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THE PHYLOGENY OF CERTAIN CERITHIIDÆ

BY ELVIRA WOOD

(*Presented in abstract before the Academy, February 7, 1910*)

CONTENTS

NOTE. The author alone is responsible for the terminology used throughout this article. EDITOR.

I. Introduction

The literature of the genus *Cerithium* is already extensive, including papers which treat the subject from both the paleontological and the zoölogical point of view. The genus is treated to a greater or less extent in all general works on conchology, but such treatment is confined to descriptions of the genus and of the different species referred to it, without any attempt to trace phylogenetic relationships, and the same is true, with few exceptions, of paleontological papers on the subject.

Recently M. Cossmann [1906] has published a monograph on the Cerithiidæ, in which he takes account of the relationship between different forms and presents an elaborate classification of the various genera and sub-genera included within the family.

M. Cossmann's conclusions are largely based on characters appearing late in the life history of the individual, and he lays especial stress upon the various features of the aperture. The present paper, being founded upon a different method of work, as explained below, necessarily reaches conclusions somewhat different from those of M. Cossmann.

A complete bibliography of the works consulted in the preparation of this paper is given on pages 86 to 91.

The principles of phylogenetic development discovered and formulated by Häckel, Hyatt, Cope and others have been successfully applied in studies of the phylogeny of several groups of greater or less extent, such as Hyatt's studies on the Cephalopoda, Jackson's on the Echinodermata and Grabau's on the Fusidæ. The present paper is an attempt to apply these principles in working out the relationships of such species of *Cerithium* as could be obtained.

The fundamental law upon which all the work is based is the law of morphogenesis, which has been stated by Hyatt[1] as follows:

> A natural classification may be made by means of a system of analysis in which the individual is the unit of comparison, because its life in all its phases, morphological and physiological, healthy or pathological, embryo, larva, adolescent, adult and old (ontogeny), correlates with the morphological and physiological history of the group to which it belongs (phylogeny).

According to this principle, a study of the life history of individuals furnishes a ready and most reliable means of tracing the development of the group to which they belong. Hence, in the present investigation, the starting point has been the study of individual development and a comparison of the records thus obtained. Similarity in the character

[1] A. Hyatt: "Genesis of the Arietidæ," p. viii. 1889.

and order of introduction of the various features of the shell are indications of relationship, and the comparison of a sufficient number of life histories will furnish a phylogenetic tree whose completeness depends upon the abundance and perfection of the material available for study. In making such comparisons, it is important to take account of parallelism in development, in consequence of which similar characteristics may appear for a greater or less portion of the life history in individuals belonging to divergent groups. An illustration of this is to be found in *Vicinocerithium bouei* DESH. and *V. parallelum* sp. nov. of the Eocenic of the Paris basin. These shells are closely similar in the adult and have been referred to the same species, but they differ in developmental history. Both have, in the adult, one extremely prominent spiral around the middle of the whorl, with strong ribs crossing it and a less prominent spiral below. The remainder of the surface is covered with spirals of secondary, tertiary, and higher orders. In the young, *Vicinocerithium bouei* has three spirals, the lowest of which is the most prominent (plate VII, fig. 6). Later, in the growth of the shell, finer spirals are intercalated, and all are crossed by ribs. At a still later stage, the upper spiral of the three primary ones becomes the most prominent and finally develops into the strong carina of the adult (plate VIII, fig. 6, and plate IX, figs. 5, 6). *Vicinocerithium parallelum* also begins with three spirals, of which the lowest one is the most prominent, but ribs are present as soon as the third spiral appears (plate VII, figs. 4, 5). Later, the median spiral becomes as prominent as the lower, and for several volutions the two are equally prominent, while the upper spiral diminishes in proportion, and additional fine spirals are introduced on the shoulder thus formed (plate VIII, figs. 4, 5). The median spiral continues to increase until it forms the carina of the adult (plate IX, figs. 3, 4), a feature which was formed in the preceding species by increase in the upper spiral of the three primary ones. These shells are parallel in the adult, but differ in development and are to be traced to different ancestors.

The phylogenetic record is obscured by the fact that not all of the history of a group is expressed in the ontogeny of a single species. As new characters are introduced in the evolution of the group the record becomes too long to be repeated during the lifetime of a single individual, and each of the ancestral stages occupies a shorter and shorter portion of the length of the shell, until some stages disappear altogether. An individual thus shows the adult characteristics of its ancestors at an early period of its life history. These facts are expressed as follows in Hyatt's law of acceleration:[2]

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[2] A. HYATT: "Genesis of the Arietidæ," p. ix. 1889.

All modifications and variations in progressive series tend to appear first in the adolescent or adult stages of growth, and then to be inherited in successive descendants at earlier and earlier stages according to the law of acceleration, until they either become embryonic, or are crowded out of the organization, and replaced in the development by characteristics of later origin.

This law is well illustrated in the development of two Paris Basin shells, *Potamidopsis tricarinata* LAMARCK of the Calcaire Grossier and *Potamidopsis roissyi* DESH. of the Sables Moyens. In the young, the surface ornamentation of the latter species consists of two rows of nodes, the lower being the more prominent. The same is true of the young *P. tricarinata,* but this stage lasts much longer in the latter than in the former species. The stage with two rows of nodes is followed by one in which there is an additional row of fine nodes intercalated between the two, and the lowest row is still the most prominent. At about the ninth volution of *P. roissyi* this ornamentation is fully developed, and it represents the adult ornamentation of *P. tricarinata,* which is found at a lower geological horizon. The adult characteristics of *P. tricarinata* last for hardly more than one volution on *P. roissyi,* which soon develops its own characteristic adult ornamentation of three rows of nodes, the uppermost of which are largest and transversely elongated. (See Deshayes, 1824, plate L, fig. 13.) *P. tricarinata* is the ancestor from which *P. roissyi* developed, and the latter records this fact in its ontogeny.

Two individuals belonging to the same phyletic series and living during the same time period frequently do not reach the same degree of complexity in structure. One may retain its primitive characteristics until late in its life history, only diverging from the ancestral type on becoming fully adult, while another may pass through its ancestral stages early in life and show a long succession of characteristics of later origin. The former is retarded in its development in comparison with the latter. *Cerithium tuberosum* is an illustration of a retarded shell, retaining, as it does, the two equally strong spirals until the tenth volution, the whorls only acquiring their acute angled outline on the twelfth volution. *Cerithium adansoni* passes through the same ancestral stages as *C. tuberosum,* but loses the obtuse angled outline of the whorls at about the sixth volution and after that acquires nodes, blunt spines and numerous additional spirals. It is a highly accelerated recent shell.

Acceleration and retardation are expressed not only in the ontogeny of the individual as a whole, but each character may be independently accelerated or retarded. *Cerithium graciliforme* (Tryon, 1887, plate XXII, fig. 77) retains the obtuse angled outline of the whorls to the ninth volution, while *C. echinatum* (Kobelt, 1898, plate XX, fig. 6) loses this type of outline at about the seventh volution. *C. graciliforme* is therefore a more retarded shell than *C. echinatum* in this respect. In the acquisition of nodes, however, it is accelerated, for it acquires nodes on the ninth volution, while *C. echinatum* does not develop them until the thirteenth volution. This differential acceleration and retardation often produces a wide difference in the appearance of adult shells, without the introduction of any new character.

Individuals having the same development for a greater or less portion of their life history, but differing in the adolescent or adult stages, may be regarded as divergent descendants from the same ancestral stock. A striking illustration of such divergence is found among recent species of Cerithium in the group of which *C. tuberosum* may be taken as a type.

In addition to the types of variation already noted, there is a kind of individual variation which seems to differ from all, and that is in the slight accentuation of the characters of the shell from their earliest appearance to the last volution. This is seen in individuals of *Cerithium lamellosum,* some of which show secondary spirals distinctly on all the whorls, while on others these spirals are but faintly indicated. This may be due to some condition in the environment, possibly to more lime in the water or to better food supply in the case of the well-marked individuals, or it may be due only to an inherent tendency to variation.

Acceleration and retardation and the introduction of new characters may cause divergence sufficient to serve as a basis for the separation of species, or they may appear to a less degree in individuals referred to the same species. Where many individuals are present, we find gradations in the various characters compelling us to establish varieties, and the more extensive the material the more insensible the gradations become, so that if our collections were sufficiently extensive, it would doubtless be possible to establish a perfect gradational series among various species of *Cerithium,* as in the classic example of the *Planorbis* of Steinheim.[3]

As might be expected, the greatest difficulty encountered in determining the phylogeny of *Cerithium* has been due to the scarcity of material. It has been impossible to secure specimens of shells from the early Mesozoic horizons which might be expected to furnish the ancestors of the forms occurring in such abundance in the Eocenic. A similar difficulty arises in connection with late Tertiary and early Quaternary material in which we should expect to find the connecting links between Eocenic and recent species. In the absence of specimens of shells, figures and descriptions have been freely used, but the figures of the early portions of

[3] A. Hyatt: Mem. Boston Soc. Nat. Hist. 1880.

the shell are unreliable, and in all the older works they were considered too unimportant even to be mentioned in the descriptions. In most later works, also, insufficient attention has been given to the character of the protoconch and early conch stages of the shell. For this reason all suggestions concerning phylogeny which are based on figures and descriptions alone are to be considered as merely theoretical and as subject to revision, if actual specimens become available.

Acknowledgments and thanks are extended with pleasure to those who have rendered assistance during the preparation of this paper; to Dr. Carlotta J. Maury for the loan of Oligocenic shells from the Paris Basin, and to Dr. Amadeus W. Grabau for many helpful suggestions The writer desires especially to express her appreciation of the very liberal manner in which Mr. Samuel Henshaw, Director of the Museum of Comparative Zoölogy, has placed at her disposal the resources of the collection in his care. The following officers of the American Museum of Natural History have also been most generous in providing opportunities for the study of the material in that museum: Dr. Hermon C. Bumpus, Director, and Prof. R. P. Whitfield and Dr. E. O. Hovey, Curators of the Department of Geology and Invertebrate Paleontology. Valuable assistance in collecting the literature of the subject has also been given by the librarians of both the above mentioned institutions.

II. Selection of a Genotype for Cerithium sensu stricto

The selection of a type of the genus *Cerithium* has given rise to much difference of opinion, and the determination of the proper species to be used as a standard of comparison for other species of the genus has led to a revision of the literature on the subject.

The name *Cerithium* was first used by Fabii Columnæ [1616] in his treatise, "De aquatilibus aliisque nonnulis animalibus." He figures a shell under the name of *Buccinum tuberosum,* which in his description he says should be referred to "Cerithia." On the margin of the page opposite this reference are the two names *Buccinum tuberosum* and *Cerithium parvum.* No description or figure accompanies the latter name, and it is possible that Columnæ intended to substitute this name for that of *Buccinum tuberosum,* for the shell figured on page 53 of his work; but since this is not definitely stated, the specific name *tuberosum* is retained for the shell figured and referred to *Cerithium.* Columnæ gives no description of the genus *Cerithium,* and his description of the species *tuberosum* is meager, but his figure of the latter is sufficiently good clearly to identify his shell with the one described by Lamarck [1843, p. 292] under the name of *Cerithium erythrœonense* and by Sowerby [1855] and Reeve [1866] as *Cerithium tuberosum.*

Adanson [1757] described and figured a shell from Senegal which he believed to be identical with that of Columnæ. His figure closely resembles *Cerithium tuberosum,* except in the aperture, which is more like that of the shell from Senegal described by Bruguière as *Cerithium adansoni.* Adanson was describing a shell collected by himself at Senegal, and his description seems to indicate quite definitely that his shell is really *C. adansoni* Bruguière, since it mentions the strongly spinose tubercles not found on *C. tuberosum* and gives the size as two inches, or about 50 mm. The youngest specimen of *C. tuberosum* seen in the collections studied was 57 mm. long, and full-grown individuals are 64 mm. or more in length. The similarity in the figures may perhaps be accounted for by a tendency on the part of the artist to imitate a figure already published and believed to be of the same species. Adanson named his shell simply "Le Cerite," and this name would not stand, since it does not conform to the binomial nomenclature.

The first published description of the genus *Cerithium* is by Bruguière [1792]. He divides the genus into three groups, the first of which corresponds to *Vertagus* Klein and the second to *Cerithium* sensu stricto. The first species of this second group is *Cerithium nodulosum,* which the author believed to be of the same species as *C. tuberosum* Columnæ, since he cites the latter species in his synonymy. The description, however, corresponds with *C. nodulosum,* as the name is now applied. The second species of this group is *C. adansoni,* the description of which corresponds closely with that of "Le Cerite" by Adanson, and Bruguière states definitely that he is describing a shell of the same species as Adanson's shell.

At a still earlier date Martyn [1784] figured under the generic name of *Clava* four species which Dall [1907, p. 366] now refers to *Cerithium,* as follows:

1. *Clava rugata* Martyn = *Murex asper* Linné.
2. *Clava herculea* Martyn = *Cerithium ebeninum* Bruguière.
3. *Clava maculata* Martyn = *Cerithium clava* Bruguière.
4. *Clava rubus* Martyn = *Cerithium echinatum* Lamarck.

On the strength of these figures, Dall [ibid., p. 368] claims for Martyn the first recognition of the genus *Cerithium,* but Martyn published no descriptions either generic or specific, and it hardly seems that these figures alone furnish a valid reason for changing the name of the genus from *Cerithium* to *Clava* Martyn. *Clava* has long been established as the name of a genus of hydroids, and the confusion that would arise in the literature furnishes another reason for avoiding such a change.

In the first published description of the genus *Cerithium* by Bruguière no genotype was designated, and the first to make a definite selection was Lamarck [1799].[4] He chose *Murex aluco* LINNÉ, which was described by Bruguière with the name of *Cerite chenille.* This shell belongs to the first of the three groups described by Bruguière, and it might well remain the type of that group to which the name *Pseudovertagus* has since been applied. It does not belong in the same group with the shell to which Columnæ gave the name of *Cerithium,* as will be seen by comparing the life histories of the two species as given on plate III, figs. 2, 3, 4; plate IV, figs. 2, 3; plate V, figs. 1, 2; plate III, fig. 6; plate IV, figs. 6, 7; plate V, figs. 5, 6, and plate VI, figs. 4, 5. Lamarck himself seems to have been dissatisfied with his own choice of a genotype, for two years later [1801, p. 85] he redescribed the genus and mentioned *Cerithium nodulosum* as an example of it.

Later authors have adjusted the claims of their predecessors in various ways. Most credit the genus to Bruguière, but others refer it to Lamarck or Adanson. A few of these may be mentioned: thus Montfort [1810] credits the genus to Lamarck, choosing the genotype selected by him in 1799. Link [1807] and Schumacher [1817] solve the difficulty by dividing the genus into two groups, the former following Lamarck, in 1799, for his first group, and Bruguière, with *Cerithium adansoni* as an example of his second group, to which he gives the name *Aluco.* Schumacher retains the name *Cerithium* for both his groups, crediting them to Lamarck, with *C. aluco* as genotype for one and *C. nodulosum* for the other. Among the authors who refer the genus to Adanson are Deshayes [1824], d'Orbigny [1842-1843], Sowerby [1855], Fischer [1887] and Tryon [1887]. Bruguière, being the first to describe the genus as such, is still more widely recognized, and a few of the authors who have followed him are Swainson [1840], Reeve [1866], Cossmann [1906] and Dall [1907].

In the choice of a genotype equal diversity is shown, for Fischer, while he refers the genus to Adanson, chooses *C. nodulosum* as the genotype. Deshayes is consistent in choosing for the type of the genus *C. adansoni.* Of those who refer the genus to Bruguière, Swainson and Cossmann choose *C. nodulosum,* and Dall and Dautzenberg and Dollfus [1882-1885] choose *Murex aluco* LINNÉ as the type of the genus.

Summarizing the facts already given, it appears that Columnæ was

[4] The author has been unable to see this work, and is indebted to Dall [1907, p. 364] for the reference.

the first to propose the name *Cerithium,* which he did in connection with a description and an easily determinable figure of a well-known species. He gave it a name which conforms to the Linnæan system of nomenclature, and it appears to the writer that these facts are sufficient ground for referring the genus to Columnæ. Apparently the only reason for discrediting his work and referring the genus to a later author is found in the rule of the International Congress of Zoölogists, according to which the date 1758 is taken as the starting point of the binomial nomenclature. This rule is useful, but to enforce it indiscriminately would do great injustice to the pioneers in science whose work conforms with the standards at present in use. This is especially true when, as in the present case, there are additional reasons for recognizing the earlier work. In actual practice the rule is not closely followed, since many genera described previous to the year 1758 are still retained under the name of the original author. For example, among the Cephalopoda we have *Belemnites* LISTER, 1678; *Orthoceras* BREYN, 1732; *Lituites* BREYN, 1732, and among Gastropoda *Planorbis* GUETTARD, 1756, and *Haliotis* LINNÉ, 1735. Furthermore, the reference of the genus to Columnæ would have the great practical advantage of settling at once the vexed question of a genotype, and this type is of such a character that it would, on the basis of phylogenetic studies, retain within the genus *Cerithium* a large number of the species known by that name throughout the literature of the subject.

The work of Adanson, like that of Columnæ, is pre-Linnæan, and it furthermore fails to conform to the binomial nomenclature.

If the rule of discrediting pre-Linnæan descriptions be rigidly adhered to, the genus would be referred to Bruguière, and the choice of *Cerithium nodulosum* as genotype seems to come nearest to that author's own conception of the genus. The choice of *Murex aluco* for a genotype, as at first suggested by Lamarck [1799], would result in substituting the name *Cerithium* for *Pseudovertagus* and the use of a new name for the group to which the former was originally applied. This would cause great confusion in the literature and make the genus a different one from what was intended by the early writers on the subject, since Bruguière was obviously trying to follow both Columnæ and Adanson in describing first, *C. nodulosum,* which he believed to be identical with Columnæ's shell, and second, *C. adansoni,* which was "Le Cerite" of Adanson. He merely fell into the common error of including under one name groups of shells which he himself recognized to be different.

Cerithium nodulosum bears a superficial resemblance to *C. tuberosum* and has been considered by some authors to be of the same species. It is, however, quite distinct. According to the youngest specimens of

C. nodulosum at first obtainable, it seemed that the two species belonged to the same phyletic series, but the absence of ribs on a somewhat younger individual, received later, throws some doubt upon this supposed relationship. The point can only be determined by a study of younger stages of *C. nodulosum* than are now available, and in case the latter shell proves to be different in its development from *C. tuberosum,* it must represent a very restricted group, for among species now referred to *Cerithium* the absence of ribs on individuals having a well developed shoulder is an extremely rare feature. In this case also, with *C. nodulosum* as genotype, the name *Cerithium* would be used in a very restricted sense, and a new name would have to be given to the genus as understood by Columnæ and Bruguière.

For the purposes of this paper, *Cerithium tuberosum* Columnæ will be used as a standard of comparison for other species of the genus.

III. Genus Cerithium Columnæ

1616. *Cerithium* Fabii Columnæ, De Aquatilibus, pp. 53, 57.
1784. *Clava* Martyn, The Universal Conchologist, London.
1792. *Cerithium* Bruguière, Hist. Nat. des Vers., Encyc. Méth., I, pt. 2, 467.
1799. *Cerithium* Lamarck, Prodrome nouv. class., p. 73 (not seen).
1801. *Cerithium* Lamarck, Syst. des animaux sans vert., p. 85.
1898. *Cerithium* Kobelt, Syst. Conch.-Cabinet von Martini u. Chemnitz, Bd. I, Abth. 26, 2.
1906. *Cerithium* Cossmann, Essais de Paléoconch. Comp., VII, 65.

Fig. 1.—*Cerithium tuberosum.* Copy of Columnæ's original figure × 1.

After the description of *Buccinum maximum* and mention of other species of *Buccinum,* Columnæ refers to this species as follows:

Sed rariorem hanc parui Buccini tuberosi candidi, ad Cerithia referendam, oris margine supra tubulum elata, et incumbens non inuersa ut in alijs magnis effigiem omittere noluimus, quanimus huiusmodi alias differentias habeamus, colore cinero orbitas depressioribus, magis densis minutisque tuberculis asperas.

While this description is meager, it is sufficient, with the aid of the figure, for the identification of the species designated. The characterization of the shell as a small one excludes *Cerithium nodulosum*, with which it has been confused. The reference to the margin of the mouth as raised above the canal and resting upon it is like *C. tuberosum* and unlike *C. adansoni*. The figure also resembles *C. tuberosum* in its high spire, in the character of the aperture and of the ornamentation, so far as this is indicated by the imperfect figure.

Description of *Cerithium* by Bruguière:

Genre de coquilles univalves, uniloculaire, à spire regulière, qui a pour caractère,

Une coquille turriculée, l'ouverture oblique, terminée à la base par un canal étroit, totalement recourbé, ou moyennement recourbé, ou droit et très-court, mais jamais échancré.

Genotype selected by Lamarck, 1799, *Murex aluco* Linné; 1801, *Cerithium nodulosum* Bruguière.

The protoconch of the genus *Cerithium* has been observed in many species and is found to be uniform in character. It forms a low, regular spiral of usually about one and one-half volutions. The limits of the protoconch are not sharply defined, as the ornament begins faintly at first and becomes gradually stronger, but for convenience the protoconch has been assumed to end where the first traces of ornament appear. Practically the only difference found in the earliest whorls of the species studied is in the extent of the smooth portion of the shell, which varies from one and one-fourth to one and one-half volutions. This is due to difference in degree of acceleration, the more accelerated forms having the ornamentation crowded back to an early stage in shell growth.

The surface ornamentation of *Cerithium* consists of spirals, ribs and nodes, the great diversity observable in the ornamentation of the different species being due to the relative development which each of these features attains. In forms sufficiently retarded to show the order of introduction of the various features of the ornamentation, it appears to begin as one spiral, or in accelerated forms as more than one, additional spirals coming in above the first. Ribs next appear and nodes are formed by the concentration of material where the ribs and spirals cross. In a few cases ribs appear after the first and before the formation of a second spiral, but in no case have ribs been observed before the appearance of at least one spiral. Intercalated spirals may come in either before or after the introduction of ribs, and they often become extremely numerous. While the order of introduction of the types of surface ornamentation is fairly constant, the precise volution at which a new feature will appear is dependent on the degree of acceleration which the shell has attained and often shows considerable variation within the same Linnæan species. In highly accelerated forms, both spirals and ribs may appear together at the close of the protoconch stage. This is seen in *Cerithium adansoni,* plate III, fig. 3.

The amount of embracing of the whorls in shells of this genus varies within considerable limits, but as a rule the body volution is shorter than the remainder of the spire.

The aperture is oval, with an oblique, more or less widely open anterior canal. Primitive forms have no posterior tooth, but in some Eocenic and later forms a projection of the callus of the inner lip forms a distinct tooth which defines a short canal between itself and the outer lip.

In the earlier literature of the subject, the name *Cerithium* was applied to all forms having in common the characters of a high spire, a short body whorl and a short anterior canal, although Bruguière himself recognized the heterogeneous character of the genus, for he separated it into three groups which are now properly recognized as distinct genera. Further subdivision has been found necessary from time to time, until in M. Cossmann's Essais de Paléoconchologie, volume 7, after the separation of several groups of family rank, we find seventeen genera, thirty-one subgenera and forty-five sections.

Choosing *Cerithium nodulosum* Bruguière as the genotype, M. Cossmann lays especial stress upon the projecting tooth on the anterior portion of the outer lip, and he restricts the genus so as to include those forms in which this tooth crosses the opening of the canal. This enables him to place only two species within the genus, the genotype and *Cerithium erythræonense* (= *C. tuberosum*), but a close study of the anterior tooth seems to indicate that its importance as a basis for classification has been greatly overestimated. It appears on the last portion of the body whorl, a position in which the highest degree of variation in the shell is to be expected, and features appearing at this stage should serve as reasons for separating end members of evolutionary series, but not for uniting species as genera, if the classification is to be a natural one—that is, based on community of descent. The tooth is formed by the more rapid growth of the anterior part of the outer lip, and when a spiral is present on this part of the shell, it often determines the point at which an extra amount of calcareous material is deposited. The development of this tooth is extremely variable among individuals undoubtedly of the same species; for example, among six adult individuals of *C.* ? *nodulosum* showing no trace of fracture, two develop this feature to a very slight extent and do not form a tooth which crosses the aperture. *C. echinatum* is referred to a different section on account of the less development of this tooth, but certain individuals have the tooth developed to a greater extent than some specimens of *C. nodulosum*.

Not only is the tooth variously developed in species which are shown by their ontogeny to be related, such as *C. tuberosum* and *C. echinatum*, but it is strongly developed in species undoubtedly of different descent; for example, *Pseudovertagus aluco* and related species have such a tooth very strongly developed, yet the wide difference between the ontogeny of *Pseudovertagus aluco* and *Cerithium tuberosum* will be readily appreciated by comparing the figures of *C. tuberosum* in the first column of plates III to VI with those of *Pseudovertagus aluco* in the fourth column of the same plates.

Of the genera and subgenera of Cerithiidæ already established, there will be considered in this paper only the *Cerithium tuberosum* group and others closely related to it.

In the description of species which follow no attempt has been made to give a complete synonymy. In each case the original description or a reference to it is given, and also a reference to a good modern description. Where necessary to make the identification of the species clearer, additional references are given. Descriptions are based on one individual which may be considered typical of the species, but where variations such as differences in color, in the number of varices and the like are characteristic features, other individuals are considered. Measurements are also from one individual, usually the largest of those referred to the species. The method of taking measurements of the apical angle is similar to that described by d'Orbigny [1842-1843, pp. 10-14], with the exception that in the case of convex or concave shells two measurements are given representing the extreme angles obtained, and, as nearly as possible, the volution at which the change takes place. The sutural angle is measured as described by d'Orbigny, holding the aperture of the shell downward and taking the upper angle made by the suture with the right side of the shell in dextral forms and the left side in sinistral forms.

IV. Ontogenetic Description of Species

A. RECENT SPECIES

1. *Cerithium tuberosum Group*

a. European Species

Cerithium tuberosum *Columnæ*

Plate I; plate II, fig. 4; plate III, fig. 4; plate IV, fig. 1; plate VI, figs. 1, 2.

1616. *Cerithium* [*Buccinum*] *tuberosum* Fabii Columnæ, De aquatilibus, pp. 53, 57.
1843. *Cerithium erythræonense* Lamarck, Animaux sans vertèbres, éd. 2, IX, 292.
1855. *Cerithium tuberosum* Sowerby, Thesaurus Conch., II, 855, pl. 178, fig. 49.
1866. *Cerithium tuberosum* Reeve, Conch. Iconica, XV, pl. 1, fig. 5, No. 5.
1898. *Cerithium erythræonense* Kobelt, Syst. Conch.-Cabinet von Martini u. Chemnitz, Bd. I, Abth. 26, 78, pl. 15, figs. 2, 3.
1887. *Cerithium erythræonense* Tryon, Manual of Conch., IX, 123, pl. 20, fig. 16.
1906. *Cerithium erythræonense* Cossmann, Essais de Paléoconch., VII, 67.

The original description by Fabii Columnæ is given under the discussion of the genus.

Measurements: Length, 64 mm.; greatest diameter, 29 mm.; apical angle, 34°, changing on the 9th volution to 29.5°; sutural angle, 91°.

Color: Pale brown or brownish yellow.

The protoconch is not preserved on any of the specimens obtainable. The first volution retained is .7 mm. in diameter, and this corresponds in size with the first volution beyond the protoconch of *Cerithium adansoni.* The surface features are entirely obliterated on this volution, but the next shows traces of the ornamentation, which is apparently the same as that of *C. adansoni* at the same age. The fourth volution has two strong spirals, the upper of which defines the shoulder, with one spiral intercalated between them. There are also four equal spirals above and two below the primary ones. All the spirals are crossed by ribs, of which there are nine on this volution. On the succeeding volutions more spirals are added on the shoulder and the lower slope of the whorls, and their number is also increased by intercalation between those already existing. At about the eighth volution the spirals become much crowded, and are raised into a strong ridge just below the suture. The same type of ornamentation persists for eleven volutions, but on the twelfth the lower of the two equal spirals becomes weaker, and the outline of the whorl changes from an obtuse angle to one both of whose sides stand at angles of about 45° with the axis of the shell. This tendency increases until, on the body whorl, the lower primary spiral is inconspicuous, and the upper forms the most projecting portion of the strong nodes into which the ribs have become contracted. The sub-sutural ridge above described is, on this volution, raised at short intervals into a row of smaller nodes, and on the lower portion of the body whorl there are three strong nodose ridges formed, like the sub-sutural ridge, of groups of fine spirals. On the under side of the body whorl ribs and nodes are nearly obliterated along the surface upon which the animal rested when withdrawn into its shell; but just beyond this area, on the side of the volution opposite the outer lip, the surface is raised into a strong varix.

The aperture is oval, with a strong posterior tooth. The outer lip is slightly flaring, with its margin crenulated by the spirals of the outer surface. The lower portion of the outer lip grows more rapidly than the upper portion, and the lowest of the nodose ridges is produced into a toothlike process which, in some individuals, crosses the opening of the anterior canal. The length of this process varies considerably in different specimens of the species. The inner lip has a strong callus. The anterior canal is long and comparatively narrow.

HORIZON AND LOCALITIES: Recent. Red Sea and Indian Ocean.
No. 20124, Columbia University collection.

REMARKS: *Cerithium tuberosum* is especially well adapted to serve as a type of the group of shells to which it belongs, since it is a retarded form passing through the various stages in its development slowly and retaining primitive characteristics until a late period of its life.

Cerithium ? nodulosum *Bruguière*

Plate III, fig. 5; plate IV, figs. 4, 5.

1792. *Cerithium nodulosum* BRUGUIÈRE, Hist. naturelle des Vers, Encycl. Méth., I, pt. 2, 478.
1887. *Cerithium nodulosum* TRYON, Manual of Conch., IX, 122, pl. 19, figs. 13, 14; pl. 20, fig. 15.
1898. *Cerithium nodulosum* KOBELT, Syst. Conch.-Cabinet von Martini u. Chemnitz, Bd. I, Abth. 26, 76, pl. 15, fig. 1.
1906. *Cerithium nodulosum* COSSMANN, Essais de Paléoconch. Comp., VII, 66,

MEASUREMENTS: Length, 95 mm.; greatest diameter, 47 mm.; apical angle, 37°; sutural angle, 84°.

COLOR: Grayish white, more or less closely covered with interrupted bands and patches of dark brown.

The youngest volution available for study is 1.9 mm. in diameter, and it is probable that several volutions have been broken away above this. It has a sharply angled outline, with the most projecting portion slightly above the middle of the whorl. It is ornamented with three strong, continuous spirals, the uppermost of which is stronger than the others. Two finer spirals are present on the shoulder, and one is visible just above the suture. The entire surface is roughened by exceedingly fine, thread-like costæ crossing the spirals at right angles. They are too fine and too closely set to appear like ribs, and ribs of the usual kind are entirely absent at this stage. The ornamentation remains similar in type, with the intercalation of finer spirals between those already existing, until the sixth volution, on which widely spaced ribs appear. At this stage the volution is about 6 mm. in diameter. The fine spirals increase rapidly in number, and on the later volutions the primary spirals seem to be made up of clusters of finer spirals with the clusters separated by deep, smooth grooves. At about the ninth volution the median of the three spirals becomes almost as strong as the uppermost spiral, so that for two or three volutions the obtuse angled outline of the whorl characteristic of *Cerithium* is suggested. The upper spiral, however, soon becomes again the most prominent one, and this tendency increases until, on the body volution, this spiral forms the margin of very large, blunt, flat-topped nodes, with the ribs nearly obsolete above and below them. On the late whorls the finer spirals are sometimes confluent and the former cluster becomes a broad, flattened ridge defined by a narrow groove on either side. The body volution below the nodes bears three broad nodose spirals.

The aperture is oval, with the outer lip flaring and thrown into strong folds by the coarse spirals of the outer surface. The lowest of the spirals on the body whorl is sometimes produced to such an extent that it forms a projecting tooth which crosses the opening of the canal. The inner lip bears a strong callus with a prominent tooth near the posterior portion of the aperture. The siphonal canal is broad and deep and slightly bent backward.

Horizon and localities: Recent. Moluccas, Philippines, Indian Ocean.

No. 40203, Columbia University collection.

The young individual figured is from the exhibition collection of the Museum of Comparative Zoölogy.

Remarks: Although the adult of this species bears some resemblance to *Cerithium tuberosum,* its development is unlike that of any species of Cerithiidæ studied. The formation of a distinct shoulder so long before the appearance of ribs and the presence of the fine costæ crossing the spirals are features which have not been observed elsewhere. So far as the information at present available goes, it would appear that *C. ? nodulosum* is the sole representative known of a distinct genus, but it is left for the present in the genus *Cerithium,* awaiting an opportunity to study still younger stages of the shell and to obtain other shells which will throw light upon this peculiar type of development.

Cerithium adansoni *Bruguière*

Plate I; plate II, fig. 3; plate III, figs. 2, 3, 4; plate IV, figs. 2, 3; plate V, figs. 1, 2.

1757. "Le Cerite" Adanson, Histoire Naturelle du Sénégal, 152, pl. 10, fig. 2.
1792. *Cerithium adansoni* Bruguière, Hist. Nat. des Vers, Ency. Méthod., I, pt. 2, 479.
1855. *Cerithium adansoni* Sowerby, Thesaurus Conch., II, pl. 178, fig. 45.
1898. *Cerithium adansoni* Kobelt, Syst. Conch.-Cabinet von Martini u. Chemnitz, Bd. I, Abth. 26, 142, pl. 27, figs. 4, 5.

The following is Adanson's description of "Le Cerite":

Fabius Columna s'est servi du mot grec latinisé Cerithium pour defigurer une espèce du genre des coquillages que je vais décrire sous le nom commun de Cerite.

La coquille de cette espèce n'a guères que deux pouces de longueur et une fois moins de largeur.

On n'y compte que douze spires, renflies dans leur milieu, qui est garni d'un rang de boussettes assez grosses, élevées sur une côte parallel a sa longueur. Le reste de leur surface est entouré de dix à douze petit filets peu élevés. La seconde spire porte quelquefois un gros bourrelet sur la gauche.

La longueur du sommet surpasse presque une fois sa largeur et la première spire.

L'ouverture est exactement ronde, et paroit beaucoup plus evasée que la précédente, parce qu'elle se porte presqu' entièrement hors de la coquille, sur sa droite. Son canal inférieur est creusé en demi-cylindre, recouvert en partie par une côte assez grosse, elevée sur la base de la lèvre gauche. Le canal supérieur est reserré, et de moitié plus profond que large.

La lèvre droit n'est pas sensiblement prolongée dans sa partie supérieure, et elle ne forme pas l'auvent comme dans la première espèce.

La lèvre gauche n'est pas non plus repliée comme la sienne; elle est recouverte seulement par une lame courte, mais épaisse, et relevée en bas d'un filet assez gros qui tourne en dedans de la coquille.

Sa couleur est blanche, sans melange dans les jeunes, et légèrement tachée de brun dans les vieilles.

Je n'ai remarqué dans cette coquille qu' une légère variété, qui consiste en ce que les boussettes des spires sont quelquefois assez longues et pointues: cela se rencontre ordinairement dans les jeunes; et c'est vraisemblablement le frottement qui les use et les arrondit dans les vieilles.

Cette espèce vit aussi dans la vase mais on ne la voit qu'en petite quantité dans le fleuve Gambie, vis-à-vis le comptoir d'Albreda.

The description of this species given by Bruguière is closely similar to that of Adanson, and much of it is even worded in the same way. Practically the only addition made by Bruguière was in giving the species a binomial name.

MEASUREMENTS: Length, 43 mm.; greatest diameter, 3 mm.; apical angle, 50° to the eighth volution, changing to 31.5°; sutural angle, 72.5°.

COLOR: White, sparingly dotted with pale brown.

The protoconch of *Cerithium adansoni* consists of about one and one-fourth volutions. The ornamentation begins as two spirals crossed by distant ribs on the first volution beyond the protoconch (plate III, fig. 2). The second volution bears three fine spirals on the shoulder. These are increased by a fourth fine spiral on the third volution, and an intercalated spiral appears between the two primary ones. Tertiary spirals and those of higher order are soon developed, and these fine spirals do not increase greatly in size, but they become extremely numerous, so that the entire surface of the adult is covered with thread-like costæ. On the fourth volution, just below the upper suture, there is an elevation of the surface to form a coarse spiral which carries with it the fine spirals already existing. Later in the life of the shell other coarse spirals arise in a similar manner on the shoulder and below the two primary spirals. The lower of the primary spirals becomes gradually weaker and the upper more prominent, until at about the sixth volution the outline of the whorl has lost its vertical element formed by the two equal spirals and has become an acute angle. On the next volution the center of the rib becomes so prominent that it might almost be called a spine, and on this volution also rows of large nodes are formed by the breaking up of the coarse spirals just below the upper suture and above the lower one. On the eleventh volution there are three coarse spirals above and three below the central extremely prominent one, all of which are irregularly nodose.

The median spiral of the body volution is spinose on the dorsal side, but on the ventral side the spines are represented by low nodes only. Below the prominent spiral on the body volution there are six or more coarse spirals with finer intercalated ones, and the whole is covered, like the rest of the surface, with the fine costæ described above.

The aperture is a broad oval in outline. The outer lip is thick, somewhat flaring, and crenulated by the spirals of the outer surface. The inner lip has a thick callus, raised into a strong blunt tooth which, with the outer lip, forms a short canal at the posterior end of the aperture. The anterior canal is short and slightly curved, and its opening is narrowed by the rapid growth of the lower portion of the outer lip. This growth does not, however, form a distinct tooth as in *Cerithium tuberosum* and some forms of *C. echinatum*.

Horizon and localities: Recent. Senegal, west coast of Africa and sparingly near the mouth of the Gambia River. M. Cossmann [1906, p. 66] assumes that this shell is a fresh-water form, but this is hardly borne out by the statement of Adanson, who collected the animals in their native locality. According to his account of the habitat quoted above, it seems that the animal is typically marine, and comparatively few individuals have migrated up the Gambia River.

No. 20125, Columbia University collection.

Museum of Comparative Zoölogy, museum collection.

Remarks: This shell, from the protoconch to the seventh volution, corresponds exactly in development with *Cerithium tuberosum*. It is, however, a more accelerated shell, since the stage with two equal spirals persists in *C. tuberosum* for ten volutions, while in *C. adansoni* this feature is lost on the sixth volution. The adult of *C. tuberosum* corresponds approximately to the seventh volution of *C. adansoni,* but the correspondence is not exact, for at this stage *C. adansoni* has not acquired a sub-sutural row of fine nodes, while its ribs have become even more spinose than those of *C. tuberosum*. *C. adansoni* is not to be regarded as a descendant of *C. tuberosum,* but rather the two are descended from a common ancestor, *C. adansoni* passing through its ancestral stages rapidly and adding new characters, while *C. tuberosum* is retarded in its development and never attains the high degree of ornamentation characteristic of the adult *C. adansoni.*

Cerithium echinatum *Lamarck*

1843. *Cerithium echinatum* Lamarck, Animaux sans vert., éd. II, IX, 291.
1887. *Cerithium echinatum* Tryon, Manual of Conch., IX, 123, pl. 20, figs. 25-27.
1898. *Cerithium echinatum* Kobelt, Syst. Conch.-Cabinet von Martini u. Chemnitz, Bd. I, Abth. 26, 100, pl. 20, figs. 5-8.
1906. *Gourmyia echinatum* Cossmann, Essais de Paléoconch., VII, 69.

Measurements: Length, 49.4 mm.; greatest diameter, 27.3 mm.; apical angle to the ninth volution, 45°, changing to 37.5°; sutural angle, 82.5°.

Color: Grayish white, sometimes marked with transverse patches of brown, which is deepest on the spirals.

The protoconch of *Cerithium echinatum* is much worn on the only available specimen showing that feature, but so far as can be determined, it is precisely like that of *C. adansoni,* and the first four volutions are indistinguishable on the two shells. On the fifth volution there is less contrast between the primary spirals and those of higher order than on

C. adansoni. In other words, the primary spirals are not so highly developed, and spirals of higher order are coarser. This difference persists throughout the remainder of the shell growth. On the sixth volution, beyond the protoconch, the upper of the two primary spirals becomes more prominent. This tendency increases until, on the body volution, the ribs have become contracted into spines, of which the upper primary spiral forms the most projecting portion. The spirals of higher order increase rapidly in number until they become so crowded that they coalesce, forming broad, flattened ridges which are in places finely striated, indicating the original spirals of which they are composed. On the body whorl the uppermost spiral breaks up into fine nodes, and just before the end of this volution three spirals on the shoulder become similarly nodose. On the lower slope of the volution there are also three strong spirals which become nodose toward the end of the whorl. Spines are absent from the under side of the body volution, as in *C. adansoni.*

The aperture is broadly oval. The inner lip bears a strong callus, with a well-developed tooth forming, with the outer lip, a short canal at the posterior portion of the aperture. The anterior canal is short and slightly curved. The outer lip is flaring, its margin being crenulated by the spirals of the outer surface. The lower margin of the outer lip grows more rapidly than the upper, forming a projection somewhat as in *Cerithium tuberosum,* but not so strongly developed as in the latter species. There is considerable difference in the degree to which this feature is developed on several individuals of *C. echinatum.*

Horizon and locality: Recent. Zanzibar.
No. 40181, Columbia University collection.

Remarks: This shell bears a strong resemblance to *C. adansoni,* but differs in the coalescence of the fine spirals, which on *C. adansoni* remain distinct throughout the life of the shell, covering all the coarser features with fine thread-like lines. On *C. echinatum* also nodes are developed to a less degree, appearing only on the latest portion of the body volution. The more rapid growth of the lower portion of the outer lip on *C. echinatum* is an important distinguishing feature, since it does not occur on *C. adansoni.*

C. echinatum, as shown by its early development, is closely related to *C. tuberosum,* but it is a more accelerated shell, since it loses the vertical element from its outline on the sixth volution, instead of the tenth, as in *C. tuberosum.* While more accelerated than *C. tuberosum,* it is more retarded than *C. adansoni,* since it does not acquire nodes until near the end of its life history.

Cerithium menkei *Deshayes*

Plate VII, figs. 2, 3; plate VIII, fig. 3; plate IX, fig. 2.

1863. *Cerithium menkei* DESHAYES, Moll. Réunion, p. 97, pl. 9, fig. 15.
1887. *Cerithium columna* TRYON, Manual of Conch., IX, 123, pl. 20, fig. 19.
1898. *Cerithium menkei* KOBELT, Syst. Conch.-Cabinet von Martini u. Chemnitz, Bd. I, Abth. 26, 208, pl. 37, fig. 1.

MEASUREMENTS: Length, 29 mm.; greatest diameter, 16.5 mm.; apical angle to the eighth volution, 47°, changing to 35°; sutural angle, 76.5°.

COLOR: Uniformly cream-colored, or occasionally having a few pale brownish spots scattered irregularly over the surface.

This shell is thin and delicately sculptured, with all the features of the surface ornamentation distinctly shown.

The protoconch is not preserved, but the first volution remaining, which is probably the first beyond the protoconch, is ornamented by two spirals and faint ribs only. This volution has a diameter of .6 mm. On the next volution three fine spirals appear on the shoulder. Intercalated spirals are first developed on the third volution, and they increase rapidly during subsequent growth until, on the body whorl, those of the fifth order may be counted. The two primary spirals remain of equal strength for eight volutions, but on the later volutions the lower spiral becomes weaker, until it is reduced to the size of a secondary spiral, and the outline of the whorl is changed from an obtuse angle to approximately a right angle. At intervals on the later volutions of the shell one rib is slightly stronger than the others, and on the body whorl there is one strong varix. A sub-sutural band, as in *C. tuberosum,* is developed on the ninth and later volutions. Toward the end of the body whorl this band becomes tuberculate, and on the lower slope of this whorl two strong spirals are developed.

The aperture is elongate oval, with a posterior tooth on the narrow callus of the inner lip. The outer lip is flaring, crenulated by the spirals of the outer surface. The anterior canal is comparatively long.

HORIZON AND LOCALITY: Recent. Indian Ocean.
No. 20126, Columbia University collection.

REMARKS: *Cerithium menkei* differs from *C. columna* in having a thinner shell, finer and more delicate sculpture, broader and less widely spaced ribs.

The development of the ornamentation of this shell is so closely parallel to that of *C. tuberosum* that, taken in connection with the similarity in the form of body and aperture, it leaves no room for doubt that the two are developed from a common ancestor. This is clearly brought out by a comparison of the figures of young whorls on plate VII, figs. 2, 3, and plate III, fig. 4.

Cerithium columna *Sowerby*

1855. *Cerithium columna* SOWERBY, Thesaurus Conch., II, 855, pl. 178, figs. 55-58.
1866. *Cerithium columna* REEVE, Conch. Icon., No. 2, pl. 1, fig. 2.
1887. *Cerithium columna* TRYON, Manual of Conch., IX, 123, pl. 20, figs. 17, 18.
1898. *Cerithium columna* KOBELT, Syst. Conch.-Cabinet von Martini u. Chemnitz, Bd. I, Abth. 26. 85, pl. 16, figs. 7, 8.

MEASUREMENTS: Length, 29.2 mm.; greatest diameter, 17.1 mm.; apical angle, 41°; sutural angle, 87°.

COLOR: Ground, white or cream white, with irregular patches of dark reddish brown, the amount of brown on different individuals varying greatly.

The shell is thick and heavy, with relatively coarse spirals and narrow, sharp ribs.

The youngest volution preserved is 2 mm. in diameter. It bears two strong, equal spirals with intercalated spirals of two higher orders and fine spirals on the shoulder. All are crossed by ribs, which on the later volutions of the shell become narrow, with wide interspaces. The ornamentation retains the same character, with an increase in the number of intercalated spirals for the three succeeding volutions, after which the lower of the two primary spirals becomes weaker, changing the outline of the volution, as described above, from an obtuse angle to a right angle. Varices occur on the later whorls to the number of about two to the volution. The spirals become closely crowded just below the suture, and there is a tendency toward the formation of a sub-sutural band, but it never becomes well developed. On the later portion of the body volution small nodes are developed on the stronger spirals.

The aperture is broadly oval, with a well-developed posterior tooth and short, oblique anterior canal. The callus of the inner lip is thick and rather narrow. The outer lip is flaring and crenulated.

HORIZON AND LOCALITIES: Recent. Indian Ocean, Japan, Oceanica.
No. 20127, Columbia University collection.

REMARKS: This species is a near relative of *C. menkei*, differing in the characters enumerated above and, like that species, reveals in its development its relationship to *C. tuberosum*.

Cerithium citrinum *Sowerby*

1855. *Cerithium citrinum* SOWERBY, Thesaurus Conch., II, 855, pl. 179, fig. 66.
1866. *Cerithium citrinum* REEVE, Conch. Icon., No. 1, pl. 1, fig. 1.
1887. *Cerithium citrinum* TRYON, Manual of Conch., IX, 123, pl. 20, fig. 21.
1898. *Cerithium citrinum* KOBELT, Syst. Conch.-Cabinet von Martini u. Chemnitz, Bd. I, Abth. 26, 110, pl. 22, fig. 23.

MEASUREMENTS: Length, 30.5 mm.; greatest diameter, 15.5 mm.; apical angle, 37°; sutural angle, 87°.

COLOR: Cream white, with streaks and patches of pale brown.

The youngest volution preserved on this shell is 2 mm. in diameter, and its ornamentation is similar to that of the fourth volution on *C. menkei.* It has two strong equal spirals, one intercalated spiral and five fine spirals on the shoulder. One spiral is on the lower slope of the whorl. The ribs on this species are broad and, for the first five volutions, broader than the spaces between them. The two primary spirals remain equal in strength for seven volutions, after which the lower spiral is weaker, but the outline of the volution never becomes sharply angular, as in the preceding species. The secondary spirals of the shoulder and the lower slope of the whorl become as strong as the primary ones, and the outline of the volution becomes regularly curved. Extremely fine spirals of higher order are rapidly introduced, while the primary and secondary spirals are raised into ridges carrying the finer spirals with them, so that the whole surface appears to be covered with bundles of fine spirals having deep grooves between them. The ribs disappear on the body volution, with the exception of one strong varix on the side opposite the aperture, as is usual in shells of this group. Nodes are absent from the entire surface.

The aperture is broadly oval. The callus of the inner lip is thick and narrow, with a prominent posterior tooth. The anterior canal is long and the margin of the outer lip thick and crenulated.

HORIZON AND LOCALITY: Recent. Bird Islands, Pacific Ocean.

No. 20128, Columbia University collection.

REMARKS: *Cerithium citrinum* differs from *C. columna* in the more delicate surface ornamentation, the rounded outline of the volutions and, with the exception of one varix, the absence of ribs and nodes on the body volution. It also has a longer anterior canal. This species differs from *C. menkei* in the absence of sharply angular volutions and in the disappearance of ribs on the body whorl.

Cerithium citrinum mut. bicolor *Hombron et Jacques*

1842-1853. *Cerithium bicolor* HOMBRON et JACQ. Voyage au Pole Sud., pl. 23, figs. 14, 15.
1887. *Cerithium citrinum* TRYON, Manual of Conch., 123, pl. 2, fig. 22.
1898. *Cerithium citrinum* KOBELT, Syst. Conch.-Cabinet von Martini u. Chemnitz, Bd. I, Abth. 26, 111.

MEASUREMENTS: Length, 29.7 mm.; greatest diameter, 16.3 mm.; apical angle, 44°, changing to 30° on the last three volutions; sutural angle, 86°.
COLOR: Cream white with patches of a slightly darker yellowish tone.

The first two of the volutions preserved are precisely similar to those of *Cerithium citrinum.* On the third volution the ribs become contracted, leaving broad interspaces, as in *C. columna,* but the spirals retain the characteristic development of *C. citrinum*—that is, bundles of spirals with deep grooves between them. This type of ornamentation is carried still farther on the mutation *bicolor,* until, as early as the seventh volution, the interspaces are smooth and nearly or quite as wide as the groups of spirals themselves. The upper of the two primary spirals becomes slightly stronger than the lower as early as the fourth volution, and the two retain the same relative strength for seven volutions. The eighth volution attains the angular outline characteristic of *C. columna.* All the spirals of this form are prominent and sharply defined, even more so than on either *C. citrinum* or *C. columna.* On the body volution all the strong spirals break up into fine nodes.

The aperture is broadly oval, with a posterior tooth and short, oblique anterior canal. The outer lip is strongly crenulated. The callus of the inner lip is strong and not closely applied to the surface of the shell.

HORIZON AND LOCALITY: Recent. Philippines.
No. 20129, Columbia University collection.

REMARKS: This shell has the prominent shoulder of *C. columna,* while retaining the thin shell, fine sculpture and development of spirals characteristic of *C. citrinum.*

Cerithium scabridum *Reeve*

1866. *Cerithium scabridum* REEVE, Conch. Iconica, XV, No. 52, pl. 8, fig. 52.
1887. *Cerithium columna* mut. *scabridum* TRYON, Manual of Conch., IX, 123, pl. 20, fig. 20.
1898. *Cerithium scabridum* KOBELT, Syst. Conch.-Cabinet von Martini u. Chemnitz, Bd. I, Abth. 26, 210, pl. 37, fig. 6.

MEASUREMENTS: Length, 20.5 mm.; greatest diameter, 11.4 mm.; apical angle, 34.5°; sutural angle, 82.5°.
COLOR: White with the more prominent spirals sparingly touched with brown.

The youngest volution preserved probably corresponds with the fourth volution of *C. menkei,* being 2 mm. in diameter. This volution has two strong, equal spirals and three intercalated ones. The shoulder has five and the lower slope of the whorl one additional spiral. Ribs are present to the number of eleven on this volution. The ornamentation resembles that of *Cerithium citrinum* in being made up of bundles of fine spirals, but the depressions between the groups are less deeply carved than in that species. The two primary spirals remain equal for five volutions, after which the outline of the volution becomes angular, but not sharply so as in *C. menkei.* On this shell, as usual in this group, it is the upper of the primary spirals which is most prominent. The ribs become weaker on the body volution and disappear on the later portion of it. On this portion of the shell, also, all the coarser spirals break up into rows of small nodes. A large varix is present on the side of the body volution opposite the aperture.

The aperture is broadly oval, with a well-developed posterior tooth, narrow callus and short anterior canal. The outer lip is finely crenulated by the spirals of the outer surface and not flaring.

Horizon and locality: Recent. Both Reeve and Kobelt report the locality of the species as unknown. The specimens in the collection of Columbia University referred to this species are from the Bird Islands, Pacific Ocean.
No. 20130, Columbia University collection.

Remarks: This little shell is nearest to *C. citrinum,* but it differs in its smaller size, white color, less deeply carved surface ornamentation, the more angular outline of the volutions and the short anterior canal. From the mutation *bicolor,* it differs in size and color and in the less prominently developed shoulder.

Cerithium mediterraneum *Lamarck*

1843. *Cerithium mediterraneum* Lamarck, Animaux sans vert., IX, 313.
1855. *Cerithium mediterraneum* Sowerby, Thesaurus Conch., II, 865, pl. 178, fig. 50; pl. 101, figs. 128, 131-133.
1866. *Cerithium mediterraneum* Reeve, Conch. Iconica, XV, No. 53.
1887. *Cerithium rupestre* Tryon, Manual of Conch., IX, 126, pl. 21, fig. 48.

Measurements: Length, 25 mm.; greatest diameter, 12.4 mm.; apical angle, 39.8°, changing to 25° on the seventh volution; sutural angle, 77.5°.

Color: Cream white, mottled with streaks of yellow or brown. Color bands usually passing transversely across the spirals, but when parallel with them seeming to occupy the depressions between the spirals rather than their more convex portions.

The youngest volution preserved is .9 mm. in diameter. This volution is ornamented by two strong, equal spirals, with two finer spirals on the shoulder and all the spirals crossed by ribs. The succeeding volution has a fine spiral intercalated between each two of the three already existing, and more spirals are rapidly introduced on the later volutions. The spirals on the adolescent and adult whorls of this shell are all flattened, their limits being defined only by the exceedingly fine grooves between them. The lower primary spiral begins to decrease in strength on the sixth volution, and the seventh has a sharply angled outline. On this volution a row of fine nodes is formed just below the upper and above the lower suture. On the body volution the shoulder is lost, and the surface is ornamented by five or more rows of low nodes.

The aperture is oval. The callus of the inner lip is thick and has a strong posterior tooth. The outer lip is thick and smooth. The anterior canal is short and slightly bent backward.

HORIZON AND LOCALITY: Recent. Mediterranean Sea.
No. 20131, Columbia University collection.

REMARKS: *Cerithium mediterraneum* has its nearest relative in *C. citrinum* mut. *bicolor*. It differs in having flattened spirals not grouped in bundles, as in the latter species. On the whorls having an angular outline the reduced primary spiral becomes so much flattened that the outline of the lower as well as the upper slope of the volution is nearly a straight line. In the preceding species, which are similar to *C. mediterraneum*, the lower primary spiral is always stronger and easily distinguishable from the secondary ones. From *C. columna* this species differs in having finer surface ornamentation, with flattened spirals and broader ribs and in the loss of the shoulder on the body volution.

The last five species and one variety, namely, *C. menkei, C. columna, C. citrinum* and its mutation *bicolor, C. scabridum, C. mediterraneum*, constitute a group of closely related forms. They are evidently all developed from a common ancestor and for the early portion of their life history follow the same path of development. The divergence observed in the neanic and ephebic stages of growth are all due to differences in the degree of development or in the grouping of the various features of the surface ornament. In *C. menkei* the development of the spirals and the sharply angled outline of the whorls are emphasized; in *C. columna* the development of the shoulder and of the ribs are distinctive, and in *C. citrinum* and its variety the grouping of the spirals in clusters is noticeable. They might all be regarded as varieties of one species, as suggested by Tryon, or their divergence in the adult stage might be considered great enough to entitle them to rank as distinct species. The latter method seems to the writer best to represent the degree of development which these shells have reached.

Cerithium dialeucum *Philippi*

1851. *Cerithium dialeucum* Philippi, Abbildungen, III, 14, pl. 1, fig. 5.
1866. *Cerithium dialeucum* Reeve, Conch. Iconica, XV, No. 18.
1887. *Cerithium dialeucum* Tryon, Manual of Conch., IX, 130, pl. 23, figs. 87, 88.
1898. *Cerithium dialeucum* Kobelt, Syst. Conch.-Cabinet von Martini u. Chemnitz, Bd. I, Abth. 26, 167, pl. 31, figs. 8, 9.

Measurements: Length, 31.4 mm.; greatest diameter, 15 mm.; apical angle, 45°, changing to 25.2° on the last two volutions; sutural angle, 79°.
Color: Grayish white on the spirals with alternating bands of dark reddish or purplish brown in the grooves between the spirals.

The youngest volution preserved is 1.5 mm. in diameter, but it reveals nothing of the development at this stage, for the ornamentation is nearly obliterated on the first three volutions. The third volution, however, indicates the presence of two strong spirals crossed by ribs. The fourth volution has an oblique-angled outline formed by two primary spirals and three intercalated ones. Spirals of the first, second and third orders are present on the shoulder and all are crossed by prominent ribs, with varices to the number of about three on a volution. The different orders of spirals on this shell are clearly indicated by a marked difference in size. The two primary spirals remain of equal strength for about six volutions, after which the lower becomes somewhat weaker and one of the spirals on the shoulder becomes stronger, so that on the last two volutions the shell has three strong spirals, of which the median one is the most prominent, and intercalated spirals to the fourth order are also present. The whorls of the neanic shell are rounded in outline, and only the later portion of the body volution becomes somewhat angular. The lower slope of the body whorl bears six or more strong spirals with intercalated ones, all of which tend to become nodose toward the end of the whorl.

The aperture is oval. The callus of the inner lip is narrow, with a prominent posterior tooth. The anterior canal is oblique and of moderate length. The interior of the outer lip is deeply grooved to correspond with the spirals of the outer surface. The grooves of this surface are white like the spirals, and the ridges are colored to correspond with the depressions of the outer surface. A narrow margin of the outer lip is thick, smooth and white.

Horizon and locality: Recent. Philippines.
No. 20132, Columbia University collection.

Remarks: This shell is distinguished from all members of the *Cerithium columna* group by the strong and regular variation in the width of the spirals to correspond with their order of introduction. The regular banding in color is also a distinguishing feature. The general form of the shell, its early development and the form of the aperture all indicate its relationship to the *C. tuberosum* group.

Cerithium album *Hombron et Jacques*

1842-1853. *Cerithium album* Hombron et Jacq., Voyage Pole Sud., V, 101, pl. 23, figs. 22, 23.

1887. *Cerithium echinatum* Tryon, Manual of Conch., IX, 124, pl. 20, fig. 26.

1898. *Cerithium echinatum* Kobelt, Syst. Conch.-Cabinet von Martini u. Chemnitz, Bd. I, Abth. 26, 102.

Measurements: Length, 31.4 mm.; greatest diameter, 17.3 mm.; apical angle, 52.5°, changing abruptly to 23° on the last two volutions; sutural angle, 76.5°.

Color: White or cream white with occasional streaks of dark brown.

Youngest volution, 3 mm. in diameter, bearing the two strong spirals always found in the young stages of this group, with three intercalated spirals. Fine additional spirals are present on the shoulder and the lower slopes of the whorl. The ribs are numerous and nearly as wide as the spaces between them. Fine spirals are rapidly introduced, becoming so crowded below the suture that they form a broad sub-sutural band which, unlike that of *Cerithium tuberosum,* retains the slope of the remainder of the shoulder. On the fifth volution preserved, which is probably the ninth of a complete shell, this sub-sutural band breaks up into a row of small nodes, and the ribs become ill-denfined, giving place to a row of strong nodes on the upper of the two primary spirals. The angle of the shoulder, except in the youngest stages, is very wide, and on the body volution it disappears altogether, being replaced by strongly nodose spirals, of which there are five on this volution with fine rows of nodes between them.

The aperture is oval, with a well-developed posterior tooth and short, oblique anterior canal. The outer lip is strongly fluted, and the callus of the inner lip is narrow.

Horizon and locality: Recent. Baker's Island, Pacific Ocean.
No. 20133, Columbia University collection.

Remarks: This species has been considered synonymous with *Cerithium echinatum,* but it differs from the latter species in several important respects. Beyond the young stages, the shoulder of *C. album* is never well defined, and the neanic whorls lack altogether the strongly spinose character of *C. echinatum* at the same age. The apical angle of *C. album* is much wider, and the abrupt change in the slope of the sides on the last two volutions is not found on *C. echinatum*. The youngest stages of this shell are closely similar to those of the species already described, but in the adult the ornamentation develops rows of small nodes instead of the shoulder angle present on many species of the group.

Cerithium graciliforme *Sowerby*

1866. *Cerithium graciliforme* Sowerby, apud Reeve, Conch. Iconica, XV, No. 49.
1887. *Cerithium eburneum* Tryon, Manual of Conch., IX, 129, pl. 22, fig. 77.
1898. *Cerithium graciliforme* Kobelt, Syst. Conch.-Cabinet von Martini u. Chemnitz, Bd. I, Abth. 26, 124, pl. 24, fig. 9.

Measurements: Length, 24.2 mm.; greatest diameter, 9.7 mm.; apical angle, 35.3°, changing on the ninth volution to 26°; sutural angle, 86.7°.
Color: White with occasional spots of pale brown.

The youngest volution preserved is .5 mm. in diameter, but it is too much corroded to show its form. The next volution is also much worn, but shows that it has two equal spirals crossed by ribs. On the third volution the same type of ornamentation continues, with three fine spirals on the shoulder. A single spiral is intercalated between the two primary ones on the fourth volution, and there are four fine spirals on the shoulder and one on the lower slope of the whorl. On the fifth volution, three varices are developed, while the ribs between them become much narrower. Varices continue to be formed throughout the life of the shell and constitute a striking feature of its ornament. The shoulder becomes nearly obsolete, and the ribs break up into nodes until, on the tenth volution, the surface is marked by a strong varix and four rows of nodes, of which the second below the suture is weaker than the others. This type of ornamentation continues for the remaining three volutions.

The aperture is broadly oval. A posterior tooth is present, but is not strongly developed. The callus of the inner lip is thin, and the outer lip is nearly smooth. The canal is short and slightly reflexed at the margin.

Horizon and locality: Recent. The locality of this species is not given in any of the descriptions of it that have been published, and the specimen in the Columbia University collection is also unlabeled.
No. 20134, Columbia University collection.

Remarks: This species resembles most closely *Cerithium eburneum*, and is considered only a variety of that species by Tryon; but it differs in its more slender form, nearly obsolete shoulder and in the great development of varices. It differs also in color, being nearly white. The few pale brown spots are visible only with a lens.

b. American Species

Cerithium eburneum *Bruguière*

1792. *Cerithium eburneum* Bruguière, Hist. Nat. des Vers, Encyclop. Méthod., I, pt. 2, 438.
1887. *Cerithium eburneum* Tryon, Manual of Conch., IX, 129, pl. 22, fig. 75.
1898. *Cerithium eburneum* Kobelt, Syst. Conch.-Cabinet von Martini u. Chemnitz, Bd. I, Abth. 26, 219, pl. 39, figs. 3-6.

Measurements: Length, 25.7 mm.; greatest diameter, 11 mm.; apical angle, 34°, changing to 29.5° on the ninth volution; sutural angle, 85.5°.

Color: White, irregularly marked with patches of color which vary from golden brown to dark reddish brown.

The youngest volution preserved, which is probably the first beyond the protoconch, is .5 mm. in diameter. It has two equal spirals, which remain the only ornamentation of the shell for about one-fourth of a volution. Less accelerated individuals retain this ornamentation for a complete volution. The next features to appear are ribs and two fine spirals on the shoulder. Intercalated spirals are first introduced on the fourth of the volutions preserved, and the same type of ornamentation continues, with the addition of fine spirals for eight volutions. Beyond this the ribs become ill defined and gradually break up into rows of nodes, which are developed on all the strong spirals until, on the volution before the last, there are five such rows. At about the ninth volution the lower of the two primary spirals becomes weaker, while the upper remains strong and defines a slight shoulder at about the middle of the volution. Varices are irregularly developed with not more than two on a volution, and frequently less than two.

The aperture is oval, and a posterior tooth is well developed. The anterior canal is short and rather widely open. The outer lip is crenulated, and the callus of the inner lip is thick and narrow.

Horizon and localities: Recent. West Indies, Florida.
No. 20135, Columbia University collection.

Remarks: The development of this species and its general form are so closely similar to those of *Cerithium tuberosum* as to leave little doubt of their descent from a common ancestor, in spite of the fact that the two shells come from such widely separated localities as the West Indies and the Red Sea. The American species of other genera, as well as *Cerithium*, show such strong evidence of relationship with European forms that we must assume some at present unexplained means of intercommunication between species of the east and west shores of the Atlantic. This connection probably existed at some earlier geological period, since Miocenic species show the same similarity to European forms as do the recent species.

Cerithium caudatum *Sowerby*

1855. *Cerithium caudatum* SOWERBY, Thesaurus Conch., II, 856, pl. 179, figs. 71, 72.
1866. *Cerithium caudatum* REEVE, Conch. Iconica, XV, No. 16.
1898. *Cerithium caudatum* KOBELT, Syst. Conch.-Cabinet von Martini u. Chemnitz, Bd. I, Abth. 26, 112, pl. 22, fig. 4.

MEASUREMENTS: Length, 31.5 mm.; greatest diameter, 14.2 mm.; apical angle, 41°, changing to 29° on the last three volutions; sutural angle, 75°.

COLOR: Golden brown. Lighter in color at the apex and on the varices. Margin of the outer lip white streaked with black.

The apex of the shell is much corroded. The youngest volution to show the surface is 2 mm. in diameter, and has the ornamentation characteristic of this group of ribs and two strong spirals. At this stage intercalated spirals are already introduced between the two primary ones, and spirals of at least two orders are present on the shoulder and on the lower slope of the whorl. The surface ornamentation remains of the same type, with the introduction of more spirals, until the eighth volution, after which the ribs become discontinuous and the stronger spirals break up into nodes. On this volution there is a sub-sutural row of nodes, and each of the two primary spirals also forms a row of nodes. The outline of the volution is an obtuse angle, with a sloping or concave upper surface and vertical sides. On the ninth volution preserved the finest of the spirals have become obsolete, and between the rows of nodes the spirals are comparatively few and coarse, with narrow interspaces. On the body volution the nodes of the lower primary spiral become very small, no larger than those of the secondary spirals. This volution has one row of strong nodes—those of the first primary spiral—a row of sub-sutural nodes somewhat smaller and three rows of fine nodose spirals on the lower slope of the whorl. The intermediate spirals are crenulated, but not distinctly nodose.

The aperture is oval and the callus of the inner lip is thin, with a well-developed posterior tooth. The outer lip is distinctly flaring and finely crenulated along its outer margin. The anterior canal is short and widely open.

Horizon and locality: Recent. Island of Guadeloupe.
No. 20136, Columbia University collection.

The shells of the *Cerithium tuberosum* group, although differing greatly in size, have a general similarity in form and in the essential characteristics of the aperture. Their variation is expressed most strongly in the features of the surface ornamentation. These features consist of spirals of the first and higher orders, ribs, nodes which may develop into spines, and a shoulder varying in extent of development and in form. In order to bring out more clearly the relation between these shells as expressed in their surface ornamentation, they have been plotted in diagrammatic form, arbitrary signs being chosen to represent certain features of the ornamentation. On plate I the numbers at the left of the page indicate the volutions, the protoconch being numbered one. The protoconch, when present, is represented by a circle. The spirals are represented as horizontal lines, for while they are actually longitudinal elements, on the shell they appear horizontal, and the diagram being intended merely to represent certain features in graphic form, it retains the line most readily associated in the mind with what is seen on the shell. For a similar reason ribs are represented as vertical lines. Secondary spirals and those of higher order are represented by two horizontal lines. Nodes are indicated by dots, and the outline of the volution is represented by the lines which would be used in drawing its two upper slopes—that is, an obtuse angle changing to a right angle to agree with the development of certain shells. The diagram is intended to represent resemblances and differences in a general way only. It records the introduction of spirals, ribs and nodes, but does not attempt to show the different kinds and degrees of development which they attain or such features as size, degree of embracing of the whorls, etcetera. More complete details are given in the descriptions and figures of the different species.

The diagram brings out the fact that some species are more retarded than others; for example, *Cerithium menkei* is a more retarded shell than *C. adansoni,* as shown by the fact that on the former species the change in the outline of the whorl does not take place until the ninth volution, and nodes are not acquired until the last volution, while both these changes occur much earlier on *C. adansoni.* A similar comparison has already been made between *C. tuberosum* and *C. adansoni.*

The diagram also shows differential acceleration and retardation of related species as in *C. echinatum* and *C. graciliforme.* On the former the oblique-angled outline is lost on the seventh volution, while retained until the tenth on the latter. Nodes are, however, acquired on the ninth volution of *C. graciliforme,* and do not appear until the twelfth volution of

C. echinatum. As compared with *C. graciliforme,* therefore, *C. echinatum* is accelerated in the acquisition of the sharply angled outline of the volution, but retarded in the development of nodes.

A marked similarity in the early development of these species is well illustrated by the diagram. If a card be placed over the lower part of it the eye is at once struck by the uniformity of the figures; moving the card downward, differences begin to appear, becoming wider as representations of the adult stages are reached. The divergence would be even more marked if all the features of the shell could be indicated, instead of the mere presence or absence of the five features represented.

2. *Genera and Species of Recent Shells closely related to the Cerithium tuberosum Group*

Genus Vulgocerithium *Cossmann*

1906. *Vulgocerithium* Cossmann Essais de Paléoconch. Comp., VII, 77.

Genotype *Cerithium vulgatum* Bruguière:

This genus is closely related to *Cerithium* sens. str. The early stages of the genotype *Cerithium vulgatum* are closely similar to those of *C. tuberosum.* The adult differs in a number of rather constant features and therefore may be considered distinct. The surface ornamentation of the adult shell is characterized by the development of ribs or large nodes, a sub-sutural row of smaller nodes, and by the coalescence of the fine spirals into flattened bands defined by extremely narrow grooves. The margin of the anterior canal is usually slightly reflexed.

M. Cossmann's main points of difference from *Cerithium* sens. str. are not only the elongate form of the shell and characteristic surface ornament, but especially the form of the aperture. The absence of the more rapid growth on the anterior part of the outer lip, which forms a projecting tooth in some species of *Cerithium*, is considered of most importance, and the shorter siphonal canal and less flaring outer lip are also mentioned.

Vulgocerithium vulgatum *Bruguière*

1757. *Le Goumier* Adanson, Histoire Naturelle du Sénégal, 1757, p. 156, pl. 10, fig. 3.

1792. *Cerithium vulgatum* Bruguière, Dictionaire, No. 13.

1855. *Cerithium vulgatum* Sowerby, Thesaurus Conch., II, 864, pl. 178, fig. 43; pl. 179, fig. 67.

1898. *Cerithium vulgatum* Kobelt, Syst. Conch.-Cabinet von Martini u. Chemnitz, Bd. I, Abth. 26, 87, pl. 17, figs. 1-8; pl. 18, figs. 1-4.

1906. *Vulgocerithium vulgatum* Cossmann, Essais de Paléoconch. Comp., VII, 77.

MEASUREMENTS: Length, 63.7 mm.; greatest diameter, 21.4 mm.; apical angle, 26.5°, changing to 23° on the twelfth volution; sutural angle, 88°.

COLOR: Background of bluish white, marked by numerous spiral bands of reddish brown, which on the young shell is deepest in the grooves between the spirals, but on the later and adult whorls irregular patches of color cover most of the surface.

The only specimen studied which retains the protoconch is somewhat worn at the apex, but the protoconch appears to be like that of *Cerithium adansoni.* The second and third volutions are so similar as to be well illustrated by the drawings of these two whorls on *C. adansoni* (plate III, figs. 3, 4), but the shell at this age is about twice the size of *C. adansoni* at the same age. The fourth volution is like that of *C. adansoni,* except that about every third rib is much larger, forming a strong varix. These varices occur at gradually wider intervals up to the eleventh volution, when they disappear from the specimen described. The presence of varices is a variable feature, since in a series of specimens otherwise similar the varices are more prominent and persist for a longer time on some specimens than on others. Except for the presence of varices, the surface ornamentation is like that of *Cerithium tuberosum* to the seventh volution, when small nodes appear on the sub-sutural band, one at the end of each rib. Beginning with the ninth volution, the lower of the two primary spirals becomes gradually less prominent and the ribs become less well marked, until on the twelfth volution the upper of the two primary spirals only is prominent, forming a row of nodes slightly above the middle of the volution. The ribs, as such, have disappeared, being replaced by the two rows of nodes. Spirals of secondary and higher orders increase rapidly in number, and on the later whorls the finest spirals become confluent, producing broad, flattened bands, with extremely narrow depressions between them. On the body volution below the lower row of strong nodes from three to five large spirals are faintly nodose.

The aperture is elongate oval, with a distinct but not very prominent tooth defining the posterior canal. The outer lip is slightly flaring and shows faint crenulations. The callus of the inner lip is thin. The anterior canal is wide and short, with its margin slightly reflexed.

HORIZON AND LOCALITIES: Recent. Mediterranean Sea, west coast of Africa, and southward to Senegal.

No. 20137, Columbia University collection.

REMARKS: Individuals of this species vary somewhat in the width of the apical angle, in the strength and spacing of the nodes, and the extent to which the fine spirals coalesce and become flattened. At present the species is made to include many synonyms and a large number of varieties, some of which, with a more detailed study of the shells, may prove to be distinct species.

The close similarity of the young stages of this shell to those of *Cerithium tuberosum* has already been referred to, but the very considerable divergence at an early period of the ontogeny entitles it to rank as a distinct, though closely related, genus.

Vulgocerithium breve sp. nov.

Measurements: Length, 34.1 mm.; greatest diameter, 15 mm.; apical angle, 43°, changing to 25.5° on the last two volutions; sutural angle, 76.2°.

Color: Grayish white, mottled with dark brown. Bands of dark brown occupy the depressions between the spirals.

The apex of this shell is much worn. The youngest volution to show the surface ornamentation is 2 mm. in diameter and has the two strong spirals, as in the young of *V. vulgatum*. At this stage intercalated spirals are present, both between the primary spirals, on the shoulder and on the lower slopes of the volutions. On the sixth volution of those preserved the ribs become especially prominent at the level of the upper primary spiral, and a sub-sutural row of nodes is also developed. On the whorl before the last the center of the rib becomes very prominent, and on its lower slope the spirals have a tendency to coalesce and become flattened, but this tendency is never carried very far on this species. On the body volution the ribs become weaker and the sub-sutural row of nodes stronger, until the two are of about equal strength.

The aperture is broadly oval, and the callus of the inner lip is thin, with a prominent posterior tooth. The outer lip is slightly flaring and faintly crenulated. The anterior canal is short, with its margin slightly recurved.

Horizon and locality: Recent. The specimens in the collection of Columbia University were collected by D. M. Sankey in deep water off the mouth of Grand River, northwest Mauritius.

No. 20138, Columbia University collection.

Remarks: The species is distinguished from *Vulgocerithium vulgatum* by its shorter form, wider apical angle and heavier and more prominent nodes, which make the outline of the volutions sharply angular. The shell is also thicker and the spirals are more rounded than is usual with *V. vulgatum*.

Vulgocerithium plicatum *Philippi*

1836. *Cerithium plicata* Philippi, Enum. Moll. Sicil., p. 192.
1887. *Cerithium vulgatum* Tryon, Manual of Conch., p. 126.

Measurements: Length, 25.1 mm.; greatest diameter, 1.4 mm.; apical angle, 42°, changing to 24° on the last three volutions; sutural angle, 78°.
Color: Background white, thickly mottled with yellow and golden brown.

The apex of the shell is much corroded, but a volution 1 mm. in diameter shows that it possesses ribs and two spirals. The fifth volution is the first to show the ornamentation plainly, and on this the spirals are broad, but not greatly flattened, and the oblique-angled outline is still retained. The embracing of the whorls is so great as to nearly cover the lower slope of the whorl. The succeeding volutions develop a sub-sutural row of nodes and the ribs are strongly defined. The upper primary spirals remain always the more prominent, and the vertical element in the outline of the shell disappears at about the eighth volution. The adult ornamentation consists of strong ribs, which are most prominent at the level of the first primary spiral, and a sub-sutural row of nodes. The spirals are broad and somewhat flattened, with narrow depressions between them. On the body volution the ribs become narrow, crowded and so low as to be nearly obsolete. The sub-sutural row of nodes is here the most prominent feature of the ornamentation.

The aperture is oval, and the callus of the inner lip is thick, with a well-defined posterior tooth. The outer lip is thick and smooth, with an entire margin. The anterior canal is short and widely open.

Horizon and locality: Recent. Locality unknown.
No. 40237, Columbia University collection.

Remarks: *Vulgocerithium plicatum* has been regarded by Tryon as a variety of *Vulgocerithium vulgatum,* but it differs from that species in its smaller size and in its more continuous and more prominent ribs, with their most convex portion at the center of the volution instead of above the center. It also has broader and more rounded spirals, and the anterior canal is proportionally shorter.

This species is related to the *V. vulgatum* group in the development of the young whorls and in the general form of the shell and of the aperture. The sub-sutural row of nodes and the ribs are the most noticeable features of the ornamentation.

Vulgocerithium gracile *Philippi*

1836. *Cerithium gracilis* Philippi, Enum. Moll. Sicil., p. 193.
1887. *Cerithium vulgatum* Tryon, Manual of Conch., p. 126, pl. 21, fig. 43.

Measurements: Length, 30.8 mm.; greatest diameter, 11 mm.; apical angle, 39.5°, changing to 17° on the last three volutions; sutural angle, 82.5°.
Color: Yellowish white, mottled with reddish brown, which usually passes in sinuous lines across the spirals.

