $90,000,000. While currently not at this level, this State still ranks high when we consider its relatively small area.

Not all of our minerals have been exploited, nor, in fact, are they known. Modern geophysical methods of exploration may indicate resources of which we had not dreamed. I urge that exploration and research be continued to reveal these latent resources.

This report on the testing of some New Jersey clays, with a view to developing new uses made possible by modern technique, is a distinct contribution to what we hope will be a new era in New Jersey's mineral production and I heartily approve its publication.

STATE DEPARTMENT OF CONSERVATION
Morgan F. Larson
Commissioner

DIFFERENTIAL THERMAL ANALYSES OF NEW JERSEY CLAYS

by

F. L. Cuthbert

Soil Science Laboratory, Department of Civil Engineering
Princeton University

During the months of March, April, and May 1945, a cooperative research project was in effect between the New Jersey Department of Conservation and Development and the Soil Science Laboratory of the Department of Civil Engineering, Princeton University. The purpose of this project was the determination of clay minerals present in clay samples collected by the State Geologist, utilizing a differential thermal analysis apparatus constructed by the writer in the Soil Science Laboratory.

A total of 29 samples were analyzed by the differential thermal method and the results of these analyses and certain conclusions based upon them are presented in this report. It is fully realized that such a comparatively small number of samples does not represent complete coverage of the clay deposits of the state; but it is believed that the results do constitute a preliminary survey and it is hoped that the value of the differential thermal method for such studies is demonstrated.

Description of Method

The differential thermal method of analysis has become increasingly popular in recent years for the study of clays and similar materials. Its advantages are: the time consumed per analysis is short, approximately two hours; the method is relatively simple requiring no really expensive equipment; and the results obtained are readily interpreted in terms of important properties of the materials.

Several excellent papers have been written describing the method and the types of apparatus used. These papers by Norton (1), Grim (2, 3), and Speil (4) are particularly valuable because of the detailed descriptions of the construction of the apparatus and the presentation of standard curves for pure clay types.

Briefly, the differential thermal method of analysis for clays consists of the measurement and recording by thermocouples of the exothermic and endothermic reactions that take place in the sample being analyzed as it is heated at a constant rate of increase to about 1000 degrees centigrade. The reactions are recorded photographically by connecting the thermocouples to reflecting galvanometers and the record consists of a line diagram or "curve" showing the reactions that take place.

Preparation of Samples

The samples were prepared for analysis by grinding a representative portion in a porcelain mortar until all of the sample would pass a 60 mesh sieve. They were then dried in an oven at 110 degrees centigrade and placed in a constant humidity desiccator containing a saturated solution of calcium chloride. The amount of air-dry moisture and the amount of controlled humidity moisture was calculated. This procedure allows the thermal curves to be compared more accurately. Care was taken to see that each sample was packed into the reaction chamber in the same manner. All of the analyses were made using the same resistance in the differential circuit so that all reactions are strictly comparable. Under some circumstances it may be advisable to vary the resistance for those materials having vigorous reactions so that the curve does not run off the paper.

Presentation of Analyses

Clay minerals can be conveniently classified into three groups: the kaolinite group, the montmorillonite group, and the illite group. Typical curves are presented in Figure 1 for each of these groups. The diagnostic reactions are:

For kaolinite minerals:

1. An absence of any dehydration reaction between 100 and 150 degrees centigrade.
2. An intense endothermic reaction between 550 and 650 degrees centigrade.
3. An intense exothermic reaction between 960 and 990 degrees centigrade.

For montmorillonite minerals:

1. An intense dehydration reaction, endothermic, between 100 and 175 degrees centigrade.
2. A fairly vigorous endothermic reaction at about 700 degrees centigrade.
3. An endothermic reaction of relatively low intensity at about 875 to 900 degrees centigrade.
4. A low intensity exothermic reaction at about 925 degrees centigrade immediately following the last endothermic reaction.

For illite minerals:

1. An average dehydration reaction, endothermic, at 100 to 150 degrees centigrade.
2. An average endothermic reaction between about 550 and 600 degrees centigrade.
3. A low intensity endothermic reaction at about 900 degrees centigrade frequently immediately followed by a low intensity exothermic reaction at about 950 degrees centigrade.

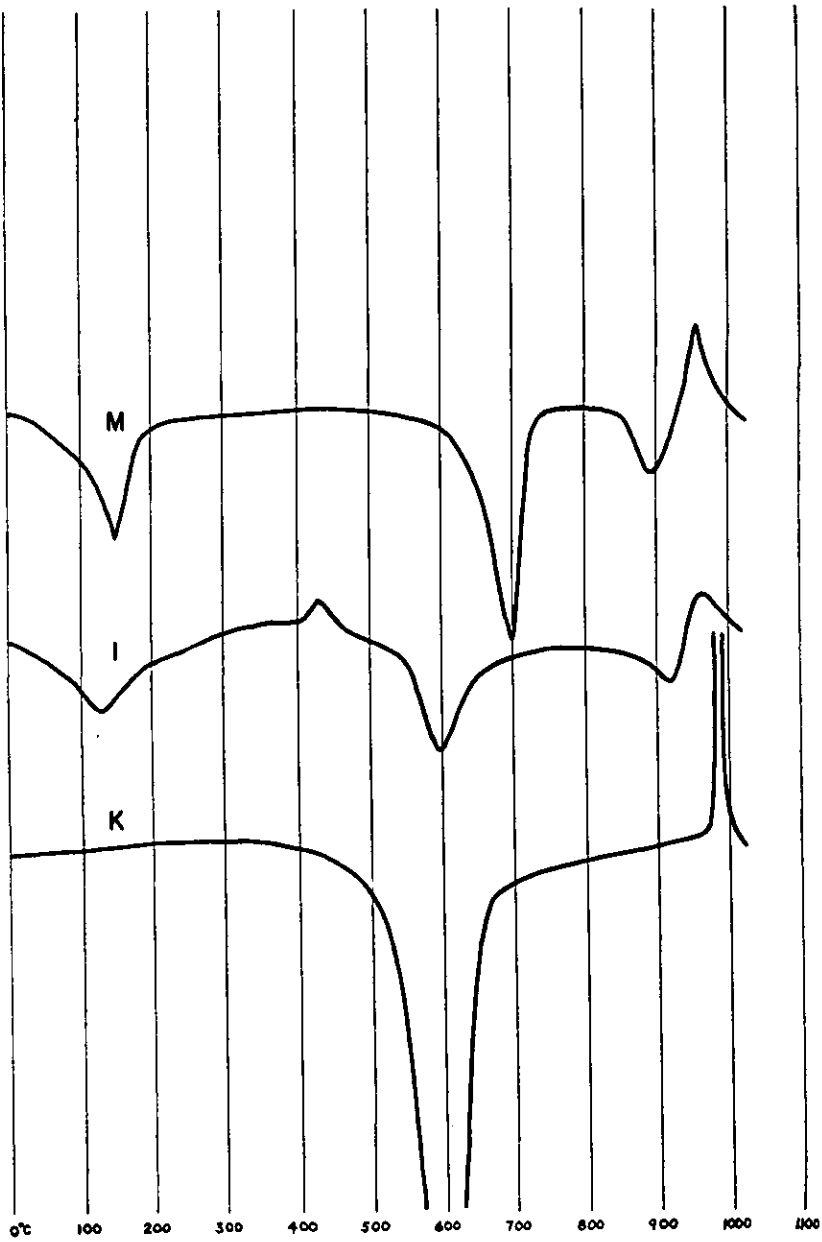

Figure 1

Thermal curves of typical clay minerals; kaolinite, illite, and montmorillonite.

Non-clay materials that frequently occur in commercial clays are: quartz, gypsum, calcite, pyrite, limonite, mica, and organic matter. Typical curves for these materials are in the literature and are not repeated here.

Largely through experience with a large number of different types of clays correlations can be established between the ceramic and non-ceramic properties of clays and their differential thermal curves. The properties and some of the uses of the pure clay types are briefly enumerated below.

Kaolinite clays are typically quite refractory having a pyrometric cone equivalent of about 30. The purer clays are white burning, have a relatively long vitrification range, and low plasticity and shrinkage. These clays are mostly used in the ceramic industry where a highly refractory clay, and one that will burn white, is needed. Specialty uses include those fields in which the clay is used as a filler, such as: the paper industry, rubber industry and so forth. These clays because of their low plasticity have not been widely used in the foundry industry for bonding molding sands but because of their refractory nature, it is entirely possible that certain castings may be improved by their use.

Montmorillonite clays are characterized by being relatively non-refractory; they also frequently burn off color. They are very plastic and possess high shrinkage due to their unusual ability of absorbing large amounts of water. The particle size of these clays is generally quite small, easily breaking down to sub-micron particles. Perhaps the greatest market for these clays is in the foundry industry where they are used to bond molding sands in what is called, synthetic sand practice. Because of their unusual adsorptive properties, they are also widely used as bleaching agents or filter aids, also in the preparation of synthetic catalysts in the cracking of high octane gasolines. Various other uses include: small amounts in the cosmetic industry, preparation of drilling muds, construction of water-tight basins, and a great variety of other similar uses.

Illite clays occupy a position which is generally half-way between the kaolinite and montmorillonite groups in its properties. It is perhaps true that in respect to its ceramic properties the illite clays are more like the montmorillonite clays than the kaolinite clays. Since it has been only a few years that this particular clay group has been defined, its uses have not been widely determined. However, at the present time illite clays are used very efficiently in the foundry industry, and some use has been made of them as drilling muds.

The above notes are presented only as generalizations concerning the properties and uses of the relatively pure types. Vast deposits of clays are frequently mixtures of two or more clay minerals and consequently their properties are generally determined by the clay that is present in greatest amount.

The differential thermal curves that were obtained for each of the clays studied are presented in Figures 2 to 7, and the location and macroscopic description of the samples, along with the interpretation of the curves, is given below.

Sample Number

1. Approximately 2/3 mi. N.N.E. of Crossley and 5 mi. west of Toms River, Ocean County. Overburden from 4 to 15 ft. Clay lens in Cohansey formation of late Tertiary age. Light gray clay containing very little silt but a pure large quartz fragments. This clay is a relatively pure kaolinite clay as indicated by the endothermic reaction at about 590 degrees centigrade and the exothermic reaction at about 975 degrees.

2. Near Clayville and 2 mi. N.E. of Millville, Cumberland County. 25 ft. below surface. Clay lens in Cohansey formation. Light gray in color, almost white, and having a distinct talc-like feel. The thermal curve of this clay is very similar to that of sample number 1, showing that it is a kaolinite clay.

3. In Wayne Twp., Passaic County, about 1-1/4 mi. N.W. of Little Falls. About 10 ft. below surface. Lacustrine clay of late Pleistocene age. Gray clay containing some root material and a few small stones. The thermal curve shows that this clay is composed of quartz, as indicated by the distinct endothermic reaction at about 580 degrees, and an illite type of clay mineral as indicated by the endothermic reactions at about 620 degrees and at 900 to 940 degrees. As is the case in many clays of this type, the typical double endothermic-exothermic reaction between 900 and 1000 degrees that is characteristic of many illities is missing. The slight endothermic reaction at about 720 degrees is thought to be indicative of a carbonate mineral.

4. In borough of Sayreville, Middlesex County, about 2 mi. S.W. of South Amboy. About 25 ft. below surface. The South Amboy fire-clay member of the Raritan formation of Upper Cretaceous age. The clay is quite similar to sample number 2 but more nearly pure. The thermal curve is characteristic of a pure kaolinite mineral.

5. Just west of Perth Amboy, Middlesex County. About 20 ft. below surface. The South Amboy fire-clay. This clay is gray and reddish in color, almost crudely stratified. The thermal curve shows that the sample is almost pure kaolinite, similar to sample number 4.

6. Just west of Fords in eastern Middlesex County. Sample from about 15 ft. below the surface. The Woodbridge clay member of the Raritan formation. The clay is light gray in color and provides a thermal curve that is characteristic of kaolinite.

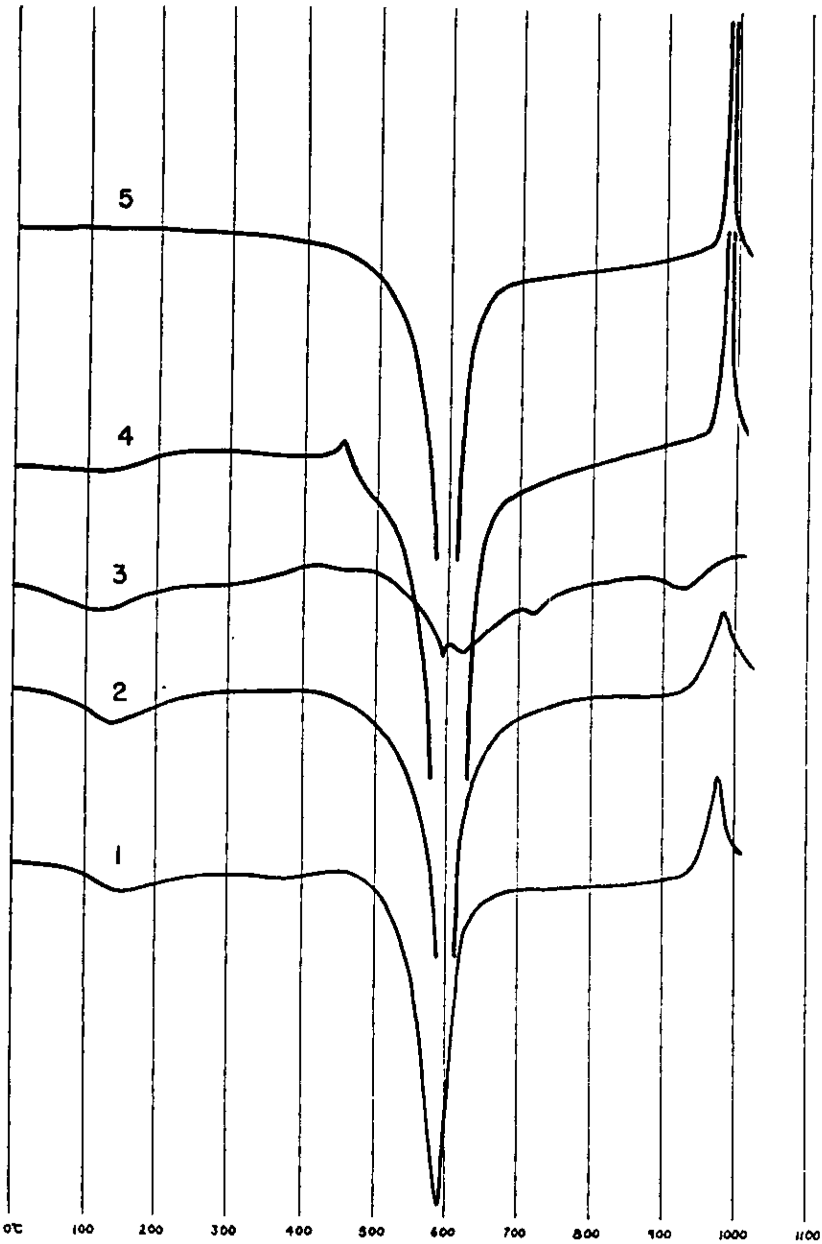

Figure 2

Thermal curves of clay samples, numbers 1 to 5.

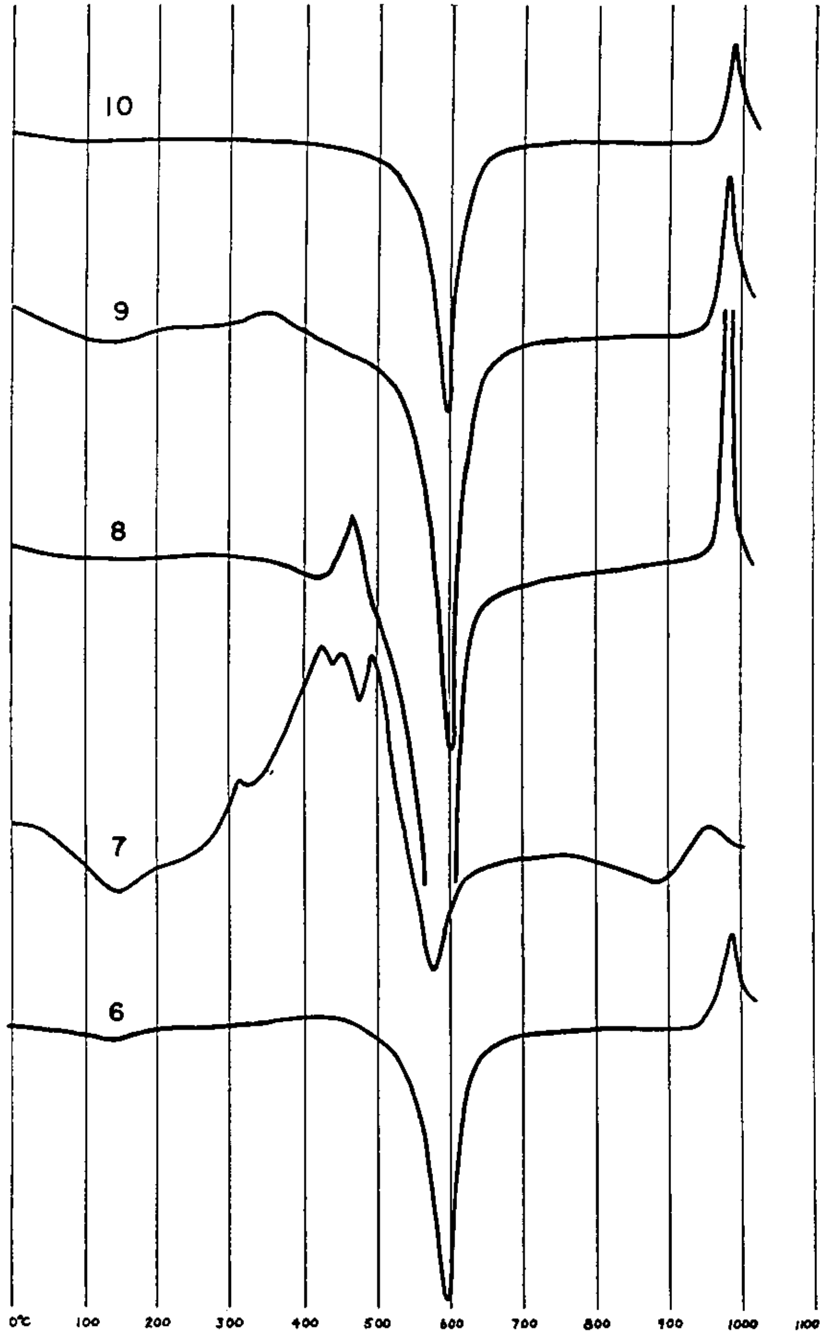

Figure 3

Thermal curves of clay samples, numbers 6 to 10.

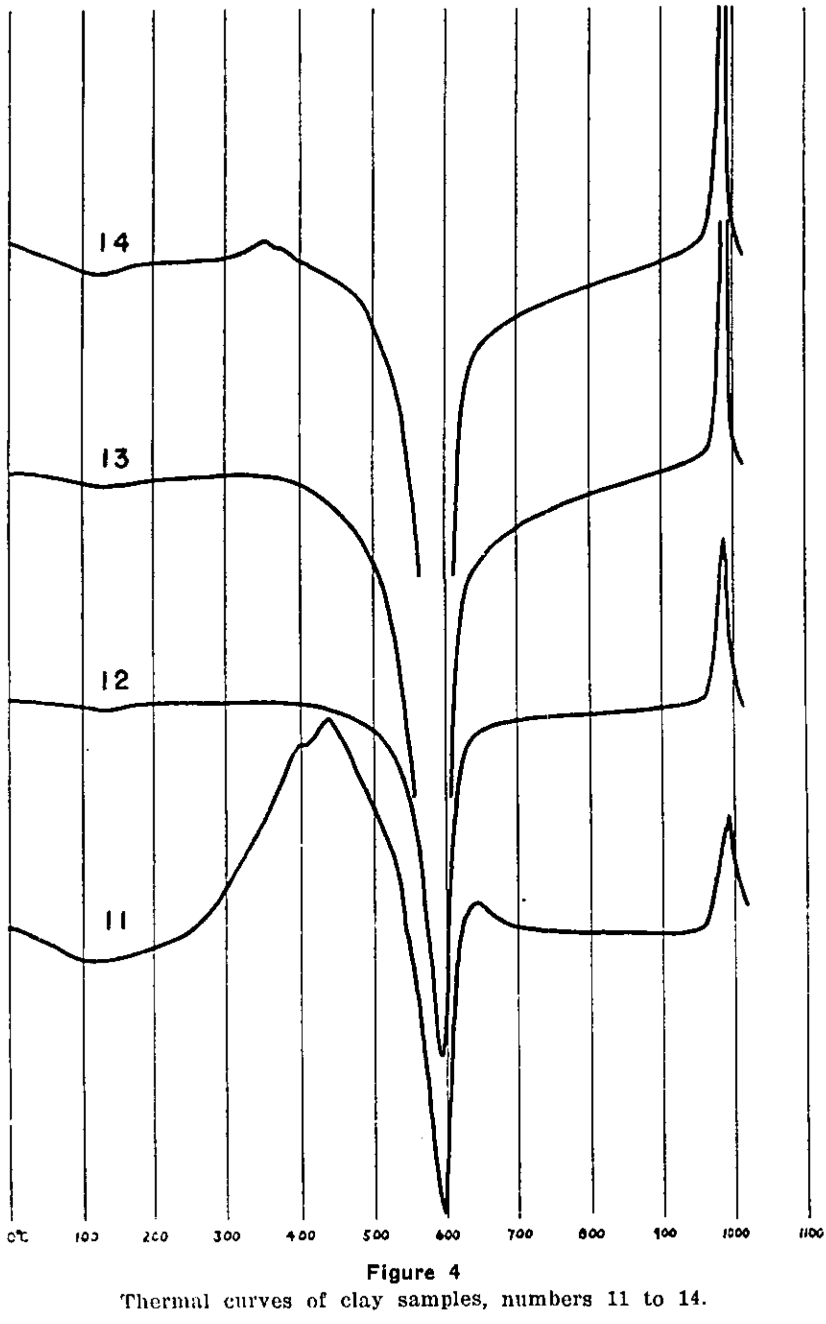

Figure 4
Thermal curves of clay samples, numbers 11 to 14.

7. In Mansfield Twp., Burlington County, 1 mi. south of Bordentown. 20 ft. below surface. Woodbury clay of Upper Cretaceous age. This sample is dark gray in color, almost black and contains a few small fossil imprints. The thermal curve shows the typical reactions of an illite clay having endothermic reactions at 150 and 575 degrees and the double endothermic-exothermic reaction at 880 to 1000 degrees. The broad, complex exothermic reaction between 300 and 550 degrees is believed to represent some organic matter and probably pyrite. The presence of pyrite is substantiated by the strong smell of sulphur that is noticeable when the clay is heated at 110 degrees in the preliminary drying procedure.

8. From a pit ½ mi. east of the South River and ¼ mi. south of Washington Road, Sayreville, Middlesex County. About 10 ft. below surface. South Amboy fire-clay. The clay is light gray in color, almost white. The sample submitted contained a single large piece of pyrite. The thermal curve is characteristic of a relatively pure kaolinite clay. The single exothermic reaction at about 460 degrees is believed to indicate the pyrite.

9. From Blue Anchor in eastern Camden County. About 5 ft. below surface. Clay lens in Cohansey formation. This clay is gray in color showing a few iron stains and appears to be quite plastic. Its thermal curve is characteristic of kaolinite, with perhaps a slight amount of organic matter as indicated by the small exothermic reaction at about 350 degrees.