The ornamentation is entirely obliterated on four volutions of the best specimen available. The fifth volution has the usual two strong spirals, and there are at this stage three intercalated spirals, with at least four on the shoulder and two on the lower slope of the volution. All the spirals are crossed by ribs, and varices occur to the number of about three to the volution. A similar type of ornamentation persists to the seventh volution. At this stage the spirals are still distinct, and the embracing of the whorls is loose enough to leave a well-marked slope below the lower strong spiral. On the next two volutions the finer spirals gradually coalesce with the coarser ones, which then become broad and flattened. The ribs between the varices become very narrow, and a sub-sutural row of nodes is developed. The adult ornamentation is characterized by numerous narrow ribs projecting in a sharply pointed but not very prominent node at the level of the first primary spiral. The slight shoulder is concave and the lower slope of the whorl gently convex. A sub-sutural row of nodes is present on the adult whorls, and a row of fine nodes appears just above the suture. The ribs become nearly obsolete on the body volution, being represented by two rows of nodes.

The aperture is of the type usual in this group, with an oval outline, a narrow callus and a posterior tooth. The outer lip is slightly flaring, and the anterior canal is a little longer than in the last species, with a narrow opening and slightly reflexed margin.

Horizon and locality: Recent. Locality unknown.
No. 20139, Columbia University collection.

Remarks: The species has been referred to *Vulgocerithium vulgatum*, but it is distinguished by its smaller size, proportionally coarser and more rounded spirals and by the more sharply pointed form of the main row of nodes. The spirals below the slight shoulder become rounded and irregularly nodose, instead of flattened and inconspicuous, as in *V. vulgatum*.

The shell bears a close resemblance to the last species described, but it differs in several important respects. The development is much more retarded than that of *V. plicatum*, since the coalescence of the spirals does not begin until the seventh volution, as compared with the fourth volution on the preceding species. The embracing of the whorls is not so close as on *V. plicatum*. The adolescent and adult stages are distinguished by the much smaller nodes of the present species and by the form of the node, which is sharp and pointed at the apex in *V. gracile,* as compared with the blunt but more prominent and more elongate nodes of *V. plicatum*. The anterior canal also differs in being longer, narrower and slightly recurved.

Vulgocerithium adenense *Sowerby*

1866. *Cerithium adenense* Sowerby, apud Reeve, Conch. Iconica, XV, No. 89.
1887. *Cerithium adenense* Tryon, Manual of Conch., IX, 124, pl. 20, fig. 30.
1898. *Cerithium adenense* Kobelt, Syst. Conch.-Cabinet von Martini u. Chemnitz, Bd. I, Abth. 26, 196, pl. 35, fig. 12.

Measurements: Length, 23.2 mm.; greatest diameter, 8.4 mm.; apical angle, 32.5°, changing to 21° on the last four volutions; sutural angle, 83.5°.

Color: Yellowish or grayish white, with ill-defined sinuous lines of reddish brown crossing the spirals.

The apex of the shell is broken away. The youngest volution studied is 1.4 mm. in diameter and has the usual two strong spirals, with one intercalated spiral and one or two spirals on the shoulder. Well-developed ribs cross all the spirals. The ornamentation remains of the same type, with the addition of spirals for the next three volutions. On the fifth of the volutions preserved a sub-sutural row of irregular, low nodes is developed, and the upper primary spiral forms sharp-pointed nodes where crossed by ribs. On the later volutions the coarser spirals become broad and flat, with fine grooves between them, and the finer spirals become obsolete. The adult ornamentation is that of widely spaced ribs, which are almost spinose where crossed by the upper primary spiral. The upper slope of the rib is concave and the lower slope straight or slightly convex, which gives the center of the rib the appearance of an upward-pointing, blunt spine. There are three rows of finely nodose spirals on the lower slope of the body volution.

The aperture is elongate oval. The callus of the inner lip is moderately thick, with a well-developed posterior tooth, and the outer lip is thin. The anterior canal is short and widely open.

Horizon and localities: Recent. Island of Karak, Persian Gulf, Gulf of Aden.

No. 20140, Columbia University collection.

Remarks: This little species is nearest to *V. vulgatum* but is distinguished by the great difference in the size of the shell and the size and extreme sharpness of the principal row of nodes, which give the volution a distinctly angular outline. The sub-sutural row of nodes is less well defined than on *V. vulgatum*.

The species is distinguished from *V. plicatum* and *V. gracile* by its sharp nodes and the greatly flattened spirals.

B. PLEISTOCENIC SPECIES OF VULGOCERITHIUM

Vulgocerithium vulgatum

M. Cossmann figures, on plate 3, fig. 14, of his Essais de Paléconchologie, a specimen from the Pleistocenic of Saix, which he refers to this species. It is smaller than the normal recent individuals, and the nodes of the principal row are prominent and somewhat widely spaced.

C. PLIOCENIC SPECIES OF CERITHIUM

No specimens of the *Cerithium tuberosum* group from the Pliocenic of the Eastern Hemisphere are available for study, and the information furnished by the literature is meager.

Cerithium crenatum Brocchi, figured in Quenstedt's Petrefaktenkunde Deutschlands, plate 204, fig. 46, is of a small specimen from the Pliocenic of Asti, which may belong in this group. It has the oval aperture, posterior tooth, and crenulated outer lip of *Cerithium* sens. str. It also has in the young stages two rows of nodes which are stronger than the others, but in the absence of specimens it is impossible to be sure that it is correctly placed here.

In the American Pliocenic several species occur which apparently belong in this group. Of these only two actual specimens were obtainable, but good figures and descriptions aid in determining the relationship of others.

Cerithium callisoma *Dall*

Plate VII, fig. 1; plate VIII, figs. 1, 2; plate IX, fig. 1.

1892. *Cerithium callisoma* Dall, Trans. Wagner Free Institute of Sci., III, pt. 2, 282, pl. 14, fig. 8.

Measurements: Length, 20.8 mm.; greatest diameter, 8 mm.; apical angle, 35°, changing to 26° on the last three volutions; sutural angle, 80°.

The youngest volution preserved on the specimens studied is .4 mm. in diameter and has three spirals, of which the two lower are equal in size and stronger than the upper one. Ribs are also present at this stage.

On the fourth of the volutions preserved one spiral is intercalated between each pair of primaries and the upper primary spiral becomes weaker, making the shoulder more pronounced. The sixth volution has three fine spirals intercalated between the two strong primary ones, with one above and one below the third primary spiral. The lower slope of the volution has at this stage two spirals, one stronger than the other. The same type of ornamentation persists throughout the growth of the shell, with an increase in the number of spirals, which vary in strength according to the order of their introduction. The third primary spiral on the shoulder remains always stronger than any secondary spiral, but not so strong as the other two primaries. The latter become very prominent and produce the well-defined oblique-angled outline of the volution so characteristic of *Cerithium tuberosum*.

The aperture has the usual oval form of the shells of this group, with a narrow, thick callus and prominent posterior tooth. The anterior canal is short and widely open.

Horizon and locality: Pliocenic of the Caloosahatchie beds, Florida. No. 12569, American Museum collection.

Remarks: The first three volutions preserved on this shell recall the seventh, eighth and ninth volutions of the Eocenic species, *Cerithium retardatum* (plate iv, fig. 10; plate v, fig. 9). On the latter shell three spirals are developed, the two lower of which are stronger than the upper, and the first intercalated spiral appears between the strong spirals. A similar development is seen on *C. callisoma*, but it is more accelerated than *C. retardatum*, since its shoulder is distinguishable from the first, while *C. retardatum* never acquires a distinct shoulder, but retains the primitive rounded outline of its volutions throughout life.

C. callisoma is most closely related to the recent species *C. tuberosum*, but it is more primitive than the latter species, since it retains the oblique-angled outline of the volutions throughout life without a trace of weakening of the lower spiral, while on *C. tuberosum* the lower primary spiral becomes gradually less prominent, until on the body volution the outline is sharply angular. The resemblance of the adult *C. callisoma* to the young *C. tuberosum* is most striking, and if the latter species were from a less distant locality, we might at once assume it to be the Pliocenic ancestor of *C. tuberosum*. As it is, we may suppose that *C. callisoma* is the American representative of this ancestor, which existed in the vicinity of the Red Sea or the Indian Ocean, but has not yet been recorded from that locality.

Cerithium floridanum *Mörch*

1876. *Cerithium floridanum* Mörch, Malacologia Blätter, XXIII, 114.
1892. *Cerithium floridanum* Dall, Trans. Wagner Free Institute of Sci., Phila., III, pt. 2, Dec., 282, pl. 14, fig. 10.

Measurements: Length, 34.2 mm.; greatest diameter, 14 mm.; apical angle, 29°, changing to 22° on the twelfth volution; sutural angle, 86°.

The protoconch of the specimen studied is much worn, but is apparently of the same form as that of *Cerithium adansoni.* The succeeding three volutions are too much worn to show the ornamentation. The first volution on which surface features appear distinctly is the fifth, which has a diameter of 1.9 mm. It bears ribs and two strong spirals. The shoulder is long and has three fine spirals, with a sub-sutural band composed of two elevated spirals. A single spiral is intercalated between the two strong ones, and the lower slope of the volution is very short. The earlier whorls of the shell bear an irregular number of varices averaging about two or three on a volution. On the sixth and seventh volutions the sub-sutural band gradually breaks up into a row of nodes and the spirals become larger, but do not increase rapidly in number. On the eighth and ninth volutions the larger spirals become nodose where crossed by the ribs, and on the next volution the nodes of the sub-sutural row and those of the first primary spiral become larger than the others and of equal strength. At the same time the nodes of the second primary spiral become weaker. On the two succeeding volutions the large nodes just below the suture and those of the upper primary spiral are in line vertically, forming distinct ribs, while the nodes of the lower primary spiral are small and twice as numerous as those of the upper row. The spirals on both the shoulder and lower slopes of the whorl alternate in strength according to their order of introduction and are strongly defined by the deep, narrow grooves between them. On the thirteenth and last volution the nodes of the lower primary spiral become very small and numerous—a mere line of beading around the shell.

The body volution and the aperture are much broken, but the inner lip is preserved, showing that it has a thick callus with a blunt posterior tooth, and the anterior canal is short and rather widely open.

Horizon and localities: Pliocenic. Caloosahatchie beds and Osprey, Manatee County, Florida.

No. 12568, American Museum collection.

Remarks: The adult ornamentation of this little shell shows some variation from the figure given by Dall [1892, plate 14, fig. 10] in the marked difference in the strength of the subordinate spirals and in the more angular outline of the adult volutions, but the shell agrees with the description and figure in essential respects. Its early development and the general character of its adult features show it to belong undoubtedly to the *Cerithium tuberosum* group.

Cerithium glaphyrea *Dall*

1892. *Cerithium glaphyrea* DALL, Trans. Wagner Free Institute of Sci., Phila., III, pt. 2, p. 283, pl. 14, fig. 4.

MEASUREMENTS (Dall): Length, 16 mm.; greatest diameter, 6 mm.; REMAINING MEASUREMENTS FROM FIGURE: Apical angle, 23°; sutural angle, 88°.

No specimen of this species has been obtainable, but from the original description and figure the following features of interest in this connection may be determined. From the figure it appears that the shell has two spirals stronger than the others, with fine spirals between the two primary ones and on the shoulder. A third strong spiral on the shoulder becomes nodose, but is not so strong as the two main spirals. All the spirals are crossed by numerous closely set ribs. The two strong spirals remain of equal strength and continue to form an oblique angle for the whorl until the body volution is reached, when the lower of the two becomes weaker.

The aperture is of the type usual in the *Cerithium tuberosum* group, with a narrow callus and strong posterior tooth, flaring, crenulated outer lip and short anterior canal.

HORIZON AND LOCALITY: Pliocenic of the Caloosahatchie beds, Florida.

REMARKS: This species has a strong fundamental resemblance to *Cerithium callisoma* in the form of the body and of the aperture, and in the persistence of the oblique-angled outline of the whorls formed by two strong spirals with a weaker one on the shoulder. The most striking difference is in the very numerous ribs of *C. glaphyrea,* which are so closely set as to appear like rows of nodes where crossed by the coarser spirals. *C. glaphyrea* appears to have the essential characteristics of the *C. tuberosum* group, but probably represents a lateral branch from the main line, expressing its divergence in the development of numerous ribs.

Cerithium glaphyrea mut. litharium *Dall*

1892. *Cerithium glaphyrea* var. *litharium* DALL, Trans. Wagner Free Institute of Sci., Phila., III, pt. 2, 284, pl. 14, fig. 9.

MEASUREMENTS (Dall): Length, 19 mm.; greatest diameter, 6.5 mm.

The mutation *litharium* evidently belongs to the same phyletic series as the species to which it is related, differing only in minor features of the ornamentation, such as more prominent nodes and additional rows of fine beading.

Cerithium algicola ADAMS and *C. muscarum* SAY, from the character of their apertures and the general appearance of the shells, seem to be related to this group, but in the absence of specimens and with very imperfect figures, it is impossible to be certain of their position.

D. MIOCENIC SPECIES

1. *Cerithium.*

So far as can be determined from the literature, the Miocenic of the Eastern Hemisphere furnishes few specimens of the *Cerithium tuberosum* group. This is due doubtless to lack of preservation, rather than to a paucity of species existing during that period.

Cerithium bronni PARTSCH, of the Miocenic of the Vienna Basin, may possibly belong here. [See HÖRNES and PARTSCH, 1856, plate 42, figs. 12*a, b*.] The figure, which gives no clue to the ornamentation of the young shell, is insufficient evidence for placing the shell definitely, but the aperture corresponds with that of *C. tuberosum*, and the ornamentation of the adult is similar in type to that of other species of *Cerithium* sens. str.

An unnamed variety of *C. crenatum* BROCCHI is mentioned by HÖRNES and PARTSCH [1856, p. 409] as occurring in the Miocenic of the Vienna Basin. According to their figures [*loc. cit.*, plate 42, figs. 13, 14], the shell has the adult characteristics of this group, but the features of the young shell cannot be determined from the figures.

Cerithium mediterraneum, described with recent species of *Cerithium*, is recorded by HÖRNES and PARTSCH [1856, p. 393] from the Miocenic of the Vienna Basin.

Cerithium calculosum *Basterot*

1825. *Cerithium calculosum* BASTEROT, Mem. géol. sur les environs de Bordeaux, p. 58, pl. 3, fig. 5.

MEASUREMENTS: Length, 29.8 mm.; greatest diameter, 14.1 mm.; apical angle, 37.2°; sutural angle, 79.3°.

The protoconch is absent from this shell, but the youngest volution preserved is probably the first beyond the protoconch, and it is 1 mm. in diameter. This volution is ornamented by ribs and two equal spirals.

The second volution is like the first, except that it has a third weaker spiral just below the suture and numerous ribs are present at this stage. On the sixth volution of those preserved the sub-sutural spiral becomes nearly as strong as the two primary spirals, and all three become strongly nodose where crossed by the ribs. On the next two volutions the shoulder practically disappears, and the volution seems to be ornamented by three rows of strong nodes with intercalated spirals between them. Varices are irregularly developed from the fifth volution onward and on the later whorls become extremely prominent, forming a conspicuous feature of the ornamentation. Both ribs and varices are set at an angle with the vertical axis of the shell, so that they appear to twist in passing from whorl to whorl. On the tenth volution of those present the two lower spirals again become more prominent than the sub-sutural row, giving an oblique-angled outline to the volution, which has vertical sides and a row of strong nodes on the shoulder. Rather coarse intercalated spirals cover all the surface between the rows of nodes. Just above the suture a row of fine nodes is partially concealed by the succeeding whorl. On the body volution the shoulder is nearly obsolete, and there are six rows of nodes, of which the two upper are the strongest. A very strong varix is present on the side opposite the outer lip.

The aperture is elongate oval, with a narrow, thick callus and well-developed posterior tooth. The outer lip in some individuals is extremely thick, and the aperture in these specimens is somewhat constricted by the addition of material to the inner margin. Other specimens do not show such thickening of the lip. The siphonal canal is short and slightly reflexed at the margin. At an earlier stage of growth the canal was bent toward the left, but the animal has abandoned this position and continued the canal in a downward direction, the earlier growth being left as a curious knob on the outside of the tube.

HORIZON AND LOCALITY: Miocenic. Martillac near Bordeaux.
No. 20141, Columbia University collection.

REMARKS: This species bears a striking resemblance to the Florida species, *C. glaphyrea*, in the closely set ribs, the number of the spirals and the form of the aperture; but it differs in being a more closely coiled form and in having numerous very strong varices.

This species has been made the type of a new genus, *Chondrocerithium*, the distinguishing characteristics being the presence of a columnellar plication and slight differences in the aperture. The development of the species shows its close relationship to *Cerithium*, and the aperture does not differ in any essential respect from many species of that genus. A faint trace of columnellar plication was found on only one of the seven specimens studied, and this barely distinguishable feature seems insufficient ground for the establishment of a new genus.

Cerithium calculosum, mut. globulus n. mut.

Like *Cerithium glaphyrea, C. calculosum* has a variety which differs from the type in having finely nodose spirals intercalated between the stronger ones and in having the row of fine nodes just above the suture fully exposed rather than covered by the next whorl, as in the case of the original species.

Horizon and locality: Miocenic. Martillac near Bordeaux.
No. 20142, Columbia University collection.

Cerithium chipolanum *Dall*

1892. *Cerithium chipolanum* Dall, Trans. Wagner Free Institute of Sci., Phila., III, pt. 2, 285, pl. 22, fig. 7.

Measurements (Dall): Length, 10 mm.; greatest diameter, 4.5 mm.

A specimen of this species has not been obtainable, but a good figure and description make possible the determination of its relationship with a fair degree of probability. The author of the species describes four spirals on each volution, and the figure shows that in the young shell two of these are more prominent than the others, forming the oblique-angled outline of the whorl characteristic of the *Cerithium tuberosum* group. Later in the growth of the shell the lower of the two strong spirals becomes weaker, giving a sharply angled outline to the whorl. On the body whorl two of the spirals on the shoulder increase in size, so that the ornamentation of this volution consists of a shoulder with two strong spirals on its slope and two below the shoulder angle.

The aperture is of the type usual in this group, with a well-developed posterior tooth and short, widely open anterior canal.

Horizon and locality: Older Miocenic of the Chipola beds, northwest Florlda.

Remarks: Dall states that *C. chipolanum* is not closely related to any of his preceding species, which would include *C. callisoma* and *C. glaphyrea,* but he does not say in what respect the divergence is expressed, unless the high development of varices mentioned is considred such a difference. Varices are, however, characteristic features of *Cerithium* sens. str. This little species is more closely coiled than the Pliocenic *C. calli-*

soma or the recent *C. tuberosum* and resembles in that respect *C. adansoni*. It may be the American representative of the Miocenic ancestor of the latter species rather than a member of the direct line toward *C. tuberosum.*

2. *Vulgocerithium*

Specimens of *Vulgocerithium vulgatum* are reported by Hörnes and Partsch [1856, p. 388] from the Miocenic of Italy and the Vienna Basin. The species seems to persist through the Miocenic and Pliocenic to recent time.

Hörnes and Partsch describe several other species which are evidently closely related to *V. vulgatum.*

Vulgocerithium minutum *Serres*

This species is recorded by Hörnes and Partsch [1856, p. 390] from the Miocenic of the Vienna Basin. Specimens have been obtained from the upper Oligocenic of Saucats, and the species is described with others from that horizon. The Oligocenic specimens differ from the figures of Hörnes and Partsch [1856, plate 41, figs. 8, 9] in their smaller size and the less prominent nodes of the median row.

Vulgocerithium zelebori *Hörnes* and *Partsch*

1856. *Cerithium zelebori* HÖRNES and PARTSCH, Abhand. der k. k. geol. Reichsanstalt, III, 391, pl. 41, fig. 10.

This species seems to be closely related to *V. minutum*, differing in the more rounded nodes, less continuous ribs and the greater distinctness of the sub-sutural row of nodes. The young stages are not described in detail, and the figures are not sufficiently enlarged to show them clearly, but the general form, aperture and surface ornamentation are so similar to those of *V. vulgatum* that they may be referred to the same group with a high degree of probability.

Vulgocerithium doliolum *Brocchi*

1814. *Cerithium doliolum* BROCCHI, Conchiologia fossile subappen., II, 442, pl. 9, fig. 10.

1856. *Cerithium doliolum* HÖRNES and PARTSCH, Abhand. der k. k. geol. Reichsanstalt, III, 392, pl. 41, fig. 11.

Hörnes and Partsch record this species from the Miocenic of Italy and the Vienna Basin. It has a somewhat shorter spire than most species of *Vulgocerithium*, but it is similar to shells of this group in the character of the ornamentation and the form of the aperture. The nodes of the sub-sutural row and of the first primary spiral have a somewhat more rounded form than most species of the genus, and rows of fine nodes are intercalated between them.

A variety represented by fig. 12*a, b,* has the high spire characteristic of the typical *Vulgocerithium.*

Vulgocerithium rubiginosum *Eichwald*

1830. *Cerithium rubiginosum* Eichwald, Naturh. Skizze von Lithauen, Volhynien u. s. w., p. 224.

1856. *Cerithium rubiginosum* Hörnes and Partsch, Abhand. der k. k. geol. Reichsanstalt, III, 396, pl. 41, figs. 16, 18.

So far as can be learned from the descriptions and figures, this little species has all the characteristics of *Vulgocerithium.* It differs from the last species in the absence of the intercalated rows of fine beading, and the nodes are somewhat more prominent. The species is recorded by Hörnes and Partsch from the Miocenic of the Vienna Basin.

E. Oligocenic and Eocenic Species

1. *Cerithium*

The relationship between the Oligocenic and Eocenic species is so close that it has been thought best to consider them together, taking up the forms in the phylogenetic rather than the stratigraphic order.

Cerithium æquispirale sp. nov.

Plate ii, fig. 5; plate v, figs. 3, 4; plate vi, fig. 3.

Measurements (last five volutions): Length, 23 mm.; greatest diameter, 10.1 mm.; apical angle, 33.5°, changing to 26.8° on the last three volutions; sutural angle, 85°.

The general form of this shell is high and narrow, with moderately embracing whorls and but slightly impressed sutures. The apex of the shell is broken away, and the earliest volution preserved has a diameter of 4 mm. and height of 1.4 mm. On this volution, two spirals are stronger than the others and are equal in strength. A third primary spiral at the base of the whorl is partly covered by the succeeding volution. Between the stronger primary spirals a secondary and two tertiary ones appear, and one primary, with four secondary spirals, is above the shoulder angle. This volution bears eleven strong, rounded ribs, which are well developed from suture to suture. The first, fourth and eighth ribs are much stronger than the others, forming varices. On the later volutions, these varices appear at irregular and less frequent intervals, having in the adult from five to ten ribs between the varices. On the succeeding volutions more spirals appear, until those of the fifth order may be counted. These are very fine, but still preserve their rounded character, and several of equal strength are crowded between the coarser spirals. The strong shoulder and the two equal primary spirals persist until the body volution is reached. On the latter volution the primary spiral on the shoulder becomes as strong as the primary ones below it, and the shoulder, which is still present on the preceding volution, disappears. The body volution bears below the three primary spirals already mentioned three more strong spirals, with finer ones between them. Here, too, the ribs become weaker, the spirals stronger, and at the crossing of the two there is a tendency to form nodes, though the development does not go far enough to form actual nodes. On the later portion of the body whorl the sub-sutural spiral becomes as strong as the two primary ones.

The aperture of the shell is oval, with short, reflexed anterior canal. A well-defined posterior canal is also present, the inner margin of which is bounded by a ridge, but not a distinct tooth, such as appears in *Cerithium tuberosum.* The inner lip is covered by a narrow callus, and the outer lip is slightly flaring and notched to correspond with the strong spirals of the exterior surface.

Horizon and locality: The precise horizon of this species is not known, but it was found in a collection of unidentified shells from the Eocenic of the Paris Basin.

No. 10323, Columbia University collection.

Remarks: *Cerithium æquispirale* has a close resemblance in form and in the features of the aperture to *C. lamellosum,* but it differs from that species in the character of the spirals, which are strongly developed and have a rounded form instead of appearing like imbricating lamellæ, as in the latter species. *C. lamellosum* also differs in the loss of its secondary spirals on the adult whorls.

C. æquispirale has the two strong spirals and the numerous spirals of higher order characteristic of *C. tuberosum,* and it retains these features throughout life. The body volution has especially strong spirals on its lower slope, and the lower part of the outer lip grows a little more rapidly than the upper part. The persistence and development of this tendency would in time produce a strong projection of the lower spirals like that seen on the aperture of *C. tuberosum.* At the same time the prominent sub-sutural spiral on the later part of the body volution of *C. æquispirale* suggests the *Vulgocerithium* group. The species may well be a type from which the *C. tuberosum* group arose, but *Vulgocerithium* probably arose from the ancestor of *C. æquispirale, C. cornuelianum.*

The young stages of *C. æquispirale* are unfortunately missing, but the adult shell is so similar in general character to *C. lamellosum* that the young stages may also have been similar, although this is not certain to be true, for similarity in adults does not necessarily mean similarity in the young.

Cerithium lamellosum *Bruguière*

Plate III, figs. 7, 8; plate IV, fig. 8; plate V, figs. 7, 8; plate VI, fig. 6.

1792. *Cerithium lamellosum* BRUGUIÈRE, Encycl. Méthod., p. 488.
1824. *Cerithium lamellosum* DESHAYES, Desc. des coquilles foss. des environs de Paris, p. 370, pl. 64, figs. 8. 9.
1866. *Cerithium lamellosum* DESHAYES, Desc. des animaux sans vert. découverts dans le bassin de Paris, III, 159.
1906. *Ptychocerithium lamellosum* COSSMANN, Essais de Paléoconch. Comp., VII, 81.

MEASUREMENTS: Length, 48.4 mm.; greatest diameter, 13.8 mm.; apical angle, 29°, changing to 18° on the eleventh volution; sutural angle, 84°.

The volutions of this species embrace but slightly, producing a long, slender shell. The general outline of the whorls is gently rounded, with slightly impressed sutures.

The early stages of growth are best seen on a young individual of nine volutions. The beginning of the protoconch of this specimen is not preserved, but it seems to have comprised about one and one-half volutions. Beyond this a spiral appears at about the middle of the whorl, the portions above and below the spiral becoming flattened until a distinct shoulder is produced. On the second volution beyond the protoconch the spiral has become elevated at regular intervals to form faint nodes, and on the third volution another spiral appears below the first, while the nodes are elongated into faint ribs. The second spiral soon becomes as strong as the first, and the two form a slight projection around the median portion of the whorl. The two equal spirals remain stronger than the others throughout the life of the animal, but the shoulder is never a conspicuous feature of the ornamentation. On the succeeding volution, the fourth beyond the protoconch, there is a faint constriction of the shell below the suture, which, with the suture itself, outlines an indistinct spiral. The two volutions which follow are like the fourth, with a gradual strengthening of the characters already introduced. On the seventh volution faint secondary spirals are intercalated between the first two and on the shoulder above the first spiral. The ribs are well defined and extend from suture to suture, about one on each volution being enlarged to form a varix, a feature which persists on all the later whorls. The ninth volution differs only in having an additional faint spiral just below the sutural one.

An adult individual shows twelve volutions, from which, as shown by comparison with the young, about four volutions in addition to the protoconch have been broken away. On the eleventh volution of this specimen the spirals are five in number, with ribs extending from suture to suture, and separated by interspaces slightly wider than themselves. Although the surface is much dissolved, faint traces of secondary and tertiary spirals may be seen. The strength of all the spirals varies considerably, not only with the condition of preservation, but in different individuals similarly preserved. Some individuals show the secondary and tertiary spirals distinctly, while they are hardly visible on others. The spirals of this species, especially on the later volutions, have their upper edge projecting sharply and their lower edge merging into the surface of the shell, so that the whorls appear to be made up of overlapping lamellæ with their edges turned upward. On the later part of the body volution the spiral just below the suture is broken up into nodes, and the three spirals below the central band become extremely strong.

The aperture is oval, with a deep anterior canal and a well-defined posterior canal. The callus of the inner lip is narrow but comparatively thick. The outer lip is folded into a series of prominent lobes, which correspond in position with the spirals on the outside of the shell.

Horizon and localities: Calcaire Grossier (Upper Eocenic). Chaussy and Grignon, Paris Basin.

No. 20143, Columbia University collection.

Remarks: This species begins its life history in a much simpler manner than any of the species thus far described, and it is not until the sixth volution that it fully acquires the shoulder, which in recent accelerated forms begins immediately after the protoconch. The primitive stages preceding the formation of ribs, and with one volution only, have been crowded out of the ontogeny by acceleration in such forms as *Cerithium adansoni* and *C. tuberosum*.

Cerithium lamellosum does not continue its development in the direction of *C. tuberosum*. for, after having acquired intercalated spirals of high orders, it nearly or quite loses them on the adolescent and adult whorls, and the form of the spirals changes to the imbricated type described above. On account of this divergence expressed in the adult shell, *C. lamellosum* may be considered a lateral branch from the line developing in the direction of *C. tuberosum*. No descendants of *C. lamellosum* have been found in the material studied, and it may have died out at the end of the Eocenic without giving rise to later species.

The young of *C. lamellosum* gives a clue to the kind of development which preceded the stage with ribs and two strong spirals, and it is to be expected that from such primitive conditions development would take place in several different directions. This we find to be the case, as illustrated by several of the following species.

M. Cossmann refers this species to *Ptychocerithium* on account of the narrow opening of the canal and the strong varix opposite the outer lip. He considers it as closely related to *Vulgocerithium,* but from the development of the early stages it seems to be more closely related to *Cerithium* than to either of these.

Cerithium inabsolutum *Deshayes* ?

1866. *Cerithium inabsolutum* Deshayes, Desc. des animaux sans vert. découverts dans le bassin de Paris, III, 170, pl. 74, fig. 28.
1906. *Ptychocerithium inabsolutum* Cossmann, p. 80.

Measurements (young individual) : Length, 10 mm. ; greatest diameter, 4 mm. ; apical angle, 23.5° ; sutural angle, 85°.

Two very small individuals probably represent the young of *C. inabsolutum,* but are referred to that species with doubt, since no adult is available for comparison with them.

A part of the protoconch is present on one specimen and, so far as can be determined, is like that of *C. adansoni*. The first complete volution is .3 mm. in diameter and bears two continuous spirals, one of which appears slightly before the other. This type of ornamentation continues for six volutions, but on the seventh ribs are developed, fine spirals appear on the shoulder and a spiral is intercalated between the two primary spirals. Strong varices to the number of one or two to the volution are developed on the remaining whorls. On the eighth volution a constriction below the suture defines a sub-sutural band which is raised into nodes where crossed by the ribs, and numerous spirals of higher order are introduced. The shell comprises eleven volutions, and the two strong, equal spirals characteristic of *Cerithium* remain undiminished in strength on the last volution present. The lower slope of the body volution bears two strong spirals with three finer ones below them.

The aperture is oval, with a long columella and poorly formed siphonal canal. No callus is present on the inner lip, and the outer lip is too much broken to determine its character.

HORIZON AND LOCALITY: Calcaire grossier. Grignon, Paris Basin.
No. 2564, Museum of Comparative Zoölogy collection.

REMARKS: The absence of a callus on the inner lip and the poorly formed siphonal canal accompanying a surface ornamentation characteristic of young *Cerithium* seem to indicate that these specimens are young individuals. They are referred to *C. inabsolutum* on account of the elongation of the lower part of the aperture and the character of the ornamentation, which seems to correspond with that described for the species. Whether or not the specific identification is correct, they belong undoubtedly to the genus *Cerithium* sens. str.

Cerithium calcitrapoides *Lamarck*

1804. *Cerithium calcitrapoides* LAMARCK, Ann. du Mus. Nat. d'hist. naturelle de Paris, III, 274.
1824. *Cerithium calcitrapoides* DESHAYES, Desc. des coquilles foss. des environs de Paris, 347, pl. 46, figs. 18, 19, 23.
1906. *Batillaria calcitrapoides* COSSMANN, Essais de Paléoconch. Comp., VII, 134.

MEASUREMENTS: Length, 50 mm.; greatest diameter, 18 mm.; apical angle, 25°; sutural angle, 87°.

The youngest volution studied has an ornamentation of one spiral only. On the next volution a second spiral appears above the first, and on the fourth volution of those preserved, the two spirals are crossed by ribs, but it is not until the fifth volution that the two spirals become equal in strength. At this stage the shell has the shoulder characteristic of *Cerithium,* with two equal spirals crossed by ribs. On the seventh volution a spiral is intercalated between the two primary spirals, and fine ones appear also on the shoulder and on the lower slope of the whorl. On the ninth volution the lower primary spiral has become weaker than the upper, a tendency which increases until, on the twelfth and later volutions, the lower primary spiral is reduced to the size of the secondary ones, and the upper spiral forms the projecting margin of a sharply angled volution.

The aperture is elongate oval, with a thick callus on the inner lip and short, widely open canal. The outer lip is slightly crenulated.

HORIZON AND LOCALITIES: Calcaire grossier, Sables Moyens. Grignon and many other localities in the Paris Basin.
No. 3377, American Museum collection.

Remarks: This species resembles *C. æquispirale* in the young but diverges from the type of development illustrated by that species in the adult. It may be considered a lateral branch from the main line of evolution of *Cerithium.*

Cerithium bicarinatum *Deshayes*

Plate II, fig. 8.

1824. *Cerithium bicarinatum* Deshayes, Desc. des coquilles foss. des environs de Paris, p. 356, pl. 53, figs. 14, 15.

Measurements: Length, 24 mm.; greatest diameter, 9.5 mm.; apical angle, 30°; sutural angle, 85.5°.

The youngest volution preserved on the specimen described is .7 mm. in diameter and is ornamented by two spirals, the lower of which is the stronger. Ribs are absent at this stage. The two succeeding volutions are like the first, except that the upper spiral becomes equal to the lower in strength. On the fourth of the volutions preserved ribs appear, and on the fifth a faint constriction below the suture defines a slight subsutural band, which, however, lasts for only two volutions and is not seen on the adolescent and adult stages. The specimen thus far described is a young individual preserving only eight volutions, but the same type of ornamentation persists on full-grown specimens, the adult ornamentation being simply two strong spirals with a long shoulder slope, a concave surface between the two spirals and a short lower slope. The body volution has two spirals below the primary ones.

The aperture is nearly circular, with a short siphonal canal so widely open that its cross-section does not represent a curve of more than 180°. The callus of the inner lip is narrow and has a slight projection near the posterior end, although a distinct tooth is not formed. The outer lip is broken on all the specimens obtainable, but it was evidently thin and, according to the figure of Deshayes, was not crenulated.

Horizon and localities: Sables Moyens (Upper Eocenic). Acy-en-Multien and many other localities in the Paris Basin.

No. 20144, Columbia University collection.

Remarks: The adult of this species corresponds in essential characteristics with the fifth volution of *Cerithium lamellosum* and with the second of *C. adansoni*, and although occurring at a higher horizon than *C. lamellosum,* it illustrates a more primitive type of development. It represents the persistence of a type of shell which was probably developed as far back in geologic time as the Triassic, since we have in Jurassic time a shell with rounded volutions and an ornament of three simple spirals, which was probably developed from a two-spiraled form just as the mutation *trispirale*, described below, arose from the type species by the development of another spiral on the shoulder.

Cerithium bicarinatum mut. **trispirale** n. mut.

Plate II, fig. 7.

1824. *Cerithium bicarinatum* DESHAYES, Desc. des coquilles foss. des environs de Paris, p. 356, pl. 53, fig. 6.

1866. *Cerithium bicarinatum* DESHAYES, Desc. des anim. sans vert. découverts dans le bassin de Paris, p. 180.

MEASUREMENTS: Length, 25 mm.; greatest diameter, 10.2 mm.; apical angle, 25°; sutural angle, 85°.

The development of the variety is precisely the same as that of the type species to the seventh volution, on which a faint third spiral is introduced above the two primary ones. This spiral grows rapidly until it equals in strength the lower primary spiral. The median spiral is slightly stronger than the others, so that the outline of the volution would be a regular curve if represented by a line touching the edges of the spirals. This type of ornamentation persists throughout the remainder of shell growth. The body volution has two strong spirals and three or more fine ones below the three primary spirals. The aperture is like that of the type species.

HORIZON AND LOCALITIES: Sables Moyens (Upper Eocenic). Acy-en-Multien and other localities in the Paris Basin.

No. 20145, Columbia University collection.

REMARKS: This mutation differs from the type species only in the presence of a third spiral, which becomes strong enough to change the outline of the volution. There is a perfect gradation between the species and its mutation, since specimens of the former are found in which the third spiral is barely distinguishable as a faint elevation on the adult whorls, and others in which this feature appears earlier and earlier in the ontogeny until the typical form of the mutation is developed. The mutation represents merely the next step in the evolution of this group.

Cerithium retardatum sp. nov.

Plate II, fig. 6.

MEASUREMENTS: Length, 27.2 mm.; greatest diameter, 1.5 mm.; apical angle, 24°; sutural angle, 86°.

The early stages of this species are described from a young individual of ten volutions. The protoconch of this specimen is missing, but the youngest volution preserved is .5 mm. in diameter and is probably the first volution beyond the protoconch. It is ornamented by a single spiral only, and no ribs are present. Another spiral is added above the first on the next volution, and on the third volution of those preserved, the two spirals become of nearly equal strength. Ribs first appear on the fourth volution and on the fifth, a fine third spiral appears above the two primaries. The three spirals are well developed on the seventh volution, and on the eighth the first intercalated spiral is introduced between the two lower primary ones. Another intercalated spiral soon appears between the two upper primary spirals, and the adult whorls have one spiral intercalated between each pair of primaries, with two fine spirals above and two below the three primary spirals. The body volution has two strong and six very fine, closely set spirals on its lower slope.

The aperture is similar to that of *C. bicarinatum,* being nearly circular, with shallow anterior canal. The callus of the inner lip is wider and the posterior ridge better developed than on *C. bicarinatum.* The outer lip is somewhat broken, but the lines of growth indicate that its lower margin grew more rapidly than the upper one.

Horizon and localities: Sables Moyens (Upper Eocenic). Le Guépelle, Acy-en-Multien, Paris Basin.

No. 20146, Columbia University collection.

Remarks: *Cerithium retardatum* represents a step in advance of *C. bicarinatum* mut. *trispirale* in the development of intercalated spirals. The three forms, *C. bicarinatum,* its mutation, *trispirale,* and *C. retardatum,* constitute a direct series in evolution. *C. bicarinatum* develops ribs and two equal primary spirals only. The mutation *trispirale* carries the development farther in the growth of a third primary spiral, and *C. retardatum* advances still farther in the introduction of intercalated spirals.

C. retardatum illustrates the law of recapitulation, for its fifth volution is like the adult of *C. bicarinatum,* and its seventh volution represents the adult of the mutation *trispirale.* At the same time the law of acceleration is illustrated by this shell, since the evolution represented by the entire life history of both *C. bicarinatum* and *C. bicarinatum* mut. *trispirale* is passed over in the first seven volutions of *C. retardatum.* But while *C. retardatum* is accelerated as compared with *C. bicarinatum.* it is retarded as compared with *C. æquispirale* and other shells occurring in the Upper Eocenic. It may be compared with the Upper Cretacic *C. albense* in the main line of evolution of the *C. tuberosum* group.

Cerithium sp. undt.

MEASUREMENTS: Length, 13.5 mm.; greatest diameter, 5.3 mm.; apical angle, 35°, changing to 26° on the last three volutions; sutural angle, 83.2°.

Two small specimens of nine volutions each are the only representatives of this species in the collections studied. They are probably young individuals, but it is impossible to identify young shells from the figures and descriptions as usually written.

The youngest volution preserved is .4 mm. in diameter and has one spiral only. The next volution is too much worn to show the ornamentation, but the third volution has two spirals crossed by ribs. The two spirals become of equal strength and, with the ribs, remain the only ornamentation until the sixth volution, when a fine spiral is introduced below the lower spiral. On the next volution a spiral is intercalated between the two primary ones, and on the eighth volution a fine spiral appears on the shoulder. The body volution retains the characteristic two strong spirals and has two fine spirals on the shoulder, with one intercalated between and one below the two primary spirals. The lower slope of the body volution has two strong spirals and several finer ones below the primary spirals. Spirals of the third order also appear on this lower slope.

The aperture is circular, with a shallow anterior canal. The callus of the inner lip is comparatively wide and has a distinct ridge near its posterior end. The outer lip is thin and not crenulated on the young shell.

HORIZON AND LOCALITY: Eocenic, Paris Basin. Precise horizon and locality unknown.

No. 20163, Columbia University collection.

REMARKS: This little shell is like *C. bicarinatum* to the sixth volution, after which it develops in a direction different from that of the two descendants of *C. bicarinatum* already described, namely, *C. bicarinatum* mut. *trispirale* and *C. retardatum*. This divergence is expressed in the acquisition of a third spiral on the lower slope of the whorl, instead of on the shoulder, as in the line of evolution just described. The spirals of the shoulder slope are introduced later, but always remain fine, and the shoulder persists to the last volution present on these forms, while it is lost on *C. bicarinatum* mut. *trispirale*. This species may be considered a descendant of *C. bicarinatum*, but it represents a different path of evolution from that, including *C. retardatum*.

2. *Vicinocerithium*

Vicinocerithium parallelum gen. et sp. nov.

Plate VII, figs. 4, 5; plate VIII, figs. 4, 5; plate IX, figs. 3, 4.

MEASUREMENTS: Length, 29 mm.; greatest diameter, 12 mm.; apical angle, 30.5°; sutural angle, 81.5°.

The protoconch of this species is not preserved. The youngest volution present bears three spirals, the lowest of which is the most prominent, and is separated by a wide interspace from the two upper spirals. On the next volution ribs appear, and the median spiral becomes stronger than the upper, but not quite so prominent as the lowest spiral. A slight ridge below the suture forms a fourth ill-defined spiral. On the third volution present the two lower spirals are equal in strength, and a fine spiral is intercalated between them. The third spiral has also become stronger, so that the outline of the volution is a regular curve. Two additional fine spirals appear just below the suture. The fourth and fifth volutions are essentially like the third, with an increase in the number of fine spirals. On the sixth volution the median primary spiral becomes stronger than the other two, and this tendency increases until, on the adult whorls, this spiral forms the margin of a sharply angled volution, with numerous fine spirals on the shoulder and the lower slope of the whorl. The uppermost primary spiral is reduced to the rank of a secondary spiral, and the lowest primary spiral, originally the strongest on the shell, is much reduced in relative size, though still stronger than the secondary spirals. This and another strong spiral just above the suture are crenulated, showing a tendency toward the formation of nodes, which on the latest portion of the body volution are fairly well developed. A third nodose spiral is present below those just described, and fine spirals are intercalated between all coarser ones on the lower slope of the body volution.

The aperture is nearly circular and the anterior canal is rather long and widely open. The outer lip is thin and the inner lip is covered by a strong callus.

HORIZON AND LOCALITY: Sables Moyens. Le Guépelle, Paris Basin. No. 20156, Columbia University collection.

REMARKS: This species has been considered identical with *Cerithium* (*Vicinocerithium*) *bouei* DESH., and if the adult characters alone are considered, they are hardly distinguishable, the only difference being that the present species has a somewhat higher spire and the shoulder is farther from the horizontal. The development of the two shells is quite different, and for this reason they should rank as at least distinct species. By comparing figs. 4, 5 on plate VII, 4, 5 on plate VIII, 3, 4 on plate IX with figs. 6 on plate VII, 6 on plate VIII, 5, 6 on plate IX, it will be seen that *V. parallelum* acquires its sharp shoulder by developing its median primary spiral and retaining the lowest primary spiral in a subordinate position, while *V. bouei* develops its uppermost primary spiral to form the shoulder angle and the median spiral is reduced to the rank of a secondary spiral, and is finally indistinguishable from them.

The development of *V. parallelum* and *V. bouei* differs so widely from that of *Cerithium* that they should be referred to a distinct genus, as is here done. A full diagnosis of the genus awaits a more extended study of related species which should be included in the same genus. The two species are described here to illustrate the case of parallelism mentioned in the introduction.

Vicinocerithium bouei (*Deshayes*)

Plate VII, fig. 6; plate VIII, fig. 6; plate IX, figs. 5, 6.

1824. *Cerithium bouei* DESHAYES. Desc. des coquilles foss. des environs de Paris, II, 347, pl. 52, figs. 9-11.

1906. *Batillaria bouei* COSSMANN. Essais de Paléoconch. Comp., VII, 134.

MEASUREMENTS: Length, 22 mm.; greatest diameter, 9.5 mm.; apical angle, 32°; sutural angle, 81.5°.

A portion of the protoconch is preserved on one specimen. It is about .4 mm. in diameter and apparently has the form of the typical *Cerithium* protoconch. The next volution beyond the protoconch has apparently but one primary spiral, forming a shoulder angle just above the suture. The third volution has more fine spirals on the shoulder, and both ribs and intercalated spirals appear for the first time on the fifth volution. On the sixth volution two of the primary spirals above the spiral of the shoulder angle become stronger, until on the succeeding volution all three are of equal strength, making the outline of the volution an obtuse angle with sloping upper surface and vertical sides. On the next two volutions the uppermost of the three primary spirals becomes stronger, until it forms the margin of an exceedingly sharp shoulder angle. Later the median spiral becomes reduced to the size of a secondary spiral, the lowest primary spiral becomes irregularly undulating, and another undulating spiral of somewhat less strength is developed just above the suture. These changes produce in the adult stage a volution that is almost indistinguishable from that of *V. parallelum*.

The aperture of this species is like that of *V. parallelum*, except that the canal is somewhat shorter.

HORIZON AND LOCALITIES: Sables Moyens. Le Guépelle and many localities in the Paris Basin.

No. 20160. Columbia University collection.

REMARKS: *V. bouei* is referred by M. Cossmann to the genus *Batillaria*, but a comparison with the type of that genus, *B. zonale*, shows a wide difference in development, the latter species resembling *Cerithium* in its early stages. As will be seen by comparing fig. 6, plate VII, with figs. 2, 3, 4, plate III, *V. bouei* differs from *Cerithium* from the protoconch stage onward, and this difference entitles it to rank as a distinct genus, as noted above.

3. *Potamides*

Genus **Potamides** *Brongniart*

1810. *Potamida* BRONGNIART, Ann. du Mus. Nat. d'hist. naturelle, XV, 468.
1822. *Potamides* BRONGNIART, in Cuvier's Recherches sur les ossemens fossiles, II.
1906. *Potamides* COSSMANN, Essais de Paléoconch. Comp., VII, 103.

Genotype *Potamides lamarcki* BRONGNIART.

The genus *Potamides* is distinguished from *Cerithium* mainly in the slight development of the siphonal canal. In the type of the genus *P. lamarcki* this canal is short, widely open, and with its anterior margin slightly reflexed. This type of canal persists with little change from the middle Eocenic to recent time.

The early stages of *Potamides*, as pointed out in connection with the description of the genotype, are closely similar to those of typical *Cerithium*, but after having developed the *Cerithium*-like outline of the volution with two equal spirals crossed by ribs, species of the genus continue to emphasize the formation of nodes as their most characteristic surface feature, instead of accenting the spirals, as in *Cerithium*. In this paper only those species are included in the genus *Potamides* which have not only an aperture similar to the genotype, but also have young stages indicating a similar path of development.

Cerithium and *Potamides* are without doubt closely related genera, and *Potamides* is the more primitive in structure. The aperture of the young *Potamides* is almost destitute of canal, while the aperture of the young *Cerithium* is like that of *Potamides*, and it is reasonable to suppose that the order of evolution has been from forms without canal to those with the slight canal of *Potamides,* and later to the well-developed canal of *Cerithium.* Hence the ancestor from which both genera are derived must have been more like *Potamides* than like *Cerithium,* although the type of *Potamides, P. lamarcki,* and other species of the genus occur at higher horizons than many well-developed species of *Cerithium.* They represent the persistence of a primitive type of structure throughout a long period of geologic time, while *Cerithium,* though descended from a common ancestor, represents a more rapid evolution of highly specialized forms.

Potamides lamarcki *Brongniart*

1810. *Potamides lamarcki* BRONGNIART, Ann. du Mus. Nat. d'hist. naturelle, XV, 468, pl. 22, fig. 5.
1824. *Cerithium microstoma* DESHAYES, Desc. des coquilles foss. des environs de Paris, II, 412, pl. 59, figs. 32-34.
1866. *Cerithium lamarcki* DESHAYES, Desc. des animaux sans vert. découverts dans le bassin de Paris, III, 177, pl. 80, figs. 25-28.
1906. *Potamides lamarcki* COSSMANN, Essais de Paléoconch. Comp., VII, 103.

MEASUREMENTS: Length, 22.8 mm.; greatest diameter, 6.6 mm.; apical angle, 19°; sutural angle, 88.5°.

The protoconch of this species is beautifully preserved on a small individual of seventeen volutions. The form is similar to that of *Cerithium adansoni,* and the surface is smooth and shining. It comprises about one and one-half volutions, after which two fine spirals of equal strength appear and remain the only ornamentation of the shell for three volutions. On the fifth volution the spirals are crossed by ribs, and for the next four volutions the shell has the characteristic ornamentation of the young *Cerithium*—that is, an angular outline formed by two equal spirals crossed by ribs. On the ninth volution a third spiral is added just below the suture, and all the spirals form nodes where crossed by the ribs. The median row of nodes lags slightly behind the others, so that the ribs are curved in crossing the volutions. The ornamentation of the adult consists of three strong nodose spirals which are rectangular in cross-section and a fine continuous spiral just above the suture. The ribs are faint or obsolete in the adult, and the entire surface of the shell is covered by extremely fine, closely set spirals, which are only visible with a strong lens. Some specimens show gerontic characters in the thickening of the shell and the loss of the nodes on the body volution. The lower slope of this volution bears three spirals in addition to those already mentioned.

The aperture is nearly circular. The callus of the inner lip is thin and spread out broadly over the lower surface of the body volution, and the outer lip is thin and strongly sinuous. The anterior canal is very short, shallow and has a reflexed margin.

HORIZON AND LOCALITY: Oligocenic. Aurillac, Paris Basin.
No. 20153, Columbia University collection.

REMARKS: This species follows the same path of evolution as *Cerithium adansoni* for the first nine volutions, but is more retarded in the development of ribs than that species. After the ninth volution the shoulder is lost, and the species diverges from the *Cerithium* line of evolution. The adult has flattened volutions and an ornamentation of rows of nodes instead of the angular outline of the whorls and several orders of spirals characteristic of *Cerithium*.

As compared with Eocenic species of *Cerithium*—*C. æquispirale*, for example—*Potamides lamarcki* is more primitive in structure, having a less well-developed canal and simpler type of ornamentation, and it represents, as noted in connection with the genus, the persistence of a primitive form while more rapid evolution was taking place in related groups.

Potamides cordieri mut. typum n. mut.

1824. *Cerithium cordieri* var. a DESHAYES, Desc. des coquilles foss. des environs de Paris, II, 338, pl. 52, fig. 8.

MEASUREMENTS: Length, 29.8 mm.; greatest diameter, 11.5 mm.; apical angle, 25°; sutural angle, 84.5°.

The youngest volution present is .6 mm. in diameter and is ornamented by ribs and two equal spirals. The same ornamentation continues for four volutions, and on the fifth a nodose spiral appears just below the suture. This spiral increases in strength and becomes more distinctly nodose until, on the eleventh of the volutions preserved, it is as strong as the two nodose spirals below it. At this stage the general outline of the volution is straight and parallel with the slope of the spire, and its surface is ornamented by three equal rows of nodes without ribs. The same ornamentation is continued until the fourteenth volution, when the loose coiling reveals a continuous spiral just above the suture. On the fifteenth volution present a fine, slightly nodose spiral appears between the two upper rows of nodes. The same kind of ornamentation continues throughout the remaining whorls. The body volution has three rows of strong nodes—one fine intercalated row and two strong continuous spirals below the ornamentation of nodes. On the later part of this volution the growth lines are crowded, the shell somewhat thickened and the nodes indistinct or obsolete.

The aperture is quadrangular, with short, widely open siphonal canal. The callus of the inner lip is thick and broad. The outer lip is strongly sinuous.

Horizon and localities: Sables Moyens. La Chapelle, Le Guépelle and other localities in the Paris Basin.

No. 20153, Columbia University collection.

Remarks: Were it not for the old-age features present on the later part of the body whorl, this variety might be taken for the young of the type species mentioned below, but the shell appears in all ways like a full-grown individual, with a length only about half that of *P. cordieri*.

The development of this form is closely similar to that of *P. lamarcki*, and the adult differs but slightly in general appearance. It is, however, larger, has a wider apical angle and lacks the extremely fine spirals covering the surface between the nodes as in *P. lamarcki*.

Potamides cordieri *Deshayes*

1824. *Cerithium cordieri* Deshayes, Desc. des coquilles foss. des environs de Paris, II, 338, pl. 52, figs. 14, 15.

1866. *Cerithium cordieri* Deshayes, Desc. des animaux sans vert. découverts dans le bassin de Paris, III, 137.

1906. *Ptychopotamides cordieri* Cossmann, Essais de Paléoconch. Comp. VII, 108.

Measurements: Length, 60 mm.; greatest diameter, 20 mm.; apical angle, 23.5°; sutural angle, 90°.

The only specimen of this species available for study is broken at the apex, but enough remains to show that the development of this shell is like that of the mutation *typum* and remains the same in all ways except in the number of spirals on the last two or three volutions. *P. cordieri* differs from its mutation only in its greater size and in the fact that while *P. cordieri* mut. *typum* has only one row of fine nodes intercalated between the coarser ones, the type species has a similar row intercalated between the two lower and also below the lowest of the three rows of strong nodes. The intercalation of fine nodes in the remaining interspaces would naturally follow their introduction in one of them, so that the adult *P. cordieri* constitutes the next step in this line of evolution beyond that of *P. cordieri* mut. *typum*. For this reason it would have been more appropriate to consider the mutation *typum* the type species; but the name being already established for the larger specimens, it should not be changed.

Horizon and localities: Sables Moyens. La Chapelle and other localities in the Paris Basin.

No. 20154, Columbia University collection.

Remarks: *Potamides cordieri* and its mutation are referred by M. Cossmann to *Ptychopotamides,* a genus which is distinguished from *Potamides* by the presence of a columellar plication, but such a plication is certainly absent from all of the eleven specimens studied, and the close similarity in development between this form and *P. lamarcki* has led to the placing of the species in the genus *Potamides.*

Potamides involutum *Lamarck*

1804. *Cerithium involutum* Lamarck, Ann. du Mus. Nat. d'hist. naturelle de Paris, III, 348.
1824. *Cerithium involutum* Deshayes, Desc. des coquilles foss. des environs de Paris, II, 328, pl. 41, figs. 10-13.
1906. *Tympanotomus involutum* Cossmann, Essais de Paléoconch. Comp., VII, 120.

Measurements: Length, 30 mm.; greatest diameter, 10 mm.; apical angle, 25°; sutural angle, 87°.

The youngest volution seen on this species is .8 mm. in diameter. It has at this stage ribs and two equal spirals. The same ornamentation continues for three volutions, and on the fourth a third spiral is introduced above the two already existing. This spiral increases gradually in strength until, on the eighth volution, it is as strong as the two below it. At this stage the shoulder has disappeared, and the surface is ornamented by three equal rows of nodes and a fine continuous spiral just above the suture. On the later whorls, at a stage varying in different individuals, the nodes are lost, leaving the surface marked by continuous spirals only. Still later the two lower spirals also disappear, leaving a single spiral which forms the margin of a strong shoulder angle just below the suture. The extent of this smoothing of the shell varies greatly on different individuals, occupying three or more volutions, or the spirals, and even the nodes, may persist nearly to the end of the body volution. Specimens on which the smooth portion comprises several volutions have also a narrower angle of slope for the sides in this portion of the shell, indicating a flattening of the whorls parallel to the axis of coiling. The embracing of the whorls is greater than in the young portion of the shell, and on some specimens also a distinct canal is formed at the posterior margin of the aperture by this overlapping of a fold in the outer lip upon the preceding whorl.

The aperture is closely similar to that of *Potamides lamarcki.* The siphonal canal is short and widely open, the callus of the inner lip thick, and the margin of the outer lip strongly sinuous.

Horizon and locality: Calcaire grossier. Cuise-la-motte, Paris Basin. No. 20155, Columbia University collection.

Remarks: The shells included under this name form a perfect gradational series from forms in which the loss of nodes appears only on the later part of the body volution to those in which both nodes and spirals are absent, if we include the forms figured by Deshayes, from nearly the whole surface. So perfect is the gradation in the cóllection studied that hardly two individuals are alike, and each may be considered a mutation, though for convenience they are described under one name.

The loss of ornamentation, the flattening of the whorls and the overlapping of the later whorls upon the earlier are all old-age features which indicate a progressive gerontism and approaching extinction in the branch of evolution which they represent.

The life history of this species is closely similar to that of *P. cordieri* mut. *typicum*, down to the stage when gerontic features begin to appear. It differs from that species in having a wider apical angle, but the two species are doubtless closely related.

Potamides lapidum *Lamarck*

1804. *Cerithium lapidum* Lamarck, Ann. du Mus. Nat. d'hist. naturelle de Paris, III, 350.

1824. *Cerithium lapidum* Deshayes, Desc. des coquilles foss. des environs de Paris, II, 421, pl. 60, figs. 21-22.

1906. *Potamides lapidum* Cossmann, Essais de Paléoconch. Comp., VII, 104, pl. 10, figs. 6-7.

Measurements: Length, 31 mm.; greatest diameter, 9.5 mm.; apical angle, 18.5°; sutural angle, 88°.

The youngest volution studied is .8 mm. in diameter, and there are evidently several volutions missing above this. Its ornamentation consists of two very fine, equal, continuous spirals. On the next volution these spirals are crossed by very faintly developed, oblique ribs which are present with varying strength and frequency on the succeeding ten volutions. These ribs are never well developed, and on the adolescent and adult whorls they give place altogether to crowded lines of growth. On the later volutions the spirals also become indistinct, and the whorls have a rounded outline, with a surface roughened by the crowded lines of growth and faint traces of one or two spirals. On the young of some specimens the lower of the two spirals is more prominent than the upper, and the ribs in crossing give it a nodose appearance, but this ornamentation also disappears from the later whorls.

The aperture is circular, with a thickened callus on the inner lip, and the margin of the outer lip is sinuous. The siphonal canal is shallow and broad, with a strongly reflexed margin.

Horizon and localities: Calcaire grossier. La Frileuse and many other localities in the Paris Basin.

No. 20157, Columbia University collection.

Remarks: The highest development of ornamentation on this shell advances but little beyond the stage with two simple spirals represented by the second to the fourth volutions of *P. lamarcki,* and the development of the ribs is so feeble as to correspond with only the earlier part of the fifth volution of that species. *P. lapidum* is doubtless developed from the same ancestor as *P. lamarcki,* but since in the adult it becomes more smooth, instead of developing a higher degree of ornamentation in the direction of *P. lamarcki,* it probably represents a lateral branch from the main *Potamides* line of evolution.

4. *Potamidopsis*

Genus **Potamidopsis** *Munier-Chalmas*

1900. *Potamidopsis* Munier-Chalmas, Congrès géol. Paris, V, Chideville. Liste générale, p. 375.

1906. *Potamidopsis* Cossmann, Essais de Paléoconch. Comp., VII, 109.

Genotype *Cerithium tricarinatum* Lamarck.

M. Cossmann distinguishes this genus from true *Cerithium* as follows:

> Enfin *Potamidopsis* se distingue des vrais *Cerithinæ* par son canal court, par son labre non replié en travers du canal, et aussi par ses tours imbriqués. La séparation—qu'a proposée Munier-Chalmas, dans de simples listes de fossiles publiées à l'occasion du Congrès de 1900, sans aucene diagnose—est donc à retenir.

The earliest stages in the development of the genotype show that this shell is derived from the same stock as the true *Cerithium,* but it diverges from the main line of evolution so strongly and at such an early stage that it deserves to rank as a distinct genus. M. Cossmann describes *Potamidopsis* as a sub-genus of *Potamides,* but the group is more closely related to *Cerithium* than to *Potamides;* hence it should not rank as a sub-genus of the latter. It is also too distantly related to *Cerithium* to constitute a sub-genus of that group, and hence it is here ranked as an independent genus. To the distinguishing characters enumerated by M. Cossmann may be added the numerous volutions producing a very high spire; the close embracing of the whorls; the general outline of the volutions, not convex, but conforming to the slope of the spire; the high development of nodes and the absence of ribs on all except the nepionic volutions of the shell. The aperture also varies in its angular outline—

the broad and thick callus of the inner lip, with no trace of posterior tooth, and the short, oblique siphonal canal. The outer lip is often thickened, and its anterior portion grows more rapidly than the posterior part, making the outline of the margin strongly sinuous.

Potamidopsis tricarinata *Lamarck*

Plate VII, figs. 7, 8; plate VIII, figs. 7, 8; plate IX, figs. 7, 8.

1804. *Cerithium tricarinatum* LAMARCK, Ann. du Mus. Nat. d'hist. naturelle, III, 272, No. 4.
1824. *Cerithium tricarinatum* DESHAYES, Desc. des coquilles foss. des environs de Paris, II, 325, pl. 51, figs. 1, 8.
1866. *Cerithium tricarinatum* DESHAYES, Desc. des anim. sans vert. découverts dans le bassin de Paris, III, p. 123.
1902. *Potamides tricarinatum* COSSMANN, Catal. illust. des coquilles foss. de l'Éoc. des environs de Paris, IV, p. 69.
1903. *Tympanotomus tricarinatum* COSSMANN, Paleontologia Universalis, Cent. I, pl. 3, figs. 1, 2.
1906. *Potamidopsis tricarinatus* COSSMANN, Essais de Paléontol. Comp., VII, 109, pl. 11, figs. 5, 6.

MEASUREMENTS:[5] Length, 45 mm.; greatest diameter, 17 mm.; apical angle, 20°; sutural angle, 87°.

The early stages of the species are described from a young individual of fifteen volutions. The protoconch is missing, but the youngest volution preserved is probably the first beyond the protoconch, as it has a diameter of only .3 mm. It has an ornamentation of two equal spirals without ribs, and the same ornamentation persists on the next volution. Ribs appear on the third volution, which has an ornamentation exactly similar to the adult of *Cerithium bicarinatum*. On the fourth volution the lower spiral becomes stronger and the upper one weaker, a tendency which increases on the next three volutions until, on the seventh and eighth volutions, the upper spiral has entirely disappeared, and the ornamentation consists merely of a single strongly nodose spiral, forming a projecting shoulder angle just above the suture. The ninth volution has a sub-sutural spiral the nodes of which are connected with those of the shoulder angle by well-developed ribs. This type of ornamentation persists for seven volutions more, and on the fourteenth volution a fine spiral is intercalated between the two already existing. Comparing this young individual with an adult, it is found that the latter is more retarded in the growth of this fine spiral than the former. It does not

[5] The specimen measured is the one which seems to correspond most closely with the figures of the type given in the Paleontologia Universalis, centuria I, plate 3, figs. 1, 2.

appear on the adult individual until the sixteenth volution, after which it becomes stronger and soon breaks up into a row of fine nodes placed half way between the two rows already formed. The ribs become discontinuous, and the last seven whorls are ornamented by three rows of nodes, of which the lowest forms a projecting shoulder angle just above the suture, and the median row is very slightly finer than the upper one. On the later part of the body whorl all the nodes become indistinct or obsolete, where the crowding of the growth lines and thickening of the shell indicate old-age conditions.

The aperture is about equal in length and width and somewhat angular in outline. The callus of the inner lip is very thick and broad, its posterior part often spreading out for a considerable distance over the posterior part of the body whorl. There is no trace of posterior tooth, as in *Cerithium* sens. str. The outer lip is often greatly thickened, strongly flaring at the margin, and it overlaps more or less upon the preceding whorl. The thickening of the shell, the loss of ornamentation and the encroaching of the later part of the body whorl upon the preceding whorl are all old-age features which indicate that the species is approaching its extinction.

Horizon and localities: Calcaire grossier, Sable Moyens. Grignon and many other localities in the Paris Basin.
No. 20122, Columbia University collection.

Remarks: The young stages of this species furnish a clue to its development from a form resembling *Cerithium bicarinatum*, since its development for the first four volutions is closely parallel to the development of that species, and the fourth volution (counting the protoconch as one) is the counterpart of the adult *C. bicarinatum*. The species could not, however, have been developed from *C. bicarinatum* itself, since it occurs at an earlier horizon, but was probably developed from the pre-Jurassic ancestor of *C. bicarinatum* mentioned in connection with that species—the same ancestor which probably gave rise along a different path of evolution to *C. corallense* and its descendants, *C. æquispirale*, *C. tuberosum*, etcetera.

Potamidopsis tricarinata has developed many mutations by the accentuation or suppression of one or another of its surface features. Of these mutations, Lamarck has described one and given it the designation "β," and Deshayes has indicated five others by letters from "b" to "f," the letter "a" being used for the type species. The mutations occur at the same horizon and localities as the type, and, as might be expected, transitional forms exist between all of them.

Potamidopsis tricarinata mut. baucis mut. nov.

1804. *Cerithium tricarinatum* var. β LAMARCK, Ann. du Mus. Nat. d'hist naturelle, Paris, III, 272.

The author says of this species:

Dans la variété β, la carène supérieur de chaque tour est un peu plus éminente que celle du milieu.

The mutation is apparently more common than the type species, since it is rare to find specimens in which the two upper rows of nodes are equal. The upper row is slightly stronger, even in the type figured in Paleontologia Universalis, but the varietal name may be retained for those forms in which the difference is strongly developed.

No. 20121, Columbia University collection.

Potamidopsis tricarinata mut. brontes mut. nov.

1824. *Cerithium tricarinatum* var. b DESHAYES, Desc. des coquilles foss. des environs de Paris, II, 325, pl. 51, fig. 2.

This mutation is distinguished by the strong carina which forms a projecting shelf around the whorls and by the fine nodes of the two upper spirals. The shells of this variety are usually larger than those of the typical form.

No. 20123, Columbia University collection.

Potamidopsis tricarinata mut. cronus mut. nov.

1824. *Cerithium tricarinatum* var. c DESHAYES, Desc. des coquilles foss. des environs de Paris, II, p. 325, pl. 51, figs. 3, 4.

The carina of this mutation is also very strong, but the nodes are more widely spaced and more prominent than in the mutation *brontes*. The median row of nodes is obsolete and the upper row is poorly developed.

Potamidopsis tricarinata mut. doris mut. nov.

1824. *Cerithium tricarinatum* var. d DESHAYES, Desc. des. coquilles foss. des environs de Paris, II, p. 326, pl. 51, fig. 6.

This mutation is similar to the last, but in this form it is the subsutural row of nodes which becomes obsolete.

Potamidopsis tricarinata mut. eris mut. nov.

1824. *Cerithium tricarinatum* var. e Deshayes, Desc. des coquilles foss. des environs de Paris, II, 326, pl. 51, figs. 4, 7.

On this species the carina is not prominent, and its nodes are nearly obsolete, leaving the margin but slightly wavy. The two upper rows of nodes are present.

Potamidopsis tricarinata mut. fatua mut. nov.

1824. *Cerithium tricarinatum* var. f Deshayes, Desc. des coquilles foss. des environs de Paris, II, p. 326, pl. 51, fig. 9.

This is an extreme mutation, which is distinguished by the almost entire absence of nodes, in the adult stages, from both the carina and the two spirals above it. The variation is carried so far in this form that it would be described as a distinct species if the nodes had altogether disappeared.

Potamidopsis acus *Deshayes*

1866. *Cerithium acus* Deshayes, Desc. des animaux sans vert. découverts dans le bassin de Paris, III, 199, pl. 75, figs. 19, 20.

Measurements (Deshayes) : Length, 25 mm.; greatest diameter, 6 mm.

Deshayes records the discovery of a single specimen only of this species. According to his figures and description, it has a long, slender spire of twenty-five volutions. The adult is ornamented by two rows of nodes connected by ribs, the lower row being more prominent than the upper. A fine undulating spiral is present just above the suture.

The aperture is like that of *P. tricarinata,* except that it does not show gerontic characters in the thickening of the shell and loss of ornamentation seen on many specimens of the former species.

Deshayes calls attention to the similarity of this shell to the young *P. tricarinata,* and it might be considered the young of that species were it not that all the specimens of *P. tricarinata* studied, of 25 mm. in length or of twenty-five volutions, have passed beyond the stage represented by the last whorl of *P. acus* in the intercalation of a finely nodose spiral between those already existing. If *P. acus* is actually adult, as it appears to be, it represents a more primitive form than *P. tricarinata* and may well be the immediate ancestor of that species. This hypothesis would be confirmed if other specimens showing young stages similar to those of the very young *P. tricarinata* were discovered.

Horizon and locality: Calcaire grossier. Mouchy, Paris Basin.

Potamidopsis mixta *Deshayes*

——. *Cerithium mixtum* DEFRANCE, Nom. nud.
1824. *Cerithium mixtum* DESHAYES, Desc. des coquilles foss. des environs de Paris, II, 324, pl. 45, figs. 6-11.
1866. *Cerithium mixtum* DESHAYES, Desc. des animaux sans vert. découverts dans le bassin de Paris, III, 123.
1906. *Ptychopotamides mixtum* COSSMANN, Essais de Paléoconch. Comp., VII, 108.

MEASUREMENTS: Length of the eleven volutions preserved, 41 mm.; greatest diameter, 15 mm.; apical angle, 27.5°, changing to 21.8° on last three volutions; sutural angle, 80°.

The youngest volution preserved on the shell studied is 3 mm. in diameter; hence a considerable portion of the apex has been broken away. The first three volutions are much worn, destroying all the finer surface features, but the fourth has precisely the ornamentation of *P. tricarinata* mut. *brontes,* namely, a strong nodose carina near the base of the volution, a sub-sutural row of rather strong nodes and a median row of nodes much finer than either of the others. This remains the ornamentation of the shell until the third from the last volution, when the sub-sutural and the lowest row of nodes become equal in strength, finer and much crowded. A fourth, finely nodose carina is developed at the base of the volution and is partially concealed by the succeeding whorl. On the body volution the nodes of the upper row are small and in places so close together as to become confluent. Two nodose carinæ and several fine spirals are present on the lower slope of the body volution.

The aperture is similar to that of *P. tricarinata,* with an expanded callus on the inner lip and a comparatively long, twisted siphonal canal. A slight columellar plication defines the posterior margin of the canal. The outer lip is broken in the specimen at hand, but the figures of Deshayes, cited above, show it to be similar to that of *P. tricarinata.*

HORIZON AND LOCALITIES: Sables Moyens. Anvers and other localities in the Paris Basin.
No. 20147, Columbia University collection.

REMARKS: So far as can be determined, the life history of this species is like that of *P. tricarinata* until the last three volutions, when the ornamentation changes to that of three rows of crowded nodes, the uppermost being slightly more prominent than the lowest. It is probably a descendant of *P. tricarinata*, showing its divergence from its ancestor on the last three volutions only.

The columnellar plication which furnishes the reason for placing this species in the genus *Ptychopotamides* is indistinct, and does not constitute a sufficient reason for separating the species from the group to which it is closely related in its development.

Potamidopsis tuberculosa *Lamarck*

1804. *Cerithium tuberculosum* LAMARCK, Ann. du Mus. Nat. d'hist. naturelle, III, 348.
1824. *Cerithium tuberculosum* DESHAYES, Desc. des coquilles foss. des environs de Paris, II, 48, figs. 1-5.
1866. *Cerithium tuberculosum* DESHAYES, Desc. des animaux sans vert. découverts dans le bassin de Paris, III, 122.
1906. *Serratocerithium tuberculosum* COSSMANN, Essais de Paléoconch. Comp., VII, 75.

MEASUREMENTS: Length, 33 mm.; greatest diameter, 12.2 mm.; apical angle, 26°; sutural angle, 86.4°.

The early stages of this species are described from a young individual of fifteen volutions. The protoconch of the specimen is missing, and the first two volutions are too much worn to show the surface ornamentation, but the third volution present is ornamented by a sub-sutural spiral and a stronger spiral forming a shoulder angle just above the suture. Both spirals are rendered nodose and connected by ribs which are continuous across the volutions. This type of ornamentation persists for five volutions and is closely similar to the ornamentation of *P. tricarinata* at a slightly later stage. The nodes of the lower and upper rows gradually become equal in strength, and the shoulder disappears. On the sixth volution of those preserved a spiral is intercalated between the two rows of nodes already formed, and two volutions later this spiral is broken up into a row of very fine nodes. The ornamentation at this stage resembles that of *P. tricarinata* at the same stage, except that the lower row of nodes is more prominent on the latter species. At the eleventh volution the nodes of the sub-sutural row become more prominent and more widely spaced than those of the lowest row. This tendency increases until a shoulder angle composed of strong, transversely elongate nodes is formed just below the suture. This becomes the ornamentation of the adult shell, except that a fourth spiral which is partially exposed just above the suture also becomes wavy or faintly nodose. The body volution bears one nodose ridge in addition to those already described and several fine spirals on its lower slope.

The aperture is nearly circular. The callus of the inner lip is broad and thin. The outer lip is thin; its margin, growing more rapidly at the anterior portion, gives it a sinuous outline. The siphonal canal is broad and deep, bordered by a strong ridge on its columellar side.

Horizon and localities: Sables Moyens (Upper Eocenic). Widely distributed in the Paris Basin.

No. 20148, Columbia University collection.

Remarks: The earliest volutions of this shell are missing, but the youngest preserved has an ornamentation similar to that of the ninth to the thirteenth volutions of *Potamidopsis tricarinata*. It adds an intercalated spiral as in the latter species, but it diverges from the line of evolution represented by *P. tricarinata* by forming its shoulder angle at the upper instead of the lower margin of the whorl. This species may be regarded as derived from the same ancestral stock as *P. tricarinata,* but it represents a divergent line of evolution.

M. Cossmann refers this species to *Serratocerithium,* a sub-genus founded mainly on characters of the aperture, but the aperture of *P. tuberculosa* does not appear to differ to a marked degree from that of *P. tricarinata.* The canal is slightly longer and the outer lip thinner and less flaring. The present reference of the species, being founded on descent as revealed by the ontogeny, necessarily arrives at a different result from one founded on adult characters alone.

Potamidopsis roissyi *Deshayes*

1824. *Cerithium roissyi* Deshayes, Desc. des coquilles foss. des environs de Paris, II, 322, pl. 50, figs. 13-20.

1866. *Cerithium roissyi* Deshayes, Desc. des anim. sans vert. découverts dans le bassin de Paris, p. 127.

1906. *Tympanotonus roissyi* Cossmann, Essais de Paléoconch. Comp., VII, 120.

Measurements: Length, 25.7 mm.; greatest diameter, 8 mm.; apical angle, 20°; sutural angle, 90°.

The protoconch is missing from the best specimen available, and it is probable that two or three more volutions are also broken away. The youngest volution present is .7 mm. in diameter, and it has exactly the ornamentation of *P. tricarinata* from the ninth to the thirteenth volutions. The same ornamentation continues for four volutions, after which the ribs disappear and the two rows of nodes become equal in strength and often alternate in position as compared across the whorl. On the sixth volution a fine spiral is intercalated at about the middle of the volution. This spiral soon breaks up into a row of extremely fine nodes. At about the same stage of growth the sub-sutural row of nodes becomes stronger than the others, a tendency which increases until the adult condition is reached. The ornamentation of the adult consists of three rows of nodes of which the upper are larger and more widely spaced than the others, and the nodes of the median row are very fine. An irregularly nodose fine spiral is barely visible just above the suture. The body volution has two strong spirals below those already mentioned. On this volution the growth lines become very much crowded, and all the nodes become indistinct, especially toward the later part of the volution.

The aperture is about equal in length and breadth and is roughly quadrangular in outline. The callus of the inner lip is broad and thin. The siphonal canal is short, widely open and somewhat twisted. The outer lip is thin and has a strongly sinuous outline.

Horizon and locality: Sables Moyens superieur (Upper Eocenic). La Chapelle, Paris Basin.

No. 20149, Columbia University collection.

Remarks: The ornamentation of this species closely resembles that of *P. tuberculosa,* both in its development and in the adult stage. The species differs from *P. tuberculosa* in its smaller size; narrower apical angle, which makes it a more slender shell; its shorter canal and more angular aperture.

This species bears the same relation to *P. tricarinata* as does *P. tuberculosa*—that is, it is derived from the same ancestor as both, but develops in the direction of *P. tuberculosa,* to which it is closely related.

Potamidopsis crassinoda sp. nov.

Measurements: Length of specimen with apical whorls missing, 39.8 mm.; greatest diameter, 26.7 mm.; apical angle, 32°, changing to 23.8° on the sixth volution; sutural angle, 85°.

This species is distinguished from *Potamidopsis tuberculosa,* to which it is closely related, in being a larger and thicker shell and in having the nodes of the surface much larger and more prominent. This difference begins at an early stage of growth and continues throughout the life of the animal. The youngest volution preserved is 2.5 mm. in diameter, and several whorls have evidently been broken away above this. The first three volutions have an ornamentation of about the same strength and character as the adult of *P. tuberculosa,* but beyond this the large nodes characteristic of all the later volutions are developed. The nodes of the uppermost row are large, blunt cones; those of the lowest row, smaller and transversely elongate. The median nodes are very fine and on some specimens nearly obsolete. The base of the volution is produced into lobes, which sometimes overhang the succeeding volution.

The aperture is similar to that of *P. tuberculosa,* but the canal is longer and more strongly reflexed, and the callus of the inner lip is thicker and is not closely applied to the surface of the shell. The outer lip is thickened with crowding of the growth line and loss of ornamentation for some distance back of it.

Horizon and locality: Sables Moyens. Rosoy-en-multiens, Paris Basin. No. 20150, Columbia University collection.

Remarks: This species has been regarded as a variety of *Potamidopsis tuberculosa,* but its much greater size, strongly marked surface features, and longer siphonal canal, as well as its more accelerated development, entitle it to rank as a distinct species. It is evidently derived from the same ancestor as *P. tuberculosa,* following the same path of evolution but strengthening all the features of the shell. The three species, *P. roissyi, P. tuberculosa* and *P. crassinoda,* possess the same type of ornamentation, and they form a series in which *P. roissyi* is at one extreme, characterized by small size, thin shell and delicacy of ornament, and *P. crassinoda,* at the other, characterized by thick shell, strong tubercles and wide apical angle.

Potamidopsis conjuncta *Deshayes*

1824. *Cerithium conjunctum* Deshayes, Desc. des coquilles fossiles des environs de Paris, II, 387, pl. 73, figs. 1-4.

1866. *Cerithium conjunctum* Deshayes, Desc. des animaux sans vert. découverts dans le bassin de Paris, III, 123, pl. 80, figs. 9-16.

1906. *Tympanotonus conjunctus* Cossmann, Essais de Paléoconch. Comp., VII, 120.

Measurements: Length of specimen from which apex is broken, 29.4 mm.; greatest diameter, 10.8 mm.; apical angle, 28.2°, changing to 18.2° on the last three volutions; sutural angle, 86°.

The youngest volution available for study is 2 mm. in diameter, and several volutions have been broken away above it. The ornamentation is that of two rows of nodes, one near each suture, the lower row being the more prominent. The upper and lower nodes are connected by ribs. This ornamentation resembles that of *P. tricarinata* from the ninth to the thirteenth volutions. On the third volution present a fine spiral is intercalated between the two rows of nodes. This spiral soon becomes finely nodose, and the ornament of the adult is that of three rows of nodes of which the uppermost and lowest are large and of equal size, while the nodes of the median row are very small. The body volution has two strong spirals and several fine ones on its lower slope.

The aperture is roughly quadrangular. The callus of the inner lip is thick and expanded posteriorly. The siphonal canal is short, twisted and has a strong columellar ridge defining its posterior margin. The outer lip is broken in the specimens studied, but, according to the figures of Deshayes, cited above, it is thin and strongly sinuous.

HORIZON AND LOCALITY: Oligocenic. Jeures, Paris Basin.
No. 20151, Columbia University collection.

REMARKS: The development of this shell is closely similar to that of *P. tricarinata,* so far as can be determined from the specimens studied. The adult differs only in the fact that the lowest row of nodes equals the uppermost in prominence, instead of exceeding it. This causes the outline of the volution to be parallel with the slope of the spire, instead of forming a shoulder. *P. conjuncta* probably occupies about the same relation to *P. tricarinata* as does *P. tuberculosa,* diverging from the *tricarinata* line of evolution at about the same stage in its development, but in a different direction. The adult of *P. tricarinata* shows greater prominence of the lowest row of nodes; that of *P. tuberculosa* emphasizes the prominence of the sub-sutural row, and in *P. conjuncta* they are equal.

Potamidopsis trochleare *Lamarck*

1804. *Cerithium trochleare* LAMARCK, Ann. du Mus. d'hist. naturelle, III, 349.
1824. *Cerithium trochleare* DESHAYES, Desc. des coquilles foss. des environs de Paris, II, 388, pl. 55, figs. 10, 11.
1866. *Cerithium trochleare* DESHAYES, Desc. des animaux sans vert. découverts dans le bassin de Paris, III, 129, pl. 80, figs. 1-8.
1906. *Tympanotonus trochleare* COSSMANN, Essais de Paléoconch. Comp., VII, 118, pl. 11, fig. 19.

MEASUREMENTS: Length, 25 mm.; greatest diameter, 12 mm.; apical angle, 25.2°; sutural angle, 85°.

One of the specimens studied shows the protoconch. This is similar in form to the protoconch of *Cerithium adansoni* and comprises about one and one-half volutions. The volutions immediately succeeding the protoconch on this specimen are poorly preserved; but another specimen, whose youngest volution is .7 mm. in diameter, retains the surface features. This is the third volution, as shown by comparison with a complete individual. It is ornamented by two nodose spirals, of which the lower is the more prominent, and a third fine intercalated spiral. This is the ornamentation of the adult *P. tricarinata.* The median spiral persists for two volutions only, after which the shell has two rows of nodes only, with the lower more prominent than the upper. The latter stage lasts for a variable number of volutions on different specimens, but usually from five to eight volutions. Beyond this the ribs disappear, and the shell is ornamented for the remainder of its growth by two extremely prominent continuous spirals with deep concave depressions between them. A third spiral, partly concealed by the embracing of the whorls, is shown on the body volution to be less prominent than the others.

The aperture is distinctly quadrangular. The callus of the inner lip is thick and rather narrow. The siphonal canal is short and deep. The outer lip is often thickened in large individuals, sinuous and folded into lobes to correspond with the spirals of the outer surface.

HORIZON AND LOCALITIES: Oligocenic. Morigny, Jeures and many other localities in the Paris Basin.

No. 20152, Columbia University collection.

REMARKS: The youngest volution of this species to show the surface has the ornamentation of the adult *P. tricarinata*. The first change to take place in this ornamentation is in the loss of the median spiral, which was the last feature to be acquired in the development of the latter species. The succeeding three or four volutions of *P. trochleare* correspond with a still younger stage of *P. tricarinata,* namely, that with two rows of nodes only. The adult *P. trochleare* has two continuous spirals, as in the earliest stages of *P. tricarinata.* The facts thus far stated seem to indicate a loss of characters by gerontism and the return to the primitive conditions of an ancestor, but that this is not the case is shown by a study of the intervening stages of *P. tricarinata.* Studying the development of that species in reverse order, the stage preceding that with two rows of nodes only is one in which the sub-sutural row of nodes is absent, and, earlier still, a fine spiral is present immediately above the shoulder spiral (plate VIII, fig. 7). This is not the same feature as the median row of nodes in the adult, although it occupies the same position, because it disappears and gives place to another character before the appearance of the adult median nodes. It is this spiral, however, which, on the fourth volution, is as strong as the spiral at the shoulder angle and forms the upper of the two continuous spirals on the second volution. In *P. trochleare,* on the contrary, it is the sub-sutural spiral which persists and forms the upper of the two strong spirals in the adult. The lower of the two corresponds with the spiral at the shoulder angle in *P. tricarinata.* These two spirals have not the character of primitive structures, but are on the contrary, extreme in their development. *P. trochleare* is a descendant of *P. tricarinata,* with its youngest stages like the adult of the latter species. From this stage it progresses toward simplification of surface forms rather than complication of them, as in the species previously described. It illustrates the fact that progressive development does not always mean complication of structures, but may also travel in the direction of simplification of structures. Although *P. trochleare* does not add new types of ornamentation, it does emphasize strongly the one feature retained in the extreme prominence of its two continuous spirals.

Illustrations of progressive development resulting in more simple structures are found in other genera; for example, *Claviger matoni* GRAY has young stages in which the whorls are ornamented by four strong spirals crossed by numerous oblique ribs, changing abruptly to an ornamentation of two very prominent continuous spirals, but without other features to indicate gerontism as a cause for the loss of ornamentation.

Deshayes's figures of this species, cited above, indicate an extreme degree of variation, including forms with three spirals, or one spiral, or rows of strong nodes, and it is probable that several of these should be considered distinct species. In the absence of specimens showing these variations, they will not be considered here.

5. *Vulgocerithium*

Vulgocerithium minutum *de Serres*

1822. *Cerithium minutum* DE SERRES, Essai pour servir a l'histoire des anim. du midi de la France, p. 60.

1856. *Cerithium minutum* HÖRNES and PARTSCH, Abhand. der k. k. geol. Reichsanst., III, 390, pl. 41, figs. 8, 9.

MEASUREMENTS: Length, 25 mm.; greatest diameter, 9 mm.; apical angle, 33.5°, changing to 16° on the last four volutions; sutural angle, 83.5°.

The youngest volution preserved on the specimen studied is 1.2 mm. in diameter. It has a well-defined shoulder with two strong spirals, one finer intercalated spiral and four on the shoulder. On the next two volutions the sub-sutural spiral becomes broad, another spiral is added between the two primaries, and one appears on the lower slope of the whorl. On the succeeding volutions the sub-sutural spirals become elevated at intervals as a row of nodes, the lower slope of the volution becomes nearly continuous with its vertical sides and numerous intercalated spirals appear. The adult ornamentation is that of a sub-sutural row of nodes, a median row with nodes slightly more prominent than those of the upper row and ribs which are more or less continuous toward the upper suture but are represented by irregularly spaced nodes below the median line. The shoulder on the last three volutions is nearly obsolete, being defined merely by the median row of low nodes.

The aperture is of the form usual in this group, with a narrow callus on the inner lip, a strong posterior tooth and a short anterior canal. The outer lip is thin and slightly crenulated.

Horizon and locality: Upper Oligocenic (Aquitanian). Saucats, France. No. 3123, Museum of Comparative Zoölogy.

Remarks: This species continues into the Miocenic, but the specimens studied are from the Oligocenic. Except for its small size, the shell is closely similar to *V. vulgatum*, and it may well be the immediate ancestor of that species.

Vulgocerithium pupæforme *Basterot?*

1825. *Cerithium pupæforme* Basterot, Mémoire géol. sur les environs de Bordeaux, p. 58, pl. 3, fig. 18.
1906. *Dizoniopsis pupæforme* Cossmann, Essais de Paléoconch. Comp., VII, 147, pl. XII, figs. 22-24.

Measurements: Length, 12 mm.; greatest diameter, 4.8 mm.; apical angle, 36.5°, changing to 26° on the last three volutions; sutural angle, 76°.

The protoconch of this species is not preserved, but a volution .6 mm. in diameter probably represents about the second volution beyond it. This whorl is ornamented by two equal spirals, and on the next volution the spirals are crossed by ribs. On the third volution of those preserved a spiral is added between the two primary spirals and one just below the suture. On the later volutions numerous fine spirals appear until those of the third order may be recognized. On the body volution the shoulder is less prominent and the nodes formed by the crossing of the ribs and the sub-sutural spiral are larger, so that without a lens the surface appears to be ornamented by two rows of nodes, the lower of which is formed by the crossing of the ribs and the shoulder. The body volution has two or three strong spirals, with finer intercalated ones on its lower slope.

The aperture is elongate oval, with a broad and thick callus on the inner lip. The siphonal canal is long and slightly curved. The outer lip is thin and not expanded.

Horizon and locality: Oligocenic (Aquitanian). Saucats, near Bordeaux. No. 2521, Museum of Comparative Zoölogy.

Remarks: The original description of *Cerithium pupæforme* has not been obtainable, and the reference to this species is somewhat doubtful.

The development of this shell, as well as its adult ornamentation, has all the characteristics of *Vulgocerithium*. It resembles *V. minitum* to such an extent that it was at first thought to be the young of that species, but it is more accelerated than *V. minutum*, acquiring its tertiary spirals at an early stage. It differs further from the latter species in having a narrower aperture and longer canal. The well-developed callus and nearly uniform size of all of the ten individuals studied seem to indicate that the specimens are fully adult.

F. CRETACIC SPECIES OF CERITHIUM

No actual specimens of true *Cerithium* from horizons earlier than the Aptien were available for study, and the following phylogeny worked out from the literature is subject to revision, if more material should be obtained.

Cerithium cornuelianum *d'Orbigny*

1842-1843. *Cerithium cornuelianum* D'ORBIGNY. Paléontol. Française, Terrains Crétacés, II, Gastéropodes, p. 361, pl. 228, figs. 11-13.
1906. *Atresius cornuelianum* COSSMANN. Essais de Paléoconch. Comp., VII, 195.

The original description is as follows:

DIMENSIONS: Ouverture de l'angle spiral, 27°; longeur totale, 27 millim.; largeur, 12 millim.; longeur du dernier tour, par rapport à l'ensemble 35/100; angle sutural, 89°.

Coquille allongée, turriculée. Spire formée d'un angle régulier, composée de tours convexes, ornés en travers, à la dernière révolution spirale, de dix côtes flexueuses, ondulées, non arrêtées, se correspondant obliquement d'un tour à l'autre. Sur ses côtes viennent se croiser de légers sillons longitudinaux très-inégaux. Bouche ovale, prolongée en avant et terminée par un sinus; labre très-échancré en arrière, saillant antérieurement.

HORIZON AND LOCALITY: Aptien. Grange-au-Ru, near the Varin bridge, commune de Wassy (Haute Marne).

REMARKS: This species has volutions of a rounded outline, ribs continuous across the whorl and numerous spirals of different orders. It is thus a simple shell, having the characteristics which might be expected in an early type of true *Cerithium*. A specimen in the Museum of Comparative Zoölogy does not show the young stages, but on the last three volutions two of the spirals are stronger than the others. This suggests the beginning of the development which becomes a characteristic feature of *Cerithium æquispirale* and later species of the genus.

A posterior tooth is not developed on the inner lip, but this would hardly be expected before the spirals have become strong on the body volution, for the presence of such a tooth appears, in many cases, to be due to a strong spiral on the body volution, which projects into the aperture and is accented by the passage of the callus over it.

M. Cossmann refers this species to *Atresius*, but in the description of that genus, the beak is said to be large and bent backward and the spire to be ornamented by nodulose costæ, characteristics which do not appear on this species. It seems to bear little resemblance to the type of the genus *Atresius*.

Cerithium albense *d'Orbigny*

1842-1843. *Cerithium albense* d'Orbigny, Paléontol. Française, Terrains Crétacés, II, Gastéropodes, p. 355, pl. 227, figs. 10-12.

The original description is as follows:

Dimensions: Ouverture de l'angle spiral, 20°; longeur totale, 13 millim.; diamètre, 4 millim.; longeur du dernier tour, par rapport à l'ensemble, 30/100.

Coquille très-allongée, aciculée. Spire formée d'un angle régulier, composée de tours convexes, séparés par des sutures, ornés, en long, de côtes inégales, dont quatre, plus grosses, plus saillantes, tranchantes, vont diminuant de grosseur des supérieures aux inférieures. Entre chacune de celles-ci existe une petite côte très-étroite; il y a encore, en travers, par révolution spirale, de onze ou douze côtes arrondies, droites, sur lesquelles passent les premières. Le dernier tour a de plus une seule côte longitudinale. Bouche ovale, prolongée en canal, en avant. Labre mince, tranchant.

Horizon and locality: Neocomian. Marolles (Aube), France.

Remarks: The figures of this species show a simple type of shell with rounded volutions, well-developed ribs and three strong spirals on each volution. A finer fourth spiral is also present just below the suture, and the shell is further ornamented by a single intercalated spiral between each pair of the coarser ones. The outer lip has the crenulated margin characteristic of *C. æquispirale* and later species of *Cerithium*.

This shell is simpler than *C. cornuelianum* in possessing two orders of spirals only, and, so far as can be determined without an examination of the shell, it seems to constitute an earlier member of the *Cerithium* line of evolution.

G. JURASSIC SPECIES OF CERITHIUM

Cerithium corallense *Buvignier*

1843. *Fusus corallensis* Buvignier, Mémoire de la Soc. Philomatique de Verdun, p. 22, pl. 6, fig. 7.

1889. *Brachytrema corallensis* de Loriol, Abh. Sweiz. Paläont. Gesell., XVI, 65, pl. 9, figs. 1, 2.

1906. *Brachytrema corallensis* Cossmann, Essais de Paléoconch. Comp., VII, p. 18.

The original description of this species is as follows:

Coquille turriculée, allongée, à côtes longitudinales, au nombre de cinq sur les tours supérieurs, mais plus nombreuses sur les autres; elles sont recoupées par des sillons transverses au nombre de trois sur chaque tour. Bouche ovale, anguleuse supérieurement, échancrure large, profonde et oblique.

Horizon and locality: Jurassic, Coral-rag. St. Michiel, France.

Remarks: This species of *Cerithium* shows primitive characteristics in its simple ornamentation consisting of primary spirals and ribs only, its moderate degree of embracing of the whorls and its simple aperture, with short, straight canal. The points of intersection of the spirals and ribs are often elevated, giving the surface a nodose appearance, but the ornamentation is composed essentially of the ribs and three simple spirals only. In this respect the shell is more primitive then *C. albense* and must resemble the young of that species before the introduction of intercalated spirals.

Specimens of this species were not obtainable, but from the evidence furnished by the literature it seems to be an ancestral form of *Cerithium* and the earliest representative thus far obtained of the line of evolution terminating in *C. tuberosum*.

This species has been referred to the genus *Brachytrema*. but a comparison with the type of that genus, *B. buvignieri,* shows a wide contrast in form and ornamentation, the latter species having the low spire and wide apical angle of the genus *Trochus,* with the outer lip much expanded and the body volution longer than the remainder of the shell.

V. Summary

Reviewing the facts already presented, it is found that, while no specimens of true *Cerithium* were obtained earlier than the Aptien, it appears from the literature that the Jurassic species, *Cerithium corallense,* may represent the earliest known species of the genus. This is a primitive type of shell of small size, with rounded whorls and having on its adult volutions three spirals crossed by ribs.

In studying the development of retarded species of *Cerithium.* it is found that the shell forms first a single spiral, with a second spiral added above the first. Later the two spirals become of equal strength and are crossed by ribs. This stage reappears constantly throughout the genus and its near relatives. The fact that it is so persistent a feature suggests that it probably formed the adult stage of an early Jurassic or Triassic ancestor of *Cerithium,* from which forms like *C. corallense* were developed by the addition of a third spiral above the two primary ones. Such a type of development is epitomized in three species of the upper Eocenic. *C. bicarinatum* has adult ornamentation like the supposed primitive ancestor of *C. corallense*—that is, two equal spirals crossed by ribs (plate IV, fig. 9). The immediate descendant of the former species is *C. bicarinatum* mut. *trispirale*, a form which corresponds with *C. corallense* in having a third spiral present above the two primary ones, producing a shell with rounded volutions and an ornamentation of three simple spirals crossed by ribs.

The lower Cretacic species, *C. albense*, shows an advance upon *C. corallense* in the introduction of intercalated spirals, and it has its parallel in the Eocenic species, *C. retardatum*, which differs from its immediate ancestor, *C. bicarinatum* mut. *trispirale*, only in the presence of intercalated spirals. *C. bicarinatum* is descended from an early ancestor of *Cerithium*, and is so retarded as to retain its ancestral characteristics nearly unchanged. Its descendants pass through rapidly, in one geological period, a path of evolution which has been traveled more slowly in the main line of evolution from early Jurassic, or possibly Triassic, to Cretacic time.

An advance upon the type of development shown in *C. albense* is seen in *C. cornuelianum*, of later Cretacic (Aptien) time. This shell has many intercalated spirals, and two of the primary spirals are stronger than the others, forming a slight projection around the median portion of the adult volutions. This projection, although similar in form, is not the developmental equivalent of the primary two-spiraled stage, for in the phylogeny of the genus it appears after the stage with three primary spirals and after the development of intercalated spirals. In recent, highly accelerated species of the genus, intercalated spirals appear so early in the ontogeny that the stage with three simple spirals is either omitted altogether or obscured by the fact that the third spiral on the shoulder never becomes as strong as the others. In such cases the stage just described seems to be continuous with the primitive two-spiraled stage, from which it differs morphologically only in the presence of intercalated spirals.

The greater abundance of Eocenic material in the collections studied furnishes an opportunity for determining the phylogeny with greater certainty than in the earlier horizons. At that time *C. æquispirale* represents the next stage in the phylogeny of the genus beyond *C. cornuelianum*, for on this specimen the two equal spirals are well developed and persist to the adult whorls, and spirals of several orders are easily recognizable. The young stages of *C. æquispirale* are unfortunately missing, but they were doubtless simpler than the youngest stage preserved, and were probably not unlike the young specimens referred to *C. inabsolutum;* but if these specimens are correctly idenified, the adult differs from *C. æquispirale* in the direction of loss of fine spirals and of the shoulder. *C. lamellosum* carries this loss of ornament still farther, and the two constitute a lateral branch in the phylogeny of *Cerithium. C. calcitrapoides* represents another lateral branch, having its young stages like the adult *C. cornuelianum,* but its later stages have a shoulder with a sharp angle of the type seen on recent species of the genus.

As stated above, the European Miocenic and Pliocenic furnish no undoubted species of *Cerithium* sens. str., but in the Miocenic of Florida *C. chipolanum* seems, so far as can be determined from the description and figure, to belong to this genus and to represent a branch in which a comparatively low spire is developed. *C. chipolanum* is probably an American representative of an undescribed European form which was the ancestor of the somewhat low-spired recent species, such as *C. adansoni, C. echinatum,* etcetera.

The Pliocenic *C. callisoma* has the high spire characteristic of the type of the genus *C. tuberosum,* and it, too, probably had its European parallel, which was the ancestor of *C. tuberosum* and other high-spired related forms. The abundance of material in the collections of recent shells reveals a great flowering out of the genus in recent time, and however different the appearance of the adult shells, all reveal their common ancestry by a similarity in their young stages, as described above and indicated on plate I.

Among the genera closely related to *Cerithium, Vulgocerithium* is perhaps the nearest, developing as it does at an early stage the two strong spirals with intercalated spirals, and diverging from the main line of evolution only in the greater development of nodes and in the absence of a sharp shoulder angle in the adult. Species of this genus seem to undergo little change from Oligocenic to recent time, and all the species described are similar in general appearance and differ from one another only in details.

The genus *Potamides* is closely related to *Cerithium.* The type of the genus *P. lamarcki* develops the bicarinate ornamentation in the same manner as in *C. retardatum* (plate III, figs. 9, 10, and plate IV, fig. 9) or other retarded or primitive species of *Cerithium,* but retains each stage for a greater portion of the spire, or, in other words, its early ontogeny is like that of *Cerithium,* but more retarded. The adult expresses its divergence from *Cerithium* by developing nodes as the chief feature of its ornamentation. As pointed out above, *Potamides* is a more primitive genus than *Cerithium* in its slightly developed canal, in the simplicity of its ornamentation and in its retarded ontogeny. It is probably developed from the same bicarinate ancestor from which *Cerithium* arose, but includes primitive types which persist throughout several periods of geological time. Eocenic species of *Potamides* form, like *Vulgocerithium,* a compact group the members of which do not diverge strongly, even in the adult stages.

The genus *Tympanotonus* is founded upon *Murex fuscatus* Linné, a species formerly referred to *Potamides,* and this shell has the typical *Potamides* young stages, forming the peculiar ornamentation of the adult by developing its median row of nodes into large spines. The genus should be restricted to those forms which are like *Potamides* in the young and only show divergence in the neanic or adult stages. As thus restricted, the genus is a direct descendant from *Potamides.*

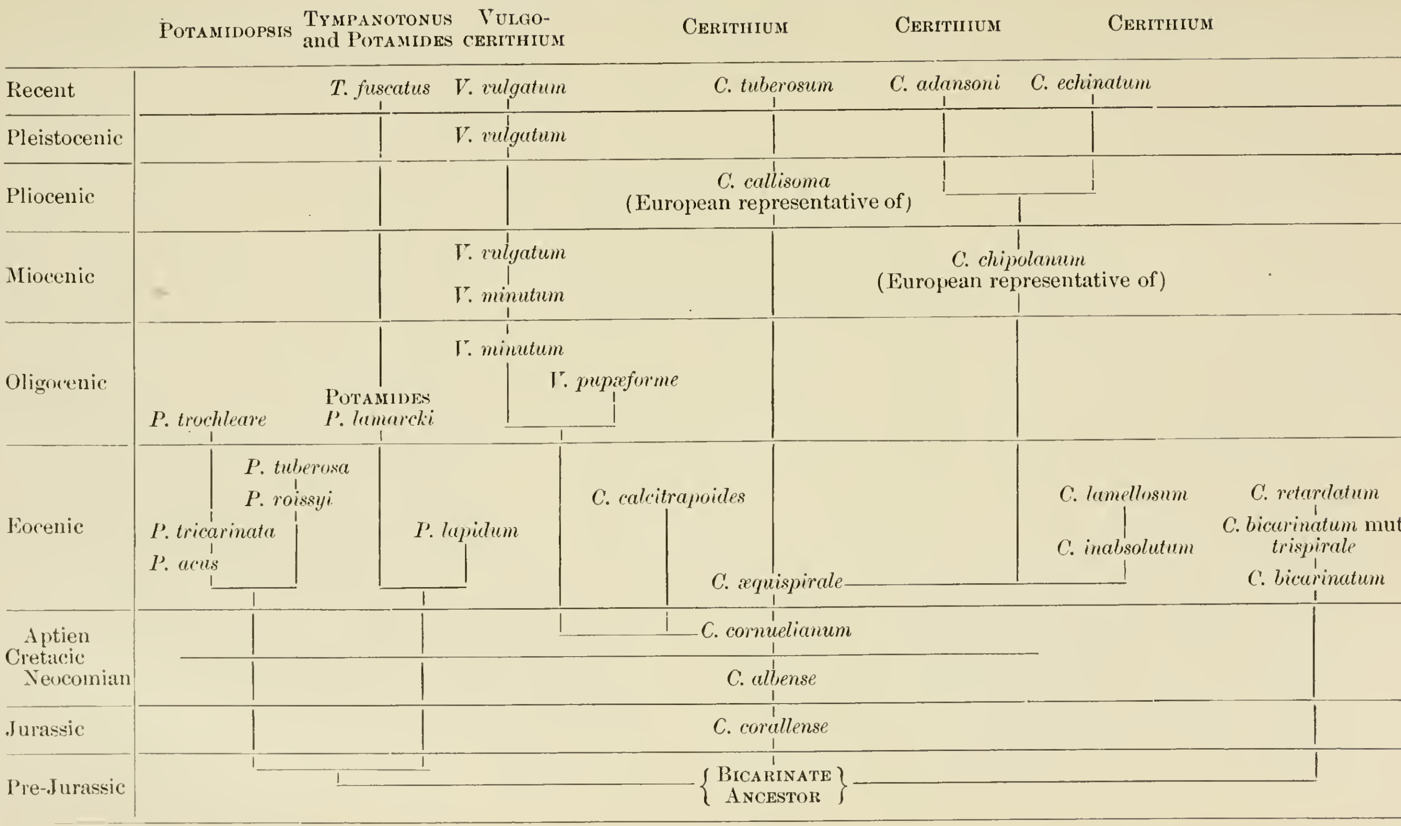
The genus *Potamidopsis,* having for its genotype *Cerithium tricarinatum* Lamarck, is also closely related to *Cerithium,* as shown by the development of the genotype. This species forms a bicarinate ornamentation in the same manner as both *Cerithium* and *Potamides* (compare plate vii, figs. 7, 8, with plate iii, figs. 9, 10, and plate iv, fig. 9), but it is more accelerated than *Potamides.* Beyond this stage, *Potamidopsis* diverges strongly from *Cerithium* in forming its shoulder angle just above the suture and in having its surface ornamented by rows of nodes. The genus as a whole is less accelerated than *Cerithium.*

As a probable ancestor of *P. tricarinata* we have *P. acus,* whose adult stages resemble the ninth to the thirteenth volutions of *P. tricarinata,* and from this species we have developed *P. roissyi* and *P. tuberculosa,* whose development is parallel to that of *P. tricarinata* up to the *P. acus* stage. After this stage these forms diverge from *P. tricarinata* by developing the uppermost instead of the lowest row of nodes.

The ancestor of *Cerithium* immediately preceding the Jurassic species described probably possessed a bicarinate ornamentation crossed by ribs and a very slightly developed canal. The young stages probably had rounded whorls, with one spiral at first and later two continuous spirals. The collections thus far studied do not furnish sufficient evidence for a statement as to the canalless form from which this primitive ancestor of the genus was derived.

Cerithium is a genus which shows a strong tendency to vary, as shown by the great diversity of forms present in the Eocenic and still greater variety in recent time; but, notwithstanding the wide differences in adults, relationship may be traced by similarity in the young stages, pointing out the path of evolution which all have traveled.

Table to Show the Phylogeny of Certain Cerithiidæ



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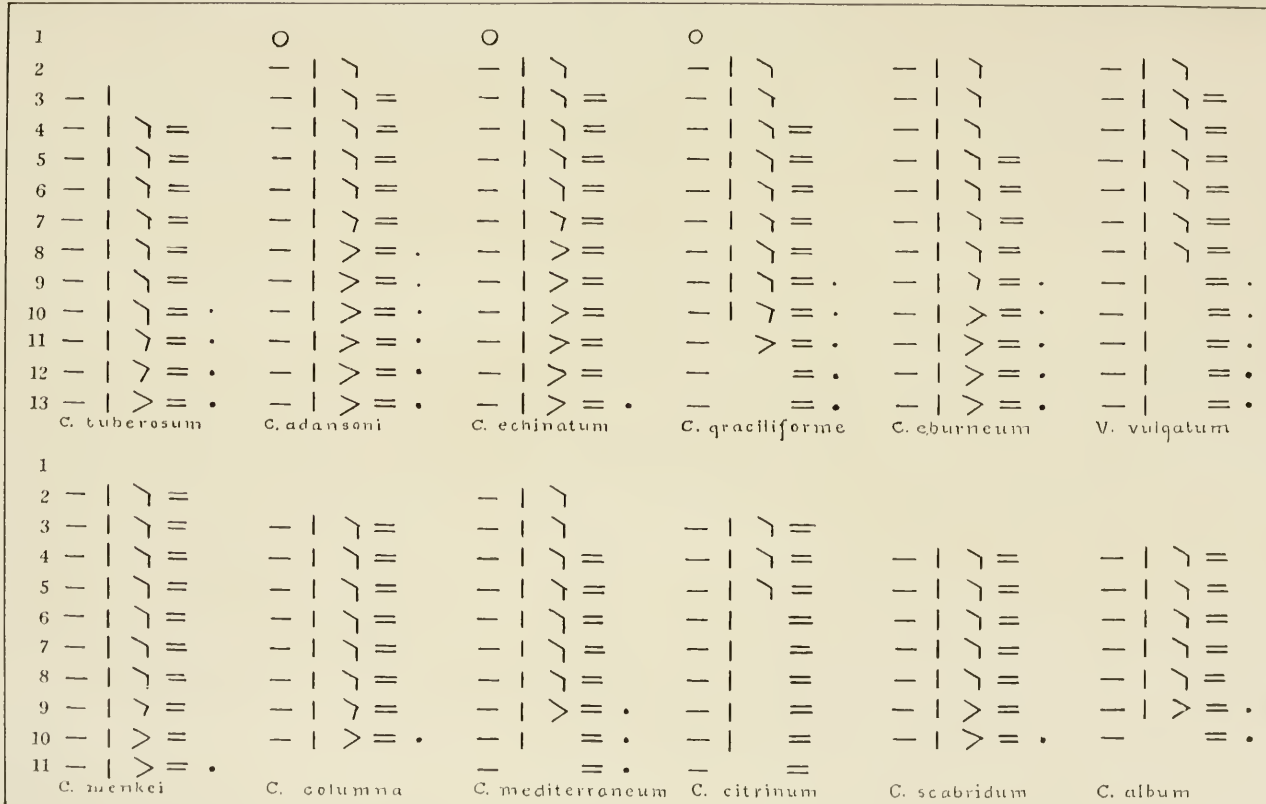
C. tuberosum
C. adansoni
C. echinatum
C. graciliforme
C. eburneum
V. vulgatum
C. menkei
C. columna
C. mediterraneum
C. citrinum
C. scabridum
C. album

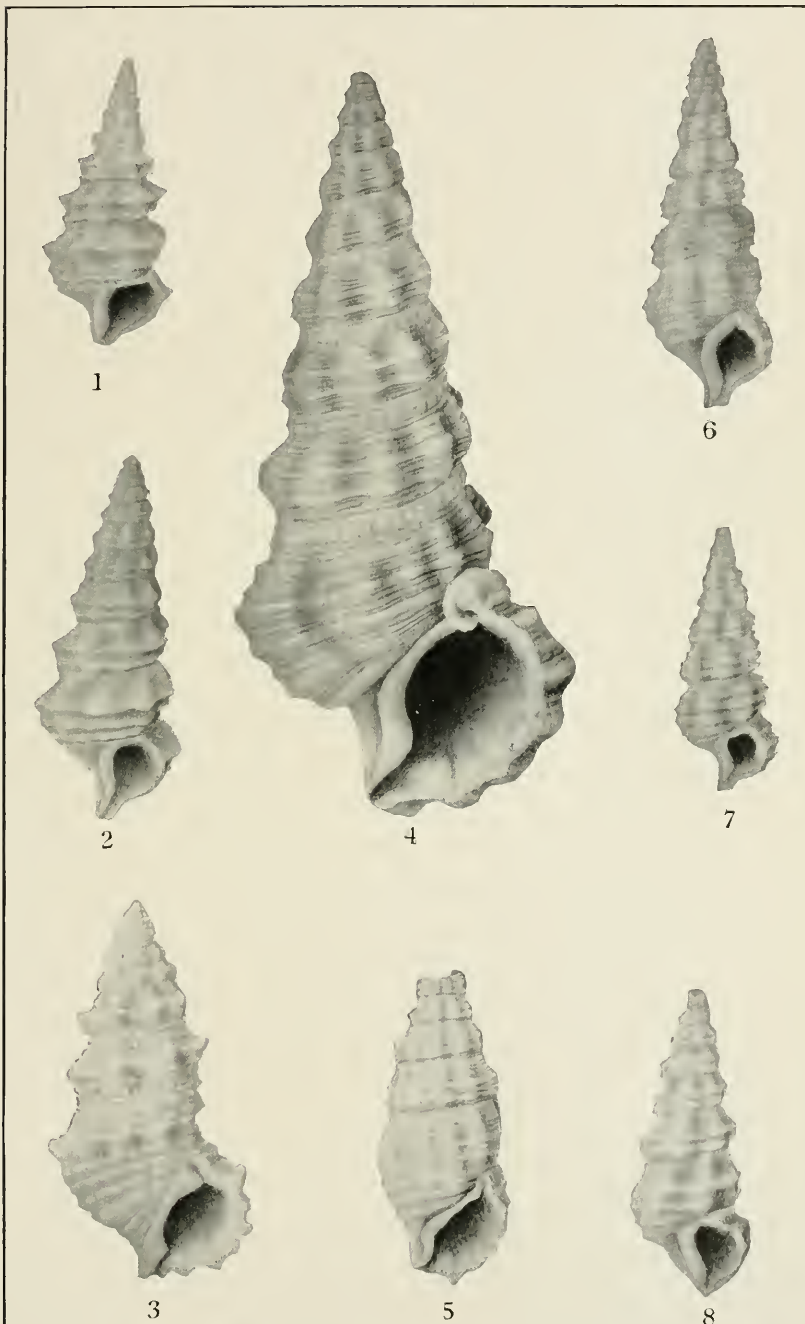
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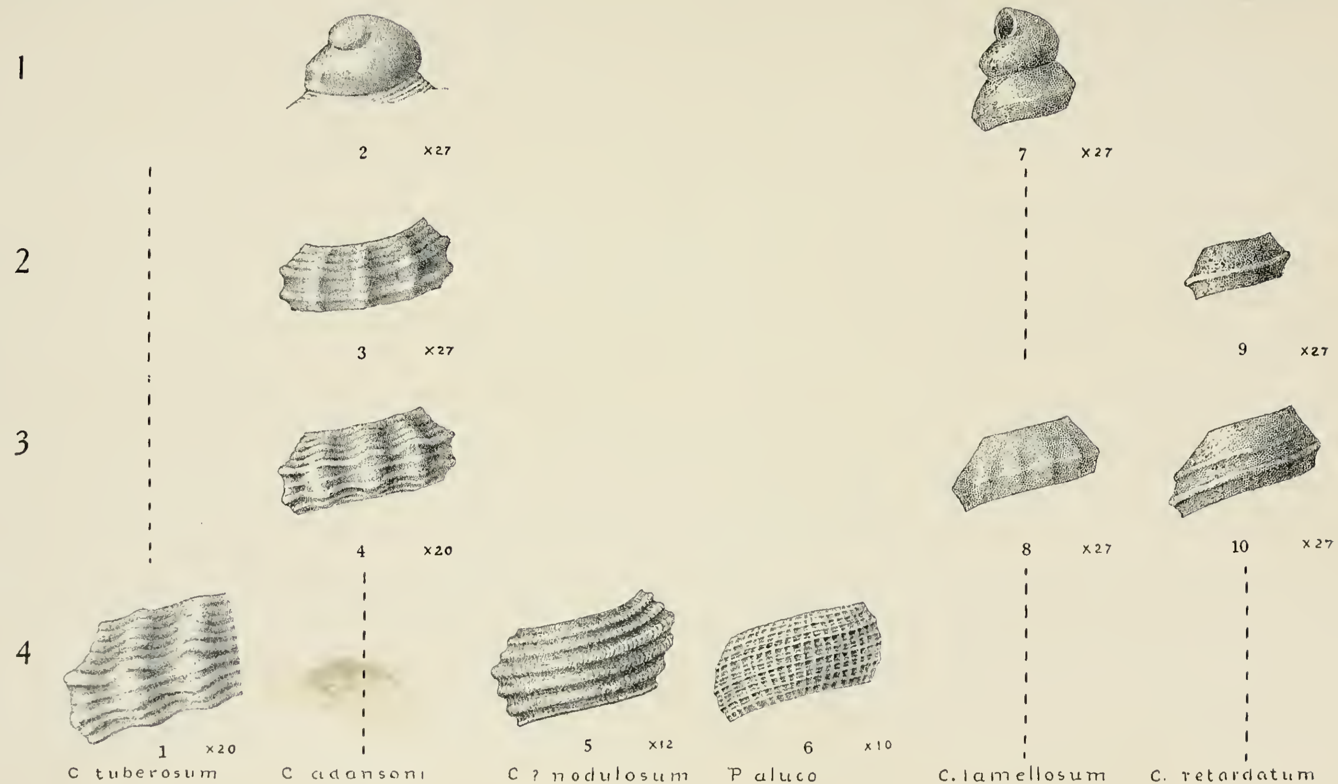
PLATE III

ONTOGENY OF SIX SPECIES OF CERITHIUM

Numbers at the left of the plate indicate the numbers of the volutions. Dotted lines indicate gradual transition from one volution to the next figured. The amount of enlargement is given on the plate; actual measurement of the portion of the shell figured is given below. All the figures on Plates III to IX are from original drawings by the author.

FIG. 1. *Cerithium tuberosum*, fourth volution. 1.6 × .3 mm.
FIG. 2. *Cerithium adansoni*, protoconch. .6 × .4 mm.
FIG. 3. *Cerithium adansoni*, second volution. .8 × .3 mm.
FIG. 4. *Cerithium adansoni*, third volution. 1.1 × .5 mm.
FIG. 5. *Cerithium? nodulosum*, fourth volution. 1.9 × 1 mm.
FIG. 6. *Pseudovertagus alueo*, fourth volution. 2.2 × 1.1 mm.
FIG. 7. *Cerithium lamellosum*, protoconch and first volution. .5 × .7 mm.
FIG. 8. *Cerithium lamellosum*, third volution. .7 × .32 mm.
FIG. 9. *Cerithium retardatum*, second volution. .5 × .25 mm.
FIG. 10. *Cerithium retardatum*, third volution. .75 × .37 mm.


1
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3
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2 ×27
3 ×27
4 ×20
1 ×20
5 ×12
6 ×10
7 ×27
8 ×27
9 ×27
10 ×27
C tuberosum
C adansoni
C ? nodulosum
P aluco
C. lamellosum
C. retardatum

PLATE IV

ONTOGENY OF SIX SPECIES OF CERITHIUM (continued)

FIG. 1. *Cerithium tuberosum*, eighth volution. 4.6 × 2.2 mm.

FIG. 2. *Cerithium adansoni*, fifth volution. 3.5 × 1.5 mm.

FIG. 3. *Cerithium adansoni*, eighth volution. 9 × 3.4 mm.

FIG. 4. *Cerithium? nodulosum*, sixth volution. 6 × 3 mm.

FIG. 5. *Cerithium? nodulosum*, eighth volution. 6 × 5 mm. Later whorls of this shell are not figured, as they are too large to show details when reduced to the scale of this plate.

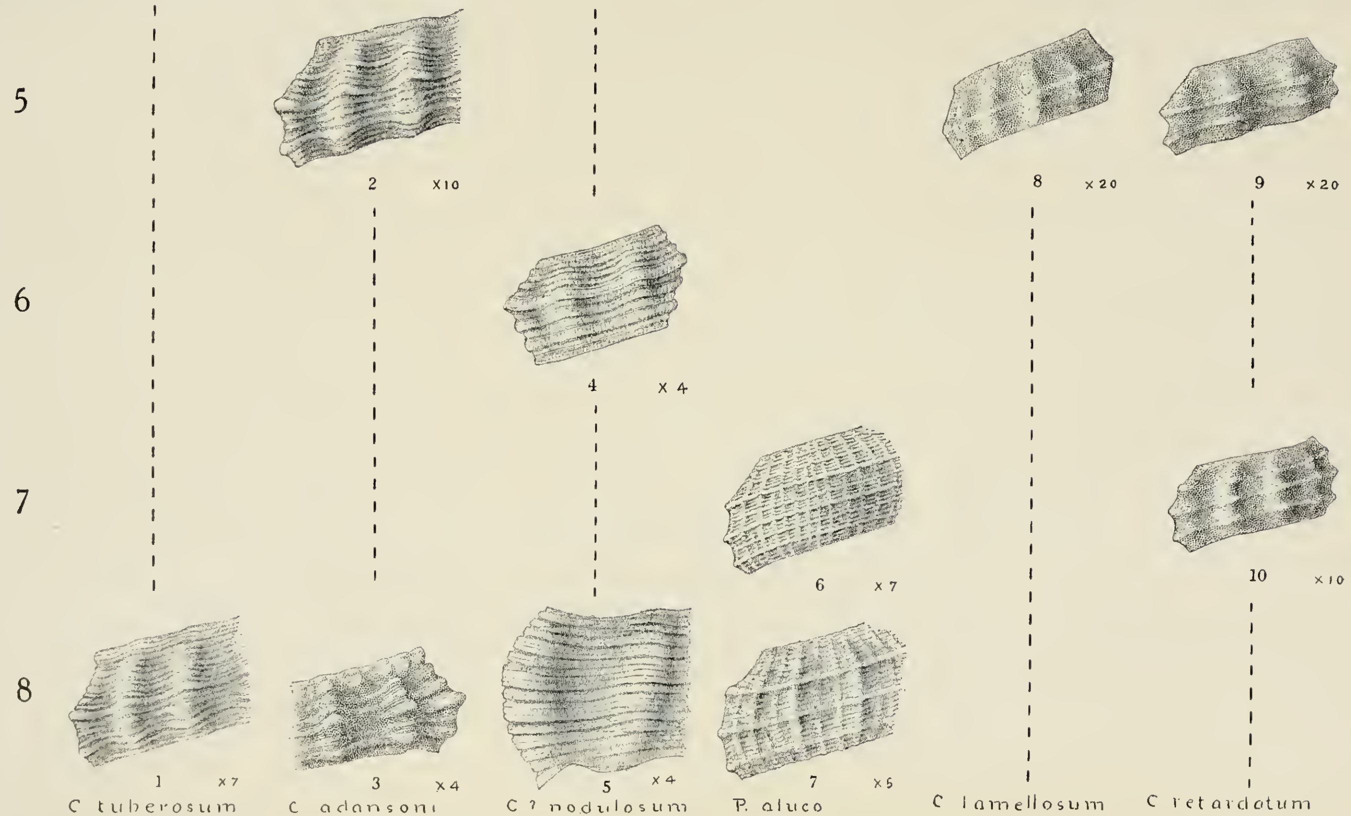
FIG. 6. *Pseudovertagus aluco*, seventh volution. 5.2 × 2.3 mm.

FIG. 7. *Pseudovertagus aluco*, eighth volution. 7 × 3 mm.

FIG. 8. *Cerithium lamellosum*, fifth volution. 1.2 × .5 mm.

FIG. 9. *Cerithium retardatum*, fifth volution. 1.2 × .5 mm.

FIG. 10. *Cerithium retardatum*, seventh volution. 2 × 1 mm.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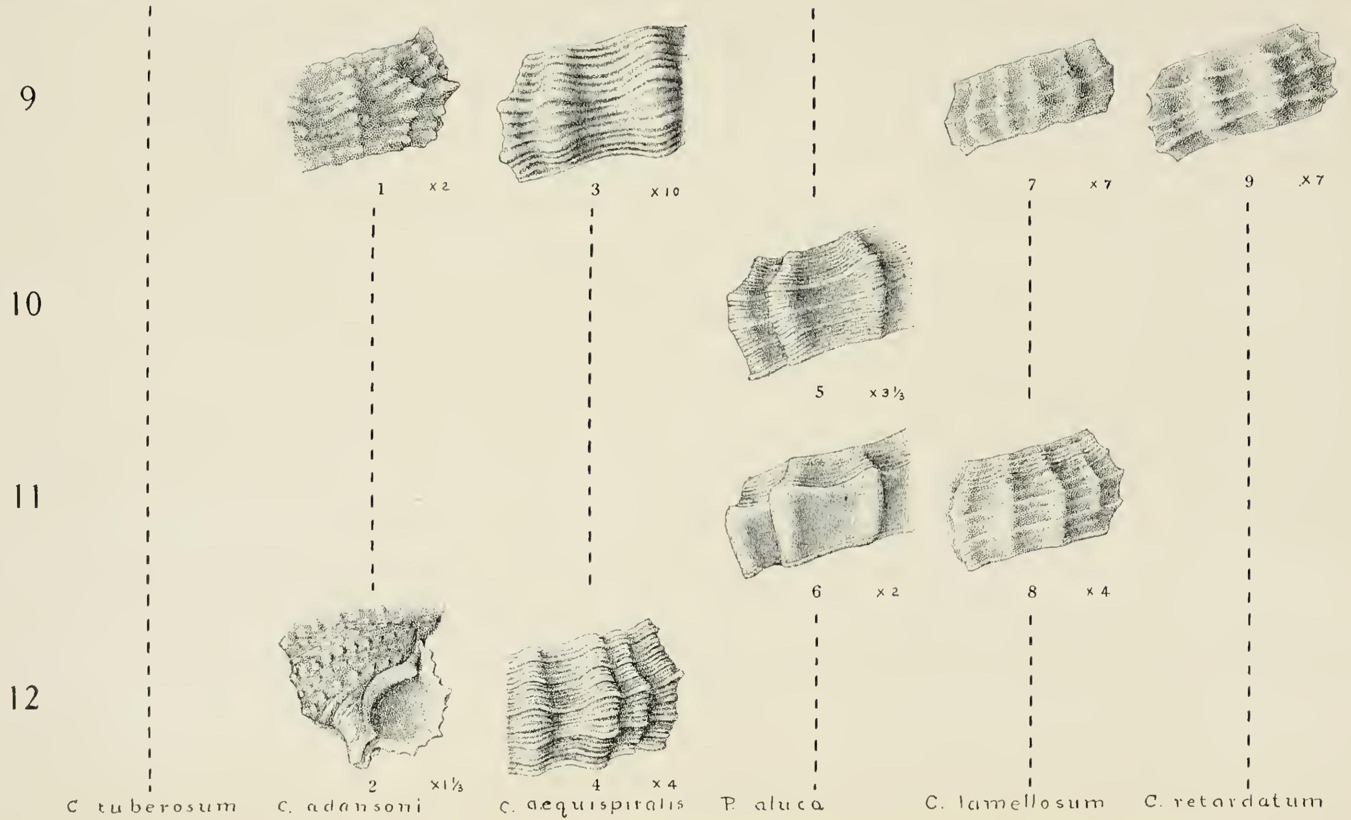
7 x5
8 x 20
9 x 20
10 x 10
C tuberosum
C adansoni
C ? nodulosum
P. aluco
C lamellosum
C retardatum

PLATE V

ONTOGENY OF SIX SPECIES OF CERITHIUM (continued)

FIG. 1. *Cerithium adansoni*, ninth volution. 12 × 7 mm.
FIG. 2. *Cerithium adansoni*, aperture. 16 × 12 mm.
FIG. 3. *Cerithium æquispirale*, ninth volution. 2.5 × 1.4 mm.
FIG. 4. *Cerithium æquispirale*, twelfth volution. 4.4 × 8.5 mm.
FIG. 5. *Pseudovertagus aluco*, tenth volution. 10 × 4.5 mm.
FIG. 6. *Pseudovertagus aluco*, eleventh volution. 16 × 7 mm.
FIG. 7. *Cerithium lamellosum*, ninth volution. 3.4 × 1.5 mm.
FIG. 8. *Cerithium lamellosum*, eleventh volution. 6 × 3.5 mm.
FIG. 9. *Cerithium retardatum*, ninth volution. 3.8 × 1.8 mm.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6 x 2
8 x 4
2 x 1⅓
4 x 4
C tuberosum
C. adansoni
C. aequispiralis
P. aluca
C. lamellosum
C. retardatum

PLATE VI

ONTOGENY OF SIX SPECIES OF CERITHIUM (continued)

FIG. 1. *Cerithium tuberosum*, thirteenth volution. 12 × 11.5 mm.

FIG. 2. *Cerithium tuberosum*, fourteenth volution. 24 × 29 mm.

FIG. 3. *Cerithium æquispirale*, fourteenth volution. 9.5 × 9.2 mm.

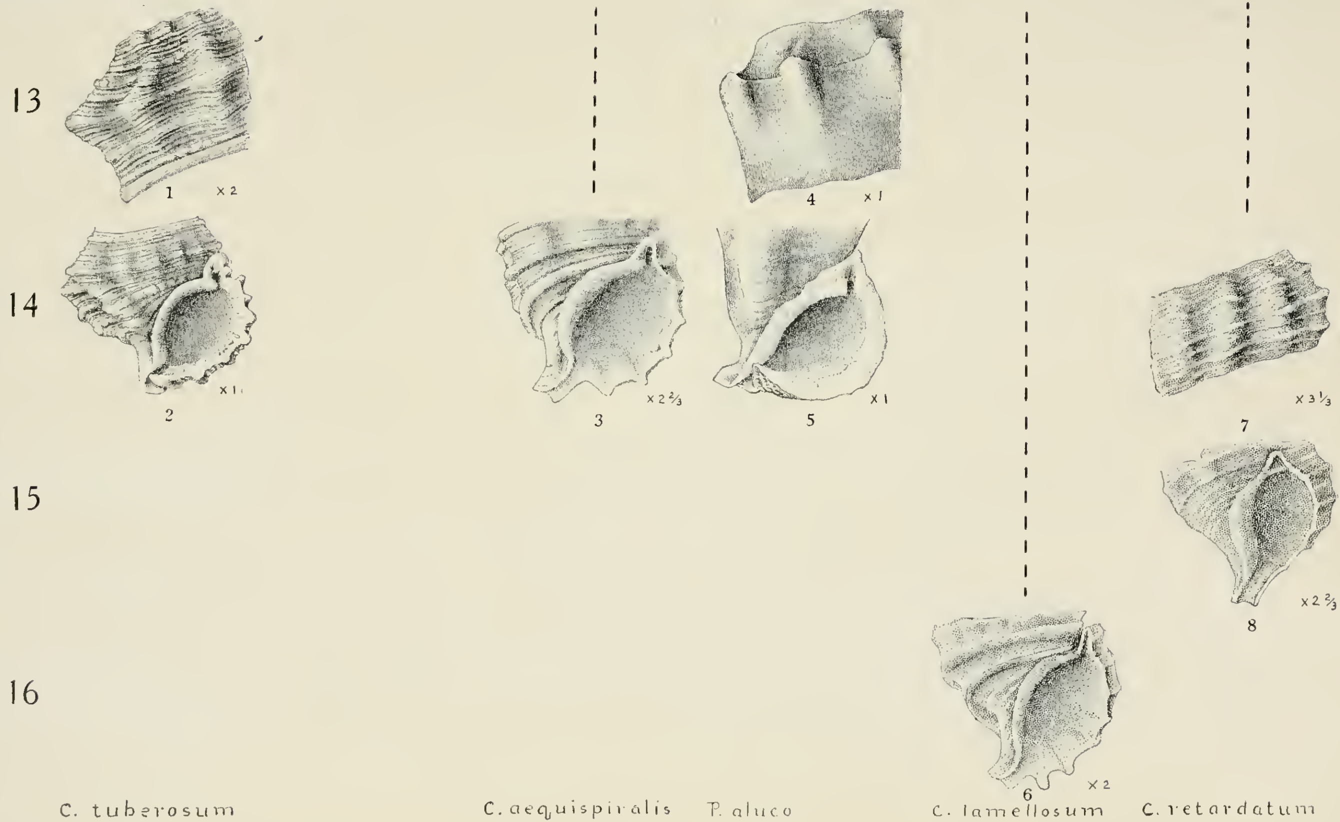
FIG. 4. *Pseudovertagus aluco*, thirteenth volution. 19 × 11 mm.

FIG. 5. *Pseudovertagus aluco*, fourteenth volution. 22 × 20 mm.

FIG. 6. *Cerithium lamellosum*, aperture. ·12 × 11 mm.

FIG. 7. *Cerithium retardatum*, fourteenth volution. 8.5 × 4 mm.

FIG. 8. *Cerithium retardatum*, aperture. 7 × 9 mm.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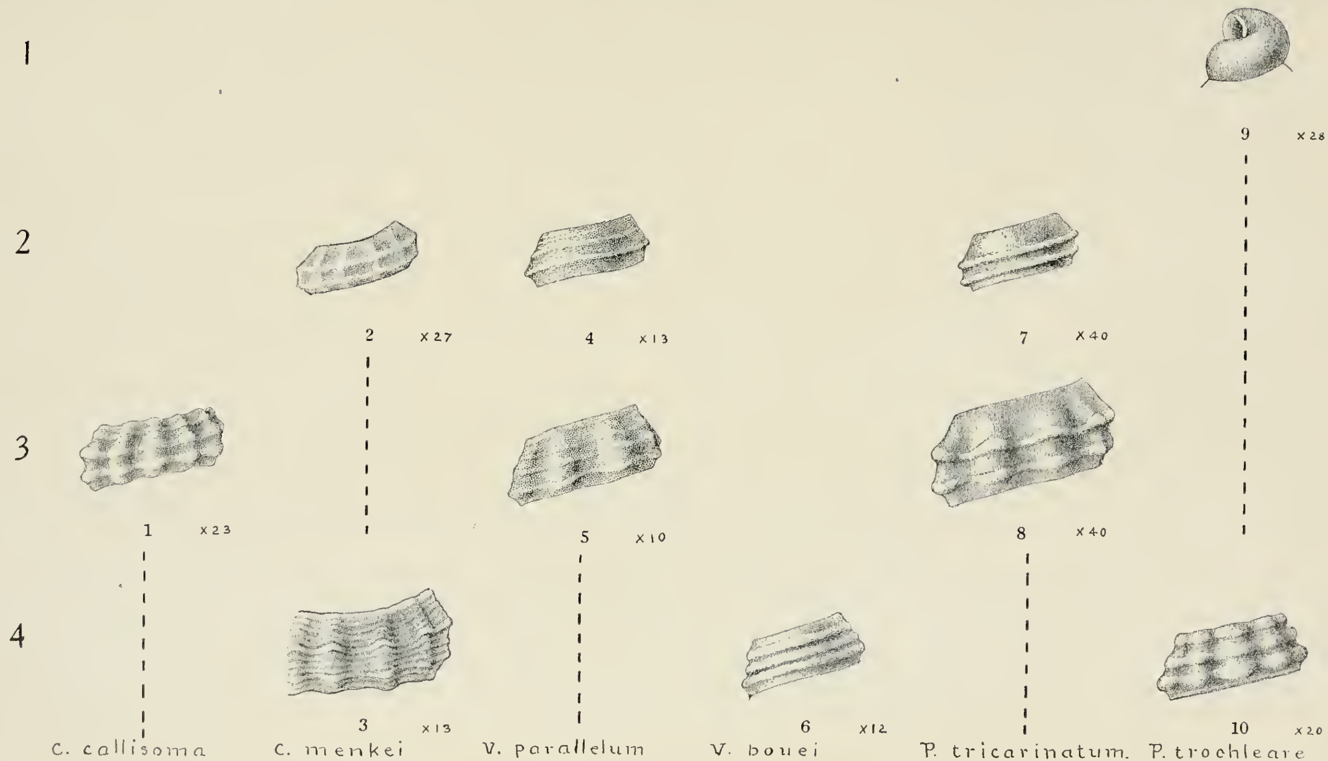
4 × 1
5 × 1
6 × 2
7 × 3⅓
8 × 2⅔
C. tuberosum
C. aequispiralis
P. aluco
C. lamellosum
C. retardatum

PLATE VII

ONTOGENY OF CERITHIIDÆ

FIG. 1. *Cerithium callisoma*, third volution. .8 × .3 mm.
FIG. 2. *Cerithium menkei*, second volution. .2 × .6 mm.
FIG. 3. *Cerithium menkei*, fourth volution. 1.8 × .8 mm.
FIG. 4. *Vicinocerithium parallelum*, second volution. 1.2 × .5 mm.
FIG. 5. *Vicinocerithium parallelum*, third volution. .2 × .8 mm.
FIG. 6. *Vicinocerithium bouei*, fourth volution. 1.4 × .6 mm.
FIG. 7. *Potamidopsis tricarinata*, second volution. .4 × .19 mm.
FIG. 8. *Potamidopsis tricarinata*, third volution. .6 × .3 mm.
FIG. 9. *Potamidopsis trochleare*, fractured protoconch. .4 × .3 mm.
FIG. 10. *Potamidopsis trochleare*, fourth volution. 1 × .4 mm.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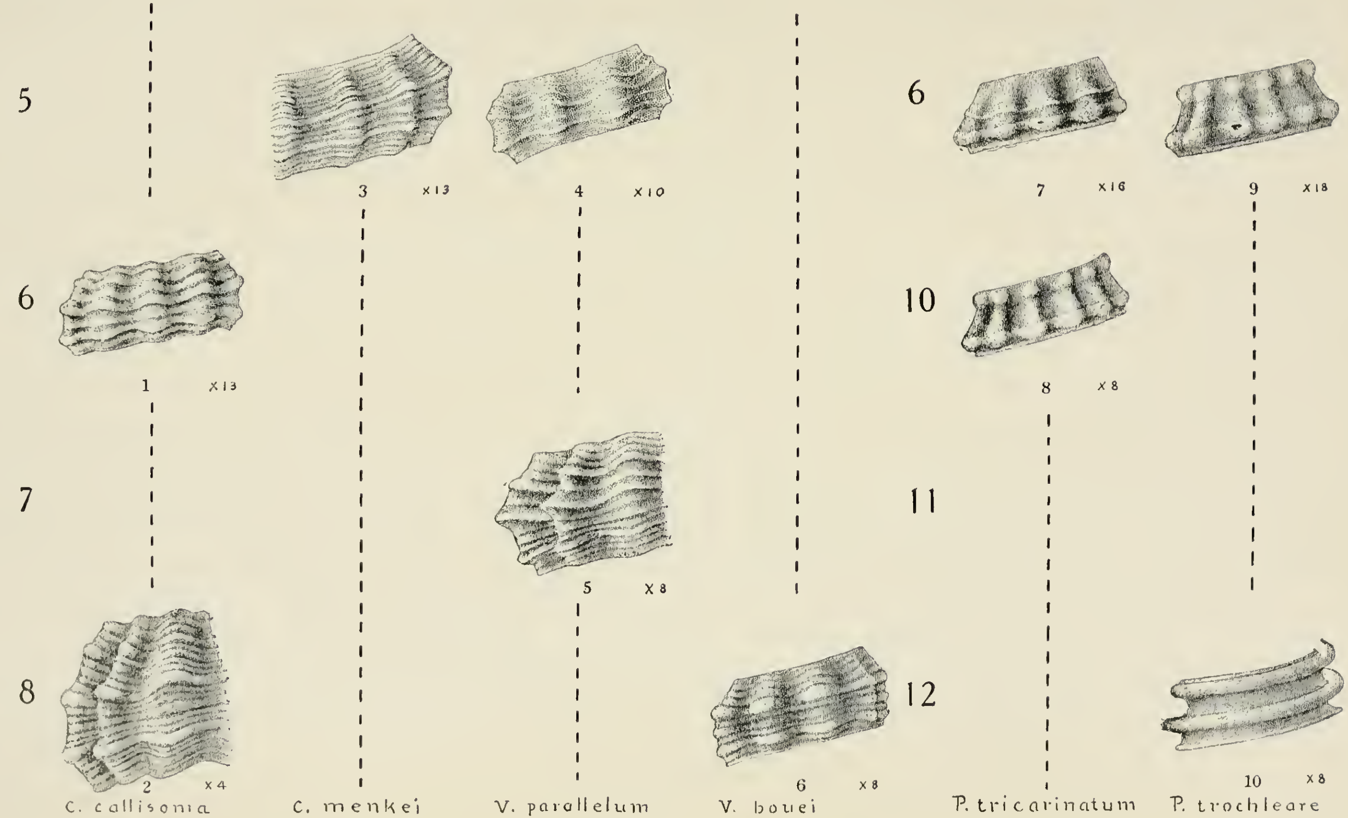
C. callisoma
C. menkei
V. parallelum
V. bouei
P. tricarinatum.
P. trochleare

PLATE VIII

ONTOGENY OF CERITHIIDÆ (continued)

FIG. 1. *Cerithium callisoma*, sixth volution. 1.8 × .8 mm.
FIG. 2. *Cerithium callisoma*, eighth volution. 2.6 × 1 mm.
FIG. 3. *Cerithium menkei*, fifth volution. 1.8 × 1 mm.
FIG. 4. *Vicinocerithium parallelum*, fifth volution. 2.4 × 1 mm.
FIG. 5. *Vicinocerithium parallelum*, seventh volution. 3 × 2 mm.
FIG. 6. *Vicinocerithium bouei*, eighth volution. 2.8 × 1.4 mm.
FIG. 7. *Potamidopsis tricarinata*, sixth volution. 1.4 × .6 mm.
FIG. 8. *Potamidopsis tricarinata*, tenth volution. 2.7 × 1 mm.
FIG. 9. *Potamidopsis trochleare*, sixth volution. 1.3 × .5 mm.
FIG. 10. *Potamidopsis trochleare*, twelfth volution. 11.8 × 7.5 mm.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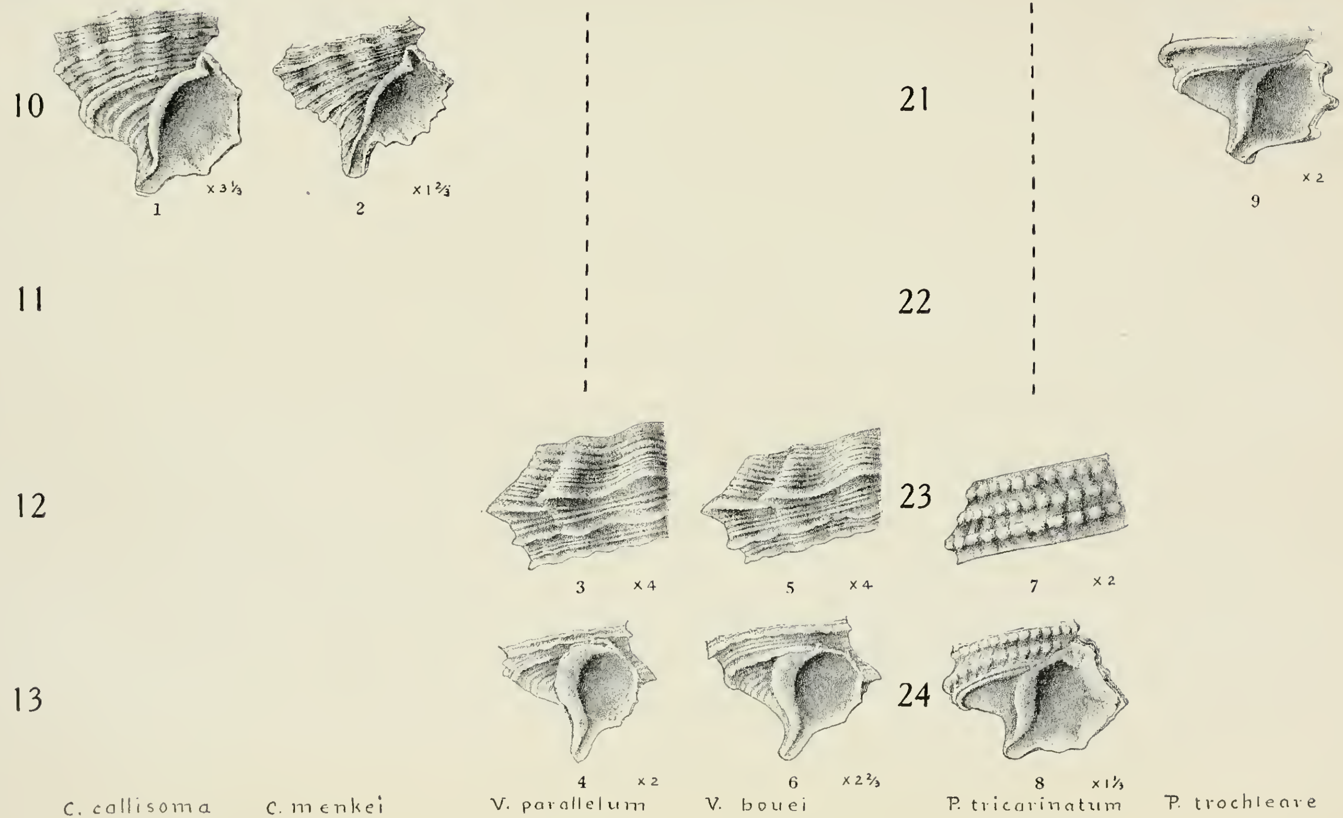
9 x18
10 x8
C. callisonia
C. menkei
V. parallelum
V. bouei
P. tricarinatum
P. trochleare

PLATE IX

ONTOGENY OF CERITHIIDÆ (continued)

FIG. 1. *Cerithium callisoma*, tenth volution. 7.3 × 7 mm.
FIG. 2. *Cerithium menkei*, tenth volution. 13 × 11.5 mm.
FIG. 3. *Vicinocerithium parallelum*, twelfth volution. 6 × 4 mm.
FIG. 4. *Vicinocerithium parallelum*, aperture. 9.8 × 8 mm.
FIG. 5. *Vicinocerithium bouei*, twelfth volution. 3 × 2 mm.
FIG. 6. *Vicinocerithium bouei*, aperture. 8.5 × 6.5 mm.
FIG. 7. *Potamidopsis tricarinata*, twenty-third volution. 12 × 5 mm.
FIG. 8. *Potamidopsis tricarinata*, twenty-fourth volution. 19 × 11 mm.
FIG. 9. *Potamidopsis trochleare*, aperture. 11.8 × 7.5 mm.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7 x 2
8 x 1⅓
9 x 2
C. callisoma
C. menkei
V. parallelum
V. bouei
P. tricarinatum
P. trochleare

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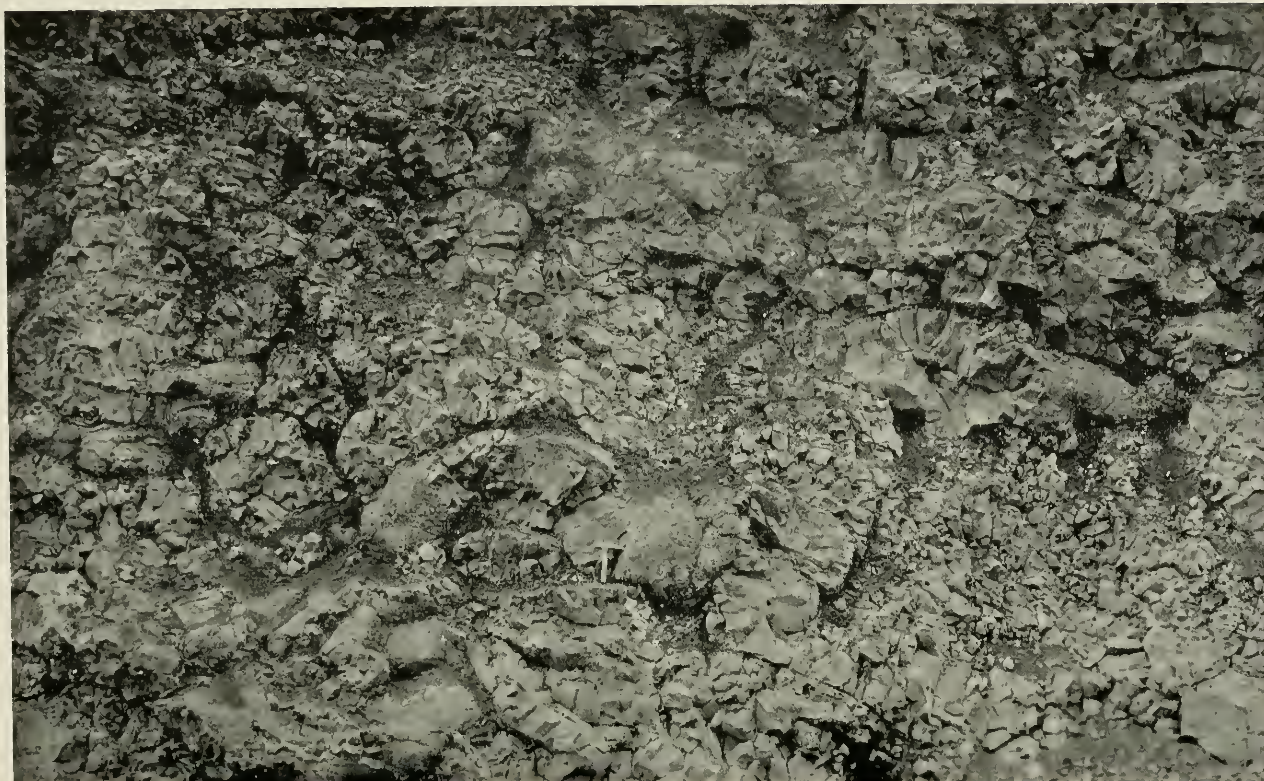

PLATE X

QUARRY IN BASALT AT WEST PATERSON, N. J.

Vertical face showing "pahoehoe" structure of basalt. Each bowlder is sheathed with glass, whose alteration has supplied the principal components entering into the secondary minerals.

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THE WATCHUNG BASALT AND THE PARAGENESIS OF ITS ZEOLITES AND OTHER SECONDARY MINERALS

BY CLARENCE N. FENNER

(*Read by title before the Academy, 2 May, 1910*)

CONTENTS

Introduction

Certain localities within the area covered by the basaltic ridge which forms the First Watchung Mountain in Northern New Jersey have for many years been famous among mineral collectors in the East for the beautiful specimens of zeolitic minerals which they have yielded. Although from a purely utilitarian point of view nothing of economic value has been discovered among these minerals or their associates, yet to the mineralogist, the size and perfection of crystal groups and the delicacy of form and coloring which are exhibited render them most attractive and desirable acquisitions. In these respects, the finest specimens found in the New Jersey localities are but little inferior to the similar zeolitic groups brought from the world-famous collecting-grounds at Berufiord in Iceland and the Poonah District in India.

Beyond the attraction which these minerals offer as objects of beauty or from a mineralogic standpoint, they present to the geologist many problems which add greatly to their interest. From this side, the relations which they bear to the enclosing rock and the cause and manner of their deposition are matters of greater importance. It is easy to recognize from their field associations that the veins and pockets in which they are found have many points of similarity with metalliferous veins, and that a full understanding of the processes involved in the formation of the zeolites would be of the greatest value in interpreting certain of the features of the economically important metalliferous deposits. From another point of view, one can recognize in the genesis of the zeolites a phase of manifestation of the processes of hydrothermal metamorphism, which operate in various forms to alter the crystalline character and the mineralogic composition of igneous and sedimentary rocks.

Study of the zeolites by various workers has resulted in considerable literature on the subject. The greater part of what has been written, however, deals purely with the crystallographic or optic properties of the minerals. It has been found that the optic characteristics present many anomalies, not all of which have found explanation, and that the laws governing the crystallographic forms of the various species are very complex, especially as regards twinning. These are matters which are largely of a physical nature and are apart from the scope of the present paper. They will not be considered, except that the results which have been attained will be utilized as offering valuable criteria for determination and discrimination. Efforts have also been made to determine the order of succession of the various associated species from different localities, but, so far as the writer is aware, the resources of microscopic petrography have been little utilized in this direction.

The present paper embodies the results of a study of various questions of geology and manner of formation of the zeolites and associated secondary minerals which are found within the area of Watchung basalt mentioned. The work has been carried out under the direction of the Geological Department of Columbia University, and the microscopic studies of rock sections have been made in the petrographic laboratory of that institution. The writer takes the greatest pleasure in acknowledging his sense of deep obligation to the members of the Geological Department, Professor Kemp, Professor Berkey and Professor Grabau, for their kindness and assistance throughout in guidance and suggestions.

The chief features which will be considered in the paper are the geologic conditions which gave rise to the formation of the secondary minerals and the order of succession of the various species as determined by petrographic methods, and in connection with this the results attained will be interpreted, so far as has been found possible, in the light of the laws of physical chemistry. The application of this branch of science in its modern aspects to the problems of the mineralogist and petrographer is at the present time at a most interesting stage, where the applicability and value of the principles are perceived, but application to specific cases has been slight.

I. Geology of the Region

CONDITIONS OF TRIASSIC DEPOSITION

An understanding of the major features of the geologic history of the region under discussion for a short period prior to the extrusion of the First Watchung basalt is essential for a comprehension of the processes which resulted in the formation of the secondary minerals. There has been some lack of agreement among different observers as to the interpretation of certain features of Triassic history. Earlier views were influenced by the supposed necessity of attributing the accumulation of all sedimentary terranes to deposition in large bodies of water. The possibilities of fluviatile accumulation on piedmont slopes or in depressed basins were not recognized. Later studies of the eastern Trias, carried out with this conception in mind, have shown that many strong arguments may be advanced favoring this interpretation, and there is now a strong tendency toward a general adoption of this point of view.[1] To the writer, the evidences in support of this view appear of great weight, and throughout the present paper it is accepted without reservation.

With this explanation, the conditions of Triassic deposition may be summarized as follows: The processes of mountain-folding which brought the Permian period to a close in eastern North America found expression along lines approximately parallel to those which had characterized previous periods of orogenic movement along the Atlantic border and resulted in the uplift of the Appalachians along axes having in general a northeasterly-southwesterly trend, but in places (as through Pennsylvania) departing quite widely from the general course. As a phenomenon which was probably closely associated with the structural instability attendant upon this period of orogenic development, secondary adjustments continued throughout a prolonged period.[2] The most important later movements of this character, so far as their history may be read, resulted in the formation of depressed areas closely parallel to the axes of Appalachian folding but in general somewhat to the southeastward of the main ridges. The downthrow or downwarping of these areas does not seem to have been sufficient to bring the depressions beneath the level of the sea, but, owing to their low-lying position, they formed, during the Triassic, areas of rapid accumulation of sediments of continental type, brought in by torrential streams as a result of the waste of the bordering uplands under climatic conditions of semi-aridity.

There is some question as to the former extent of the areas on which

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[1] For evidences of sub-aërial accumulation see

W. M. Davis: 18th Ann. Rept. U. S. Geol. Surv., pt. 2, p. 32, 1896-1897.

J. V. Lewis: "The Origin and Relation of the Newark Rocks," Ann. Rept. State Geol. N. J. for 1906, pp. 99-129.

C. N. Fenner: "Features Indicative of Physiographic Conditions Prevailing at the Time of the Trap Extrusions in New Jersey," Jour. Geol., vol. 16, pp. 229-327, 1908.

[2] I. C. Russell: "The Newark System," Bull. 85, U. S. Geol. Surv., pp. 77 and 83, 1892.

E. J. Schmitz: "The Structure of the Richmond Coal-Basin," Trans. Am. Inst. Min. Eng., vol. 24, pp. 397-408, 1894.

J. V. Lewis: *Op. cit.*, p. 107.

O. J. Heinrich: "The Mesozoic Formation in Virginia," Trans. Am. Inst. Min. Eng., vol. 6, p. 266, 1878.

W. M. Davis: "The Triassic Formation of Connecticut," 18th Ann. Rept. U. S. Geol. Surv., pt. 2, p. 35, 1896-1897.

the sediments accumulated. On the one hand, it is contended that they were of wide-spread distribution and that the present more or less detached areas are merely remnants of a broad terrane. Others have argued in favor of local basins or troughs of depression, which may have presented analogies to the "graben" of the Rhine or to the Rift Valley of East Africa. To the writer, the intermediate view presented by the New Jersey Survey appears to offer many grounds for favorable consideration. It is as follows:[3]

> These conditions are believed to be fully met by the hypothesis of river deposition across a relatively smooth Piedmont plain, fronting the newly uplifted crystalline foreland, or protaxis, of the Appalachian Mountains, with concurrent synclinal wrinkling and down-faulting of the long basin-like areas in which the present remnants of these rocks have been preserved. . . . Numerous short but vigorous streams brought down the débris of the disintegrating and decomposing granites, gneisses and metamorphic sediments of earlier Paleozoic age and deposited them in coalescing alluvial fans across the smoother plain of the crystalline Piedmont. Occasional downward movements, of warping or faulting, gave opportunity for local thickening of the deposits along the belts affected.
>
> According to this conception, the Piedmont plain was of much greater width than the present areas of the Newark strata, and it probably merged into coastal marine and estuarine deposits along the eastern border. As a rule, however, the deposits were probably not very thick except in the elongated areas of progressive or intermittent deformation. Hence, when the whole Piedmont was eventually uplifted, the relatively thin mantle of débris was removed by erosion from the greater part of the region, and only those narrow belts that were protected by downwarping and faulting between adjacent areas of the harder crystalline rocks have been preserved to the present time.

The writer is inclined to lay especial stress upon the movements of deformation, which appear to have been renewed at intervals through a prolonged period at the same time that deposition was proceeding. They may have been a consequence, in part, of accumulating load, but they were also probably due to deep-seated causes connected with the primary movements. After each movement, the streams were rejuvenated, and the topographic depressions which otherwise would have been eliminated by the constant degradation of the bordering uplands and the accumulation of sediments were accented afresh.

Within these areas of fluviatile aggradation, certain depressed portions of the surface (in New Jersey at least) were occupied by a series of shallow lakes when the First Watchung lava-flow occurred.[4] The existence of these lakes and their arrangement along lines parallel to the bordering

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[3] J. V. Lewis: *Op. cit.*, p. 107.

[4] C. N. Fenner: *Op. cit.*, p. 309 ff.

highlands support the view that the movements of deformation caused the areas of accumulation to assume at times troughlike characteristics.

The lakes are believed to have been an all-important factor in giving rise to the conditions which resulted in the subsequent alteration of the basalt and the formation of the zeolitic minerals. Indications of their existence beneath the First Watchung flow can be found at Paterson and for a number of miles southward, and again near Plainfield.