10. From Morris Station in northern Camden County. About 10 ft. below surface. Clay lens in Raritan formation. The macroscopic characteristics are very similar to those of sample number 9. It gives a thermal curve showing the characteristics of kaolinite.

11. From Blue Anchor in eastern Camden County, and a pit $^{5}/_{10}$ mi. south of that from which sample number 9 was taken. About 7 ft. below surface. Clay lens in Cohansey formation. The sample is dark and light gray mottled and contains some root material. The reactions at 600 and 980 degrees centigrade are representative of a kaolinite clay. The broad exothermic reactions between about 300 and 540 degrees are indicative of organic matter and probably a little pyrite.

12. Hamilton Twp., Mercer County, about 2 mi. east of the city limits of Trenton. 10-20 ft. below surface. Clay lens in Raritan formation. This is a reddish and white mottled clay, feeling quite plastic when wet. The thermal curve shows that it is predominantly a kaolinite clay.

13. From a pit $^{3}/_{5}$ mi. west of Sayreville Jct., Raritan River Railroad, eastern Middlesex County. About 15 ft. below surface. South Amboy fire-clay. This clay is light gray, almost white in color having a talc-like feel. Its thermal curve is that of a typical pure kaolinite.

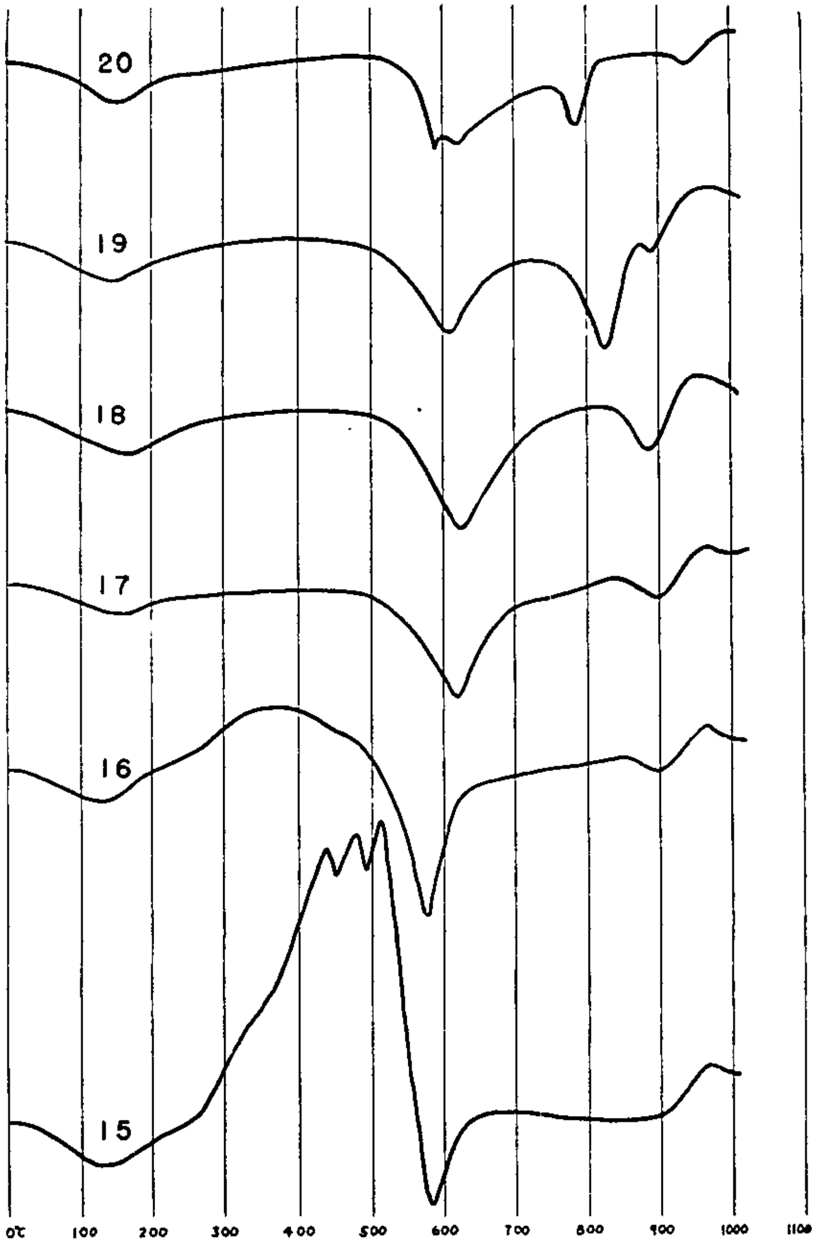

Figure 5

Thermal curves of clay samples, numbers 15 to 20.

14. Sample from exactly the same location as number 13, but is red in color, slightly mottled with yellow-gray. The thermal reactions are the same as those of sample number 13 except for the slight exothermic reaction at 350 degrees. This is thought to represent a slight amount of organic impurity in the kaolinite.

15. From Maple Shade, Chester Twp., in western Burlington County. 10-15 ft. below surface. Merchantville clay of Upper Cretaceous age. This sample was black in color and felt quite silty. The clay mineral present is shown to be an illite type. The presence of organic matter and pyrite is indicated by the broad complex reaction between 300 and 550 degrees.

16. From Oakland, Salem County, about 3 mi. south of Woodstown. 3-7 ft. below surface. Clay from Kirkwood formation of Miocene age. Gray clay containing a very small amount of some very fine-grained vitreous mineral. The initial dehydration reaction at 140 degrees and the reactions at 580 and 960 degrees are indicative of an illite type of clay. Some organic matter is indicated by the exothermic reaction between 300 and 500 degrees.

17. From roadcut 1½ mi. west of Millstone, Somerset County, and just west of Reading Railroad. 2-3 ft. below surface. Shale from Brunswick formation of Triassic age. Red, very hard shaly material. The thermal reactions of this sample show it to be composed of an illite clay.

18. From roadcut at Stelton Station, Middlesex County. 3-8 ft. below surface. Shale from Brunswick formation. Red, very hard shaly material, some white and black mottling. The thermal curve shows the sample to consist of an illite type of clay similar to sample number 17.

19. From quarry in east part of Kingsland in southern Bergen County. 20 ft. below surface. Triassic shale. Macroscopic examination shows the sample to be similar to number 18. The thermal curve is typical of an illite clay. The endothermic reaction at about 825 degrees probably represents a carbonate mineral.

20. From pit 1/3 mi. north of traffic circle, Little Ferry, Bergen County. 5-15 ft. below surface. Lacustrine clay of late Pleistocene age. Light gray clay, quite soft and thinly laminated. The predominant clay-mineral is shown to be illitic in nature. The presence of quartz is indicated by the sharp endothermic reaction at about 580 degrees.

21. From pit at Keasbey, eastern Middlesex County. 25 ft. below surface. Upper part of the Woodbridge member of the Raritan formation. Gray clay with some fine vitreous mineral dispersed throughout the sample. The nature of the reactions at about 580 degrees and at 975 degrees indicate a kaolinite clay. The additional endothermic reaction at about 900 degrees probably indicates the presence of some illite. Pyrite and organic matter are also shown to be present by the reactions between 300 and 500 degrees.

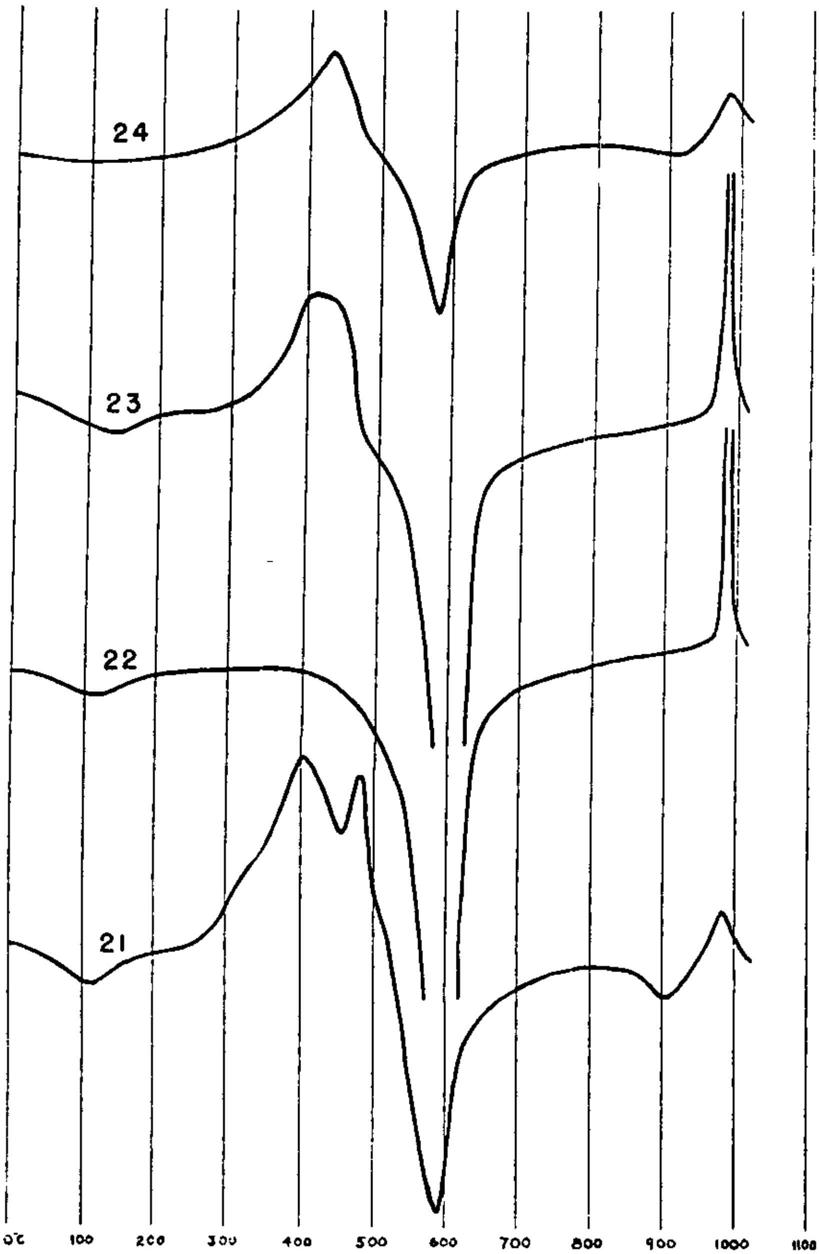

Figure 6
Thermal curves of clay samples, numbers 21 to 24.

22. From pit adjoining Metuchen Avenue, 1 mi. west of Woodbridge, northeastern Middlesex County. About 30 ft. below surface. Lower part of Woodbridge member, Raritan formation. Almost white clay. Talc-like feel. The thermal curve shows that the sample is almost pure kaolinite.

23. From pit in borough of Sayreville, on Kearney Dock Road, 1 mi. northwest of South Amboy. 10-25 ft. below surface. South Amboy fire-clay. Gray clay, slight talc-like feel. The thermal diagram of this sample is much the same as that of a typical kaolinite with the exception of the exothermic reaction at about 400 degrees. This is believed to be caused by a small amount of organic matter.

24. From boring, Cheesequake State Park, eastern Middlesex County. 1½-10½ ft. below surface. Clay lens in Magothy formation of Upper Cretaceous age. Grayish-yellow clay, slightly iron stained. Small amount of root material. The reactions at 580 and 975 degrees would indicate that the clay mineral present in this sample is largely kaolinite. Organic matter is shown by the reaction at 430 degrees.

25. From pit in Chessequake meadow, eastern Middlesex County. Amboy stoneware clay lens in Raritan formation. Gray clay, feels slightly silty. Some pieces of sample slightly darker than others. The thermal curve of this sample is indicative of a relatively pure kaolinite clay. The significance of the small exothermic reaction at about 475 degrees is not known.

26. From pit 1 mi. south of Millville, Cumberland County, and on west bank of Maurice River. 22-24 ft. below surface. Clay lens in Cohansey formation. Gray, chunky clay. Slight talc-like feeling. This clay provides a thermal curve indicating that it is composed of kaolinite, and perhaps a small amount of illite as shown by the slight endothermic reaction immediately preceding the final exothermic reaction. Some organic matter is also present accounting for the reactions between 250 and 450 degrees.

27. From pit 1-¾ mi. south of Millville and ½ mi. west of Maurice River. 9-11 ft. below surface. Clay lens in Cohansey formation. Light gray clay, chunky. Quite soft. The thermal diagram shows that the sample is composed of kaolinite with perhaps a small amount of illite and organic matter.

28. From borrow pit 2 mi. west of Clinton, Hunterdon County. 12 ft. below surface. Weathered shale from Martinsburg formation of Ordovician age. Very hard, almost slate-like, brownish-red in color. Has a definite tendency to break into small sharp splinters. This sample gives a thermal curve showing the characteristics of an illite clay.

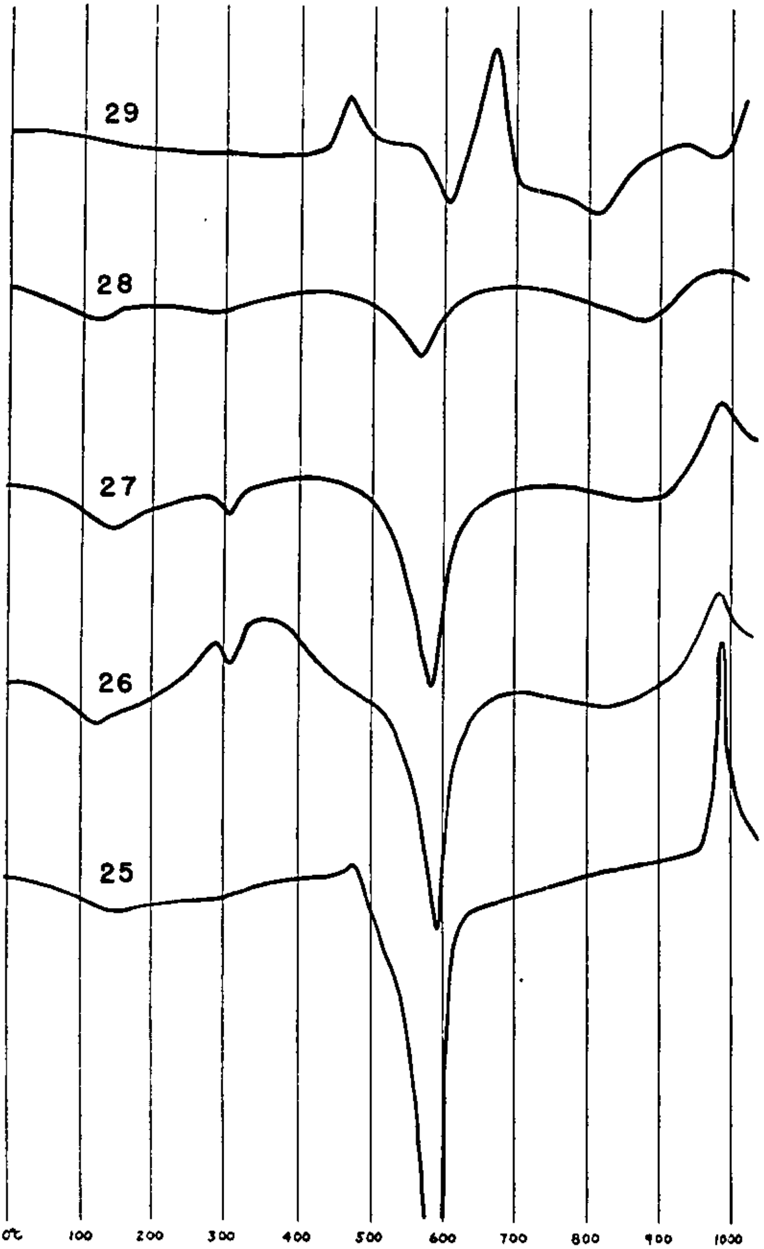

Figure 7

Thermal curves of clay samples, numbers 25 to 29.

29. From quarry just west of Newton, Sussex County. 15-150 ft. below surface. Slate from Martinsburg formation. Very hard, slate-like. Black-gray in color. Has well developed cleavage. The thermal curve of this sample indicates that it is composed of illite and organic matter.

Discussion and Conclusions

The series of 29 samples analyzed by the differential thermal method can be conveniently divided into four groups, according to the interpretation of their thermal diagrams. Group A is made up of sample numbers 4, 5, 8, 13, 14, 22, and 23. These clays all give a thermal curve that is very similar and shows the clay to be composed almost entirely of pure kaolinite.

Group B consists of sample numbers 1, 2, 6, 9, 10, 11, 12, 24, and 25. The thermal curves of these clays also show kaolinite to be the predominant clay mineral. However, the intensity of the reactions that are significant in the curves of these samples is not nearly as great as in those of the pure kaolinites. Two possible interpretations have been proposed for this reduction in intensity. One, that it is due to a dilution of the clay mineral by fine-grained silica; and two, that it is caused by a less perfect crystallization of the kaolinite. Grim (3) believes that the latter cause is more correct and the present work tends to substantiate this. A series of synthetic mixtures of pure kaolinite and finegrained Ottawa silica, ranging from 10 per cent silica content to 50 per cent silica gave thermal curves in which the intensity of the reactions was slightly reduced but the nature of the reactions remained the same. A less perfectly crystallized kaolinite is also believed to be more plastic than a pure kaolinite and this too seems to be true for the samples studied in this work.

Group C consists of sample numbers 3, 7, 15, 16, 17, 18, 19, 20, 28, and 29. These samples are shown to contain the clay mineral illite as the main clay constituent.

Group D is made up of sample numbers 21, 26, and 27. These samples appear to be a mixture of both kaolinite and illite.

The ceramic and non-ceramic properties of these clays can be estimated by referring to the discussion of the characteristics of the three main types of clay minerals. Group B, composed of the clays possessing a thermal curve typical of a kaolinite clay but of less intensity than a pure kaolinite, will very likely have the properties of a kaolinite clay but to a lesser degree. That is, these clays are not apt to be quite so refractory, will likely have a shorter vitrification range, and may possess greater shrinkage. The properties of Group C will be very much like those of the illite type, whereas Group D will be somewhere between kaolinite and illite in its properties.

It is interesting to note the correlation between the type of differential curve obtained and the source of the sample. In all instances the South

Amboy fire-clays gave thermal diagrams which were very similar and were typical of pure kaolinite. Clays from the Raritan formation other than the South Amboy fire-clays, proved to be kaolinitic with the exception of sample number 21 which is a mixture of both kaolinite and illite. The clays which were noted to be from a clay lens in the Cohansey formation, numbers 1, 2, 9, 11, 26, and 27, were all of a kaolinite nature with the exception of the last two which were judged to contain some illite in addition. Both the lacustrine clays of late Pleistocene age proved to be illitic in nature and this is more or less true of lacustrine clays wherever they are found. This correlation tends to show the value of the differential thermal method of clay analysis as a means of prospecting for clay deposits.

In conclusion it can be said that the present study of a series of 29 New Jersey clays shows them to be either kaolinite clays of varying purity and crystallization, or illite clays or mixtures of both. No samples were studied which can be said to be montmorillinitic in nature.

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A Triassic Armored Reptile from New Jersey

by GLENN L. JEPSEN

STATE OF NEW JERSEY
DEPARTMENT OF CONSERVATION
MORGAN F. LARSON, *Commissioner*
DIVISION OF FORESTRY, GEOLOGY, PARKS AND HISTORIC SITES.

MISCELLANEOUS GEOLOGIC PAPER
TRENTON, N. J.

1948

STATE OF NEW JERSEY
DEPARTMENT OF CONSERVATION

MORGAN F. LARSON, *Commissioner*

Division of Forestry, Geology, Parks and Historic Sites
State House Annex, Trenton, N. J.

LETTER OF TRANSMITTAL

Mr. Charles P. Wilber, *Director*
Division of Forestry, Geology,
Parks and Historic Sites,
Trenton, New Jersey.

Sir:

The attached manuscript describes in scientific language the fossilized remains of a lizard-like creature which lived in this region many millions of years ago. Those who have not studied the Triassic formations and are unaware of the rarity of such evidence of former life on this planet cannot appreciate the thrill I received upon recognizing the specimen brought me as being probably new evidence of this long extinct vertebrate life. Neither can they appreciate the joy with which this description will be greeted by all those scientists throughout the world whose work requires knowledge of the life of the Triassic period as a prerequisite to the accurate dating and correlation of the sediments deposited in that period. Since the scientific description and naming of such a fossil is a task for an expert paleontologist, I was grateful that there resided at Princeton, only eleven miles distant, just such an expert to whom I could turn for help. It gives me a great deal of pleasure, therefore, to acknowledge to Dr. Glenn L. Jepsen of Princeton my own indebtedness and that of all those who will read this report for the many months which he devoted to the careful and skillful uncovering of that part of the fossil not previously exposed, the weeks spent in detailed study of similar fossil remains found in other parts of this country, and the necessary perusal of all the literature describing the relatively few vertebrate fossils of Triassic age found in other parts of the world. All this work was done as a matter of co-operation with an agency of the State in which he resides, and this writer therefore sincerely hopes that the recognition given him by other scientists for a splendid piece of work will provide the compensation he so richly deserves.

Yours very truly,

MEREDITH E. JOHNSON,
State Geologist.

A TRIASSIC ARMORED REPTILE FROM NEW JERSEY

by

GLENN L. JEPSEN

ABSTRACT

Nine segments of the tail cuirass and four caudal vertebræ of an armored reptile disinterred from shale constituting part of the Brunswick formation of late Triassic age and found near Neshanic, New Jersey, are described as representing a new subspecies, *Stegomus arcuatus jerseyensis,* tentatively assigned to the family Stagonolepidæ, suborder Pseudosuchia, order Thecodontia, subclass Archosauria.

Tetrapod remains are so rarely recovered from the Newark series of rocks that each discovery merits attention not only for its contribution to biological studies but also for its yield of information about geological events and facies conditions in late Triassic times.

An interesting fragment, herein described, of the tail armor and some vertebræ of a reptile from the particularly unfossiliferous Brunswick shale formation, was submitted for identification and study by Meredith E. Johnson, State Geologist of New Jersey. The specimen is especially significant in that it probably represents an individual of a species of reptile, *Stegomus arcuatus,* which was named nearly fifty years ago but of which, paradoxically, no actual remains have been seen heretofore; the type and only other known specimen consisting merely of an impression on coarse matrix which was found in New Haven, Connecticut, and described by Marsh in 1896.

Although areal maps of eastern North America indicate that Newark sediments are exposed for thousands of square miles in the region, all but very small areas of rock are concealed by a mantle of soils and plants. Hence, most of the fossil vertebrates which have been recovered from Newark strata have come from mines and quarries, and from excavations for wells and buildings and roads and reservoirs. Favorable collecting sites are therefore not only small but they are not long available for search, and the accidentally discovered fossils have been removed less often by refined collecting techniques and instruments than by dynamite, steamshovel, and bulldozer. As a result most of the specimens are badly damaged; it is frequently impossible to ascertain the exact position they occupied *in situ,* and some, known to be in certain spots, are nevertheless unavailable for study. Part of one skeleton was recovered from a quarry in Connecticut but the rock containing the skull and fore quarters was inadvertently built into the abutments of a bridge where it has remained for more than 60 years. Another famous specimen was found in a boulder which had been transported by ice-age glaciers to a spot conveniently near the campus of Mount Holyoke College in Massachusetts.