IGNEOUS ACTIVITY

During some portion of Triassic time, probably the middle or later portion, the general uneasiness which had manifested itself in repeated crustal deformation assumed a somewhat different phase of expression. Numerous outbreaks of igneous activity occurred throughout the entire region from Nova Scotia to North Carolina. There is little indication that these outbursts anywhere assumed the form of centralized volcanic activity, but the fused material appears to have been ejected quietly through fissures whose direction coincides closely with the dominant lines of weakness. "It seems safe to conclude that both the dikes and faults are closely related and were probably, in part at least, contemporaneous." [5]

The dikes and extruded sheets are found not only in the areas now covered by Triassic sediments, but petrographically similar dikes have been traced through the intervening areas, and the region traversed by them is prolonged southward through South Carolina and Georgia and into Alabama, where they disappear beneath younger strata. The known length is about 1,000 miles. On the borders of the Triassic also, they occur in approximately parallel lines. The various intrusions are regarded by Russell[6] as probably referable to the same general period, and the evidence appears to indicate that an area parallel with Appalachian folding, 1,000 miles or more in length and attaining a maximum width of 200 miles, was involved in a history of deformation and igneous injection which presents somewhat similar features throughout.

The chemical and mineralogical composition of the erupted magmas shows a remarkable uniformity.[7] The general coincidence of the areas of eruption with the areas of deformation, and the extrusion of magmas which may be referred to closely related petrographic types, have undoubtedly a profound significance, but only the more superficial aspects can be interpreted.

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[5] I. C. RUSSELL: *Op. cit.*, p. 77.

[6] *Op. cit.*, pp. 71-72.

[7] E. S. DANA: Am. Jour. Sci., 3rd ser., vol. 8, p. 390, 1874.

In Northern New Jersey, the igneous rocks associated with the Triassic (Newark) sediments include the intruded sheet of the Palisade diabase and the three extruded flows of Watchung basalt. The Palisade diabase appears to form a continuous sill, approximately parallel to the stratification, stretching diagonally across the State from New York into Pennsylvania but concealed in places by late sediments or glacial drift. The Palisade ridge in the North and Rocky Hill and Sourland Mountain in the South are considered portions of the same sheet. Its thickness is everywhere several hundred feet and in places is believed to reach nearly 1,000 feet.[8] At several places, dikes and apophyses thrown off from the main mass reach the surface in small detached areas.

The three surface flows form the Watchung ridges and several isolated knobs. A maximum development of 1,200 feet is believed to be attained in the thickest parts of Second Mountain. In both First and Second Mountains, certain slight differences in composition and appearance vertically indicate a composite character of flow. An interbedded shale in the southern portion of Second Mountain is held by Lewis[9] to be evidence of differential downward movements within the area between successive flows. Such movements would not be unexpected in a region experiencing the history described.[10]

LOCAL PECULIARITIES OF THE FIRST WATCHUNG SHEET

The basal layer of the First Watchung sheet apparently marks the initiation of igneous activity. The flow spread over the surface of the accumulating sediments and filled the depressions occupied by the playa lakes. Over the dry areas, the lava came to rest quietly, and the normal process of cooling and crystallization followed without interruption. The rock formed under these conditions presents a dense, homogeneous mass, which, under the microscope, is found to have the holocrystalline texture normal to basalts. Over the lake beds, however, the lava, which appears to have approached in composition the eutectic ratio of its component minerals and to have been almost at the temperature of crystallization thus determined,[11] was quickly chilled from the effects of water and vaporized steam. An exposure of the bottom layer in a quarry in the southwestern part of Paterson shows a mixture of lava and very fine mud

[8] J. V. Lewis: Ann. Rept. State Geol. N. J. for 1907, p. 129.

[9] Ann. Rept. State Geol. N. J. for 1906, pp. 110-115.

[10] Compare the geological history of the Rift Valley of East Africa, as described by J. W. Gregory: "The Great Rift Valley," London, 1896, especially chapter 12.

[11] C. N. Fenner: "The Crystallization of a Basaltic Magma from the Standpoint of Physical Chemistry," Am. Jour. Sci., 4th ser., vol. 29, pp. 217-234, 1910.

several feet in thickness, and in many other places the lava was rendered extremely vesicular. The upper portions were not so thoroughly impregnated with steam but were, nevertheless, quickly cooled and became viscous. The jets and tongues of fused material seem to have assumed the consistency of a thick syrup and instead of spreading laterally they solidified in smoothly rounded bowlder-like masses, having considerable similarity to the "pahoehoe" of Hawaiian flows which were first reported by J. D. Dana[12] and more fully described and illustrated by C. E. Dutton.[13] The pasty character of the fluid and its sluggish movements are well attested in the billowy forms presented when quarrying operations have attacked bodies of trap of this character (Plate X). The rounded forms are sometimes built up to a thickness of 60–70 feet. The interior

FIG. 1. Microlitic growth of phenocrysts in vitrophyric crusts. × 35. Slide 132.

of the bowlders cooled with sufficient slowness to permit the basalt to crystallize with normal texture, but each is sheathed with a crust of glass (tachylite) varying from an inch to several inches in thickness, having often a laminated structure.[14] Where unaltered, the color is usually dark olive-green or brown, and the appearance is decidedly vitreous. Under the microscope the rock is found to consist of a paste of glass, in which are set a few phenocrysts of labradorite and diopside, commonly surrounded by aggregates of hairlike microlites, which mark the continuation of growth of the phenocrysts during the initial stages of chilling before crystal-growth was wholly blocked by increasing viscosity (fig. 1).

[12] U. S. Exploring Expedition—Geology, p. 162.

[13] 4th Ann. Rept. U. S. Geol. Surv., pp. 96 and 98, 1882-1883.

[14] B. K. EMERSON: "Diabase Pitchstone and Mud Enclosures of the Triassic Trap of New England," Bull. Geol. Soc. Am., vol. 8, pp. 59-86, 1897.

Between the glassy crusts and the holocrystalline interior, transitions of crystal-development produce aphanitic phases.

The crusts frequently present a shattered appearance due to the sudden chill which they experienced, and at times pockets among the bowlders are filled with considerable masses of breccia of this nature. This was probably originally a usual feature, but, as will appear presently, such pockets of glass were, for several reasons, peculiarly subject to the action of the processes which formed the secondary minerals.

The chemical composition of the basalt is shown in the following analyses of typical examples:[15]

	I	II	III	IV
SiO_2	51.78	51.36	51.82	50.19
Al_2O_3	12.79	16.25	14.18	14.65
Fe_2O_3	3.59	2.14	0.57	3.41
FeO	8.25	8.24	9.07	6.96
MnO	0.44	0.09	0.13	0.07
MgO	7.63	7.97	8.39	7.95
CaO	10.70	10.27	8.60	9.33
Na_2O	2.14	1.54	2.79	2.64
K_2O	0.39	1.06	1.26	0.75
TiO_2	1.41	....	1.17	1.13
P_2O_5	0.14	....	0.17	0.18
H_2O / CO_2	0.63	1.33	1.70	3.04

Analysis I was recast by Hawes to show percentage of mineral constituents as follows:

Anorthite, 15.52; albite, 22.16; potash feldspar, 2.32; augite, 54.47; titanic iron, 2.68; magnetite, 1.76; apatite, 0.32; total, 99.23.

The augite was isolated by specific gravity solutions and found to have the following composition:

SiO_2	50.71
Al_2O_3	3.55
FeO	15.30
MnO	0.81
CaO	13.35
MgO	13.63
Na_2O / K_2O	1.48
Loss on ignition	1.17

[15] I. West Rock, New Haven, Conn., G. W. Hawes, Analyst, Proc. U. S. Nat. Mus., vol. 4, pp. 129-134, 1881.

II. Watchung Mt., N. J., L. G. Eakins, Analyst, Bull. 150, U. S. Geol. Surv., p. 255, 1898.

III. Scotch Plains, N. J., R. B. Gage, Analyst, Ann. Rept. State Geol. of N. J. for 1907.

IV. Nr. Springfield, N. J., R. B. Gage, Analyst, Ann. Rept. State Geol. of N. J. for 1907.

Petrographic examination of the unaltered basalt in the area with which we are more especially concerned accords with the above analyses and shows a rock of simple mineralogic composition. The components are a pyroxene approaching diopside in optic properties, but shown by a large extinction-angle to deviate somewhat from the typical mineral; a plagioclase feldspar of the composition of labradorite; and magnetite. The texture is normal ophitic. The appearance is illustrated in Plate XI, fig. 1.

In both the crystalline and glassy facies, remnants of phenocrysts of resorbed olivine are not uncommon. These phenocrysts appear to have been developed during a period of intra-telluric crystallization and to have become unstable as a consequence of changes in temperature and

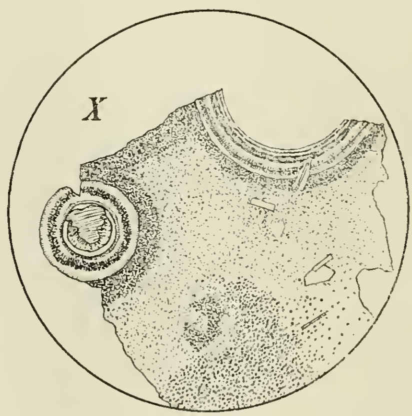

FIG. 2. Chloritic nodules from resorption of olivine (X = open field). × 35. Slide 48.

pressure attendant upon extrusion, with simultaneous variation in the composition of the magma consequent upon the evolution of contained vapors. Resorption of olivine by the magma often proceeded so far that the only traces of the mineral that survive are small, spheroidal nodules, which, by subsequent alteration, have been converted almost wholly into chlorite or serpentine (fig. 2). The general character of the crystallized rock and such special features as the resorption of olivine are of importance in following out the process of formation of the secondary minerals; for vestiges of the primary character often remain even in advanced stages of alteration and show clearly that much of the action of recrystallization proceeded from stage to stage in a close-textured rock, without the presence of any important cavities.

A study of the field relations has shown that the spheroidal masses of basalt, sheathed with glassy crusts, appear in those areas which, at the time of the lava flow, were covered by shallow lakes, and that these areas are coincident with those in which the formation of zeolitic minerals has occurred.

Evidence along various lines leads to the belief that the processes of alteration were directed by the features impressed upon the solidified basalt by the presence of the bodies of water. Among the spheroidal masses, a considerable amount of interstitial space had been left. Moreover, the crusts were much shattered, and frequently the interiors of the masses were penetrated by a multitude of cracks produced by shrinkage in cooling. Where the openings were of sufficient size to permit the free passage of superheated aqueous vapors from the water-impregnated sediments beneath, these gases appear to have rushed upward with great force and velocity, carrying with them quantities of finely comminuted dust from the lake beds and depositing it in the various interstices, in the form of a reddish-brown powder. Much of this is probably of a clayey nature, but it is so fine that it is not resolvable under the microscope, though some of it shows also grains of quartz and feldspar such as are found in the coarser sediments. Mingled with this material, there are many fragments of basaltic glass, whose nature is easily recognized. In some cases, these deposits appear to have filled open spaces of considerable size and in others to have penetrated minute cracks. At a quarry formerly worked near Great Notch, the igneous rock carries between the bowlder-forms irregular blocks of this character, ranging in size up to a foot or more in diameter, at first sight counterfeiting inclusions of fine-grained sandstone. Examination under the microscope, however, shows the presence in this pseudo-sandstone of a notable admixture of glass, and the manner in which the material ramifies into cracks of the basalt suggests its origin. Hand-specimens may sometimes be found, in which the peculiar relation appears of small dikelike bands of reddish sandstone cutting the basalt. This reversal of the usual relations is interesting from its unusual character.

The formation of such deposits appears in some instances to have sealed the larger spaces left open after the consolidation of the igneous masses, but nevertheless the brecciated material around the bowlders and the multitude of shrinkage-cracks often present would offer spaces of capillary size or larger and would undoubtedly render the piled-up masses of bowlder-like structure above the lake beds distinctly more porous and susceptible to the circulation of water than the dense, massive basalt beyond the borders of the lakes. Field observations lead to the conclusion that such is clearly the case.

SOURCE OF THE WATERS WHICH EFFECTED RECRYSTALLIZATION AND OF THE NEW MINERALS DEPOSITED

The query arises as to the origin of the circulating waters, whether meteoric or magmatic. The writer adheres strongly to the views enunciated by J. F. Kemp and other authorities that in the majority of metalliferous deposits the metallic minerals are almost wholly, and the solutions largely, of magmatic derivation. In the case of these zeolitic deposits, however, several lines of evidence lead to the conclusion that the waters were of extraneous origin. Field observation shows that the secondary alteration extends to within a few feet of the lower surface of the trap sheet, and points to the uprise of waters from the underlying shales. In its theoretical aspects, the situation is distinctly different from that of mineral veins. In the latter case, it is conceived that underlying masses of fused material, slowly cooling and crystallizing, give off various emanations which are forced to rise to the surface either through channels in the overlying rock, or through fractures in previously consolidated portions of the same mass, toward which the emanations are driven in their effort to find vent.

In surface flows, however, there is little obstruction to the escape of the vapors into the open air. It can hardly be conceived that the evolution of vapors from surface flows continues long after the complete consolidation of the magma, for the process of crystallization necessarily excludes the gaseous material. The structure of the Watchung sheet, in the situation which we are considering, indicates that consolidation was almost simultaneous with accumulation and, consequently, that the emanation of vapors must have ceased shortly after the termination of the flow. On this point, the following quotation from Professor Kemp's article on "The Role of the Igneous Rocks in the Formation of Veins" [16] is pertinent.

> The vapors contained in surface-flows of igneous rock pass off directly into the atmosphere, and therefore do no geologic work of this character. The most that could be expected of them would be small incrustations in the cracks in their upper and first chilled portions, such as the copper minerals and specular hematite found in the crevices of Vesuvian lavas.

The greater number of the secondary minerals are traceable to the primary minerals of the magma. Pectolite, prehnite, amphibole, the zeolites, hematite, chlorite etc., contain only elements which are present in feldspar, diopside and magnetite. There are others, however, such as datolite and various metallic sulphides, containing elements that are only

[16] Trans. Am. Inst. Min. Eng., vol. 31, pp. 169-198, 1901.

found in minute quantities at most in the normal basalt. These could not have been formed by a simple rearrangement of the ingredients of the primary minerals in contact with the circulating waters.

If the conditions under which the lava consolidated have been correctly interpreted, it is not difficult to account for the relative concentration of these latter ingredients. The elements which are in excess are those which have often been observed as sublimates deposited in crevices in lava flows. They differ from aqueous vapors in that the temperature of sublimation is high, and a relatively slight cooling causes deposition in the solid form, often near the point of derivation.

The elimination of vapors of B_2O_3 from consolidating lavas and their deposition in crevices appear to be normal phenomena of volcanic activity. Deville and Leblanc in their observations at Vulcano[17] found that gas from one of the craters, issuing at a temperature above the melting point of lead and emitting flames, deposited boric acid. At the "soffionis" of Tuscany, jets of steam carrying boric acid emerge from the ground. The condensible vapors from the fumaroles of Monte Cerboli contain boric acid, together with ammonia and hydrogen sulphide. Borates are also found in hot springs in numerous volcanic regions,—Northern California, the Yellowstone Park, the Cordilleras of Coquimbo, Argentina, Tibet, on the sea of Azov and in other localities. Borates appear, indeed, to be among the commonest volcanic sublimates.[18]

A. von Groddeck[19] has reviewed the geological occurrence of boron minerals and expresses the conviction that the borosilicates (tourmaline, axinite, datolite, danburite) and water-free borates (rhodizite, jeremejevite etc.,) with the exception of boracite, appear exclusively as autogenic forms in eruptive, archean and metamorphic rocks; and that in the whole series of fossil-bearing strata, borosilicates which have been formed without doubt in situ are wanting. By the latter, however, he doubtless did not intend to exclude the effects of contact metamorphism by means of vapors given off by an intruded eruptive, by which tourmaline is frequently formed. He emphasizes the fact that axinite, danburite and datolite are only crevice and druse minerals, and he considers that the chief field of distribution of axinite and datolite is notably in basic eruptive rocks, hornblende schists, chlorite schists and green schists, in which tourmaline almost not at all or only seldom appears.

It is interesting to note, however, that at the contact of the diabase sill which forms the Palisades along the Hudson, the arkose Newark shales

[17] F. W. Clarke: "Data of Geo-Chemistry," Bull. 330, U. S. Geol. Surv., p. 214, 1908.
[18] A. Geikie: "Textbook of Geology," London, p. 269, 1903.
[19] Zeitschr. deutsch. geol. Gesell., vol. 39, p. 253, 1887.

have been metamorphosed in places to a tourmaline hornfels,[20] while in the sill itself fissures are lined with nests of datolite.

Metallic sulphides, pyrite and chalcopyrite especially, are often observable among the secondary minerals but are rarely seen in the unaltered basalt. Although present in but small amount, there was undoubtedly some concentration of sulphides in and near the channels of circulation. This may likewise be accounted for by the emanation of sulphur compounds and sublimates of copper and iron given off by the magma. Covellite (CuS) has been found on the lavas of Vesuvius,[21] and atacamite ($CuCl_2$, $3Cu(OH)_2$) is also found in crevices in the Vesuvian lavas, as well as the chlorides of iron.[22] Among the fumarolic deposits in the crater of Vulcano,[23] which are partly sublimates and partly secondary products, A. Bergeat gives compounds of cobalt, zinc, tin, lead and copper. Sulphides have also been found as sublimation products at Vesuvius, formed perhaps by the action of H_2S upon volatilized metallic chlorides.

The small amount of fluorine represented by apophyllite may also be referred to the magma. Fluorite sometimes appears on volcanic lavas.[24] It is possible, however, that the crusts of glass retained sufficient fluorine to supply the very moderate amounts required to account for the formation of apophylite.

Such sublimates given off by the consolidating Watchung lava were probably deposited in crevices and interstitial spaces upon a slight fall of temperature. The places favorable for deposition were the very ones which would be easily reached later by circulating waters.

The aqueous contents of the lava would be completely expelled into the open air. The source of the waters which effected alteration must therefore be sought elsewhere. A theory of derivation from meteoric sources by a process of underground circulation appears to fulfill the requirements of the situation and to offer no obstacle. The preëxistent topographic depressions in the areas occupied by lakes, although buried by the flow of lava, would nevertheless be reached by waters flowing in from the edge of the sheet through the porous sedimentary strata lying just beneath the impervious mass of normally crystallized igneous rock. Having reached such depressions, the hydrostatic head would be that due to the difference in elevation between the depressions and the point of ingress. The somewhat loose and porous structure of the accumulations of lava

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[20] ANDREÆ and OSANN: Verh. des naturhist.-med. Ver. zu Heidelberg, n. f., vol. 1, 1892.
[21] E. S. DANA: "System of Mineralogy," 6th edition, p. 68, 1893.
[22] *Ibid.*, p. 165.
[23] F. W. CLARKE: *Op. cit.*, p. 220, ff.
[24] F. W. CLARKE: *Ibid.*, p. 274.

above the preëxistent lakes being favorable for percolation, the waters would naturally tend to rise to the surface. A circumstance favorable to this result lay in the fact that the lava retained a store of heat long after consolidation. Immediately after the latter event the temperature was so high that apparently all water which gained access was vaporized, notwithstanding the impediments to escape caused by restrictions of the channel; but as the temperature fell, the water level in this arm of the system of circulation slowly rose.

The system of circulation thus conceived is analogous to that of artesian flows, only modified in this respect, that the effective head was due not so much to a difference in elevation between the points of ingress and exit, as to vaporization of the water in the upper portions of the channels of exit. It embodies the principle by which C. R. Van Hise has sought to explain the deposition of metallic minerals in fissure veins.[25] Exception has been taken to Van Hise's conception of the origin of metalliferous deposits, and in this case, where the operation of the principle seems almost demonstrable, the effects are distinctly different from what he has conceived that they should be. In justice, however, attention should be called to the fact that present exposures show only the lower portions of the return channels, and the possibility that higher levels would present more similarity to metalliferous veins is not necessarily excluded.

An alternative hypothesis to the one which has been offered should be considered, that is, the descent of meteoric waters direct from the surface through the channels in which alteration was effected. The form of this hypothesis which would consider cold surface waters as the agent may be dismissed almost at once; the results are entirely at variance with it. At the present time, such waters are effecting the solution of certain of the minerals, are decomposing others to pulverulent or clayey masses, are oxidizing the iron compounds to hydrated, rusty-looking material, and in short are giving to the whole the appearance which is characteristic of surface weathering. There still remains, however, the idea that the action may have taken place while the rocks were still highly heated. Two chief objections appear. The leaching which the rocks experienced while alteration was in progress, as shown by the great reduction in iron and magnesia contents, and the marked migration of other compounds implies a fairly rapid circulation. It is difficult to conceive of the means by which this could be secured under the hypothesis which we are now considering. Secondly, the nature of the secondary minerals shows conclusively that the process was not one of oxidation. Surface waters passing through

[25] Trans. Am. Inst. Min. Eng., vol. 30, pp. 27-177, 1900.

several miles of underground channels might easily be deprived of their dissolved oxygen in several ways, but waters descending directly from the surface would necessarily produce oxidizing effects.

CHEMISTRY OF THE PROCESS BY WHICH ALTERATION WAS EFFECTED

The principal rôle of the water seems to have been to form a medium in which recombination of the elements of the rock could be easily effected. The minerals arising from the crystallization of the magma were those which were in mutual equilibrium under the conditions of temperature, pressure and concentration prevailing at the time of consolidation. In the presence of heated water, they were, to a slight extent, dissolved and were thereby transferred to a solution in which entirely different conditions of temperature, pressure and concentration were present. As the chemical equilibrium is dependent upon these factors, new reactions followed, and it may be profitable to devote a short space to an inquiry into the mechanism of the process. According to modern conceptions of ionization, a mineral or salt which is soluble in only minute quantities in water undergoes in such a solution a change by which the molecular grouping which characterized the solid is broken up into simpler groups termed ions.[26] A familiar example of this is the dissociation of AgCl, by which an Ag and a Cl ion are formed, carrying electrical charges which are equal and of opposite sign. The quantity of un-ionized AgCl in the solution is extremely minute, but is not negligible. Addition of a second salt, such as NaCl, which has an ion in common, drives back the ionization of AgCl and causes some to be deposited from the solution.

Chemical reactions between such salts in solution are believed to be chiefly of an ionic nature. If in the formation of new compounds, the quantity produced to satisfy the conditions of equilibrium demanded by the nature of the reacting substances is in excess of the solubility, a portion will be deposited in the solid state. Such a reaction abstracts ions and permits a further dissociation of molecules. This in turn permits more of the original solid to pass into solution, and in this manner the process is continuous and will proceed until all the available material has been used up.

The process thus described enables us to form a mental picture of the mechanism of alteration but does not suggest any explanation of the

[26] There has lately arisen some doubt as to whether the theories of ionization which have been founded upon older conceptions of the molecule represent with exactitude actual conditions and processes. Whether this is true or not, the idea forms a practical working hypothesis, not out of harmony with main facts, and of value accordingly. There is no tendency to abandon it, until a better substitute can be found.

forces by which the mechanism is urged forward. A little further insight into this is permitted by the fact, which has been ascertained to be true in many instances and is believed from thermodynamic considerations to be a general law, that in any association of compounds, the stable forms are those for which, under the given conditions of temperature, the vapor pressures are a minimum. The vapor pressures of solids are generally so minute as to appear almost infinitesimal, but are not therefore negligible. Even without the intervention of a medium of solution, molecular re-arrangements take place. This is well established for metallic alloys and sometimes occurs with natural minerals. In general, however, a solvent is requisite, and in its presence the compounds having higher vapor pressures pass more readily into solution and those with least vapor pressures crystallize out.

The principle is of immediate applicability in explaining the facility with which the glassy crusts of the basalt were attacked by the circulating waters. A glass, as is well known, is, from the standpoint of physical chemistry, a greatly under-cooled liquid, in which crystallization has been checked by the viscosity. Its metastable condition is expressed in the excess of its vapor pressure over that which the component minerals would possess in their crystalline phase. It should therefore pass into solution more readily than the normally crystalline basalt, and such seems undoubtedly to have been the case. When the structure of the deposits is examined in the field, it is found that the secondary minerals form nests and pockets in the angular spaces between adjacent bowlder-forms and wrap around them in bands in the situation in which the glassy crusts were originally developed. This is in part due, no doubt, to the fact that channels of easiest circulation followed such features, but the whole effect cannot be ascribed to the latter cause, for cracks produced by shrinkage or by deformation and passing through the interior of the bowlders do not exhibit an equal development of alteration products. Confirmatory evidence of selective alteration of glass is found in the slides. In a number of instances, crystalline crusts of later minerals show structures which seem best explainable as survivals of original forms in glass. Recrystallization seems to have been checked, however, when the normal basalt was reached, and at times its effects almost disappear within the area of the thin section.

Slide 53 affords an instructive illustration of several of these points, as is shown in Plate XI, fig. 5. The microscope shows crusts of recrystallized minerals composed of prehnite, green amphibole, specularite, secondary albite and garnet. Although recrystallization has produced large crystals, an indication of a former structure survives in certain curved bands and circular markings, suggesting in form the spherulites and similar features found frequently in the glasses. The resemblance to the chloritic nodules of fig. 2 and other sketches is obvious, and their occurrence in the present case is ascribed to a persistence of the spherulitic structure during recrystallization, the effects being preserved by an insoluble dust of TiO_2 or MnO_2. Next to these crusts lies a narrow band in which the basaltic texture appears, but in finely crystalline development, and this is believed to mark the transition from glass to normal basalt in the original rock. Beyond this the texture is that of ordinary basalt. Recrystallization has been complete in the glass, except for the insoluble inclusions. In the finely crystalline border and in the normal facies of the rock, it has made sufficient advance to change the labradorite and diopside to prehnite and albite for a short distance without much disturbance of the texture. A little further, and both the texture and mineralogic composition are almost unchanged. Similar phenomena, showing that alteration was checked when the crystalline portion of the basalt was reached, are seen in several slides.

The fact that circulation was comparatively rapid had important results in the nature of the secondary minerals. Under these conditions, rapidity of solution or time taken for a mineral to form a solution of a certain strength, considered apart from total solubility or quantity present in a saturated solution, affects the nature of the changes which take place. When water is at rest in the interstitial spaces in a rock, a mineral which dissolves slowly may nevertheless reach a comparatively large total solubility, but if the water moves along channels of circulation, the amount of a slowly soluble substance which is taken up may never reach the amount necessary to carry forward sufficiently those reactions by which new minerals of less solubility containing its elements are deposited, and whatever amount goes into solution is removed altogether.

In the original basalt, magnesia and the oxides of iron reach a large percentage, being principal constituents of the diopside and magnetite. In the later minerals, the proportion of iron and magnesia is insignificant. In places, large masses of zeolitic minerals and calcite are found from which all compounds containing iron and magnesia have been removed.

Another effect of the circulation of the waters is that the substances dissolved are distributed through the solution, and new products may crystallize at a distance from those from which their elements were derived. With standing, interstitial water diffusion of dissolved substances can only occur through the slow action of osmotic pressure. Consequently, under the latter circumstances, the new minerals are much more apt to show intimate association with the old and little tendency to migrate. In the more open channels of these rocks, the circulation was naturally much more rapid than in the capillary spaces. Some difference in concentration of dissolved material thus arises, and to this cause in part is probably to be attributed a marked banding parallel with cracks, which appears in many slides (Plate XII, figs. 3 and 4).

It appears from what has preceded that the glassy crusts of the bowlder-like forms of basalt, lying next to relatively open channels and being in a chemically metastable condition, were naturally the portions of the rock most attacked. Alteration also follows the shrinkage cracks which penetrate the normally crystallized interior of the bowlders and produces veinlike bands of secondary minerals in a breccia of unaltered basalt. There is also evidence that deformative stresses acted upon the region within a comparatively short period of the extrusion of the basalt, for shear-planes often show alteration. On the whole, however, movements or mechanical disturbances of any nature appear to have been almost negligible during recrystallization.

EVIDENCES AS TO TIME INVOLVED

It has not been found possible to determine from field observations what depth the flow of lava reached. At the quarry at West Paterson which has been mentioned, a section shows a thickness of 60–70 feet from the underlying shale to the surface of the ground, throughout which the characteristic features of pahoehoe are developed. This merely indicates what the minimum thickness was at this point and does not afford information as to the amount removed by erosion. There are indications, however, that the entire thickness of the First Watchung sheet was not involved, for in several localities, it has been found that the phase of the basalt in which the bowlder-like structure is prominent passes under normal massive basalt, which appears to be a later flow. If this inference is correct, the whole history of alteration must have occupied only a comparatively brief period, geologically considered; for a second flow of lava, it would seem, would spread an impervious seal over the entire area and terminate the process at whatever stage had been reached. From other considerations also, the history is believed to have been brief. A sheet of lava, even several hundred feet in thickness, subjected to the cooling effects of percolating waters, would not retain its store of heat for a period which would be considered long from a geologic standpoint.

DEGREE OF SUPERHEATING OF THE SOLUTIONS

Although a rapid circulation has been spoken of in referring to the movements of the waters, this term has been intended merely in a relative sense. It is believed that the openings in the rock were in general only of capillary dimensions. Great obstacles were thus presented to the easy circulation of water in the lower part of the channels and to the free escape of steam in the upper part. The temperature of vaporization was thus increased and superheating permitted. The maximum temperature possible under the circumstances was that corresponding to the pressure to which the water was subjected due to the hydrostatic head. Before the temperature fell to this point, the water was probably converted into steam and escaped in this form, but it is not believed that any important recrystallization was effected, until the temperature reached the point at which the liquid form was retained.

On account of uncertainties as to the thickness of the lava sheet, no close estimate can be made as to the probable degree of superheating, but some approximation can be arrived at. If a thickness of 300 feet is assumed as a probable maximum, the pressure at the bottom of a column of water of this height would be 130 pounds per square inch, or, taking account of additional atmospheric pressure, 145 pounds per square inch. The corresponding temperature of vaporization is 180° C., and this may be considered as a probable maximum for the temperature which the solutions attained. No great degree of accuracy is to be claimed for such an estimate, but it will serve to show the probable order of superheating, and it indicates that no approach to the critical temperature of water (364.3° C.) was attained. Nevertheless, the minerals formed at this stage were similar to those which are found in highly metamorphosed schists and gneisses.

From the maximum, the temperature gradually fell as the mass of rock cooled. There are indications that, to the last, the temperature was somewhat above average climatic temperature. Among the products in the last stages, actinolite and chalcopyrite appear to have been formed, and these would hardly be expected as products of cold solutions.

The general process was that of the slow but constant and uninterrupted cooling of a mass of igneous rock through which aqueous solutions were percolating, deriving their temperature from the inclosing rock and cooling as it cooled. Material for solution was contributed by the basalt and by the previously evolved sublimates, and reactions followed by which new minerals were crystallized out. With progressive fall of temperature, conditions of chemical equilibrium within the solutions were shifted, and new species were deposited. In these later changes, the material which participated was derived both from the first-deposited minerals, which had now become unstable, and from new supplies of igneous rock to which access was gained.

The constant removal of material in solution undoubtedly enlarged the channels of circulation and, in places, produced cavities of considerable size. The most perfect crystals are naturally found in vugs of this kind. It does not appear, however, that such openings were at all necessary for recrystallization, and in most cases they were not present. The leaching appears to have been somewhat selective, for iron and magnesia are greatly reduced in the later stages.

II. Petrography of the Secondary Minerals

METHODS OF STUDY OF MUTUAL RELATIONS OF MINERALS

All the material for petrographic work has been obtained from the region lying between Paterson and Montclair Heights. In many places throughout this district, natural exposures of surface rock show evidences of the features which have been ascribed to underlying lake beds; but weathering has produced its usual effects of solution and decomposition, and such exposures do not afford desirable material for investigation. In a number of places, however, quarries have been opened for the purpose of obtaining road material or railroad ballast, and the fresh rock thus brought to view offers all the desired opportunities for study. A quarry at West Paterson and two at Great Notch have furnished the bulk of the material, but a considerable amount has been obtained from the waste-dump of a tunnel driven through the mountain near Great Notch a number of years ago for a water-supply system.

Before beginning the microscopic study of the relations which the various minerals bore to each other, it had been observed from macroscopic specimens that there was probably a definite order of deposition, and the writer presented a tentative determination of the sequence in a previous paper,[27] although stating that there were often great difficulties in coming to a decision. As the petrographic work progressed, it was found necessary to revise previous ideas along several lines. Certain criteria which had been followed in accordance with general conceptions were found in this instance to be unreliable guides. The manner in which bands of granular calcite frequently appear between unaltered basalt and other secondary minerals may be cited as an example. The inference would be that the calcite was of earlier formation and was the first to be deposited on the basalt, but in numerous instances, it has been found to be later, and the latter relation is believed to be the general one. Similar effects appear with other minerals. Not infrequently, partial

[27] Jour. Geol., vol. 16, pp. 297-327, 1908.

replacement causes an earlier mineral to appear to rest upon a later, and often those minerals which have an acicular habit seem to have had the ability to penetrate without difficulty through earlier-formed minerals of a more massive nature. For these reasons, it is believed that macroscopic observation alone is unreliable. On the other hand, microscopic observations have certain limitations, and it has been found advantageous to employ both methods as supplementary to each other.

In some respects, the zeolites are difficult subjects for petrographic study in random rock sections, when it is desired to differentiate the various members of the group, because of the rather negative character of the optical properties and the resemblances among different species. By careful study of known sections, however, it was found that differences of habit could be perceived which were often sufficiently distinctive for rapid identification, when checked in doubtful cases by further tests.

Throughout the various portions of the district covered, the relations of basalt and secondary minerals appear to be almost identical. There are differences in the same quarry which are as great as in parts of the field several miles apart. Such differences embrace the greater or less prevalence of the bowlder-structure in places and the variations in the predominant minerals. The latter is probably an effect of the somewhat variable amount of sublimation products condensed in the crevices and of the facility with which solutions percolated through the channels.

LIST OF MINERALS

In the hand specimens the following minerals are observed to occur in quantity: quartz, datolite, prehnite, pectolite, analcite, chabazite, heulandite, stilbite, natrolite, laumontite, apophyllite, thaumasite and calcite. Gypsum is found, but is much more rare. Pyrite and chalcopyrite are frequent, but almost always in small grains. Galena and sphalerite are known to occur, but they have not been met by the writer. Hematite is often noticeable as a finely divided purplish dust disseminated through crystals of silicates and calcite. Tabular hematite crystals of larger size also occur. Gmelinite has been reported, but in a number of instances which have come under the writer's observation the specimens appeared to be more probably chabazite. The two, however, doubtless form a continuous series analogous to the plagioclases, and considerable variability in composition is to be expected. The relation of chabazite and of gmelinite to other zeolites probably presents no essential difference, and no attempt was made to distinguish the two in microscopic work. Scolecite has also been reported, but the writer has not met with satisfactory examples in hand-specimens. In several thin sections, small remnants of a mineral which is probably scolecite were observed in association with natrolite. The chemical relationship between natrolite and scolecite is somewhat similar to that between chabazite and gmelinite, but the group appears to present an example of a different type of solid solutions, namely, that in which the two components do not form a continuous series of mixed crystals, mutual solubility being limited and the end members being of distinct crystallographic forms.[28] Most of the specimens are plainly natrolite. Chlorites, probably of several species, are very abundant, but are more prominent under the microscope than in larger specimens. Serpentine is also found in thin sections, but is not of so frequent occurrence as chlorite. Several minerals occur in small quantities and have been identified by optical methods. Albite, garnet and several varieties of green amphibole were thus recognized, and their occurrence will be described in its appropriate place.

APPLICATION OF THE PHASE RULE

In reviewing the list of minerals given, it will be observed that the majority of the species are composed of those elements which form the plagioclase feldspars. Frequently there is an addition of the water molecule, but otherwise there is no change except in the relative proportions of the various oxides. Different forms of combination of soda (Na_2O), lime (CaO), alumina (Al_2O_3), silica (SiO_2) and water (H_2O) are accountable for all of the following minerals: labradorite, albite, quartz, prehnite, pectolite, analcite, chabazite, heulandite, stilbite, natrolite, scolecite and laumontite. In what follows, it is proposed to make a special investigation of the mutual relations of these species, based upon those methods of physico-chemical analysis which are embraced under Gibbs's phase rule. It is desirable, therefore, to make a preliminary inquiry into their composition.

The plagioclase feldspars: The recent investigations of A. L. Day and E. T. Allen[29] into the nature of the plagioclases, carried out in the Geophysical Laboratory at Washington, have shown almost beyond question that the albite and anorthite molecules form a continuous series of solid solutions of the type in which mutual solubility is unlimited and in which the fusing points of intermediate members lie between those of the isomorphous end-compounds. All the members from albite, $Na_2OAl_2O_3$-

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[28] For analogues among artificial salts, see ALEXANDER FINDLAY: "The Phase Rule and its Applications," New York, p. 189, 1906.

[29] Am. Jour. Sci., 4th ser., vol. 29, pp. 52-70, 1909.

$6SiO_2$, to anorthite, $CaOAl_2O_32SiO_2$, form, therefore, a single chemical phase. While natural plagioclases are, in the great majority of instances, combinations of albite and anorthite, there are reasons for thinking that soda anorthite ($Na_2OAl_2O_32SiO_2$) and lime albite ($CaOAl_2O_36SiO_2$) are also possible compounds. Doelter showed a number of years ago that fusion and slow recrystallization of some of the zeolites resulted in the formation of the compound $CaOAl_2O_36SiO_2$, and H. S. Washington and F. E. Wright[30] have lately investigated the composition of a feldspar from Linosa, whose formula from analysis corresponds to ($\frac{1}{3}$ Ca, $\frac{2}{3}$ Na) Al_2Si_3-O_{10}. They consider the most probable explanation of composition, on chemical and crystallographic grounds, to be the presence in solid solution of Ab, Or, An and a new compound, $Na_2OAl_2O_32SiO_2$, for which they propose the name carnegieite. They point out the resemblance of the mixed crystals which compose the feldspar to an unhydrated natrolite or mesolite. The matter has an important bearing upon the relations of the zeolites to the feldspars.

Quartz (SiO_2), *prehnite* ($H_2Ca_2Al_2Si_3O_{12}$ or $2CaOAl_2O_33SiO_2H_2O$) and *pectolite* ($HNaCa_2(SiO_3)_3$ or $Na_2O4CaO6SiO_2H_2O$) form each a phase of invariable composition. They are composed of the same oxides as the other members of the group which we are considering, but they do not present the same analogies in chemical structure.

The zeolites proper are all feldspathoid compounds whose resemblance in composition to the plagioclases has often been commented upon. The ratio of lime plus soda to alumina is 1 : 1, but the amounts of silica and water vary. They and the feldspars might all be embraced under a general formula $ROAl_2O_3mSiO_2nH_2O$. With certain of the species, the composition appears to be fixed, as in laumontite ($CaOAl_2O_34SiO_24H_2O$), but the majority of species form groups whose composition varies within rather wide limits. A typical example of this is the chabazite group, whose variability appears only explicable on the assumption that four distinct feldspar-like molecules enter independently ($CaOAl_2O_32SiO_2$-$4H_2O$), ($Na_2OAl_2O_32SiO_24H_2O$), ($CaOAl_2O_36SiO_28H_2O$) and Na_2O-$Al_2O_36SiO_28H_2O$). The resemblance in composition which the various molecules bear to albite and anorthite and the assumed calcium-albite and sodium-anorthite is evident, and, like the ordinary plagioclase molecules, they appear to possess unlimited mutual solubility and form but a single phase. The structure of stilbite is similar, but less complex. The essential molecule appears to be $CaOAl_2O_36SiO_26H_2O$, with which is united in small but variable proportions the corresponding soda molecule,

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[30] Am. Jour. Sci., 4th ser., vol. 29, pp. 52-70, 1909.

$Na_2OAl_2O_36SiO_26H_2O$. In heulandite we have similar relations, but with $5H_2O$. Typical analcite is $Na_2OAl_2O_34SiO_22H_2O$, but a small amount of lime usually enters. Similarly, natrolite is $Na_2OAl_2O_33SiO_2$-$2H_2O$, with a little lime sometimes present.

With most of the species, a little potash is frequently present and doubtless would be found by analysis in the Watchung minerals, but no distinctively potash zeolite has been noted.

From the manner in which the ratios of the molecules vary in the same mineral, it appears necessary to consider the form of union in the zeolites to be that of solid solutions rather than that which is usually termed chemical combination.

Each of the species enumerated may be considered a separate and distinct chemical phase. Including prehnite, pectolite and quartz, the phases present are as follows:

1. Labradorite and albite,
2. Quartz,
3. Prehnite,
4. Pectolite,
5. Analcite,
6. Chabazite,
7. Heulandite,
8. Stilbite,
9. Natrolite,
10. Scolecite,
11. Laumontite.

The phase rule states the number of phases which may be present in a system in equilibrium under given conditions of temperature, pressure and concentration.[31]

In the fundamental equation $P = C + 2 - F$,

P = number of phases,

C = number of components,

F = degrees of freedom (i. e., the numerical value of the variables, temperature, pressure and concentration).

In the system which we are considering, the components are five in number as follows: Na_2O, CaO, Al_2O_3, SiO_2, H_2O.

With regard to the numerical value which should be ascribed to F, some consideration is necessary. Temperature is without doubt in this case an independent variable. Pressure should be considered as dependent upon temperature, for in those portions of the system in which it was somewhat independent of temperature, no gaseous phase was present. Concentration probably varied from an independent function in the earlier stages to a dependent function in the later on account of the disturbing feature introduced by the presence of boric acid. After this had

[31] ALEXANDER FINDLAY: *Op. cit.*, p. 16.
W. D. BANCROFT: "The Phase Rule," Ithaca, N. Y., pp. 1-5, 1897.

been taken completely into solution and had reacted with lime and silica to form datolite, no further supply was available, and it became an almost negligible factor. It appears probable from observations as to the period of stability of datolite which will be noted later, that from the beginning of alteration up to the time of formation of zeolites (a period in which garnet, amphibole, prehnite and pectolite were deposited, but in which feldspathoid compounds are small in amount or entirely lacking), concentration should be considered an independent variable, but in the later periods, in which zeolites are prominent, it should be considered to be nearly or altogether a function of temperature. To a minor degree, the presence of ferromagnesian silicates acted in a manner similar to boric acid in giving to the factor concentration an independent character, for the presence in solution of any compound having an ion in common with the feldspathoid series would affect their solubility, independently of temperature. The chief effect of these also is believed to have been in the first stages of alteration and to have become more nearly negligible during the later stages. The numerical value of F may be considered to vary from 2 in earlier stages to 1 in later.

Solving the equation for P, it appears that during the earlier period the greatest possible number of phases which could exist in equilibrium was five. The liquid and gaseous phases may be neglected, leaving three solid phases. During the later period, it seems at first that four solid phases in equilibrium would be a possibility, but a number of limiting conditions may be applied.[32]

In all the feldspathoid combinations, which alone are now to be considered, the proportion $Na_2O + CaO : Al_2O_3 :: 1 : 1$ obtains. This decreases by one the number of phases possible and limits it to three. It appears also that with certain members of the series, there is merely a difference in the ratio of SiO_2 or H_2O to the other components. With analcite and natrolite, for instance, the only essential difference appears to be in the ratio of SiO_2: analcite $= Na_2OAl_2O_32SiO_22H_2O$; natrolite $= Na_2OAl_2O_33SiO_22H_2O$. These two species, therefore, cannot coexist in equilibrium under any change of conditions.[33] With heulandite and stilbite, the essential factor of difference appears to be the ratio of combined water.

With chabazite, the constitution is very complex, and it is doubtful what molecules could be removed without causing the crystals to break up. It is apparent, however, that one of the molecules cannot coexist

[32] W. D. Bancroft: *Op. cit.*, p. 234.

[33] In the application of the phase rule, there is no concern with the absolute composition of the molecule. Only the ratios are of importance.

with the anorthite molecule of plagioclase or with the essential molecule of laumontite and a second with the albite molecule, except at transition points, which, in the present case, are of little importance.

It is possible that there are other limiting conditions which are more obscure or regarding which present knowledge is insufficient. The evident relations, however, make clear the fact that not more than three of the feldspathoid minerals could exist together in stable equilibrium, and with several combinations not more than two could coexist.

It is necessary, however, to keep in mind the fact that, even under unstable conditions, solution may be so slow that portions of the mineral or even perfect crystals may persist through a prolonged period. There are indications that certain minerals formed during the first stages of recrystallization disappeared utterly and their nature can only be guessed at, but with the great majority of species, portions have survived throughout.

In applying the phase rule to the problem, the author does not wish to imply that he believes that a case of this kind is capable of treatment with a high degree of mathematical rigidity. The nature of the case renders this impossible. Each of the minerals present in addition to the feldspathoid compounds introduces an element of uncertainty which cannot be taken into account. It is believed, however, that these effects were rather feeble except with boric acid, which has been considered, and that, using some broadness of interpretation, the deductions of the phase rule are applicable.

The general results which should be expected are that the minerals formed from various combinations of soda, lime, alumina, silica and water should present a series in which one mineral after another will be found to have been deposited, to have survived through a certain period of stability, and then, with progressively changing conditions, to have passed again into solution, to be redeposited in new combinations. Regarding the order in which various species should appear, the phase rule affords no information. The tracing out of the sequence will form a chief feature of the petrographic portion of the present paper.

Without enlarging here upon the evidence which will be presented, it may be stated that the general inferences and conclusions drawn from the application of the phase rule appear to be fully warranted. Careful examination of hand specimens gives additional confirmation. Numerous examples have been collected which afford proof of the instability and breaking down and even the total removal of minerals. Such proofs are the etched and rounded surfaces of crystals, the development of porosity and drusy openings and finally the "negative pseudomorphs," or cavities from which crystals have been removed. Before a detailed study was made, such effects were ascribed to ordinary processes of weathering, but they occur repeatedly in material in which oxidation and other normal effects of weathering are lacking, and it is frequently seen that later minerals have been deposited in the cavities formed by the removal of earlier.

The ferromagnesian minerals present a series parallel to the feldspathoid compounds, but in these rocks their quantity is too small to form the basis of an investigation similar to that which has been applied to the others. They present a number of interesting features, however, which will be described.

The phase rule supplies no information as to sequence of deposition, but simply shows how many phases can coexist in equilibrium. Nevertheless, if conditions were the same throughout the region, a sequence which has been determined in any instance should apply to all cases. In general, this appears to be true, but occasionally exceptions occur, implying local variations in concentration. This should be expected in a system of circulation of the kind described, depending probably upon the restrictions or freedom of flow and upon the tendency of minerals toward segregation.

Effects of this kind are exhibited especially by the ferromagnesian compounds. It is found, for instance, that the deposition of pleochroic green amphibole was conditioned largely by questions of concentration; and that, depending probably upon circulation becoming more free, amphibole which had been deposited was dissolved again at an early period, while under other circumstances its deposition was still continuing.

Another example is furnished by certain observations on analcite. From the prevailing evidence, it appears that in general analcite was one of the first of the zeolites to form, and, in several slides, it is found that chabazite and heulandite encroach upon it. On the other hand, a specimen has been found in which crystals of analcite rest upon heulandite in such a manner as to seem of necessity to imply later deposition. In this case, some local enrichment of the solutions in soda or impoverishment in lime is suggested. In later pages some inquiry will be made as to how far the sequence of minerals which has been observed should be considered an invariable one.

The processes of alteration may be divided along the lines indicated into two periods, which with their characteristic minerals are as follows:

Period I. Boric acid period.

Stage 1. Albite, quartz, garnet, amphiboles, specularite, sulphides.

Stage 2. Datolite, prehnite, pectolite, amphiboles, specularite, sulphides.

Period II. Zeolite period.

Analcite, chabazite, heulandite, stilbite, natrolite, scolecite, laumontite, apophyllite, amphiboles, chlorite, specularite, sulphides.

To these may be added a third period, whose significance will be shown later.

Period III. Calcite period.

Thaumasite, calcite, gypsum, amphiboles, chlorite, specularite, sulphides.

FIRST PERIOD OF ALTERATION

In the primary stage of alteration, temperature and pressure were at a maximum. The resulting minerals are those which are characteristic of a rather intense form of hydrothermal metamorphism. They include albite, arfvedsonite and other amphiboles, specularite (specular hematite), sulphides, garnet and quartz.

Albite

The feldspar of the unaltered basalt is a medium labradorite of about the composition albite 40, anorthite 60, occurring in hypidiomorphic crystals of lathlike habit, whose largest dimensions seldom exceed 0.5 mm. Among the alteration products, this is replaced by albite, whose size seldom falls below the maximum of the labradorite and ranges from this to a length of 3 mm. or more.

The process by which the transformation of labradorite into albite has been effected appears most explicable, if the plagioclase feldspars are regarded as members of a continuous series of solid solutions formed of the two molecules albite and anorthite, as appears to have been rendered certain by the researches of A. L. Day and E. T. Allen, to which reference has been made. The ratio in which the two will enter a crystal is dependent upon the composition of the solution in which crystallization is proceeding, and the crystal will continue in equilibrium with the solution only so long as the ratio of albite and anorthite molecules in the latter undergoes no change.

It is evident that, as the two molecules are chemically distinct, their fields of stability will not coincide and that, under a change of conditions, the crystals may find themselves in contact with a solution in which the anorthite molecule is unstable, while albite is not affected. Under these circumstances, the small amount of albite which dissolves in the liquid soon effects saturation, but the anorthite enters reactions by which new compounds are formed from it and its identity is destroyed. The original crystals are thus placed in contact with a solution saturated with albite but lacking anorthite, and with such a solution only pure albite is in equilibrium.

At the beginning of the recrystallization of the basalt induced by the passage of heated aqueous solutions, the anorthite molecule appears to have undergone reactions by which garnet and datolite and possibly other compounds were produced from it. Albite under the new conditions was stable. Anorthite was therefore continually leached out of the labradorite, while albite was deposited in its place, a chief feature of the process being probably a growth of crystals at the expense of others in the vicinity.

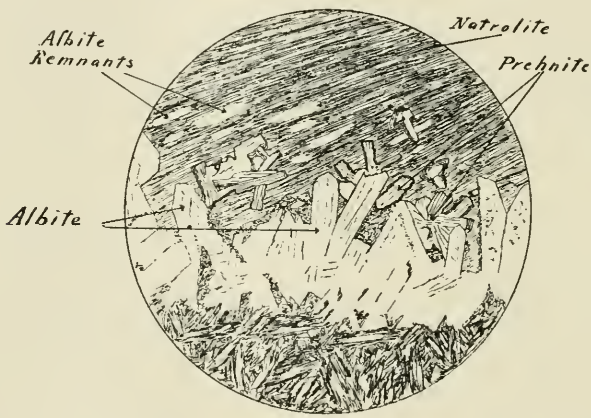

FIG. 3. Basalt bordered by vein of albite, prehnite and natrolite. Albite is developed from the labradorite of the basalt. Crystals of prehnite rest upon it and both are replaced by natrolite. × 35. Slide 127.

In figs. 3–7 and in Plate XI, figs. 2, 3, albite is shown in characteristic forms and in typical relations with the basalt and with secondary minerals. Slide 127, a portion of which is sketched in fig. 3, was taken from a hand specimen in which the ordinary dense basalt is seen to be cut by narrow veins of secondary minerals. Under the microscope, the basalt presents the usual microcrystalline development, and the veins are found to consist of natrolite, prehnite and plagioclase feldspar. The crystals of the last occur in interlocking aggregates of varying crystallographic orientation. They form borders to the basalt and project at various angles into the veins, whose principal filling is natrolite. Crystals 0.5 mm. in length are not uncommon. Most of the crystals show albite twinning repeated in two or three stripes. Terminal faces are often well developed.

These features characterize the secondary plagioclase in most of the slides in which it occurs. The identification of the plagioclase as albite has been determined by numerous tests. The statistical method of Michel-Lévy, applied to a great number of crystals, gives maximum extinction angles of 15° to 16°. The index of refraction is slightly less than that of balsam; optical character, positive. Sections perpendicular to the acute bisectrix Z give extinction angles of 13½° to 15°, measured from the 001 cleavage. These tests are mutually confirmatory and indicate a practically pure albite.

An interesting feature observed in many instances is that the crystals of vein feldspar are plainly in crystallographic continuity with the plagioclase laths in the walls. It is notable, however, that among those which project farthest, the larger and stouter forms show a tendency to parallelism in a direction at right angles to the walls, as if their growth had been favored at the expense of those which projected at more acute angles. The average of size is decidedly larger than that of the plagioclase in the unaltered basalt. It is what might be expected if the original feldspars had grown until they occupied the space left by removal of diopside and magnetite, and in some cases, the relations are such as to force the conviction that this has occurred.

In the process of chemical readjustment by which crystals of a solid solution place themselves in equilibrium with the surrounding medium, when the composition of the latter becomes altered, two methods seem possible. The crystal might wholly dissolve and new and distinct crystals of the stable form might be deposited, or the identity of the crystal might be preserved, while the excess of one constituent was removed by solution and its place taken by a sufficient amount of the second constituent to supply the deficiency. The evidence of the thin sections described indicates that the process was to a large degree at least of the latter nature, the identity of the crystals being preserved. It is probable that this method of substitution, however, can advance only when the liquid in contact is very mobile and capable of penetrating within the interior of the crystals. If of the viscous constituency of most magmas, the contact would be merely at the surface and exchange between solid and liquid could proceed only through the almost infinitely slow agency of osmotic diffusion in the solid.

Albite in much larger crystals and showing a very different form of development appears in several slides. In these, the process of readjustment by which labradorite was transformed into albite appears less evident than is the case with the smaller form of albite crystals, but it is believed that the same process prevailed in a slightly modified form. Crystals of the larger type are best seen in slides 133 and 134. The hand

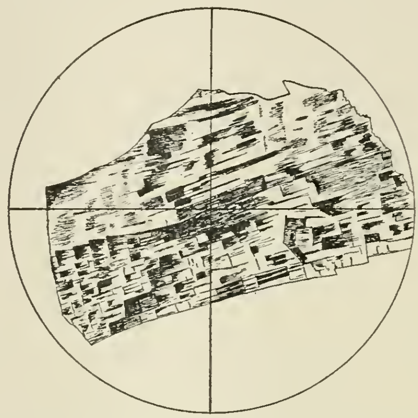

Fig. 4. Single crystal of secondary albite showing both carlsbad and albite twinning. Crossed nicols. × 35. Slide 133.

specimen from which both of these slides were prepared shows numerous clear, glassy crystals imbedded in pectolite. The microscopic appearance

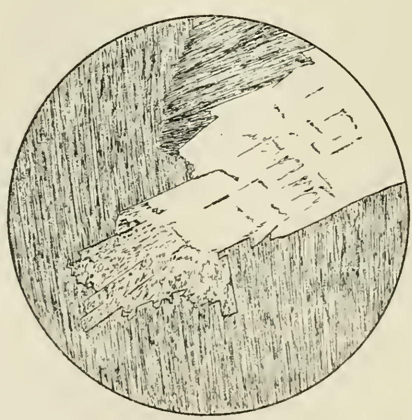

Fig. 5. Crystal of secondary albite partly replaced by pectolite. Outline is corroded and interior clouded in places, and pectolite fibres are advancing across it. × 35. Slide 134.

of a single crystal between crossed nicols is shown in fig. 4, and one in which the albite has been partly replaced by pectolite is shown in fig. 5.

The appearance is so unlike that of the commoner form that numerous tests were made to establish its identity. Some of these were as follows:

1. All sections giving maximum interference (perpendicular to optic normal) give practically parallel extinction.
2. Sections perpendicular to both albite twinning and to basal cleavage give extinction angles of 13° to 16°.
3. Crystals which were found to be nearly or quite perpendicular to the acute bisectrix Z give extinction angles of 11° to 18° with the basal cleavage.
4. In most crystals, a combination of albite and Carlsbad twinning is found. By selecting those crystals which give approximately maximum extinction for albite lamellæ in both halves of the Carlsbad twin, corresponding angles of extinction were found as follows: 12½° and 13½°, 12½° and 13½°, 13½° and 14½°, 11½° and 13½°.
5. The index of refraction is less than that of balsam.

With all these facts in mutual accord, it can hardly be doubted that the mineral is nearly or quite pure albite.

The crystals are many times the size of the form of albite first described, attaining a maximum length of 3 mm. or more, being thus comparable with the crystals in granitoid rocks. Carlsbad twinning is very common. The two parts are joined along a somewhat irregular line, as shown in fig. 4. The most characteristic feature is the curiously mottled appearance, due to the irregular manner in which the albite twinning lamellæ are placed in juxtaposition. The lamellæ do not in general traverse the whole length of the crystal, but often they stop abruptly. Between crossed nicols, the different interference colors thus brought to view in a single crystal have a patchwork effect, and careful study shows that, curiously enough, the form of the patches outlined is suggestive of a multitude of lathlike plagioclase crystals disposed more or less at random. It is conceived as possible that this is a clue to the manner in which these large crystals of albite originated; that in fact each individual is built up of a multitude of labradorite laths of the original basalt, which have been incorporated within a single expanding crystal, and whose molecules have been swung into approximately correct crystallographic orientation. That the crystallizing forces of the major crystal were not able to exert rigid control throughout is indicated by certain anomalies in extinction and by a curving of the ends of the crystals which is frequently shown.

In slide 129, several groups of albite crystals of the large type shown in slides 133 and 134 appear in the midst of apophyllite. The borders are corroded and the interiors muddy, and they are plainly remnants giving way to the apophyllite. It is not improbable that a great deal of secondary albite of this form appeared among the first products of alteration, but little of it now survives. Intermediate forms between the large and small types described appear in several slides, for instance, 68, 70, 119 and 120, generally in isolated crystals or small groups, and show active replacement.

A frequent mode of occurrence of albite in these rocks is as part of the filling of small, sharply defined veins which often cut the walls of quarries. They have a northeasterly and southwesterly strike. The veins bear evidence of being the result of deformative stresses which have affected the region. The presence of albite, which was probably one of the first products of recrystallization and which was formed while the rocks were still in a superheated condition, indicates probably that the regional adjustments by which the cracks were formed took place within a comparatively short period after the extrusion of the lava.

Replacement of Albite

A normal association of albite with fibrous amphibole, garnet and specularite, in which the relations are but little obscured by further stages of replacement, appears in slide 98 (Plate XIII, fig. 1). In this slide a normally crystalline basalt is crusted with a variety of secondary minerals, which in places show evidence in their structure of having replaced a glassy crust of lava. The primary alteration seems to have resulted in albite, green amphibole, garnet and specularite, which appear in close association next to the unaltered basalt. Further out, these products are giving way to prehnite, and at one place shown in the sketch, chabazite is the replacing mineral.

The typical manner in which replacement attacks the albite is shown in Plate XI, fig. 3, from slide 62. In this slide, finely crystalline basalt is cut by veinlets (probably originating as shrinkage-cracks in cooling) whose filling consists principally of albite and prehnite. In the more minute veins, where there is little prehnite, the albite looks perfectly fresh. The crusts, between crossed nicols, have the appearance shown in Plate XI, fig. 2, the albite being finely granular next to the basalt and assuming a development of larger crystals at a short distance. In the more open areas, where prehnite is abundant, the albite crystals have assumed a spongy appearance (suggestive of ice which has been exposed to the sun) and have lost their sharpness of outline. Fanlike groups of prehnite appear to spring up at any point within the massed crystals of albite and gradually encroach upon them, as shown in Plate XI, fig. 3. The albite in association then appears corroded at the edges and turbid within. By a continuation of the invasion, albite has disappeared over large areas, and the only trace of it left is a hazy or muddy appearance of the prehnite. In many places, the patches of turbid material within the prehnite still show in their outlines the appearance of albite groups.

In slide 65, a similar process of replacement has produced the results shown in fig. 6. As in slide 62, veinlets of albite and prehnite are found cutting a crystalline basalt. The albite lies next to the walls and gives way rather abruptly to prehnite, but a few outlying crystals of albite, greatly corroded, appear to have survived within the prehnite at some distance from the walls. Still farther out, phantom forms of former albite crystals are outlined by a slight turbidity in the prehnite. They are completely replaced by prehnite and can be connected with albite only by the appearance of the terminal crystal faces. These, however, are characteristic. The radiating and fanlike groups of prehnite crystals

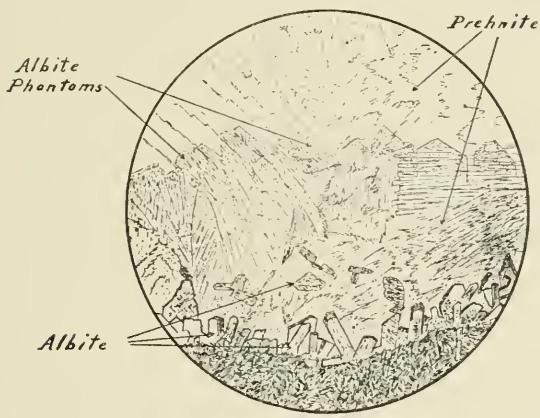

FIG. 6. Replacement of albite by prehnite. Phantom forms of former albite crystals are dimly perceptible. × 35. Slide 65.

are superimposed upon the former structure of the albite, but in places the albite has had an influence upon the crystallization of the prehnite.

In slide 63, minute veins similar to those described are filled with albite and datolite. The albite crystals occur in interlocking aggregates of varying crystallographic orientation. In places, they occupy the veins to the exclusion of all other material, or they may project at various angles from the sides of the vein into masses of datolite. Crystals up to 0.5 mm. in length are not uncommon, and the general average of size is noticeably larger than the plagioclase rods in the walls. In most places, there is no evidence of corrosion of albite at contact with datolite, but in some areas, phenomena of replacement similar to those which have been described in association with prehnite appear.

Hand specimen 70 consists of a crystallized mass of secondary minerals, among which natrolite, heulandite and datolite are prominent. The slide shows at one point a group of rather large albite crystals within the datolite, evincing much corrosion of outline.

In 133 and 134, the hand specimen shows large, apparently clear crystals of albite, imbedded in beautifully crystallized pectolite. Under the microscope, the albite appears quite turbid in places, and the outlines show evident encroachment of pectolite fibres (fig. 5). In 136, albite and natrolite appear as the filling of a shear vein in dense trap. The manner in which natrolite is replacing albite is sketched in fig. 7. It is evident that the orientation of natrolite has been strongly influenced by the direction of elongation of the albite crystals which they are replacing. In 127

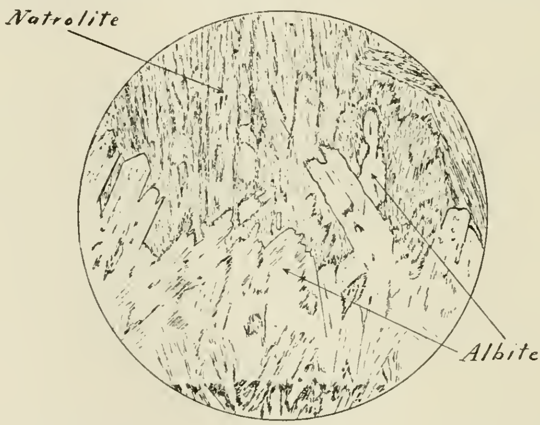

FIG. 7. Replacement of albite by natrolite. × 35. Slide 136.

(fig. 3), the relations are similar, but in this case an intermediate stage is shown, for little groups of prehnite crystals are perched upon the partly corroded terminal faces of the albite. The prehnite, however, did not attain a strong development, and both it and albite are giving way to natrolite. It appears probable that, conditions being suitable for the formation of natrolite, albite would yield to its advance with great facility on account of the similarity in the composition of the two minerals (albite $= Na_2O, Al_2O_3, 6SiO_2$; natrolite $= Na_2O, Al_2O_3, 3SiO_2 + 2H_2O$).

In 136, numerous remnants of albite are buried in natrolite fibres, and the natrolite appears to have always assumed a position parallel to the elongation of the albite. Slides 56 and 137 resemble 136 as being minute veins in zones of vertical shearing, which produced sharply defined cracks in quarry walls. In 56, the filling of the veinlet appeared to the naked eye to be wholly stilbite, but with the microscope it is found that this is replacing albite, of which numerous remnants are seen. Similarly in 137, small albite crystals are being replaced by chabazite. In 123, veinlets, which may be due either to shrinkage on cooling or to shear movements, contain albite, datolite and calcite, whose succession is in the order given. In 129, a large crystal of apophyllite carries several isolated inclusions of turbid-looking and much corroded albite of the larger type described.

Numerous other slides show more or less albite, in some places in rather fresh-looking crystals and in others in isolated groups of greatly clouded appearance. Occasionally its alteration has proceeded so far that the only trace of its former existence lies in turbid patches in other minerals, suggestive of albite merely by their form.

As to the mode of occurrence of albite in these rocks, it has been found most frequently in minute veins, but this may be due to the fact that under such circumstances the formation of the first products of alteration would tend to seal up the veins and render it difficult for later solutions to enter and attack the albite. In 95, the relations are different. Small, amygdaloidal cavities are filled with secondary products, among which albite and green amphibole and minute grains of garnet appear. It seems also that phenocrysts of diopside of the primary crystallization of the magma have been replaced by albite groups, illustrating two facts observable in many cases in these rocks, namely: that ferromagnesium minerals tend to disappear and that the replacing minerals often pay little attention to the composition of the material replaced. Slide 62 also shows this replacement of diopside by albite. Slide 100 illustrates again the filling of amygdaloidal cavities by albite and amphibole, but in this instance later stages of alteration are shown, and chabazite, calcite and chlorite are prominent.

In several slides, albite is found in a mode of occurrence which has been referred to before in discussing the manner in which solutions attacked the rock. The original texture of the normally crystalline basalt is preserved, but the mineralogic make-up is quite altered. In such cases, the laths of labradorite of the original have frequently been altered to albite. Slides 62 and 118 show this effect plainly.

The position of albite in the replacement series is determined by the minerals in respect to which it has been found to exhibit instability. Datolite, prehnite, pectolite, chabazite, stilbite, natrolite, apophyllite and calcite have all been found in relations which indicate energetic corrosion and replacement of albite, and these minerals are therefore regarded as belonging to later periods of alteration. This conclusion is confirmed by the relations of these minerals among themselves and to other minerals and may be regarded as established. On the other hand, albite has not been found in any case to replace minerals other than those of the primary consolidation of the magma. It is concluded, therefore, that it appeared among the first results of alteration. At the same time quartz, green amphibole, garnet, hematite and sulphide minerals (pyrite and chalcopyrite) appear to have been produced. Where albite is found in association with these, the contacts show no alteration on either hand.

In the breaking-down of the original labradorite into albite and various lime minerals, the presence of boric acid and other sublimates was undoubtedly a factor of great importance. Similar results of the action of hot aqueous solutions upon igneous rocks, by which an original lime-soda feldspar has disappeared and albite has been deposited in its place, are of fairly common and widespread occurrence, and it appears that in general the albite molecule possesses a much wider range of stability under conditions which are apt to occur in nature than does the anorthite molecule. While the more calcic feldspars normally occur as products of crystallization from igneous fusion, albite is most frequently found under conditions indicative of deposition from aqueous or aqueo-igneous solution at much more moderate temperatures. Fouqué[34] observed that albite never occurs individualized among the crystals of the volcanic rocks. Dana[35] mentions instances of its formation under metamorphic conditions or as a product of aqueo-igneous deposition as follows:

It is found in disseminated crystals in granular limestone, thus in the limestone (Jura and Trias) of the Col du Bonhomme, near Modane in Savoy; also in microscopic crystals with quartz and orthoclase in limestone at Meylan near Grenoble; in minute crystals in fossil radiolarians in limestone near Rovegno, Province of Pavia, Italy, also in the limestone itself; in limestone at Bedous, Basses Pyrénées, at the contact with diabase. Some of the most prominent European localities are in cavities and veins in the granite or granitoid rocks of the Swiss and Austrian Alps, associated with adularia, smoky quartz, chlorite, titanite, apatite and many rarer species.

An instance of the passage of a lime-soda feldspar into albite is cited by Dana[36]:

Münzing has investigated the Pfitschthal pericline and finds that the crystals consist essentially of an oligoclase, rich in soda, upon which albite has been deposited in parallel position, especially in the cavities of the original crystals.

W. C. Brögger,[37] in following out the paragenesis of the minerals of

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[34] C. Hintze: "Handbuch der Mineralogie," Leipzig, p. 1433, 1892.
[35] "System of Mineralogy," 6th ed., p. 331.
[36] *Ibid.*, p. 1026.
[37] Zeitschr. für Kryst. und Min., vol. 16, p. 167, 1890.

the nepheline-syenite pegmatite veins of southern Norway, notes a development of secondary albite in a form of microperthitic intergrowth with orthoclase along cleavage lines. He finds evidence that the formation of this secondary albite belongs to a period of mineral-formation previous to zeolite-deposition, and continues:

> One finds also at times that the albite of the microperthite was later removed again during the zeolite-phase, whereby quite cellular, spongy, porous feldspar-remnants result. Perhaps a small part of the analcite of the vugs may even have been formed at the expense of the dissolved albite.

The process and results described by him appear to be closely analogous (taking account of somewhat different conditions) to those which occurred in the Watchung rocks.

W. Lindgren,[38] in discussing the minerals characteristic of various zones of vein-formation, considers soda-lime feldspars unstable in all vein zones, while albite is found in contact-metamorphic deposits, in deeper vein zones and in middle vein zones. The physical conditions prevailing in the Watchung rocks during the short period of formation of albite appear to have corresponded, so far as can be inferred, to those of deeper or middle vein zones.

The stability of the albite molecule, under conditions under which anorthite breaks down into other compounds, gives rise at times to the special effect which Sir Archibald Geikie[39] terms "albitisation,"

> a process in which, while the lime of the plagioclase is removed or crystallized as calcite, instead of forming a lime-silicate like epidote or zoisite, the rest of the original mineral recrystallizes as a finely granular aggregate or mosaic of clear grains of albite.

F. Becke[40] describes an occurrence of secondary albite which offers considerable similarity to the manner of occurrence in the Watchung rocks. His explanation of its formation is interesting and suggestive in this connection. Referring to changes in the rock after consolidation, epidote and zoisite are recognized among the products, and in the same category is placed albitic plagioclase, which, in the form of irregular veins of crystallographically parallel orientation, penetrates the original plagioclase crystals. He continues:

> I cannot recognize in mechanical effects upon the rock the origin of these new forms. I would much rather believe that our rocks, after the magmatic consolidation was finished, were for a long time under other conditions, in

[38] "The Relation of Ore-Deposition to Physical Conditions," Econ. Geol., vol. 2, pp. 105-127, 1907.

[39] "Textbook of Geology," London and New York, vol. 2, p. 790, 1903.

[40] "Petr. Stud. am Tonalit der Rieserferner," Tsch. Mitth., vol. 13, p. 420, 1892-1893.

which the combinations created by consolidation did not present the condition of most stable equilibrium; especially does this apply to the basic plagioclases, whose silicates tended toward a breaking-up into soda-aluminum silicate (albite) on one hand, into lime-aluminum silicate (zoisite, epidote) on the other.

In this citation, Becke brings out clearly the conception that the stability of a mineral compound depends upon the conditions surrounding it, and that a compound which is stable under the conditions of its formation may become unstable under later conditions, and, if opportunity is afforded, will recrystallize in stable form. The writer wishes to emphasize this point on account of the manner in which a mineral is often spoken of as being very stable or very unstable. Unless the surrounding conditions are known, these terms have little meaning, for a reaction which proceeds in a certain direction under given conditions will (generally) proceed in the opposite direction under a reversal of conditions. This is very clearly expressed by C. R. Van Hise, who, in his work on "Metamorphism,"[41] refers repeatedly to the manner in which reactions occurring in the zone of katamorphism are reversed in the zone of anamorphism, but many writers appear to ignore the principle. Throughout the present paper, one of the chief objects which has been kept in view is to show how quickly minerals respond to an alteration of external conditions, and express this facility of response in recrystallization, if opportunity is given.

Hintze[42] gives numerous additional illustrations of the formation of secondary albite. In the vein-granite of the Riesengebirge, it is found in druses in the form of clustered rosettes or cockscomb crystal-aggregates. At Striegau, it covers walls of vugs and at times rests upon potash feldspars; in the Harz, it occurs in beautiful crystals in gabbro; near Marburg, Hesse, it forms a later deposit in crevices in diabase.

These various illustrations of the occurrence of secondary albite are cited to show its relations to the feldspars of the original rocks and are believed to confirm the view held by the writer that the various molecules which enter into feldspars are chemically independent and that the anorthite molecule (in some cases also the orthoclase molecule) may enter new combinations without affecting in any manner the stability of the albite molecule.

Quartz

Unlike albite, whose crystals are generally minute, quartz is often prominent in hand-specimens. The crystals frequently attain a thickness

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[41] Monograph 47, U. S. Geol. Surv., pp. 170, 172, 176, and especially 364-368.

[42] *Op. cit.*, pp. 1433-1454.

of 10–15 mm., and much larger ones occasionally appear. It is generally colorless, but not infrequently amethystine, and more rarely smoky. The faces shown are usually simple combinations of prism and pyramid. In addition to the groups of euhedral crystals which are most common, granular aggregates sometimes occur, as well as deposits of chalcedonic silica.

Frequently specimens are found which show numerous cavities, indicating plainly the removal of groups of crystals of some mineral which was intergrown with the quartz. Most of the cavities are diamond-shaped in cross-section, but others are apparently rectangular. They are undoubtedly due to the removal of groups of crystals, but the forms do not suggest those of any of the species known from these localities. It appears most probable that among the various transformations experienced one or more minerals disappeared completely. There are indications that formation and removal occurred early in the history of the series, for at times the cavities have been filled with later-deposited quartz.

Replacement of Quartz

In slide 70, of which the hand specimen consists principally of datolite, heulandite and natrolite, the datolite, under the microscope, is seen to contain at one place a small group of albite crystals, greatly corroded

Fig. 8. Fragments of quartz outlining former crystal, now almost completely replaced by datolite. × 35. Slide 70.

as previously described, and scattered through the datolite are minute remnants of quartz. One occurrence takes the form shown in fig. 8. It is clear that the scattered particles are portions of the pyramidal termination of a single quartz crystal, which has been almost completely replaced by datolite. There is little turbidity in either quartz or datolite. In

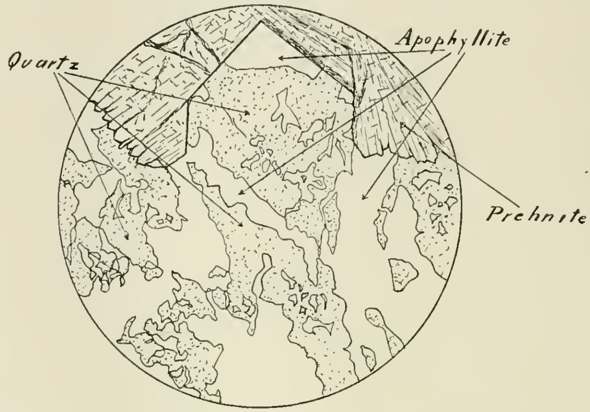

Fig. 9. Fragments of quartz with prehnite being replaced by apophyllite. Quartz is conventionally stippled to distinguish it from apophyllite. × 35. Slide 138.

numerous other places, parting planes in the datolite appear to outline former quartz crystals, that is, the replacement of quartz has given rise

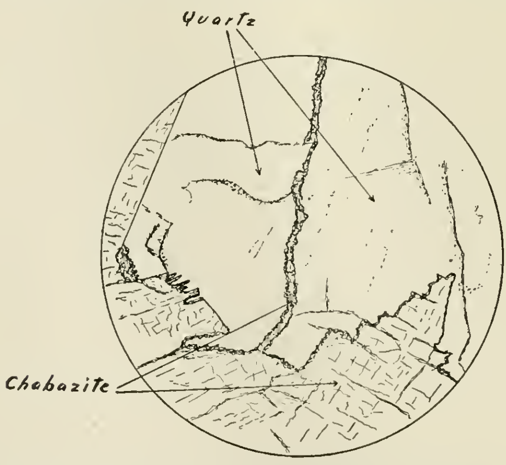

Fig. 10. Quartz cut by vein of chabazite and corroded by same on margin. × 35. Slide 146.

to roughly pseudomorphic forms of datolite. In 125, also, pyramidal quartz crystals have been slightly replaced by datolite.

In 138, a large apophyllite crystal carries a great variety of inclusions, most of which are in process of replacement by the apophyllite. They comprise quartz, garnet, amphibole, prehnite, pectolite and calcite. Fragments of quartz are numerous. Relations to both apophyllite and prehnite are shown in fig. 9. The prehnite carries a sharply defined impression of a quartz pyramid, but only portions of the quartz crystal are left. The remainder of the space is occupied by apophyllite. The relations indicate that prehnite was deposited upon the terminal pyramid of a quartz crystal and that later both were removed during the formation of apophyllite or were partly incorporated within the latter.

In 87, fragments of quartz are inclosed in prehnite and pectolite in such a manner as to indicate replacement by both. In fig. 10, the rela-

FIG. 11. Replacement of quartz (clear) by chabazite (blocky). The quartz extinguishes nearly as a unit. Outside the field the radiating crystals of quartz spring from a centre. × 35. Slide 77.

tions of quartz and chabazite in slide 146 are illustrated. The contact along one margin is perfectly straight, and it appears that corrosion has had no effect there. In other places, the quartz is greatly attacked, and chabazite has replaced it. A narrow vein of chabazite crosses the crystal, probably following some minute crevice which gave access to the solutions, and in various places lines of turbidity show the manner in which replacement begins.

In 77, replacement of quartz by chabazite in somewhat different relations appears. Heulandite also replaces the quartz. It is believed that the slide as a whole illustrates a frequent form of attack and replacement of quartz by later minerals. Figs. 11 and 12 show characteristic features. The original habit of the quartz in this slide seems to have been as groups of radiating crystals, the individuals increasing in size outward. There was also probably a small amount of the unknown mineral whose removal by solution left the prismatic cavities previously described. In this case, the cavities have been refilled by heulandite, but are still sharply outlined. In other parts of the slide, quartz is giving way to heulandite, but in such cases the habit of the heulandite is different from that shown in its deposition in the open cavities.

In fig. 11, some indication of the radiating form of the quartz can be distinguished, and outside the field the center of radiation is plainly seen. The replacement by chabazite has taken a most irregular form, but the influence of the crystallographic character of the quartz upon its solution and removal are perceptible in places.