Mr. Johnson states in a letter that the new New Jersey fragment "was unearthed in excavating for the cellar of a home . . . and there is no evidence of where the material . . . may have been dumped or spread on the surface." Mr. John Higgins found the specimen in 1936 on the property of Mr. Dwight W. Coburn in western Somerset County. It was placed on exhibition in the nearby Clover Hill school where speculations about its nature continued until 1940 when, at the suggestion of the principal, Mrs. Yandal, it was taken to Mr. Johnson by Mr. John Trippe, whose daughter taught at the school.

It is fitting to pay tribute to the wisdom and thoughtfulness of those who were associated with the discovery and safe keeping of the specimen. Too often, particularly in the Eastern states, the scientific value of fossils is not appreciated, and they serve as door-stops or other domestic trivia until by accident they come to the attention of someone who appreciates their possible scientific values.

When the fossil was cleaned and further freed from the investing rock and when X-ray photographs had revealed the vertebræ inside the matrix within the cuirass (see Plate 1) its reptilian nature became obvious, contrary to earlier opinions that it represented a plant or a cephalopod, both of which it superficially resembled in several respects. The conjectures which had placed the specimen among the plants or the invertebrates emphasize the fact that fossil tetrapods are extremely uncommon and hence unexpected in the Newark series in New Jersey. In addition to the phytosaur *Clepsysaurus manhattanensis* (Huene, 1913) Camp, 1930, and the procolophonid cotylosaur *Hypsognathus fenneri* Gilmore 1928 (see also Colbert, 1944, 1946, and Rapp, 1944), a few undeterminable bones of phytosaurs represent the State's contribution to the reptilian fauna of the Triassic.

Comparisons of the New Jersey specimen with the types representing two species of armored reptiles from the Triassic of New England show that its affinities are much closer to *Stegomus arcuatus* Marsh, 1896, than to the diminutive *Stegomosuchus longipes* (Emerson and Loomis, 1904) Huene, 1922. It is in fact here regarded as part of an individual of *Stegomus arcuatus,* although for taxonomic convenience and because the two specimens probably were genetically separated (not members of a single inter-breeding population) it is treated as representing a new subspecies, *S. a. jerseyensis.* This conservative decision about its systematic treatment is susceptible to adjustment if and when better specimens are discovered. As noted above, the type of *S. arcuatus* is a mold of the original; it is not even a natural cast such as the type of *Dyoplax arenaceus* which is a surficial duplicate of the cuirass in "very fine green clayey mud" (O. Fraas, 1867). Further, it represents the ventral (inner) surfaces of some of the dorsal and lateral plates, a part of the anatomy which presents few diagnostic structures and is usually unavailable for study in better specimens. Unfortunately this ventral mold has sometimes received consideration as if it were a dorsal aspect of the actual specimen. Impressions

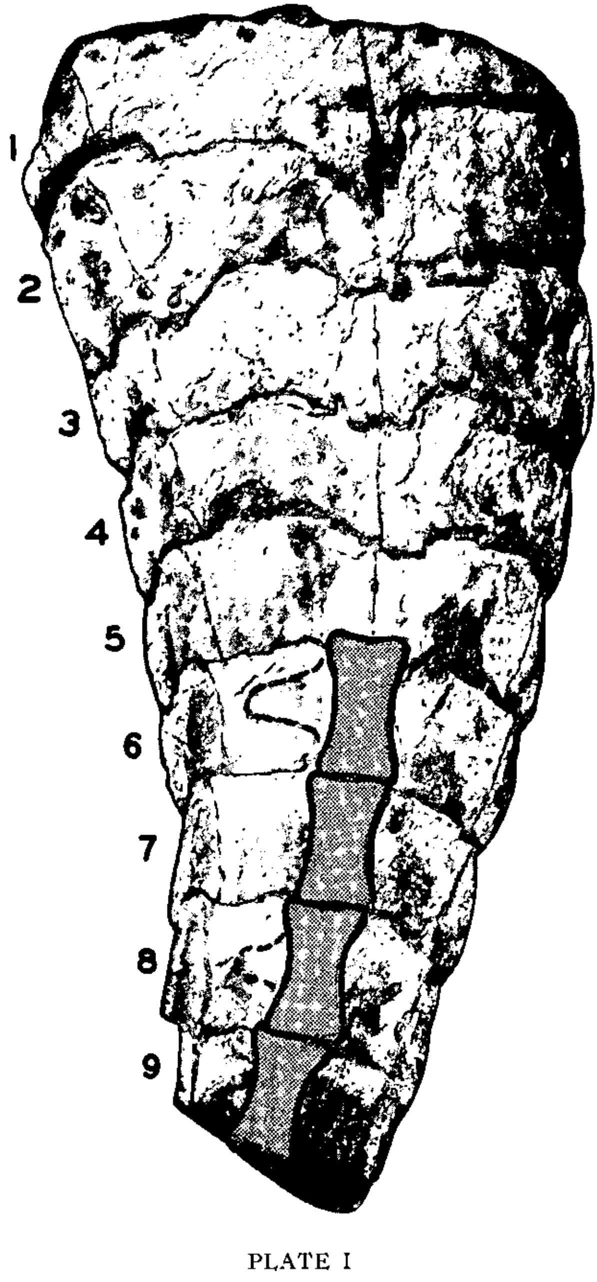
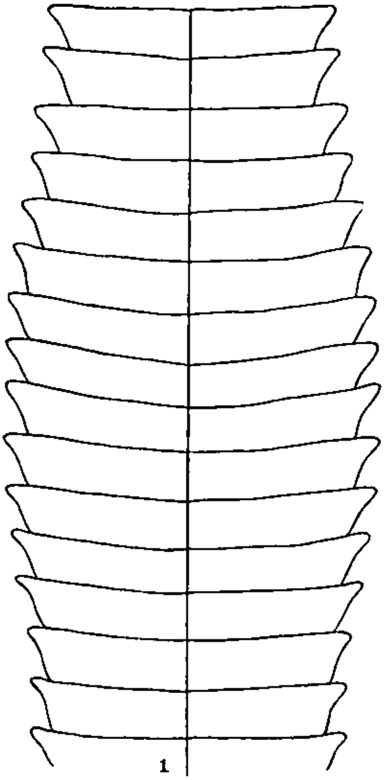


PLATE I

Type of *Stegomus arcuatus jerseyensis,* New Jersey State Museum no. 10740. Dorsal view, natural size.



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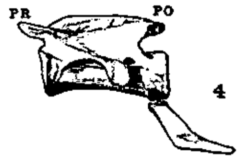

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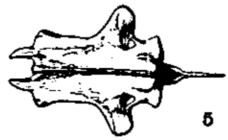

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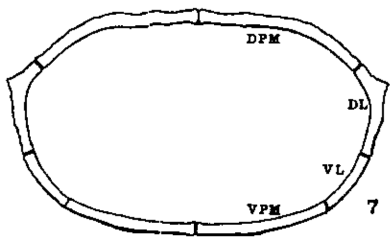

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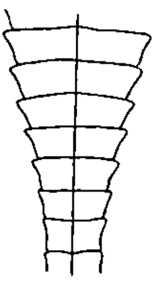

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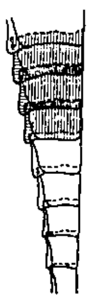

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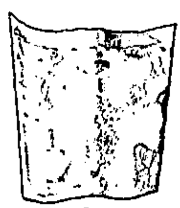

8

PLATE 2

FIG. 1. Outlines of interplate ridges on matrix, type of *Stegomus arcuatus arcuatus,* Yale Museum no. 1647. See text for explanation. About x ¼.

FIG. 2. Similar outlines for type of *Stegomus arcuatus jerseyensis,* New Jersey State Museum no. 10740. About x ¼.

FIG. 3. *S.a.jerseyensis*, type. Outlines of dorsal paramedian and dorsolateral scutes, left side. About x ¼.

FIGS. 4, 5, 6. Same. Left, top, and rear view of vertebra of segment number nine. Natural size. Symbols: DL, dorsolateral; DPM, dorsal paramedian; VL, ventrolateral; VPM, ventral paramedian.

FIG. 7. Same. Transverse section, reconstructed, through middle of segment five, Natural size.

FIG. 8. Same. Left ventral paramedian plate of segment four. Anterior edge at top, midline edge toward left. Natural size.

of parts of the external surfaces of a few plates were noted on some additional pieces of arkose by Marsh (1896) and by Lull (1915, pp. 101-2), but as the latter author remarks "the upper surface is apparently obscured by the coarse granulation of the material taking the impression." However, he made a cast of this rock surface and reported his observation of "tiny punctuations in series approximately parallel to the long axis of the animal's body."

Marsh thought that adjoining plates were "somewhat separated by connecting tissue . . . which held the whole dorsal armor together as a carapace," and failed to observe the imbricate relationships of the scutes; but Emerson and Loomis (1904, p. 378) noted that the plates of *Stegomosuchus longipes* are obviously imbricate and made the suggestion, sustained by Lull (1915, p. 101), that the armor of *Stegomus arcuatus* had a similar structure, although the amount of overlap could not be determined from the type specimen. It was therefore instructive to compare the type of *S. arcuatus* with the corresponding aspect of the New Jersey fossil which does show the approximate extent of overlap. Plate 2, fig. 1 was prepared by placing a flat sheet of transparent flexible plastic directly on the type of *Stegomus arcuatus* and drawing the outline of the ventral impression of each plate separately. Impressions of the most anterior two pairs of plates were not drawn because they indicate some kind of natural position or post-mortem distortion or breakage which was not characteristic of the other 16 pairs of plates. The lines indicate matrix ridges which were along the front and the lateral edges of the scutes and along the dorsal midline. This drawing process required continual adjustment of the plastic sheet but gave the effect of a separate projection of each scute and assembled them all on a plane. The method introduces some distortion but not as much as do photographic images of the curved specimen (Marsh, 1896, Pl. I; Huene 1914, fig. 49) where it is projected as a unit to a plane. Fig. 2 of Plate 1 is a similar preparation for the New Jersey fossil. The anterior ridge for the first and the posterior ridge for the last, the ninth, plates are not preserved, and are hence omitted from the drawing.

As the specific name suggests, the back of the type of *arcuatus* is in a strongly convex or arched position from front to rear, whereas the middle of the new specimen is depressed below a straight line from the anterior to the posterior edges. These differences in position may account in small part for the apparent transverse bowing in opposite directions of the outlines of the scutes on the two specimens, but this curve reversal from the thoracic to the caudal regions is a normal structural condition among armored reptiles (see Sawin, 1947, fig. 13 and Plate 34).

Relationships of these impressions on the matrix to the actual scutes may be seen in Plate 2, fig. 3 and by comparing it with fig. 2. In fig. 3 the vertically ruled areas indicate the sizes of the dorsal median plates, and the extent that the rear border of each scute overlaps the anterior edge of the succeeding plate in the series. Thus the lines representing the anterior and the posterior ridges of a single plate impression in fig. 2

correspond to the dashed lines along the anterior edge of the same plate and that of the next posterior plate in fig. 3. It may be noted, by the latter figure, that approximately the posterior one-fifth or one-sixth of each plate overlaps the anterior border of the next posterior one.

The New Jersey and the Connecticut specimens are not comparable in many respects, not only because the latter is merely a kind of matrix ghost of part of the original animal, but because it represents the prepelvic armor; whereas the New Jersey fossil is a portion of the post-pelvic skeleton. Aetosaurs, like most of the armored pseudosuchians, probably have from 21 to 27 presacral vertebræ (see Camp, 1930; Case, 1922, 1932A; Heune, 1932, 1938; Kuhn, 1937; McGregor, 1906; Sawin, 1947), with about the same number of segments of dorsal armor.

As mentioned above, irregularities of the anterior scutes of the type of *Stegomus arcuatus* suggest that they pertain to the cervical region, and that the 18 preserved segment impressions represent most of the region between the head and the pelvis. Marsh (1896, p. 60), unaccountably stated that remains of 20 segments were present.

It is impossible to calculate the exact original position which was occupied in the tail of the living animal by the New Jersey specimen, although speculations may be based upon the fracture habits observed in comparable fossils and upon comparisons of dimensions. Individual reptiles of the famous Stuttgart slab of *Aëtosaurus ferratus* show more breakage and displacement in the cervical and in the sacral regions than elsewhere (O. Fraas, 1877).

It may be noted, on Plate 2, fig. 1, that the transverse width across the middle of each successive dorsal plate of the type of *Stegomus arcuatus* increases from the third segment (most anterior one indicated) to the ninth or tenth and then decreases. The following straight-line dimensions of matrix impressions of the dorsal scutes of the type of *S. arcuatus* differ slightly from the measurements given by Heune (1914), and Lull (1915);

Plate	*Transverse width*	*Plate*	*Transverse width*
3	68 mm.	10	90 mm.
4	67	11	88.5
5	?	12	88.5
6	76.5	13	87
7	83	14	85
8	88	15	80.5
9	90	16	76
		17	73

Similarly measured, the lateral dimensions of the dorsal paramedian plates of the New Jersey specimen are:

Segment	Transverse width Left	Transverse width Right
2	33.0 mm.	
3	29.5	29.0 mm.
4	25.8	26.0
5	22.4	22.6
6	19.0	19.8
7	16.5	16.3
8	14.0	13.6

If the width decrease from the 10th to the 17th segments of the type of *S. arcuatus* is diagrammatically extrapolated posteriorly it diminishes to the width of the most anterior dorsal plate of the New Jersey individual in the position of about the 29th to the 33rd segment. This rather far-fetched manipulation might suggest, in view of the number of presacral vertebræ in pseudosuchians, that the latter specimen is the anterior part of the tail, or at least a section immediately posterior to the cloaca. However, the anterior-posterior dimensions of the plate impressions of the two specimens do not show a similar progression; their measurements vary irregularly from 22 mm. to 27 mm. in the type of *S. arcuatus* and from less than 16 mm. to about 17 mm. in the New Jersey fossil. Further, it is stated by E. Fraas (1907) that the anterior caudal back plates of *Aëtosaurus* are larger than those of the posterior trunk region. This size relationship was in part the basis for the specific name of *A. crassicauda.* Among the dimensions of *Typothorax meadei,* cited by Sawin (1947, p. 236) for the anterior-posterior length of dorsal plates it may be noted that the 24th, presumably an anterior caudal, exceeds the others.

It is of course impossible to select as correct any one of the numerous possibilities of individual size and proportion which these comparisons suggest, even assuming that the New Jersey and the Connecticut specimens represent a singles species.

Stegomus arcuatus jerseyensis, n. subsp.

Type: New Jersey State Museum No. 10740, nine incomplete segments of caudal armor and four vertebræ.

Horizon: Lower part of the Brunswick shale formation, about 2800 feet above its base.[1]

Locality: Near the top of the hill northwest of Neshanic River 0.4 of a mile from its junction with the South Branch of the Raritan River; about 1.25 miles southwest of Neshanic Station; about 1.5 miles east of the Clover Hill School in west Somerset County, New Jersey.[1]

[1] *Fide* Meredith E. Johnson, personal communication.

DISCUSSION: As noted above, the specimen consists of fragments and impressions of bony plates or scutes of nine of the series of imbricated bands which completely girdled the tail muscles, and of vertebræ inside of the four posterior bands. The bone, not well preserved, is softer than the indurated red shale matrix, and has partly disintegrated within the rock. Even the surfaces which have been carefully exposed in the laboratory are covered by a soft granular substance which appears to be a decomposition product of the original bone. Plate 1 shows the approximate size, dorsal view. In this photograph only the lighter shades represent actual bone. Dorsoventrally the specimen has an almost uniform thickness, in the medial region, of about 16 mm.

Displacement and crushing and the absence of ventral plates at the anterior end of the specimen, and the lack of vertebræ in this region suggest that the preserved part of the tail, and perhaps the posterior part which is now missing, was torn from the rest of the animal before burial, and that the armor plates interlocked with such rigidity that a more extensive collapse during the time that sediments were surrounding the bone was prevented. The extent of flexibility of the tail during the animal's life cannot be computed, but some movement must have been possible between adjacent scutes.

Plate 1 presents to view more area of the left and less of the right lateral scutes than would be seen in dorsal aspect if they were in normal position (as restored in Plate 2, figs. 3 and 7), because the dorsal surface has been displaced toward the right with respect to the ventral scutes.

There are eight elements in each segment or ring of plates (Plate 2, fig. 7), four on either side of the midline plane. Beginning at the middle of the carapace, these four may be called the dorsal paramedian (DPM) the dorsolateral (DL), the ventrolateral (VL), and the ventral paramedian (VPM), the latter extending to the midline on the ventral surface.

Each dorsal paramedian plate is wider at its anterior than at its posterior border, a configuration which can be observed (Plate 2, fig. 1) for the inter-plate ridges of the type of *S. arcuatus* also. Sawin's (1947) dimensions for the type of *Typothorax meadei* show that each of the anterior ten or eleven dorsal plates is narrower at its front than at its rear border but that the posterior scutes are wider along their anterior than along their posterior edges. Although the anterior plates of the dorsal paramedian series of the New Jersey specimen have greater lateral than axial diameters, this relationship is reversed posteriorly. It can be seen, however, that the actual anterior-posterior length of the successive plates decreases toward the rear. The dorsolateral scutes are elongate posterolaterally, with convex anterior and concave posterior borders, and each has a raised scalloped keel directed lengthwise, similar to the structures of corresponding plates of *Aëtosaurus crassicauda* (see E. Fraas, 1907), but unlike the spines on the lateral scutes of *Episcoposaurus* [*Desmatosuchus*] (see Case, 1922). Plate 2, fig. 3 presents an almost edgewise outline of these dorsolateral scutes. They are seen in a similar position along the right side of the photograph, Plate 1, whereas those of the left side in this picture (note especially the one near the number 2) are rotated so that the lateral outline is in view.

In the anterior segments the line of contact between a dorsal paramedian scute and an adjoining dorsolateral scute forms a sigmoid curve, whereas the contacts between similar plates in the posterior segments are simple curves.

Unfortunately not much remains of the external surface of any of the dorsal paramedian scutes, but small areas of the dorsolateral plates show a pattern of irregular ridges, furrows, and punctuate depressions. The ventral surfaces of the dorsal paramedian scutes bear shallow longitudinal ridges whose impressions show as furrows on the matrix.

There is no apparent strong overlap of the dorsal paramedian plates on the inner edges of the dorsolaterals as described for *A. ferratus* (O. Fraas, 1877), but it is possible that the longitudinal ventral edges of the dorsolaterals overlapped the adjacent edges of the ventrolaterals.

Matrix still covers about one-third of the fossil's ventral surface which is relatively flat anteriorly but is laterally convex at the posterior fracture. Like the dorsal paramedian members the ventral paramedian scutes have a shingle arrangement from front to back, and their edges are thickened at the midline. The ventral paramedian scutes of the fourth band are subsquare in outline (Plate 2, fig. 8), but anteriorly the scutes of this series are broader than long whereas posteriorly they become narrower from side to side in the manner of the dorsal scutes. Lateral to each ventral paramedian plate is a long, narrow ovoid ventrolateral plate with a small keel beginning near the middle of the plate (and hence not indicated in the diagram, Plate 2, fig. 7) and rising to the posterior border. The outer or lateral margin of each of these ventrolateral scutes touches (and may have underlapped) the ventral side of a dorsolateral plate. Thus a segment or band of eight plates completely girds the tail.

This arrangement of plates is different from that on some of the Triassic crocodilians such as *Protosuchus* (Brown, 1933, 1934) where in the caudal region there are (about) two ventral tranverse rows of plates for each segment of the dorsal plates, and where the segments or rings appear to be composed of twelve rows of plates. Another ancient crocodilian, *Hoplosuchus* (see Gilmore, 1926, p. 334) may have had only half as many, six, scutes per segment.

Each caudal armor segment of *Aëtosaurus ferratus* is composed of twelve plates, two dorsal, two lateral, and eight ventral; but *A. crassicauda*, like *S. a. jerseyensis,* apparently had only eight. In the type of *Typothorax meadei* several anterior caudal bands may have consisted of eight elements but the mid-caudal segments were apparently composed of six scutes, and the posterior rings of five.

Crushing is partly or wholly responsible for the anterior-posterior offset position of the dorsal and ventral plates, for although at present the anterior edges of the ventral paramedian plates of each band are opposite about the middle of the dorsal plates of the same band, it is probable that in life the anterior edges of the eight scutes of a ring were about even with each other. Except for the keels on the dorsolateral and ventrolateral elements, the bone of the scutes is thin, averaging a little less than a millimeter in thickness.

In the bone of each dorsal and ventral plate Haversian canals radiate from a region just posterior to the midpoint of the plate, and there are two anterior-posterior parallel rows of canals on each of these scutes near the midline of the body, and also zones of especially numerous canals near the lateral borders. The radial distribution may suggest that there was a surface sculpture of radiating ridges and furrows similar to that of *Aëtosaurus crassicauda* and of *A. ferratus,* or that there were low "knobs" and radiating pits and furrows similar to those described by Case (1932A).

There are other ways that the scutes of *S. a. jerseyensis* resemble those of *A. crassicauda* (see E. Fraas, 1907, and Heune, 1921) and those of the unnamed form from the Triassic of Texas (Case, 1932A). The caudal dorsal paramedian plates of these three reptiles are of similar shape, wide transversally and tapering toward the rear; not quadrangular like those of *A. ferratus* (see O. Fraas, 1877; Heune, 1920) and *Stegomosuchus longipes.*

To judge from the isolated plates of *A. crassicauda* for which Heune (1921) gives dimensions, and from the measurements of the type of the species (O. Fraas, 1907), there cannot be a great disparity in the sizes of those individuals and the two specimens of *S. arcuatus;* but all of them are much larger than members of the species *A. ferratus.* The midline length of the known dorsal paramedian plates of *A. crassicauda* range from 23 mm. to 30 mm., slightly larger than the greatest similar dimensions for *S. a. jerseyensis* and probably encompassing the range of dimensions for corresponding parts of *S. a. arcuatus.*

E. Fraas (1907) calculated that the length of *A. crassicauda* was at least 1.5 meters whereas the largest known individual of *A. ferratus* is 0.86 meter long, somewhat larger than *Dyoplax arenaceus* which O. Fraas (1867) estimated to be 0.75 meter. All of these forms are much smaller than the unnamed specimen described in 1932 (A) by Case, and than the mounted specimen of *Typothorax meadei,* 3.03 meters long, in the Texas Memorial Museum (Sawin, 1947).

After the photograph of Plate 1 was taken, the most posterior of the four vertebræ, that of the ninth segment, was well exposed for study and the left sides of the vertebræ of the sixth and eighth segments were cleaned, although this necessitated the destruction of overlying parts of the carapace. The outlines of the centra of the vertebræ are shaded in Plate 1 and the dashed lines indicate the shapes of the lateral processes. The vertebræ are shallowly amphicoelous (Plate 2, fig. 6) and the centrum of the posterior one is "hour-glass shaped" and hollow like those in the tails of many fossil reptiles including, apparently, *A. ferratus* (see Heune, 1920, p. 476). There seems to be no bone partition separating the neural canal from the centrum cavity, at least in the posterior part of the vertebræ of segment nine, except a small lip projecting anteriorly from the dorsal border of the posterior wall. Presumably the space within the centrum was occupied by soft tissues which may have been part of or associated with the central nervous system or the blood or lymph (see Grodzinski, 1929) circulatory systems or other organs. (The interiors of the centra of the caudal vertebræ of some living vertebrates are hæmopoetic sites.) The posterior end of the centrum on the ninth segment vertebra shows no indication of a notochordal perforation. There is no suggestion in the structure of the vertebræ that the animal was capable of caudal autotomy (see Woodland, 1921) and hence no evidence for the intriguing possibility that the creature survived after the loss of this tail and grew a new one.