FIG. 12. Replacement of quartz (clear) by heulandite (stippled). Arrows show direction of vertical axes of quartz crystals. Many of the crystallographic lines approach parallelism, but few are strictly parallel. × 35. Slide 77.

In fig. 12, the major portion of the field is occupied by a single quartz crystal, in nearly basal section, as is shown by the interference figure. Surrounding it are other quartz crystals of various optical orientation. Replacement by heulandite has taken the form shown, extremely irregular but yet plainly governed more or less by differences of solubility in the quartz.

Plate XI, fig. 4, illustrates one of the complex zeolitic groupings often found. Even at this stage of alteration, vestiges of the original texture of the rock and of the results of mechanical action upon it can be seen in many places. Phenocrysts of diopside are quite numerous outside of the field illustrated. Traces of plagioclase laths can be made out, and the subcircular chlorite nodules due originally to resorption of olivine are plentiful. There are many fracture-lines, into some of which a reddish-brown deposit of sand and clay has been carried from the underlying lake beds. Most of the slide is in the stage of recrystallization in which zeolites are prominent, but in places has advanced to the stage of calcite and kaolin. Stilbite and analcite can be recognized, and others may be present. In the illustration, the radiating groups somewhat simulating forms of vegetation are probably crystals of quartz surviving from a much earlier period. They appear to branch from minute cracks. In some portions of the slide they show strongly the effects of solution. As regards the replacing mineral, it is not possible to be more specific than to say that it is probably a zeolite. In 125, quartz crystals which have begun

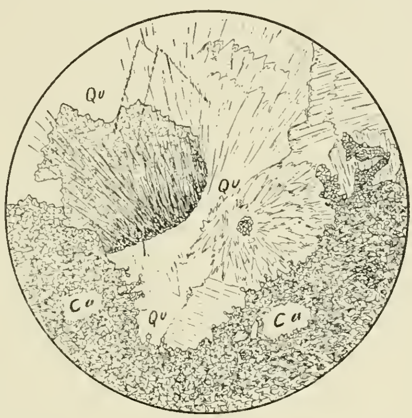

FIG. 13. Replacement of quartz by calcite. The quartz has the fan structure generally supposed to be typical of vein quartz, but it has probably replaced basalt. The granular-looking calcite shows features which are plainly a survival of those in the quartz. × 35. Slide 58.

their growth in similar groups radiating from cracks have reached a large size.

In slide 58, a dense, normally crystalline basalt is crusted with quartz and chalcedony. The quartz has the fanlike crystallization supposed to be typical of vein quartz, although certain circular lines and markings (similar to those shown in fig. 2, though not so pronounced) suggest that much of the quartz may have replaced a glassy crust of basalt. The chalcedonic SiO_2 has a fibrous appearance and negative elongation. Within the basalt, the normal texture is preserved, but with crossed nicols it is seen that in places both diopside and plagioclase have been replaced by a mosaic of quartz. In the outer crusts, calcite in a finely granular form is working in and replacing the quartz. It is developed most strongly in a band lying between the quartz and the basalt, and it might appear at first that it was earlier than the quartz, but its general character and the manner in which it branches minutely into the quartz are indicative of replacement. In addition, certain features shown in fig. 13 can be explained only in this way. Inclusions, plainly original in the quartz, survive within the replacing calcite.

This form of replacement, by which later calcite has worked in between crystallized quartz and basalt, seems to have been very common. Another good example is found in slide 41, and in repeated instances hand specimens are found to show a narrow band of calcite between the two, which, without microscopic examination, would naturally be inferred to be earlier than the quartz. A similar development of calcite as regards other minerals is referred to elsewhere.

It is not easy to understand why a deposition of calcite should effect the simultaneous removal of quartz or why the solution of quartz should cause the deposition of calcite, since the two minerals have no ion in common. It is known, however, that the solubility of a salt in water is often diminished by the presence of another salt, even when there is no common ion.

The observed relations indicate that quartz is earlier than datolite, prehnite, pectolite, chabazite, heulandite, stilbite, apophyllite and calcite. It is referred therefore to the first period of alteration.

Garnet

In several of the thin sections, numerous small grains of some mineral of high relief and hexagonal or rounded outline are found, regarding whose identification there is some slight doubt, but which may be referred to garnet with most probability. They occur normally in association with that group which is believed to have been the result of the most intense metamorphic action. In hand specimens, individual grains cannot be distinguished, but the presence of small clumps of some substance of a peculiar, light, ashy-green color in certain associations have been found to be due to a multitude of grains of this character.

One of the best examples is slide 98. The relations are sketched in Plate XIII, fig. 1. The garnet is here associated with albite, actinolite, specularite and prehnite, forming crusts on dense basalt. The grains in juxtaposition form considerable aggregates, or they are scattered in swarms through the prehnite. The average diameter of individual grains is 0.02 mm., and the maximum is not much greater. Each individual consists of a clear, colorless exterior and a darker nucleus of a brownish color, which, under the highest powers, has a granular appearance. This opaque substance is not identifiable with certainty but is evidently some material which could not be worked over or digested in the process of recrystallization and therefore remained as an insoluble residue. It would appear that either TiO_2 or MnO_2 might act in this manner. Both are shown by analysis to be present in the basalt, and the opaque, brownish dust generally present in the garnet and at times in other secondary minerals may be referred with great probability to one or both of these oxides. The relief of the crystal grains is very high. The Becke test indicates much higher index than adjacent prehnite and therefore higher than 1.65. The characteristic outline is that of a regular haxagon. On account of the high relief, it is sometimes possible with good magnification to make out a number of faces of an individual grain and to determine that the form is that of a rhombic dodecahedron (110). In most cases, the grains appear isotropic, but occasionally a very low birefringence is perceptible. The crystalline form, high relief, habit of including foreign material, lack of cleavage and anomalous birefringence correspond with garnet. This mineral has not heretofore been recognized under exactly similar circumstances, so far as the writer is aware.

The hexagonal outline of the garnet is best preserved where the growth of the associated prehnite has made least advance. Where the prehnite reaches a more notable amount, the garnet grains become rounded, and, with good magnification, the surface appears pitted. At a further stage, the grains become smaller and finally disappear, leaving the brown dust remaining as a turbidity in the prehnite. There is some evidence that the garnet is likewise yielding to the advance of the green amphibole. The inference is that the period of deposition or field of stability for the garnet was very limited.

In slide 53 (Plate XI, fig. 5), an original glassy crust on dense basalt has been metamorphosed to a mixture of garnet, green amphibole and specularite, which has subsequently been attacked by prehnite. The insoluble residue of the original glass (TiO_2 or MnO_2) has been included as before as a muddy brown sediment in the garnet grains, giving to many of them an opaque appearance. By reflected light, this has a milky look. The spherulitic markings and curved bands, which have been spoken of before and which are illustrated in the figure, are probably surviving structures of the original glass. The garnet grains are individually rather larger than those in 98 (about 0.075 mm.) and in places are so crowded as to form considerable masses, some of which are perfectly opaque from undissolved residue. Where invasion by prehnite has progressed, the garnets are much corroded. Slide 109 is from the same hand specimen as 53, and, so far as the relations of garnet are concerned, is almost a duplicate (Plate XIII, fig. 2).

In 115 and 118, the same relations hold. In several places in 115, the geometrical patterns in which the garnet grains are arranged show up in a remarkable manner. Plate XII, fig. 5, is a sketch of a portion of the slide. With encroachment of prehnite, the figures become obliterated. The resemblance to chloritic nodules derived from resorbed olivine, shown in fig. 2, slide 48, is striking.

In most of the slides in which garnet has been found in any notable quantity, these circular patterns are a marked feature. The resemblance in form to chlorite nodules is so close that a similar explanation of genesis appears probable. The origin of the chlorite nodules may be traced backward through intermediate steps to phenocrysts of olivine, which, it appears, became unstable during the primary consolidation of the magma and were largely resorbed. Such nuclei of olivinitic material, which had suffered refusion and partial absorption, remained unchanged in the glass after consolidation until circulating waters gained access. The time required for this varied according to the relations of the channels of circulation, and the nature of the resulting minerals depended upon this period. It appears that when alteration was delayed until a rather late stage, the nodules of resorbed olivine passed over into chlorite, but in an earlier period, while temperature was high, garnet was the chief mineral formed.

The garnet seems to alter into prehnite with great facility. Both in the derivation of garnet from olivinitic material and in its transformation into prehnite, the process appears to have followed the usual line taken in these rocks, by which magnesia and iron were reduced.

In several other slides (for example, 50, 95, 100), small grains of similar characteristics (isotropic and of high relief and hexagonal outline) are found. Occasionally they form considerable clusters, but further stages of alteration have supervened and obscured the relations. In slide 50*a*, Plate XI, fig. 6, clusters of them are seen to form a band in prehnite immediately adjacent and parallel to what appears at first to be unaltered basalt. In the latter, it is found, however, that the feldspars and diopside have been wholly replaced by prehnite, garnet and amphibole, while the magnetite has been left almost undisturbed and still outlines the original texture.

The Amphiboles

A number of distinctly different varieties of amphibole occur among the secondary minerals. Some of these possess decidedly abnormal characteristics. Their relations among themselves and to the associated minerals present several interesting features.

Variety 1. In a hand specimen of pectolite, altered in part to crystalline calcite, small, tabular crystals of some mineral of a dark-green color were noted. A thin section (116) disclosed the relations shown in fig. 14. The dark mineral is surrounded by calcite, and between the two there is often a muddy border, indicative of decomposition. The process of replacement has frequently left the curious projecting shreds shown in the figure. The general habit and the optical properties indicate an amphibole, but several features are abnormal.

The pleochroism is strong. X = dark blue-green, Y = claret and Z = pale yellow-green. Intermediate sections show tints of gray, lilac,

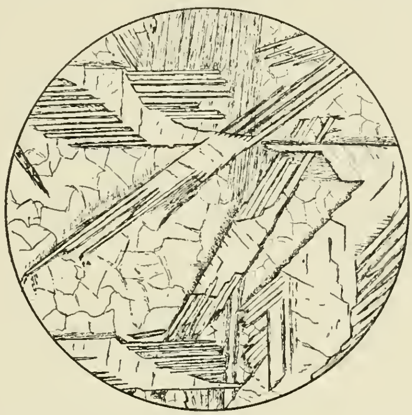

FIG. 14. Shreds of an abnormal amphibole (probably arfvedsonite) in calcite. × 32. Slide 116.

purple and brown. Absorption formula, X > Y > Z. There is a well-defined cleavage, probably parallel to the prism, and probably another cleavage whose character could not be determined. Elongation tabular parallel to the prism. Optic character biaxial and negative, optic angle large. Extinction measured from the X-axis of elasticity to what is probably the vertical cleavage makes a maximum angle of 14–15°.

Unusual features are the reversal of the ordinary formula of absorption for amphiboles, the position of the X-axis, and the great range of pleochroism. These features agree very closely, however, with the rare variety arfvedsonite $(Na_2, Ca, Fe)_4\ Si_4O_{12}$ with $(Ca, Mg)_2\ (Al, Fe)_4\ Si_2O_{12}$, as described by A. N. Winchell.[43] In the same slide, a small de-

[43] "Optical Mineralogy," p. 114, 1909.

tached portion of the section shows calcite and quartz, with a shred of amphibole. Using the birefringence of the quartz as a basis, the amphibole gives a maximum birefringence of 0.025, which agrees very well with arfvedsonite. The possibility of ægirite was considered, but the properties agree much less perfectly with those of that mineral. Not many occurrences of arfvedsonite in this country have been noted and these only in eruptive rocks. A further study of its properties with more certain identification would be of interest. It is to be regretted that so little of it has been found. In slide 153, containing pectolite and large albite crystals, a few shreds appear to be the last remnants of arfvedsonite. In 108, a single shred shows the characteristic pleochroism (blue-green and lilac) and in 77, a half dozen remnants show pleochroism as in 116.—X blue-green, Y claret and Z yellow-green, with $X > Y > Z$. A search has been made through a large number of hand specimens in the endeavor to find other occurrences. A few cases were observed, but always so much decomposed that thin sections could not be obtained. In its typical habit, the mineral consists of groups of tabular crystals or somewhat scattered individuals resting upon or intergrown with quartz, datolite, pectolite or albite. It was always decomposed to a large degree to a grayish-green, pulverulent substance, or its total removal had left narrow gashes in the associated minerals. An interesting feature brought out was that similar gashes were not uncommon in many specimens in which there was no other evidence of arfvedsonite. Their frequent occurrence suggests that arfvedsonite may have been formed in considerable quantity at one stage of alteration but that in most cases it has totally disappeared.

Varieties 2 and 3. The usual amphibole found in the slides is of very different character. It occurs in tufts or bundles of fibres or in groups of slender prisms, and in general character resembles actinolite. It is found in small quantities in a great number of the thin sections, but in several in which the minerals associated with it are those belonging to the first periods of alteration, it is present in notable amounts. In 98, it occurs in tufts of small fibres, dispersed in columnar or plumelike forms, and at times occupying most of the field (Plate XIII, fig. 1). Pleochroism strong, from a clear emerald-green parallel to Z to pale brown tinged with green at right angles to Z. No difference in pleochroism between X and Y can be perceived. Absorption strong parallel to Z, weak parallel to X and Y. Extinction nearly parallel to elongation of the needles, but angles up to 11° were obtained. Direction of elongation makes an acute angle with the Z-axis of elasticity. Index of refraction greater than prehnite and approximating that of calcite, indicating a value of about 1.65. The maximum interference color in the section is a blue of the first order, corresponding very closely to that of associated prehnite, and indicating a value of birefringence of about 0.033. Its affinities seem to be with actinolite. Its strong pleochrism points to a high content of ferrous iron.[44]

In 53, green amphibole occurs in associations very like those in 98. Plate XI, fig. 5, shows a portion of the slide, but not that in which the amphibole is best developed. The pleochroic colors are the same, and the general appearance is very similar, but the habit is more columnar, and the plumose development is much less prominent. Extinction angles measured from the elongation gave maximum angles up to 32 or 33° (in a doubtful case still higher). Pleochroism, emerald-green parallel with Z, pale yellow and brown parallel with X and Y. Absorption corresponds. The elongation makes an acute angle with the vibration direction Z. The birefringence is practically that of prehnite, or about 0.033. Index of refraction greater than that of calcite (> 1.66). The high birefringence may indicate an approach to the iron amphibole, grünerite, but the large extinction angle and character of the pleochroism are somewhat anomalous.

The relation of the amphibole and garnet in this slide is at variance with what was found in 98 (described under garnet). In the latter, the amphibole held inclusions of the garnet and was quite plainly replacing it. In 53, it is even more evident that garnet occupies areas formerly held by the amphibole. The replacing garnet is transparent (free from opaque dust), so that the forms of the former amphibole prisms are distinctly outlined. In some instances, the replacement is not complete and remnants of amphibole are still left.

In 109, from the same hand specimen as 53, there appears to be the following relation of garnet and amphibole (Plate XIII, fig. 2). The stouter prisms of amphibole have been partly replaced by garnet. This has not proceeded very far, and a reversal of the process has occurred by which a bordering rim of fibrous amphibole has grown out among the garnet grains, partly replacing them. At the same time, the stouter prisms themselves have broken up into the fibrous form, which preserves fairly well the outward boundary but has assumed an internal structure which is even plumose in places, without much regard to the original crystallographic orientation. In the middle portion of the drawing, a single prism of amphibole illustrates both processes. At one end, the amphibole has been replaced by colorless garnet. Toward the other end, fibres of amphibole have shot out among the garnet grains for considerable distances beyond the original border of the rod. The structure of the

[44] Dana: *Op. cit.*, p. 389.
Winchell: *Op. cit.*, p. 109.

interior of the prism has altered into masses of fibres of various orientation.

The fibrous form of amphibole with low extinction angle is found in numerous slides. In 115 and 118, it occurs in abundance. Invasion of garnet areas by amphibole is exhibited in a number of places. In 117, a series of subspherical growths of amphibole, built up of plumose or ray-like fibres, form a border between comparatively unaltered basalt and transparent prehnite. Pyrite (or chalcopyrite) is in intimate intergrowth. The pleochroism of the amphibole is much less marked in this instance. Colors vary from yellow-green, parallel to Z, to very pale bluish green or almost colorless at right angles to this. Elongation of fibres is nearly parallel to Z as before.

In the occurrences described, the very fibrous amphibole is found under circumstances which show that its formation began in early stages of alteration. Its range of stability appears to have been very extended, however. It has been observed macroscopically in small acicular tufts or sheaves resting upon the free crystal faces of heulandite, laumontite, apophyllite and calcite, minerals of a late stage of alteration, in such manner as to show later deposition. This inference is confirmed in the slides. In 72, very fresh-looking groups are found in the midst of heulandite, and in 51*a*, it is associated with heulandite and calcite. In 120, a group of fibres is surrounded by laumontite, and in 98 perfectly fresh amphibole is surrounded by chabazite. Slide 129 shows a sheavelike bundle of amphibole fibres in the midst of a large apophyllite crystal. In the hand specimen of the last, similar tufts were seen, resting on a free face of the apophyllite crystal. Slide 138 shows similar inclusions. In a great many other slides (50, 50*a*, 62, 110), small quantities are found in various associations. In some cases, there might be a question whether the amphibole might not be a survival from a previous period of more intense metamorphic activity, but when it is seen macroscopically, resting upon the faces of projecting euhedral crystals, the only inference which appears justifiable is that it is of later formation. From these relations, it appears probable that it continued stable at rather moderate temperatures. There was, however, in the more open channels, a tendency toward solution because of a diminution of iron and magnesia in the circulating waters. In the places where it is found, there appears to be always some comparatively unaltered basalt within a short distance, generally in the same slide, but in the large masses of secondary minerals sometimes found in the cavities in the trap sheet, there is no distinctly iron or magnesia mineral left. The writer has seen masses a foot or more in size consisting of pectolite, prehnite, natrolite and thaumasite lying between the bowlder-forms of basalt, and showing apparently the complete removal of iron and magnesia compounds. The inference is that in the channels in which circulation was most free, the waters were too dilute in iron and magnesia for the deposition of these minerals, and it was only where the circulation was more obstructed and therefore slower, and where a supply of iron and magnesia was at hand in the less altered basalt, that these compounds were deposited.

The manner in which the amphibole was removed by dilution of the solutions appears in slide 108. The bundles of acicular fibres are losing their characteristic euhedral terminations and appear as small masses with irregular outline. There is no indication of alteration products, and

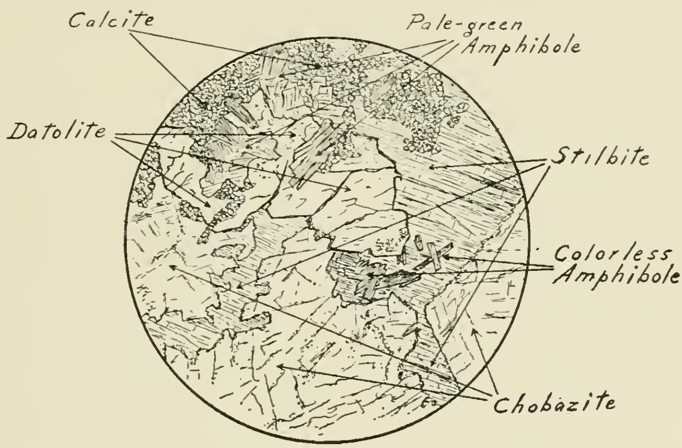

FIG. 15. Association of amphibole, datolite, chabazite, stilbite and calcite. The amphibole shows both green and colorless varieties. Datolite shows corrosion at contact with zeolites, chabazite is cut by veinlike stilbite, and granular calcite replaces all. × 32. Slide 108.

it appears as if the amphibole were simply being dissolved out. Datolite and heulandite are the associated minerals.

Variety 4. Under certain circumstances, the amphibole appears to suffer a diminution in iron content without destruction of the crystals, perhaps altering in the direction of tremolite. This is observable in several slides. The green and brown pleochroic colors have practically disappeared. The crystals retain their outline and fresh appearance, but are colorless or show a very faint tinge of green. A group in slide 108 (fig. 15) shows transitions between individuals which are decidedly pleochroic and those in which the green is barely perceptible. Datolite is associated, but zeolites and calcite are the prominent minerals present.

In other parts of the slide, the amphiboles are a pale green to deep green. In several places in 94, groups of very pale green crystals are seen. In 120, 100 and 51*a*, similar, almost colorless crystals are observable.

Among the several varieties of amphibole present in these rocks, the arfvedsonite is believed to have been first in order of formation, the columnar prisms with large extinction angle second, the fibrous form resembling actinolite third and the colorless variety fourth.

The changes noted in the amphiboles conform to those which a complex solid solution might be expected to undergo when the external conditions are continually changing. The relations of amphiboles among themselves and to pyroxenes are undoubtedly very complex and are not well understood, but the researches which have recently been carried forward in the Geophysical Laboratory at Washington have cleared up a number of hitherto doubtful matters.

In a study of the nature of the $MgSiO_3$ series of minerals, E. T. Allen, F. E. Wright and J. K. Clement[45] found that $MgSiO_3$ exists in four modifications or phases: a monoclinic and an orthorhombic pyroxene and a monoclinic and an orthorhombic amphibole, and that the last three pass into monoclinic pyroxene at high temperatures (1150° and upward) with a slight evolution of heat. They draw the conclusion that all are monotropic toward the monoclinic pyroxene, which is the only stable phase at all temperatures. Somewhat opposed to this inference, however, is the fact, which they and other investigators record, that monoclinic amphibole is produced experimentally by heating the necessary ingredients at moderate temperatures (375–475°) for 3 to 6 days in aqueous solutions; also the numerous examples in which the transformation of pyroxene into amphibole has been observed in nature (as in uralitization). They regard natural occurrences of amphibole as examples of the persistence of metastable phases, but this explanation seems hardly adequate to account for all the phenomena which petrographers have observed. A factor which is undoubtedly of great importance in the matter is that no member of the series ordinarily occurs pure in nature, but contains other members associated with it either in chemical combination or in solid solution. This may exert a powerful effect upon the direction of transformation under given conditions.

Further study in the same laboratory on "Diopside and its Relations to Calcium and Magnesium Metasilicates" [46] has brought out very interesting relations. The investigation was devoted to pyroxenes and did not

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[45] Am. Jour. Sci., 4th ser., vol. 22, p. 385, 1906.

[46] Allen, White, Wright and Larsen: Am. Jour. Sci., 4th ser., vol. 27, pp. 1-47, 1909.

include the amphiboles, but it may be inferred that somewhat analogous relations hold. It seems most probable that the amphiboles consist of a series of metasilicates which are capable of uniting among themselves in compounds of definite composition and in mixed crystals (solid solutions) of variable composition. In such complex solid solutions as are formed by associations of various members of the series, equilibrium with the liquid with which the crystals are in contact is necessarily easily displaced by changes in the composition of the liquid, and perhaps also by changes of temperature. The metamorphoses which the amphiboles of the Watchung rocks are found to have experienced are in harmony with this conception and would be expected from the conditions to which they were subjected.

Somewhat similar phenomena to those described are mentioned by J. P. Iddings:[47]

> Common hornblende and basaltic hornblende in some instances alter by the loss of color and subsequent passage into pale or colorless amphibole, resembling actinolite and tremolite; often becoming recrystallized as acicular or fibrous aggregates (strahlstein). . . .
>
> The chemically simpler varieties, like tremolite and actinolite, are more stable than the more complex hornblendes. In fact, the former frequently result from the breaking-down of the more complex amphiboles.

Regarding relative stability, however, the present writer would adopt a somewhat different form of expression. The more complex hornblendes are probably perfectly stable under the conditions of deposition, but with a change of external conditions they tend to change in accordance.

In the study of the transformation of labradorite into albite, it was found that the original crystals gave up to the liquid that constituent which was in excess and received that which was deficient, but with the amphiboles it appears that the process which prevailed was a breaking-up and solution of old crystals and deposition of new.

Specularite (*Specular Hematite*)

Specularite is seldom present in large quantity, but a small amount is often found. It has been observed without the microscope in dark bladelike crystals or groups or as a bright crimson or iridescent purplish dust on faces and as inclusions in crystals of almost every mineral in the series. The magnetite of the original rock appears to have broken up almost as soon as recrystallization began, and its place was taken by hematite. In slide 53, it is found in tabular crystals, reddish-brown by transmitted,

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[47] "Rock Minerals," p. 340.

blue-black by reflected light. In 98, crystals with hexagonal outlines are prominent (Plate XIII, fig. 1). One of these reflects light in such a manner that the three upper faces of a flat rhombohedron can be seen. In 61, hexagonal tablets are associated with analcite, heulandite and calcite. It is occasionally found in other slides, but no features of special interest have been observed.

During the process of ordinary weathering, hematite is not usually formed, but some hydrated compound of the sesquioxide of iron. This applies to the original basalt and to its secondary minerals. Surface decay results in the familiar rusty brown color from the iron compounds, and the hematite itself partakes of this transformation. It is quite evident, therefore, that the processes which were at work in the formation of the zeolitic and associated minerals were essentially different from weathering. The principal factor involved, so far as the hematite indicates, would seem to be difference of temperature. There is probably a fixed point at which transition occurs under ordinary conditions from hematite into hydrated forms of Fe_2O_3, or vice versa, and the presence of hematite indicates that the temperature throughout was in excess of this minimum.

The presence of a purplish dust of hematite often adds to the beauty of crystal specimens. It occurs both as an outer coating and as inclusions, and the inclusion of hematite in a very finely divided condition may account for the delicate pink or flesh tints which the zeolites often show. There is some question, however, whether in the latter case the phenomena may not frequently be due to a ferric compound in solid solution. It has been found in the thin sections that some of the specimens which show such tints carry inclusions of ferric oxide, but on the other hand many of them exhibit nothing to which the color can be attributed. According to interpretations of mineral analyses which have prevailed until recently, the presence of ferric oxide in a zeolite would at once be attributed to a mechanical impurity. It is now recognized, however, that quite diverse compounds may enter a solid solution. A great deal of work requires to be done to ascertain the limitations of this form of combination and what interpretation is correct for individual cases.

Pyrite and Chalcopyrite

The total amount of pyrite and chalcopyrite is small, and their occurrence is of interest chiefly because of the indication it affords of the nature of the processes of alteration. Their presence is attributed to emanations from the consolidating magma and deposition in crevices. In contact with circulating waters some migration and recrystallization may have followed, but the survival of such readily oxidizable compounds argues strongly against any oxidizing property in the waters. They have been observed with the naked eye associated with many members of the series under conditions which imply contemporaneous deposition. When surface waters have reached them, the ordinary oxidation products appear, but when seen in their original condition, they are fresh and bright.

One is apt to consider chalcopyrite as a mineral deposited from highly heated solutions, and its formation among the later minerals of the Watchung series might be considered an argument that a high degree of superheating still prevailed. This, however, is opposed to evidence from other directions and does not appear necessarily true. W. Lindgren[48] places pyrite and chalcopyrite among minerals persistent from igneous conditions up to near surface, and also believes that they were formed at times in the lower ground-water zone (zone of sulphide enrichment). Direct evidence on the formation of chalcopyrite at moderate temperatures is supplied by the observations of Daubrée[49] upon copper minerals found upon Roman coins at the hot springs of Bourbonne-les-Bains. The temperature of the water in this case was only 58–68°C. It carried in solution chlorides and sulphates of alkaline bases and of lime and magnesia, together with bromides, carbonates and silicates, and traces of various other compounds. A number of copper minerals of recent deposition were recognized: cuprite, chalcocite, tetrahedrite, covellite, tennantite and chalcopyrite. The last was recognizable both by its characteristic yellow color and by its octahedral crystalline form. Mammelonated forms were also deposited.

The minerals so far studied appear to have been formed in the first stage of recrystallization. Some of the new species were limited to a very short period of deposition, while with others the range was more extended. It is interesting to observe that all of the minerals resulting from the primary consolidation of the magma were attacked and recrystallized during this first stage of alteration. The chemical rearrangements, however, were not so complete as is implied in the disappearance of all the mineral species. Of the two molecules which made up the plagioclase feldspar of the basalt, anorthite was broken up, but albite remained stable and recrystallized as such. Several of the molecules which formed the mixed crystals of diopside probably merely suffered a change of phase in their recrystallization into amphiboles. A portion of the magnetite was

[48] Econ. Geol., vol. 2, pp. 122, 125, 1907.
[49] "Géologie Expérimentale," Paris, pp. 72-86, 1879.

split off as hematite, implying a certain amount of chemical reaction. For the formation of such compounds as are entirely new, reactions must be assumed. In this way, garnet, quartz and some of the amphibole molecules must be accounted for.

The second stage of alteration was characterized by prehnite, pectolite and datolite. Of the three, prehnite and pectolite are formed of the oxides to which the phase rule was applied in the earlier pages of this paper; that is, they belong to the soda-lime-alumina-silica series, to which quartz, the feldspars and the zeolites belong, and their relations to preceding and following members of the series are of especial interest in the inquiry as to the applicability of the phase rule. Datolite cannot be considered a member, on account of the presence of boric oxide. Its relations to other minerals are of interest, however, on account of the evidence of changing conditions which they offer.

Datolite

In the slides, the datolite is easily recognized by its moderate refraction (much higher than most of the associated minerals) and brilliant polarization tints. Prehnite is the only mineral with which it might be con-

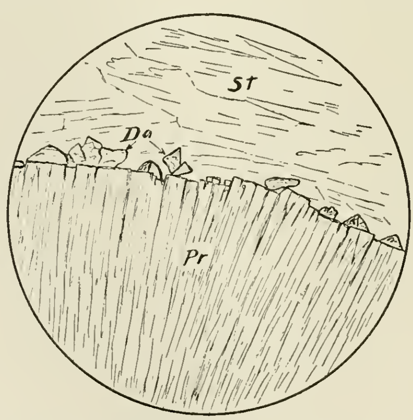

FIG. 16. Remnants of datolite crystals (Da) perched upon prehnite (Pr) in contact with stilbite (St). × 35. Slide 101.

fused, but this assumes a radial development or a twinning structure which are unmistakable. In hand specimens, datolite is often seen in large, beautifully developed crystals, not infrequently an inch or an inch and a half in diameter, clear, glassy and of a light green color, showing a great number of distinct crystallographic faces. The finely granular aggregates, however, in which it is mixed with other minerals, afford better subjects for the microscopic study of replacement phenomena.

In slide 63, in which datolite is in association with albite, as previously described, the normal appearance of the unaltered mineral is shown. It forms an aggregate of interlocking anhedral crystals, approximately equidimensional. The character is biaxial and negative, optic angle large, dispersion formula $\rho > v$. The manner in which albite is replaced by datolite in slides 63, 70 and 123 was described under albite, and the replacement of quartz in 70 under quartz. The last is shown in fig. 8.

The relations of datolite and prehnite are shown in several slides. The deposition of the two minerals is considered to have been approximately contemporaneous, on account of similar relations to preceding and follow-

FIG. 17. Corroded crystals of prehnite (Pr) in the midst of datolite (Da). × 35. Slide 67.

ing species, but in the cases where it has been possible to determine the relative succession of the two, datolite appears to be later than prehnite. In slide 101, small crystals of datolite are perched upon a radiate group of prehnite crystals in contact with stilbite, as shown in fig. 16. From their position, it seems necessary to suppose that they were deposited upon previously-formed prehnite. In 67, radial and columnar prehnite is mixed with datolite in an involved manner. In places, the prehnite shows strong corrosion, and outlying fragments are on the verge of disappearance. Small portions have been isolated by datolite. The apparent relations are shown in fig. 17. In 74, there is undoubted replacement of prehnite by datolite.

The relations of datolite to the zeolitic minerals seem very plain. It appears that under normal conditions datolite was in process of removal during the entire period of formation of zeolites. Such a condition does not appear surprising, if the inferences as to the source of the boric acid are correct. The amount deposited by sublimation in the crevices of the lava would be a definite quantity, and no further supply would be available during progressive alteration of the basalt. Under the continual leaching of the uprising waters, it should therefore gradually disappear.

In section 95, the relations of datolite and chabazite are well shown. The rock is a quickly chilled basalt, in which phenocrysts of plagioclase and diopside are scattered through a groundmass of feathery microlites. It contains numerous irregular cavities which probably represent steam vents. The chief filling of the spaces is chabazite and heulandite, but along the margin of the amygdules are numerous corroded crystals of

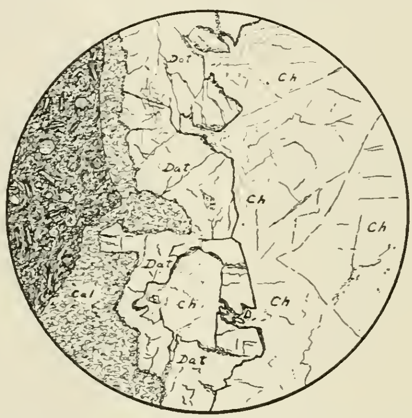

FIG. 18. Datolite (Dat) replaced by chabazite (Ch) and calcite (Cal). × 35. Slide 95.

datolite. The manner in which the datolite is yielding to chabazite is sketched in fig. 18. Frequently the datolite crystals retain strong suggestions of their outward form, but the core is gone and its place is occupied by chabazite. Between the datolite and the less altered basalt, finely granular, muddy-looking calcite has entered in the manner which has been found to be so frequent.

In 110, there is a similar replacement of datolite by stilbite (fig. 19). It is noticeable in many cases, as the figures indicate, that parts of the datolite crystals are unattacked and retain their proper outlines, while other parts are deeply corroded.

In 94, there is replacement by heulandite. At one point, there is a suggestion in the structure of the datolite, heulandite and associated calcite, and in the radial disposition of included dust, of a former spherulite in the basalt, various occurrences of which have been described.

In 75, there is probably a replacement of datolite by natrolite. Slide 108 furnishes a fine example of deeply corroded crystals in contact with

Fig. 19. Replacement of datolite (Da) by stilbite (St). × 35. Slide 110.

stilbite, heulandite and chabazite. Fig. 15 shows the association at one point. With the datolite, a considerable quantity of amphibole is found. In one or two places, the basalt is very little altered and is seen to have a typically vitrophyric texture. The remnants of datolite and amphibole

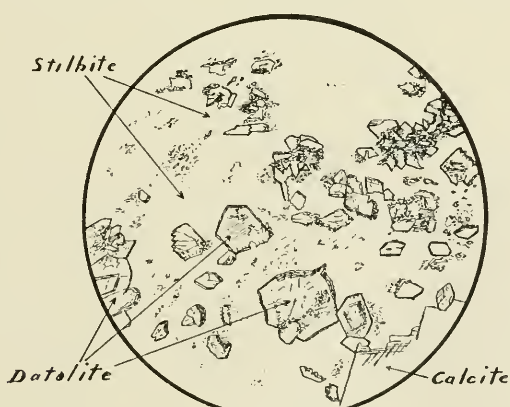

Fig. 20. Swarms of corroded crystals of datolite in stilbite. × 35. Slide 83.

show a distinct tendency to form borders to the less altered rock, while the zeolites are best developed farther out. This is probably the result of leaching-out of datolite where circulation was most free.

Fig. 20 shows the appearance of swarms of corroded datolite crystals in stilbite in 83. Many of them have the rounded and etched appearance which is seen when crystals of a salt slowly dissolve in water.

Other examples might be given of the corrosion of datolite in contact with heulandite, chabazite, stilbite and calcite. In a great number of slides, there are at least a few remnants of datolite, and it may have been present originally in great quantity. The general relations and mode of replacement have been brought out in the examples given. These show that albite, quartz and prehnite were replaced by datolite, which in turn yielded to chabazite, heulandite, stilbite, natrolite and calcite. This order has been found to be true in so many cases that there is little doubt that it is general. Nevertheless, one abnormal occurrence has been observed, in which crystals of heulandite and calcite are encrusted with datolite, implying deposition at a much later period. The formation of datolite was probably conditioned chiefly by the concentration of boric acid in the solutions. In the ordinary course of events, the solutions appear to have gained access to the available supplies of this material at an early period and to have effected the reactions by which datolite was formed, while at a later period the process appears to have been one of gradual removal; but it is not difficult to conceive that under somewhat irregular conditions of circulation the boric acid might have been left until a much later period before it was taken up in the general circulation.

Prehnite

Prehnite is found in the familiar form of groups of tabular crystals, more rarely in small, distinct prismatic forms. Both varieties appear in the thin sections. The structural characteristics and optic properties are normal. The microscopic twinning lamination, which produces a plaid effect, is well shown in a number of the slides, and when seen, differentiates it immediately from all other minerals present. Equally characteristic is the deep azure-blue, low-order interference color. It is observed that when sections give the normal gray tone as the minimum interference, the dispersion may be either $\rho > v$ or $\rho < v$, but in those in which the minimum is the abnormal Berlin blue, the dispersion for red is much less than that for violet. Iddings gives $\rho > v$, in some cases $\rho < v$. Leather-brown tints are also distinctive. The interference figures rarely show distortion, except when it is evident that several individuals or groups of twinned crystals are concerned in the effect. Commonly the habit is radiating or plumose, but in two or three slides (for example, 74 and 67), it is found in small distinct prisms. The feathery forms and brilliant polarization colors often suggest bright-colored plumage.

The relations of prehnite to albite, quartz, garnet and datolite have been described. With regard to pectolite, the slides appear to present evidence that in its growth, needles of the mineral have been advanced through previously deposited prehnite, as if the latter offered no resistance. It will appear later that natrolite also, whose habit of growth is in similar slender needles, possesses the same property of advancing through previously existing crystals. In 87, finely felted pectolite lies in contact with a spherical mass of radiating prehnite. The terminations of the prehnite crystals have lost their characteristic appearance and sharpness of outline, and the borders appear muddy. In places, the felt of pectolite is plainly advancing across the prehnite.

In 76, masses of prehnite are thoroughly impregnated with pectolite needles. These cross the prehnite areas singly or in groups of three or

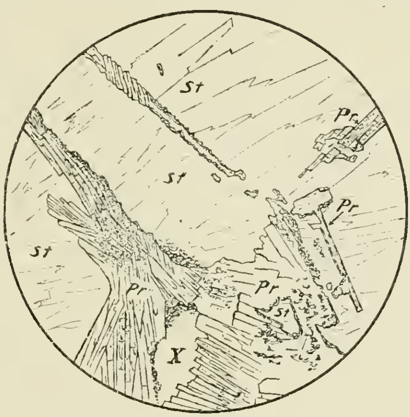

FIG. 21. Remnants of prehnite groups (Pr) in stilbite (St). × 35. Slide 74.

four or lie in bundles or diverging rays. The perfectly straight and sharply defined needles pierce numerous grains of prehnite without diversion. Similar effects, though not developed so extensively, appear in 50*a* and are illustrated in Plate XI, fig. 6. In this illusrtation, the straight needles near the center represent pectolite.

In 93, the hand specimen shows grains of prehnite, the size of buckshot or smaller, which lie isolated in the midst of masses of pectolite. In the thin section, the prehnite appears turbid and between crossed nicols has a mottled look. Along the borders, it is difficult to decide what is pectolite and what is prehnite, though normally the two have a very different look. In 67, badly corroded prisms of prehnite are being replaced by chabazite.

Fig. 21 (slide 74) illustrates the manner in which originally radiate groups have been broken up by stilbite into isolated individuals or small scattered clusters. In 101, a prehnite group is cut by veins of stilbite.

In 127 (fig. 3), which was described under albite, it is found that the prehnite clusters which had been deposited upon albite are in turn giving way to natrolite. In 68, also, prehnite is being replaced by natrolite, and portions of groups have been cut off by the later mineral.

The relations of prehnite and apophyllite are shown in 138. Small groups and fragments of prehnite are isolated by the apophyllite in numerous instances. The manner in which a vein of apophyllite cuts off a portion of a radiate group of prehnite crystals is illustrated in fig. 22.

Calcite effects striking results. Crystals appear in the midst of prehnite and develop in euhedral forms, which cut out areas of the earlier mineral as sharply as by a knife. This appears in slides 53, 62 and 76.

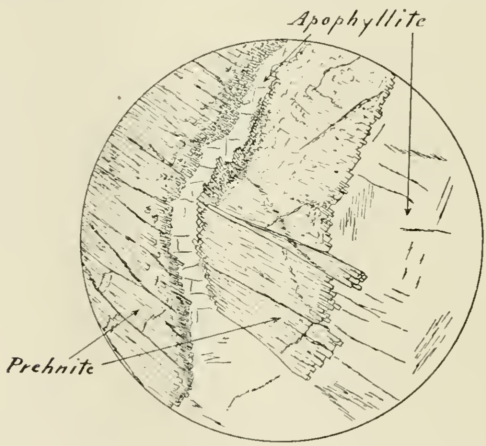

FIG. 22. Prehnite cut by vein of apophyllite. × 35. Slide 138.

By a continuation of the process, fragments of prehnite of extreme irregularity are left, whose outer form is determined by calcite, but through all portions of which the same fan structure prevails.

Occasionally in specimens of basalt which appear to the naked eye perfectly normal and unaltered, small, shotlike nodules of prehnite are seen. The rock seems entirely impervious, and the relations are such as to make it appear that the prehnite had developed in the fused magma. This is so improbable that another explanation is naturally looked for, and the effects seem to be very well explained by certain phenomena which appear in several of the slides, for example, 50*a*, 53, 65 and 118. In 50*a*, crusts of prehnite border areas of basalt in which the texture appears normal at first sight, but it is found that the diopside and plagioclase have been almost wholly replaced by prehnite, whose brilliant tints and radial structure when seen with crossed nicols give a quite unexpected appearance to the former diopside and plagioclase areas.

Although without doubt the effects of alteration and replacement are generally most pronounced immediately adjacent to cracks and crevices of various kinds, or where the solutions acted upon the glassy phase of the rock, nevertheless it appears that in places the solutions were able to penetrate by capillary action to considerable distances within unbroken rock of normally crystalline character and effect almost complete mineralogic rearrangement. At the same time, the texture was left almost undisturbed. Prehnite seems to be especially characteristic of this process, and the effects are visible in the slides mentioned. Under such conditions, large diopside phenocrysts or nuclei of resorbed olivine would partake of the transformation and would appear as prehnite nodules. A nearly circular form of radial prehnite, probably of the latter derivation, appears in slide 65.

Prehnite is determined to be later in the sequence than albite, quartz and garnet, and earlier than datolite, pectolite, chabazite, stilbite, natrolite, apophyllite and calcite.

Pectolite

Pectolite occurs in the usual groups of radiating fibres, some of which reach a length of two or three inches, but usually they are smaller. It commonly occurs in hemispherical masses. It is very frequently associated with prehnite, but it is found also with a great variety of other minerals. It is not specially well represented in the slides, but the position in the series can be fairly well determined. In descriptions of albite, quartz and prehnite which have preceded, it was found to replace these minerals. It appears under the microscope as masses of finely radiating fibres of rather high birefringence, elongated parallel to Z. It strongly resembles natrolite, but is distinguished therefrom by the higher interference colors.

In 143, the hand specimen shows an association of pectolite and natrolite in which the appearance of pectolite suggests decomposition. This inference is confirmed in the slide. The radiating needles of pectolite are buried in a mass of natrolite, the sharpness of outline has been lost and at the terminations, the crystals appear to fade out gradually, as it were, instead of terminating abruptly with sharp definition.

In 130, the hand specimen shows small clumps of pectolite fibres which are quite evidently portions of originally larger masses, buried in chabazite. The thin section was taken at the contact and shows the increasing turbidity of the pectolite in the vicinity and the manner in which the fibres disappear in the chabazite. At one point, the pectolite area is cut across by small veins of chabazite and calcite.

FIG. 23. Masses of pectolite needles and isolated remnants of same in the midst of apophyllite. × 35. Slide 129.

In the hand specimen from which 86 was cut, crystals of chabazite rest upon the hemispherical surfaces of pectolite masses. In fig. 23, the replacement of pectolite by apophyllite in 129 is sketched. Slide 135 shows practically the same relations.

General Results of the First Period of Alteration

In the slides which have been described, in which the minerals belonging to the first period of alteration are best developed, there are commonly but obscure indications as to the nature of the original material which has been replaced. Mention has been made, however, of certain circular figures and curved lines and markings, due apparently to an insoluble residue of TiO_2, etc., upon which the forces of recrystallization had no effect. These have been interpreted as survivals of an original structure in the glass. Examples are shown in Plate XI, fig. 5, Plate XII, fig. 5, and Plate XIII, fig. 2. There are instances, too, in which the secondary minerals are separated from the basalt of normal texture by a marginal band in which the texture is of much finer grain. This is believed to represent a transition between glassy crusts and more slowly cooled interiors. In all these cases the original glass has totally disappeared, and with it such phenocrysts of diopside and plagioclase as may have been present, but in a few instances it is seen that portions of it survived.

Slide 61 is plainly a shattered glass, with whose angular fragments considerable quantities of reddish-brown clayey sediment from the underlying lake-bottom are mingled, forming a remarkable-looking mosaic. The greater portion of the glass breccia is now altered to analcite and chlorite, but in certain areas albite groups survive. Slide 119 is quite similar in origin, but alteration has proceeded to the calcite period. In many places, nevertheless, remnants of albite groups and a small quantity of pleochroic green amphibole are perceptible.

In 12, we have again a breccia mingled with sedimentary dust, but the greater portion of the glass is now represented by groups of interlocking albite crystals. The complex appearance is illustrated by Plate XII, fig. 1. In this, the lighter areas throughout are mostly albite, through which there is a sprinkling of insoluble residual dust (TiO_2 or MnO_2), distributed without regard to the crystallization of albite. The light gray in the figure is chloritic material which appears to have migrated into cracks, and the darker portions are chiefly foreign sediment. Diopside crystals are present in several places in the slide. Their outlines appear rounded, whereas the interiors have remained perfectly fresh. A little acicular amphibole is visible. The effects of later alteration are represented in a little calcite and in the bands of chlorite. In none of the slides in which the reddish sediment is present does it seem to have been affected in the slightest degree by the processes of alteration. Although it appears that the solutions reached it at the early period at which albite and amphibole were formed, nevertheless its areas and lines of distribution remain sharp and distinct.

In 120, a little albite and amphibole are scattered through zeolitic material. In one portion of the section, there are indications of an original glassy texture. In 59, the groups of minute quartz crystals shown in Plate XI, fig. 4, occur in what was originally a glass breccia. In those slides in which the geometrical figures similar to those illustrated in Plate XI, fig. 5, and Plate XII, fig. 5, appear, the distribution of minerals is suggestive of replacement of a breccia.

On the whole, the processes of recrystallization during this period are believed to have acted so vigorously upon the glass that a very small portion of that to which the solutions gained access escaped such thorough transformation that the structure was almost completely destroyed. A decided contrast is presented to the effects of the second period (that of zeolitic alteration). In the latter, it is possible to trace with ease the progress of the changes. In the less altered portions, the channels through which the solutions percolated may be followed and the differential effects upon more and less soluble material and the gradual spread of the areas noted.

Further evidence of the more intense activity of the metamorphic processes in the earlier stages is supplied by the fact that the holocrystalline phase of the basalt was undoubtedly attacked and recrystallized to a certain degree and that the phenocrysts of diopside and plagioclase left little or no trace. In the later stages, recrystallization appears to have acted only upon the glass or upon aphanitic basalts whose crystallization was of the hairlike microlitic type, and remnants of phenocrysts persist for a long time.

Second Period of Alteration

Progress of the Changes

At this point, a marked change occurs in the nature of the minerals deposited. The differences between the two periods have been ascribed, both on theoretical grounds and on the evidence of the microscopic sections, to falling temperature and to the disturbing influence of boric acid in the solutions during the first period and its elimination during the second period.

In the primary consolidation of the magma, plagioclase was present in abundance. During the first period of alteration, the anorthite molecule was immediately broken up to form new compounds to which it bore no resemblance in chemical structure. The albite molecule persisted for a short time, but soon followed a similar course. The molecular groupings characteristic of the plagioclases were destroyed. The components entered into such compounds as garnet, arfvedsonite, prehnite, pectolite and datolite. Other compounds may have been formed in the solutions, but they did not reach the point of crystallization, unless represented in minerals which subsequently disappeared completely.

During the second period, there was no further source of boric acid which could be drawn upon, and that which had been deposited as datolite was gradually taken up by the solutions and removed. The effects of the presence of boric acid disappeared. Ferromagnesian constituents also became greatly diminished. Feldspathoid compounds reappeared, and it seems as if the conditions approached those of a closed system in which feldspathoid combinations alone were present and in which the only independently variable factor of importance was temperature, which gradually diminished. As a result, the feldspathoid group of the zeolites formed the principal constituents deposited during the second period. Coincident with the change in the chemical nature of the minerals, a change in physical characteristics appears. The minerals of the first period were predominantly rather hard and of fairly high relief and birefringence. In the second period, the characteristic minerals are soft, the refraction is less than that of balsam and the birefringence is very low.

In the glassy crusts of basalt, there is frequently a lamellated appearance, which is doubtless an original structure developed at the time of consolidation. In addition to the parallel parting-surfaces due to this feature, the glass is cut by numerous chill cracks running in every direction, so that only a little force is required to break it into a multitude of angular fragments. Definite openings of these kinds, though of capillary dimensions, doubtless offered the means for the first ingress of waters, and along these cracks, alteration first attacked the rock. This is well shown in slide 30, illustrated in Plate XII, fig. 2. Along the cracks, which show a predominant parallelism, the glass has become bleached to a much lighter color and shows a hazy birefringence. The lighter portions represent the first step in alteration and probably consist of an intermixture of zeolites and chlorite, so complete that it is entirely beyond the powers of the microscope, and no individual crystals can be perceived. It is worthy of note that among the first effects there is always a distinct bleaching, indicating removal of ferromagnesian compounds.

In addition to the openings by which the solutions were directed, there were present in the glass a number of features of physical or chemical nature which strongly influenced the course which alteration first took and traces of which remained at a stage at which recrystallization had become complete. Such were the phenocrysts of plagioclase and diopside, bubble cavities, and, perhaps more marked in their effect than all others, the nodules of olivine which were in process of resorption when solidification occurred. In the refusion of olivine, each nodule supplied a source of material somewhat different in composition from the average of the magma, and this material streamed out along flow-lines before being incorporated in the liquid. The interruption of the process by stiffening and solidification fixed and retained these differences of chemical composition. Effects of this kind may not be perceptible in the glass, but they are accentuated in the process of alteration. Brecciation of the glass and an overwhelming of the fragments in a fresh supply of lava also probably had its effect in determining differences of a physical or chemical nature and gave rise to a lack of homogeneity, which was accentuated by subsequent alteration. Various features of this kind influenced the course of alteration, and their results may be traced in many of the slides. Phenomena which are ascribed to them are shown in Plate XII, figs. 2, 3, 4 and 6, and Plate XIII, fig. 3. In some cases, the complications are of an extreme order, and it is only by following the process through various degrees of alteration that it has been possible to arrive at satisfactory conclusions as to the genesis of the forms.

In slide 54 (Plate XII, fig. 6), the inception of the process is illustrated. The greater portion of the slide shows a fairly normal glass of a dark olive-green color, with a sprinkling of phenocrysts. Serpentinous or chloritic nodules from resorbed olivine are numerous. The attack by heated waters results characteristically in the appearance shown in the figure. The lighter bands represent lines of replacement, which often assume vermicular or crescentic forms. The course of the waters was in many cases guided by chill cracks which often show distinctly along the middle of bleached bands. Phenocrysts and spherulites have had an influence in the replacement, and there are indications that differences of composition or of physical state along flow lines, and the form of fragments of partly reabsorbed breccia were not without effect. The change consisted of a chemical rearrangement by which the soda-lime-alumina silicates passed into zeolites, and the ferromagnesian constituents were altered to chloritic aggregates or, less commonly, to serpentine.

At the point sketched, the zeolite appears perfectly isotropic and almost structureless. In other parts of the slide, similar bands show a feeble but unmistakable polarization. Analcite, chabazite and heulandite are suggested as possibilities, but specific identification is not attainable.

In 30 (Plate XII, fig. 2), the process has reached a slightly more advanced stage. In both this illustration and in Plate XII, fig. 6, a structure may be seen which is very characteristic of these incipient stages of alteration, that is, a sort of "stream effect" from the darker to the lighter areas. This may possibly be similar in origin to the stream lines seen when crystals of a soluble salt are placed in water, and is accentuated by the first stages of alteration. In other portions of the slides, the transitions from the bleached into the darker areas are by almost imperceptible gradations.

Much of the original diopside looks fresh, but it is plainly breaking up into separate granules by chloritic alteration along cracks. The small plagioclase laths retain their form, but have altered into some material giving aggregate polarization.

Slide 3 was prepared from a specimen of glass which appears to have been shattered in cooling. Along the cracks thus opened up, ferruginous sand from external sources had been deposited. Later the heated solutions followed the same lines. The resulting alteration has taken a similar course to that described for 54 and 30, but it has advanced farther, and less of the original structure survives. The resulting forms appear very complex at first and would be difficult of interpretation, if clues had not been found in other sections. Plate XIII, fig. 3, illustrates a typical portion. In the upper part, one large and two small diopside crystals are seen, survivals of original phenocrysts of the vitrophyre, and at various points there are remnants of small feldspar laths. Some parts of the original glass are little altered and retain the brown or olive-green color. In other places alteration has bleached the color or has formed chloritic aggregates.

The presence of much analcite is a prominent feature of slide 3. It follows generally the vermicular courses of percolation, but in two places it lies in broad bands between lines of ferruginous sand and would seem to have filled open cracks of some width. A portion of one of these bands appears in the upper right-hand portion of the figure. The width of this band is about 0.2 mm. The other is broader, averaging 0.75 mm. The analcite includes aggregates of light-colored plumose chlorite. A small amount of non-isotropic zeolitic material is also present.

Slide 61 (Plate XII, fig. 3) is another example of a shattered glass whose angular fragments have become mingled with ferruginous sediment. The sedimentary material appears to be unaltered, whereas the brecciated glass has been changed to albite, zeolites and chlorite. Among the zeolites, analcite is prominent. There are also aggregates of hematite scales and a few grains of chalcopyrite. The forms assumed in alteration resemble those which have been described for other sections and are illustrated in the figure.

Slide 60 (from the same hand specimen as the last) shows similar phenomena. Analcite is exceptionally prominent, and other zeolites almost lacking. Chlorite and serpentine are in notable quantity. Plate XII, fig. 4, shows the characteristic structure. The banding assumed by the secondary products, which forms a prominent feature in many of the slides, is well brought out. The broad band which lies across the field a little below the center consists of a middle portion of light-green chlorite in rather large scales, bounded by darker and lighter bands of similar material in finer scales, possibly with some serpentine. Beyond, on each side, there is a sharply defined narrow band of colorless analcite, followed in most places by a band of fibrous chlorite, and more analcite in broad areas. The large circular form in the upper portion of the field is a chlorite nodule, encircled by narrow bands of analcite and chlorite. A small grain of chalcopyrite appears in the middle of the large band at the intersection with the vertical cracks.

The supposition that the bands represent original cracks is confirmed in another portion of this slide, where a very fresh-looking diopside crystal has been broken across. The two parts are now separated about 0.2 mm. and have been faulted slightly out of line, but still extinguish in unison. The faulting band is filled with chlorite and a small amount of ferruginous sediment from external sources. These cracks undoubtedly formed the passages along which the heated waters percolated, and the chemical rearrangement proceeded outward into fragments of breccia. To this process the banding must be ascribed, but it frequently reproduces the effect of a succession of layers deposited in a cavity.

Analcite

In the Watchung series, analcite was one of the first of the zeolites to appear, but under exceptional circumstances was apparently preceded by others. In the slides, it appears quite frequently, and conclusions regarding its sequence have been supplemented by macroscopic observations.

When fresh, it is perfectly isotropic and, where free from inclusions, is water-white, but with incipient decomposition it becomes very muddy. Further advance produces a porous mass, riddled with cavities. Under the latter conditions, it loses its isotropic character and becomes noticeably birefringent. Crystal outlines are sometimes lacking or very doubtful. In the fresher specimens, there appears to be a slight indication of cubic cleavage, but the fracture is in general conchoidal or follows irregular lines. Index of refraction less than balsam. Chabazite resembles analcite in its low refraction and low double refraction, but chabazite has such very low refraction that the effect of high relief is given. In addition, it has a form of blocky cleavage which is characteristic, and, in most cases, there is very little doubt as to which is present.

Analcite sometimes occurs in broad areas, as in 60 and 61, but is also apt to appear in vermicular bands. Both modes of occurrence are shown in Plate XIII, fig. 3, from slide 3. The bleached bands and cusplike figures which have been spoken of in connection with the manner in which zeolitic alteration attacks the rock are believed to consist largely of analcite, mixed probably with some lime zeolite. The transformation of albite and anorthite molecules of the glass into zeolites was probably effected with the greatest facility on account of the small amount of chemical rearrangement necessary. The first effect of such a change would probably be an intimate intermingling of species, but later, on account of the tendency which large crystals have to grow at the expense of smaller, segregation would occur, and the crystals would be individualized.

In slide 94, the chief constituents are analcite, chabazite and heulandite. The last two appear perfectly fresh, while the analcite is turbid and shows evident corrosion in contact with the other two.

In 92, the first period is represented by remnants of albite, green amphibole and datolite, which have probably replaced aphanitic basalt. The second period is represented by analcite and stilbite, with a little heulandite, and the third period by calcite. The analcite, which has become very turbid and is quite decidedly anisotropic, has been corroded and replaced by stilbite. Calcite appears to replace everything.

In 61, the analcite is found in areas of considerable size, in some places perfectly clear and isotropic and in others showing turbidity and incipient alteration. At one place, calcite is encroaching upon the analcite. In a hand specimen, large crystals of analcite are covered with a solid crust of stilbite, composed of tabular crystals disposed normally to the crystal faces of the analcite. There is no doubt of the later deposition of the stilbite.

These relations of analcite to chabazite, heulandite and stilbite are in mutual accord and appear to make the period of analcite earlier than that of either of the others. This may, however, have been true in only a limited sense. Analcite is a soda compound, whereas chabazite, heulandite and stilbite are essentially lime compounds, and the period of analcite may have overlapped those of several lime zeolites. If such were the case, a slight difference in the relative concentration of soda and lime in the solution might suffice to cause the deposition of analcite at one point, while it was being removed at another. One of the hand specimens shows a reversal of the order of analcite and heulandite, probably thus explainable. Large cockscomb crystals of heulandite have small crystals of analcite resting upon their surfaces. There seems to be no doubt that this analcite is of later deposition.

The relations of analcite and natrolite are of especial interest because of the inferences derived from the application of the phase rule. It should be found that where the two exist together, one belonged to a period of higher temperature and remained stable until a definite transition point was reached, when it began to pass over into the other. It appears that this is true and that the direction of the change is from analcite to natrolite. The relations are brought out in slide 82 (fig. 24). In the specimen from which this was prepared, small nests in a mass of porcelainlike natrolite contained crystals of analcite and laumontite, easily recognizable macroscopically. With these, natrolite crystals of much larger size than the general average of the mass were mingled. In the thin sections, the analcite appears spongy and decomposed and has lost its normal isotropic character. The natrolite, on the contrary, looks perfectly fresh. The outline of the contact is very irregular, but it is observed that at some distance back in the natrolite, the crystals of the latter suddenly change from a finely felted to a coarsely crystalline character. The border between the two varieties is easily seen in the thin section with the naked eye and suggests the outline of an analcite crystal. It does not seem impossible that the natrolite replaced various minerals (of which laumontite and analcite were two), and that the coarseness of crystallization depended upon the facility with which replacement was accomplished. In portions of the slide where it is plain that laumontite is being replaced, the crystals of natrolite are of a fine character, but where there are reasons for supposing that analcite has been replaced,

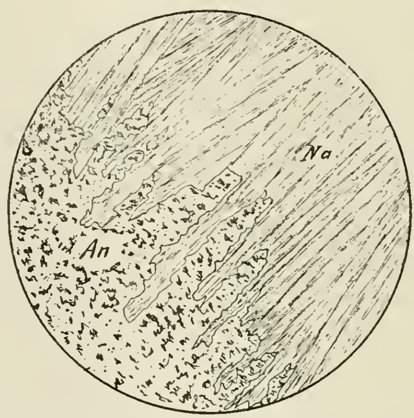

FIG. 24. Porous, decomposed analcite (An), penetrated by needles of natrolite (Na). × 35. Slide 82.

the natrolite crystals reach dimensions many times those shown in the first variety.

Slide 124 is from the same hand specimen as 82 and shows essentially the same relations. In *73b*, there is again a sudden increase in the coarseness of crystallization of natrolite along definite boundaries. Within the masses of larger crystals, there are two extremely irregular patches of a nearly isotropic, spongy mineral which appears to be analcite. This is confirmed in another portion of the slide, where similar forms still show crystal outlines. Replacement of analcite by calcite is also shown. In 68 also, a small group of isotropic crystals in natrolite show in places typical outlines of analcite. Portions are corroded, and replacement by natrolite is evident.

In a hand specimen, there is an association of analcite and natrolite in what appears to be a reversal of the usual conditions, that is, analcite crusts appear to rest upon natrolite. It is found, however, on close examination, that the analcite crystals are porous and drusy, while the natrolite is fresh, and the crystals show characteristic pyramidal terminations. They grow up among and probably through the analcite. The specimen is a good example of the deceptive appearance which replacement relations often assume.

The observations of Brögger[50] upon analcite found as a mineral of late development in the Norwegian syenite-pegmatite veins are of interest. He finds that analcite is the oldest and most widespread of all the zeolites found in open vugs and continues his description as follows:

> As Lemberg has ascertained, analcite is formed very easily at the expense of various soda-rich silicates at somewhat high temperature. Friedel and Sarasin[51] obtained beautiful crystals of analcite by heating the ingredients of albite with water up to 400°; A. de Schulten[52] obtained, by 18 hours' heating of a solution of soda silicate or of soda in closed tubes of an aluminous glass at 180°-190°, analcite crystals up to 0.1 mm. in size, also[53] by heating (during 17 hours up to 180°) soda silicate and soda aluminate in the proportions corresponding to the composition of analcite in lime-water in closed copper tubes. We recall further that among the soda-rich zeolites of Plombières observed by Daubrée (where the thermal waters, which have here deposited zeolites in recent times, show only about 70°), analcite was not found, so we may almost venture to estimate the temperature at which the abundant deposition of analcite in our veins ensued at more than 70°, perhaps at about 200°.

The high temperature which Brögger assumes for analcite deposition hardly appears justified for the Watchung rocks, but a considerable degree of superheating may well have existed.

Chabazite, Heulandite and Stilbite

Chabazite, heulandite and stilbite are so frequently associated, both in hand specimens and in the slides, that they may very well be considered together. In the larger specimens, they are among the most abundant minerals and frequently form showy groups. The chabazite crystals are usually of a light salmon or salmon-pink color, and in general show only rhombohedral faces (or pseudorhombohedral, if this view be taken). Heulandite sometimes exhibits pink tints but more frequently is almost colorless. Single crystals occur, but grouped forms with curved faces,

[50] Zeitschr. für Kryst. und Min., vol. 16, p. 169, 1890.
[51] Compt. rend., vol. 97, p. 290, 1883.
[52] Bull. de la soc. min. de France, vol. 3, p. 150, 1880.
[53] *Ibid.*, vol. 5, p. 7, 1882.

frequently in cockscomb growths, predominate. Stilbite is prevailingly of a light straw color, and the usual sheavelike clustering is the common mode of growth.

In the thin sections, heulandite and stilbite bear such a close resemblance to each other that great care must be used to distinguish them. There are two tests, however, depending upon optical characteristics, which are of such a nature that one is especially applicable to those sections in which the other fails to give good results. The first is that heulandite is positive in character and stilbite is negative, but in sections in which the lamellar cleavage is most apparent, this test fails. In such sections, however, the direction of the plane of the optic axes can usually be ascertained. In heulandite, this plane is perpendicular to the cleavage, but in stilbite, it is parallel.

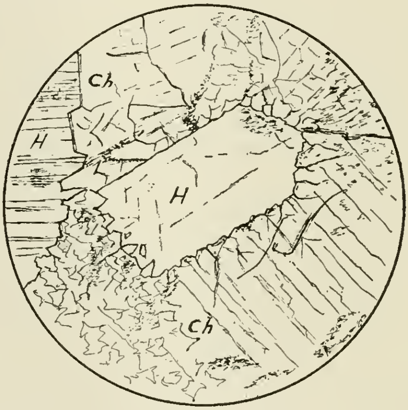

Fig. 25. Replacement of chabazite (Ch) by heulandite (H). × 32. Slide 95.

There is some variability in the size of the optic angle in both heulandite and stilbite. It is never large but may become very small. In 121, a section of stilbite gives practically a uniaxial cross. The positive or negative character, however, does not seem to vary. In chabazite, the figure is usually biaxial and always positive so far as tested. In some crystals, the interference figure is distinct and the optic angle rather large, but, in many, the birefringence is so weak that it is difficult to perceive any figure whatever.

The relations of chabazite to heulandite are shown in a number of slides (for example, 95, 108, 94, 51*a*, 77 and 128), and it appears that chabazite always precedes heulandite. With growth and advance of the later mineral, the chabazite breaks down along the border in a characteristic manner. An example is shown in fig. 25 (slide 95). In the upper left-hand portion of the sketch, the chabazite retains its normal outline, but at most places along the border it has a brecciated appearance. This feature is observable in a great number of instances.

The replacement of chabazite by stilbite usually takes a similar form. It is well shown in slides 110, 108, 80 and 121. In slide 108 (fig. 15), the chabazite is cut by distinct veins of stilbite, portions of which are shown in the sketch. The irregular boundaries of the veins are probably determined both by differential solution of chabazite and by the crystallizing tendencies of stilbite. In fig. 26 (slide 121), also, stilbite is advancing into chabazite in irregular veinlike form.

In slide 110, isolated crystals of chabazite surrounded by stilbite show deep corrosion. At one point in the slide, the phantom forms shown in

Fig. 26. Replacement of chabazite (Ch) by stilbite (St) and of both by natrolite. The natrolite needles have shot forth with apparently little opposition across areas of chabazite and stilbite, and they have also worked in along cleavage lines of chabazite. × 35. Slide 121.

fig. 27 appear. These are simply inclusions in stilbite, but the forms outlined are plainly those of preëxistent crystals, which are believed to have been chabazite.

Heulandite and stilbite frequently occur together, but it is rather rare for either to show unmistakable corrosion at the contact. In slide 108, however, the evidence is fairly good that heulandite inclosed within stilbite is being replaced by the latter. In 110 and 92 also, some confirmatory evidence is found. The more usual form of contact is shown in 88, where it is perfectly sharp. In several hand specimens, more indubitable evidence is given. The heulandite appears fresh and glassy but is crusted with stilbite. The inference from the phase rule is that heulandite and stilbite cannot coexist in equilibrium except at one fixed temperature, which represents a transition point. Although heulandite might very well persist in an unaltered form beyond this point, it should never be deposited from solution simultaneously with stilbite.

The replacement of chabazite, heulandite and stilbite by natrolite seems to have been effected with great ease, natrolite needles shooting out across areas of the three lime zeolites as if no obstacle were offered. The manner of growth as regards chabazite and stilbite appears in 121 and is illustrated in figs. 26 and 28. In the hand specimen, a polished face was prepared, and it could be seen that the chabazite and stilbite were filled with slender filaments of natrolite radiating from a large area at one side.

FIG. 27. Phantom crystals of some replaced mineral (probably chabazite) found as inclusions in stilbite, which extends uninterruptedly across the areas. × 35. Slide 110.

In the microscopic section, the effects are similar. The slender needles of natrolite cross areas of the older minerals and also work in along joints of chabazite.

A similar replacement of stilbite by natrolite appears in 71 and of heulandite by natrolite in 70. These two are from the same rock. In both cases, crystals of the earlier minerals have become isolated in masses of natrolite. The characteristic outlines have been lost, and the borders are so impregnated with natrolite fibres that one mineral seems to fade into the other.

In 84, the hand specimen consists largely of dense white natrolite, in which small pinkish areas have a geometrical appearance and suggest that some mineral has been replaced. In the thin section, several of these areas appear. It is seen that the pink color is due to separated grains of hematite, while the areas thus outlined have the form of chabazite, although wholly occupied by interlocking natrolite crystals. In 94 also, natrolite is seen to be advancing across chabazite.

Several hand specimens show a distinctive method of replacement of chabazite by laumontite. The laumontite appears to start from some nucleus within a solid crystal of chabazite and grow in radial crystals, until there may be only a crust of chabazite left. Slide 147 contains several radial groups of this kind. In 77 also, there is replacement of chabazite by laumontite, though in neither of the thin sections does the evidence appear as decisive as in large specimens.

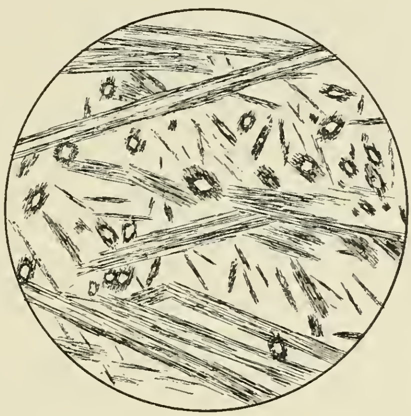

FIG. 28. Needles of natrolite which have penetrated areas of stilbite. × 35. Slide 121.

In 120 and 128, there is an association of laumontite and heulandite. The relations are not as clear as might be desired, but laumontite appears later.

Replacement of all three minerals by calcite is seen in numerous instances. It appears that chabazite, heulandite and stilbite followed each other in this order and that they were all earlier than natrolite, calcite and laumontite.

Laumontite

Because of the friable nature of laumontite, it was found difficult to get good microscopic sections showing it. There are only a few, therefore, which illustrate its occurrence, and in these the relations rarely appear of a decisive nature. On the other hand, fortunately, it is one of the few minerals which occur in the large specimens in such a manner as to make the sequence beyond question. It is frequently seen resting upon drusy chabazite crystals, and the manner in which it replaces chabazite has been described.

In slide 120, it appears to be replacing heulandite, and in a great many hand specimens, it is seen to have been deposited upon previously formed heulandite. In one or two instances, it has been found resting upon stilbite.

In 82, it is found in contact with natrolite, and it is quite certain that natrolite crystals are advancing through the laumontite. On the other hand, in a large specimen, the appearance is decidedly in favor of the interpretation that laumontite is later than natrolite. It is probable that the relations of laumontite and natrolite are similar to what was found for heulandite and analcite, that is, the periods of the two overlap, and relations in a given case depend upon slight differences in concentration of lime and soda.

Similarly, in 128, it appears that calcite replaces laumontite, but in a great number of hand specimens, laumontite groups are perched upon calcite crystals. From this last occurrence it appears that laumontite forms one of the end members of the zeolite series. The period did not come to a sudden end, but a transition period intervened, during which both laumontite and calcite were deposited.

Scolecite

In a number of slides (89, 73*b*, 68, 71, 143), remnants of some mineral are found which is believed to be scolecite. It gives inclined extinction and is probably triclinic. Birefringence about 0.007, refraction $>$ natrolite and $<$ balsam, elongation negative, optical character indeterminate.

It has been found only in association with natrolite, which replaces it in the manner shown in fig. 29. Its exact position in the series is therefore uncertain.

Natrolite

Natrolite is one of the most abundant zeolites and is found in a great many of the thin sections. There is little to add to what has already been written, for the reason that, like laumontite, it is one of the end members and replaces practically everything else, and these replacements have been described under the corresponding minerals. In its relations with calcite it appears to differ from laumontite, for wherever the two come together, the natrolite always appears earlier. The replacement is well illustrated in 121. Natrolite needles which have advanced through stilbite and chabazite are wiped out abruptly by encroaching calcite.

In hand specimens of natrolite, several features are notable. It is often observed that a finely felted variety changes abruptly to one more coarsely crystalline. The border between the two frequently has a geometrical pattern. There may also be a deposition of hematite dust within the figure outlined, which produces areas of a pinkish color in the midst of

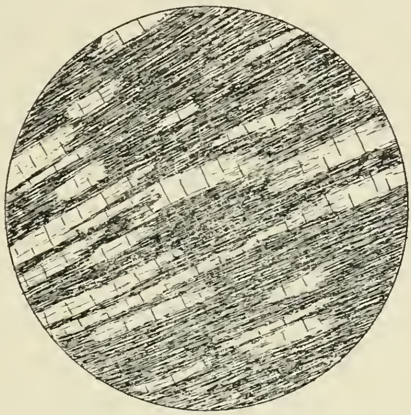

Fig. 29. Remnants of scolecite needles in the midst of natrolite. × 35. Slide 143.

solid natrolite. At times, small cavities of similar appearance are lined with projecting natrolite needles. These features are interpreted as attributable to the solution and removal of some preëxistent mineral. Generally, this has gone on *pari passu* with the growth of the natrolite, but in some cases it has been more rapid, leaving cavities for the development of well-formed terminated crystals.

Apophyllite

The replacement of various minerals by apophyllite in several of the slides has been described (figs. 9, 22, 23). From these relations, but more especially from its relation to calcite, its period of deposition is believed to be among the late members of the zeolite group. In slide 138, it is found in contact with calcite, which appears to be encroaching upon it, but on the other hand, it has been observed in hand specimens apparently resting upon calcite. It is probably one of those minerals whose period overlaps that of calcite.

Ordinarily, a small amount of fluorine is found in apophyllite (on the average about 1.5 per cent). It is possible that in our rocks, this can be ascribed to some preëxistent mineral, but it seems more probable that it was derived from a small quantity locked up by the magma when it stiffened into a glass and was subsequently set free by the decomposition of the latter by solutions.

Apophyllite is the first mineral met in the series in which potash plays a prominent part in the formula. The source of the potash, however, is not far to seek. The analyses of typical examples of basalt given on an earlier page show potash to be universally present, and while the earlier-formed minerals are essentially soda and lime compounds, some of them undoubtedly carried a certain amount of potash replacing a portion of the soda.

Chlorite

Chlorite is almost universally present. In those slides, however, in which the minerals are prevailingly of the first period of alteration, the quantity of chlorite is so small as to lead to the suspicion that it does not properly belong here. Throughout the second period, however, it seems to have been developed in considerable quantity and to have extended through the third period likewise.

Considerable variation in appearance and properties is observable, and a number of members of the chlorite group may be present, but it has not been considered a favorable opportunity to make a detailed study to determine this. The color varies from bright emerald-green to pale yellowish green, or almost colorless. Birefringence is never strong, but varies from moderate to almost isotropic. The general habit is aggregates of minute scales, but it may develop in fairly large blades, especially when in nodules from alteration of resorbed olivine. There is quite a tendency to become segregated in definite areas or to migrate into cracks.

The constant tendency for magnesium and iron to be leached out throughout the whole process of alteration has been mentioned in several places. It was observed that the green amphibole was usually found in close association with the less altered basalt, while in the less obstructed channels it was seldom found. This relation is probably even more characteristic of chlorite. One exception has been noted, however. It is not uncommon to find vugs lined with calcite crystals which show small spheroidal groups of chlorite perched upon them.

Green amphibole is often found in the same slides as chlorite but seldom in intimate association. There is little to indicate an alteration of one into the other.

Serpentine

The quantity of serpentine is so small as to be almost negligible. It is probably present in some cases, associated with chlorite.

THIRD PERIOD OF ALTERATION

Calcite

Calcite occurs in quantities almost equal to all the other minerals combined. In habit, it is very variable. The most common form of crystal is probably the unit rhombohedron, but slender scalenohedrons (dog-tooth spar) are frequently found, and complex combinations of crystal faces are not unusual. It is also frequently developed in finely granular masses. Its presence is so nearly universal that it is rather rare to find a specimen of any mineral or group of minerals which does not show the presence of calcite, if tested with acid. In the earlier part of the work, it was found a hindrance, because of the frequency with which it obscured the study of desired relations. It was finally found necessary to apply the acid test in every case before making sections, in order to make sure that the later introduction of calcite had not destroyed the desired evidence. Its frequent presence necessitated the rejection of a great quantity of otherwise available material, and in some cases required that a long search be made before specimens free from calcite could be found.

Reference has already been made to the manner in which granular calcite of later growth frequently develops between crusts of earlier minerals and the less altered basalt and simulates earlier deposition. At times, this takes the form of well-developed crystals, upon which the older crusts appear to rest, but in such cases, microscopic examination frequently shows certain abnormalities in the relations.

In the great majority of cases, there can be little doubt that calcite is of later formation than all the minerals of the feldspathoid series, with the exception of laumontite. Occasionally its deposition may have begun somewhat earlier, but this was a rather abnormal condition, and in general, calcite is the replacing mineral.

It was found difficult at first to account in a satisfactory manner for the introduction of such quantities of carbonic acid as the abundance of calcite requires. The writer was disposed to look for its sources in vapors evolved from the magma, but although such vapors were probably given forth, they would, like aqueous vapors, have opportunity under the conditions of consolidation to dissipate freely in the air, unless they were locked up in some nonvolatile combination until the late period at which calcite appeared. Search was made for evidence of some intermediate mineral to whose decomposition the carbonic acid of the calcite could be ascribed, or for indications of an early appearance of calcite, but evidence in both directions appeared to be entirely lacking.

The possibility was also considered that while the majority of the minerals originated through the form of circulation described, the formation of calcite should be assigned to a far later period, in fact to the present cycle of events, in which cold surface waters carrying CO_2 in solution leach directly downward. The vital objection to this conception is that such waters would also be oxidizing in nature, and the associations of the greater part of the calcite render this idea very improbable.