In *A. crassicauda* the first six caudal vertebræ are about the same length as the two measured vertebræ of *S. a. jerseyensis* but are much wider and more massive. In comparison with the caudals of *Typothorax meadei* those of *S. a. jerseyensis* are proportionately low and wide and slender and are relatively small.

On the vertebræ of segment nine of *S. a. jerseyensis* (see Plate 2 ,figs. 4, 5, 6) the low dorsal spine is about as long, anteroposteriorly, as the centrum and was apparently appressed along its straight superior border against the midline edges of the dorsal paramedian plates. The neural spine of segment six vertebræ is higher and heavier and has an arched superior border.

As indicated in Plate 2, fig. 4, the prezygapophyses project anteriorly beyond the centrum, as Heune (1921, p. 332) noted for *A. crassicauda* and as shown by the illustrations for the specimen which Case described in 1932 (A), and also as Camp (1930, p. 71) observed for *Machaeroprosopus;* whereas the postzygapophyses are anterior to the posterior border of the centrum. Arising from the sides of the centrum, the small transverse processes of the last vertebra curve ventrally as they project posterolaterally. The lateral processes of the next anterior vertebra are larger and straighter, and those of segment six are comparatively large and plane; and although their posterior edges arise from the centrum, their anterior borders are apparently continuous with the prezygapophyses. None of these processes is like the massive structures which E. Fraas (1907) observed on the anterior caudals of *A. crassicauda* and believed to be a distinctive feature of the genus and a necessary correlate of the closed armor system of the tail.

At the posterior dorsal base of the transverse process of the last vertebra there is a perforation through the wall of the tubular centrum, and a similar but smaller hole appears on the vertebra of segment eight, but this region of the first vertebra, that of segment six in the preserved series of annular scutes, is plane.

Comparatively large and laterally compressed, the chevrons (Plate 2, figs. 4, 5, 6) are attached to two facets which seem to be posterior enlargements of longitudinal ridges which border a shallow groove along the ventral surface of the centrum. Many authors have remarked about similar grooves on the ventral sides of caudal vertebræ, particularly in the posterior part of the tail of pseudosuchians and phytosaurs (see Camp, 1930, on two species of *Machacroprosopus*; Case, 1932A, p. 70, on a phytosaur; Heune, 1921, p. 332, on *A. crassicauda;* 1939, p. 64, on *Parringtonia gracilis;* Sawin, 1947, p. 212, on *Typothorax*). Case (1932B, p. 82) noted the absence of such grooves on the vertebræ of a dinosaur, but they may appear on some dinosaurs (Heune, 1932).

From the end view, Plate 2, fig. 6, the haemal arch of the vertebra of segment nine appears almost as large as the neural arch, although the two differ in shape.

Additional dimensions of the type of *S. a. jerseyensis* are:

Segment	Dorsal paramedian plates, anterior-posterior length (middle of plate)	Dorsolateral plates Transverse midwidth	Vertebrae Length of centrum	Width post. end	Height post. end
2	22 mm.	12.8			
3	21	11.6			
4		11.0			
5		11.7			
6	19	11.0	17.0	8.8	
7	18	11.0			
8		9.5			
9			17.5	8.9	5.9

The left ventral paramedian plate of segment four has a transverse width at the anterior end of 22.3 mm. and at the posterior end of 17.7. Its anterior-posterior length along the middle of the plate is 21.8 mm. The left ventrolateral scute of segment two is 22.5 mm. long and has a transverse width of 8 mm. The chevron of segment nine is about 13 mm. long.

Taking the known facts and many inferences derived from them into consideration it appears more satisfactory to place the New Jersey specimen in a new subspecies of the species *Stegomus arcuatus* than to erect a new species for it. It is impossible now to know whether or not this treatment will prove to be acceptable in the future, but it has the merit of nominally differentiating the fossils from Connecticut (*Stegomus arcuatus arcuatus*) and New Jersey (*S. a. jerseyensis*) and at the same time of calling attention to their obvious similarity. They may have been contemporary, and possibly but improbably were members of a single interbreeding population and hence represent a single subspecies. Another possibility is that they represent different species which were not contemporary. It is unlikely (but not impossible) that they pertain to different genera.

To a paleontologist who is accustomed to describing and classifying mammals the state of the taxonomy of thecodont reptiles seems chaotic. Much of the confusion arises from the facts that most of the specimens are fragmentary and represent non-comparable parts of different individuals, and that various authors use different anatomical parts of the fossils for establishing classification hierarchies. However, many descriptions and taxonomic manipulations are not satisfactory for other reasons; some authors repeatedly fail to make optimum use of their materials and base "firm" opinions upon insufficient and infirm evidences.

Stegomus has been assigned to several different families, usually within the pseudosuchian thecodonts. Marsh (1896) put the genotype, *arcuatus*, in the Belodontia (now, in general, the Phytosauridæ). Hay, in 1902, placed the species in the *Aëtosauridæ*, a practice which was continued by Emerson and Loomis (in 1904, when they unfortunately described *longipes* as another species of *Stegomus*), Huene (1914 and 1920), Lull (1915), Abel (1919), Williston (1925), Hay (1930), Zittel (Eastman revision, 1932), and Romer (in 1933, but not in 1945). In 1915 Huene suggested that *Stegomus* and *Typothorax* might be closely related (as several previous authors had maintained) but also said (p. 490), "I leave it open to the future to decide whether *Typothorax* belongs with the Pseudosuchia or with the Parasuchia [Phytosauria] . . ." A few years later (1922B) Huene perceived and emphasized the differences between *Stegomus arcuatus* and *S. longipes* and formalized his conclusions by erecting a new genus for the latter, *Stegomosuchus*, and a new family Stegomosuchidæ, of the Pseudosuchia. *Stegomus* he then provisionally placed in the Stagonolepidæ as a parasuchian, but in 1936 he transferred the stagonolepids to the Pseudosuchia, and at the same time put *Typothorax* ("*vide* Camp") in the Phytosauria. In 1938 he reiterated his opinion that *Stegomus* is a stagonolepid. Camp and VanderHoof (1940) cashiered Huene's family Stegomosuchidæ by including it in the Stagonolepidæ but apparently listed *Stegomosuchus* (p. 468) as a member of the Aëtosauridæ and also as a member of the Stagonolepidæ (if their "*Stegomuschus*" and "Stegomuschidæ" are misspellings of *Stegomosuchus* and Stegomosuchidæ). They placed *Stegomus* and *Typothorax*, as stagonolepids, in the Pseudosuchia. Romer (1945) referred *Stegomus*, *Stegomosuchus* and *Typothorax* to the Stagonolepidæ, the family to which, presumably, Camp, Taylor, and Welles (1942) relegated *Stegomosuchus*. Nopcsa (1928) classified *Stegomus* in the Belodontidæ and Schmidt (1928) put the genus in the Proterosuchidæ.

Huene's creation in 1922 of the generic category *Stegomosuchus*, for the species *longipes*, has been subsequently rejected or overlooked by several authors, among them Camp (1930), Romer (1933, not 1945), and Colbert (1946). Sawin (1947) also apparently includes both *arcuatus* and *longipes* in the genus *Stegomus*.

Various other terminologic and taxonomic confusions involving these and other thecodont groups are in the literature, but these problems of classifications have little chance of being solved until more and better specimens are discovered or until an enormous amount of skillful morphologic study is made of the known specimens.

At the moment as good a plan as any and the one involving the least confusion and taxonomic change is to follow Huene (publications since 1922), Romer (1945), and others by placing *Stegomus* with *Stegomosuchus* and *Typothorax* and other genera in the family Stagonolepidæ of the Pseudosuchia. The value of this practice cannot be adequately judged however, until *Stegomosuchus* is restudied and until more skeletal parts of individuals of *Stegomus arcuatus* are found. When they are discovered and studied it is possible that *Stegomus* will continue to be considered as a stagonolepid or that it and *Stegomosuchus* will be placed with *Dyoplax* and *Aëtosaurus* in the Aëtosauridæ.

This tentative placement of *Stegomus* in the Stagonolepidæ is an expedient which has little more than tradition and convenience for its support; it does not reflect conviction or good evidence or judgment.

It is generally agreed that the Newark rocks are contemporary with part of the late Triassic Keuper (perhaps including some of the Rhætic) of Europe and with parts of the Dokum and Chinle of Arizona, Texas, New Mexico, and Utah (see Camp, 1930[1]; Daugherty, 1941; Huene, 1922A, 1926, 1940; Reeside, 1932; Roberts, 1928; Schuchert and Dunbar, 1941; Ver Wiebe, 1933; Young, 1946). However, some of these authors as well as others have suggested that the exposures of the Newark in North Carolina, Virginia, Pennsylvania, and New Jersey are older than those in Connecticut and Massachusetts and may correlate with the Lettenkohle and Muschelkalk of Germany.

Lull (1915, p. 80) suggested "that the Pennsylvania localities represent an older faunal phase than the dinosaurs of the Connecticut valley" which occur only in the upper series of sandstones and shales (above the Posterior trap). He also remarked that the matrix and fossils from some localities in Pennsylvania "point to very different environmental conditions from those of the New England and New Jersey areas . . .", and that the Newark "as a whole may bridge the time between the Triassic and the Jurassic . . ." (p. 20).

Later (1926) Huene, as quoted by Colbert (1946, p. 269) reported the conclusion that the Newark probably extended from some part of Muschelkalg time to about the close of the Triassic. In 1940 Huene (chart between p. 248 and p. 249) correlated the Phoenixville tunnel locality (Lockatong formation) with the lower Keuper and the Lettenkohle. Colbert (1946) summarized and charted (fig. 20) various opinions about the ages of different parts of the Newark. He also devised columnar sections (fig. 19) to show his interpretation of the stratigraphic relationships of igneous rocks (all of which he calls "intrusive sheets"), sediments, and fossils of the Newark series in the Connecticut Valley and in New Jersey, apparently under the assumption that the basaltic lavas of the Anterior, the Main, and the Posterior traps in the Connecticut valley correlate with the three principal basaltic flows, those of the First Watchung, the Second Watchung, and Hook Mountain, in the Brunswick shale formation in New Jersey. This undemonstrated but appealing assumption was suggested also by Schuchert and Dunbar (1941, p. 306).

[1] Nopcsa (1934, p. 83) loosely or erroneously interpreted Camp's (p. 5) correlation chart and assigned *Stegomus* to the "lower and upper Chindle." Nopcsa (also Camp and Colbert, as noted above) did not recognize Huene's genus *Stegomosuchus*.

In view of these and other opinions about the age of the Newark as a whole and of its sediments in various areas a study was undertaken to review the previous evidences for correlation and to judge the significance of the specimen herein described in providing new stratigraphic knowledge. No satisfactory results can be reported, and it is therefore useless to enumerate and discuss at length the complications which attended this study.

However, as added, but weak testimony to the suggestion that the Connecticut Valley expression of the Newark formation is not as old as the Newark rocks farther south, it may be significant that whereas the Connecticut type of *Stegomus arcuatus* comes from the lower of the two "series," below the Anterior trap, the New Jersey specimen is from the uppermost of the three formations in the region, presumably above one or more intrusive sheets. This statement is not intended to suggest that the intrusives of New Jersey are contemporary with the extrusives of the Connecticut Valley. Unfortunately it has been impossible to measure accurately the Newark strata in either New Jersey or in Connecticut; no one knows the exact total thickness of the Triassic in either area. About all that can be said here in summarizing numerous attempted calculations of the thicknesses of Newark strata above and below the two specimens in their respective areas, using the estimates provided by Longwell (1928) and others for Connecticut and those of Kümmel (1940) for New Jersey, is that the Connecticut specimen is less (probably much less) than 6,000 feet from the bottom and (much) more than 6,000 feet from the top of the Newark, whereas the one from New Jersey occurred more than 8,600 feet from the base and less than 5,200 feet from the top. Actually, of course this line of reasoning has only slight validity, and it is summarized here only to anticipate the possibility that it might be used for heavier conclusions than it can support. The fact that footprints which might have been made by an animal such as *Stegomus arcuatus* occur in the upper "series" in Connecticut, above the Posterior trap is likewise almost without significance, other than in facies studies.

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A New Conularid from the Esopus Formation, Sussex County, New Jersey

by HENRY HERPERS

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DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
CHARLES R. ERDMAN, Jr., *Commissioner*
DIVISION OF PLANNING AND DEVELOPMENT
WILLIAM T. VANDERLIPP, *Director*

MISCELLANEOUS GEOLOGIC PAPER
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1949

A NEW CONULARID FROM THE ESOPUS FORMATION, SUSSEX COUNTY, NEW JERSEY

by

HENRY HERPERS*

In May, 1948, while engaged in a field study of the upper Silurian and lower and upper Devonian rocks of Sussex County, New Jersey, an interesting exposure of fossiliferous rock belonging to the Esopus formation of Devonian age was found. Among the fossils collected at the time was the specimen described in this report.

The outcrop from which the fossils were taken is near the village of Montague in Montague Township, Sussex County, New Jersey. The rock there exposed is a dark grey to black, slightly calcareous sandy shale in which cleavage is developed to a high degree. It is fairly typical of the Esopus formation as seen elsewhere in New Jersey. On the weathered bedding plane surfaces, the characteristic fossil, *Taonurus cauda-galli* Vanuxem, which gave the formation its old name of Caudagalli Grit, is well developed. Closer examination of the outcrop revealed the presence of other fossils, particularly in the weathered portions of the rock; however, specimens of *Conularia* were found in fairly fresh rock also. The holotype specimen, which was found in the less weathered rock, is in a remarkably fine state of preservation and shows no evidence of crushing. It consists of an almost complete individual. In addition, several other specimens and a few fragments of individuals were found. The excellent state of preservation of the material makes possible the following description.

Phylum Coelenterata
Class Scyphozoa
Conularida
Conularia Miller
Conularia sussexensis Herpers n. sp.
Plate 1, Figs. 1-4

Shell elongate, and pyramidal in form, the sides tapering uniformly and forming an apical angle of approximately 35°. In cross-section, the shell is quadrangular. The sides, which are equal in size, are slightly convex, and the angles at the intersection of adjacent sides are rather deeply sulcate. Each side is marked by transverse, parallel costae, each of which is directed from the sulcus toward the aperture, the costae from the opposite sulci meeting at the centre of the side, where they form a rounded angle of approximately 131½° at the median line. The costae are rather sharply incurved at the sulci. From 2 to 3 of the costae are included in the space of 1 mm., but nearer the apex, the costae are finer and as many as 4 of them may be included in 1 mm. The spacing of the costae becomes

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coarser as the distance from the apex increases. The costae are separated by channels which are 2 to 3 times wider than the costae themselves. The bottoms of the channels are rounded. The channels are crossed by rounded, raised bars, which are somewhat thicker than the costae, but not quite so high. The space of 1 mm. includes approximately 3 of the bars. Although to the unaided eye the pattern on the sides appears to be that of a network of small squares formed by the costae and the bars, examination under a binocular microscope shows that the bars make an acute angle of approximately 70° with the costae, making a pattern of rhombs which have sides more or less equal in length. Microscopic examination also reveals that the bars in adjacent channels are not in line but are more or less offset. The offset of the bars in any particular channel from the bars in the adjoining channel nearer the apex, is generally toward the median line of the side. The amount of offset is not great, so that the sides present a general appearance of being striated from apex to aperture.

The dimensions of the type specimen, which is incomplete at both apex and aperture are: length: 44 mm.; diameter near aperture: 26 mm.

The holotype and 4 paratypes are deposited in the New Jersey State Museum in Trenton, New Jersey, and their museum numbers are:

Holotype: Museum Number 10749 (cast and mold).
Paratype: Museum Number 10750 (1 specimen).
Paratype: Museum Number 10751 (3 specimens).

Occurrence: In the Esopus formation of lower Middle Devonian age, near Montague, Sussex County, New Jersey.

Remarks: The only other species of *Conularia* which appear to be similar to this form are *C. huntiana* Hall (Hall, 1859, p. 348) and *C. gaspesia* Sinclair (Sinclair, 1942, p. 158). The former species were found in the "shaly limestone of Lower Helderberg group, Schoharie County", New York (New Scotland limestone), and the latter species was found "in the Lower Devonian, on the beach below Shiphead, Cape Gaspé", Quebec. (Presumably the Grand Grève limestone.) Through the courtesy of Dr. Winifred Goldring, New York State Paleontologist, the writer was privileged to compare the specimen of *C. sussexensis* with Hall's original holotype of *C. huntiana*. In *C. huntiana,* the costae appear to be doubly ridged on their tops and are incurved at the sulci less sharply than in *C. sussexensis.* In addition, the longitudinal bars are lower and far less pronounced and the sulci are not so deep as in *C. sussexensis. C. gaspesia* differs principally in that it is much smaller and that it has on apical angle of only 22½°.

The finding of the new species of *Conularia* in the Esopus formation is of particular interest on two counts. First, and most important, is the fact that fossils of any kind are rare in the Esopus formation in New Jersey, as well as in New York (Howell, 1942, p. 73) and Pennsylvania (Willard, 1939, p. 145). Probably the most complete fauna from this formation has been recorded from Pennsylvania (Willard, 1939, pp. 156 ff.), where it consists chiefly of brachiopods, with a few corals and pelecypods and one trilobite, the entire fauna including only some 20 species. In New York, a number of brachiopods, gastropods and one species of *Conularia* (Howell, 1942, p. 92) have been found. In New Jersey, Weller (Weller, 1903, p. 102) reported only a single occurrence of "*Lingula* or *Orbiculoidea*" near Flatbrookville, Sussex County, and Meredith E. Johnson, New Jersey State Geologist, found *Leptocoelia acutiplicata* Hall in the Esopus near Wallpack Center, Sussex County (unpublished records of the Geologic and Topographic Survey of New Jersey). The second reason for the importance of the finding of a new species of *Conularia* in New Jersey is that it represents only the second reported occurrence of the genus in this State, the species *C. trentonensis* Hall having been reported previously from the Jacksonburg limestone of Ordovician (Trenton) age by Weller (Weller, 1903, p. 188).

The writer wishes to express his thanks and indebtedness to Mr. Meredith E. Johnson and Dr. Bradford Willard for their encouragement in this study, and to Dr. Winifred Goldring, Dr. G. Winston Sinclair, Dr. Benjamin F. Howell and Dr. Bradford Willard for assistance in identifying the specimen.

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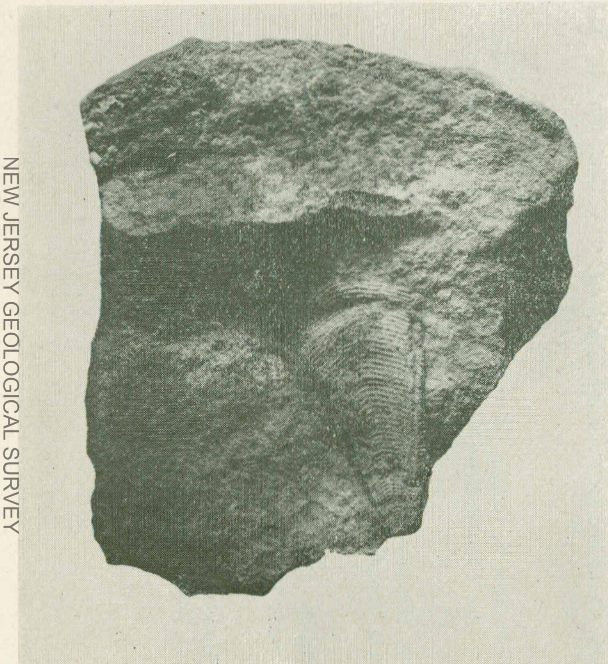


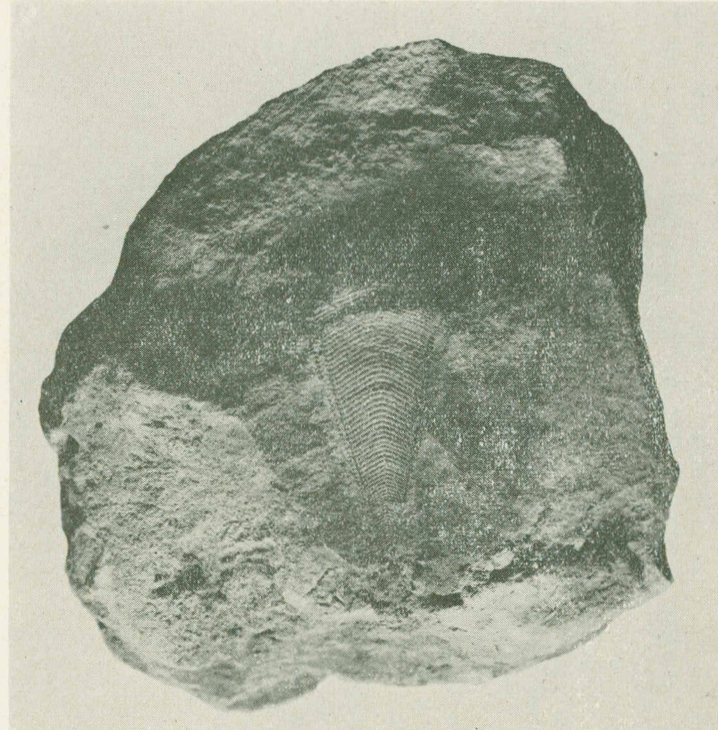
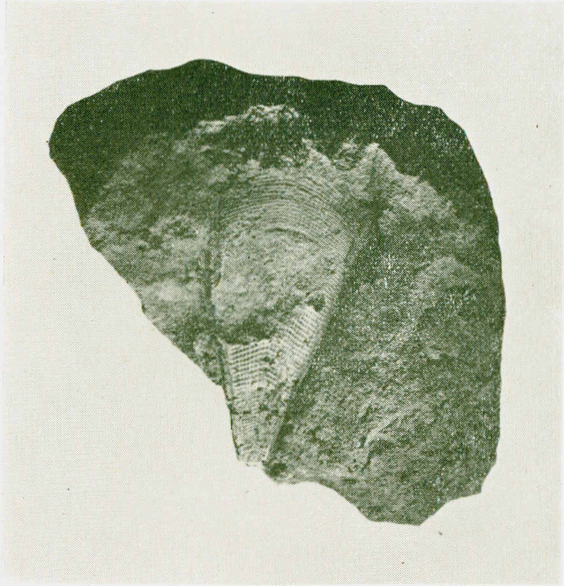


PLATE I—*Conularia sussexensis* Herpers, n. sp. specimen from Montague, Sussex Co., N. J.

FIGURE 1. Cast of side of holotype, (X1).

FIGURE 2. Mold of side shown in figure 1, (X1).



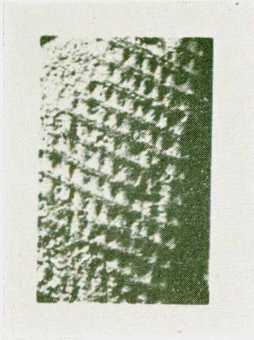


PLATE II—*Conularia sussexensis* Herpers, n. sp. specimen from Montague, Sussex Co., N. J.

FIGURE 1. Another side of holotype, showing more clearly the character of the surface markings. (X1).

FIGURE 2. Enlargement of a portion of the surface shown in Figure 1, (X4.5).

THE STRATIGRAPHY OF THE RONDOUT LIMESTONE IN NEW JERSEY

by Henry Herpers[1]

Abstract

The Rondout formation in New Jersey has been restudied stratigraphically and paleontologically. Eleven additional species and three additional unidentified forms are reported. The fauna and lithology indicate that deposition occurred in a relatively shallow, partially land-locked basin, probably in brackish water, in a warm climate. The Rondout represents a sort of non-marine phase of deposition in a cycle beginning with marine conditions in Decker time and ending with the restoration of such conditions in Coeymans time. A *Leperditia* zone in the formation appears to form a recognizable marker bed throughout New Jersey.