The hypothesis which was finally adopted as being most probable was that the meteoric waters of the general form of circulation, which has been accepted as responsible for the series of earlier minerals which we have considered, retained some store of the originally dissolved carbonic acid (probably as bicarbonate of lime, $CaH_2(CO_3)_2$, and carbonates of the alkalies) at the period of their history at which they entered the basalt sheet on the return journey to the surface. When conditions became favorable, this supply of dissolved carbonic acid reacted with the various original and secondary lime compounds and gave rise to the formation of calcite. Carbonation, as is well known, is one of the most common effects of the action of meteoric waters upon lime silicates at moderate temperatures. When the temperature is high, on the contrary, the process is reversed, so that carbonate rocks carrying silica, passing from the zone of katamorphism into the zone of anamorphism, where high temperatures prevail, have the carbonic acid driven off, while the lime combines with silica and produces lime silicates. The process is, therefore, evidently an easily reversible one under variations of temperature. This probably accounts for the observed fact that little or no calcite appears to have been formed in the Watchung series during the prevalence of the more elevated temperatures under which the minerals of the first and second periods were deposited, and it was not until very moderate temperatures were reached that carbonation became the chief feature, tending to destroy the previously formed silicates. Naturally, no sharp border-line can be drawn between the periods. For a time more or less prolonged after the deposition of calcite had begun, the formation of silicates continued. Laumontite and apophyllite were deposited simultaneously with calcite almost beyond question. It is not impossible that some slight deposition of calcite began at an earlier stage, but decisive evidence of this is lacking. The fact must not be overlooked that the temperature at which deposition of calcite began would be a function of the concentration of the carbonic acid in the solutions. Under the conditions which seem to have existed in our rocks, the quantity of carbonic acid was probably minute, and the large amount of calcite found must be referred to the continued passage of the water for a prolonged period.

Under different conditions, a much larger quantity of CO_2 might be present, and the formation of calcite would begin at an earlier date. For example, in the not unusual zeolitic deposits in which the minerals form distinct veins cutting sheets of basic eruptives, it is extremely probable that circulation is generally begun while emanations are still being given forth by the cooling magma and that these are added to the ascending waters. Under such circumstances, the concentration of CO_2 might be supposed to reach a much higher value, and as a consequence, the period of calcite deposition would be much advanced. In the zeolitic veins cutting the great intrusive sill of Palisade diabase, it is observed that large crystals of calcite are encrusted with analcite and stilbite. An earlier period for calcite is indicated, which may thus be accounted for. In specimens from other localities, also, with whose geological relations the writer is not familiar, an early period of deposition of calcite has been observed.

Thaumasite and Gypsum

At about the same period as calcite, a small amount of gypsum was deposited and also the unusual mineral thaumasite. The latter is apparently a combination of silicate, carbonate and sulphate of lime. Its occurrence has been noted in only a few localities throughout the world. Gypsum has been observed resting apparently upon calcite crystals, and masses of thaumasite are found to contain nodules of pectolite, heulandite and apophyllite, imbedded like raisins in a pudding. These relations indicate a late period of deposition for the two minerals. The sulphates necessary for their formation can likewise be considered referable to meteoric sources.

During the calcite period, green amphibole, chlorite, specularite and probably pyrite and chalcopyrite were also deposited as has been described.

The presence of gypsum affords an approximate mark on the thermometrical scale. Van't Hoff and his associates[54] have made elaborate investigations on the relations of gypsum and anhydrite. They fixed the transition point between gypsum and natural anhydrite at 63.5° C. and 175 mm. vapor pressure. The presence of other salts in solution somewhat affects the value of the transition point. In a saturated solution of NaCl, they decided upon a mean value of 30° for the temperature of formation of anhydrite from gypsum. In our solutions, not all the conditions are known, but it seems certain that if the temperature at this time had exceeded 63.5° C., the sulphate of lime would have been deposited in the form of anhydrite instead of gypsum.

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[54] Zeitschr. phys. Chem., vol. 45, pp. 257-306, 1903.

III. Comparison with Other Deposits and General Conclusions

With these minerals, the processes of alteration through ascending waters appear to have been brought to a close. This may perhaps be considered due to any one or to a combination of several causes. The waters may have reached a temperature which was practically the average climatic temperature of the region and were therefore unable to effect further changes, or the circulation may have become much enfeebled because of diminution of the stores of heat-energy in the rock, or the velocity of reaction at these lower temperatures may have become so small that its effects are negligible. The writer is inclined to believe that all of these causes coöperated.

The general order in which the minerals appeared is shown in the accompanying chart (page 179). The question arises as to the extent to which this sequence should be considered an invariable one applying to all zeolitic deposits. In considering this, the first point which must be kept in view is that the conditions under which the formation of minerals occurred in other deposits must have been similar in order that the results should be comparable. A frequent occurrence of zeolites is in fissure-veins cutting masses of intruded igneous rock, as in the Palisades. In such cases, sublimates given off by the magma at the same time that processes of alteration are in progress (such as boric oxide, carbonic acid, fluorine vapors, sulphur compounds and possibly others) and passing into the channels of circulation must affect most decidedly the periods of deposition of the compounds into which they themselves enter. Such minerals as datolite, calcite, apophyllite and the metallic sulphides might therefore appear at periods somewhat different from what has been observed in the Watchung minerals.

It has been shown, too, that the presence of boric acid in considerable quantity acts as a disturbing factor, which affects the nature of the other minerals deposited, and such other emanations as are capable of uniting with soda and lime would probably have similar effects. On the whole, however, it appears that the zeolites proper would usually follow a similar sequence in such fissure deposits to that observed in the Watchung rocks.

In zeolitic formations in surface flows of basalt, which have been brought about by a similar uprise of meteoric waters, the processes should normally be very similar, but it appears that in some instances interruptions occur. From the studies of Whitman Cross and W. F. Hillebrand[55] on the minerals from the basalt of Table Mountain at Golden, Colo., it appears that the zeolitic deposits there occur both in fissures and in

[55] Bull. 20, U. S. Geol. Surv., 1885.

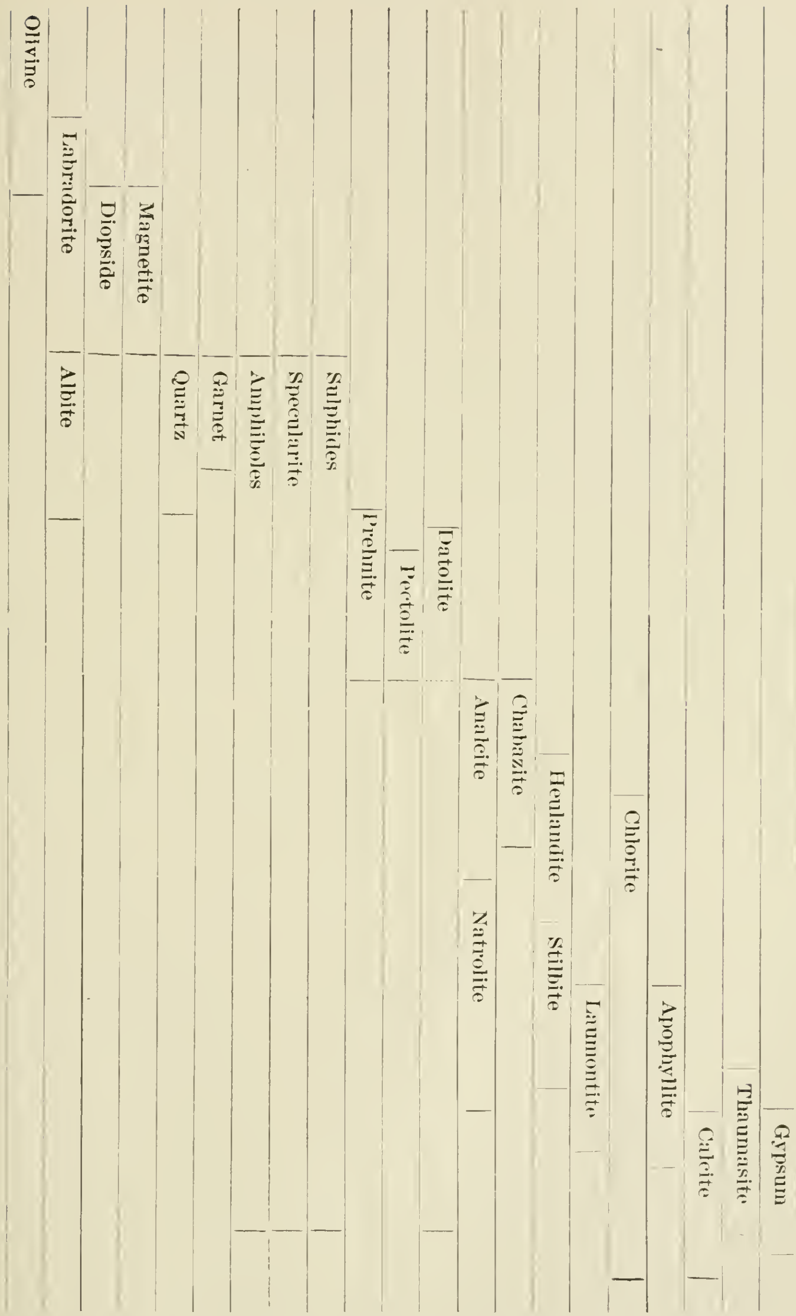

Chart Showing Order of Deposition and Periods of Stability of the Various Primary and Secondary Minerals roundish cavities in an amygdaloidal zone near the surface of the older of two basaltic flows. They may be divided into two groups, according to mode and time of formation. On considering all the species which occur in relations which permit inferences to be drawn as to relative age, the following sequence was determined:

1. Laumontite,
2. Stilbite,
3. Thomsonite,
4. Calcite (yellow),
5. Stilbite,
6. Chabazite,
7. Thomsonite,
8. Analcite,
9. Apophyllite,
10. Calcite (colorless),
11. Mesolite.

It will be observed that this order is different from that which has been found in the Watchung sheet, but it is seen at once that several species are repeated at intervals, implying irregularities in conditions which would have to be explained before comparisons could be made with other localities in which the sequence is normal. In such cases as this, we have, perhaps, a reversal of conditions by which the circulating waters which should, in the usual course of events, gradually become cooler, are again highly heated.

A somewhat similar condition is implied in the zeolitic deposits occurring in the copper-bearing amygdaloids of Lake Superior. The sequence here as determined by Pumpelly[56] was as follows:

> The chlorite of the melaphyre, and consequently the distinctive character of that rock, is due to the alteration of hornblende or pyroxene. This seems to have been the first step toward the production of melaphyre proper. Laumontite . . . appears to have been formed either contemporaneously with the chlorite, or as the next step in the process.
>
> The next step appears to have been the individualization, in amygdaloidal cavities, of nonalkaline silicates, viz: laumontite, prehnite, epidote, respectively, according as the conditions favored the formation of one or the other of these.
>
> Following these came the individualization of quartz in these cavities.
>
> Perhaps we may be warranted in considering these minerals, together with the lime of the calcite that more rarely occurs in this portion of the series, as chiefly due to the decomposition of the pyroxenic ingredient of the rock.
>
> So far as we may infer from the tabulated results, the concentration of copper in the amygdaloidal cavities does not appear to have begun till after the formation of the quartz.
>
> In this part of the series falls also the formation of a chloritic or green-earth mineral, which in some manner has displaced prehnite, quartz, calcite, and with which copper, when present, appears to stand in intimate relation.

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[56] "Paragenesis and Derivation of Copper and its Associates on Lake Superior," Am. Jour. Sci., 3rd ser., vol. 2, pp. 188-198, 243-258, 347-355, 1871.

Subsequently to this came the individualization of the alkaline silicates, viz: analcite, apophyllite, orthoclase. Here also seems to belong the formation of datolite. . . .

The fact that calcite occurs at almost every step in the paragenetic series and forms one of the most common of the secondary minerals is proof that carbonic acid was very generally present throughout the whole period of metamorphism; it was probably the chief mediating agent in the processes, without being sufficiently abundant to prevent the formation of silicates.

In this series again, the sequence is quite different from that observed in the Watchung rocks. Pumpelly, however, has hardly touched upon the question of the conditions under which the secondary minerals originated, especially as regards attitude of the beds, and those who have paid some attention to these matters have considered it rather from a theoretical standpoint than from internal evidence. Portions of the copper-bearing series are now buried to a depth of several thousand feet, and an unknown thickness has been removed by erosion from their upper surface. Such facts as the not unusual paramorphic change of laumontite into orthoclase might be considered to imply a reversal of the progress of alteration brought about by deep burial subsequent to a cycle of alteration in a more superficial zone. A detailed investigation of these deposits, which would include a review of former evidence in the light of more recent knowledge and a consideration of additional evidence brought to view in the depths to which mining operations have now penetrated, would be most interesting and valuable in throwing light on the difficult question of the origin and circumstances of precipitation of the native copper. Until more information is available regarding the conditions of deposition of the secondary minerals in the Lake Superior rocks, they will hardly afford a basis of comparison as regards sequence with the Watchung series.

There are undoubtedly numerous zeolitic deposits in which conditions of formation were closely analogous to those prevailing in the Watchung rocks, but, as was remarked in the early pages of the present paper, few observers appear to have made detailed observations regarding the sequence in which the minerals were deposited. Instances have been met also, in going through the literature, which bear internal evidence of rather hasty judgment in drawing conclusions as to sequence. This does not appear surprising from the misleading character of the evidence encountered in some instances in the study of the Watchung rocks, which has brought into prominence the necessity of constant caution.

In Hintze's "Handbuch der Mineralogie" a compilation is made of a great number of occurrences of the zeolites, with short summaries of the relations which they bear to each other and to other minerals. In such cases as observations on sequence have been made, the order appears to correspond in most instances to that observed in the Watchung series. There are a number of instances recorded, however, of pseudomorphs of minerals which, from observations of the Watchung series, should be of early formation, but which have taken the form of zeolitic species. Prehnite and orthoclase appear especially likely to do this. This may possibly be due, as was suggested before, to a reversal of the normal sequence by a change of conditions due to external agencies. On the other hand, the data available are not sufficient to exclude the possibility that this was a normal order under the conditions of the case and that such factors as the composition of the original rock may enter in determining the sequence of deposition.

In discussing in previous pages the application of the phase rule to the problem and again in describing analcite, the inference was drawn that analcite and natrolite should possess a transition point, at which single point only they could coëxist in equilibrium; and the observed relations of the two were found to confirm this conclusion. Two instances taken from Hintze[57] add further evidence: On the Kunetitzer Mountain, Bohemia, analcite crystals are found

up to 12 mm. in size in cavities of the basalt; often porous and covered with natrolite;

and again in the Tyrol

at the Cipit-Bache at the north foot of the Schlern-Gebirg, milk-white to flesh-red crystals, scarcely more than 1 cm. in size, covered with apophyllite, more seldom with calcite and natrolite-needles; many crystals porous and altered to an aggregate of small needles (?natrolite).

Heulandite and stilbite are believed to possess a similar transition point. The well-known German mineralogist, Breithaupt, devoted special attention to paragenesis of minerals. His work dates back sixty years or more but as far as macroscopic observations go appears to be accurate and reliable. In regard to heulandite and stilbite, he records the sequence (*a*) heulandite, (*b*) stilbite, and remarks:[58] "This paragenesis is followed with perfect constancy in many localities of occurrence." It should be noted that in Breithaupt's usage, stilbite was called "desmin" and heulandite "stilbit." He gives numerous examples of the order observed for various other zeolites and for quartz, prehnite, datolite and calcite

[57] *Op. cit.*, p. 1717.

[58] "Die Paragenesis der Mineralien" Freiberg. p. 105, 1849.

from many localities.[59] In nearly all cases, they agree with that which the author has determined for the Watchung series.

Breithaupt arrived at certain well-founded conclusions regarding the conditions of formation of zeolites,[60] as follows:

It is notable that it (that is, their formation) occurs not only in the younger eruptive rocks, in whose bubble cavities the zeolites are especially at home, . . . but also in much older varieties of rock. But where the zeolites also appear, they can be observed as always only products of leaching, and have depended upon lateral secretion, and herein they accord perfectly with the occurrences in bubble-cavities. The bubble-cavities, as well as the veins in which they appear, are mostly wholly free from magnesia or iron-oxide containing minerals; at the most, only traces of these ingredients occur, whose nonexistence is related to the mineralogical-chemical character of the zeolites.

In a recent article appearing in the Annals of the New York Academy of Sciences, vol. XIX, pp. 121-134, 1909, W. G. Levison has recorded his observations on the sequences of the minerals of the Newark igneous rocks at various New Jersey localities. His results indicate that he found no fixed order in the sequence in which the minerals appeared even in specimens from the same locality. His work, however, was done without the aid of the microscope. The present writer's investigations have indicated that replacement phenomena in these rocks have followed such a course that it is hardly possible to reach satisfactory conclusions from macroscopic observations alone.

As a final citation, which bears upon both the sequence of deposition and the general nature of the process, Brögger's well-known paper on "Die Mineralien der Syenitpegmatitgänge der Südnorwegischen Augit-Nephelinsyenite"[61] is so interesting and instructive that the writer desires to quote certain parts at considerable length.

Brögger takes up the geological relations in the following order:

1. Phase of magmatic consolidation.
2. Chief phase of the pneumatolytic minerals. These are rich in fluorine, boron and sulphur, whose derivation he ascribes to the magma.
3. Phase of zeolite formation.

Regarding this phase, he says in part:

Under the continued cooling of the veins and their surroundings, the conditions of mineral formation must by degrees change more and more; finally the pneumatolytic exhalations, which at first must have consisted principally of fluorine, chlorine and boron-rich combinations, then of sulphurbearing combi-

[59] *Op. cit.*, pp. 103-107, 260-261.
[60] *Op. cit.*, p. 259.
[61] Zeitschr. f. Kryst. und Min., vol. 16, 1890.

nations, appear to have ceased by degrees, and the circulating solutions became, therefore, principally aqueous solutions which, at relatively low temperature, strove to effect among the earlier formed vein materials the recombinations possible under these changed conditions. The products of mineral deposition in cavities still open (or produced by destructive work), as well as the products of pseudomorphosis of the earlier formed vein minerals, must, therefore, now become different; observation shows that almost exclusively waterbearing silicates—zeolites—were thereby formed. Just as little as we could draw a sharp boundary between the first and second phases, can we perceive the second and third phases of vein formation to be sharply differentiated from each other. Indeed, the formation of sulphurbearing ores continued after the beginning of zeolite formation. . . .

That the zeolites have been formed at relatively low (although not ordinary) temperature has been determined with certainty through the researches of Daubrée, Lemberg, de Schulten and others; apparently the successive changes of temperature with constant decrease thereof has influenced the formation of zeolites in this manner, that certain zeolites can form preferably within a somewhat higher, others within a somewhat lower range of temperature. It appears that in that way most simply can the sequence of the zeolites be explained, which everywhere is in the main nearly constant in the veins of the border-zone.

The sequence for the deposition of zeolites in open vugs is as a rule the following:

Analcite,	
Eudidymite,	Thomsonite,
	Stilbite,
Apophyllite.	

Of all the zeolites formed in open vugs, analcite is the oldest and also the most widespread in our veins. . . .

The analcite is often formed in greatest extent at the expense of the elæolite; in part, however, other soda-rich silicates, especially sodalite and albite, have also given rise to the formation of analcite, as will shortly be mentioned below. Where it has been formed from elæolite, so much substance appears to have been removed simultaneously in part with its appearance that apparently new open druses were thereby formed, in which besides the analcite other minerals also could later be deposited. In part, however, the analcite has been deposited in older, preëxisting vugs, for it rests often on crystals of leucophane and fluorspar, for example, of the second phase of vein-formation. . . .

The next zeolite in the sequence is eudidymite, which is only known from one vein upon the island of Ober-Arö. It rests here upon analcite and is itself covered with natrolite. . . .

The normal sequence of zeolites in the vugs of our veins shows natrolite after analcite. . . .

Apparently simultaneously or nearly simultaneously with the formation of natrolite, that of thomsonite began.

In a single specimen belonging to the Imperial Museum from an unknown occurrence of our veins, fine blades of stilbite rest upon thomsonite needles as a younger formation in secondary vugs in a hydronephelite spreustein formed from elæolite.

Younger than the natrolite is apophyllite in all occurrences where it appears; it is, however, in comparison with the soda-rich zeolites—analcite and natrolite—almost always present in wholly subordinate amount. I have not observed it with stilbite; it is, therefore, not possible to say with certainty whether the stilbite or the apophyllite is the older of the two; but to judge by the character of its occurrence, the last may be considered with some probability as almost always the youngest of all zeolites of our veins. Apophyllite also belongs to the zeolites of Plombières made known by Daubrée, formed at a late period at only about 70°.

4. Phase of fluo-carbonates and carbonates, etc.

. . . As the youngest formation in the vugs, perhaps deposited at almost ordinary temperature, one finds here and there calcite, usually only compact, seldom in idiomorphic crystals—for example, upon natrolite of Risö; only traces of a chloritic (?) mineral have I observed as a still younger deposit upon the calcite.

Résumé

The zeolites and associated secondary minerals of the Watchung basalt are found in certain localized areas of the sheet. These areas possess well-marked peculiarities of structure which are plainly of primary origin and due to conditions present at the time of consolidation. The chief peculiarity in these limited areas is an accumulation of bowlder-like masses of "pahoehoe" lava, which consist of an interior of normally crystallized basalt and an exterior crust of glass. From a study of the geological relations in the field, it is believed that the basalt sheet represents a surface flow of lava poured out over a continental area which had been depressed by crustal movements of deformation (either warping or faulting) and in whose lowerlying portions a lake or series of lakes occupied shallow basins. The pahoehoe structure of the basalt is believed to have been developed over or immediately adjacent to the lake beds through quicker cooling of the flow.

The secondary minerals are held to have been developed from the elements of the basalt (especially the glassy crusts) and from sublimates given off by the magma in cooling, and deposited in crevices of the flow. The medium in which recrystallization took place was an aqueous solution, which was enabled to percolate through the sheet of basalt, because of the more permeable structure above the lake beds. A purely meteoric origin is indicated for the waters, which probably worked in from the edge of the sheet through the porous sandstones below and returned to the surface through the interstices of the basalt in the situations described.

Recrystallization was probably begun as soon as the lava had cooled sufficiently to permit the waters to hold a liquid form. A considerable degree of superheating was permitted because of the head to which they were subject. By degrees, however, the whole mass of lava became cooler, so that in the final stages of alteration, the temperature may have been but little above the average climatic temperature of the region.

The majority of the secondary minerals are found to consist of the elements present in the original plagioclase feldspar, with or without the addition of water. The possibilities of equilibrium among the great number of compounds present was considered in the light of Gibbs's phase rule, and some inquiry was made into the applicability of this rule to the conditions of the problem. It was deemed most probable that, although various modifying conditions entered whose effect could not be wholly taken into account, the general conclusions to which the phase rule pointed should hold and that the possibility of all the compounds present coëxisting in equilibrium could not be admitted.

Petrographic examination of thin sections confirmed these conclusions, and the sequence of minerals and the form taken by processes of replacement have been described at length. It was found that in addition to the zeolitic minerals which form such a prominent feature of the occurrence, and to such minerals as prehnite, datolite, quartz etc., which are present in notable amount, traces of other minerals have survived. Such are albite, garnet, arfvedsonite etc., which represent the effects of intense metamorphism in the early stages of recrystallization. There is reason to believe that these were formed in considerable quantities, but were almost destroyed during succeeding stages.

It was found possible to trace very perfectly the alteration of the glass, or less often the normal basalt, into various associations of secondary minerals; and several features present in the original rock were found to have left traces through all stages of recrystallization. In some instances, the theory of solid solutions was of assistance in affording a basis of explanation of the changes which minerals had undergone. This was especially true in the case of the development of albite from original labradorite and in the transformations of the amphiboles.

As a final effect of alteration, quantities of calcite were formed. The greater part of this is believed to have been produced at temperatures but little above the ordinary. The presence of the carbonic acid is attributed to a derivation from the atmosphere at the beginning of the cycle of circulation.

Comparison was made between the Watchung deposit and similar mineral formations elsewhere. In some cases, there was evidence that conditions during the formation of zeolites were different, or that the subsequent history had effected changes which made impossible a strict comparison with the Watchung rocks. In most cases, however, judging from the rather scanty evidence available, conclusions regarding sequence are confirmed.

PLATE XI

MAGNIFIED SECTIONS OF BASALT AND SECONDARY MINERALS

FIG. 1. Normal crystallization of dense basalt. × 24. Slide 18.

FIG. 2. Dense basalt bordered by secondary albite. × 24. Slide 62.

FIG. 3. Dense basalt bordered by secondary albite (Ab) with fanlike groups of prehnite (Pr) and some calcite (Ca). × 24. Slide 62.

FIG. 4. Groups of radiating quartz crystals surviving from an early period of alteration in a slide in which zeolites and chlorite form the principal features. × 24. Slide 59.

FIG. 5. Garnet (Gr), fibrous green amphibole (Am) and prehnite (Pr) encrusting dense basalt. The garnet forms clear grains where it borders the prehnite, but the greater portion is in masses which are nearly opaque from dust of TiO_2 or MnO_2. The circular markings are interpreted as due to nuclei of resorbed olivine in the original glass which the secondary minerals have replaced. × 24. Slide 53.

FIG. 6. Garnet grains (Gr), acicular amphibole (Am) and long needles of pectolite (Pc) in prehnite (Pr). × 24. Slide *50a*.

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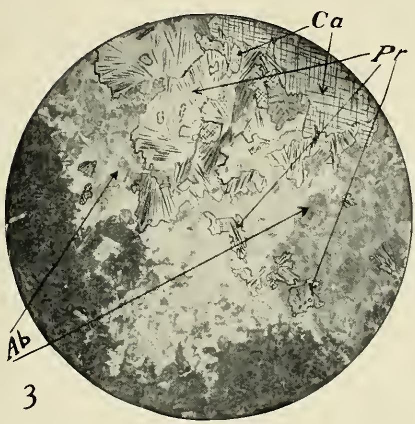

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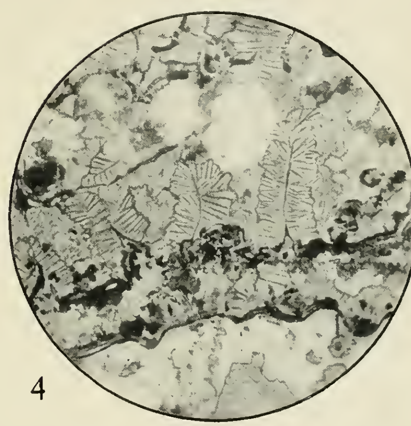

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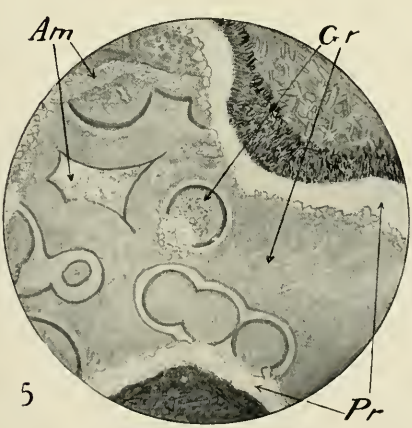

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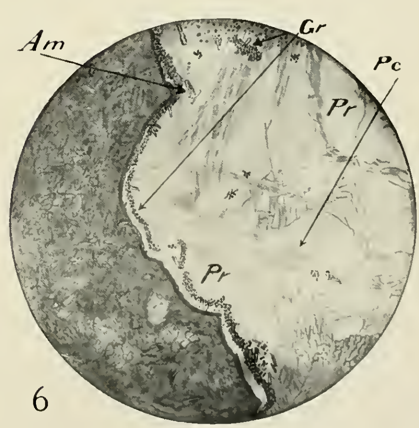

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PLATE XII

MAGNIFIED SECTIONS SHOWING ALTERATION IN BASALT

Fig. 1. Breccia of an original glass, whose interstices have been filled with ferruginous clay from the lake bottom. Recrystallization of the glass has resulted chiefly in albite and chlorite. × 24. Slide 12.

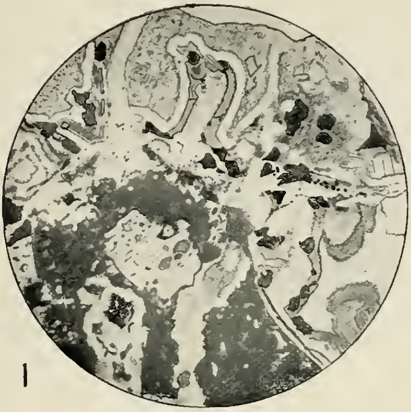
Fig. 2. Incipient stage of zeolitic alteration of glass, showing effect of chill cracks in directing percolation of solutions. × 24. Slide 30.

Fig. 3. Alteration effects in brecciated glass. × 24. Slide 61.

Fig. 4. Prominent banding in secondary products, due to cracks in the original glass. The darker portions are chiefly chlorite, the lighter analcite. × 24. Slide 60.

Fig. 5. Geometrical patterns in garnet, interpreted as due to resorption of olivine. Gr = garnet, Am = amphibole, Pr = prehnite. × 32. Slide 115.

Fig. 6. Incipient alteration of glass, showing accentuation of physical and chemical differences by a slight degree of alteration. × 35. Slide 54.



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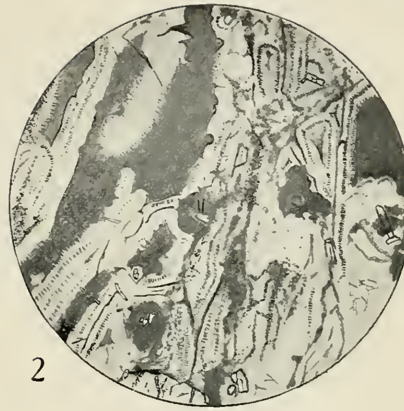

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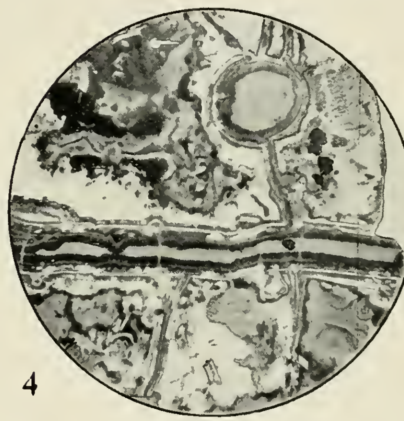

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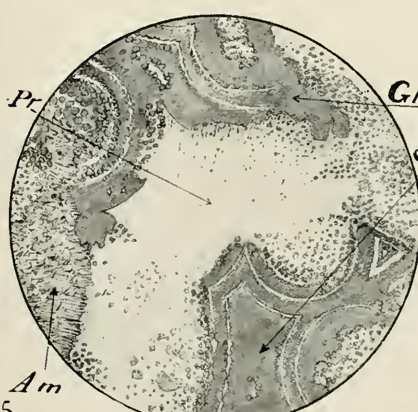

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26 October, 1910]

NEW GENERA AND SPECIES OF CARBONIFEROUS FOSSILS FROM THE FAYETTEVILLE SHALE OF ARKANSAS[1]

BY GEORGE H. GIRTY

(Presented by title before the Academy, 3 October, 1910)

The Fayetteville shale is named from its occurrence about Fayetteville in northwestern Arkansas. Its character and distribution in this region are described in detail in the Fayetteville folio,[2] and only a brief summary will be given here. It is a black, fissile shale containing beds of sandstone and thin limestone, and, in the southeastern part of the Fayetteville quadrangle, it attains a thickness of 200 feet, owing to the development of a sandstone member in its middle portion. The shale rests either directly on the eroded surface of the Boone formation or on some sandy strata of sporadic occurrence which have been correlated with the Batesville sandstone.

The more or less impure limestones of the Fayetteville contain abundant fossils. A rather persistent calcareous bed at the very base of the formation has furnished the new species described below, except for a very few which came from a locality in the Batesville sandstone near the town of Fayetteville. This collection from the Batesville shows, as would be expected, a close relationship with the fauna whose horizon is just above. Geographically, most of the collections studied came from the Fayetteville quadrangle, but a few were obtained beyond its borders, where the typical character and relationship of the formations are maintained.

The Fayetteville shale has usually been referred to the horizon of the St. Louis limestone. A discussion of this point is deferred until the entire fauna of the Fayetteville has been studied.

Michelinia meekana sp. nov.

Zoarium lenticular, attaining a large size, about 85 mm. in diameter and 45 mm. in thickness, more or less. Upper surface irregular. Coralites very variable in size; the large ones reach a diameter of 7 mm., but very few are of this size. The rudimentary septa consist of fine ridges, more distinct in

[1] Published by permission of the Director of the United States Geological Survey.
[2] U. S. Geol. Survey, Folio 119. 1905.

some specimens than in others, and are very numerous. They are so fine and obscure that no satisfactory count can be made in the material available. Mural pores apparently are small and regularly disposed. They seem to occur in longitudinal rows near the angles of the cells. Tabulæ very closely arranged and irregular. In some instances, they are one fifth to one eighth of a cell diameter apart and seem to extend completely across in parallel plates. In other instances, they are somewhat farther apart, oblique and vesicular. Walls moderately thick.

Menophyllum excavatum var. arkansanum var. nov.

Corallum rather small, conical, showing much variation in the rapidity of enlargement and in the amount of curvature. Exterior marked by the usual longitudinal striation, the striæ being rather numerous and closely arranged but not very strong. Calice deep. Septa at maturity about 28, fewer, of course, in the earlier stages. Secondary septa present only toward the upper limit of the theca where they appear merely as slightly elevated ridges. Septa and walls much thickened by stereoplasma, so that the interseptal loculi are nearly closed. The three fossulæ are often clearly distinguishable, especially in the more mature part of the corallum. Interseptal tissue practically absent, rarely developed about the margins of the calicinal portion.

Palæacis carinata sp. nov.

Corallum much compressed, having flattened sides, narrowly rounded ends and carinated lower portion. The height is less than the breadth, and the ends are considerably lower than the middle. The cell-like cavities in the specimens examined open onto the upper surface. They are few in number, only four or five, and very shallow. The walls which separate them are low and moderately thin. Fine and strong liræ cross the external surface. The liræ are slightly narrower than the striæ and begin near the point of attachment as tubercles, which arrange themselves in rows and become connected into continuous linear elevations.

Fistulipora excellens var. harrisonensis var. nov.

Under the present title, I am including thin zoaria characterized tangentially by having rather large, closely arranged zoœcia with a distinct lunarium. The zoœcia average about .28 mm. in diameter, have a well-developed lunarium and a conspicuously petaloid shape. They are sometimes in contact, but usually are separated by narrow intervals of about one half their own diameter occupied by single rows of cells. In or near macular areas, they stand at about their own diameter apart and are separated by two rows of cells. When closely arranged, 5 zoœcia come in a distance of 2 mm.

In vertical section, the zoœcia are seen to have between them single columns of subquadrate mesopores, while the diaphragms are rather abundant though variable, standing at about a tube diameter apart.

Fistulipora excellens var. williamsi var. nov.

The zoaria occur as thin sheets 1 mm. or less in thickness and of no great spread. The zoœcia are small, about .21 mm. in diameter, with strongly marked lunarium. They are separated by one or two rows of mesopores and stand at one half or one diameter apart, coming about 5 or more in 2 mm. In longitudinal section, the mesopores are seen to occur in one or more tiers, and the zoœcia develop few or no diaphragms.

This form is more closely related to the variety *harrisonensis* than to typical *excellens,* but it has smaller zoœcia which are rather more distantly arranged (since none are in contact), and fewer diaphragms.

Batostomella anomala sp. nov.

Zoarium consisting of slender cylindrical branches about 2 mm. in diameter. Cortical zone sharply defined but very narrow, about .25 mm. wide. Zoœcial tubes very long and slightly oblique in the median portion of the stem, near the outer end abruptly bent outward to a direction perpendicular to the surface. Where the direction is longitudinal, the zoœcial walls are thin; where radial, strongly and abruptly thickened. The thickening sometimes has the appearance of two partly fused beads; more often it has only an oval shape without trace of moniliform structure. Occasional slight swellings occur at other points in the wall. Apertures rounded, usually elongated, separated by walls equal to or greater than their own diameter, the longitudinal distance being often a little greater than the lateral. Owing to the thickness of the wall, the diameter of the apertures is unusually small; about 5 cells occur in 2 mm. when they are end to end, and about 7 when they are side by side. Large acanthopores occur at the corners of the cells, but, owing to the thickness of the walls, they do not encroach upon them. There is also developed near the surface a row of small granules through the middle of most of the walls, possibly through all. Mesopores are rare, possibly absent altogether. Diaphragms are also rare, 1 or 2 near the aperture in many of the zoœcia, some of them distinctly perforated.

Batostomella parvula sp. nov.

Zoarium in the form of slender, solid branches having a diameter of 2 mm., more or less. Branching irregular, three or four branches being occasionally given off at a time, in which case the stem is very much enlarged, often broadened and relatively compressed. Zoœcia thin-walled and longitudinal in the middle of the stem, thick-walled in the mature zone, which is very narrow. They meet the surface obliquely, or with a very short horizontal portion. The apertures are more or less elliptical to subpolygonal, elongated in the longitudinal direction of the branch, separated by intervals of about one half their own width, but showing extreme variation. Six or 7 occur in 2 mm. longitudinally, more transversely, although as the average branch has a diameter of about 2 mm., the number is not readily ascertained in those terms.

Mesopores rather rare, irregularly distributed, in some places apparently absent, in others occurring in groups of two or three. Acanthopores numerous and large, occurring in the angles of the cells, most of the angles being furnished with them. Owing to the thickened walls, the zoœcia have a rounded shape, and the acanthopores imbedded in the walls do not indent them. Where the walls are especially thick, and possibly where thin, there are additional small spines or granules in single rows. Therefore tangential sections vary considerably in appearance. In some, mesopores are rare, in others, abundant; in some again, only the large acanthopores at the cell angles can be made out, while in others, there are smaller spines in addition in varying numbers.

It may be that two distinct types have been confused under this title, but, from the study of weathered specimens, such is thought not to be the case. As a rule, however, only the larger spines are seen on weathered surfaces. Owing to the thinness of the mature portion, the irregularity of growth and the character of fossilization, it has been found extremely difficult to secure satisfactory tangential sections, even such as are correctly oriented being more or less altered and obscured as to structure. The thickening of the walls is not as a rule periodic, but is restricted to the superficial portion. Rare instances of thickening can elsewhere be noticed. The remainder of the walls is probably very thin, but its character is largely obscured in all material by alteration or by secondary deposits. There is occasional evidence, however, of appreciable deposits which are intrinsic, although not at all moniliform. Diaphragms are developed at rare intervals, more commonly near the surface. In so far as my observations extend, they do not show the characteristic perforations of *Stenopora*.

Batostomella? armata sp. nov.

Zoarium ramose, slender, about 4 mm. in diameter, bifurcating or laterally branched. Zoœcia longitudinal in the central part, gradually sloping outward, then more abruptly until, for a short distance, a radial direction is assumed. Zoœcia rounded owing to the thick walls, 6 or 7 in 2 mm. Walls much thickened for a short distance near the surface, either strongly moniliform or fused into a continuous mass. Mesopores (young cells ?) rather abundant. Acanthopores numerous and very large, occurring in most of the angles.

In tangential section, the walls appear to be greatly thickened in some areas and much thinner in others. The zoœcia are completely rounded or subangular, according to the degree of development of this feature. The large acanthopores are imbedded in the thick walls but indent the cells where the walls are thinner. Where the walls are thick, a row of large granules occupies the median line; where thin, the granules are wanting, but a strong, continuous line appears. Diaphragms are developed to a limited extent and chiefly in the cortical zone. Their distribution is rather scattering and far apart, slightly more than one diameter on an average, but varying from about two thirds to nearly 2. Maculæ probably present and indicated in thin sections by groups of not conspicuously larger cells, possibly also by the varying thickness of the walls.

Dyscritella subgen. nov.

The two species included in this group are ramose with well-differentiated and rather thick, mature zones. Zoœcia, mesopores and acanthopores are all present. The zoœcia are rounded in section, circular or oval. Mesopores are fairly numerous, rather more numerous than in typical *Batostomella* and much less numerous than in typical *Lioclema*. The acanthopores are also fairly numerous and in both species of two different sizes. In typical *Batostomella*, the acanthopores are much more numerous and all small. In typical *Lioclema*, the acanthopores are perhaps not quite so numerous and all large. Tabulæ appear to be entirely lacking in both mesopores and zoœcia. In typical *Lioclema*, tabulæ are abundant in the mesopores and rather rare in the zoœcia. In *Batostomella*. the diaphragms are remote, delicate and originally perforated. The mesopores are open as in *Batostomella*, not closed as in the typical section of *Lioclema*.

On the whole, perhaps, these species are more closely allied to *Batostomella* than to *Lioclema*, but they can hardly be included under either genus without introducing anomalous features.

Type.—*Dyscritella robusta*.

Dyscritella robusta sp. nov.

Zoarium consisting of solid cylindrical stems having a diameter of about 8 mm. The stems increase, according to the only specimen examined, by lateral branching, the branches making an angle of about 45° with the main stem. Zoœcia are longitudinal in the axial region, those nearer the side leaning slightly outward. By a rather abrupt turn, they assume a radial direction, and at the same time their walls are thickened, and mesopores and acanthopores are introduced. The mature zone occupies one fourth of the width at either end of the axis.

The apertures are small, circular to oval, from .083 to .11 mm. in diameter. Mesopores are fairly numerous, varying in number and circular in shape. Rather extensive aggregations of these cells make large maculæ, but for the most part, they occur in single rows between the zoœcia, or in groups of two or more in the angles between several of the tubes. Occasionally the zoœcia are in juxtaposition without any mesopores intervening. As many as 10 or 11 of the zoœcia occur in 2 mm. (though straight rows of that length are hard to find), where the mesopores are in normal abunadnce. In or near a macula, the number is of course much less. The walls are thick, varying from one half the diameter of a zoœcium to twice the diameter. Acanthopores are abundant and of two orders, differing greatly in size. The larger ones are extremely large and rather scantily developed, two to four near each zoœcium. The smaller acanthopores are very unequally distributed, being rare in some areas and abundant in others. Tabulæ seem to be entirely absent from both mesopores and zoœcia. The mesopores, however, are hardly discriminable in longitudinal or transverse sections, and may be tabulated.

Dyscritella inæqualis sp. nov.

Zoarium ramose, branching freely at intervals of about 16 mm. Branches slender, 4 mm. in diameter. Cortical zone well defined, .5 mm. or less in thickness. Zoœcia thin-walled and longitudinal in the median portion of the stem, rather abruptly changing to a radial direction in the cortical zone, where the walls are considerably thickened. Apertures oval to circular and arranged with some regularity, usually 8 in 2 mm., probably more when the oval apertures are measured in lines passing through their short diameters. The apertures seldom exceed .14 mm. in diameter. Mesopores fairly numerous, of varying size, much smaller than the zoœcia, between which they occur as a rule in single rows. Occasionally, however, the zoœcia have no mesopores between them (laterally), and occasionally the mesopores are grouped in more than single rows. Acanthopores are fairly abundant and of two sizes, the larger ones perhaps the more numerous. Three or four of the larger and one or two of the smaller occur around each zoœcium. The walls are rather thick, their diameter being usually equal to or greater than the short diameter of the mesopores, which are apt to be elongated. They are sufficiently thick, so that the larger acanthopores, which are very large, do not indent the walls. Tabulæ appear to be entirely lacking in both zoœcia and mesopores.

Stenopora perattenuata sp. nov.

Zoarium in the form of thin expansions having a discoidal or infundibuliform shape, more or less contorted. Lower surface with a concentrically wrinkled epitheca. The size is large for the thickness, which only measures one half to 1 mm., while the diameter may be 50 mm. or more.

In some sections, the zoœcia appear to rise directly from the epitheca, but others show that there is a brief prostrate portion. The zoœcia are rather regular, so that a hexagonal shape and a linear arrangement are locally somewhat conspicuous. In size, they vary, and it is possible that there are maculæ of larger cells. Owing to the tendency noted above as to shape and arrangement and the fact that the hexagons are apt to be wider than long, as many as 8 may be counted in 2 mm. when measured through a short diameter, but ordinarily only 6. The zoœcial walls are moderately and regularly thickened, but not annulated. A more or less obscure median line, lighter than the rest, can be made out. Diaphragms are irregularly developed, in some cells none at all, in others one or two. Acanthopores and mesopores appear to be altogether absent.

The extreme thinness of the zoarium, the apparent absence of acanthopores and the non-annulated condition of the walls distinguish this form from other species of *Stenopora*. In fact, in a general way it is suggestive of *Proutella*, but it fails to show the peculiar characters of that genus.

Stenopora longicamerata sp. nov.

Zoarium apparently massive, hemispherical. The present material consists of a single specimen having an irregularly conical shape. The longest diameter of the upper side is 28 mm. and the height 22 mm. (perhaps 30 mm., when complete). It does not consist of superposed layers, but the cells are continuous and consequently 20 mm. long or more. They are very irregular in size. Some of the smaller ones are suggestive of mesopores, but may be merely immature cells, the introduction of which was necessitated by the radiating direction of the zoœcial structure. There is no conspicuous arrangement into maculæ, the very largest and the very smallest being contiguous in many cases. To a certain extent, however, the smaller cells are grouped together (interspersed with others), but there are considerable spaces without them. Even if the very small cells are avoided, the number varies considerably. When a row of large ones is brought under the microscope, a little over 5 occur in 2 mm., while as many as 7 of the smaller or 6 to 6½ of the medium size occur in the same distance. The large cells vary from .28 to .35 mm. in diameter.

The walls are somewhat thickened. In some instances, the median line can be seen, but it is not conspicuous. The acanthopores are small and may be readily overlooked. They do not indent the cells, being determined chiefly by a densification of the material at the junction of the walls. In longitudinal section, the characteristic annular thickenings are almost absent. The diaphragms are situated at irregular, usually long intervals, seldom as close together as the diameter of the cell—sometimes three or even four diameters apart. The maximum interval observed is about 1.5 mm. The diaphragms occur throughout the length of the tubes examined. Their characteristic perforations are clearly shown in many instances.

Stenopora emaciata var. inæqualis var. nov.

Typical *Stenopora longicamerata* is based on a form which grows in hemispherical masses and has long zoœcial tubes intersected by relatively few diaphragms. Another and much more abundant type occurs in the collection which resembles *longicamerata* in most of its microscopic characters, but differs in having an explanate mode of growth. The thin sheets, which seldom have a thickness of more than 4 mm., are much contorted, in some cases bending around completely so that the edges are confluent and hollow cylinders are formed. The cell walls are thin, with only occasionally a beadlike swelling. Transverse sections show thick- as well as thin-walled areas, the thickened walls being probably where the section passes through these swellings. The acanthopores are small and the diaphragms relatively distant.

Stenopora emaciata var. arkansana var. nov.

Zoarium consisting of lamellar expansions covered on the under side by a wrinkled epitheca. The expansions seem to range to 20 mm. in thickness, but are usually less than 10 mm. and in many cases much less. Relatively massive bodies are formed by the superposition of successive layers which are irregular in thickness and in shape, being often much contorted.

Zoœcia rather large, very variable in size, aggregations of larger ones forming maculæ. The maximum diameter of very large cells is .7 mm., but as a rule, the larger ones are not over .56 mm. in diameter and the smaller .35 mm. (even .29 mm. or less). Thus, about 4 of the larger ones or 5.5 to 6 or 7 of the small ones occur in 2 mm. Mesopores rare or absent. The walls are thin and the zoœcia polygonal. Acanthopores moderately large, developed at the angles of the cells which they often indent, rarely at the sides. Occasionally, a section is so directed that acanthopores seem to be almost absent. In longitudinal section, the prostrate portion is seen to be short and the rest of the zoœcium long and straight. The walls are thin, with inconspicuous thickenings which are small in degree and apt to occur at long and rather irregular intervals. For this reason, the walls in cross section appear thin, the cells angular and the acanthopores projecting into them. The diaphragms are thin, often conspicuously perforated, abundant, occurring from one half to two diameters apart. The average is one diameter or less, and the longer intervals are rare, tending to occur simultaneously in several cells.

Stenopora emaciata var. megastylus var. nov.

Zoarium explanate, from 2 to 7 mm. thick in different parts. Lower surface covered with a wrinkled epitheca. Distinctly monticulate with large cells on the monticules. Zoœcia very variable in size, 6 or 7 in 2 mm., subangular. Walls thin, with gently elongate swellings. In tangential section, thin-walled areas alternate with areas made up of cells having distinctly thicker walls. Acanthopores large, usually on the cell angles, truncating the angles or indenting the cells. Diaphragms closely arranged, from one half to one diameter apart, conspicuously perforated.

Stenopora intermittens var. harrisonensis var. nov.

Zoarium in the form of thin expansions less than 5 mm. in thickness. Superficial characters not known. Aggregations of larger and smaller cells rather conspicuous. About 6 occur in 2 mm. In sections transverse to the tubes, their walls show great variation in point of thickness, the thin ones being almost linear and the thick ones in extreme cases one half the diameter of the tube. The cells which are bounded by them are in the one case angular and in the other circular. The acanthopores are extremely large. Where the walls are thin, they indent the cells, although part of the wall is carried around on either side, tending to give the cells a more circular shape, but they are completely imbedded in the walls, when the latter are thick. When such is the case, there is seldom any visible median line, but there are occasional spines in addition to the true acanthopores. In longitudinal section also, two types of thickening can be noted, some of the walls being almost linear with only occasional short but not very strong swellings, while others are continuously and regularly thickened,—some very heavily so. Diaphragms are irregularly distributed, a diameter or less apart in some areas and much more than a diameter in others.

Stenopora miseri sp. nov.

Zoarium consisting of thin expansions covered below by a wrinkled epitheca. The individual sheets are apt to be contorted. They occur singly or superposed, or interlaminated with *Fistulipora excellens*. In combination, they form bodies of considerable thickness, but they are not solid, since relatively large cavities are left between the contorted layers. The different sheets are seldom over 2 mm. thick.

The zoœcial walls are much thickened, but areas in which this feature is developed occur adjacent to others in which the walls are thin. When the walls are thick, the zoœcia are more or less circular; when thin, they are more or less angular. They are rather irregular in size and shape. Maculæ composed of groups of larger or smaller cells seem to be present, but the difference in size is not great nor are the areas well defined so far as observed. The thickening of the walls is accomplished by means of strong swellings close together or more or less confluent. Typical acanthopores rare or possibly absent. The thickened walls, however, show a strong median line, in some sections appearing as a row of granules, often with a group of granules at the cell angles. The median line is usually observable even where the walls are thin, and it can also be made out in longitudinal sections. About 6 cells occur in 2 mm. The larger ones are from .28 to .35 mm. in diameter (measured from the median line of the thickened walls). Mesopores (young cells ?) fairly abundant. Diaphragms scantily developed. In some sections, they seem to be absent; in others, one or two occur in each cell.

Stenopora miseri var. tubulata var. nov.

This form resembles *S. miseri* in most of its characters, differing only in the degree in which they are developed. The acanthopores are more numerous, most of the cell angles being occupied by them, but they are for the most part small, not indenting the zoœcia. The thin-walled areas are more extensive than in the other. When thickened, the walls usually show a distinct median line and they are marked by fine granules, varying in quantity in different parts of the zoarium. The diaphragms are rather abundant and closely arranged, usually less than a diameter apart. Groups of large cells occur such that only five or even four are found in 2 mm.

Stenopora simulans sp. nov.

This species, in its mode of growth, is like *S. mutabilis*, forming extremely irregular bodies partly ramose, partly explanate or massive, and apparently more or less confluent. The branches are small, 5 mm. in diameter.

The walls vary from thick to thin, in some places changing rather abruptly, and while this may be due in part to the irregularity of growth, in part it must doubtless be assigned to variation at the same stage of development. The cells vary from subcircular to more or less strongly polygonal and occur about 6 in 2 mm. Mesopores are rare. Normal acanthopores (with concentric structure) appear to be absent. At the same time, the walls are beset with large acanthopore-like granules, many of which seem to have a tubular axis about which little dots of denser material are assembled. Where the walls are thick, the dots are more spread out, and where the walls are thin, they are more concentrated. Where the walls are thin, also, the granules sometimes indent the cells. Similar and not conspicuously larger granules occur at the cell angles. The granules are developed in the thin as well as the thick walls, although they are less numerous in the former. Even where the walls are more attenuated, however, a few can occasionally be distinguished. The mature zone is long and the walls as a rule continuously thickened, though in varying degree. Here and there the characteristic moniliform structure is shown or suggested. Diaphragms are fairly abundant and very irregularly distributed, varying from one half to 2 or more diameters apart.

Stenopora mutabilis sp. nov.

Zoarium in the type specimen in form of a slender cylindrical branch a little less than 3 mm. in diameter, but assuming in other specimens a very irregular growth, partly explanate, partly more massive, very much contorted and sending up from its base short (?) branches of varying size, but probably always small, which appear to inosculate with one another and with the rest of the zoarium, when the irregular mode of growth brings them in contact.

Zoœcia small, rounded, about 9 in 2 mm., varying considerably in size, but without conspicuous groups forming maculæ. Walls usually thick, measuring about one half the diameter of the zoœcia, thin in the central portion, but with a very long mature region. At the same time, the walls vary greatly in thickness (in tangential section) within very short distances and are in places almost linear, in which case, of course, the cells are polygonal. Owing to the very irregular, contorted growth of this form, the variation in the thickness of the walls may sometimes be due to varying distances from the immature region. The thickening of the walls is continuous and not beaded. Mesopores (young cells ?) rather rare and in the preservation of my specimens difficult to distinguish from acanthopores. Acanthopores extremely large, in some cases about one half the diameter of the cells, which they strongly indent, except when the walls are thick. Diaphragms numerous and irregularly arranged, from one half to rather more than a diameter apart, somewhat doubtfully perforated.

Stenopora ramosa var. fayettevillensis var. nov.

Zoarium consisting of rather slender, solid, cylindrical stems about 5 mm. in diameter. Zoœcia vertical in the median region, rather gradually bending outward to the circumference, only a short portion, however, having a radial direction. Five or 6 apertures occur in 2 mm. Mesopores moderately abundant for the genus, occurring singly or in groups, associated with cells larger than the ordinary. Zoœcia and mesopores polygonal with rounded angles. Walls moderately thickened in the mature region, which is narrow, two or three times the diameter of the larger cells. The thickenings are continuous, but swollen and irregular. The division lines in the walls are well defined, in places intermittent or granulose. Acanthopores are of moderate size and abundance occupying nearly all the angles, but not indenting the zoœcia. Tabulæ are rather abundant in the narrow cortical zone to which they are perhaps restricted; from one half to one cell diameter or more apart.

Stenopora gracilis sp. nov.

Zoarium ramose, consisting of solid branches which have a diameter of 5 mm. or more. The zoœcial tubes run lengthwise in the axial region and bend gradually outward, meeting the surface either somewhat obliquely or with a very short radial portion. The walls are thin throughout, only slightly thickened toward the surface, the thickenings being continuous, but suggesting the moniliform structure by their irregular outlines. Mesopores appear to be few (more abundant in a second specimen than in that from which this description is drawn). Acanthopores nearly absent, but better developed in the second specimen just mentioned. Tabulæ few and irregularly distributed. Walls with a fairly distinct median line where thickened. Zoœcia 5 or 6 in 2 mm.

Stenopora inermis sp. nov.

Zoarium in the form of rather large, solid, clumsy branches having a diameter of 8 to 12 mm. or more. Surface marked by maculæ about 5 mm. apart, often elevated into monticules, a few of which are prominent. Zoœcia thin-walled and vertical in the axial region, gradually bent outward so that the mature portion has a radial direction. Mature region not well defined, one fourth of a diameter on a side or less. Mesopores abundant for the genus, groups of them in conjunction with zoœcia of unusually large size forming maculæ. Five or occasionally 6 zoœcia occur in 2 mm. The walls are often much thickened, but may be fairly thin, strong contrasts occurring close together in the same specimen. Acanthopores are either exceedingly rare or absent altogether. A few doubtful occurrences have been noted in tangential section, but they probably represent the starting point of one of the numerous mesopores. Tabulæ appear to be absent in the mesopores, but are abundant in the mature region of the zoœcia, usually less than a diameter apart and showing the characteristic median perforation. The thickening of the walls is a marked feature, and it is continuous, not moniliform, though occasional suggestions of that structure are presented in sections passing lengthwise through the walls. The median line is strongly marked, in whatever way the walls are cut.

Amphiporella gen. nov.

The term *Amphiporella* is introduced for a type of bryozoan which is related to *Stenopora* and others of the Batostomellidæ, to which family it obviously belongs, but differs therefrom in growing in large, tortuous, bifoliated fronds. The Batostomellidæ have been described as never bifoliate, and the present type is only bifoliated in a sense. It has a median immature region from which the cells bend outward in two opposite directions and open on surfaces which are relatively parallel to one another, but it does not consist of two colonies growing back to back, and consequently there is no median plate. This growth can therefore be considered as consisting of branches which are greatly expanded laterally, rather than as exemplifying the typical bifoliate structure. Acanthopores are fairly abundant and of very large size in the type species. Mesopores are also fairly abundant and are apt to be grouped together in maculæ associated with large zoœcia. Their distribution is irregular.

Diaphragms are of the typical perforated sort and are abundant. The cell walls are thickened and strongly moniliform in the mature region.

This type probably begins as a basal expansion of considerable extent and thickness, covered underneath by a wrinkled epitheca, and from this expansion the fronds or flattened branches spring. Organisms having such an expanded growth, but otherwise having all the characteristics of the bifoliate fronds, occur associated with them. *Amphiporella* differs from all the members of the Batostomellidæ in its mode of growth, but seems to be especially related to *Stenopora*. This is shown by the annular thickenings of the walls. It differs in the abundant development of mesopores, the grouping of which is also a peculiar character.

TYPE.—*Amphiporella maculosa.*

Amphiporella maculosa sp. nov.

Zoarium large, consisting of a basal expansion, sending off extensive tortuous bifoliate fronds. The latter seem seldom to exceed 7 mm. in transverse diameter, but may be 80 mm. or perhaps very much more in length. The cell walls are thin in the immature region, which occupies from one fourth to one third the thickness of the frond. In the mature region, the cells are nearly straight and perpendicular to the outer surfaces. Their walls are thick, showing, however, great variability. That is, in tangential sections parallel to the surface, some of the walls are rather thin and others are much thickened. Of course, where the walls are thick, the cells are subcircular and where thinner, proportionately angular. Mesopores are rather abundant, and their distribution is irregular. Occasionally 6 or 8 or more occur together, making a noticeable macula, but usually they are distributed in twos or threes, though considerable areas can be observed in which none are developed at all. The zoœcia vary considerably in size, the larger ones usually occurring where the mesopores are most abundant. The maculæ caused by the groups of mesopores are, however, a much more striking feature than the congeries of cells of larger size. Usually 6 or 7 zoœcia occur in a distance of 2 mm.; when unusually large, 5; or when unusually small, 8, the measurements being made where mesopores do not interfere.

The walls are generally divided by a distinct median line of darker color than the rest, and in one or two cases where the walls are especially thick, the slender, solid line appears broken up into a broader band of granules. Acanthopores are numerous and very large. They usually occur at the angles, but occasionally on the sides of the cells, and not all the angles are occupied. Where the walls are thick, the acanthopores do not greatly indent the cells, but where the walls are thin, they do indent them, especially when of large size. When the cells are cut longitudinally, the walls have the characteristic swellings conspicuously developed. They are large, abrupt and closely, though somewhat irregularly, arranged. In this view, also, the walls sometimes show fine, transverse bands of lighter and darker color, as if they were originally composed of alternating layers of varying density. The mesopores appear not to be tabulated, except perhaps very rarely. In the zoœcial tubes, the tabulæ are numerous, usually about a diameter apart, occasionally somewhat less, more often somewhat more, rarely two diameters. They are centrally perforated after the manner characteristic of this group.

To this species I have also referred some specimens which occur associated with the types and agree with them in microscopic peculiarities, but differ in being uniserial expansions, one side of which is covered by an epitheca (?). The growth is very irregular and attains a thickness of 15 mm. or more, appearing to consist of several successive layers in some cases. Sections through such specimens transverse to the zoœcia show the rather characteristic groups of mesopores with extra large zoœcia associated with them. The walls manifest great diversity in thickness, being exceedingly thin in some areas and much thickened in others nearby. Acanthopores are somewhat sparsely developed, but are very large, strongly indenting the chambers when the walls are not too thick. In some cases, where the thickness is very great, there seem to be a number of granules distributed along the median line instead of one large acanthopore situated at the angle. Sections cutting the walls longitudinally show them to be thickened in the mature region and annulated, the annulations being strong, abrupt and frequent. The diaphragms are rather closely arranged, a diameter or less apart, but, in the younger region and also near the outer surface, occasionally much more. The early prostrate portion appears to be, in some cases at least, very long and very slender. Owing to irregularities of growth, such areas of slender, non-tabulated cells occasionally recur in the midst of the more mature conditions. In some cases, if not all, the zoœcia, after they leave the prostrate position and are of more nearly mature size, are thin-walled and non-tabulate for a longer or shorter distance, after which the annulations and tabulæ begin to appear. In the explanate specimens, the tabulæ are sometimes quite closely arranged over considerable areas, one half a cell diameter apart, more or less.

Cœloclemis subgen. nov.

Of this variety of structure, only one species is known and it is therefore taken as the type. It comprises small, irregular, hollow, dichotomous branches lined with an epitheca. The zoœcia are naturally short, as the central cavity of the branches is large and the bounding zoarium thin. They are prostrate and thin-walled in the immature portion, erect and thick-walled in the mature. The amount of thickening varies much from point to point, and it is regular and not moniliform. Maculæ and monticules are present, but are neither well marked, abundant nor regularly arranged. Tabulæ may be present (in the prostrate portion), but they are rare. Acanthopores are large and moderately numerous. Mesopores absent.

This type belongs without much question to the Batostomellidæ but can not be placed in any of the groups there recognized as at present defined. The mode of growth is that of *Anisotrypa*, but the structure is otherwise different. The structure is that of some not quite typical species of *Stenopora* (not typical because of the rarity of the diaphragms and the continuous or fused thickening of the mature wall), but the mode of growth is distinct from that of *Stenopora*.

To some extent, the mode of growth seen in this group appears generally to be regarded as a generic character, and probably the present type can with propriety be assigned to subgeneric rank on that account.

TYPE.—*Cœloclemis tumida*.

Cœloclemis tumida sp. nov.

Zoarium consisting of hollow stems lined with an epitheca; irregularly branched and with swollen portions, monticules (?), etc. Cross sections generally circular, just preceding bifurcation, compressed. The largest diameter observed is 9 mm., but the average is about 5 mm., while the smallest noted is 3 mm. The thickness of the wall, that is the thickness of the zoarium, is from .5 to 1 mm. or more.

The zoœcia appear to have a rather long, prostrate portion from which they bend outward strongly to a radial direction. The presence of tabulæ has not been definitely determined. If developed at all, they appear to be rare and restricted to the prostrate portion. The walls are as usual thin in the immature zone. At the surface, they vary, certain areas being thin- and others thick-walled. The thick-walled areas are sometimes, though not always, associated with prominences (monticules). The zoœcia vary in size, there being occasional groups of large cells, though there are considerable areas upon which the cells appear to be undifferentiated in that way. The apertures are angular, with rounded corners where the walls are thick. Five or 6 occur in 2 mm. Acanthopores are fairly abundant, situated at the angles where developed, but not all the angles are filled. Where the walls are thin, the acanthopores indent the cells; otherwise they are imbedded in the walls without deforming the zoœcia. In addition to the large acanthopores, the walls where thickened have many small spinules distributed through them. Though especially abundant there, these are not restricted to the median line, which is well defined by a continuous dark band. The median line is also shown when the walls are quite thin. When cut lengthwise, the walls are thin in the immature and usually much thickened in the mature region. This thickening begins abruptly and is continuous.

Pycnopora subgen. nov.

This name is introduced in a subgeneric sense for a bryozoan type whose affinities are clearly close with *Lioclema*. The type species grows in a thin lamellar expansion, a type of growth also possessed by another species which can with propriety be placed here (*Lioclema? araneum* Ulrich). It has rather numerous mesopores and rather rare and small acanthopores. Diaphragms are fairly abundant in the zoœcia, and they are centrally perforated. The walls are thickened in the mature region. All these characters belong also to *Lioclema*, from which the present type is distinguished by the degree of their development. It differs from *Lioclema* in the greatly reduced number of mesopores and the much smaller acanthopores. The difference is so marked as to deserve separation into a distinct group, probably of subgeneric importance.

TYPE.—*Pycnopora regularis.*

Pycnopora regularis sp. nov.

Zoarium consisting of a thin expansion, one side of which is covered with a wrinkled epitheca. Thickness .5 to 1 mm. Zoœcia circular, usually in contact, the interspaces occupied by mesopores, generally 2 or 3 in a group. Eight zoœcia occur in 2 mm. The walls of the mesopores are of equal size with those of the zoœcia, and the mesopores are often not distinctly angular. Acanthopores are rare and small and imbedded in the rather thick walls so that they do not indent the cells. The zoœcia vary considerably in size, and there are maculæ at rather wide intervals formed by groups of mesopores of various sizes with which are usually associated a few large zoœcia. The average diameter of the apertures is .17 mm., but the larger ones measure .22 mm. The tubes are prostrate for a short distance, later becoming erect and the walls are somewhat obscurely moniliform. Tabulæ are fairly abundant, considering the length of the cells, and they are in many cases incomplete when seen in longitudinal section, owing to the central perforation. They seem to be restricted to the zoœcia, none having been observed in the mesopores.

Pycnopora bella sp. nov.

Zoarium in the form of a thin expansion. The zoœcia are at first slender and prostrate for a considerable distance, later erect. Near the surface, the walls are somewhat thickened, and the apertures are rounded. The apertures occur about 8 in 2 mm. They have a diameter of .17 to .21 mm., the average being nearer the smaller size. In spite of the rather thin walls, the zoœcia are usually but obscurely polygonal, owing to occasional mesopores and the numerous acanthopores. Mesopores are scantily developed and small, more abundant on some areas than on others. Acanthopores are rather abundant and rather large, more or less strongly indenting the cells. They are strikingly tubulate. In addition to the acanthopores, the walls in some cases have small granules along their margins. Diaphragms are rare and appear to be restricted to the prostrate portion of the zoœcia.

This form resembles *P. hirsuta*, from which it is distinguished by its larger and less numerous acanthopores and thinner walls.

Pycnopora hirsuta sp. nov.

Zoarium in the form of a very thin expansion. Thickness .14 mm.

Zoœcia prostrate and thin-walled below for a short distance, thick-walled and erect at the surface. The apertures are rounded, more or less elongated, rather regularly arranged in quincunx, about 7 or 8 in 2 mm. (7 in the direction of their longitudinal diameters). They are about .21 mm. long and from .11 to .14 mm. wide. The mesopores are small, rounded, distributed one or two at a time in the angles between the zoœcia. Walls thick, the intervals between the zoœcia being from one fourth to one half the shorter axis of the latter or about as thick as the average mesopore. Acanthopores very numerous, imbedded in the walls, occasionally indenting the cells, to which they then give an irregular and undulating outline, medium-sized to large, often 10 or 12 around a zoœcium. In some areas, the acanthopores are much larger than in others, and I believe that this is not due to distance from the surface. Tabulæ very rare in the zoœcia and absent from the mesopores.

Stenocladia subgen. nov.

Zoarium in the form of bifoliate fronds which branch and perhaps inosculate. A median plate is probably lacking. In no instance can the presence of such a structure be demonstrated, and usually there is no trace that could be so construed.

Zoœcia elongated, slender and longitudinal in the median portion of the frond; considerably larger and perpendicular to the surface at maturity. The walls are thin in the immature zone, thickened near the surface. Mesopores fairly abundant, variable in distribution, occasionally forming large groups or maculæ. Acanthopores moderately abundant, small, not greatly indenting the cells. Zoœcia and mesopores thin-walled and angular to near the surface, where the deposit of sclerenchyma closes the mesopores completely or in large part and gives the zoœcia a circular or oval shape at the same time diminishing their caliber. The acanthopores also are metamorphosed nor do they project as spines. The walls at the surface appear to be marked by granular dots of several sizes, the larger ones distributed down the center of the walls, the smaller ones more marginal. The acanthopores have conspicuous tubular axes which proceed in straight lines to the surface. In addition to these structures, the walls in sections at right angles to the surface show many fiber-like lines of denser material which appear to curve and divide, seldom being normal to the surface. There are thus three fairly distinct zones on each side: an axial zone, a superficial zone in which all the structures are modified by sclerenchyma and an intermediate zone in which the zoœcia, acanthopores and mesopores have their more usual characters.

Type.—*Stenocladia frondosa.*

Although presenting many analogies to the type of structure which I have included under *Idioclema*, it seems probable that this must be regarded as having widely different affinities. The most marked resemblances are found in the wall structure, with its inosculating fibers and granulose, strikingly tubulated acanthopores. On the other hand, we have the mode of growth, bifoliate in the present type and ramose in *Idioclema,* the entire absence of any structures resembling the hemisepta seen in the latter, and the presence of a stage with numerous angular mesopores and normal acanthopores which is not found in *Idioclema.*

On the whole, and chiefly because of the stage with distinct angular mesopores and normal acanthopores, I am including this form as a subgenus under *Lioclema* in which a group of species is also known having a superficial sclerenchymatose deposit. In some respects, this form suggests *Intrapora* (cf. *I. basalis*) and some analogies can be drawn, but the absence of hemisepta in the present form and of acanthopores in *Intrapora* seems to show widely different affinities.

Stenocladia frondosa sp. nov.

Zoarium in the form of rather extensive though thin bifoliate fronds which are considerably flexed or distorted and which divide and perhaps anastomose, being considerably thickened at such points. Normal thickness .5 mm. to 2 mm.

Zoœcia small, longitudinal and thin-walled in the median portion of the frond, considerably expanded toward the surface, near which they are directed outward and have thick walls. The apertures are rounded and generally somewhat elongated, .17 to .2 mm. in longest diameter. Eight or 9 apertures occur in 2 mm. and they are separated by about one half their own diameter. Cortical and mesial zones sharply and strongly marked. The cells are oblique and the walls thin in the mesial portion; the cells perpendicular to the surface and the walls thick in the cortical portion, the changes being effected very abruptly. The mature zone is of varying length in different specimens, relatively narrower in the narrower specimens, ranging from about one third to one sixth of the width on each side. Acanthopores and mesopores are present in abundance, but they are obscured near the surface by a deposit of sclerenchyma, so that sections present remarkably different aspects, according as they pass through different levels. Apparently in the young part of the mature zone, the mesopores are numerous and rather large, very variable in numbers in different areas of the zoarium. They form rather extensive aggregations or maculæ in some areas. In others the zoœcia are in contact, with the mesopores distributed in groups of two or three, while in still others the zoœcia are separated by single rows of mesopores. Acanthopores are fairly numerous and small, but nevertheless they indent the cells more or less by reason of the extreme thinness of the walls. Diaphragms are very rare and appear to be non-perforated. They are confined to the zoœcia. At the surface, the mesopores are closed by a deposit of sclerenchyma, and the acanthopores also seem to be modified to some extent. The surface namely appears to be without spines and often without mesopores, though, when slightly weathered, and perhaps here and there when not, the mesopores are clearly to be seen in varying numbers as described above. When the mesopores are not visible, the interspaces between the zoœcia appear to be thick and structureless. Thin sections just at the surface show few, if any, mesopores. Acanthopores are numerous. Whereas below the surface they appear as small dense bodies having, however, a tubular axis, in the thickened mature portion they are much larger and more nebulous, apparently composed of many little fibers. Rows of large ones range down the middle of the thickened walls, and smaller ones occur more marginally. A little deeper, the walls appear to be thin, the zoœcia larger, and angular, more or less numerous, mesopores appear, while the acanthopores are less numerous and smaller. In some tangential sections, instead of distinct acanthopores of two sizes, the wall appears to be intersected by numerous small uniform granules or fibers. In sections cutting the walls longitudinally, the tubular axes of the acanthopores can be seen passing completely through the thickened walls, which are, in addition, more or less speckled with the granules mentioned in the description of the tangential appearance.

Syringoclemis gen. nov.

Zoarium consisting of hollow cylindrical branches lined with an epitheca (?). Zoœcial apertures somewhat elongated, irregular, ovate or subpetaloid. Mesopores abundant, subangular. Acanthopores scantily developed, of two sizes in the typical species, the larger very rare, the smaller much more abundant but reduced to mere granules. Mature region narrow. Walls thin below, much thickened in the cortical zone to which the mesopores are confined. Diaphragms apparently lacking.

TYPE.—*Syringoclemis biserialis.*

The affinities of this form are somewhat doubtful. In some respects, it is suggestive of the Rhabdomesidæ or Cycloporidæ. It is provisionally placed with the Batostomellidæ, although the thin layers of which the zoarium is composed, together to some extent with its growth as hollow branches, joined with the character of the zoœcia with their raised peristomes, are not characteristic of that group. *Syringoclemis* differs from typical *Lioclema* in several particulars, especially in its mode of growth, since none of the species referred to that genus form hollow branches. The narrow mature zone, the absence of diaphragms, the obsolescence of acanthopores and the open mesopores are all characters which are alien to typical *Lioclema.* The mode of growth is, of course, like that of *Anisotrypa*, but the other characters are different.

In a general way, this is similar to the form which I have called *Callocladia*, but that type possesses hemisepta, has a vestibulum, etc., and probably belongs to an altogether different group. In some respects, it resembles *Dyscritella.* It differs markedly in the mode of growth, the shortness of the zoœcial tubes, their elevated peristomes and the great abundance of mesopores.

Syringoclemis biserialis sp. nov.

Zoarium consisting of hollow, dichotomous branches having a diameter of 5 mm. or less. The zoarium itself is less than 1 mm. in thickness and lined with an epitheca. Apertures with a slightly projecting peristome and an irregularly oval or slightly petaloid shape. Variable in size and outline, usually from .18 to .21 mm. in longest diameter, rarely .28 mm. Irregularly arranged, rarely in contact, more often with one or even two rows of mesopores intervening. Mesopores irregular in size and arrangement. The largest are of about half the diameter of the zoœcia, but it is rare to find them so large. They are subangular and of regular shape, usually separating the zoœcia in a single row, less often two rows, rarely three. Six or less of the zoœcia occur in a linear distance of 2 mm. There are rare maculæ consisting of mesopores or small cells. Acanthopores are of two sizes. One kind is very large and very rare, developed in the walls of the zoœcia, which they indent. The other is much smaller, developed as rows of granules along the middle of the walls of the zoœcia, occasionally in the mesopore walls. Both kinds are, however, scantily developed and considerable areas occur in which no acanthopores can be seen at all.

When the cells are cut lengthwise, they are seen to be slightly oblique, very rapidly expanding, with a short prostrate portion, perhaps strictly vertical only in the mature region, which is quite narorw (.14 to .28 mm.). The cortical zone is abruptly and greatly thickened, the mesopores being confined to it, so that the zoœcia are much larger below than near the surface. Tabulæ, so far as observed, are entirely lacking both in the zoœcia and the mesopores.

Polypora mesleriana sp. nov.

Zoarium apparently rather small for the genus, very irregular in growth, with the surface contorted and the branches often strongly bent. Owing to this irregularity, the measurements and relations vary greatly. There are 5 branches and 4 rows of fenestrules in 5 mm., but 4 branches and 3 rows may occur on the same specimen. The branches are relatively slender when first introduced and about twice as broad before division, to which circumstance and the fact that they sometimes diverge rapidly the difference in measurement noted above may be ascribed. Longitudinally, from 2 to 2.5 or even 3 fenestrules occur in 5 mm. They are usually elongate, nearly twice as long as they are wide and subrectangular to subelliptical in shape, but they vary considerably in proportion. The branches range from one half to nearly twice the fenestrules in width in extreme cases, but the average is intermediate. They are rounded when narrow and flattened when broad and are very much broader than the dissepiments which are slender (on the reverse) and somewhat depressed. On this side, the branches are marked by fine but sharp and regular longitudinal striæ, which, in some instances, swing off onto the dissepiments. Over the older portions, these markings appear to be lost, but they are apt to show when exfoliated, indicating that they are structural as well as superficial. There is some evidence that they are marked by fine granules or spines.

On the obverse, tne apertures usually occur in 4 rows (more rarely 3 or 5). They are situated in grooves, which lie between rather strong ridges. The crests of the latter seem to have a zigzag course and bear strong spinules which have a regular arrangement alternating with the aperture. Of the latter, 5 to 7 occur opposite a fenestrule. They are oval in shape with sharply elevated peristomes and appear to be covered in some cases at least with centrally perforated opercula.

Septopora pustulifera sp. nov.

Zoarium probably small, very irregular in growth. Four rows of fenestrules and 3 branches to 4 rows and 5 branches, occur in 5 mm. Three and one half to 4 fenestrules occur in the same distance longitudinally. The branches and dissepiments are usually about equal in size, both more or less expanded at their juncture. Fenestrules subquadrate to subcircular, irregular in size and shape. Dissepiments sometimes oblique, sometimes forming zigzag lines, rarely meeting in an angular or curved figure, as is rather characteristic of the genus. On the obverse, the zoœcia are in two rows separated by a carina (?), and the dissepiments also show two rows. The reverse is marked by rather numerous, large, conspicuous pustules or accessory pores. These often look like spines which have been broken off, but probably are crater-like openings with raised edges. There are also (in one specimen) smaller pointed elevations like low papillæ. Liræ are likewise present, but they are discontinuous. Infrequently a median lira is found, which causes the back to have a more or less carinated appearance, while there are finer, less persistent liræ lateral to it. The pustules occur on both branches and dissepiments, but the liræ appear to be restricted to the branches.

Rhombopora persimilis var. miseri var. nov.

Zoarium ramose, bifurcating at frequent but irregular intervals. Branches about 1.5 mm. in diameter. Apertures regularly arranged in longitudinal and oblique rows of which there are about 16 lengthwise around the stem. The oblique series intersect at angles of about 30° longitudinally and 60° transversely. The apertures are strongly elongated and separated by thick angular walls. Longitudinally, 4 apertures occur in a distance of 2 mm. One or two large tubercles are developed in the long distance which separates the top of one aperture from the bottom of the one above in the longitudinal series, and a row of smaller spinules occupies the crests of the dividing ridges laterally.

This form is known chiefly from thin sections, and such statements as relate to superficial appearance are based upon few observations. In transverse sections, the thickened portion seems to be narrow, often not more than one sixth or one eighth of the whole at either end of a diameter. The bounding ridges appear as elliptical bodies with their long axes in a radial direction when the section cuts through a cell. When it passes between two cells, the thickenings of course coalesce, and when it passes through a spinule, it terminates in a strongly projecting point. Each thickened mass shows a median line of darker color which has of course a radial direction.