Introduction

The Rondout limestone, of the late Silurian (Cayugan) age, was named by Clarke and Schuchert (1899, p. 877) from its characteristic development in the cement quarries in the vicinity of Rondout, New York. Their definition of the Rondout limestone, or, as they termed it, the Rondout waterlime, includes those beds underlying the Manlius limestone and overlying the Salina beds. The formation was known in earlier reports as the "Waterlime", although this name has also been applied to a number of other formations of late Silurian and early Devonian age. (Wilmarth, 1938, p. 2283). In New Jersey, the Rondout was formerly known as the "Waterlime" (Cook, 1868, p. 155). The Rondout limestone has been traced northeast from New Jersey as far as Schoharie County, New York, thence westward into Seneca County, New York, "where its thinned edge is overlain by the Onondaga". (Hartnagel, 1912, p. 57). The formation continues southwest from New Jersey into Pennsylvania, but loses its distinctive character a few miles southwest of Stroudsburg, where it is replaced by the Keyser limestone, which is the correllative of the combined Decker, Rondout and Manlius limestones, (Swartz & Swartz, 1941, p. 1183, Pl. I).

The Rondout Limestone in New Jersey

So far as is known, the Rondout limestone is present in New Jersey only in the northwestern part of Sussex County, where it extends from Wallpack Bend of Delaware River, northeast for some 30 miles to the New York State line.

Exposures of the Rondout are rare because the formation has little resistance to erosion, and because the entire area underlain by these rocks

[1] New Jersey Geologic and Topographic Survey, Trenton, N. J.

in New Jersey lies within the glaciated region. However, sufficient scattered exposures are available so that it is possible to trace the formation across the State. It has not been found in the Silurian-Devonian Section of the Green Pond area (Kümmel and Weller, 1902, p. 3), but has been reported in the northward extension of this block of Paleozoic formations, near Cornwall Station, New York (Hartnagel, 1907).

Lithologically, the Rondout is a series of fine-grained, dark-grey, argillaceous limestones (cement rock) and limy shales, which often weather to a distinctive buff color. In New Jersey it is overlain by the Manlius limestone and underlain by the Decker limestone, both of which are also of late Silurian age. The contacts of the Rondout with the Manlius and Decker are conformable, somewhat indistinct, and probably transitional. This feature has been noted in New York (Hall, 1852, p. 339; Stevenson, 1901, p. 365; Ulrich and Schuchert, 1902, p. 650 footnote; Hartnagel, 1903, p. 1115). In New Jersey, the Rondout limestone attains its maximum thickness in the north, where Weller (1903, p. 58) measured 39 feet of beds referable to the formation, at the Wm. Nearpass quarry. It decreases in thickness toward the southwest as shown by a section which I measured at Wallpack Centre where it is 20.2 feet thick. Still farther to the southwest, Swartz and Swartz (1941, p. 1171) measured 24.5 feet of Rondout at Decker's Ferry near Wallpack Bend. A partial section which I measured at Croasdale Manor, at the north edge of the village of Delaware Water Gap, Pennsylvania, also appears to show progressive thinning of the Rondout toward the southwest. The thinning is shown graphically on the chart, Figure I.

The attitude of the Rondout limestone in New Jersey is, in general, monoclinal. It strikes in a northeasterly direction, and dips northwest at an average angle of 30°. In at least two localities minor folds are superimposed on the regional structure.

Stratigraphic Sections

The following stratigraphic sections show the lithology and thickness of the Rondout in New Jersey and in parts of Monroe County, Pennsylvania:

I. Wm. Nearpass Quarry
on Clove Road, about 2 miles south of the State Line
(After Weller, 1900, p. 20; 1903, pp. 58, 59)

DEVONIAN SYSTEM
Coeymans limestone

	Thickness *Beds*	*Total*
Concealed	30′	40′3″
Coarser-grained crystalline, grey limestone with masses of *Favosites*	10′3″	10′3″
Total thickness of Coeymans limestone measured		10′3″

SILURIAN SYSTEM

Manlius limestone

	Thickness Beds (Feet)	Thickness Total (Feet)
Hard, fine-grained, knotty blue limestone, with some bands of fossils	12′	34′8″
Hard, nearly black limestone, with bands of fossils	9′8″	22′8″
Hard, bluish-black, semi-crystalline limestone, with many fossils	5′	13′0″
Hard, bluish-black limestone	1′6″	8′0″
Hard, bluish-black, stromatoporoid limestone	4′6″	6′6″
Hard, bluish-black limestone, with some fossils	2′	2′
Total thickness of Manlius limestone		34′8″

Rondout limestone

	Beds	Total
Thin-bedded, crumpled grey shale, with some bands of denser limestone	15′	39′1″
Leperditia alta Conrad		
Dense, fine-grained, compact, argillaceous limestone; bluish on freshly fractured surfaces, but buff or yellowish on the weathered surfaces	5′	24′1″
Undetermined foraminifera or ostracods.		
Thin-bedded, buff or greenish, calcareous shale	5′3″	19′1″
Leperditia alta Conrad?		
Hard, fine-grained, blue or grey, brittle limestone filled with ostracods and *Stromatopora*	2′3″	13′10″
Hyattella lamellosa Weller		
Leperditia gigantea Weller		
Thin-bedded, calcareous shale, with no fossils	1′6″	11′7″
Fine-grained, dark limestone	6′4″	10′1″
Leperditia elongata Weller		
Earthy shale, with limestone bands	3′9″	3′9″
Leperditia sp. undet.		
Total thickness of Rondout limestone		39′1″

Decker limestone

II. 1 mile S.W. of Wallpack Centre
Exposure in fields on S.E. side of road to Flatbrookville
(Section paced off by H. Herpers & M. E. Johnson, 1950)

DEVONIAN SYSTEM

Coeymans Limestone

	Thickness Beds (Feet)	Thickness Total (Feet)
Medium-grained, grey sandy limestone. Estimated thickness	35	35
Gypidula coeymanensis Schuchert		
Stropheodonta cf. *planulata* Hall		
Total thickness of Coeymans limestone exposed		35

SILURIAN SYSTEM

Manlius limestone

	Beds (Feet)	Total (Feet)
Knotty, medium-grained, grey crystalline limestone. Estimated thickness	25	25
Within 3 feet of top noted:		
Tentaculites gyracanthus (Eaton)		
Holopea sp.		
Total thickness of Manlius limestone	25	25

Rondout limestone

Dense, grey argillaceous limestone. Weathers buff.

III. Road Cut 1 Mile S.W. of Wallpack Centre
(Section measured by H. Herpers, 1950)

SILURIAN SYSTEM

Manlius limestone

	Beds (Feet)	Total (Feet)
Top concealed.		
Dark-grey, dense, argillaceous limestone with many interbedded undulating laminae of sandy shale	8.0	13.8
Tentaculites gyracanthus (Eaton)		
Ostracods		
Concealed	1.3	5.8
Dark-grey, dense, argillaceous limestone	2.5	4.5
Tentaculites gyracanthus (Eaton) (c)		
Stropheodonta varistriata (Conrad) (a)		
Concealed	2.0	2.0
Total thickness of Manlius limestone measured		13.8

Rondout limestone

	Thickness Beds (Feet)	Thickness Total (Feet)
Weathered, massive, fine-grained, buff argillaceous limestone. Unweathered rock not seen	1.5	20.2
Brown shale (May be highly weathered limestone)	1.4	18.7
Weathered, massive, fine-grained, buff argillaceous limestone. Unweathered rock not seen	2.0	17.3
Dense, grey, argillaceous limestone. Weathers to a brown, shale-like material	1.6	15.3
Brown shale. (May be weathered limestone) *Leperditia alta* Conrad	0.9	13.7
Hard, dense, argillaceous limestone	0.2	12.8
Brown shale	0.8	12.6
Dark-grey, dense, argillaceous limestone containing many ostracods (*Leperditia* bed #2) *Leperditia alta* Conrad (aa) *L. gigantea* Weller (a)	0.9	11.8
Brown weathered shale	0.4	0.9
Dark-grey, dense, argillaceous limestone containing many ostracods (*Leperditia* bed #1) *Leperditia alta* Conrad (aa) *L. gigantea* Weller (aa) *Kloedenia* sp. nr. *K. crassireticulata* F. M. Swartz & Whitmore. (ms. name)	0.4	10.5
Dense, grey, fine-grained, knotty, argillaceous limestone with many thin shaly and sandy interbeds *Stromatopora* sp. (a) *Enterolasma strictum* (Hall) (a) *Zaphrentis roemeri* ? M. Edwards & Haime (a) *Aulopora* cf. *tonolowayensis* C. K. Swartz *Lichenalia* cf. *torta* Hall (aa); and also, in the upper part, *Leperditia alta* Conrad *L. gigantea* Weller	6.4	10.1
Brown clay (weathered shale)	0.3	3.7
Weathered, fine-grained sandy limestone	0.8	3.4
Dark, blue-grey, dense limestone	0.7	2.6
Brown, highly weathered shale *Zaphrentis roemeri* ? E. & H. *Chaetetes* (*Monotrypella*) cf. *abruptus* Hall *C.* (*M.*). cf. *arbusculus* Hall Small crinoid columnals Bryozoa	1.1	1.9

	Thickness Beds (Feet)	Total (Feet)
Stropheodonta varistriata (Conrad)		
Stenochisma deckerensis (Weller), (c)		
Pterinea ? sp.		
Dense, blue-grey, fine-grained limestone	0.8	0.8
Total thickness of Rondout limestone		20.2

Decker limestone

Very fine-grained, dark blue-gray, slightly sandy limestone
Zaphrentis sp.

IV. Section along Bushkill Road, Near Decker's Ferry, Pennsylvania (after Swartz & Swartz, 1941, p. 1171)

DEVONIAN SYSTEM

Helderberg group

Coeymans limestone

	Beds (Feet)	Total (Feet)
Concealed to approximate top of Coeymans limestone, possibly 6 to 8 feet	7	80
Dark, fine-grained limestone, some black chert nodules..	9	73
Gypidula coeymanensis Schuchert		
Massive grey crinoidal limestone	30	64
Gypidula coeymanensis Schuchert, and other fossils		
Concealed on road but exposed in cliff north of road....	16	34
One foot calcareous sandstone at base, concealed above along road	18	18
Total thickness Coeymans limestone approximately		80

DEVONIAN or SILURIAN SYSTEM

Keyser group

Manlius limestone

	Beds (Feet)	Total (Feet)
Irregularly-bedded, grey, fossiliferous limestone; partially concealed	23.5	34
Howellella vanuxemi (Hall)		
Stropheodonta varistriata (Conrad) and other fossils		
Concealed on road. Beds like the overlying are reported in this interval, bearing *Tentaculites gyracanthus*, (Eaton), 6 to 10 feet above base	10.5	10.5
Total thickness Manlius limestone		34

Rondout limestone

	Beds (Feet)	Total (Feet)
	Thickness	
Concealed	6	24.5
Argillaceous limestone, weathering to irregular, yellow fragments. White's Stormville hydraulic cement rock ("pethstone")	7	18.5
Blue limestone, upper part laminated, *Leperditia* sp. (aa) near and at top. White's Decker's Ferry limestone	5	11.5
Concealed 15 feet horizontally	6.5	6.5
Total thickness Rondout limestone		24.5

Decker sandstone

Conglomeratic grey sandstone		1.5
Concealed		

Note by HH.: The thickness of the Rondout at Decker's Ferry may be slightly less than that indicated in the section by Swartz and Swartz because the relatively large concealed intervals at the top and base of the formation have made the delimiting of the formation boundaries somewhat arbitrary.

V. Section at Croasdale Manor
at north end of the village of Delaware Water Gap, Pennsylvania
(Measured by H. Herpers, 1950)

DEVONIAN SYSTEM

Coeymans limestone

Coarse-grained, grey, crystalline limestone *Gypidula coeymanensis* Schuchert Crinoid columnals	20	20
Concealed	20	20

SILURIAN SYSTEM

Rondout limestone

Fine-grained, dense, grey, crystalline limestone containing many ostracods. (*Leperditia* sp. (a)) in upper part of exposure. Thin shaly interbeds present. In part a ribbon limestone	10	10

Decker limestone

Fine-grained grey sandy limestone

Note: Although the top of the Rondout is concealed in this section, crystalline limestone carrying crinoid columnals and *Gypidula coeymanensis* Schuchert (Coeymans limestone) was found about 20 feet, stratigraphically, above the highest exposed Rondout. Since the concealed interval must also include all of the Manlius limestone, and probably a few feet of the Rondout and Coeymans limestones, the total thickness of the Rondout cannot be great.

Additional exposures of the Rondout limestone have also been observed at the following places in New Jersey:

1. *B. Cole Farm,* 1 mile S. E. of Montague. In the fields east of the woods and the abandoned Cole quarry in the Manlius limestone, ledges of dark-grey limestone containing many ostracods crop out. Kümmel,[2] from such measurements of dip and width of outcrop as he could make, estimated the thickness of the Rondout at this locality as 30 to 35′.

2. *Haney's Mill,* 2.5 miles S. W. of Wallpack Centre. The Rondout crops out at several places along the crest of the knoll, west of the bridge over the Flat Brook. Here it is a dark-grey to bluish, fine-grained, argillaceous limestone, containing many small ostracods, including *Leperditia alta* Conrad, and *L. gigantea* Weller.

3. *Flatbrookville.* The Rondout is found at two places near the village. The first locality is a road cut about 0.3 miles N. E. of the bridge over the Flat Brook, where some 8 feet of dark-grey, fine-grained, slightly argillaceous limestone containing a few ostracods are exposed. The second locality is on the slope of the hill west of the Flat Brook, about 0.3 mile S. W. of the bridge, where about 5 feet of fine-grained, grey limestone containing *Leperditia* sp. were noted.

PALEONTOLOGY

The limited fauna of the Rondout limestone in New Jersey is restricted almost entirely to ostracods. Weller's (1903, p. 36) entire fauna from the formation, found at the Nearpass quarry, consisted of only 5 species, viz.:

Hyattella ? lamellosa Weller
Leperditia alta Conrad
L. elongata Weller
L. gigantea Weller
L. sp.

In the section at Wallpack Centre I found the following faunule:

Aulopora cf. *tonolowayensis* C. K. Swartz
Chaetetes (*Monotrypella*) cf. *abruptus* Hall
C. (*M.*) cf. *arbusculus* Hall
Enterolasma strictum (Hall) (a)
Stromatopora sp. (c)
Zaphrentis roemeri ? M. Edwards & Haime (a)
Coral, unidentified
Crinoid columnals (small)
Lichenalia cf. *torta* Hall (aa)
Bryozoa, unidentified
Stenochisma deckerensis (Weller) (c)

2. Unpublished notes on file in office of N. J. State Geologist.

Stropheodonta varistriata (Conrad)
Pterinea ? sp.
Kloedenia sp. nr. *K. crassireticulata*
F. M. Swartz & Whitmore (ms. name.)
Leperditia alta Conrad (aa)
L. gigantea Weller (aa)

In this section, the fossils, other than ostracods, were found in two horizons. The lower horizon, a bed of brown, highly weathered shale, 0.8 feet above the base of the formation and 1.1 feet in thickness, carried *Zaphrentis roemeri* ?, *Chaetetes* (*Monotrypella*) cf. *abruptus*, *C.* (*M*) cf. *arbusculus*, small crinoid columnals, bryozoa, the brachiopods *Stenochisma deckerensis* and *Stropheodonta varistriata*, and a pelecypod fragment which resembles *Pterinea*. Most of the fossils, particularly the corals, were fragmentary, worn or crushed, and appear to have been transported. The lithology of the bed suggests that the rock originated as a limy mud, and it is not probable that the corals grew in an environment of this sort. The concentration of worn and broken fossils in a single horizon also suggests deposition from an outside source by currents. The brachiopods, particularly *Stenochisma deckerensis*, which is fairly abundant, are not particularly damaged and may be autochthonous, although their relatively small size may have protected them from being worn or broken. The crinoid columnals are quite small (1.5 to 2 mm. in diameter) and do not show effects of wear.

The upper fossiliferous horizon is a bed of dense, grey, fine-grained, knotty, argillaceous limestone, with thin shaly and sandy interbeds, 3.7 feet above the base of the formation and 6.4 feet thick. In it were found *Zaphrentis roemeri* ? (a), *Enterolasma strictum* (a), *Aulopora* cf. *tonolowayensis*, *Stromatopora* sp. (a), *Lichenalia* cf. *torta* (aa), and the crustaceans *Leperditia alta* and *L. gigantea*. The ostracods make their first appearance in force at this horizon. The corals, stromatoporoids and the bryozoan *Lichenalia* are worn, crushed and broken, again suggesting that they were transported from another place. As in the case of the lower fossiliferous horizon, the lithology suggests a depositional environment unfavorable to the growth of corals and bryozoans. It is impossible to say with certainty what effect the environment of deposition had on the stromatoporoids, because so little is known about their habitats. I have noted stromatoporoids, apparently in growing position, in the overlying argillaceous Manlius limestone and in the lower part of the Coeymans limestone which is crystalline and non-argillaceous. The carapaces of the ostracods are not crushed, nor do they appear worn. They are disposed in a somewhat aligned fashion, suggesting the influence of relatively gentle currents.

Higher in the section, only ostracods, particularly *Leperditia*, are present but are not as abundant as in the *Leperditia* zone. Ostracods are also present in the overlying Manlius, but there they are associated with *Tentaculites gyracanthus* and *Stropheodonta varistriata*, which are presumably marine forms.

Paleoecology

Because it is difficult to discuss the paleoecology of the Rondout limestone without reference to the underlying and overlying formations, I shall include some discussion of them.

The basal part of the underlying Decker limestone is a typical marine limestone and contains a prolific marine fauna. Going up in the section, the limestone becomes somewhat sandy, and its fauna is greatly diminished. The basal Rondout is fine-grained argillaceous limestone and shale, with few fossils, of which only the brachiopods *Stenochisma deckerensis* and *Stropheodonta varistriata* appear to be indigenous. The other fossils found in the Rondout (corals, crinoids and bryozoa), are marine forms, but are allochthonous. The middle part of the Rondout, a typical cement rock, contains only ostracods (*Leperditia* zone). Overlying the *Leperditia* beds are shales, limy shales and limestones, indicating that clastic material was transported to the area. Overlying the Rondout is the Manlius limestone, which carries such distinctly marine fossils as *Tentaculites gyracanthus* and *Stropheodonta varistriata* in its lower portion, and several species of marine gastropods in its upper portion (Weller, 1903, pp. 78-80). Finally, with the advent of Coeymans time, marine conditions returned. Thus we have both lithologic and paleontologic evidence of a cycle beginning with unquestioned marine conditions, passing to an environment with distinctly abnormal marine characteristics, and back to a marine environment.

Based on lithology, the cycle suggests deposition of the Rondout in a relatively quiet body of water, since only fine-grained materials were laid down. The water was probably quite shallow, for in the type area of the formation, at Rondout, New York, the upper portions possess a sort of columnar jointing which has been interpreted as the result of mud-cracking of the original sediments, and some of the beds are ripple-marked. (Wanless, 1921, p. 58-59). Ripple-marking has also been noted on the upper surfaces of the Rondout at South Bethlehem, New York (Ruedemann, 1930, p. 41). These features are evidence for the shallow-water origin of the Rondout. Features of this sort have not yet been noted in New Jersey, but I know of no reason to believe that conditions of deposition in New Jersey were any different than those in Eastern New York. The presence of currents is shown by such evidence as the beds of broken corals and bryozoans, the alignment of the ostracod carapaces and the shaly and sandy interbeds. Although Ewing[3] has obtained photographs of ripple marks and sand and gravel at the bottom of the deep sea, indicating current action even there, I believe the mud cracks *and* the ripple marks are conclusive evidence of shallow water origin. The intercalated fine-grained sandy beds in the cement rock suggest rhythmic alternations in current strength and a relatively close source of coarse material; therefore, shallow-water conditions not far from land.

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[3] Photographs shown by Dr. Maurice Ewing in a talk given to the Lehigh Chapter of the Society of the Sigma Xi, 1950.

Van Ingen and Clark (1903, p. 1184) mention the presence of quartz sand in most of the layers of the Rondout at its type locality, which, because of "its resemblance to the wind-blown sand of deserts—may be considered to have been brought by the wind from some nearby arid lands . . ." I believe this is good evidence of a near shore environment, though not necessarily of shallow-water conditions. I do not believe that the sand grains, even though wind-blown, necessarily indicate arid conditions.

The paleontological record suggests an abnormal marine environment. The only animal remains which characterize the Rondout are ostracods. The ostracods tell us little about the environment in which they lived, for they are euryhaline organisms, and may inhabit environments where considerable variation in salinity is the rule (Allee, 1949, p. 341). Ostracods (Ulrich and Bassler, 1923, p. 279; Shimer & Shrock, 1944, p. 664), with the exception of two fresh water genera, inhabit either marine or brackish waters. They dwell also in foul waters and sulfur waters. They are not limited, as a class, by depth, some forms swimming about at the surface and some being bottom dwellers. Therefore, we must look for an environment of deposition for the Rondout which produced, among others, the conditions best suited for intensive development of ostracods. Because characteristic forms of marine life are not present in the fauna of the Rondout, it seems to me that the most probable environment was some sort of land-locked, or nearly land-locked basin or arm of the sea, into which fresh water, carrying clay and calcium carbonate mud flowed. The waters in the basin were thus rendered brackish and probably cloudy, and therefore unsuitable for the support of stenohaline organisms. The profusion of ostracods, especially in the *Leperditia* zone, shows some condition that caused an acceleration in the life cycle of such forms. Ward (in Allee, 1949, p. 334) has shown that temperature is the most important single factor controlling ostracod populations. This factor controls the reproductivity rhythms in these forms, an increase in temperature causing an increase in reproductivity. Although Ward conducted her observations on modern fresh-water forms, it seems plausible to me that Paleozoic marine ostracods might very well have reacted in the same manner to changes in temperatures. Therefore, it is probable that the climate was relatively warm. The fine-grained nature of the limestone in the Rondout suggests that part, at least, of the calcium carbonate was precipitated. If a significant quantity of calcium bicarbonate was carried in solution by the streams flowing into the basin, it may have been precipitated as calcium carbonate because of loss of carbon dioxide from the water, caused by warming. A warm climate, therefore, may have caused both the precipitation of calcium carbonate and the profusion of ostracods. I have noticed nothing in the Rondout of New Jersey that would indicate super-saline conditions in the basin in which the formation was deposited. Casts or molds of salt crystals and deposits of evaporites were not seen in the Rondout in New Jersey, nor could I find any reference in the literature to deposits of this sort associated with the formation in other places.

Under the conditions described above, the adjoining land areas were probably low. This is corroborated by the fact that there are no continental clastics associated with the Rondout. Parts of the Decker are sometimes quite sandy and even conglomeratic, but invariably contain marine fossils. The basin was evidently quite large, since the Rondout maintains essentially the same lithologic and faunal characteristics throughout its areal extent.[4] The large size of the basin as well as its persistence, is also suggested by the transitional relation of the Rondout with the overlying and underlying formations over a wide area.

Summing up then, the sea of early Decker time, apparently shrank, leaving a large land-locked, or partially land-locked basin. The basin may have been connected with the sea from time to time, or it may have had a continued, but restricted connection with the sea. The waters of the basin were probably brackish to such a degree that they could not support stenohaline marine organisms, but in them, the euryhaline ostracods flourished. Later, the sea returned gradually. By Manlius time, conditions were more nearly marine, and by Coeymans time, strictly marine conditions were restored. During the existence of the basin, the climate was apparently rather warm.

Correlation

With the Rondout of New York State.—The original definition of the Rondout limestone by Clarke and Schuchert which included those beds lying between the overlying Manlius and the top of the underlying Salina beds was subsequently found to be in error. The lower part of their Rondout was found to carry fossils clearly indicative of the fauna of the Decker limestone of New Jersey (Weller, 1903, p. 77). This part of the original Rondout was later designated as the Cobleskill limestone (Hartnagel, 1912, Table 2), and the Rondout, as now accepted, comprises the beds lying between the Manlius and the Cobleskill limestones. (Hartnagel, *op. cit.*) Thus redefined, the Rondout of New Jersey was correlated by Weller (1903, p. 77) with that of New York, on the basis of its stratigraphic position.

With formations to the southwest.—As mentioned previously, the Rondout is replaced by a part of the Keyser limestone a few miles southwest of Stroudsburg, Pennsylvania. Its equivalence, however, may be recognized at least as far as Western Maryland and West Virginia by beds of the Keyser which carry *Leperditia gigantea.* (Bassler & Kellett, 1934, p. 73). This species is typical of the Rondout. (F. M. Swartz, personal communication).

Within the area.—The *Leperditia* zone which is found some 10 feet above the base of the Rondout in the area studied, appears to form a rather reliable marker bed. I do not know how far this bed can be traced beyond the limits

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[4] The *Fuyk sandstone* member of the Rondout in the Catskill, New York area, described by Chadwick (1944, p. 45), is believed by him to be a "wave-built sandbar, and the comparative absence of marine fossils on its lee (east or landward) side in contrast with their exceptional abundance on its wave-swept outward slope is consonant with the idea of the lagoons hemmed in behind it."

of the area under discussion, but would like to point out, as a matter of interest only, that at Rondout, New York a persistent bed, known locally as the "*Leperditia* limestone", about 3½ to 5 feet thick is found approximately 10 feet above the base of the Rondout. (Wanless, 1921, p. 57, fig. 64; Van Ingen & Clark 1903, p. 1183).

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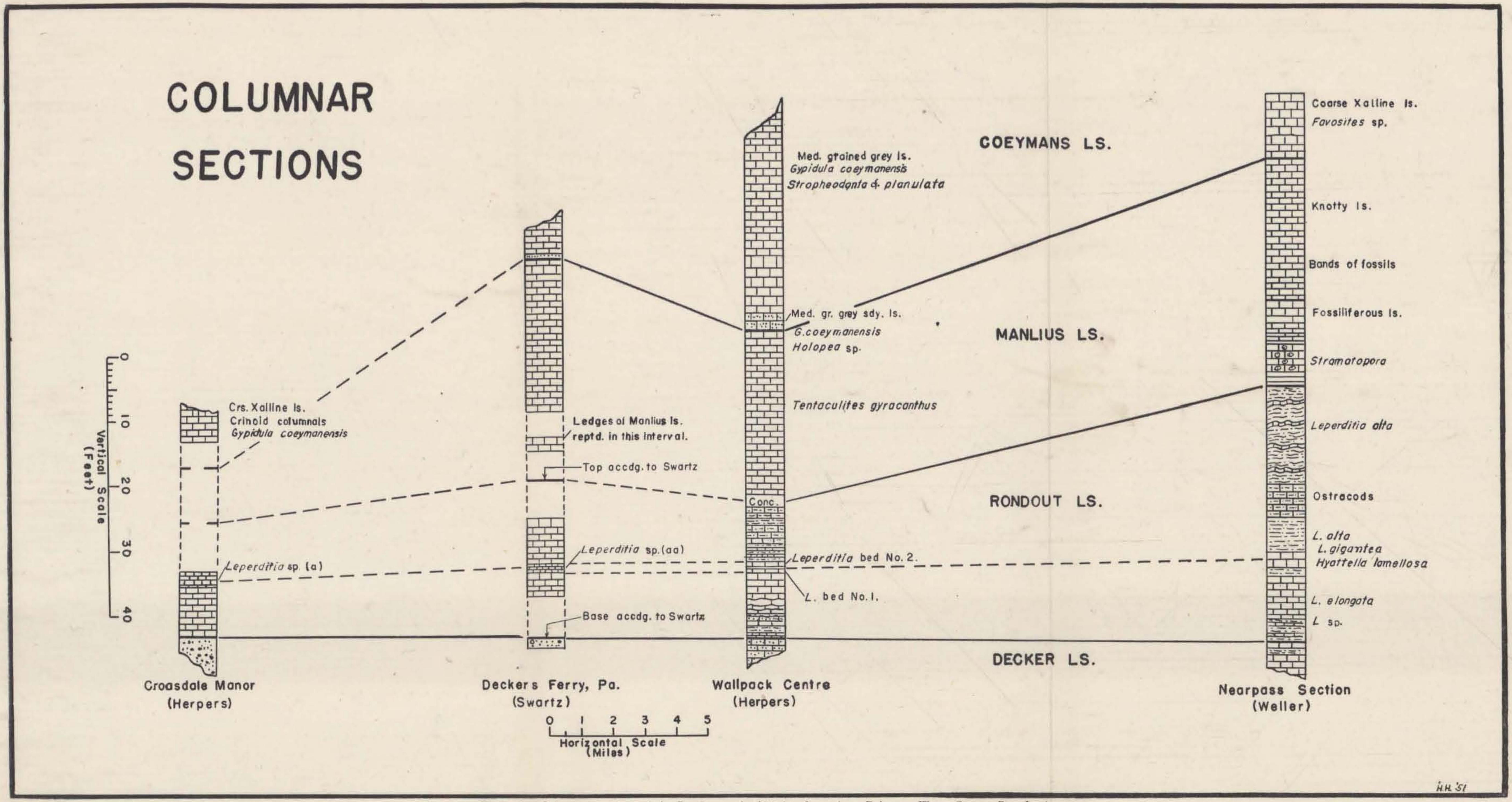

FIGURE 1 — Columnar sections of the Rondout and adjoining formations, Delaware Water Gap to Port Jervis.

GEOLOGY AND MINERALOGY OF THE MANGANESE DEPOSIT AT CLINTON POINT, NEW JERSEY[1]

by

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[1] A thesis submitted in partial fulfillment of the requirements for the degree of Master of Arts in the Faculty of Pure Science, Columbia University.

Introduction

During the First World War the rise in price of raw materials essential to war production made it possible to exploit what ordinarily would have been submarginal mineral deposits. This statement applies especially to the ores of certain ferro-alloys, notably manganese. In 1918 several carloads of low grade manganese ore were mined from a hillside near Clinton Point, New Jersey. The present war[2] has revived local interest in the possibilities of renewed exploitation but no work has been done to date.

This occurrence of manganese has long been known and other attempts have been made to utilize the ore: Weeks (1, p. 336) noted in 1885 that manganese ore from Clinton was unsuited to the making of spiegeleisen. The sporadic interest shown in the past in this deposit has never resulted in the publication of a detailed description. The present work aims to describe the character and occurrence of the ore, and to suggest its mode of origin.

Acknowledgements

The writer is indebted to Mr. H. M. Roche of Dover, New Jersey for directing attention to the locality and for many favors while working in the field. Mr. M. E. Johnson, State Geologist of New Jersey, supplied much information on the activities of 1918. The initial phase of the work was facilitated by advice from Dr. E. N. Cameron of the Department of Geology, Columbia University. Throughout most of the study Dr. C. H. Behre, Jr., contributed valuable criticism and encouragement. The preparation of polished surfaces of the ore for microscopic examination was directed by Mr. J. E. L. Evans, and Messrs. R. J. Holmes and Ford Young supervised and aided in the X-ray studies. Quantitative chemical analyses were made by Mr. John Kanner. The writer wishes to acknowledge his appreciation for this varied and generous assistance.

Location and Surface Features of the Area

The hillside on which the ore crops out is one and a half miles east of the town of Clinton, Hunterdon County. The section is known locally as Clinton Point and centers around the intersection of Highways 28 and 30. The area lies south of the crystalline highlands of the Reading Prong and on the margin of the Triassic Lowland. Gently rolling hills rise to an elevation of about 400 feet but differences in elevation rarely exceed 100 feet; this is in marked contrast to Musconetcong Mountain, three miles to the northwest, an irregular ridge of the Highlands rising to 1000 feet.

Economically, mining is of only very slight importance in this area. Small truck and dairy farms, scattered throughout the section, furnish the chief means of livelihood.

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[2] Publication has been long delayed through no fault of the writer.—M.E.J.

Geology

General Stratigraphy

For the sake of uniformity, the stratigraphic designations of the Department of Conservation and Development of the State of New Jersey (Kümmel, 2, pp. 51-55) have been followed. The normal stratigraphic sequence in the Clinton Point area is as follows:

Sedimentary Rocks

Cenozoic	Pleistocene	Glacial drift (Unconformity)
Mesozoic	Triassic	Newark Group (Unconformity)
Paleozoic	Ordovician	Martinsburg shale (Unconformity) Jacksonburg limestone (Unconformity)
	Cambro-Ordovician	Kittatinny limestone (Unconformity)
	Cambrian	Hardyston quartzite (Unconformity)

Igneous Rocks

Pre-Cambrian		Gneiss

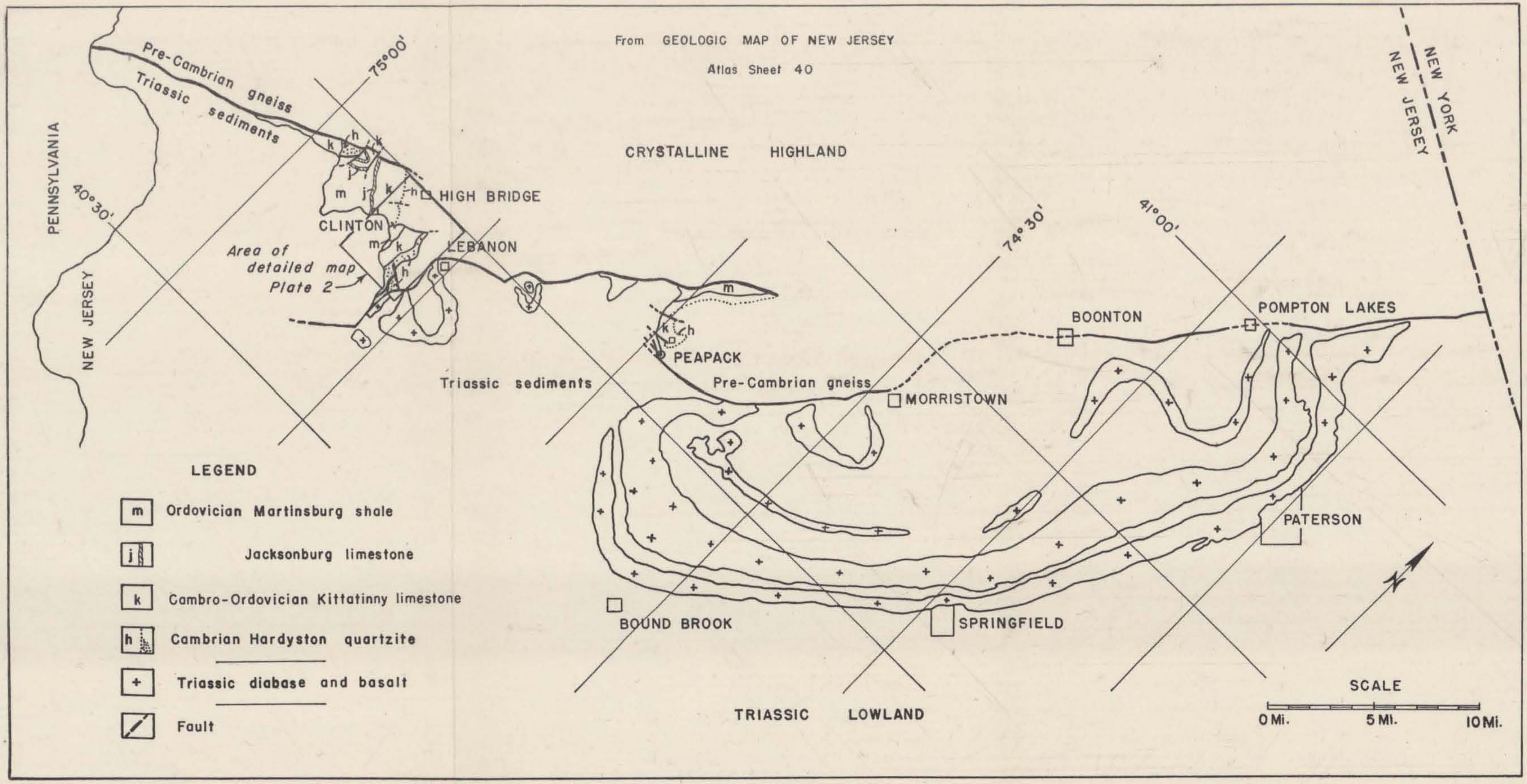
The only formation involved in the study of the manganese occurrence is the Martinsburg shale. Many pits and trenches were dug over a length of some 1500 feet, with about 75 feet difference in elevation from the lowest to the highest. They are all situated within the Martinsburg formation.

Martinsburg Shale

The typical Martinsburg shale is described (3) as a "black slaty shale (roofing slate in places) with thin beds of sandstone (flagstone) especially in the upper part". In the Clinton Point area the beds of sandstone are not present. The color of the shale within half a mile of the manganese deposits is far from being typical of much of the formation in this region as a whole. In the pits and trenches it is bright red where unstained by manganese. To the north the formation is dominantly red but bears layers of varying shades of green and greenish-brown; to the east it is dominantly dark olive-green, with some light green and yellowish-green layers. The exposures where these color differences were noted show very fresh rock.

In several outcrops, notably the large roadcuts along the new highway half a mile east of the property, manganese stains are prominent on all the fracture surfaces; in fact, from a distance the moist, fresh shale appears purplish.

Figure I



GEOLOGIC MAP OF PART OF NORTHERN NEW JERSEY

The shale is very fine grained and where intensely sheared appears clayey. Despite the general description previously mentioned, silty and sandy layers are rare in this area. A few pits at the north foot of the hill are located in a slightly sandy brown shale; otherwise the workings are in the red variety described.

General Structure

Through most of New Jersey the crystalline rocks of the Highlands are separated from the sedimentary rocks of the Triassic Lowland by a marginal fault trending in a northeast-southwest direction, generally parallel to the strike of the older rocks. Usually Triassic shales abut against the pre-Cambrian gneiss. At Peapack, some 15 miles northeast of Clinton, the marginal fault is offset four miles to the northwest but maintains its strike. Farther west, near Lebanon, which is four miles east of Clinton, the marginal fault curves and swings southward into the Lowland. Here the gneiss is again offset four miles to the northwest.

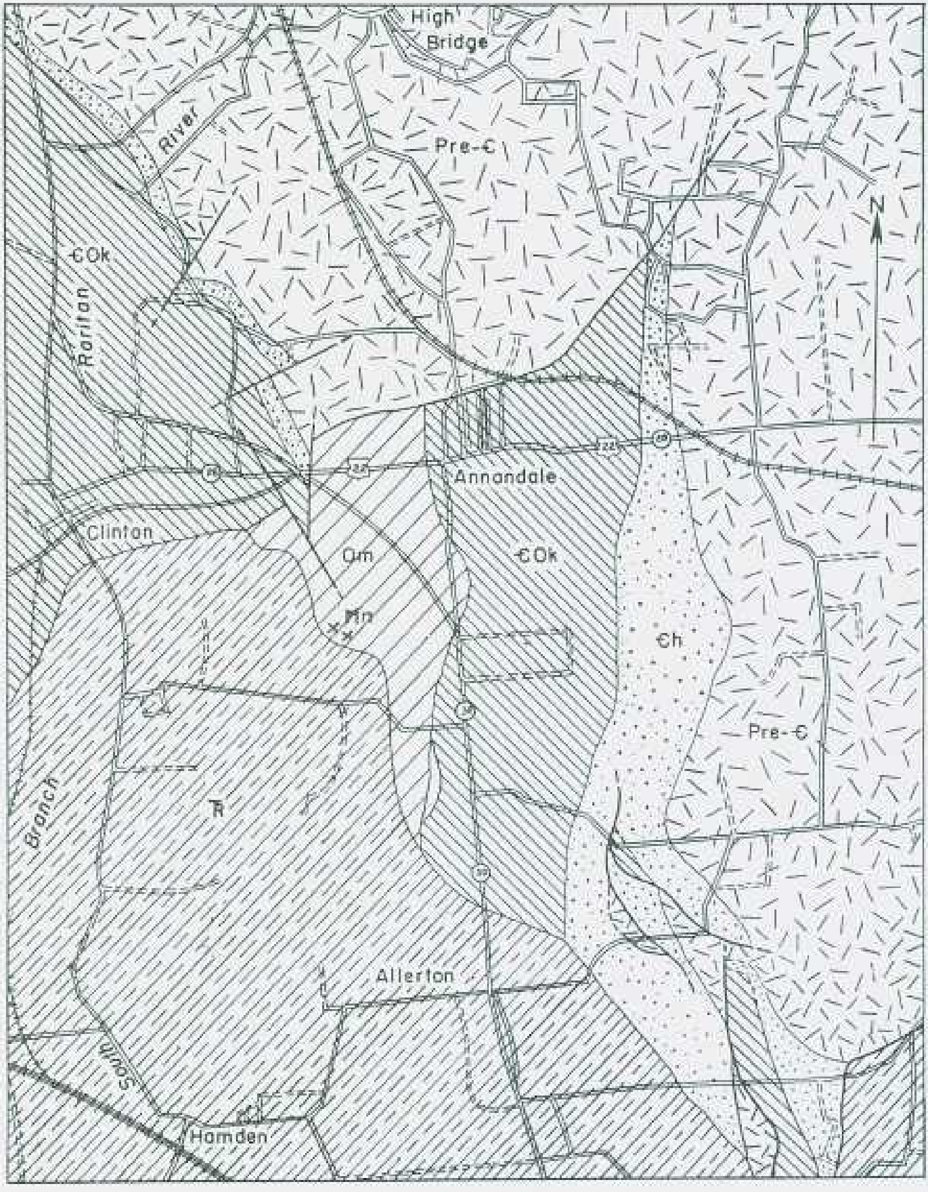
In the re-entrant angle centering around Clinton the Triassic beds do not meet the pre-Cambrian crystallines; instead, the sharply deformed Paleozoic formations are exposed. These general relations are shown on Fig. 1.

Within this Paleozoic complex the faulting is roughly transverse to the line of major displacement separating the sediments from the crystalline rocks. The larger folds inferred from the map are complicated by a multitude of small, sharp undulations of purely local importance. The different rock types have behaved under stress each according to its own properties; structures are not necessarily continuous from one formation into another.

Fig. 2 shows the structural environment of the manganese deposit. It lies close to the gneiss in a zone of considerable faulting. The Martinsburg shale is intensely sheared and deformed, and the exact structure cannot be determined due to the cleavage and the slickensiding. Numerous fractures have a conspicuously uniform strike of about N. 8°E. and coincide very closely with the trend of the line of pits. The strike of the shale varies between north and northeast; the dip is to the west or northwest, and ranges from nearly horizontal to very steep.

On the whole there is no strong evidence for disagreeing with the structural interpretation given on the geologic map of New Jersey, (3) as shown in Fig. 1. A minor alteration in the location of a probable fault is suggested by an outcrop of Martinsburg shale to the east of the workings. The strike at this point, some three-quarters of a mile away, is still about due north with dip to the west; this strike is parallel to the line of supposed faulting, previously mentioned.

On the brook north of the workings, a marked change in the strike of the shale and the absence of the Jacksonburg formation seem to justify the inference that another fault marks the contact between the Martinsburg formation and the beds to the north. The strike and cleavage of the shale



GEOLOGY OF THE ANNANDALE AREA

FIGURE 2

LEGEND

Triassic formations	TR
Martinsburg formation	Om
Jacksonburg formation	Oj
Kittatinny formation	€Ok
Hardyston formation	€h
Pre-Cambrian formations	Pre-€
Known formation boundary	———————
Inferred formation boundary	- - - - - - - - -
Fault	— ———— —

Scale

Base map by U. S. Army Map Service

are oblique to the strike of the other beds, but are parallel to the inferred fault or contact. The actual contact is covered, however, and the findings are thus inconclusive.

The western side of the salient in the gneiss shows a normal sequence of early Paleozoic sediments overlying the pre-Cambrian crystallines, but farther south, at the tip of the salient, marginal faulting has determined the boundary. On the south side the Jacksonburg formation is missing, and the gneiss itself nearest the presumptive fault shows a wide zone of sheared rock so greatly broken that it has been excavated without blasting.

Manganese Ore Deposits

Prospects and Development

The general location of the present pits and other openings is shown on the map, Figure 2. All told, some twelve openings, chiefly along a trend of N. 8° E., have been made, exposing rock and ore. Some are no longer accessible, being partly or wholly caved. The present study, being largely a laboratory investigation, did not undertake a detailed description of each occurrence as seen in the field.

At present the openings are masked by debris that has slumped inward during the twenty-odd years of inactivity. No quantity of ore is visible in place; a few pits show small stringers of manganese oxides, but the bulk of the specimens were collected from abandoned ore piles.

For the following account, quoted from H. B. Kummel (4), the writer is indebted to Mr. Meredith E. Johnson:

> ". . . in 1918 the mining development consisted of 'a series of openings extending in a N. 8° E. direction. The deepest and largest is about 50 to 60 feet long, 20 to 25 feet deep and 3 to 5 feet wide at the bottom . . . The new and old diggings extend over a length of 1500 to 1800 feet, but the newer excavations are toward the south', (and the top of the hill). ". . . some of the ore seams were followed down until they pinched out at a depth of 20 to 40 feet."

Description of the Ore

General Features

The ore occurs as stringers less than two inches thick along fracture planes in the shale. Four moderately well defined planes of fracture have the following orientations: approximately N.10°E., N.40°E., N.35°W., N.65°W. The first dips steeply to the west; the rest have approximately vertical dips. The planes are very closely spaced and the intersections are such that the shale is divided into small polygonal slabs. In places the largest face of a slab is defined by a prominent northward trending plane. In many cases this plane is a bedding plane. In some instances, however, there seems to be a fracture surface whose strike coincides or approaches but whose dip differs from that of the bedding. One such surface contains a nodular vein-like incrustation of manganese oxide about a quarter of an inch thick.

Slickensiding is common along the fracture surfaces. In places the shale at a fracture is bleached to a light brownish red and rendered somewhat powdery. The manganese veinlet referred to above was also bordered by such a narrow bleached zone.

The ore is generally hard and somewhat porous. It is banded in some instances: layers of a dull black mineral alternate with layers of a shiny blue-black mineral, and with bands of quartz. The quartz is roughly conformable in alignment to the ore, and is found within the stringers. The banded appearance is also accentuated by shale fragments and partings within the ore. More commonly the ore consists of a tangle of intersecting streaks, lumps, and lenses of manganese and quartz, with varying amounts of included shale. Typical examples of the ore are illustrated in Plate 1.

All gradations are encountered in the ore from masses of shale with minute fracture fillings of manganese minerals and quartz, to hard, heavy and compact masses of ore. Microscopically, the massive ore proved to contain a network of very narrow veinlets of quartz arranged along subrectangular lines, and minute linear streaks of unreplaced shale. It seems likely that the massive ore represents an advanced stage in the introduction of manganese: from mere deposition along fractures, the process extended in favored areas to replacement of the shale bordering fractures.