None of the longitudinal sections examined probably passes quite through the middle of a branch. The blocks of thickened tissue have a rectangular shape and are much longer than in the transverse section, but they are somewhat similarly modified as they cut different portions of the zoarium. The zoœcial tubes are without tabulæ.

In tangential section, the zoœcia are seen to be elliptical in section, not quite twice as long as wide. The intervals laterally are slightly less than the width of the tubes. Longitudinally, the distance is more than the length of the long diameter, but occasionally less and occasionally also twice as great. A large acanthopore-like spine occurs near the end of each aperture, while a row of smaller ones traverses the middle of each wall. The smaller spines are more superficial than the large ones, and fewer of them show in proportion as the section is cut farther from the surface, so that in some cases they appear to be well-nigh absent.

Streblotrypa nickelsi var. robusta var. nov.

Zoarium in the form of long, cylindrical stems which are sometimes more or less bent and but seldom branched. Diameter a little less than 1 mm. Apertures in alternating linear rows, about 12 to the circumference. They are ovate, broader and more truncated on the posterior side, surrounded by a distinct peristome which is confluent with the raised longitudinal lines that divide the rows of apertures. The longitudinal lines are somewhat sinuous, contracting downward from the base of one aperture to the top of the next. Spaces between the zoœcial apertures in the same row twice or more the length of the apertures themselves, somewhat depressed, occupied by about 12 pores, variable in number and in size. Usually they are arranged in 2 rows, 5 or 6 pores in each, while the widening of the interzoœcial areas toward the top leaves room for an additional intermediate incomplete row of 2 or 3. There are 4 apertures and 4 interzoœcial areas in 2 mm. longitudinally. The zoœcial tubes are long, gradually diverging, rather abruptly turning outward when near the surface. Hemisepta about as in *S. nickelsi.*

Cœloconus tuba sp. nov.

Zoarium in the form of a gradually enlarging cone, more or less contorted, attaining a length of at least 13 mm. and a diameter of 3.5 mm. Usually the fossil appears as a mold of the interior, partly embedded in rock, the zoarium itself adhering to the external rather than to the internal matrix. In this condition, it appears to be marked by more or less closely arranged, regular constrictions or by fine sharp annulations. In one specimen, the constrictions are much coarser and more irregular. There are also fine concentric striæ and obscure linear longitudiual markings. Some of the specimens taper gradually to a point, while others contract suddenly, so that the lower end appears truncated and rounded. These differences may be indicative of different species, but my material is so scanty that it has seemed inexpedient to sacrifice it to ascertain this fact by sectioning.

As the specimens examined show no external characters beyond those mentioned, which are probably not truly specific in value, the essential part of the description is based on thin sections. The walls of the zoarium are .28 mm. in thickness. The basal plate is thin. The partitions extend obliquely upward; the ends bend somewhat inward into hook-like hemisepta, while the outer surface is abruptly and strongly thickened, forming more or less quadrate blocks when seen in longitudinal section. The inferior hemisepta have not been observed. Tangential sections show the cells to be circular or slightly elongated and arranged rather regularly in quincunx, so as to form oblique rows as well as longitudinal ones. About 7 cells occur longitudinally in 2 mm. The walls are thick, those separating laterally adjacent cells being about one half the width, and those separating longitudinally adjacent cells about one half the length of the cells. The central line of the walls is occupied by a row of spinules outlining a hexagon having perhaps 2 spinules to a side and one on each of the angles, although such an arrangement is by no means constant.

Idioclema gen. nov.

The following description is based upon the only species known, and it may therefore have to be modified when other related forms are brought to light. The name *Idioclema* is then introduced for a Bryozoan type having solid, straight, probably branching stems of small diameter. There is a well-defined cortical zone in which the zoœcia are radial and have greatly thickened walls, and an inner or immature region in which the zoœcia have thin walls and for a long distance preserve a longitudinal direction. On the interpretation of structure adopted here, mesopores are absent, but acanthopores of abnormal type are abundant. In fact it would appear that the cortical zone, in which alone these structures occur, was dominated by them and that they formed the walls by which the irregularly oval or even tortuous zoœcial tubes are separated, by becoming confluent with one another as they come in contact. Each acanthopore is as thick as the entire wall, and by uniting laterally they form inosculating bands. The constituent unit can often be made out as (in tangential section) large circular bodies having a tubular axis and a row of elongated granules about the margin. The granules are perhaps oblique inosculating fibers and show conspicuously when the tubes are cut longitudinally. They appear to be irregular in direction and do not make continuous lines for any considerable distance. Tabulæ appear to be absent. Hemisepta are, however, developed just within the cortical zone. One projects upward and somewhat obliquely inward from the proximal portion of the wall at the commencement of the thickened zone and about at the point at which the tubes turn into a radial direction. A second projects upward and somewhat obliquely outward from the opposite wall a little farther down the tube.

The affinities of the form are very much in doubt by reason of the very unusual character of the wall structure. The presence of hemisepta, however, is a diagnostic character and seems to forbid placing the genus with the Batostomellidæ, to which it shows some points of resemblance.

While forced to conclude that *Idioclema* cannot rightly be referred to the Batostomellidæ, I am none the less in doubt as to where it should properly be placed. Provisionally I am including it in the Rhabdomesidæ. It may form the nucleus for an independent family, the Idioclematidæ.

TYPE.—*Idioclema insigne.*

Idioclema insigne sp. nov.

Zoarium in the form of freely branching stems, more or less circular in cross section, but expanded and compressed at points of bifurcation. Diameter ranging to 5 mm., usually less, and averaging about 3 mm. Superficial characters not known.

Cortical zone strongly marked and very variable in thickness, probably according to age, ranging from one third to one sixth of the diameter of the stem on each side. Zoœcial tubes long and straight in the axial region where they are .098 to .14 mm. in diameter, then slightly inclined to the surface and later abruptly turned to a radial direction. Diaphragms appear to be wanting, but hemisepta are well developed. There occurs an incomplete partition projecting inward and upward from the lower wall of each tube just as it turns into an axial direction. A second incomplete partition projecting obliquely upward and outward frequently occurs a little farther down the tube on the opposite wall, where it has a slightly inclined direction.

The structure of the walls is difficult to describe, and the terms used depend largely upon whether the appearances in section are interpreted as much modified acanthopores with large tubular axes or as mesopores without true acanthopores. The walls are thin in the axial region and strongly and abruptly thickened in the cortical zone. In tangential section, the zoarium appears to consist of tortuous, inosculating bands which leave between them the openings for the zoœcia. The bands, representing the walls, seem to maintain a rather regular width, but the tubes between are irregular in size and shape, subcircular, oval, or even more or less tortuous. The structure of the walls is peculiar. In places, they are represented by what may be considered very large abnormal acanthopores, having a circular shape in section and a diameter about that of the entire wall. In the center is a relatively large tubular axis and about the circumference a few fairly regularly arranged granules which are slightly elongated and radially arranged. It appears to be the fusing of these acanthopores (?) that produces the continuous walls, which are intersected by similar granules, especially about the margins, and have distributed down the centers a row of similar axial tubes. When the zoœcia are cut longitudinally, the structure of the cortical zone appears to be more regular, consisting of the tubular cavities of the zoœcia alternating with bands of varying width representing the walls and separable into units by the tubules of the acanthopores. These large straight persistent tubular axes are a striking feature, and there are in addition granules like those of the tangential section, circular or elongated and either without conspicuous agreement in direction or directed more or less obliquely downward toward the tubular axis, showing that, if they are continuous fibers, the granules must run irregularly through the acanthopore-like mass.

There can hardly be a doubt that the unit of which the walls is constructed is the cylindrical body with small tubular axis and oblique fibres or granules. This structure may be interpreted as a small mesopore (the tubular axis) and a wall beset with granules, but the interpretation here tentatively adopted seems to be the more likely. Stellate acanthopores, somewhat comparable to these, are figured by Ulrich in *Bactropora simplex*.

Callocladia gen. nov.

This type forms hollow cylindrical branches with the walls made up of one or more layers. The walls of the zoœcia are thin in the immature region, much thickened in the mature region, with angular crests on the external surface. Acanthopores are fairly abundant, showing clearly on the exterior, rather obscure in thin sections unless the latter cut the walls where they are thin, in which case the acanthopores are striking and indent the cells. Mesopores are abundant, usually in groups of two or more. Hemisepta are present.

The superficial appearance of this organism is extremely suggestive of *Intrapora* (*I. basalis* and *I. undulata*), but the mode of growth, not bifoliate but in the shape of hollow cylinders, and the undoubted presence of acanthopores, etc., debars it not only from that genus but from the same family. The mode of growth, the presence of acanthopores and presence of hemisepta suggest a relationship with *Cœloconus*, in the Rhabdomesidæ, but the presence of abundant mesopores debars it from that genus and all but debars it from that family.

If the structures the nature of which is not clear but which are suggestive of hemisepta can be interpreted as perforated diaphragms, this form could find admission into the Batostomellidæ with the relationship probably closer to *Stenopora* than to the other members of the family. The mode of growth as small, hollow, cylindrical branches having very thin walls is rather alien to *Stenopora*, as is also the shortness of the zoœcial tubes and the increase by superposed layers, rather than by the extension of the tubes themselves. Mesopores are abundant—much more so than in any species of *Stenopora*. Tabulæ appear to be wanting or extremely rare, which is also uncommon in *Stenopora*, while the walls are strongly thickened in a solid mass, instead of by annulations. On the external surface also, they have an angular crest which gives the cells an appearance of being vestibulate. Acanthopores are rather more sparingly developed than in most species of *Stenopora*.

If the structures which suggest hemisepta have really that nature, *Callocladia* would clearly be debarred from the Batostomellidæ and would probably find place among the Rhabdomesidæ.

TYPE.—*Callocladia elegans*.

Callocladia elegans sp. nov.

Zoarium in the form of hollow tubes which vary in size in different specimens, the largest, however, rarely exceeding 5 mm. in diameter. The walls contract and expand more or less irregularly in the same specimen. Inner surface lined with an epitheca. Zoarium thin, 1 mm. more or less in thickness, made up of one or more layers each of which is from .43 to .70 mm. in diameter.

The zoœcia are oblique for a short distance, when they bend abruptly to a radial direction, increasing rapidly in size. The walls are thin where oblique and strongly and abruptly thickened where they have a radial direction. The appearance in fact is as if there were two distinct walls, the inner one thin and oblique, to which just back of its extremity is attached another, very much thicker and almost at right angles to it. The projecting end of the inner wall makes a structure like a hemiseptum, and there is evidence of another on the opposite side answering to it. On the external surface, the walls have an angular crest from which a slope descends on either hand to the rounded tubes. In thin section, they show a median line which is more or less distinct. The apertures are rather regularly arranged in oblique rows and come about 5 in 2 mm. Maculæ and monticules are absent. Owing to the thick walls, the zoœcia are subcircular or obscurely polygonal. The average diameter is .28 mm., but it varies from .21 to .35 mm. Mesopores are abundant, 2 or 3 occurring in the angles where three cells meet. In some cases, a row of mesopores separates a cell from that which lies above or below it on the branch, but laterally the zoœcia are in contact. The mesopores are of various shapes and sizes, their naturally angular outline being modified by the thick walls. Acanthopores are fairly abundant on the external surface, projecting as small granules from the angles of the cells. In thin section, they are rather obscured in the thick walls, with which they merge to a greater or less degree. Just below the thickened portion, however, they are again conspicuous and indent the cells. The occurrence of projections resembling hemisepta seems to be rather regular, one to a zoœcium, and they must be interpreted as perforated diaphragms, if this genus is to be admitted to the Batostomellidæ.

Cystodictya pustulosa var. arcta var. nov.

Zoarium growing in flat bifoliate branches which have a width of about 2.5 mm. and a thickness of about .5 mm. There is considerable variation in both these measurements, the width ranging from less than 2.5 mm. to 3 mm. or a little more, and the thickness from somewhat less than .5 mm. to nearly 1 mm. The branches divide frequently but irregularly, bifurcations occurring close together in some examples and far apart in others. My material, though abundant, is too much broken up to show the range of this variation, but 6 mm. is perhaps the average length between divisions. The zoœcia often appear to have no regular arrangement either longitudinally or diagonally. In some instances they occur in two oblique, intersecting series. Rarely they are developed on short, oblique ridges near the margin of the branch. The longitudinal order is perhaps less conspicuous than the oblique, and it is difficult to determine the number of longitudinal rows in which the zoœcia occur.

When determinable, from 6 to 8 seems to be the number, which varies according to the width. In parts of some specimens, the zoœcial openings seem to occur in rows which are neither longitudinal nor transverse but slightly inclined from a strictly longitudinal direction. The apertures are circular or slightly elongated, and, when not worn down, their margins are elevated in such manner as to give the surface a strongly pustulose appearance. Longitudinally about 4 apertures and 4 interspaces, or 5 apertures and 4 interspaces occur in 2 mm. They are separated on an average by intervals which are about equal to their own diameters (about .17 mm.), but vary from considerably less to double the diameter. The intervals between the apertures are smooth. Of longitudinal furrows or ridges there is no trace. In fact, the irregular distribution of the apertures would hardly be correlated with such superficial markings.

Orthotetes subglobosus sp. nov.

Shells attaining a rather large size, maximum width about 50 mm. Shape semicircular, transverse. Cardinal angles often rounded so that the greatest width is a little in front of the hinge.

Ventral valve generally flat or slightly concave, moderately elevated posteriorly, rarely distorted. Cardinal area nearly perpendicular to the plane of the margins. Pseudodeltidium narrow, higher than broad with a sulcus down the middle. Upon the inside, a long median septum unites with the two dental plates, thus forming with the pseudodeltidium a small chamber.

Dorsal valve convex. Often highly inflated, especially in the umbonal region.

Surface marked by thin, sharp radii separated by relatively broad, flat interspaces, crossed by rather strong, coarse, crenulating liræ. The radii are often strikingly and regularly unequal. In number and appearance, they vary greatly owing to the number of intermediate ones that happen to be present. In some specimens, only about 7 large subequal liræ can be counted in 5 mm., having broad interspaces between; in others, 7 with alternating small ones occur; and in still others, 13 or 14 rather fine subequal ones; but in still others, the latter number can be observed alternating with very fine initial liræ. As new liræ are not interpolated with absolute regularity, the count varies much within the broad limits indicated, depending not only upon what liræ are actually present, but also upon how many are regarded as primary and secondary, or even are sufficiently well developed to be counted at all.

Orthotetes subglobosa var. protensa var. nov.

This variety is based upon a single specimen distinguished principally by having a more elevated and distorted ventral valve than the normal. The height of the pseudodeltidium must have been about 11 mm. and a width below of 7 mm. The area is rather strongly inclined to the plane passing through the margins of the shell.

This specimen was found associated with a ventral valve having the low area and regular growth of the typical form, of which it will probably be best to regard it as a distinct variety. In addition to the typical specimen, several other examples have more or less doubtfully been assigned to this group.

Chonetes sericeus sp. nov.

Shell of medium size, a width of 16 mm. being about the maximum observed. Frequently rather transverse with somewhat extended hinge line; some specimens with proportionately greater height and more quadrate shape.

Convexity of ventral valve moderate. In some specimens, this valve is only slightly convex with an inconspicuous beak and presumably a rather high area. Occasionally in specimens of this type, the chief convexity lies towards the margins. In other specimens, the umbonal region is moderately vaulted and the beak fairly prominent. The cardinal spines are rather slender, strongly oblique, and there are probably four or five on each side.

Dorsal valve like the ventral in shape, varying from flat to gently concave.

Surface marked by fine radiating liræ of which some 13 to 15 occur in a distance of 2 mm. They are rather sharply defined and crossed by strong, somewhat irregular striæ of growth, which over some areas are prominent and sinuous. They are also specially noticeable on the cardinal angles, where the radii are apt to be faint or lacking for a considerable distance.

Strophalosia subcostata sp. nov.

Shell small, productiform. Ventral valve strongly arched; umbo flattened by attachment. Ears strongly depressed and rather spreading. Sculpture consists of moderately strong, coarse striæ of growth, of large spines upon the ears, which spring directly from the surface, and of interrupted costæ or elongated spine bases which end abruptly with the formation of a small spine at the anterior end.

Dorsal valve unknown.

Productus inflatus var. clydensis var. nov.

Shell rather small, often much produced and deeply enrolled. Fold and sinus more or less evanescent. Ears small, subquadrate.

Surface marked by fine, rigid liræ, about 16 in 10 mm. In specimens which are much produced, they seem to become evanescent anteriorly. In the ventral valve, a cluster of large spines occupies the ears, while a considerable number of smaller ones are scattered over the surface. The visceral area is crossed by transverse wrinkles which tend to be coarse, faint and irregular.

Productus inflatus var. coloradoensis var. nov.

?1890. *Productus boliviensis* (non d'Orbigny). Nikitin, Com. Géol. [Russia], Mem., vol. 5, No. 5, p. 57, pl. 1, figs. *4a*, *4b*, *4c*.
Gschelstufe: Near Moscow, Russia.

?1902. *Productus inflatus* (non McChesney). Tschernychew, Com. Géol. [Russia], Mem., vol. 16, No. 2, p. 261, pl. 28, figs. 1-6.
Gschelstufe: Ural and Timan Mountains, Russia.

1903. *Productus inflatus* (non McChesney). Girty, U. S. Geol. Survey, Prof. Paper 16, p. 359, pl. 3, fig. 1-1*b*, 2, 2*a*, 3.
Hermosa formation: San Juan region and Ouray, Colorado.
Weber limestone: Crested Butte and Leadville districts, Colorado.
Carboniferous: Glenwood Springs, Colorado.

1904. *Productus inflatus ?* (non McChesney). Girty, U. S. Geol. Survey, Prof. Paper 21, p. 52, pl. 11, figs. 5, 6.
Pennsylvanian (Naco limestone): Bisbee quadrangle, Arizona.

In 1903, I referred to McChesney's *P. inflatus* a group of shells from the Pennsylvanian of Colorado, expressing at the time a certain doubt whether they were actually identical with it. For this group I would now suggest the varietal name *coloradoensis.* The western variety is of different geological age and associated with a very different fauna from typical *Productus inflatus.* Intrinsically it is larger and broader and marked by much larger spines.

The Arkansas shells provisionally referred to the same variety are associated with *P. inflatus* in the Fayetteville shale and probably intergraduate with it. They are chiefly distinguished by being larger and broader, though, as the specimens thus far obtained are neither numerous nor perfect, other differences may develop with closer knowledge. I have observed, upon most of the specimens sufficiently preserved to show this character, a diagonal line of spines about where the ear may be said to join the body of the shell. This feature occurs in *P. inflatus* rarely, if at all, but I have called attention to a similar thing in *Productus semireticulatus* var. *animasensis.* There are few specimens about which one would hesitate whether to refer them to *P. inflatus* or to *P. inflatus* var. *coloradoensis,* and perhaps there would be fewer still if the specimens themselves were more perfect.

These Arkansas shells simulate typical *P. inflatus* var. *coloradoensis* rather closely. Much of the Arkansas material is broken or exfoliated, but I believe it does not have as numerous or as large spines as that from Colorado. The sinus is also deeper.

Productus arkansanus sp. nov.

The shells included under this title present so many variations that it is difficult to frame a general description of them. They attain a size which may be called medium or even rather large, but many of the specimens actually handled are small. In the young (small) stages, the shape is subquadrate and rather transverse, while in a mature condition, the length is sometimes greater than the breadth. Nevertheless, the transverse shape is in certain instances retained to the mature condition, while, on the other hand, the tendency to elongate is sometimes manifested at an early stage. The outline usually contracts toward the hinge, and the ears are small and inconspicuous.

Ventral valve strongly convex with gradually enlarging umbo. Of course, in the narrow specimens the umbonal angle is more acute than in the broader ones. Ears small and depressed. There is usually a broad, shallow, sometimes indistinct median sinus.

In the dorsal valve the shell is gently concave over the visceral area, more strongly flexed around its border. A median fold is usually present. The ears are small and indistinct.

The costæ vary greatly in character. They are usually rather irregular, with relatively broad striæ in between. At rather frequent and regularly increasing intervals they give off small spines and are swollen and elevated at the spines and constricted and depressed just in front, so that in some cases the surface looks as if marked less by continuous costæ than by elongated spine bases which terminate rather abruptly at the anterior end with the development of the spine which gave rise to them. This effect is more marked in some specimens than in others, and also in some specimens the costæ are finer and more closely arranged than in others. Toward the front, the costæ tend to be more regular and continuous. Distinct striæ of growth usually show upon well-preserved specimens, to which are in some cases added transverse wrinkles more or less irregular and obscure, except on the ears. In some cases, also, there are well defined, regularly arranged transverse bands. The arrangement of the spines is more regular in some specimens than in others, and occasionally they appear to occur in transverse rows, especially in connection with the sub-lamellose bands just mentioned.

In the dorsal valve, the sculpture is the reverse of that described. In the most strongly characteristic specimens, the external mold appears to be marked by sharply defined regular spine bases with prominent spines. In others, the appearance is more that of continuous costæ. Regularly concentric sub-lamellose bands frequently occur, and spines are developed on this valve, as well as on the other.

Productus arkansanus var. multiliratus var. nov.

One or two localities have furnished a phase of this species which seems to warrant discrimination as a distinct variety. It is characterized by being unusually large, broad and with very fine continuous liræ and small spines. The dominating form at these two stations, it is yet even there associated with examples which can most appropriately be referred to the original species, while with the latter an occasional specimen is found which, by reason of its finer markings, might perhaps be referred to the variety *multiliratus*. Because of this intergradation, more or less complete, the present form could hardly be considered more than a variety.

Diaphragmus subgen. nov.

This name is introduced for *Productus elegans* Norwood and Pratten, a specific name for which Worthen later substituted *cestriensis*. The general aspect of this species is that of *Producti* of the *semireticulatus* group, only somewhat abnormal in that the typical *semireticulati* are broad, subquadrate shells and marked by numerous regular concentric wrinkles passing across the visceral area from one large ear to the other. *P. elegans,* however, has a narrow, more gradually expanding shape; the ears are small and the concentric wrinkles few and irregular. The costæ are strong and subequal, but tend to be discontinuous over the visceral parts and to have the appearance of appressed spines. While not one of the typical *semireticulati* in expression, *P. elegans* is at least typical *Productus.* The diagnostic character is internal and consists of a partition passing completely across the interior of the shell. This structure appears to be an outgrowth of the dorsal valve from the geniculation, where the flattened visceral area abruptly joins the lateral areas. It lies in the same plane with the visceral area and appears, as it were, an extension of it.

This structure frequently forms a plane of dehiscence when specimens are broken out of the rock, the visceral area of the dorsal valve, the visceral area of the ventral valve and the diaphragm remaining on one piece, while the lateral and anterior extensions of both valves (which are almost in contact), together with the mold of the diaphragm and of the visceral area of the dorsal valve, remain on the other. The diaphragm and visceral area of the dorsal valve, while essentially on the same plane, are readily distinguishable, being separated by a slight ridge (or groove) and marked by different sculpture, the regular strong costæ of the external shell being replaced on the diaphragm by fine radiating striæ.

There is no doubt that this type should be distinguished from true *Productus,* but there may be some question as to whether it is not already covered by Waagen's genus *Marginifera.* Waagen's description reads as if *Diaphragmus* might be an extreme example of *Marginifera,* but there can hardly be a doubt, I believe, that *Diaphragmus* is something distinct from *Marginifera splendens,* the typical species of *Marginifera.* Indeed, I am inclined to suspect that Waagen, who apparently did not have access to specimens of the American species and was working from the literature alone, may have been led to misinterpret the figures and descriptions of *N. splendens* so as to imagine that the bevel of the dorsal valve was an internal feature exposed by fracture rather than an external feature which is shown on the outside of all perfect, well-preserved specimens. However this may be, it seems to me that *Marginifera* must adhere to the characters shown by *M. splendens,* and that that species is clearly a distinct type of structure from *Diaphragmus.*

TYPE.—*Diaphragmus elegans.*

Camarotœchia purduei sp. nov.

Shell rather large, a length of 15 mm. being about the maximum. Length and width nearly equal, the one being greater in some specimens and the other in others. Outline variable, subtriangular, subpentagonal or subovate, the greatest width being sometimes nearer the anterior end and sometimes about midway. Beak of the ventral valve small, suberect and somewhat flattened. Fold and sinus strongly elevated and sharply defined.

Surface marked by subangular plications reaching backward to the beaks. As a rule, 4 of these occupy the fold and 3 the sinus, but in many instances the fold has 3 and the sinus 2 plications. Rarely are 5 developed on the fold. When 3 are present, sometimes they are of equal size, but sometimes the median one is larger and more elevated so that the fold and sinus are pointed. In some cases, 3 of the mesial plications are equally elevated, while the fourth is developed on one side of the fold or on the other. In a few cases, there are 3 mesial plications and an additional one on either side, making 5 altogether. As a rule, the 4 plications are of equal size and elevation. The lateral plications number 5 usually, but occasionally 6 and sometimes 4 or even 3. The plications vary in different specimens in size and angularity. Some specimens are more tumid than others, and in some the front is rounded downward, thus obscuring the fold, which is usually highly and abruptly elevated.

Although from this it will be inferred that specimens might be selected to present rather widely different expressions, as a whole these shells make up a fairly uniform group.

Camarotœchia purduei var. laxa var. nov.

In a few instances, there have been obtained specimens which seem to deserve recognition as a distinct variety, though their relationship to *C. purduei* can not be doubted. They have about the same number of plications similarly arranged, their chief claim to distinction resting on the fact that while in the typical variety the plications are rather angular, in the present one they are obsolescent, depressed-convex and separated by narrow, shallow striæ. The plications in this condition appear to be somewhat coarser, but apparently they are not so, as the number remains about the same.

Harttina brevilobata var. marginalis var. nov.

The shells referred to *H. brevilobata* are only two in number. Our collection contains, however, a series of specimens rather numerous, which are of the same general type as the others, but differ in being, though larger, much less convex and marked by less deep fold and sinus and less distinct lobation. Even the examples in which these characters are most marked are evidently inferior in their development to the specimens upon which Swallow bases his description of *Terebratula brevilobata.* In the smaller examples, of course, the convexity is still lower, and no trace of lobation is to be seen.

While recognizing the relation of these faintly plicated shells to the two examples which more closely agree with Swallow's description, it has seemed to me from the evidence at hand that it would be well to recognize them as representing a distinct variety.

Harttina anna var. graciliformis var. nov.

Under this title, I am including two specimens which I at first, though really against the evidence in hand, provisionally identified with *Dielasma gracile.* Their size is much smaller, but their shape is almost exactly that of the larger shell, elongate and subpentagonal, with the greatest width near the middle or a little below. No fold or sinus appears to have been developed. The ventral valve has the usual dental plates and the dorsal a median septum.

Harttina indianensis var. exporrecta var. nov.

Associated with examples which have been referred to *Harttina brevilobata* var. *marginalis* and to *H. indianensis*, I have in several instances found shells more or less closely resembling them, but distinguished by having a broader, rounder shape. Neither valve has a distinct sinus, but traces of a sinus can sometimes be noticed in both valves.

So far as observed, the specimens referred here have only the median septum of Harttina without the lateral plates and platform of Dielasma.

Dielasma formosum var. whitfieldi var. nov.

This species is abundant at two or three localities almost to the exclusion of other types of *Terebratula.* It is one of the poorly characterized forms, having a broadly ovate shape and nearly obsolete fold and sinus. The greatest width is usually below the middle, and the outline in front is often somewhat flattened. The sinus, when present, is developed only toward the front, where it is shallow and undefined. Ventral beak small. The convexity varies from rather low to rather high. There is also variation in the width, some specimens being wider than others.

Dielasma formosum var. seminuloides var. nov.

This form resembles *D. formosum* var. *whitfieldi,* except that it is much more spreading. Though the variety *whitfieldi* manifests a tendency to pass into these rotund forms, some of them could not, I think, with any propriety be included immediately with the typical specimens or with the variety *gracile*. Nevertheless, it is difficult to establish any line between them, partly, no doubt, because of imperfect material, whose real characters must be more or less estimated, but partly also because of intermediate specimens. The specimen selected as the type has both valves of nearly equal convexity. It has a subpentagonal shape with a distinct, though ill-defined, sinus in the ventral valve. Another example is still more rotund.

Dielasma planiconvexum sp. nov.

Shape broadly subovate or spatulate, length but slightly in excess of the width. Outline regularly rounded. Ventral valve moderately convex longitudinally and transversely. Dorsal valve nearly flat, slightly convex in a transverse direction. Fold and sinus practically absent, although the anterior portion of the ventral valve is flattened out and slightly bent upward, causing an almost imperceptible deflection of the margin.

This species is described from an imperfect specimen.

Ambocœlia planiconvexa var. **fayettevillensis** var. nov.

Shell small, subcircular and transverse. Width probably always slightly in excess of the length and in some specimens considerably so. Cardinal angles rounded; hinge much shorter than the width below. Greatest width occurs about the mid-length or a little posterior to it.

Ventral valve only moderately convex for the genus and rapidly expanding. Beak rather small, not strongly elevated, inclined backward, or incurved. The area is not very distinctly defined, and it is intersected by a moderately broad delthyrium, much higher than broad, which occupies from one fourth to one third of its width at the cardinal line.

Dorsal valve gently convex to subplanate, with a fairly distinct though narrow sinus developed near the front of mature and half-grown specimens.

The shells of this genus vary so little that the greater portion of a detailed description of the present form would apply to most of its species.

Spiriferina subelliptica var. **fayettevillensis** var. nov.

Shell small, rarely exceeding 12 mm. in width, transverse. Cardinal angles rounded with the greatest width a little anterior.

Dorsal valve moderately convex.

Ventral valve strongly convex with a high, well-defined area which is considerably narrower than the greatest width. Area slightly convex and strongly oblique to the plane of the valves. Foramen rather broad. Beak strongly projecting and moderately incurved.

The surface is marked by rather few, very strong, high, rounded plications. The fold and sinus are simple and distinctly larger and higher (especially the latter) than the lateral plications. The sinus is flattened or perhaps very obscurely elevated along the median line, but no median plication is developed in it, and no corresponding sulcus has been observed along the fold. The lateral plications number from 5 to 7 on either side of the sinus. The sculpture consists of regular, transverse, imbricating lamellæ.

Hustedia multicostata sp. nov.

Shell rather large, a length of 13 mm. being about the maximum observed. Shape regularly ovate, broad in some specimens, narrow in others. Convexity moderate to high, about equal in both valves.

The ventral valve has a distinct though undefined sinus and a beak moderately projecting and incurved.

The dorsal valve is without a distinct fold. Its cardinal line is short.

The surface is marked by from 25 to 32 gradually enlarging costæ. When unexfoliated, these are high and narrow and separated by striæ of about their own width. When exfoliated, the ribs are narrow and abruptly elevated from broad, flat interspaces.

Composita subquadrata var. lateralis var. nov.

The shells included under this title are rather large with a subquadrate shape and strongly elevated fold and sinus. The sides are extended and sharply rounded.

In the ventral valve, the sinus begins as a narrow depression and remains so until the shell is about half grown. Then it becomes the median line of the real sinus, which then develops with rapid increase of width and depth. The fold is developed with equal rapidity, when it once begins to appear, being defined by two strongly diverging grooves, which curve downward, and, if it were not for the fact that they appear to bend backward at their posterior end, are so directed that they would intersect some little distance in front of the posterior margin.

Composita acinus sp. nov.

Under this title is subsumed a group of diminutive shells which have, in spite of their size, characters indicating maturity. They are elongate, ovate and highly convex. The ventral valve has a fairly prominent incurved beak and a moderately deep, narrow sinus. The dorsal valve does not develop a distinct fold to correspond to the sinus of the ventral, the effect of which is often to produce an emargination of the anterior outline, an effect which is in some instances enhanced by the circumstance that the dorsal valve not only does not develop a fold but sometimes develops a median sulcus of its own.

Cliothyridina sublamellosa var. atrypoides var. nov.

Shell rather small, a length of 17 mm. being about the maximum. Length and breadth nearly equal; sometimes one is observed to be distinctly greater and sometimes the other. The greatest width is usually about midway, but occasionally it is posterior to the middle, the shell having rather prolonged cardinal slopes which join the lateral outline in more or less distinct shoulders.

The ventral valve is moderately convex with a rather small, not strongly incurved beak. A fairly deep, though undefined, sinus is a constant feature in mature shells.

The dorsal valve is apt to be gibbous at maturity. A moderately strong fold is present, though seldom conspicuous except along the front margin. Sometimes it is quadrate and comparatively well defined, sometimes rounded and scarcely distinct from the general convexity, very rarely low with a faint median sulcus.

The surface has the usual spinose lamellæ, which are apparently rather crowded. Most of our specimens, however, are exfoliated and the sculpture is obscure. In this condition, the surface is apt to appear nearly smooth; sometimes with more or less crowded but regular concentric ridges; sometimes with more or less discontinuous radiating costæ and sometimes with both, so that a cancellated effect results. The shell appears to be thick and not pearly.

Cliothyridina elegans sp. nov.

Shell rather small, probably not exceeding 17 mm. in width. Regularly, though not strongly, transverse. Greatest width posterior to the middle. Often the hinge is extended, and the greatest width is just in front. Shape lenticular.

The ventral valve is transversely subelliptical with a small, not very strongly incurved beak. The convexity is low. A rather narrow, shallow, undefined sinus is developed toward the front.

The dorsal valve is transversely elliptical, gently and regularly convex. Instead of a fold, there is usually a shallow, linear, median depression, creating with the ventral sinus an emargination of the anterior outline.

The surface is marked by fine, sublamellose liræ, a few of which are more prominent than others.

Solenopsis nitida sp. nov.

Shell of medium size, linguliform, very transverse. Width nearly three times the greatest height. Convexity low, compressed posteriorly. Beak very small and inconspicuous, situated posterior to the front margin by one half or one third the height. Anterior end apparently gaping, especially above. Upper and lower margins subrectilinear and parallel over the median portion, curving together symmetrically toward the posterior extremity, and abruptly rounded at the end. Anterior extremity broadly and regularly rounded.

Surface marked by concentric striæ and very fine concentric liræ.

Sanguinolites simulans sp. nov.

Shell rather small, very transverse, subelliptical. Convexity moderate. Umbonal ridge not very prominent, but very distinct. Post-cardinal slopes compressed. Beaks small, strongly incurved, situated near the anterior extremity. Cardinal line long, apparently over two thirds the entire width, nearly straight. Lower border gently convex, nearly parallel to the hinge, bending upward more strongly behind. The short anterior end is strongly rounded beneath the beak. The posterior outline is doubly truncated, the lower truncation being nearly vertical and the upper slightly oblique, so as to make an obtuse angle with the hinge. There appears to be a small but distinct lunule, while the shell back of the beaks is sharply inflected so as to form an elongated escutcheon the entire length of the hinge line.

The shell is thin, and the surface is marked by strong, regular, subequal, concentric plications, extending from the front to the umbonal ridge. At the umbonal ridge they abruptly cease, the post-cardinal slope being marked by much finer, less conspicuous striæ, which are, however, stronger and coarser than growth lines. The umbonal ridge is an angular plication. A second somewhat similar radiating line divides the post-cardinal slope about midway. It is scarcely distinguishable as an elevation, however, though very noticeable as a line along which the striæ and the posterior outline abruptly change direction.

Sphenotus branneri sp. nov.

Shell small, transversely subovate, strongly contracting toward the front. Greatest width about twice the greatest height or a little more. Convexity strong. Umbonal ridge indistinct. A constriction more or less pronounced passes across the shell, meeting the lower border a little anterior to the middle. The beak is small, strongly depressed and almost terminal. The cardinal line is nearly straight or gently convex, about three fourths of the entire width. The lower border converges with it toward the front, having a slightly sinuous course. The posterior outline is strongly and rather regularly rounded, sometimes more or less straightened or obliquely truncated above. The anterior outline below the almost terminal beaks is narrow and strongly rounded.

The surface is marked by radiating plications or costæ, which are confined to the posterior portion back of the constriction. The highest of the plications marks an inflection of the shell near the hinge to form a long, rather broad escutcheon. Below and anterior to this, there are about nine regularly disposed costæ, diminishing in strength toward the front. Where well preserved, the surface shows traces of fine radial liræ intermediate with the costæ. In most specimens, these and all but three or four of the costæ are obscured. There are also numerous concentric striæ and sharp, regular, concentric liræ.

The internal characters are unknown, save that some specimens show a large anterior scar.

Sphenotus washingtonense sp. nov.

Shell of medium size, subquadrate, very transverse. Greatest width distinctly more than twice the greatest height. Cardinal line straight, somewhat longer than half the greatest width. Lower margin subrectilinear and parallel with the hinge, curving up rather strongly in front. Anterior outline concave above for about one third the height, rather strongly convex below, more abruptly rounded near the emarginate portion. Posterior outline somewhat obscurely truncated in a broken line. The upper truncation, which covers about one half the height, is very oblique, while the lower is nearly perpendicular to the lower margin. No distinct angles are formed where the lines join. The convexity is high. The beak, rather small and strongly incurved, is situated but a short distance posterior to the margin. The umbonal ridge is strongly elevated and angular. A second distinct, though not very prominent ridge divides the post-cardinal slope longitudinally, and the shell is abruptly inflected near the cardinal line to form a large, long escutcheon with sharply angular outlines. The post-cardinal slope is somewhat compressed, as is also the anterior portion. A broad, shallow constriction occurs just in front of the umbonal ridge.

The surface is marked by regularly arranged, moderately fine and deep concentric striæ, which toward the front and back, and possibly all over when the preservation is good, are separated by rather thin, high, concentric liræ. Traces of fine radial liræ have been seen on the post-cardinal slope of one or two small specimens.

There is a large subcircular anterior scar.

Sphenotus dubium sp. nov.

Shell small, transverse, subquadrate. Greatest width twice the greatest height. Beak about one fourth the width posterior to the margin, small, strongly incurved. Convexity high, somewhat compressed posteriorly. Umbonal ridge rounded. Mesial portion, or the portion just anterior to a line from the beak to the middle of the base, somewhat flattened or slightly depressed into a broad, shallow constriction. Anterior extremity bent inward and downward to form an elongated lunule with very sharply defined, angular border. A long narrow escutcheon is similarly formed along the margin behind the beak. The post-cardinal slope descends somewhat abruptly and is divided longitudinally by a more obscure ridge.

The hinge line is straight nearly three fourths the entire width of the shell. The lower margin is gently convex, straightened through the middle, subparallel to the hinge, but bent upward behind, so that this end is distinctly narrower than the other. Posterior extremity truncated by a nearly straight outline very slightly oblique, making a distinct cardinal angle somewhat greater than 90°. Anterior outline abruptly truncated by the nearly straight oblique line formed by the flexure of the shell which produces the lunule; sharply rounded below.

Surface marked by rather strong, more or less irregular and unequal concentric striæ, which are distinctly weaker over the post-cardinal slope, and by fine papillæ which tend to have a radial arrangement.

Sphenotus? meslerianum sp. nov.

Shell rather small, subcuneate, transverse. Greatest height a little less than half the extreme width. Strongly convex; umbonal ridge subangular, distinct. Post-umbonal slope somewhat compressed. A slight constriction defines the anterior third of the shell. The beak is about one third the width back from the front margin, small, strongly incurved. The anterior extremity is nasute. The hinge is straight, about one half the entire width. The lower margin is gently and regularly convex. The posterior outline is gently convex, truncating the shell with a slight obliquity such as to make the posterior superior angle somewhat obtuse and the posterior inferior angle somewhat acute. The anterior outline is abruptly rounded and concave under the beak.

The surface is marked by very fine subequal concentric striæ.

Edmondia equilateralis sp. nov.

Shell very small, transversely elliptical. Width slightly less than one half the greatest height. Hinge line straight, about one half the width. Basal margin gently convex. Anterior and posterior outlines strongly and regularly curved, nearly equal, gradually merging with the outlines above and below. Convexity rather high and regular. Umbonal ridge indistinct. Beak small, depressed, scarcely projecting beyond the hinge line, only slightly posterior to the margin.

Surface marked by fine, strong, sharp, subequal concentric liræ. The internal structures are not known, and the reference to the genus *Edmondia* is therefore provisional.

Cardiomorpha inflata sp. nov.

Shell of medium size, the largest specimen having a length along the umbonal ridge of 29 mm. Convexity high, equal in the two valves. Upper and lower margins gently convex, somewhat converging toward the front. Posterior margin subrectilinear, strongly oblique, merging with the cardinal border in a gentle curve and with the inferior border in an abrupt turn. Anterior end subtruncate. Beaks nearly terminal. Inferior-anterior angle sharply rounded. Convexity high, especially along the broad, undefined umbonal ridge, from which the shell descends abruptly to the hinge anteriorly and more gently posteriorly. A distinct, though ill defined, sinus passes diagonally across the shell just in front of the umbonal ridge, meeting the lower margin about midway.

Surface marked by numerous closely arranged subequal lamellose lines.

Leda stevensiana sp. nov.

The size is small, a larger specimen when complete having a width of 10 mm. and a smaller a width of only 7 mm. The greatest height is one half the width. The beak is situated about one third the width back from the anterior outline. The lower margin is gently convex, the posterior extension long and subangular, the anterior end symmetrically rounded. The upper posterior border is gently concave. The convexity is moderate and the surface marked by very fine, somewhat inosculating liræ.

Of this species, our collection contains but two specimens, both right valves, one of them complete but small and failing to show the sculpture, the other larger and retaining the sculpture, but imperfect at the anterior end.

Paleoneilo sera sp. nov.

Shell small, attaining a width of 12 mm., transverse, subovate. Greatest width about 1.5 times the height. Beak about one third the width back from the anterior extremity. Lower margin strongly convex, straighter toward the posterior (longer) end. Cardinal line nearly straight, strongly converging with the lower border. Posterior extremity narrow and abruptly rounded. Anterior extremity broadly and regularly curved. Convexity rather high; umbo small and strongly incurved.

The surface is marked by regular and closely arranged concentric lines.

Cypricardinia fayettevillensis sp. nov.

Shell small, attaining a width of 10 mm., which is about twice the greatest height. Shape subrhomboidal. Cardinal line straight, about one half the entire width. Ventral border straight in the middle, rounding upward at the ends, more rapidly at the anterior end. Posterior extremity obliquely truncated with a broad, rounded posterior inferior angle and a distinct posterior superior angle of about 150°. Anterior extremity strongly and regularly rounded under the nearly terminal umbo which is large and strongly incurved. Convexity high. Umbonal ridge rounded, undefined. A distinct constriction passes across the shell, meeting the ventral margin a little in front of the middle.

Surface marked by a few (about 9) strong, regularly arranged striæ which give the shell a lamellose appearance. No trace of radial sculpture has been observed.

Conocardium peculiare sp. nov.

Shell small, highly convex, triangular. Length along the umbonal ridge distinctly less than the width along the hinge. Umbonal ridge broad, well defined on both sides, prominent, moderately oblique. Beaks subcentral, nearer the anterior end. Umbonal ridge sharply defined from and elevated above the posterior portion. On the anterior side, the shell is strongly compressed.

The sculpture is different on the three portions of the shell thus defined. On the anterior side, the liræ are rounded, separated by angular striæ and rapidly decreasing in size toward the extremity. They do not conform to those of the umbonal ridge which is defined by an unusually large rib on the anterior side, but run obliquely, so that new ones are introduced at intervals toward the ventral margin. On the umbonal ridge itself, the costæ are rather smaller than on the anterior portion and separated by broad, flat intervals, about twice the width of the costæ. Two or three of the latter are crowded together near the anterior boundary of the ridge. The costæ on the posterior portion are broader than those on the anterior, flat-topped and separated by narrow, rather flat striæ. The whole surface is crossed by fine, equally spaced, lamellose, concentric lines.

Caneyella? peculiaris sp. nov.

Shell small, the largest specimen referred here having a length of 15 mm., equivalve, oblique, the axis sloping slightly backward. Hinge line nearly as long as the greatest width, much longer behind than in front. Outline broadly and regularly rounded below and in front, curving strongly inward toward the hinge, where it is slightly straightened. On the posterior side, it is convex below and concave above, sloping strongly outward in a gentle curve below the broad posterior wing. Convexity moderately high. Anterior wing small and undefined. Posterior wing large, triangular, usually though not always abruptly depressed and distinctly defined.

The sculpture consists of fine regular concentric undulations or striæ and fine radiating liræ. The undulations are shallow and rounded, and they are broad in comparison with the angular ridges which separate them and which are lamellose at least toward the sides. The radial sculpture is on a finer scale than the concentric, subordinate to and more or less interrupted by it. The radii are very fine and slender with relatively broad interspaces. They seem to die out toward the posterior side of the left valve and to be replaced by a few of larger size on the posterior wing of the right valve.

Aviculipecten squamula sp. nov.

Shell small, the largest specimen referred here having a length of 7 mm.; length and width about equal; slightly oblique, somewhat inclined backward. Hinge line but little shorter than the greatest width. Outline gently contracted below the hinge, then widening again. Lower extremity broadly rounded. Convexity low. Wings broad and undefined, the posterior one having perhaps for its boundary a low, narrow fold extending obliquely from the umbo to the posterior margin not far below the hinge line.

The sculpture consists of fine, regular, concentric striæ crossed radially by fine irregular costæ so obscure that they are made out with more or less difficulty. They are interrupted and obscured to some extent by the concentric markings.

Aviculipecten jennyi sp. nov.

This form resembles *A. squamula*, having a subquadrate shape, a hinge nearly as long as the width below, and subparallel sides with scarcely any deflection defining the wings. The convexity is low. The umbo small and inconspicuous and the axis nearly perpendicular to the hinge line. In one specimen, the posterior wing has a fold as in *A. squamula*.

The sculpture consists of somewhat irregularly distributed costæ with relatively broad, flat interspaces. The costæ, though low and rounded, are well defined, but they do not extend onto the wings. There are also very fine, equal, closely arranged, concentric liræ and numerous stronger incremental striæ, especially conspicuous over areas near the hinge where the costæ are not developed.

Aviculipecten multilineatus sp. nov.

Shell small and subquadrate, about as in *A. squamula*, which is closely related. Convexity moderate; hinge long, but little shorter than the greatest width, which is about equal to the greatest length. Umbo moderately elevated. Axis but slightly oblique, inclined backward. The wings are large, subquadrate and poorly defined either upon the surface or by any deflection in the outline. The posterior one is bounded by a fold which in fact appears to be double.

Surface marked by very numerous, fine, sharply elevated, radiating liræ, which decrease in size and definition toward the sides and are not developed at all on the posterior wing. The intervening striæ are about equal in size and shape to the liræ. There are also many closely arranged, more or less irregular and unequal concentric striæ, finer than the radiating liræ and subordinate to them. Occasional varices of growth sometimes deflect the liræ and give them a wavy appearance.

Aviculipecten morrowensis sp. nov.

Shell small, a length of 11 mm. being about the maximum observed. Length and breadth nearly equal, or the breadth a little in excess. Hinge long but considerably shorter than the width below. Axis slightly inclined backward, with a greater development of the shell behind than before. Wings broad, undefined either by being abruptly depressed or by a sinus in the outline which is nearly straight and slightly oblique on the anterior side, slightly concave and strongly oblique on the posterior side. The lower part of the outline is regularly rounded. The anterior wing is larger than the posterior. The convexity is low and the umbones small and inconspicuous.

The surface is crossed by numerous exceedingly fine liræ which are scarcely visible without a lens. These are sharply elevated, rounded, with interspaces of about their own width, and they are in some cases slightly wavy. They bifurcate occasionally and thus tend to form groups or fascicles which in one specimen are visible to the naked eye as very obscure, regularly arranged costæ, of which there appear to be six or seven. The radii are also more or less alternating. They are crossed in some cases by regular, fine, sublamellose, concentric liræ, which are differently arranged in different examples. In one specimen, they are much farther apart than the radiating liræ; in another, only slightly farther apart. In most examples, they do not appear at all, the concentric markings consisting of fine, incremental striæ, of which a few at irregular and distant intervals are stronger than the rest. On the wings, the radii become very obscure, while the concentric striæ are intensified and conspicuous. In some specimens, the radii are sharp and strong; in others, possibly by exfoliation, they are more obscure. It may be owing to the same causes that the lamellose concentric liræ appear to be absent.

Aviculipecten inspeciosus sp. nov.

Shell small, a length of 16 mm. being about the maximum observed; length and breadth nearly equal. The hinge is rather short, about one half as long as the greatest width. The axis seems to be curved so that the greater development of the shell is on the anterior side. The posterior wing is small and not defined by a sinus in the outline. The latter contracts strongly as it approaches the hinge, near which, however, it appears to be somewhat straightened on the posterior side. On the anterior side, it rounds strongly inward to the base of the anterior wing, where it changes direction, becoming nearly straight and sloping gently inward (from below) so as to meet the cardinal line at a slightly obtuse angle. The convexity is rather high. The posterior wing is small, depressed, oblique and undefined; the anterior wing larger, more abruptly depressed and therefore more sharply defined.

The sculpture consists of rather indistinct, subequal, radiating costæ, becoming finer and fainter toward the sides, which, with the wings and umbonal portion, appear to be uncostate. The costæ are relatively broad and flat and the striæ between them narrow and shallow. Concentric markings are indistinct or absent.

Cypricardella subalata sp. nov.

Shell small, subquadrate, transverse. Width about 1.5 times the height. Beak prominent, about one third the width posterior to the margin. Hinge line straight, two thirds of the width. Lower margin gently convex, nearly parallel to the hinge. Posterior outline almost vertically truncated, the posterior cardinal angle being if anything rather acute than obtuse. Lower margin bends up strongly in front to about one half the height, from which point, by an abrupt change of direction, the outline becomes concave to the beak.

The convexity is moderate to low. There is no distinct umbonal ridge. The post-cardinal portion is, however, somewhat compressed, and a faint constriction crosses the shell to about the middle of the base. Probably there is a well-defined lunule beneath the beak.

The surface is marked by relatively coarse, deep, regular striæ, separated by thin lamellose ridges. In the type, this sculpture dies out along the line where the umbonal ridge should lie, and the post-cardinal slope is crossed only by very fine striæ, but in other specimens it appears to be persistent to the hinge line.

Euconospira disjuncta sp. nov.

Shell of medium size. Maximum diameter 23 mm. Height 20 mm. Volutions about 7, gradually enlarging. Umbilicus small, open (?). Peritreme section very transverse, subrhomboidal, gently concave on the upper interior side, nearly straight on the upper exterior side, gently convex on the lower exterior side and strongly convex on the lower interior side. The upper interior surface slopes gently downward; the upper exterior surface slopes strongly downward in the opposite direction, and the lower exterior surface slopes gently downward. The periphery is therefore acutely angular and carries a narrow slit band defined by sharply projecting edges. The volutions do not embrace quite to the slit band, so that the conical shape of the shell, as a whole, is broken into steplike descents. The peripheral portion on which the slit band occurs is rendered more or less carinate by two relatively narrow sulci, one above and one below, of which the latter is the more conspicuous, because of being more distinctly defined on its outer side, where there is a fairly distinct shoulder. It is up to this shoulder that each volution embraces the preceding one.

The surface is marked by regular transverse striæ having a gently convex curvature and a strong backward direction. On the lower surface of the peritreme, they have a sigmoidal curve, concave toward the band and convex toward the umbilicus. They also have a strong backward sweep, so that the aperture is very oblique. In crossing the slit band, they make strong, regular crenulations, which do not extend onto the elevated edges of the band. Traces of revolving lines are present also, especially on the lower surface.

Bembexia lativittata sp. nov.

Shell small, subglobose, consisting of three or four rather rapidly expanding volutions. The largest specimen seen has a diameter of about 5 mm. The height is equal to the greatest diameter or a little greater. The spire is about one third the entire height. The sutures are deeply depressed. The peritreme section is very nearly circular except for the impressed zone, somewhat flattened above, regularly rounded below. The slit band is very broad, situated on the periphery, defined by thin elevated edges.

The sculpture consists of fine growth lines which are fasciculated at regular intervals, producing transverse costæ. These are more distinct above the band than below, and near the suture they are apt to be especially strong, forming little elongated nodes. They slope backward gently from the suture to the band and are curved, presenting the convex side toward the aperture. On the band, they are distinct and rather strongly concave, but assume the convex curve below and are nearly transverse.

Patellostium lævigatum sp. nov.

Shell rather small, rapidly expanding. At maturity, the growth appears to be rather straight than involved, and the widely expanded lip extends completely around the aperture and is continuous, though with a slight emargination, on the inner side. Umbilicus small. Slit band not elevated above the general curvature, except toward maturity, when it is raised into an angular ridge.

Surface without radiating striæ, it would appear, and with only fine incremental lines. These indicate that the aperture has a slight median insinuation, with a shallow notch where the band occurs.

Oxydiscus venatus sp. nov.

Shell small, sublenticular. Whorl section helmet-shaped. Sides somewhat flattened, strongly rounded inward at the broad (?) umbilicus, regularly converging to the periphery, which is keeled, the keel being defined on either side by a slight though distinct groove and bearing a median ridge down its center. The sculpture consists of costæ which have a transverse direction for one third the distance across the side and then are strongly and abruptly bent backward. This angular change of direction taking place at a corresponding point causes the surface to appear broken into a distinct band about the umbilicus, an appearance which is enhanced by the fact that after the backward turn, the costæ abruptly become much finer, and some of them bifurcate so that the median portion of each side is more finely and more closely costate than the band near the umbilicus. Over the broad, carinated portion, however, the costæ again become coarser, stronger and more distant, some of them dying out to allow this transformation to be effected.

Anomphalus? discus sp. nov.

Shell rather large, discoidal. Diameter 10 mm. Height 3.5 mm. Spire flattened. Volutions probably 4 or 5 in number, rather rapidly expanding. Peritreme section transversely elliptical with slightly pointed ends; flattened above, subangular on the periphery, about one third of the upper surface depressed by contact with the preceding volution. The volutions are embraced up to the keeled periphery, so that the top of the shell is nearly flat. Suture scarcely depressed. Umbilicus probably closed. Surface without ornamentation.

Platyceras subelegans sp. nov.

Shell small, rapidly enlarging, completing about one half a turn, more strongly curved at the apex, but very slightly spiral, broad on the outer side, contracting toward the inner, so that the section is subtriangular; marked by numerous longitudinal plications, especially by a narrow peripheral carina defined by two deep sulci and more persistent toward the apex than the others. Surface crossed by lamellose concentric lines whose direction is made very sinuous by the plications.

Orthonychia compressa sp. nov.

Shell of medium size, oblique, conical, compressed, nearly complanate or bilaterally symmetrical, very rapidly enlarging and slightly bent, making one half a volution or less. Cross section subelliptical, very much longer than broad. Surface nearly smooth, marked only by obscure sublamellose growth lines. No costæ or spines.

Two specimens have been included in this species, each having certain individual peculiarities. The larger contracts distinctly toward the outer or convex edge of the shell, while the smaller is more nearly symmetrical, if anything, has the external side somewhat broader and marked by an obscure carina defined by two faint grooves. In this specimen also, the aperture appears to have been rather strongly oblique, one side projecting considerably farther than the other.

Paraparchites nickelsi var. cyclopea var. nov.

This species is represented primarily by an extremely large specimen, which agrees with *P. nickelsi* in most characters, except that it is very much larger than any of the associated fossils referred to that species, and the shell is much more coarsely pitted or punctate. The left valve has the base of a well-developed spine, but the right seems to be without a spine. This specimen clearly shows a small subcircular, undefined muscle (?) spot, situated near the center of the shell. It is characterized by being slightly depressed and by being smooth, without the punctæ with which the rest of the surface is covered. Traces of a similar spot have been observed also upon specimens referred to *P. nickelsi*.

Primitia fayettevillensis sp. nov.

Shell small, transverse, subquadrate. Lower margin gently convex, converging anteriorly with the long, straight hinge line. Anterior extremity strongly rounded. Posterior extremity obliquely truncated, projecting. Convexity high. Umbilical pit deep, elongated but not continued to the hinge, posterior to the middle.

Primitia seminalis sp. nov.

Shell small, transversely subovate. Cardinal line straight or nearly so, converging strongly toward the front with the gently convex lower margin. Anterior end sharply rounded. Posterior end broadly and rather regularly rounded. Post-cardinal angle distinct. Convexity moderately high, with a flattened band about the margin. This band is narrow and sharply defined around the potserior portion of the shell, broad and not well defined at the front end, narrow and ill defined along the middle of the dorsal and ventral borders. Central pit rather large, subcircular, poorly defined, situated very near the middle of the convex portion, slightly above and distinctly posterior to the middle of the entire shell.

Halliella? retiferiformis sp. nov.

Shell small, subrhomboidal. Dorsal border long and straight. Ventral border gently curved along the middle, strongly curved at the ends, converging anteriorly with the cardinal line. Anterior extremity strongly rounded. Posterior extremity more broadly rounded, subtruncate. Convexity high and inflated at the anterior end, more gentle across the broad posterior end. A deep, somewhat elongated pit is situated a little above and distinctly posterior to the middle. It lies near the dorsal border without apparently extending to it. The shell posterior to the pit is elevated into a sort of low tubercle.

Surface rather coarsely reticulate.

Kirkbya Jones

The genus *Kirkbya* has for its type the species *K. permiana,* which is distinguished by having somewhat the shape of a parallelogram, but with the posterior end higher than the anterior. The obliquity is backward. There is a subcentral muscular pit. The surface is reticulated, and the free margins are provided with one or two flanges. The right valve is larger than the left and overlaps it on the ventral border. With this species were associated in the same genus other forms presenting very considerable differences in sculpture and general expression.

A number of species more or less resembling the English ones have been found in the lower Fayetteville fauna, but they present differences from one another which make it undesirable, in my judgment, to include them all in a single genus. Three groups of generic or subgeneric rank can in fact be distinguished. One of these seems to have the essential characters of typical *Kirkbya* and includes *K. lindahli* var. *arkansana, K. oblonga* var. *transversa, K. reflexa* and *K. simplex.* Another group which it is proposed to call *Amphissites* has the two valves equal, neither overlapping the other. The surface is reticulate, but is also marked by prominences and projecting lamellæ. Only one species belongs to this group, *A. rugosus*. A third type has the surface marked by relatively very coarse, oblique, inosculating costæ and has the two valves unequal, but the left overlapping the right, just the reverse of typical *Kirkbya*. This group, *Glyptopleura*, includes *G. inopinata* and *G. angulata*.

I have not been able definitely to ascertain to what family it has been the practice to refer the Kirkbyas, but I have the impression that they have been considered as belonging to the Beyrichiidæ. It seems to me a question deserving careful consideration whether these shells do not constitute an independent family, the Glyptopleuridæ. Indeed, the differences between *Glyptopleura*, on one hand, and *Kirkbya* and *Amphissites*, which are doubtless more closely allied to one another than to *Glyptopleura*, on the other, are such as to suggest that careful revision might even prompt the erection of a third family, the Kirkbyidæ.

Kirkbya lindahli var. arkansana var. nov.

The general appearance and sculpture are like those of *K. lindahli*, though the size is much smaller and the width proportionately greater. The shape is subrhomboidal, narrowing slightly toward the front, and with a distinct backward swing. The surface is finely checkered as in *K. lindahli*, and there is a subcentral pit. The right valve overlaps the left on the free margins. The double rim shown by Dr. E. O. Ulrich's figures seems to be lacking, and the ventral border of the left valve is rather abruptly infolded for a short distance toward the middle. Because of its smaller size, its lack of marginal bands and its infolded margin, I am disposed to regard this as varietally distinct from *K. lindahli*.

Kirkbya oblonga var. transversa var. nov.

Our collection contains but a single specimen of this species, which is so similar to the form which Dr. Ulrich identified as *K. oblonga* that I am a little doubtful whether the varietal distinction here suggested is altogether justifiable. The shape is strongly transverse, the dorsal border being straight and extending very nearly the entire width. The ventral border is nearly straight along the middle, more strongly rounded toward the ends. One cardinal angle of our specimen is nearly quadrate, the other is imperfect, but I believe was slightly extended. There is a well marked flange separated from the ventral and lateral borders by a sulcus and defined also upon its upper side by another sulcus. The remainder of the shell is moderately convex, somewhat pinched together near the middle with a subcentral pit a little below the median line. The surface is finely reticulated.

Kirkbya reflexa sp. nov.

Shell rather large, strongly transverse. Dorsal border straight, very nearly as long as the greatest width. Ventral margin gently convex across the middle, more strongly curved toward the ends. Ends very nearly symmetrically formed. Cardinal angles almost equal, the anterior being slightly more acute than the other. A deep groove surrounds the ventral and lateral borders, the marginal portion of the shell being bent upwards in a broad border or flange. The remainder rises gradually and regularly to the middle of the dorsal border, and this portion of the shell would have the shape of one half of a spreading cone, if it were not that the posterior (?) half of the cone is somewhat compressed, which makes the most elevated portion into a curved oblique ridge.

The surface is finely and deeply reticulated, the apertures increasing in size toward the reflexed border, upon which they are prolonged into relatively large, transverse grooves, so that the border looks fluted or perforated, though having the margin entire.

Kirkbya simplex sp. nov.

Shell small, transverse. Dorsal border long and straight, converging anteriorly (?) with the gently convex ventral outline. Ends nearly equally rounded, the anterior being narrower and more strongly curved. Convexity moderate, chiefly marginal, regular, without sulci or tubercles. Surface strongly and finely reticulate, except marginally, where the shell seems to be smooth and dense. Position of median pit not determined.

Amphissites gen. nov.

A number of ostracod shells in the fauna of the basal Fayetteville shale belong to types which have been loosely referred to the genus *Kirkbya*, but they really appear to represent three generic or subgeneric groups. *Kirkbya* itself is described as having the right valve larger than the left and overlapping it. This is the condition of *K. lindahli* var. *arkansana*. The shell described below as *Amphissites rugosus* has the two valves equal, meeting each other along a line, neither one overlapping the other. It is furthermore distinguished by having the surface marked by a number of tubercles in addition to the fine reticulations. On both these accounts, it seems that this form can readily and advantageously be distinguished from *Kirkbya* proper. The third type is represented by *Glyptopleura inopinata*, which has the left valve overlapping the right. Conjoined with this difference in configuration is one of sculpture, the sides being without knobs or plications, but ornamented with oblique, inosculating costæ instead of the fine reticulations and flanges of the other types.

TYPE.—*Amphissites rugosus.*

Amphissites rugosus sp. nov.

Shell small, subquadrate, with the two ends nearly symmetrically formed, so that it is difficult to distinguish which is anterior and which posterior. The dorsal and ventral margins are straight and parallel. The ventral is curved upward at the ends, which are regularly rounded; the posterior is slightly oblique and projecting. Cardinal angles rounded.

The convexity is rather high, developed especially about the margins. The surface is modified in a rather complicated manner, there being four flanges or ridges, while the median portion of the side is occupied by a large knob or boss. The margins of the base and sides are slightly thickened and projecting, making what may be called the first flange. The second is just above, separated by a narrow, deep groove, and it projects beyond the true margin. The third lies considerably within the second and does not conform to it, since a broader space is left at the inferior angles (especially the anterior one) than along the ventral border, while it meets the dorsal margin at the cardinal angles. The fourth flange or ridge is less distinct than the others, tending to become obsolete ventrally, becoming much thicker and more elevated anteriorly, so that where it terminates abruptly at the dorsal border, it forms in the cardinal view a large flat triangular area. The median pit is small and situated just below the inflated umbonate median portion of the shell. The surface is finely reticulated, except along the flanges, which are dense and smooth.

Glyptopleura gen. nov.

Shell rather small, subquadrate, with a backward swing, the posterior end being higher than the anterior and somewhat truncated. Inequivalve; the left valve is much the larger and overlaps the other all around save along the distinct straight hinge. There is a subcentral pit. The surface is marked by inosculating costæ.

Type.—*Glyptopleura inopinata.*

This type has the general appearance of certain species referred to *Kirkbya*, but it is distinguished from *Kirkbya* by the fact that the left valve is larger than the right—the reverse of *Kirkbya*—and that it overlaps the right strongly and throughout the circumference save along the hinge. This difference, of course, depends partly upon the orientation of the shell. In the Beyrichiidæ and in *Kirkbya* itself, the shape is subrhomboidal, and the higher, truncated, more projecting end is called the posterior. If the same criteria are applied to the present species, the left valve is the larger and overlaps the right as described above. In the contrary interpretation, the overlapping of the valves in the present shell would more nearly correspond with *Kirkbya*, though more pronounced, but the other data of orientation would be reversed. It seems to be more probable that the configuration is the same as in *Kirkbya* and the Beyrichias.

Glyptopleura inopinata sp. nov.

Shell rather small, transverse, subquadrate. Width about 1.75 mm., which is distinctly less than twice the height. Hinge line nearly as long as the greatest width. Lower margin gently convex over the median portion, more strongly curved in front and behind, convergent anteriorly with the dorsal border. Posterior outline distinctly truncate and oblique, so that the post-cardinal angle is distinct and obtuse. The anterior extremity is acutely rounded above. The convexity is moderately high and obscurely constricted across the middle, with the anterior portion more inflated than the posterior. A small, deep, circular pit forms a depression a little above and a little posterior to the center. The sculpture consists of large curved, inosculating ridges which cross the surface transversely and more or less obliquely. There is a smooth, finely striated border which surrounds the shell everywhere, save along the hinge.

The two valves are distinctly unequal, the left being the larger. The left valve thus overlaps the other on all sides save along the hinge, at the ends of which this arrangement appears to produce a primitive sort of articulation.

Glyptopleura angulata sp. nov.

Shell small, transverse, subovate. Hinge line straight, nearly as long as the entire width, converging anteriorly with the gently convex lower border. Anterior end strongly rounded. Posterior end more broadly rounded, not much produced beyond the hinge extremity. Convexity high, chiefly centered along a diagonal ridge, extending obliquely from near the upper anterior angle to the lower posterior angle. As the lower margin also is oblique, the descent to this margin is abrupt and regular, while that to the post-cardinal angle is long and gradual. Anterior extremity of the ridge very prominent and embellished with a little knob.

Median pit situated above the middle (above the ridge) and near the middle transversely or a trifle posterior to it.

Surface marked by a few rather coarse, strong, angular liræ, more or less transverse and inosculating.

Bairdia attenuata sp. nov.

Shell rather large, very transverse. Lower margin nearly straight across the median portion, strongly and equally turned upward at the ends, which are pointed and slightly lower than the middle. Upper margin strongly convex across the median portion, slightly concave near the ends. The point of greatest convexity, and therefore of greatest height, is distinctly posterior and the outline is more concave near the posterior than the anterior end. Convexity moderate, compressed at the ends. Surface smooth. Left valve slightly overlapping the right at the hinge; elsewhere neither valve seems to extend beyond the other.

Bairdia cestriensis var. granulosa var. nov.

This form is very closely related to *B. cestriensis*, of which Ulrich figures two specimens, a large and a small. It is a more slender shell than the larger specimen and larger than the other—larger even than the larger of the types, from both of which it appears to be distinguished by having the surface conspicuously roughened over the convex portion but smooth about the margins. The shape is extremely similar to that of the smaller of Ulrich's specimens. This is a highly convex little shell, rather strongly compressed at the ends.

Griffithides mucronatus sp. nov.

Head: glabella large, inflated, considerably narrower behind; basal lobes triangular, small, strongly defined. Neck ring defined from the glabella by a deep sulcus, strongly arched in the middle with moderately long lateral projections. Eye lappets small, oblique. Border anterior to the glabella, moderately narrow, depressed, slightly convex, defined by a groove. Surface of glabella granulose, much more finely in front than behind. Median portion of neck ring and projecting end of eye lappets also marked by coarse granules. Outer margin of anterior border with fine parallel raised lines. The remainder of the surface, including the more depressed portions, finely pitted.

Free cheek with a wide, gently convex border defined by a strong groove. Eye large, prominent, many faceted, bounded below by a curved ridge. Genal angle much produced into an elongated spine. Surface finely pitted, outer margin marked by regular, fine, parallel liræ.

Thoracic segments nine, strongly lobed, axial portion a little less than one third of the whole. Longitudinally furrowed.

Pygidium semi-elliptical or shield-shaped, length and breadth about equal. Border broad and gently convex or nearly flat. From its well defined inner margin, the main portion of the pygidium rises abruptly, the axis being also abruptly and strongly elevated above the pleural areas. At its anterior end, the axial and pleural portions are about equally broad, and the border about one half as broad as the three other divisions. In old specimens, the border is relatively narrower. The segments are defined by deep angular grooves. There are 16 on the axis and 9 or 10 on the sides. The lateral segments are sometimes partly divided by indistinct furrows. Besides the number given above, there is a small articulating segment at the front end of the axis, and the anterior of the lateral segments is made double by a groove which divides it into two parts, the posterior having the normal size, the anterior being somewhat smaller. The surface of the lateral segments is rather coarsely granulated, and sometimes the granules are segregated along a raised line. Each of the axial segments is marked by a row of still larger granules. The border is traversed by a few delicate, inosculating lines and is finely roughened.

This species is abundant in the basal limestone of the Fayetteville shale, rare and somewhat doubtfully identified in the Batesville sandstone below.

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NEW SPECIES OF FOSSILS FROM THE THAYNES LIMESTONE OF UTAH[1]

BY GEORGE H. GIRTY

(*Presented by title before the Academy, 3 October, 1910*)

The few species described below are from the rocks in the Wasatch Mountains of Utah, which were discriminated by the geologists of the Fortieth Parallel Survey under the title "Permo-Carboniferous." At the same time, Meek, in describing *Aviculipecten occidaneus*, a species which is abundant in and characteristic of the "Permo-Carboniferous," cites the horizon as the "Upper Coal Measures Limestone," a series which occurs below the "Permo-Carboniferous" and in which *A. occidaneus* is not found at all.

As a result of more detailed study of the "Permo-Carboniferous" in the Park City district of the Wasatch Mountains, Mr. J. M. Boutwell found occasion to divide the series into three formations, which he named from below upwards, the Woodside, the Thaynes and the Ankareh. From the typical Woodside, which is a red shale formation, no fossils are known. The Thaynes, consisting of thin muddy limestones and earthy beds, has furnished an extensive molluscan fauna, chiefly characterized by a great diversity of pectinoid species which may belong to several genera. Of these a few have already been described, *Aviculipecten utahensis, A. weberensis, A. curticardinalis, A. parvula, A. occidaneus*, together with *Sedgwickia concava, Myacites inconspicuus* and the shells probably wrongly identified as *Myalina aviculoides* and *M. permiana*. All of these species occur in the Thaynes and were probably originally described from that formation. The Ankareh has proved scantily fossiliferous in the typical area, but the fauna so far as known is closely related to that of the Thaynes.

The "Permo-Carboniferous," however, is not confined to the area of the Wasatch Mountains, but it outcrops through central Utah and is found again in the Grand Canyon region, where it constitutes the Permian of Walcott's Kanab Canyon section. There is yet no reason to believe that Walcott's Permian is not essentially the same in its limits as the "Permo-Carboniferous" and that it does not contain beds equivalent to the Woodside, the Thaynes and the Ankareh.

[1] Published by permission of the Director of the United States Geological Survey.

The "Permo-Carboniferous" extends also to the northward, where it outcrops extensively in southern Idaho and also in Wyoming. There is every reason to believe that in this region also the three formations of the "Permo-Carboniferous" occur, for there is a remarkable agreement faunally, stratigraphically and lithologically between the beds in southern Idaho and in the Park City district. Indeed, they have already been mapped in Idaho by Veatch. Furthermore, the "Permo-Carboniferous" of southern Idaho contains the strata furnishing the ammonite fauna which Hyatt and Smith have assigned to the lower Trias. The ammonite beds occur at the horizon of the Thaynes limestone, which is conventionally taken to begin with the lowest ammonite zone. In this region, the lower red shale corresponding to the Woodside contains thin limestones having a fauna which agrees closely with that of the Thaynes. Thus the three members of the "Permo-Carboniferous" are related faunally and form a natural lithologic group also, with distinct boundaries above and below, especially the latter. This instrinsic relationship of the rocks found expression in their inclusion by the earlier geologists in a single formation or series.[2]

Although the evidence is not yet in shape for presentation in detail, it seems all but certain that the "Permian" of the Grand Canyon area, the "Permo-Carboniferous" of the Wasatch Mountains and the "Lower Triassic" of southern Idaho are a single series of strata originally continuous from one region to the other and having essentially identical faunas. The whole group, therefore, must be either Permian or Triassic. It remains for a more careful and critical survey of the evidence to determine which.

Aviculipecten ? boutwelli sp. nov.

Shell small, subovate, a little longer than wide. Hinge line more than one half the greatest width, which is found about midway. From there the shell contracts rather regularly in both directions. The ventral outline is narrower than the cardinal and strongly rounded. The sides straighten somewhat toward the hinge or even bend slightly outward but without producing any distinct sinus. While fairly symmetrical, the greater development appears to be on the anterior side of the shell. Convexity moderately strong, especially about the umbo. Beak subcentral, small, incurved. Wings about equal, un-

[2] The relationship of the beds in southern Idaho with the "Permo-Carboniferous" was recognized in a general way by the earlier geologists. The relation was more satisfactorily demonstrated several years ago by collections of fossils made by F. B. Weeks and reported on by me. It was not until the season of 1909 that evidence was obtained, by a party in charge of H. S. Gale, with which I had the pleasure of being associated, showing that the lower Triassic ammonite fauna occurs within the limits of this series. After his work in southern Idaho, Mr. Gale visited the typical section of the Park City district, verifying the close lithologic and sequential relationship which exists between the beds in the two areas.

defined, a small portion of each near the hinge slightly upturned. This flattened area, which may possibly be regarded as the entire wing, is larger and more sharply defined on the posterior side.

Surface nearly smooth, marked by fine, somewhat irregular and unequal concentric striæ and by obsolescent radial costæ. Of the latter, 9 or 10 are stronger than the rest, but between these and at the sides are other very fine obscure raised lines, 5 or more between 2 of the stronger ones. The whole sculpture is rather irregular and so fine and obscure as to be hardly visible without a lens.

The type specimen, from the absence of a byssal sinus, is evidently a left valve, unless the two sides of the shell are similar in configuration, in which case the genus would be neither *Pecten* nor *Aviculipecten.*

In its specific relations, this form is doubtless most closely allied to *A. occidaneus*, from which it is distinguished by some differences in shape, such as the less well-defined wings and by the nearly obsolete sculpture.

Aviculipecten wasatchensis sp. nov.

Shell small, subovate, distinctly longer than wide. Hinge line straight, slightly shorter than the greatest width below. Ventral margin regularly rounded. Sides nearly straight, gently contracting toward the hinge near which they curve slightly outward.

Convexity moderately high, rather strong at the umbo. A small triangular area either side of the beak is slightly flattened into an undefined wing. The sides below these areas are deflected from the body of the shell, forming a larger feature, which may also be regarded as the wing instead of the other. Beak nearly central. Axis about perpendicular to the hinge.

Surface marked by fine, regular, closely arranged concentric striæ and by radial costæ of several sizes. Between each pair of larger ribs are one or two distinctly smaller, while a third series, one or two at a time, occurs between the second ones. This arrangement is subject to more or less irregularity, and toward the sides the costæ tend to be more distinctly of one size, but the general effect is that of regularity. The costæ are not sharply or strongly elevated and do not extend onto the sides.

The absence of any sinus for the byssus indicates that the specimen described is a left valve. The right valve is unknown.

This species differs from *A. boutwelli* in having the costæ stronger and more conspicuously alternating and in having sharper and more regular concentric striæ.

Aviculipecten thaynesianus sp. nov.

Shell small, subovate, longer than wide. Hinge line straight and shorter than the extreme width below. Ventral margin regularly rounded. Sides nearly straight, curving gradually below into the ventral outline and contracting slightly toward the hinge.

Convexity moderate, fairly prominent in the umbonal region. Sides depressed, especially near the hinge, but without forming well-defined wings. Beak nearly central, somewhat posterior to the middle of the hinge. Axis about parallel to the hinge line and the whole growth nearly symmetrical.

Surface marked by fine, fairly strong and sharp, subequal to somewhat alternating radial costæ, which extend obscurely onto the anterior wing, but probably not onto the posterior. There are also moderately strong, irregular and widely spaced concentric striæ due to unequal growth and probably between these more or less distinct concentric striæ of a finer character. The concentric markings are more sharply expressed on the wings than on the body of the shell.

Astartella ? forresteri sp. nov.

Shell small, subquadrate, nasute. Width about one and one third the height. Cardinal and ventral margins slightly convex, almost parallel or gently converging posteriorly. Posterior truncated with a slightly oblique outline which tends to make a little more than a right angle with the cardinal outline and a little less than a right angle with the ventral outline. Posterior inferior angle strongly rounded; posterior superior angle more or less distinct. Anterior extremity strongly projecting, in some specimens about one third the entire width. The outline is concave above for about one half the height, leaving the beaks small and incurved but rather prominent. Convexity low; valves occasionally somewhat compressed near the hinge. Lunule and escutcheon large, sharply defined.

Surface smooth, except for an occasional strong stria of growth near the margin.

The proportions vary considerably, some specimens being less transverse than others. Another point of variation consists in the degree of projection of the anterior extremity. The contraction of the upper and lower margins varies likewise, those specimens in which it is strongest having a less distinct cardinal angle. In extreme cases, the shape is somewhat like that of an abbreviated *Leda*. This occurs where the anterior portion is unusually long, the posterior unusually short, the cardinal line oblique and the posterior superior angle not well defined. So completely do these different modifications intergrade, however, that it seems unwise to attempt to distinguish separate varieties.

The dentition of this form is unknown, but the configuration is that of our Carboniferous Astartellas. All the Astartellas, however, have strong, concentric lamellæ. *Cypricardella* (*Microdon*) has also much the same shape, but these regularly have strong concentric striæ. There is no form in our American Carboniferous with which this species is liable to be confused.

I have the honor to name it for Mr. Robert Forrester, of Salt Lake City, who collected the specimens on which it is based.

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THE COAL BASIN OF DECAZEVILLE, FRANCE

By John J. Stevenson

(*Read in abstract before the Academy, 7 November, 1910*)

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INTRODUCTORY NOTES

The Decazeville coal basin, named from the chief city within its borders, is in the department of Aveyron, about 400 miles south from Paris and about 190 miles south from Commentry. The mines, originally opened for the Duc de Decazes, have been in operation for more than a century. The proporties are controlled by two great organizations, the Compagnie anonyme de Commentry, Fourchamboult et Decazeville, with important steel works at Decazeville, and the Compagnie des Mines de Campagnac at Cransac, five miles farther south. Within a short distance from the latter city, is the widely extended area of exploitation by the Société des Acieries de France, from which the greater part of the coal has been removed.