Mineralogy

Technique of Microscopic Identification

The material in the piles of sorted ore at Clinton Point was examined critically and a large number of specimens illustrating the full range of variations was selected. Of these twenty-odd were ground and polished as slabs for observation under the microscope. Critical areas within the slabs were later sawed out, mounted in bakelite, and polished on the Graton-Vanderwilt machine for photographing and for final confirmatory examination. Although only four highly polished surfaces were finally made, careful examinations were made of fourteen different polished slabs having a total area equivalent to thirty-five average polished surfaces.

The identification of the minerals was based principally on microscopic examination of optical and physical properties and upon etch reactions and microchemical tests. This work was confirmed by X-ray and chemical analyses.

The manganese minerals were identified by using most of the tests and methods of Short (5), Thiel (6), Smitheringale (7), and Orcel and Pavlovitch (8). The measurement of reflective power used by Orcel and Pavlovitch was not attempted. Since the specimens were all fine-grained and the crystal orientations unknown, success in applying this method seemed too unlikely to warrant procurement of the necessary apparatus. For the microchemical tests a set of reagents recommended by Short (5, p. 184) was used. With a few additions, this set also served for making etch tests. In

Table 1 a comparison is made of the etching reagents used by the investigators mentioned with those used in this work.

Before working with the unknown material the tests were all tried on known manganese minerals in the Economic Geology Collection of Columbia University. These were preserved for comparison during the examination of the ore specimens.

The first attempt at identification consisted of performing a series of tests and comparing the results with the systematic descriptions of the minerals given in the references noted. This method failed to give conclusive results. The descriptions are necessarily subjective, and there appeared to be lack of agreement in the reported etch reactions. It was found necessary to tabulate the minerals according to their outstanding characteristics. Then many species could be eliminated on the basis of negative results with the appropriate tests.

TABLE I

COMPARISON OF ETCHING REAGENTS USED

	I	II	III	IV	V
HNO_3 conc.				X	
1:1	X	X		X	X
1:7					X
HCl conc.			X	X	X
1:1	X	X		X	X
dilute			N/6		1:5
Aqua regia	X				X
H_2SO_4 conc.		X	X	X	X
H_2O_2 commercial[a]	X	X		X	X
30%			X		
H_2SO_4, H_2O_2		X	X	X	X
KCN 20% by weight	X	X		X	X
$FeCl_3$ 20% by weight	X	X		X	X
$FeCl_2$ conc.			X		
$HgCl_2$ 5% by weight	X				X
$SnCl_2$ conc.		X	X	X	
dilute	X[b]	X	X		X[b]
KOH 40% by weight	X				X
$AuCl_3$[c]		X			
$NaNO_3$, K_2CO_3[d]		X			
K_2MnO_4 20/N		X			

[a] approximately 3%
[b] 2% solution in 1:5 HCl
[c] 1 gram per liter of distilled water
[d] 1:1 mixture of saturated solutions of each

I Short (5, p. 99)
II Thiel (6, p. 111)
III Smitheringale (7, p. 481)
IV Orcel and Pavlovitch (8, p. 110)
V The present work

Each of the remaining species was sought among the ore minerals. For this phase of the work the descriptions of all the authors for the mineral were used simultaneously. As the examination proceeded and familiarity with the minerals was gained, it became clear that the lack of agreement as to the reactions of the minerals to particular etch tests was more apparent than real. The conflicts lie partly in the wording used but mainly in the specific nature of the change produced. However, a comparison of a series of reactions, as described by different observers, showed that in most cases similar degrees and similar kinds of change had been noted by all, even though the judgment of such a factor as color had differed. The manganese minerals suffer, perhaps more acutely than other groups of ore minerals, from having many traits in common, giving anomalous results, and requiring fine discrimination for distinguishing the character of the etch reactions.

The reaction of a mineral to a reagent is affected to a greater or lesser extent by factors such as the following: orientation of the mineral grain (in the case of crystalline substances), character of the surrounding material, impurities within the mineral, perfection of polish, and slight differences in the reagents used. In addition to the recognized variations in composition of a mineral, the difficulty of identification is increased among the manganese species, especially the oxides and hydroxides, by their property of absorbing other compounds. In the etching of psilomelane the impression was gained that there may be critical points or "thresholds" of a physico-chemical nature affecting the results: slight changes in the concentration of a reagent or in the composition of the mineral may determine whether or not there will be a reaction within a given time. In rare instances a very slightly stronger solution of a reagent may give a marked reaction where the weaker solution was completely ineffective.

In making the etch tests a drop of the reagent was applied to the surface with a platinum loop, and the area covered was observed for one minute, noting changes in both the mineral and the drop. At the end of one minute the surface was flooded with distilled water and the area previously covered by the drop of reagent studied through the water. The water was then removed with a soft paper tissue and the dry area examined. Lastly, such marks or stains as remained were rubbed gently with a tissue and observed, and then rubbed briskly and observed.

This general procedure was repeated several times over the surface, on grains whose optical and physical properties indicated that they were of the same mineral. For special cases the procedure was varied in some respects. Thus if the drop of reagent tended to evaporate too rapidly it would be moistened with distilled water in some cases and with more of the same reagent in others, noting whether there was any difference in the reaction. Again, the permanence of the stains might be investigated by allowing them to stand under water for some time. Later in repeating the tests to check particular reactions, the irrelevant steps were frequently omitted.

Ore Minerals

The ore minerals were determined to be psilomelane and pyrolusite. Detailed descriptions of their characters as seen under the reflecting microscope are tabulated below:

Psilomelane—The following properties, taken collectively, are generally diagnostic of psilomelane:

Color: Gray, mottled or streaky due to slight variations in the shade of gray.

Hardness: Great, barely indented by heavy pressure. Brittleness apparent when worked with the point of a needle.

Polish: Slow to polish but takes a high polish. When free from pits or scratches gives a very bright, slightly mottled surface.

Optical Properties: Isotropic to weakly anisotropic.

Etch Reactions:

H_2O_2: Effervesces profusely. Washes clean.

HNO_3: Fumes tarnish. Drop darkens. Area washes to a finely pitted surface.

HCl: Fumes negative. Drop turns pale brown and slowly darkens to yellowish brown. Area washes to show a small amount of etching; scratches and streaks are produced rather than the sharp pits of the HNO_3 test.

$SnCl_2$: Fumes sometimes tarnish. Drop quickly turns yellowish brown. Washes to a finely etched surface with pits.

$FeCl_2$: Similar to but paler than $SnCl_2$.

H_2SO_4: Slight darkening of the area under the drop. Fumes negative.

H_2SO_4, H_2O_2: Violet effervescence, and very rapid production of a completely black etch mark.

Remarks: When highly polished the surface shows little or nothing of the texture of the mineral; the psilomelane appears as an almost continuous mass, broken only by other minerals and structural features external to the mineral itself. After the etch tests have been carried on for a time, the action of stray fumes and etch marks that are only superficial tend to bring out colloform structure and aggregations of bleb-like grains.

Within a single surface of psilomelane several varieties may be recognized. Plate 4 shows a minute veinlet of psilomelane traversing a mass of psilomelane. The veinlet differs from the mass in being slightly darker gray in color, and reacting more slowly to the etch tests though identical reactions are finally obtainable.

In contact with quartz, the psilomelane is dull gray in color; in contact with the lighter pyrolusite, it appears slightly bluish.

No X-ray or chemical analysis of the psilomelane was possible due to difficulties in obtaining samples. The mineral is too hard to be drilled out with a needle or steel burr, and no diamond point or other hard tool was available in a sufficiently small size to guard against contamination with the intimately associated shale, quartz, and pyrolusite.

Pyrolusite—This mineral was distinguished by the following characteristics:

Color: Cream white, i.e., white with faint yellowish cast, especially when in contact with psilomelane.

Hardness: Scratched by needle under pressure. Not brittle.

Polish: Readily polished but retains cleavage and boundary cracks.

Optical Properties: Strongly anisotropic and pleochroic. (See Plate 5)

Etch Reactions:

H_2O_2: Effervesces profusely.

HCl: Fumes tarnish. Drop turns greenish and leaves brown stain. Washes and rubs to a pitted surface without stain.

$SnCl_2$: Stains very slowly. Washes and rubs to a blackened pitted surface.

$FeCl_2$: Drop turns gray and leaves yellow stain. Washes and rubs to a gray, slightly etched surface.

H_2SO_4: Darkens the surface slightly.

H_2SO_4, H_2O_2: Effervesces violently and leaves a deep black etch.

Remarks: Bladed grains are apparent in pyrolusite whether the surface is roughly polished or finely polished.

The faint yellowish cast of the color of pyrolusite is usually apparent even to the naked eye when in contact with the blue-gray psilomelane in polished surface.

Of the two minerals, pyrolusite is by far the more distinctive in appearance, and the more constant in its reactions to etch tests.

X-ray Analysis of Pyrolusite—To confirm the identification of the pyrolusite, areas of the polished surfaces showing the uniform mineral were drilled out under the microscope with the aid of needles and thin steel rods held in a dental drill. Frequent regrinding and repolishing was necessary to expose pyrolusite free from impurities in sufficient quantity to accommodate the drilling tool.

The finely ground powder was cemented to a fused quartz hair, mounted in a Debye camera, and exposed to X-rays. The pattern obtained on a photographic film was compared with the patterns of two standards selected from the collections of the Department of Geology. The standards selected consisted of pyrolusite from Coburg, Gotha, which had been previously identified by X-ray analysis, and pyrolusite from the Baire region of Cuba, which showed all the characteristics regarded as typical of the mineral. The three patterns are identical, and are reproduced in Plate 4.

Chemical Analysis of Pyrolusite—Quantitative chemical analyses of the samples of pyrolusite were made by Mr. John Kanner. The results are compared in Table 2.

TABLE 2

COMPARISON OF CHEMICAL ANALYSES OF PYROLUSITE

	From Coburg, Gotha	From Clinton Pt., New Jersey	Cuba From Baire,
Mn	57.76%	58.5%	57.87%
MnO_2 (calculated)	91.43	92.59	91.60

THE GANGUE

Fragments of shale included within the masses of manganese make up the greater part of the impurities in the ore. Other than this only two gangue minerals could be found, quartz and a mineral hitherto unidentified.

Quartz.—Quartz introduced with the manganese is the most constant and intimately associated gangue mineral. It is massive, generally white to gray in color, and in many cases shows signs of fracturing and rehealing by the presence of a network of later quartz veinlets. Tiny veinlets of the manganese minerals may also be present. Under the microscope rude bands of quartz grains are distinguishable in what appears megascopically to be massive quartz. In these bands the quartz grains are commonly elongate and parallel, and aligned at an angle of roughly 45° to the border. They are discolored irregularly with limonitic stains, and give shadowy and uneven extinction between crossed nicols. The contacts of grains are in many instances highly convoluted. A few veinlets with elongate grains showed stringers of manganese minerals cutting through the center of the veinlet; replacement is indicated by the optical continuity of the grains intersected by the manganese minerals.

Where several generations of quartz are seen, the later and smaller grains tend to be equidimensional and show no banded arrangement.

Occasionally there are found mottled red and white quartzose blocks containing many shale particles, but no manganese. Their relation to the ore veins is unknown, but evidently they represent intense silicification under conditions in which manganese was entirely absent from the depositing solutions. Possibly they were formed at a period when solutions were low in manganese. This possibility is suggested by the fact that the quartzose blocks can be found in the ore piles as though they were mined with the ore and occurred in close proximity to the ore. Some quartz also occurs in crustified veins in the ore and shale.

Calcite.—Like the quartz crusts just mentioned, calcite is found in open crustified veins in the ore and shale. It is of no quantitative importance and continuous veins of it are relatively uncommon.

Unidentified mineral.—An unidentified mineral, occurring with the ore in negligible quantities, is shown in Plate 5. It is anisotropic and pleochroic from colorless to pale yellowish-brown (distinguishable with difficulty from limonitic stains); there are slight changes in the definition of its structure as the stage is rotated. The index is distinctly higher than that of balsam. Since the mineral is everywhere surrounded by balsam-filled cracks its index cannot be compared directly with that of other minerals; on the basis of the amount of motion of the Becke line, however, it is estimated that the index is higher than that of quartz.

Between crossed nicols a concentric scalloping of the mineral is very marked. This feature gives a cross-like extinction that radiates from several points in or near what is presumed to be the center of an aggregate of fibrous or scaly grains. As the stage is rotated the "cross" moves around through each aggregate, the arms maintaining their parallelism with the planes of vibration of the nicols.

The patches of this mineral are rarely completely circular but in perfect development they undoubtedly would be. Sectors of circles intersect in much the same way as is seen in colloform structure. The aggregates are found in minute clusters along the margins of quartz veins, usually between the quartz and the manganese oxides. Due to the small size and mutual interference, no interference figure was obtainable. A crushed part of the specimen from which the thin-section was cut failed to give recognizable fragments of the mineral.

Paragenesis of the Ore

The accompanying photomicrographs (Plates 2, 3, 4, and 6) illustrate the general relations summarized in the paragenetic figure below. Quartz is commonly replaced by the ore minerals (Plate 6), and is found as later veinlets. The late veinlets may be replaced in turn by veinlets of manganese minerals. More than one generation of psilomelane is indicated by these relations, but there is no conclusive microscopic evidence of a corresponding facies of pyrolusite. Fringes of pyrolusite on exposed surfaces of psilomelane, as seen in hand specimens, indicate that at least some of the pyrolusite is derived from the psilomelane.

Figure 3

Paragenesis

Origin of the Ore

The exceedingly simple mineral association, the absence of any minerals of recognizable magmatic or hydrothermal origin, and the shallowness of the deposit leave little doubt that the deposit is supergene in origin. This superficial deposit was formed by the long-continued precipitation of minute amounts of manganese oxide and hydroxide as fillings in fractures and as replacements of the shale. The process of deposition of manganese from migrating meteoric waters appears feasible for explaining this relatively small occurrence in view of the great length of time that this area has been free of structural deformation.

The process by which this deposit was formed seems quite clear; the parent material from which the manganese was derived is unknown but there are several possible sources. Since the principal drainage of the Highlands is to the southeast, it may have been derived from the decay of manganiferous minerals in that area. The manganese might more probably be assigned to leaching from the host rock. An analysis of the unaltered Martinsburg shale by Mr. John Kanner failed to show any unusual concentration of the element. Mr. Kanner determined that the manganese content was certainly below 0.5% and probably below 0.25%. Clarke (9, p. 552), in a summary of analyses of 84 shales, reports manganese oxide in all but two shales in amounts up to 0.40%. The Martinsburg formation, though not markedly rich in manganese, is not devoid of the element and must therefore be considered a possible source. Alternatively, the manganese may have been leached from an overlying formation although no primary manganese minerals have been found in any of the formations known to have overlain the Martinsburg.

The igneous eruptive rocks of Triassic age, of which the nearest mass is three and a half miles to the southeast in Cushetunk Mountain, are not regarded as either direct or indirect sources of the mineralizing solutions. Minor manganese stains and replacements were seen in the Martinsburg west of the deposit studied, and away from the Triassic eruptives, but not in the vicinity of Cushetunk Mountain.

On the whole, the preceding considerations suggest that the simplest explanation is the best; namely, that the manganese oxide was leached from overlying Martinsburg shale, especially along fractures, carried downward in descending waters, and that it replaced deeper parts of the shale along similar joints or fissures.

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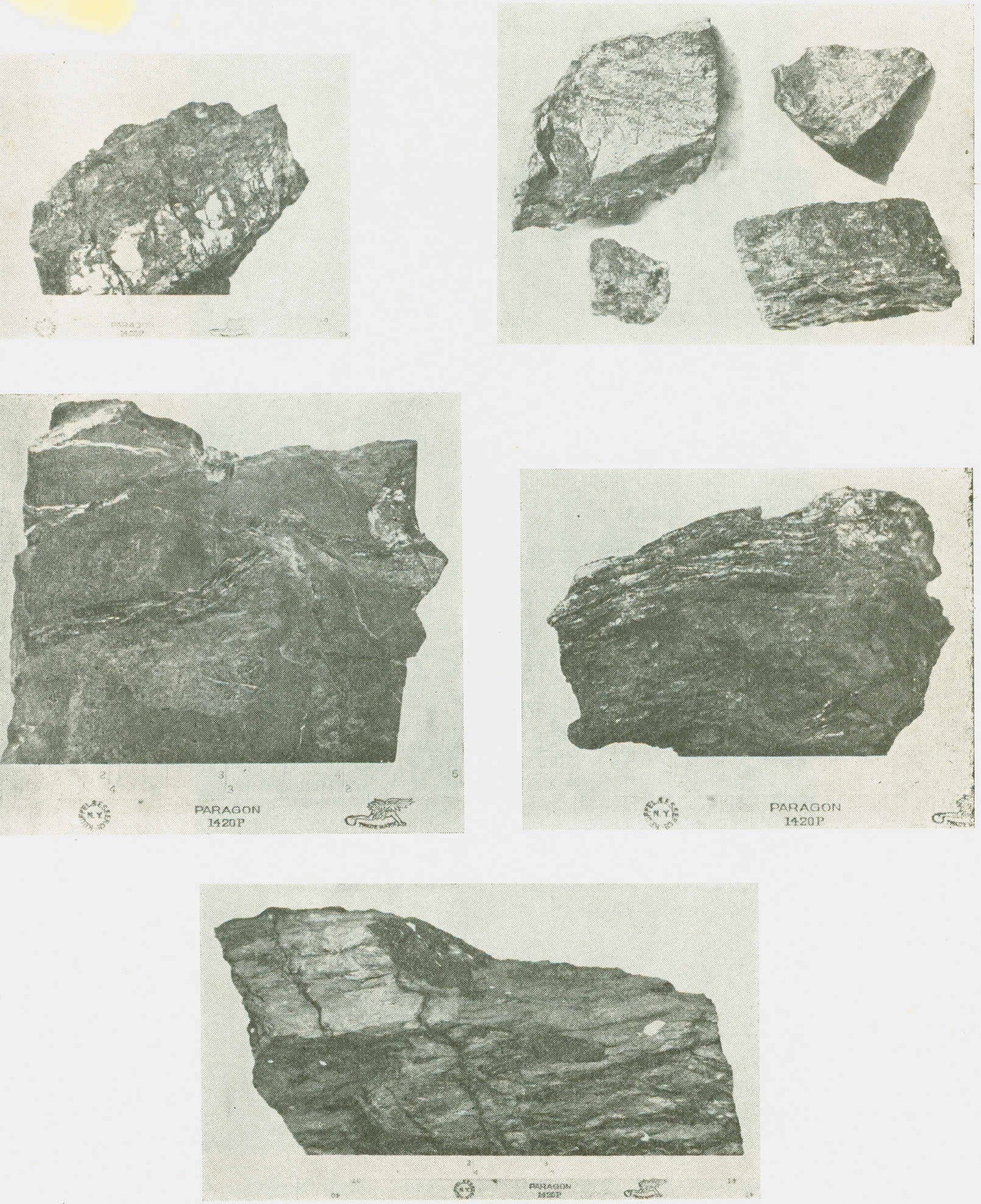


Plate I — Photographs of hand specimens of the ore.

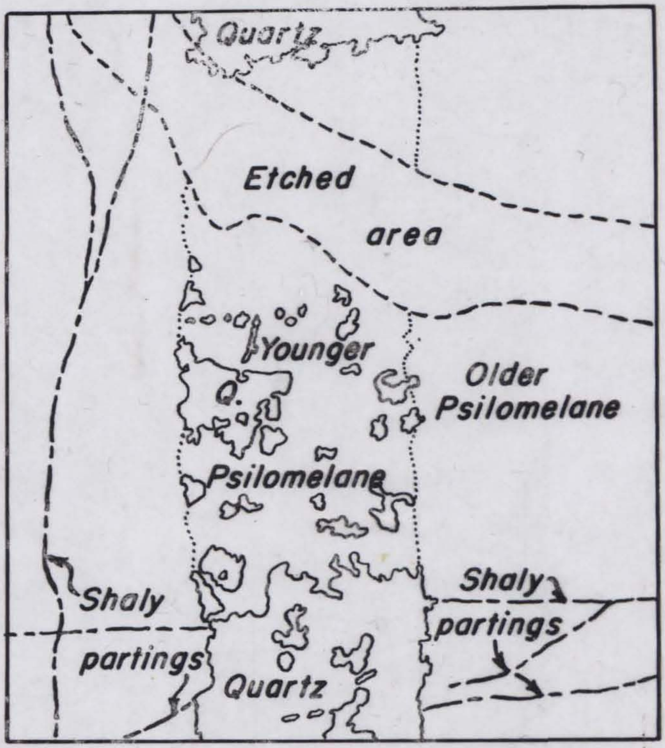
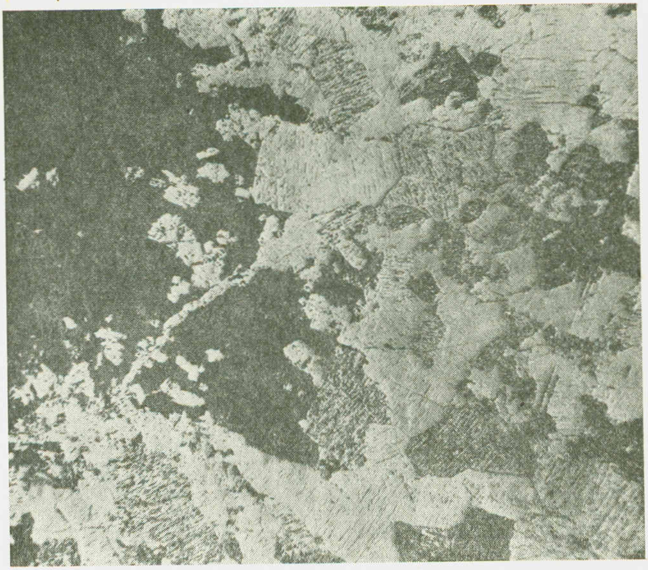


PLATE II—Photomicrograph of an etched polished surface of psilomelane, quartz and shale. The groundmass of psilomelane and unreplaced shale is cut by a einlet of quartz which is partly replaced by a later generation of psilomelane. Plane light, 120X.



A — Plane light. Psilomelane dark and mottled. Pyrolusite shows fine cracks and varies in color from light to dark but is predominantly light.

B — Crossed nicols. Same area. Psilomelane dark. Pyrolusite in various stages of extinction.

PLATE III — Photomicrographs of a polished surface of pyrolusite and psilomelane, 120X.

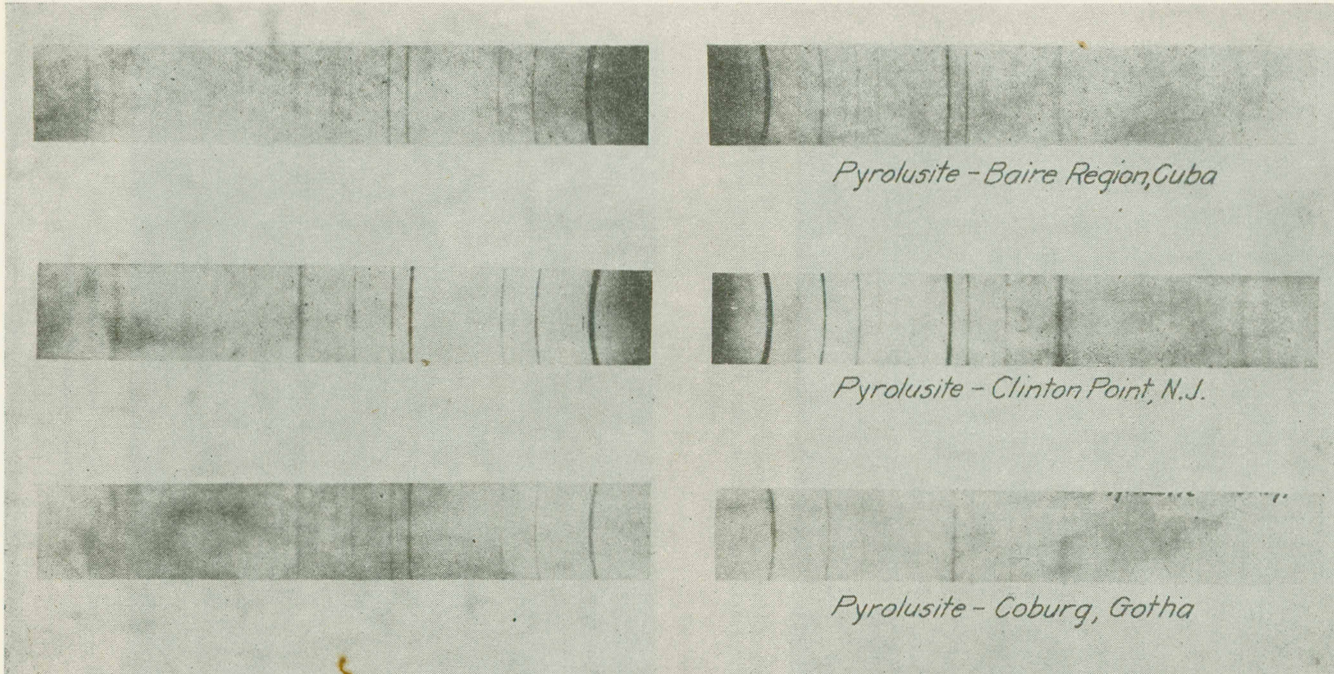
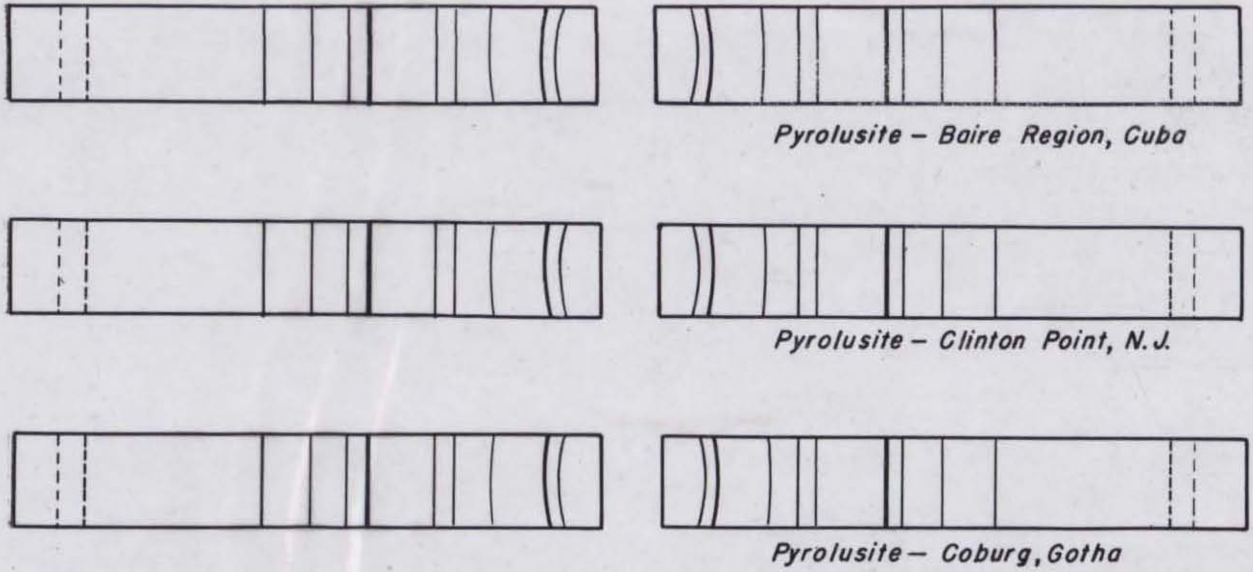
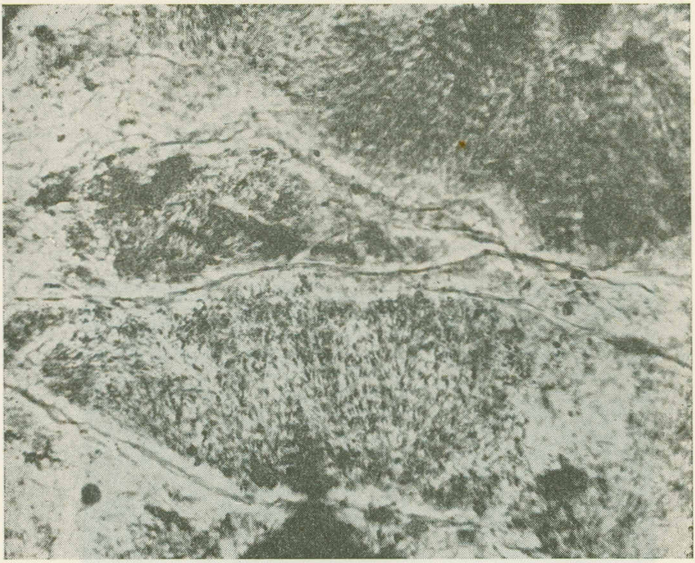


PLATE IV — X-ray powder diffraction patterns of pyrolusite taken in a Debye camera of radius 57.3. Unfiltered iron radiation.

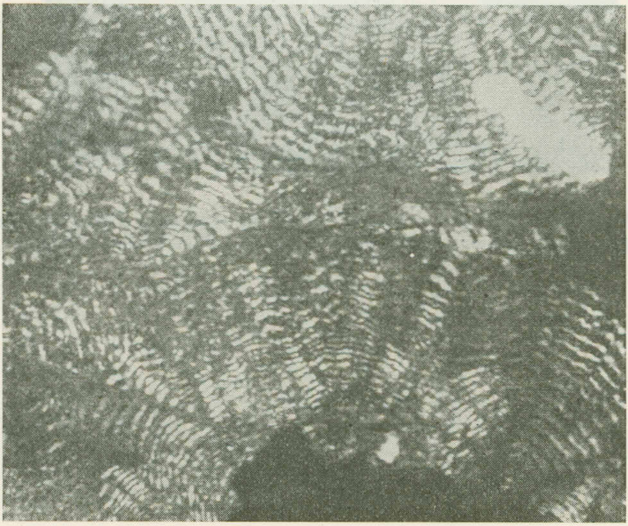
Plate 4 Overprint



Sketch of principal lines of X-ray powder diffraction patterns of pyrolusite.
Debye camera radius 57.3 mm. Unfiltered iron radiations.



A — Plane light.



B — Same area. Crossed nicols.

PLATE V — Photomicrographs of a thin section of an unidentified mineral. Magnification, approximately 570X.

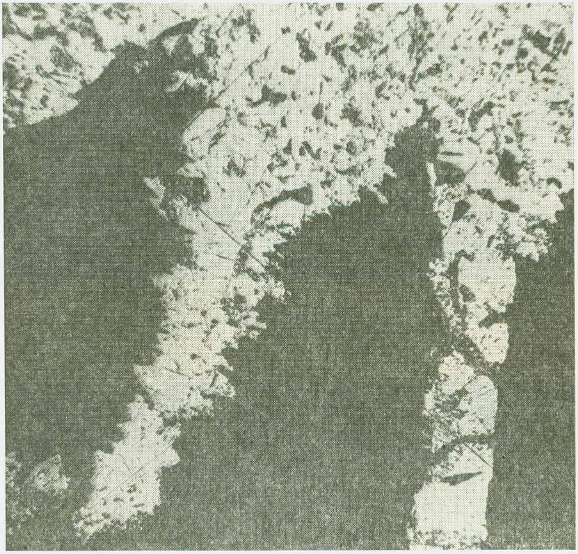


PLATE VI — Photomicrograph of a polished surface of pyrolusite (light and showing fine scratches) replacing quartz (solid black). Plane light. 120X.

SOME RECENT DISCOVERIES OF PLEISTOCENE MAMMALS FROM NEW JERSEY

by

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The recent discovery of the fossil remains of a ground sloth in an excavation for the New Jersey Turnpike has suggested a review of some unrecorded finds of vertebrate fossils from the Pleistocene and post-Pleistocene of New Jersey. This review is not intended to be exhaustive, but merely to cover a few of the more significant finds of recent date, especially those in the collections of the New Jersey State Museum and the Academy of Natural Sciences of Philadelphia. For earlier records of Pleistocene vertebrate fossils from the State, the reader is referred to the work of Hay (1923). The following symbols are used in referring to the source of specimens:

A.M.N.H.	American Museum of Natural History, New York, N. Y.
A.N.S.P.	Academy of Natural Sciences, Philadelphia, Pa.
N.J.G.S.	New Jersey Geological Survey, Trenton, N. J.
N.J.S.M.	New Jersey State Museum, Trenton, N. J.

Megalonyx cf. *jeffersonii* Desmarest (Giant Ground Sloth)

Five vertebrae and several unidentified bones (A.N.S.P. 15232) were found by James Ruhle in September, 1950, in the excavations for the New Jersey Turnpike at the crossing of a branch of Pensauken Creek, 1 mile southwest of Fellowship at the Burlington-Camden County line. The bones were obtained from Pleistocene gravel which overlies the Marshalltown formation (Cretaceous) at this point. Since the bones were obtained from the dump, it is impossible to determine their exact position in the gravel. The gravel is mapped as the Cape May formation. The generic identification was verified by Dr. E. H. Colbert of the American Museum of Natural History in New York. The specific identification is somewhat uncertain.

Thomas Jefferson first reported some fossil remains of this animal from a cave in West Virginia in 1797 in a paper read before the American Philosophical Society. While Jefferson at first was under the impression that he had found the claws of a large lion, the true relationship was soon pointed out, and the fossil today bears the name of its original describer.

Cope in 1899 described four species of *Megalonyx* from a Pleistocene cave deposit at Port Kennedy, Pa. as *M. wheatleyi*, *M. loxodon*, *M. tortulus* and *M. scalper*, all of which were described from fragmentary material. As pointed out by Hay (1923, p. 31) the exact status of these species is somewhat uncertain. It is very possible that they will prove to be synonyms of the previously described *M. jeffersonii*.

This marks the first record of the genus *Megalonyx* from New Jersey, although there are records from Pennsylvania, Ohio, Virginia and West Virginia.

A heel bone of another sloth (*Megatherium americanum* Blumenbach) was found in 1883 at Long Branch, N. J. (A.M.N.H. 14443). See Hay (1923, p. 31).

Mammut americanum (Kerr) (Mastodon)

Several recent records of mastodon can be added to those reported by Hay (1923) and Rhoads (1903):

a. In 1936 two tusks and some miscellaneous bones were obtained from the bed of a small stream flowing into Rahway River in the Nomahegan Section of Rahway River Parkway, 1¼ miles north of Cranford, Union County, N. J. The larger tusk measured 4 feet 3 inches (N.J.S.M. 10418).

b. In December 1939, James Nagy and Edward S. Reed collected some mastodon bones and teeth at Shotwell Pond, Stokes Forest, Sussex County, N. J. (N.J.S.M. 9841).

c. Four teeth were discovered in a late Pleistocene swamp deposit one mile west of Quaker Church, Warren County, N. J. in May, 1941. (Data from N.J.G.S.)

d. Mastodon teeth have several times been dredged from the bottom of the ocean off the New Jersey coast. The writer has seen specimens dredged off Atlantic City, Barnegat Inlet and Cape May, as well as off Norfolk, Va. The exact locations are uncertain, but they are believed to have come from water 100 to 200 feet deep, 10 to 75 miles off shore. (A.N.S.P. 15231, off Atlantic City).

e. The collections of the American Museum of Natural History contain mastodon teeth dredged 63 miles off Sandy Hook and 53 miles southeast of Ambrose Light.

f. In addition to the records cited in the literature (Hay) the Academy of Natural Sciences has mastodon teeth from Lumberton, N. J. (A.N.S.P. 28).

Elephas primigenius Blumenbach (Mammoth)

Several teeth and a few pieces of bones of a mammoth were obtained in June, 1932, from a pit on Hidden Lake Golf Course, two miles east of Blackwood, Camden County, N. J. The bones came from late Pleistocene gravel overlying the Kirkwood formation (Miocene). (Data from N.J.G.S.).

Equus sp. (Horse)

It is very difficult to distinguish between the teeth of the Pleistocene horse (*E. complicatus* Leidy) and the modern variety. A tooth, probably of a Pleistocene species of horse, was found in a pit of the Seguine Sand and Gravel Company at Kenvil, Roxbury Township, Morris County, N. J. (N.J.S.M. 10411).

According to Hay (1923) the only records of Pleistocene horse from New Jersey are specimens of *E. complicatus* from Swedesboro and Fish House, unidentified *Equus* remains from Navesink Hills, Monmouth County, and a partial skull (unfortunately lost) referred to *E. fraternus* Leidy by Cope.

Odobenus rosmarus Linné (Walrus)

In March, 1951, a highly mineralized walrus tusk was submitted to the writer by Albert Kubel who reported that it was dredged off the New Jersey coast. (A.N.S.P. 15223). A similar specimen was reported a year or so ago, but unfortunately the specimen cannot be located. The American Museum has a skull dredged 55 miles southeast of Ambrose Light (A.M.N.H. 32628).

Leidy (1860) reported several walrus skulls from the beach near Long Branch, N. J. (N.J.S.M. 10412), and Hay (1923) reports a similar skull from the beach near Ocean Grove, N. J., obtained in 1910.

It is believed that these are all of Pleistocene age.

Ursus sp. (Bear)

The collections of the Academy contain the radius (a bone in the forearm) of a bear found at Pemberton, N. J. (A.N.S.P. 11623).

Bison bison (Linné) (American Bison)

A bison tooth was found by Halsey W. Miller, Jr., in 1945 along Salem Creek near Woodstown, Salem County, N. J. The age is probably late Pleistocene or post-Pleistocene. (A.N.S.P. 15167).

A fragment of a bison jaw was found by Harold K. Woolley along a stream near Walnford, Monmouth County, N. J. The bone was associated with Indian artifacts. (N.J.S.M. 38.38).

The only other record of Bison from New Jersey is part of a femur (probably *B. bison*) collected by Ernest Volk in the "Yellow Drift" at Trenton in 1911. (Hay, 1923, p. 267).

Castor canadensis (Kuhl) (American Beaver)

The Academy's collections include a skull of this species obtained from Pleistocene deposits near Medford, N. J. (A.N.S.P. 11583).

Casteroides sp. (Giant Beaver)

A tooth of the extinct Giant Beaver was identified by Mary Y. Ayer, formerly of the Academy of Natural Sciences, from excavations conducted by the New Jersey State Museum in 1936 at Fairy Hole Rock Shelter near Johnsonburg, Warren County, N. J. This marks the first record of this animal from New Jersey although it was found in a cave deposit near Stroudsburg, Pa. Since the tooth from the Shelter was associated with Indian artifacts, it is most probably very recent in age, although it is possible that it predated the Indian material. It is very probable, however, that *Casteroides* did not become extinct in this area until well into recent time. (Cross, 1941, p. 148). (N.J.S.M. 200036).

Ondatra zibethica (Linné) (Muskrat)

A lower jaw was obtained from a "marl pit" in New Jersey. (A.N.S.P. 11586).

Low Sea Level of the Pleistocene

It has long been believed that sea level fell some 300 feet during the climax of the glacial stages of the Pleistocene. This would have resulted in the New Jersey coast extending some 90 miles east of the present shoreline. The finding of the mastodon teeth at the bottom of the ocean offshore may be taken as possible evidence for this low sea level. The remains could also have been brought to the sea by streams and redistributed by shore currents. However, the fact that these teeth are apparently relatively abundant suggests that the animals actually lived on land now submerged beneath the sea.[2]

Check List of Pleistocene Mammals

The recorded Pleistocene mammal fauna of New Jersey is very small indeed, a fact which is probably largely due to unfavorable conditions for preservation. The present paper has added a few new records of *Megalonyx* and *Ursus*. The accompanying list records the Pleistocene mammal fauna thus far known. For further details see Rhoads (1903) and Hay (1923).

Mammut americanum (Kerr)	Mastodon
Elephas primigenius Blumenbach	Mammoth
E. columbi Falconer	Mammoth
Odobenus rosmarus Linné	Walrus
Odocoilus virginicus (Zimmerman)	Deer
Megalonyx cf. *jeffersonii* Desmarest	Giant Ground Sloth
Megatherium americanum Blumenbach	Giant Ground Sloth
Equus complicatus Leidy	Horse
E. fraternus Leidy	Horse
Mylohyus nasutus (Leidy)	Peccary
Cervus canadensis Erxlben	Elk
Rangifer caribou (Gmelin)	Reindeer
Casteroides sp.*	Giant Beaver
Castor canadensis (Kuhl)	American Beaver
Ondatra zibethica (Linné)	Muskrat
Cervalces scotti Lydekker	Extinct Moose
Ursus sp.	Bear
Bison bison (Linné)	American Bison
Cetaceans	

* probably post-Pleistocene

[2] Additional teeth and bones from the bottom of the sea off the New Jersey coast are in the collections of Princeton University.

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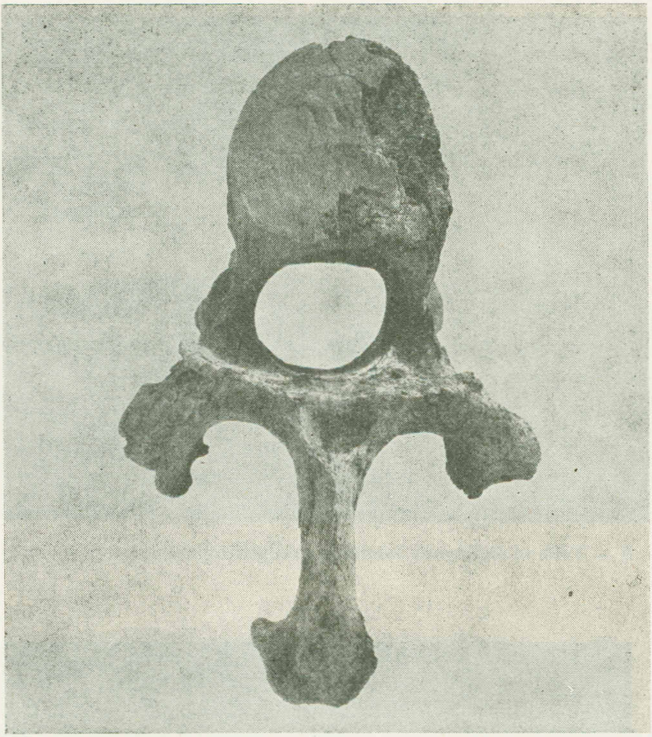
ILLUSTRATIONS

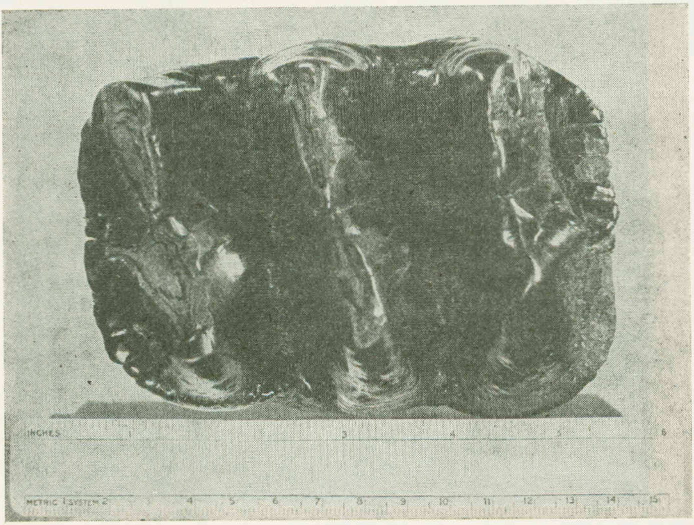
PLATE I. A. Vertebra of *Megalonyx* cf. *jeffersonii* from Fellowship, New Jersey (X⅝).
B. Tooth of *Mammut americanum* dredged off Atlantic City, New Jersey.

PLATE II. A. Tusk of *Odobenus rosmarus* dredged off the New Jersey coast.
B. Tooth of *Bison bison* from Woodstown, N. J. (X1)

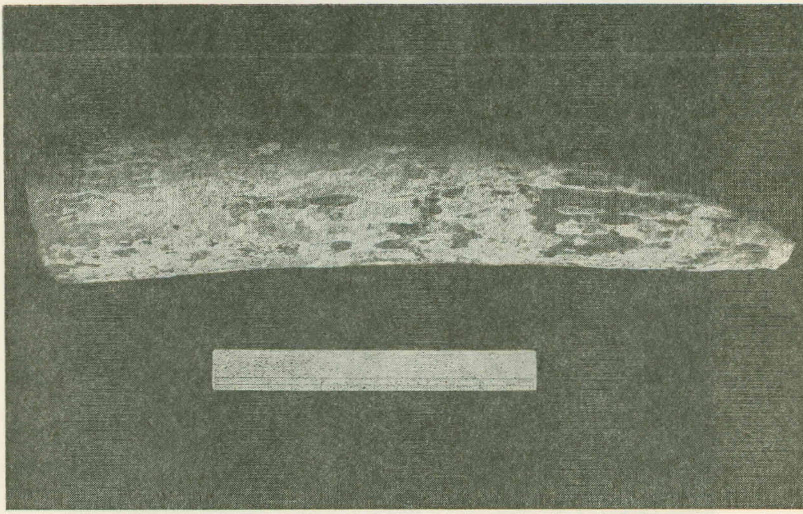
Plate I



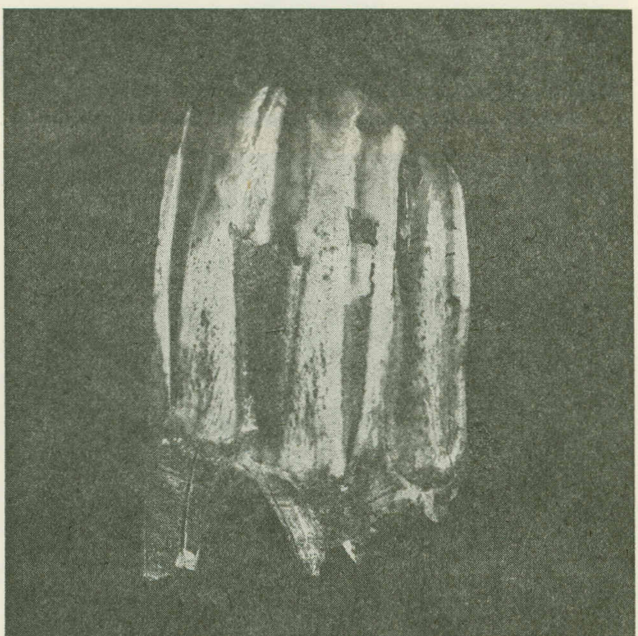
A — Vertebra of *Megalonyx* cf. *jeffersonii* from Fellowship, N. J.



B — Tooth of *Mammut americanum* dredged off Atlantic City, N. J.



A — Tusk of *Odobenus rosmarus* dredged off the New Jersey coast.



B — Tooth of *Bison bison* from Woodstown (X1).