The basin is rudely triangular in form; the longer axis, from west of north to east of south, is about 12 miles long, and the width varies from nearly six miles at the south to barely one third of a mile at the north, where the coal rocks pass under deposits of early Tertiary age. The total area of Coal Measures is not far from 30 square miles, so that it is about five sixths as large as a township in Ohio. The interest attaching to the basin is far out of proportion to its extent; the coal beds are of unusual thickness, the plications and other disturbances are very complicated, and the conditions observed there have been regarded as arguing strongly in favor of the doctrine that coal beds have been formed from transported vegetable matter.

No elaborate description, such as that by Fayol of Commentry or that by Gruner of Saint-Étienne, has appeared respecting the basin of Decazeville; but several brief memoirs have been published, some of which are important. Blavier in 1806 described the coal, which even then had been opened at several localities; Cordier in 1809 made incidental reference to the coal beds and expressed surprise at the irregularity of their occurrence; Dufrenoy in 1841 discussed the region somewhat in detail; Boisse in 1870 differentiated the deposits and grouped them into two systems, while suggesting that there may be three. Somewhat later, Grand' Eury investigated the Coal Measures of this basin from the viewpoint of paleobotany and made correlations with other areas.

The first systematic statement known to the writer was given by Bergeron[1] at the reunion of the Geological Society in l'Allier. He recognized three systems of deposits and described the method by which the basin was filled and the coal beds formed, applying the doctrine of deltas as announced by Fayol in the preceding year. This paper was accompanied by a preliminary map, showing the positions of three deltas. His memoir, published in the following year, defined sharply the three systems of rocks, to which the terms Auzits, Campagnac and Bourran were applied. The conclusions throughout are the same as those in the earlier paper, of which this is but an elaboration, in so far as it relates to the Decazeville area. Three years later, the properties near the city of Decazeville passed into the possession of the Compagnie de Commentry et Fourchambault, and, under direction of M. Fayol, the engineers of that company began careful researches throughout the basin, which still continue.

In 1900, an extremely important memoir appeared,[2] in which the authors summed up the results of studies made by Jardel and Picandet and their associate engineers, as complementary to the work done by Bergeron prior to the consolidation of the properties. It explains the relations of the three systems, the mode in which the basin was filled, the sources of

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[1] J. Bergeron: "Note sur les bassins houillers de Graissessac et de Decazeville," Bull. Soc. Géol. de France, 3me. Ser., t. xvi, p. 1032. This contains detailed reference to the work of his predecessors.

———. "Étude du massif ancien situé au sud du Plateau central," Ann. des Sci. Géol., t. 22, p. 196.

[2] J. Bergeron, (A) Jardel et Picandet. "Étude géologique du bassin houiller de Decazeville (Aveyron)," Bull. Soc. Géol. de France, 3me. Ser., t. xxviii, pp. 715-749, map and plate of sections.

the materials, the directions of the contributing streams, the development and the interferences of the little deltas during advance from the shore. This admirable synopsis has been utilized throughout by the writer; its clear descriptions enabled him to pass rapidly over some portions, rendered unnecessary the examination of others and made possible the practical confining of his attention to localities in which the phenomena of coal accumulation are shown most notably.[3]

ROCKS SURROUNDING THE BASIN

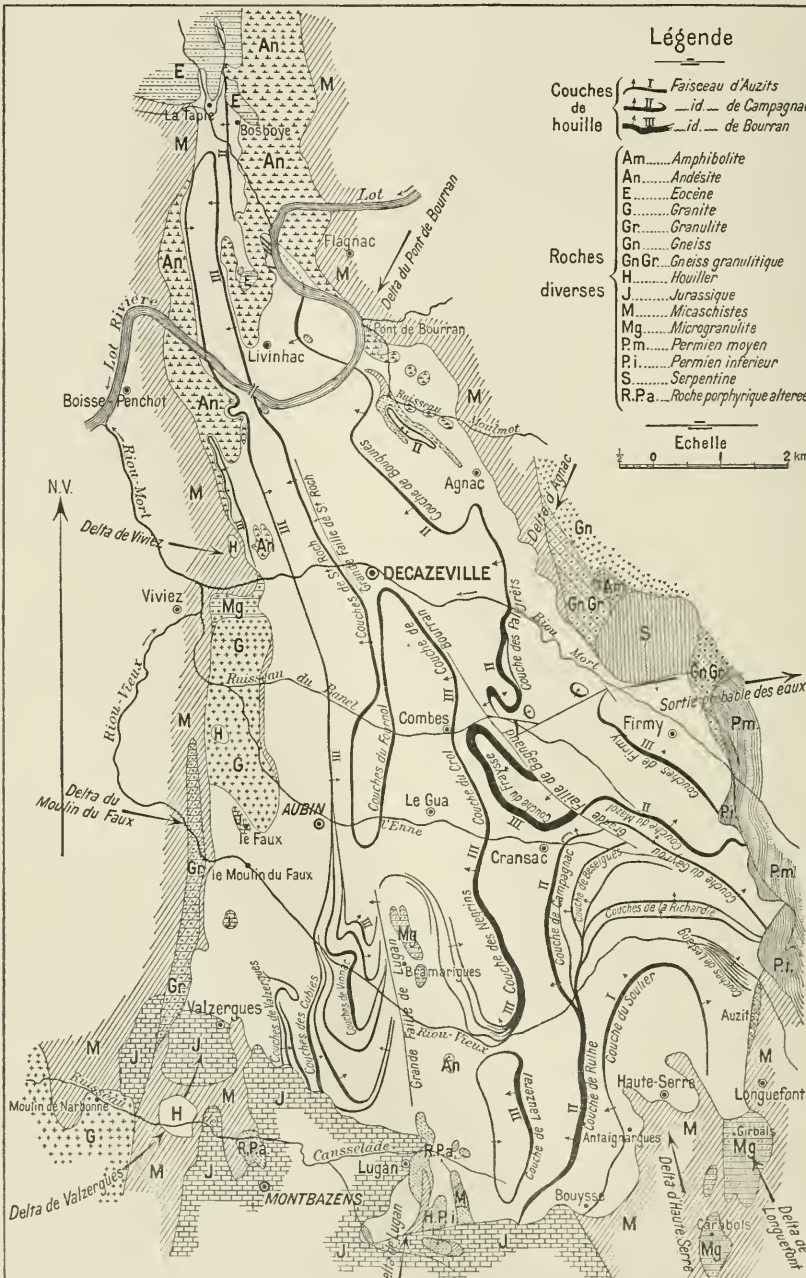
Long ago, it was recognized that the basin of Decazeville, like those on the central plateau, occupied a depression in Archean rocks; the mica schists with granite being continuous from the Commentry to the Decazeville basin. But patches of other rocks exist, whose distribution on the borders is of great importance to one endeavoring to trace the history of the area. Bergeron in his first paper gave some notes respecting these rocks, but the later memoir by Bergeron, Jardel and Picandet gives in detail their distribution along the approximately 30 miles of contour. A synopsis of their statement is essential, though the relations are shown on the accompanying map,[4] page 246.

The prevailing rock is mica schist, containing here and there some granulite and occasionally becoming gneissoid. Granite appears at the southwest, and, on the western side, a narrow strip of gneiss extends northward from the southern boundary for about four miles. Just beyond is a mass of granite, sharply defined as if by a fault at the west, which is about half a mile wide and three miles long, extending almost to the Riou Mort and showing on its eastern side a very narrow strip of mica schist. A small area of microgranulite is cut by the Riou Mort. At a little way north from that stream, one reaches andesite which extends to the northern end of the basin, forming the western boundary for about four miles.

Andesite forms the eastern boundary also to beyond the Lot River. It is almost continuous across the basin at the extreme north, but it has suffered great and irregular erosion in the broad valley of the Lot, and the Coal Measures reach eastward to the mica schists. These form the boundary for somewhat more than four miles, to be succeeded by grani-

[3] I must express my high appreciation of courtesies received from M. H. Fayol, Director of the Comp. Anon. de Commentry, etc., M. A. Jardel, Director of that company's mines in the Decazeville basin, and M. E. Brocard, the metallurgical engineer of the company, as well as from M. Saint-Martin, geometrician of the Campagnac company. The generous assistance given by these officials makes me regret keenly that the studies at Decazeville compel me to the belief that the coals of that basin, like those of Commentry, are of *in situ* origin.

[4] This map has been taken from the memoir by Bergeron, Jardel and Picandet; the scale has been reduced slightly, but no change has been made in the geology.



MAP OF THE COAL BASIN OF DECAZEVILLE.

Reproduced with slight reduction from the memoir by Bergeron, Jardel and Picandet.

toid gneiss, in which is implanted a boss of serpentine. These rocks are well shown in the valley of Riou Mort, being reached at only a few rods from the stream. Opposite the village of Firmy, one finds Permian beds, which are the boundary thence for four miles to the end of the ridge overlooking Auzits, where they rest on the mica schist. From Auzits southward and then westward, mica schist is probably the boundary rock, though for nearly two thirds of the distance along the southern border, an irregular line of more than six miles, it is covered by Jurassic beds. In the southeast corner are some patches of microgranulite, whose relations should be well fixed in mind, as fragments derived from those patches gave the first positive clue to the mode in which the basin was filled.

One finds occasionally within the basin fragmentary areas of rocks belonging to the boundary types. Two small patches of Jurassic remain in the southwest at one and three miles from the outcrop. Permian is present in the region south from Decazeville to beyond the Ruisseau de l'Enne. Midway along the southern boundary, some bosses of a "roche porphyrique alterée" project into the Coal Measures, and a similar rock appears in small quantity at several places beyond the border of the basin. These bosses are in line with islets of andesite and microgranulite, the last of which is more than four miles from the southern boundary.

Aside from these rocks, one finds indicated on the map a small area of Coal Measures in the extreme southwest corner; another of less size on the granite, and still another on the mica schist of the western boundary.

DESCRIPTION OF THE BASIN

To determine the stratigraphical relations from surface exposures would be well nigh impossible. The region has suffered greatly from erosion, but the slopes of the hills, though usually rather steep, rarely give any but fragmentary exposures; while side cuttings on the well-graded roads are too widely separated to yield satisfactory information respecting an area which is closely folded and is slashed by faults. The great open workings, termed "découvertes," and the extensive underground developments have provided material for determination of the structure. The conditions are far less simple than in les Pegauds of Commentry, where the coal accumulated in a wholly insignificant area.

The cutting to which the present topography is due was determined by the Lot River, which crosses the north end by a tortuous course. The Riou Mort, Ruisseau Banel, Ruisseau de l'Enne and the Riou Vieux, draining the basin, unite beyond the western boundary near Viviez and enter the Lot River within three miles. The course of that river within the basin seems to have some relation with the distribution of andesite, while that of Riou Vieux at the southeast appears to owe its direction in great measure to the distribution of rocks in that region. This erosion is later than the middle Tertiary and, by most writers, is referred to the Quaternary. All phenomena testify to its recent origin. The valleys, for the most part, are narrow and the hill slopes are abrupt, while the summits are clearly remnants of a plain. The granitic rock on the west side has yielded much the same topography as that of the Coal Measures area. The steep hillsides must have been captured early by vegetation, as they show comparatively little gashing.

The later work of removal has been confined chiefly to corrasion, and erosion has done comparatively little toward leveling the region. But a long-anterior erosion, probably preceding the Jurassic and following the time of folding and faulting, removed the Permian and newer portions of the Coal Measures from much of the basin and exposed the oldest deposits in the southeast. The Quaternary erosion increased the area in which the early beds reach the surface; while trenching of the basin by valleys 400 to 600 feet deep has made the coals accessible at many places and rendered possible those mining operations which have attained so great economical importance.

Boisse, forty years ago, recognized at least two distinct systems of deposits and suggested that the succession might be divided into three. Bergeron, twenty years ago, determined the three systems, Auzits, Campagnac and Bourran. This division may not be supported strongly by paleontological evidence, but it is sufficiently distinct, for the physical conditions are unlike in the several systems.

The Auzits system consists of a succession of conglomerates, sandstones and some shales, the materials having come almost wholly from the southern border. These deposits have been exposed by erosion, and they pass under the newer rocks at a very short distance north from the Riou Vieux; but the upper beds are at the surface in the valley of Riou Mort, on the eastern border. This system includes toward the base the Soulier-Abiracs coal bed and, apparently higher, the unimportant coal deposits north from Auzits known as the beds of l'Estang.

The Campagnac system, beginning with the coal bed known as Rulhe, Campagnac, Paleyrets, Bouquies, in the several localities where it is worked, consists very largely of conglomerates with some sandstones and shales. Its rocks are exposed in much of the eastern half of the basin, and the great coal bed at the bottom is mined at many places. The conglomerates are shown frequently on the roads and, though the composition varies, the features are such as to show that substantially the same physical conditions prevailed along most of the streams which supplied the material. The deposit of conglomerate began very soon after accumulation of the Campagnac coal bed.

The Bourran system, beginning with the Grande Couche de Bourran, known as Negrins, Crol, Fraysse, Firmy, Bourran, Saint-Roch at the several mines, consists of shales and shaly sandstones succeeded by a considerable thickness of coarse, more or less conglomeratic sandstone. It occupies the central and western parts of the basin; and a small area, caught in the jaws of faults, remains on the eastern side near Firmy. The studies by Bergeron, Jardel and Picandet leave little room for doubting that practically all of the water-carried deposits west from the central line of the basin date from the beginning of the Bourran system.

The Decazeville basin, unlike that of Commentry, is characterized by great irregularity of structure, the beds being folded and faulted in complicated fashion. The folds will be noted in the local descriptions, but the principal faults must be mentioned here that those descriptions may be clear.

The Grande Faille de Bagnaud is distinct at la Puech, the summit of the road from Firmy to Cransac, about a mile east from the latter town; but southeast from la Puech it could not be traced, as exposures thence to Auzits are indefinite; northward, however, it seems to be crossed by the Riou Banel and its existence is highly probable thence to Riou Mort at Decazeville, where a well-marked fault exists. Northeast from Cransac, the throw is sufficient to bring the Campagnac and Bourran beds to nearly the same level.

An east and west fault passes from the Bagnaud fault to the eastern border; it will be spoken of as the Firmy fault. A third fault is very distinct between the outcrops of the Bourran bed, northwest from Cransac. A fourth was recognized by Bergeron, Jardel and Picandet in the south-central part of the basin and designated as the Grande Faille de Lugan. These four are the only ones with extensive throw, but the mine maps and the découvertes exhibit many others of 20 to 50 feet, some of them very complicated. These, however, though numerous and perplexing to the mining engineers, need no consideration here.

The writer's detailed observations were made in the space between the Riou Mort and the Ruisseau de l'Enne, where the coal beds have their chief development; but the southeast corner as well as the area north from Riou Mort was visited and the relations were made out. No studies were attempted along the southern border or in the southwest corner, where investigations by Bergeron, Jardel and Picandet have made the conditions so clear that nothing except visual familiarity with the phenomena could be gained by an examination. For the localities not visited, citations will be made from the memoir by those students.

The Auzits system of Bergeron.—The Auzits system is exposed in the southeast corner of the basin and passes under the Campagnac at a little way north from Riou Vieux. Only the highest beds are shown farther north along the eastern side, so that its full extent cannot be determined. The faults bounding the basin at the east bring the newer systems against the old rocks. The earliest deposits of the system are not shown along the road followed by the writer, as they are within the space inclosed by the Soulier outcrop. The oldest deposit assigned to this system is near Antaignargues, where a mica-schist breccia, composed of great blocks with angles barely rounded, rests on the mica schist of the region. Above this and passing over to the mica schist is a conglomerate, which has been followed for several kilometers; its fragments are smaller and much more rounded, though still breccia-like; they are mica schist, microgranulite and white quartz. This is succeeded by a conglomerate rich in microgranulite at the west, but in granulitized mica schist at the east. The overlying rock is a coarse sandstone of more or less greenish tint, becoming yellowish eastward. This contains the Soulier coal bed. The coarse rocks underlying that coal bed have an extreme thickness of 200 meters, as determined by A. Jardel.

In going northwestward from Auzits, one finds only indefinite exposures along the road, and those are mostly sandstone. The l'Estang coal beds are reached in somewhat more than a half-mile from the village. Little is known respecting them beyond the fact that a company formed for their exploitation soon came to grief, but evidently coal is present in small quantity. The incomplete exposures show only some thin streaks of coal associated with shale, and not coarse sandstone, dipping northeastwardly at approximately 30 degrees. A similar sandstone is exposed on the opposite side of the stream. These beds are above the middle of the Auzits system.

Less than half a mile beyond the l'Estang property, one reaches an abandoned coal opening at about 500 feet south from the road. Exposures along the road are widely disconnected, and one passing along cannot determine the relations; but loose pebbles on the hillsides at several places indicate the existence of a conglomerate, which is well marked at the opening, and there is clearly an underlying sandstone which is associated with the coal bed. The opening is on the Soulier bed, the first well-defined coal deposit in the basin. The coal was not seen, as the opening is closed by mud and water, but the dip is northward at about 30 degrees. On another tributary stream, possibly half a mile farther, there was at one time an extensive group of openings from which a large quantity of coal was taken out. The works seem to have been abandoned completely and a definite measurement of the bed cannot be obtained now; but A. Jardel states that the bed is double, divided by a thick clay parting, and in all about 16 feet thick. The strike of the bed has been changed to almost north-south, for the openings are along the stream which flows toward the north. There is in this space a fold with sharp northward pitch, there being easterly dips on the Auzits side, northerly dips where the coal was first reached, and now on the western side distinctly westerly dip, so that the Soulier bed has an elongated curved outcrop. The thickness is such that one should expect to find the bed in a boring at a considerable distance north from Riou Vieux.

Separated from the coal bed by a sandstone rich in feldspar is an extraordinarily coarse conglomerate, broken by thin shales and, at its maximum, almost 400 feet thick as determined by A. Jardel. This, the feldspathic conglomerate of Bergeron, Jardel and Picandet, is persistent eastward to where it passes under Riou Vieux and equally persistent southward along the western side of the exposed area. It consists mostly of microgranulite pebbles, thoroughly rounded and varying from one inch to upwards of one foot in diameter, those of the largest size being very numerous. Pebbles of other rocks occur locally. Study of these fragments enabled those investigators to determine finally the source of the materials; the microgranulite came from the areas indicated on the map, the most distant being, at its southern termination, barely four miles south from Riou Vieux. This conglomerate seems to become less coarse east and west from the first coal opening observed. The sandstones and shales enclosing the l'Estang coal beds have been taken by Bergeron, Jardel and Picandet as being most probably equivalent to the upper part of the conglomerate, which has its full development at half a mile toward the west. Those students have worked out the details of the area so thoroughly by investigation of the fragments as to prove beyond question that three little streams entering near Auzits, Haute Serre and Lugan, contributed to the formation of these deposits, now exposed in an area of about three square miles, and that the course of the main or central stream during deposition of the later beds is marked distinctly by distribution of the larger fragments.

The feldspathic conglomerate is succeeded by conglomerates and shales, in all about 600 feet as determined by A. Jardel, which continue to the top of the system; they are exposed here and there beyond Riou Vieux. The extreme thickness of the Auzits system is not far from 1800 feet, the measurement being made along the line of maximum development, near the supposed course of the Haute Serre stream. The average thickness is very much less.

The Campagnac system of Bergeron.—The deposits of the Campagnac system in the southeastern part of the basin are clearly a continuation of those seen within the Auzits, for study of the included fragments leaves no room for doubting that they came from the south. The outcrops of the coals give evidence of the relationship, which is not masked by the Bagnaud fault, as the section seems to be continuous along the eastern side to Firmy, where one reaches the Bourran system.

Folding and subsequent erosion have removed much of the Campagnac coal bed from the southeastern corner, how much, of course, cannot be determined. But the series from the upper part of the Auzits into the Campagnac is distinctly conformable, and the dips in the Rulhe bed, as well as in its branch, Richardie, would carry the coal only a short distance above the hills on the southerly side of Riou Vieux. The conditions justify the suggestion that the Campagnac coal bed at one time covered much of the Auzits area. The Campagnac deposits were made in this southern area by the three streams already mentioned, and the character of the material shows that each was torrential and short, not more than three or at most four miles long.

The outcrop of the Campagnac coal bed extends practically to the southern edge of the basin. Near the hamlet of Rulhe, the bed is said to be irregular, tending to lens-form, and it is triple, the main bed being on top. Half a mile farther north, near where the outcrop is crossed by Riou Vieux, the intervals between the divisions increase and the lower benches show an east and west outcrop as they cross the fold. Centrally along this, they have a northward dip, showing that the fold retains its pitch in that direction. The Bagnaud fault interrupts the continuity at the north end of this area, but the condition was the same throughout, for near Cransac the outcrop of the main bed curves toward the east, to be cut off by the fault.

On Riou Vieux, the Campagnac bed is reached just beyond the place where the railroad from Auzits to Viviez leaves that stream. The mine has been abandoned, and no examination of the coal could be made, but it is apparently on a lower division of the bed, probably the Couche de Richardie. The overlying rocks are shale and sandstone with, at somewhat more than 30 feet above the entry, a sandstone containing much conglomerate. At about one third of a mile farther, one comes to the shaft of Sainte Genevieve on the main bed. No work was in process when the locality was visited, but the mine is extensive, the coal having been removed from a rudely triangular space almost 1100 by 1700 feet. The coal is said to be 45 feet thick. An exposure at about 75 feet above the coal and continuing for nearly 200 feet showed shales underlying the conglomerate and the dip is almost southwest at 18 to 20 degrees.

Pits have been opened at several places between Sainte Genevieve and Cransac; near the latter place, the Compagnie des Mines de Cransac has removed the coal by open workings, or découvertes, from an extensive area, and now the mining is done in underground workings, which reach westwardly for a long distance, the coal having been taken out to a distance of more than a kilometer from the shaft. Faults are very numerous, and the coal varies from 33 to almost 100 feet in thickness.

Exposures outside of the great découvertes are so rare that any continuous section becomes interesting to the student. In going eastward along the railroad from Cransac station, one comes to a through cut in shales. These have been stripped alongside from a considerable space in order to secure the ironstone which they contain. The succession, descending, is, the thicknesses being estimated,

	Feet
1. Dark shale with ironstone and streaks of coal	6
2. Shales, mostly hard, weather yellowish, are gray or drab on fresh surface	6
3. Shale, distorted, with irregular patches of coal toward the bottom	15
4. Shales, rather hard, dark to brown, with some streaks of black band	8
5. Shales with ironstone and coal streaks	3
6. Coal and clay, with 3 inches of fireclay below	1
7. Shale and coal streaks	5
8. Shale, mostly drab, weathers dark	20
9. Coal, irregular, with clay parting	1
10. Fireclay	1
11. Shale and conglomerate sandstone, with irregular pockets of coal	10
12. Coal in lenses of 12 inches thickness, mingled with fireclay	1
13. Shale and sandstone, some conglomerate	9
14. Sandstone and shale, with irregular lenses of coal	12

No. 9 is thicker on the southern side of the railroad, and it is said to reach three feet at some places, but it is always irregular. The underlying shales and sandstones rise very rapidly on that side toward the east, and they are shown in somewhat distorted condition on the northerly side where the Rulhe-Cransac road crosses the railroad. The dips there are all westward, varying from 27 to 35 degrees, but on the other side of the railroad, the dips in the same direction increase to 60 degrees. Evidently the axis of a fold is near, but it is not exposed. The lenses of coal in No. 12 are apparently fragments of a small bed broken up during the sharp folding. No effort was made to determine the exact relations of this section, but it is in the Campagnac system at a considerable distance above the main coal bed; judging from exposures elsewhere, the conditions may be local, but the section is of interest, as it is of the type familiar to those who work in American coal fields.

Eastward from the main outcrop, the southeast area of the Campagnac system reaches almost to the village of Firmy and covers most of the area north from Riou Vieux. The road from Auzits to Firmy follows a very tortuous line, as divides between the several streams are high and rather rugged, showing the hard conglomerates of the Campagnac system. On the ridge road, northeast from Auzits, one sees the reddish brown, more or less conglomeratic beds of the Permian resting on the mica schist. Within an eighth of a mile the Coal Measures are reached, but the exposures of conglomerate and shale are fragmentary. They belong to the Auzits system and have northeasterly dips. As one descends from the summit near la Vignerie towards la Bussière, half a mile from Cransac, he sees an occasional exposure of shale, with here and there something which resembles a coal blossom and at times a block of conglomerate shows itself. The deposits belong to the Campagnac and the traces of coal mark places of the lower subdivisions of the Campagnac bed. At la Bussière, where the road crosses the Ruisseau de l'Enne, coal has been mined, but the bed seems to be unimportant.

From la Bussière up to la Puech, the summit between Cransac and Firmy, there are many though disconnected exposures, but, in the upper part, there is an exposure of nearly 100 feet of shale, sandstone and conglomerate underlying a coal cropping near the summit. That coal seems to be the highest of the Campagnac divisions, possibly the Couche de Mazol. It underlies about 15 or 20 feet of shale on which rests a massive conglomerate. When the summit is reached at la Puech, one sees the bold conglomerate as a rounded boss descending toward Firmy. The Bagnaud fault is crossed west from the summit, but it is obscure farther toward the southeast, and it does not interfere with continuity of the section. The conglomerates of the Campagnac system are sharply defined to within half a mile of the village of Firmy.

The second important area of the Campagnac is bounded at the south by the Firmy fault. It extends continuously to the north end of the basin and is limited at the west by the outcrop of the Bourran coal bed.

Along the eastern outcrop, going northwardly from Firmy, the characteristic conglomerates of the Campagnac system appear somewhat abruptly at about half a mile from that village, the fault having been crossed near the hamlet of la Foresie. The coal bed has been opened at la Gouzinie and la Buscalie, but no work is in process. The dip at la Buscalie is not wholly definite, but it is westerly at not more than 18 degrees. The important work in process, south from Riou Mort, is at Tramont, the "découverte nouvelle," recently opened by the Decazeville company. This great excavation is at the summit of a narrow ridge and opens to both north and south.

The road southward from Decazeville to Tramont passes the grande découverte on the Bourran bed, the Bourran shaft on the same bed, as well as the broad expanse on which the Decazeville company roasts the blackband ore. Where the road turns eastward at somewhat more than a mile from Decazeville, an exposure of sandstone and conglomerate, belonging to the Campagnac system, dips westwardly at 25 to 30 degrees, and a similar dip is shown at another exposure beyond. The Campagnac coal bed has been mined for a long time along the west face of the ridge at about 250 feet above Decazeville, and work is still carried on in some of the openings. The last dip observed in coming up the hill is westward, but at the first pit reached, the dip is eastward at 55 degrees, so that a sharp fold has been crossed within 500 feet. At that pit, the coal underlies a coarse conglomerate, but at the entrance to the découverte, 100 yards beyond, the coal is covered by five to six feet of clay shale. The short through cutting which leads into the découverte shows the coal greatly disturbed, and a complex fold is displayed on the westerly wall within the quarry. As the longer axis of the découverte crosses the fold diagonally, a good section of the coal is exposed in the easterly wall, where disturbances are of limited vertical extent. The following measurements are approximately correct, as they are almost vertical to the bedding. The order is descending:

	Feet	Inches
1. Conglomerate	....	....
2. Coal and shale; very irregular owing to erosion during deposition of the overlying rock; coal and shale layers are very distinct; but films of coal pass downward into the underlying shale as irregular wedges. 4 feet to	8	0
3. Clay shale; this also has been removed in places; it contains numerous plant impressions with films and lenses of coal, as well as some ironstone...........	5	0
4. Coal, 3 to 4 inches, black shale, 6 to 8 inches..........	0	10
5. Clay shale, somewhat contorted, contains streaks of coal, some of which come from below and extend for a foot or more across the laminæ..................	3	7
6. Coal, with regular roof, many thin partings, of apparently mineral charcoal	4	6
7. Coal and argillaceous sandstone; 7 layers of coal and 5 of sandstone. In some places, the coal layers become thin and the mass is mostly sandstone, while in others the upper sandstones disappear and the coal layers become continuous with the overlying		

		Feet	Inches
	bench. The lower 2 feet, very argillaceous, contains many strings rising from the underlying coal and dividing into branches. This is one of the most persistent members of the section............6 feet to	9	0
8.	Coal, containing several thin clay streaks and partings, which seem to be persistent along the whole face of the wall. The coal is very regular, having suffered little distortion. The dip is 25 degrees E. N. E......	10	5
9.	Clay and coal, the latter midway and 8 inches thick; the clay is light colored and has thin films of coal..	1	8
10.	Coal, with two clay partings apparently persistent and varying from 1 to 3 inches; they carry some ironstone	2	2
11.	Clay, persistent along the whole face................	0	2
12.	Coal, with four partings, all very thin except when ironstone is present; balls of iron-stone are common in the coal, which is always distorted around them....	9	5
13.	Ironstone, persistent......................1 inch to	0	2
14.	Coal	2	0
15.	Ironstone	0	5
16.	Coal with persistent thin clay parting midway........	1	8
	The beds, Nos. 8 to 16 inclusive, may be taken as a single mass, 28 feet thick.		
17.	Coal and clay shale; 4 bands of coal, 4 to 19 inches, and 4 of clay, 4 to 10 inches; all showing great variation in thickness. Thin streaks of coal are in each of the shale bands.........................	5	0
18.	Clay shale, irregularly bedded, somewhat distorted, has a 2 to 8 inch coal layer and several thinner streaks..	8	0
	This mass is a notable feature on the opposite wall.		
19.	Coal with thin partings...........................	6	0
20.	Shale with ironstone.....................2 inches to	0	6
21.	Coal with midway a bony parting of 2 to 8 inches.....	4	0
22.	Clay, persistent, irregular, contains a lens of coal.....	1	8
23.	Coal	5	0
24.	Shale, dark, argillaceous.................6 inches to	1	0
25.	Sandstone, coarse, feldspathic; hardly coarse enough to be conglomerate, as no fragments larger than a pea were seen. The thickness is uncertain as this rock, shown only midway in the découverte, is folded closely; as exposed in a pit it seems to be not less than	15	0

Nos. 23 and 24 fold over the sandstone.

Ignoring the layers above No. 6, the bed, known here as the Paleyrets, is about 70 feet thick; the coal on this easterly side is very regular in bedding and shows few traces of disturbance; in that respect it is greatly in contrast with conditions to be described in the Bourran bed; and it is unexpected, for on the western side of this découverte, one finds the most complicated of the folds in this basin.

The conglomerate, overlying the coal in some places but separated from it by clay shale at others, is recognizable at once as that belonging in the Campagnac system. In ascending order, the succession at Tramont is

	Feet
1. Conglomerate, light gray; pebbles vary from grains to 10 inches, ordinarily not more than 3 inches, though those of 4 inches are abundant; white quartz, microgranulite, white mica schist and gneiss are the rocks represented; some large chunks of shale as well as irregular blocks of coal were seen in the lower portion..........................	9
2. Sandstone, somewhat argillaceous, not coarse grained, a few pebbles, much cross-bedded; contains streaks of coal and coaly material	3
3. Conglomerate, like No. 1, except that the pebbles are not so large	5
The dip is eastward like that of an underlying coal; it passes rather abruptly into	
4. Sandstone, fine grained and cross-bedded above, where it is markedly argillaceous; the lower portion contains some pebbles, but they are small and not abundant; lenses of coal, 2 to 3 feet long and 2 inches thick...........8 feet to	12
5. Massive conglomerates, closely resembling Nos. 1 and 3, divided by an occasional shaly bed......................	40

Still higher beds are here, but they were not measured. Evidently there is a succession of mostly coarse conglomerate for more than 150 feet above the Paleyrets bed. Some petty faults were seen in the eastern wall near the line of measurement, but the largest is barely 10 feet. The whole series, coal and conglomerate, has the same dip; but the contact between the conglomerate and the upper parts of the coal bed shows notable uncomformability of erosion. At times, everything has been removed down to No. 6; occasionally the upper portion of No. 2 was lifted like a flap and the mass of pebbles thrust in under it as a wedge. At several places, the top coal is bent down under the conglomerate, the laminæ following rudely the contact between coal and conglomerate; at some other places the upper layers of the section were shoved into irregular folds and conglomerate occupies the synclinals. It is evident that the passage from coal making to deposition of conglomerate was very abrupt and that the coal, though perhaps well advanced in transformation, was still imperfectly consolidated.

In the western wall, the coal and the accompanying rocks have been pushed into an exceedingly close double fold. This begins at a little distance north from the découverte and increases very rapidly toward the southeast. At the bottom of the western wall, the sandstone, No. 25, rises barely 5 feet above the floor of the excavation; at 120 feet southward, it is 15 and at an equal distance farther it is 25 feet above the floor. The fold continues to increase; in the western wall the top of the coal is reached on the sixth bench, whereas on the eastern wall the coal rises to the tenth bench and the crest has not been reached. Apparently the fold extends southwardly to the Firmy fault. The full extent of the disturbance is not shown in the découverte wall, for the folding is conspicuous beyond on the way down the hill. The anticlinal evidently consists of not less than three close folds in a width of not more than 350 feet. The coal is removed in benches, each about 13 feet high.

That the fold is at least double is apparent at once in the first bench; the disturbance is less on the northeasterly side and there the succession is regular. The same condition is found on the second bench, where the partings of No. 6 are undisturbed, though the coal has been pressed into laminæ, usually almost vertical to the bedding, but sometimes distinctly curved. The mass, Nos. 8 to 16, being somewhat nearer to the axis, is more affected, some portions being finely polished. On the third bench the coals on the easterly side are often polished like a mirror. On the westerly side the coal is cut off by a fold in the shales, but farther on both coal and shales reappear. This coal comes up thick from the second bench, but in the folding it was cut out by the conglomerate, which comes down from the fourth bench.

In this fourth bench the conglomerate describes two petty folds and then turns almost vertically alongside of the coal. Though folded with the coal, the conglomerate is not conformable with it, for almost 20 feet of the coal is missing. The relations seem to suggest that when the conglomerate was deposited, the coal was torn away; indeed, one is almost justified in conceiving that here is cut the course of a streamlet loaded with pebbles, for at a few feet from the abrupt change in dip, conglomerate is seen resting on the edges of the coal and shale. Above the conglomerate is a mass of more or less argillaceous, crossbedded rock, Nos. 2, 3 and 4 of the overlying section, apparently much thicker than in the eastern wall, for it reaches to the top of the fifth bench. In crossing the axis here, two folds are seen, but the coal is still quite regular on the easterly side.

On the fifth bench, on the westerly side, the shaly beds of the conglomerate seem to follow the folding of the underlying conglomerate, but exposures on the bench above indicate that the apparently increased thickness is due to a squeeze and that the more yielding rock has been pressed into a pocket between the two rigid conglomerates. On this bench, the double fold becomes more intricate, for the westerly wrinkle has been pushed past the vertical, the conglomerate underlies the coal, while the shaly mass above the conglomerate shares in the fold. On the easterly side, the conglomerate rests on the eroded surface of No. 6, but at a few feet away it has the same dip as Nos. 8 to 16, which underlie the badly crushed and contorted mass, No. 7.

The highest exposure of the coal is on the sixth bench, where it is overlain by shale. The coal rises to not more than three feet above the floor of this bench. Thirty feet away on the easterly side the conglomerate is at the floor; at the crest of the fold, it is 10 or 12 feet; at 25 feet away toward the southwest it is again at the floor. But in the latter interval it describes an extremely close fold; the two conglomerates are almost in contact; the shaly mass has been so squeezed that barely one foot of shale separates the conglomerates, the rest being in the pocket seen on the lower bench. This shale has laminæ of carbonaceous matter, which pass down vertically alongside of the conglomerate, in which the pebbles have their longer axis almost vertical.

The distortion of the conglomerate is most marked on the southwesterly side of the fold, the dip being quite regular on the opposite side. The severe effect of the crush was expended on the coal and the shaly beds above the first conglomerate, which moved between the massive beds above and below, giving local faulting in the coal and local crumpling in the shales. Higher up on the hillside, where one reaches the thicker conglomerates, evidence of extreme distortion is wholly wanting, and the dips throughout are comparatively regular.

The easterly outcrop of the Campagnac-Paleyrets coal bed has been followed northwardly beyond Riou Mort to the Lot River at the north end of the basin. The Grande Faille de Bagnaud evidently crosses Riou Mort just west from Decazeville, for the conglomerates of the Campagnac system are reached at little more than 50 rods north from that stream; but no trace of them appears in the hills west from Decazeville, where apparently all of the deposits belong to the Bourran or highest system.

The Campagnac conglomerates appear rather abruptly on the road leading northward from Decazeville to Levinhac by way of the hamlet of les Estaques, and they remain in sight almost continuously until one passes beyond the Bouquies mine near the river. Those conglomerates, in beds 6 to 20 feet thick, alternate with fine grained sandstones and argillaceous shales, 8 to 10 feet thick, showing alternations of torrential and moderate flow in the stream which supplied the material. The pebbles, often flattened in shape, are one to three inches long, but many of them have a longer diameter of six inches. The difference in form as well as in the composition of the pebbles enabled Bergeron, Jardel and Picandet to determine that the stream giving this deposit entered the basin at the northeast near the Pont de Bourran. The dip of these beds, though slightly interrupted at times, is southwestward or south of west at not far from 30 degrees, until one passes the summit at les Estaques, somewhat more than a mile north from Decazeville.

At barely 750 feet from the fork in the road at les Estaques, a conglomerate is shown dipping south of west at 30 degrees; but there the dip is reversed to north of east. At 300 yards farther the southwestward dip is resumed, and it is retained until one is directly above the entrance to the Bouquies mine. There a deep side cut shows a sharp fold with steeper dips on the northeasterly side, the beds being almost vertical; but this decreases to 20 degrees within a few rods, and that rate continues as far as the beds were followed. The exposure at this place shows between sandy and conglomerate beds, a mass of shale almost 25 feet thick and containing some thin streaks of coal. No other trace of carbonaceous material was observed at any exposure along this line; this exposure is more than 200 feet above the Bouquies mine. No closer determination was made, as atmospheric conditions rendered the aneroid useless. The coal at this mine was not measured; it is reported as being 48 feet thick.

The Campagnac deposits show only slight differences in type, and such as are shown are due mostly to the sources whence the materials were derived. They were made by streams from the southeast and northeast, and the physical structure of the deposits shows that practically similar conditions of flow existed contemporaneously on all. The thickness of the Campagnac system varies. A cross section constructed by Saint-Martin of the Campagnac company seems to make the interval between the Campagnac and Bourran coal beds not far from 175 meters at the bottom of the syncline west from Cransac. But A. Jardel, director of the Decazeville company's mines, states that in the Puits de Decazes, near Cransac, he reached the Campagnac coal at about 200 meters below the surface, and he is inclined to think that the interval between the beds is nearly 300 meters, the dip of 27 to 30 degrees being ignored. It is wholly probable that each determination is correct for its locality and that the interval between the beds decreases toward the west. A trial pit was sunk below the Bourran coal bed near Decazeville, but the test was not continued directly; at the bottom of the pit a horizontal entry was driven in the direction of the dip and a new pit was sunk at its end near the bottom of the syncline. It is difficult to determine accurately the relation of the two pits to the Bourran bed, but beyond doubt the test was carried to approximately 1000 feet without reaching the Campagnac bed. In this the dip of at least 30 degrees is ignored. Apparently, the interval between the coal beds is between 750 and 800 feet along the middle line of the basin and decreases toward the west.

A stream entering at the southwest near Valzergues is believed by Bergeron, Jardel and Picandet to have begun its work during the Campagnac period. They refer to the agency of this stream an isolated area of granite conglomerate south from Valzergues, covering about 30 hectares and resting on mica schist. It consists of granite blocks, four to five meters in diameter, with rounded angles, and the intervals are filled with granitic sand rich in feldspar. They think that the great size of the blocks proves that they had been carried only a short distance. Farther north is a conglomerate of mica schist and granite, also resting on mica schist and succeeded by sandstones and shales containing some thin coal beds, which are thought to be older than the Bourran system.

The Bourran system of Bergeron.—Prior to the close of the Campagnac system, streams bringing noteworthy loads of detritus came almost wholly from the south and the northeast, as proved by fragments inclosed in the deposits. The outlet of the basin is supposed by Bergeron, Jardel and Picandet to have been near Firmy, where those observers found a commingling of materials from the north and the south. There is every reason to accept this conclusion as correct. During the long period of the Auzits and Campagnac systems, the western part of the basin received little material, for except in the extreme southwest corner, there is hardly anything on that side which can be recognized as certainly older than the Bourran. The Lugan and Valzergues seem to have been important during the formation of the earlier Bourran deposits; and another, entering from the west near the present Moulin du Faux, is supposed to have become efficient at the beginning of the Bourran.

The earliest deposit, as described by Bergeron, Jardel and Picandet, is a conglomerate formed everywhere of enormous granite blocks, whose "colossal dimensions" are seen as one goes from the Riou Vieux up to the hamlet of Faux. Some of them measure "10 metres cubes." The intervals are filled with granitic sand, and blocks of granulite are seen occasionally. This "granite conglomerate" is followed readily southward for three miles, to near Montbazens, the blocks becoming smaller, though still of great size. An insignificant outlier remains north from Faux on the granite itself. The "granite conglomerate" is succeeded by a mica schist-microgranulite conglomerate, derived in chief part from the south; and this in turn is succeeded by sandstones and shales with some coal beds, most of which are too thin to repay working. This whole series is referred by its describers to the Bourran system. Its rocks were not examined by the writer.

In descending the Enne valley from Cransac to Viviez, one finds only few and isolated exposures along both the railroad and the wagon road. For the most part the sandstones, as shown, are not very coarse. The coal of the Bourran system is cut by the stream, but the thin beds, being without economic importance at present, are not mined, and no trace of them was observed along the roads. At a very little distance from Aubin, one passes abruptly from Coal Measures to gneiss and to granite as by a fault. This granite must be largely of the type which yields readily to weathering, as the topography is almost as rounded as that in the basin.

From Viviez to Decazeville along Riou Mort, the conditions are unlike those observed in the Enne valley. At Viviez, one is in the mica schists, which are less yielding than the granite west from Aubin. The Riou Mort valley passes abruptly from the bold angular hills of schist to the rounded hills of the Coal Measures. But before reaching the latter, one crosses a narrow prong of microgranulite, which intervenes between the schist and the Coal Measures. The contact with the latter rocks is not shown at road level on either side of the valley, but on the northerly side the concealed space is very small, and one comes quickly to a great conglomerate with the pebbles all rounded and frequently six inches in diameter. The exposures begin opposite the pottery at Laboudie and continue to within half a mile of Decazeville, the higher beds being less coarse and containing much shale as well as fine-grained sandstone.

On the southern side, everything is concealed beyond the microgranulite exposure for almost half a mile by a thick deposit of stream clay, used in the pottery. Beyond that the conglomerate is shown, containing pebbles of white quartz, white mica schist, some of gneiss and very many of microgranulite. These pebbles are smaller than those seen on the northern side and are from one to three inches in diameter. The source of the material is from the direction of Viviez, as suggested by Bergeron, Jardel and Picandet. At about 200 yards farther, as one reaches the outskirts of Decazeville, an imperfect exposure at the roadside shows higher rocks for 100 feet,

	Feet
1. Conglomerate with some shale..............................	10
The pebbles are one fourth of an inch to one inch; there are very few of white quartz, white mica schist and gneiss prevail; none of microgranulite was seen.	
2. Shales, weathering light gray..............................	15
Contain pockets of coal 2 to 3 inches thick; the shales are contorted and the coal pockets may be fragments of a continuous bed.	
3. Shales and shaly sandstones..............................	10

The dip of No. 3 is eastward at about 25 degrees.

All of the beds along this line are to be taken as belonging to the Bourran system and the Bourran coal bed extends northward beyond Riou Mort to be known as the Couche de Saint-Roch. It is continuous almost to the north end of the basin, but, though retaining considerable thickness, it contains much shale, and, owing to the proximity of the great deposits of both Campagnac and Bourran systems, its economic importance at present is very small.

At Decazeville, one reaches the area in which the Bourran bed has its great development. The Bourran coal bed has escaped erosion at only one locality in the eastern portion of the basin, where a small area remained, south from the Firmy fault. The coal has been mined there for much more than a century, but mining operations are almost at an end, as the workings have reached the village under which the bed passes. The découverte is about 2 kilometers long by one fourth to one half kilometer wide, and the coal has been removed to be replaced by waste from the iron and steel works at Decazeville. As now exposed. the coal at Firmy is compressed into a very close fold, whose axis passes directly under the Firmy church. Only a small part of the bed is shown, as rubbish covers the slope on both sides of the exposure. The dips are abrupt, 50 to 60 degrees on the northwesterly side, but so crumpled and distorted on the opposite side that no determination can be made. Exposures on the road to Auzits show that the fold is double.

The company's engineers give the thickness of the coal as about 50 feet. Blavier, as cited by Bergeron, gave the visible thickness in 1906 as 70 meters, and he believed that the mass exceeded 100 meters. This exaggerated estimate was due to the fact that the workings at that time exposed the face of the double fold. The dips become comparatively gentle at a little way from the fold, so that winning of the coal by découverte was a simple and not expensive method, the amount of cover to be removed being comparatively small. In this découverte, one observes the unfortunate tendency of the Bourran coal to spontaneous combustion, which has led to loss of vast quantities of coal in the several découvertes. The ignited mass gives ashes at the surface. coke lower down and still lower a beautiful anthracite with no apparent trace of porosity or weakness of structure. This charred coal cannot be utilized by the company, as a very small proportion ruins the coke, but it is employed in manufacture of brick and in some other industries.

Passing over to the principal area of the Bourran, one finds the coal with only moderate thickness toward the southern border; and no mines are in operation south from Cransac, because the thicker deposits are available at the north. The bed forms a syncline, cropping out again at the west as it approaches the line of eruptive rocks. It is said to be thinner and less pure toward the west, where it breaks up into several benches separated by considerable shale partings. Openings, no longer in operation, were seen along the eastern outcrop south from Cransac, where the extreme thickness reported is 18 feet. At Cransac, one is barely 1,000 feet from the great découverte of the Société des Acieries de France. The outcrop of the coal in this space is represented by an oval on the map and the deposit is known as the Couche de Fraysse; but the coal is continuous from Cransac to Decazeville and the interrupted outcrop indicates only erosion where the anticline is crossed by the Ruisseau de Banel.

Note has been made of a serious disturbance in the beds near Cransac. If one go north-northwest from that city and climb the hill, following a path passing an abandoned opening in the Bourran and crossing the summit near the old house known as la Montet, he sees, in the rolling space beyond, the Fraysse découverte, which occupies a space of fully half a square mile. A broad complex fold has kept the coal near the surface and made it so readily accessible throughout the space that now comparatively little remains. The present workings on the east side were not visited; the thickness varies from 15 to 20 meters. A vast quantity of coal has been lost by spontaneous combustion, and one portion of the area is known as "les Estuves."

Going northward along the ridge with the old workings constantly in sight at the east, one soon reaches an abandoned découverte, in which the laminated sandy shales overlying the Bourran coal are dipping sharply toward the west; but within a few rods an anticline is reached and the same beds have eastward dip of 35 degrees. At the La Gua-Combes road, a quarter of a mile beyond, the lower portion of the bed describes two close folds. West from this point as the road descends toward La Gua, the coal and its overlying laminated sandy shales are shown with sharp westward dip, while the upper part of the bed is high up in the hill overlooking the summit of the road. At this summit, one looks northward to the Banel, erosion having removed most of the coal bed along the axial line.

The fold diminishes northwardly with great speed. At the road summit, only the lowest part of the bed is shown, the greater portion being in the hill at the west. Descending thence towards the découverte Domergue, belonging to the Decazeville company, one sees the coal outcrop dropping in the hill at the west, while the middle lines of the fold are distinct in the declining hill followed by the steep road. At the Domergue, almost 300 feet below the summit of the La Gua road, the coal is under the surface on the western side and its overlying laminated shales are shown in the bluff behind the machine house, a northward fall of fully 500 feet in less than half a mile. The coal is traceable directly from the Fraysse to the Domergue découverte and the lower portions have been mined at several places along the hill descending to the Banel.

The dip of the coal is sharply westward on the hillside facing the Enne valley. A serious and somewhat complicated fault exists between the Fraysse area and the hill west from Cransac, where one finds the outcropping Couche du Crol, the same bed. This fault apparently decreases toward the north.

The section above the coal in Domergue découverte is

	Feet
1. Sandstone, more or less conglomeratic, in thick beds, xiii, xii.	60
2. Sandstone and shale, xii	15
3. Shale, light colored, xi	4
4. Shale, dark with ironstone, xi	10
5. Shale, fissile, bluish gray, xi	20
6. Sandstone and shale, the sandstone in part laminated and cross bedded, xi, x	12
7. Shales weathering dark, x, ix, viii	40
8. Sandstone, light gray, viii, vii	9
9. Shales, 4 feet to viii, vii	20
10. Sandstone, light gray, fine grained, vii, vi	8
11. Shales and sandstones, laminated throughout; thickness cannot be determined exactly from the exposures; is very undulating on the benches; extremely flexed at west end of découverte; appears to rest directly on the coal south from the La Gua road; thickness not far from	50

So that the interval from the coal to the first of the conglomerates sandstones is approximately 170 feet, filled mostly with argillaceous shale. No trace of coal was seen anywhere in this interval or in the sandstones above, of which only 60 feet were measured. The exposure is complete throughout. The coal is mined by shaft on the east side of the découverte. The removal of material in the open work is by benches and the Roman numbers in the table indicate the benches on which the exposures occur.

This découverte cuts the axis of the Cransac-La Montet anticline, but exposures are very poor below the fifth bench. In great part, the exposed coal has been destroyed by spontaneous combustion, and fire is still at work; the hill is known as the "volcano," for clouds of smoke rise from many fissures. The coal, below the surface on both sides, rises midway to the seventh bench, about 150 feet below the summit on the La Gua road, where only the lowest part of the bed is shown.

On the fifth, sixth and seventh benches, the coal is thrown into complex folds, which are faulted, for on the seventh, the sandstone, No. 8, is at only three or four feet above the coal, from which it is separated by shale, rolled into flakes like pastry. The shales, No. 7, are closely plicated as they pass over the folds, but all complexity ends with the sandstone, No. 6, which shows, as the only trace, a crumpling of the thin inclosed shales. The higher beds are regular. The faulting and sharp folding end with No. 6; the effects of the lateral pressure were expended on the yielding lower rocks, which slipped and bent sharply or were faulted locally, while the hard upper rocks made simply a broad fold, the conditions in this narrow anticline being precisely those observed in disturbed regions of great extent, where some beds are faulted, crumpled or pushed into pockets, while other and more massive inclosing beds seem to be little affected by the disturbance.

The fold is very narrow. Climbing out of the découverte at the eleventh bench on the eastern side, one finds the easterly dip already gone, the beds on the twelfth and thirteenth benches show westerly dip of 25 to 30 degrees, and this dip prevails to the supposed line of the Bagnaud fault, only a few rods farther east. Just outside of the découverte is the road from Decazeville to Combes; following that to the summit, one sees fumes issuing from many fissures, while farther west on the hillside is the outcrop in an old découverte, marked by a broad space of white, whence dense fumes arise constantly. Here one looks down on the ventilating shaft of the Bourran mine, now used for removal of waste and the blackband which in that mine covers the coal bed. The coal crops out in the steep road just below an abandoned dwelling, where it is exposed for several rods. The dip is such that, if continued, it would carry the coal far above the Tramont découverte, barely one fourth of a mile away at the east; but it is interrupted, for Bergeron, Jardel and Picandet have recognized the Bagnaud fault in the interval.

The Bourran shaft is reached at somewhat more than half a mile from the Domergue. The coal, 40 meters below the surface, is said to be 45 meters thick. At the Domergue, the thickness is given as 60 meters, the dip being ignored. At the Domergue, the dip where last seen at the east is 40 degrees eastward; near Bourran, the surface rocks dip between 25 and 30 degrees.

The great découverte of Decazeville is only 700 feet north from the Bourran shaft. Like the découvertes already mentioned, it was begun along the crest of a close fold and the old workings were confined to a narrow space on each side of the anticline, where that was at nearly the maximum. The great excavation is farther north and reaches better coal, as this fold, like the others, decreases toward the north very rapidly.

The coal in the newer portion is 120 meters below the hilltop, and the whole of this cover must be removed. The work of removal is done in benches, each four meters high, and the coal occupies the first eight, midway in the excavation. The disturbance in the coal is such that a definite section cannot be obtained such as that at Tramont; it is impossible to determine even the original thickness of the bed. But the fine exposure on the easterly wall enables one to ascertain the general structure of the bed, while that on the southerly wall exhibits in part the fold. Serious faults are distinct, but the mass of coal reaching to the eighth bench is outside of the main fault and is continuous.

On the eighth and seventh benches, there are eight meters of coal with indefinite partings; whether or not these were persistent in any case cannot be determined, because the coal is crushed by petty faults and irregular folds. A clay parting three inches thick was seen on the sixth bench and was followed for some distance, but it disappears abruptly, as if cut off by a fault. Ironstone concretions are numerous on this bench, and the coal has concentric structure around them. Some partings and pockets of shale were seen on the fifth bench, but they are not in their original position and their relations cannot be determined. A three-inch bed of clay is shown on the fourth bench, where also are numerous thin clay partings; but most of them have been broken up into small pieces with polished surface. A large mass of ironstone is a notable feature at this exposure. Throughout, the coal has been broken into wedges, large and small, some of the former showing a lens-shaped section. On the third is a streak of hard clay, six inches to one foot thick, evidently persistent, for it crosses a fold on the main floor of the excavation. The coal on this bench, as on those below, is much curled, and faults of two to three feet are numerous.

Here is a face, more than 100 feet high, and containing no certainly persistent parting more than a few inches thick; indeed, to all intents, the mass is continuous coal. Dips of 25 to 40 degrees were observed; one may take 25 degrees as the average without danger of underestimating the mass; the thickness of the bed may be about 90 feet.

But underlying this coal is an argillaceous shale with some sandstone, the top of which is seen in the lowest part of the découverte. It is a striking feature in the southerly wall, where its light color makes clear the vagaries of the fold. When first encountered in the northerly part of the excavation, this mass was 22 meters thick; but it decreased rapidly, so that in the bottom of the découverte it is only six meters, while in the Bourran shaft, 200 meters away, it has disappeared. Below it is coal, more than six meters thick, which is not removed in the open workings, being reserved for underground working by means of a shaft outside. It is exposed in the southerly wall.

The top of the coal is reached on the eighth bench, where one finds a few feet of the overlying shale; but there is no continuous section above, as at Domergue, for this easterly wall is cut by some important faults, whereby the coal reaches successively higher benches toward the south, before the folded area has been reached. In descending the incline from the thirteenth to the twelfth bench, one crosses a fault which brings the conglomerate sandstone, No. 1 of Domergue, against the laminated beds No. 11 of Domergue, while on the eleventh bench that sandstone and the coal are almost in contact. This fault appears on the thirteenth bench at the point of the hill, but it is equally well defined at the northerly end, where exposures reach to the fifteenth bench and the coal, rising eastward, is shown much folded and with only 10 feet of shale between it and the fault. This fault, viewed from the southwest corner, is very distinct from the thirteenth bench down into the coal of the ninth. The measurement of the coal already given was made on the easterly side of this fault; at a few yards southeast, the coal reaches to the tenth bench. The other faults are of slight vertical extent.

The interval between the coal and the great sandstone is not fully shown in this wall, owing to the faults, but the beds in contact with the coal resemble those seen in the Fraysse and Domergue workings. The sandstones above are light gray, with many layers of pea to chestnut conglomerate and are not far from 200 feet thick; while near the top of the hill are reddish or reddish brown beds which have been recognized as Permian. When the great disturbance occurred, the massive rocks above broke into huge blocks or were pushed into a broad fold, but the coal and shale, the weaker materials, were crumpled, thrown into multitudinous petty folds and broken by local faults. At the Bourran shaft, one is apparently outside of the faulted area, for there one sees the shales and sandstones to fully 200 feet above the coal, the dip of rather more than 30 degrees being ignored in the measurement. The succession seems to be regular on the westerly side of the Decazeville découverte, where the section resembles that at Domergue, except that two sandstone beds, six to eight feet thick, in the lower part contain streaks of conglomerate with pebbles sometimes one inch in diameter. Several sandy layers show many impressions of plants and of stems, some of them large enough to be regarded as tree trunks.

Standing at the northwest corner of this découverte and looking toward the southeast, one sees in the southerly wall a sharp carinated fold, whose abrupt middle portion is marked by the light-colored shale underlying the main coal. Beyond that is a broad valley, rising rapidly and marking the place of the old découverte, whence the coal was taken prior to the consolidation of the Commentry and Decazeville companies. The direction of these old workings is indicated by a white space covered with ashes and by the fumes which rise in such dense clouds that the hill is known as the "montagne-qui-brule." An immense quantity of coal was removed from this old découverte, where owing to rapid development of the fold the bed was reached with minimum of stripping. But the crush was very great, and the coal must have been much more broken than in the present workings. The systematic methods pursued by the director, M. Antoine Jardel, have led to securing coal much less injured and to reducing very greatly the loss by fire.

The coal in the southerly wall is no longer recognizable above the twelfth bench; but before the great destruction by fire, the face of coal shown along the fold must have been at least 250 feet high and more than 300 feet wide at the bottom, fully deserving the name, "mountain of coal." The bizarre arrangement in the wall, which is not well shown in the defective photograph, is that of the underlying clay; the great coal was exposed on both sides. This clay enables one to recognize the rapidity with which this fold, like the others already mentioned, decreases toward the north. In the southerly wall, one of the lower clays is squeezed into a carina on the eleventh bench; but, midway in the excavation at the level of the third bench, the highest of the clays folds over the anticline, a fall of 130 feet in barely 300. The exposures in the wall are very good and illustrate well the manner in which the readily yielding clays were divided and pushed into spaces between blocks of more rigid materials.

The coal is traceable on the twelfth as well as on the eleventh bench, but in great part it has been baked so as to be worthless. A fine exposure on the eleventh consists almost wholly of beautifully compact anthracite with no macroscopic evidence of porosity. This proves that, under proper conditions of pressure, bituminous coal can be converted into anthracite within a brief period by slow distillation alone. On the lower benches, beyond the influence of the fire, there are many illustrations showing the effect of pressure on structure. The shales vary according to composition; the harder, coarser beds have been folded so as to show long curved faces, often along the bedding, while the finer, more argillaceous beds have been squeezed into wrinkles, sometimes vertical to the bedding, sometimes parallel; while in many cases they have been crushed into lenses, polished so as to resemble talcose schist.

The coal above the shale is distorted seriously only in the lower portion, where the wrinkling is complex on the easterly side, the dips sometimes reaching 70 degrees. The thicker coals on that side, in several places, have lost their original structure and they are now in slabs, one to three inches thick, extending continuously in the wall of two or even three benches. The dips on the opposite side rarely exceed 40 degrees, and the coals above the clay are less affected, but they are folded gently and occasionally show petty faults.

Within the fold of shale, the underlying coal has suffered materially. An accurate measurement of this exposure cannot be given, as the wall is sometimes diagonal to the dip and at others parallel to the strike; the succession descending is

	Feet	Inches
1. Shale, argillaceous, much contorted..................	1	0
2. Coal, irregular, much twisted................1 foot to	1	6
3. Shale, argillaceous, drab, foliated like schist, has a coal streak midway..............................	8	0
4. Coal, many pockets of shale, much ironstone; the shale is argillaceous, irregular and flaky...............	15	0
5. Argillaceous shale; this has its carina on the eleventh bench, but forks on the tenth and it is the roof of the underlying coal bed; averages.................	4	0
6. Coal	6	0
7. Clay	1	0

The coals are broken into wedges with polished and often rounded surfaces. Exposures in this wall are complete down to the third bench; as one descends, the effects of the crush become more complex, the coal and shale are broken into large fragments and intermingled, until on the third bench the material seems to be hardly worth removing.

But northwardly, the condition becomes simpler. An exposure at the foot of the incline, on the level of the third bench, shows the decreased fold with these beds:

	Feet
1. Coal, mined on the third bench, where it is wrinkled into a fold, which is distinct on the fourth and fifth benches.....	....
2. Shale, argillaceous, dark, often with an almost cone-in-cone structure; when blown down, it breaks into rudely cylindrical fragments with highly polished surface............	4
3. Coal and shale, rolled into laminæ one eighth to one inch thick, with curved and polished surfaces.................	6
4. Sandstone or sandy shale..................................	5
5. Coal	3
6. Shale, apparently the upper light colored shale seen in the southern wall; is sharply contorted on the westerly side of	

	Feet
the fold, the condition being complicated by a small fault, so that it has been rubbed into close wrinkles by the vertical movement	7
7. Coal and shale, involved in the fault, beyond which it is almost vertical, but its laminæ are curved with concavity toward the fault..	2

There are few exposures in the hill west from Decazeville. The coal passes under it at the découverte. Just beyond the church square, one sees the Vialarel mine at a short distance above the level of the street. Around the hollow occupied by the mine buildings as well as along the road leading to a hamlet higher up the hill, are exposures of massive sandstone, with thin beds of shale and with many pebbles, though not enough of them to make a conglomerate. This rock has no resemblance to the conglomerates of the Campagnac system, which are exposed at barely half a mile away toward the north beyond Riou Mort; it resembles rather the sandstones above the Bourran bed. The coal bed reached in this shaft was supposed to be the Campagnac, but a tunnel, driven through from the découverte, encountered no conglomerate. The bed evidently belongs to the Bourran system and is low down in it, but its precise relation to the great bed is still undetermined. The coal is 15 meters thick and of excellent quality.

CHARACTER OF THE COAL

The following analyses are by M. Neyron Saint-Julien, chemist of the Decazeville company.

	Vol. mat.	Fixed—C.	Ash	Fuel ratio
1. Bourran	34	55	11	1.6
2. Fraysse	35	59	6	1.67
3. Domergue	35	51	14	1.5
4. Firmy	35	57	8	1.6
5. Miramont	37	53	10	1.44
6. Vialarel	35	52	12	1.5
7. Campagnac	32	58	10	1.8
8. Bouquies	35	57	8	1.6
9. Rulhe	37	56	7	1.5
10. Soulier	28.3	54.6	17.1	1.94

The analysis in each case is of dry coal, the moisture not exceeding 0.47. Nos. 1 to 6 are from the Bourran bed; from 7 to 9 are from the Campagnac bed; the one analysis from the Soulier bed is that of a hand specimen taken from the old workings,[5] so that it may not represent

[5] I am indebted for this analysis to M. E. Brocard, who collected the specimen and secured the analysis after my departure.

fully the composition of the coal. There is notable variation in the several parts of the bed, Nos. 1, 5 and 6 being from contiguous localities. There seems to have been little change as the result of the abrupt folding; hence, a series of analyses showing the composition of the coal in each yard from the bottom to the top ought to prove serviceable to the student busied with the origin of coal; such a series should show variations like those in the Mammoth bed of the Southern Anthracite field. The coals from Miramont, Domergue and Bourran are under cover of the Bourran and Permian deposits; but the coal of Fraysse and Firmy are in localities which must have been freed from most or all of the Permian and perhaps some of the Bourran load during the pre-Jurassic erosion.

At first glance, one might be tempted to draw some conclusions from the relations of the fuel ratios; but several ultimate analyses by M. Neyron Saint-Julien induce hesitation. These show that the composition is unusual for a Carboniferous coal; at all events, it is very unlike that of Carboniferous coals in Great Britain and America. The results are:

	Carbon	Hydrogen	Oxygen and nitrogen
1. Bourran	63	4	33
2. Firmy	70	5	25
3. Miramont ...	69	5	26
4. Rulhe	70	6	24

The composition is that of the dry coal in each case. M. Brocard states that a cold solution of caustic potash ordinarily has no effect on the coal, but, most commonly, boiling colors the solution pale yellow to black. This test is employed to determine the coking value of the coal; when the coloration is brown, the coal gives a poorly consolidated coke. This incidental observation by M. Brocard is evidence that material differences in composition exist within the bed. Several years ago, Stevenson[6] subjected a number of Carboniferous and Cretaceous coals to the caustic potash test and found that those giving a good coke were not attacked even after long boiling, while the open burning were attacked readily. He supposed that he was in the way to discover a convenient mode of determining the value of the coal, but Canadian reports of recent years give numerous instances of coals readily attacked by caustic potash yet yielding strong coke. These coals are closely allied in composition to lignites. The Decazeville coal cokes readily, but the coke is not strong and the burden must not exceed 60 feet.

The peculiarity of the Bourran coal which at once attracts attention is its tendency to spontaneous combustion. A heap more than six feet

[6] J. J. STEVENSON, "Jurassic coals of Spitzbergen," Ann. N. Y. Acad. Sci., vol. xvi, p. 90, 1895.

high quickly develops an internal temperature of 60° C., and, if neglected, ignites within a few days. The zinc company at Viviez, two miles from Decazeville, stored a great quantity of the coal in a heap somewhat more than 8 feet high. The rapidly increasing temperature was discovered just in time to prevent destruction of the mass. The danger is always present at outcrops, new or old. Fifteen jets of smoke were seen at one time on the easterly wall of the Decazeville découverte, where the watch to prevent conflagration is incessant. Everywhere in the great découvertes the ravages of spontaneous combustion are proved by areas of whitened surface and cindered rocks. Some of the underground workings are charged with grisou and miners use only safety lamps. The Campagnac coal has the same tendency, but it is less marked, for an official of the company at Cransac stated that heaps eight feet high are safe. The sulphur in these coals is not excessive, little more than one per cent.

In this connection, it may be well to note that the Campagnac bed is separated at most by two or three yards from the overlying conglomerate beds, open-grained rocks, while the Bourran bed underlies a great thickness of more or less argillaceous deposits, close-grained rocks. If the process of transformation continue to any great extent after burial of the coal material under the inorganic load, the Campagnac coal should show a greater difference from that of the Bourran than is indicated by the analyses; the more so as they are separated by an interval of 750 feet.

The writer's purpose in studying the Decazeville basin was to ascertain whether or not the conditions existing there favored the doctrine that coal beds are composed of transported vegetable matter. Any hypothesis offered to account for formation of the coal beds must take into consideration certain important features of the basin, such as

The original extent and character of the basin,

The manner in which the mineral detritus was deposited and the features of the streams which did the work,

The extent and distribution of the coal beds.

Certain structural features, such as the folding and faulting, being of later origin, have no bearing upon the general question.

THE ORIGINAL EXTENT AND CHARACTER OF THE BASIN

The Decazeville Coal Measures occupy a depression in the Archean schists and are bounded, at least in part, by faults which have no direct relation to those observed within the basin.

The limiting fault at the west, recognized by Bergeron[7] in 1888, is distinct from the southern border northward, passing on the west side of the granite area, but making an angle at Riou Mort, whence it is traceable to its disappearance under post-Carboniferous rocks at the north. On the eastern side a well-defined fault extends northwardly to beyond Riou Mort, east from Firmy; and the map by Bergeron, Jardel and Picandet makes it very probable that a fault continues from Riou Mort to the northern part of the basin, as was suggested long ago by Bergeron. Whether or not the basin was limited by a fault at the south cannot be determined from the observations now available; but the existence of such a fault seems to be more than probable. Bergeron's sketch-map marked it as extending from the western boundary near Valzergues southeastward to the mica schists on the opposite side, but the map in the later memoir does not show it, as its place along the greater part of the southern border is concealed by Jurassic beds. The basin owes its origin to these limiting faults, along which as lines of weakness those adjustments were made which, by changing the relative levels, made possible the deposition of a thick mass of Coal Measures. They may have been involved in the final changes, causing the present complicated structure, but their share in them was merely subordinate. The Permian on the ridge road above Auzits appears to be affected very slightly by the limiting fault.

The area of deposit was confined at first almost wholly to the southeast corner, but it expanded gradually until, at the close of the Campagnac period, it embraced almost the whole of the eastern half and a considerable space along the southern border. During the Bourran, the whole of the present area received deposits. The studies by Bergeron, Jardel and Picandet leave no doubt respecting conditions in the western part of the basin during the Bourran, and the writer adds his testimony in corroboration for localities examined by him. There is no reason whatever to believe that the basin was occupied at any time by a body of deep water; for a long time a great part of the area was exposed to subaërial action. The evidence is positive.

Bergeron, Jardel and Picandet report the occurrence near Antaignargues of a mica-schist breccia, composed of great blocks, which they seem inclined to regard as part of a delta, therefore as deposited by running water. This explanation of the origin is open to question. The vast size of the angular blocks would lead one to think rather of subaërial disintegration as the causal agent. Somewhat similar deposits are described from the southeastern corner. A small area of about eight

[7] Réunion, etc., dans l'Allier, p. 82.

acres, south from Valzergues, is covered with a mass of granite blocks with rounded angles, 13 to 16 feet in diameter, and bound together by a granitic sand rich in feldspar. This rests on mica schist and in general character is closely related to a granitic mass at a little distance southeast. Along the western border and extending to the granite area inside of the limiting fault, the earliest deposit is a "granite conglomerate" which can be followed from near Montbazens to the granite north from Riou Vieux. The fragments are of large size even near Montbazens, but they increase northwardly until beyond Riou Vieux, as one approaches the granite, very many of them are "10 metres cubes" and the intervals are filled with granitic sand, holding blocks of granulite. A small patch of similar conglomerate exists farther north on the granite itself.

When one considers the colossal dimensions of the blocks at these localities, the conception of transport by the insignificant streams entering and traversing the basin becomes at least improbable. The phenomena point rather to atmospheric action; the rounding of the angles in the great blocks west from Montbazens is a commonplace feature of granite-weathering beginning at the joint planes. The writer long ago observed many instances in Colorado, one of which he placed on record.[8] But it is unnecessary to go far from Decazeville to find a deposit like the "granite conglomerate." Along the railroad from Bort to Aurillac and thence to Capdenac, one sees at many places a thick deposit of granitic sand holding great rounded and angular blocks of granite. At Viescamp-sous-Jalles, near Aurillac, this is well exposed in a long cut, and it covers the hillsides for a considerable distance southward toward Capdenac. Where this readily disintegrating granite prevails, the valley widens, but beyond in the schist it narrows. The granite area within the Decazeville basin must be largely of the readily disintegrating type, for its topography is hardly more abrupt than that of the Coal Measures.

The presence of these conglomerates, the absence of deposits earlier than Bourran in the western portion of the basin and the resemblance to dejection cones shown by the earliest deposits in the southeast corner, all indicate that for a long period much of the basin was dry land, that the water encroached very slowly and that the entire area was not submerged or water-soaked prior to deposition of the Bourran system. The isolated conglomerate south from Valzergues cannot be regarded as affecting the question of the original extent of the basin; and it appears to be altogether probable that Bergeron, in his original paper, defined the limits of the depression as nearly as possible. The width can have suffered very

[8] U. S. Geogr. Expl. W. of 100th Mer., vol. iii, p. 348, 1876.

little contraction by lateral pressure; the folding and faulting of the beds may be due to a different cause. Apparently, the only difference between present and original limits is due to the slight transgression of Jurassic at the south and of andesite at the north.

MODE IN WHICH THE BASIN WAS FILLED

More than 20 years ago, Bergeron recognized in the Decazeville basin all the features required by Fayol's doctrine of delta formations. Deltas deposited in a body of deep water are subaqueous cones of dejection, whose characteristics have been discussed elaborately from the mathematical viewpoint by Lemière. Bergeron saw evidence of three such deltas, two at the southern end and one at the northeast. Twelve years later, when the careful studies, initiated under Fayol's direction and conducted according to the method employed at Commentry, had led to a great accumulation of facts, Bergeron, Jardel and Picandet were able to prove by the included fragments the existence of at least four depositing streams along the southern border, of one at the northeast and the probable existence of two on the western border. Their observations have been referred to incidentally in preceding pages, but they must be summarized here. They show the value of patient study in what too many think petty matters, for the results are farther-reaching than appears at first glance. The writer desires to pay tribute to those students, whose accuracy of observation and acuteness of discrimination provoked admiration at more than one locality.

Three streams coöperated in forming the early deposits at the southeast corner of the depression, one passing near Longuefort and entering near Auzits after having crossed microgranulite and mica schist; a second at less than a mile westward, entering near Haute Serre, and a third entering near Lugan. The especial deposit of each is characteristic and the confluence of the cones is well marked. The course of the Haute Serre, the most important of the brooks, is made distinct by the distribution of coarse fragments for a considerable distance northward. A fourth stream, entering at the southwest near Valzergues, contributed its share somewhat later in the history, while a fifth, entering at the northeast near the Pont du Bourran, gave the deposits marking that portion of the basin. All of these were active during the deposition of the Campagnac system, and the inflowing waters found exit on the east side near Firmy, where elements from north and south are commingled. The western streams, those entering near the Moulin du Faux and from Viviez, gave no deposits in the western part of the depression until the beginning of the Bourran, when they coöperated with the Valzergues and possibly with the Lugan in filling up that side of the basin.

The studies by Bergeron, Jardel and Picandet have shown that each of these streams was short, especially those entering along the southern border. Those students make no reference to this matter, but the facts recorded by them leave room for no other conclusion. The Longuefort-Auzits stream as well as the Haute Serre could have cut back their valleys barely three miles into the ancient rocks, even so late as the end of the Auzits system. The same is equally clear respecting the Lugan: for the massive conglomerate above the Soulier coal bed consists almost wholly of microgranulite pebbles, so that by that time the stream headed in the microgranulite area, the Auzits brook had cut back across the schists to the other area of microgranulite, for its deposit shows mingling of the two rocks. In the case of each one of the three streams, the source of the fragments is open to no doubt. The streams were longer during deposition of the Campagnac beds, though even then the character of the materials shows little change; possibly there was a rehandling of the older beds. Studies of deposits made by the other streams lead to similar conclusions, so that up to the close of the Campagnac, one has to do only with streams of insignificant extent outside of the basin and which in no case could have had an additional length of more than four miles within the basin.

The matter is somewhat less clear on the western side, where, except in the southwest, no deposit was made prior to the Bourran and the conditions already described indicate dry lands during the Auzits and Campagnac. The streams recognized by Bergeron, Jardel and Picandet may have been in existence throughout the whole period, carrying their load over to the eastern side of the basin, comparatively gentle streams contributing largely to the finer deposits separating the Campagnac conglomerates. But certainly at the beginning of the Bourran, these streams became rapid, bringing in large pebbles, which were dropped abruptly on the border of the basin, while the finer materials were carried farther eastward.

The suggestion that the Viviez and Moulin du Faux streams were already old at the beginning of the Bourran seems all the more probable, when one compares the conditions above the Campagnac coal bed with those above the Bourran. At times, the Campagnac bed passes upward through the ordinary changes of coal and shale to the coarser rocks above, while at others, the passage to coarse conglomerate is abrupt, with evidence of erosion during deposit of the first layers of the overlying rock. Everywhere, the interval from coal to the mass of conglomerate is short, represented at most by a few feet. But the interval between the Bourran coal and the coarse rocks above is great, nowhere less than 150 feet, filled with shale and mostly fine-grained sandstone, while the overlying coarser sandstones are only finely conglomeratic, as though composed of older deposits worked over.

Evidence derived from the character of the transported material leaves no room for doubt that the streams were short. The quantity of material transported by them leads to equally positive conclusions. The extreme thickness of the Auzits system approximates 1800 feet, but this measurement is made along the supposed line of the Haute Serre stream. The basal deposit, with an extreme thickness of 600 feet, is very coarse, its fragments are subangular and the exposed area is somewhat less than two square miles. The general character suggests that the material is very near its original source and that it is largely of subaërial origin. It must decrease very rapidly in all directions, especially toward the north, and the Soulier coal bed, if it exist, should be very near the Archean beyond Riou Vieux. The Auzits area increased with the newer beds, so that at the close, its deposits must have covered the eastern half of the depression. One seems to be justified in assigning to this system an area of six square miles with an average thickness of 1000 feet and a content of somewhat more than a cubic mile. For this considerable mass, one must look in great part to the three streams at the south, since the exposed area is in their region and the recognized materials could have come only from rocks cut by them. If those streams by the end of the Auzits had dug valleys such as one sees in the upper reaches of the Enne or Riou Vieux, the removed material would suffice for the whole deposit. The Campagnac system covered the eastern half of the basin, not less than 15 square miles in area, with an average thickness of say 600 feet. The content would be somewhat less than two cubic miles, to which all streams contributed. The Bourran system covered apparently the whole area, 30 square miles, with a thickness of say 450 feet and a content of two and one half cubic miles, to which all streams contributed, not only those whose work has been recognized, but also others of less importance.

These estimates may be open to charge of exaggeration, but they have been made liberally. A calculation of cubical content of the deposits suffices to make wholly clear that the whole work of removal and distribution could have been done by streams, gradually lengthening and deepening their ways until at the close of the Coal Measures the streams and valleys in the schists resembled in size and extent those now existing in the Decazeville basin.

EXTENT OF THE COAL BEDS

Little can be said respecting the original or even the present extent of the Soulier-Abiracs coal bed; the outcrop marked on the map encloses an area considerably less than two square miles, from most of which erosion may have removed the bed. How far the coal extends northward and westward under the Campagnac system has not been ascertained, as the matter has no economic importance and no explorations have been made. The greatest thickness is west from the supposed line of the Haute Serre stream, where there is about 10 feet of coal; the total amount must be large, as the bed goes under cover with undiminished thickness.

It is less difficult to determine approximately the extent and distribution of the great Campagnac-Paleyrets-Bouquies coal at the base of the Campagnac system. That bed is practically continuous along the outcrop indicated on the map, though it is said to be lens-shaped at some localities. How far it extends toward the west has not been ascertained in the northern part of the basin; an exploratory pit in the Bourran mine did not reach it, having been stopped before coming to its place; but near Cransac the underground workings of the Compagnie des Mines de Cransac have been pushed beyond the outcrop of the Couche de Crol, the Bourran coal bed. This is clear from all the cross-sections constructed by Saint-Martin, in which the bed shows only the ordinary variations, thinning toward some of the faults, thickening towards others. This bed has been recognized definitely nowhere west from a line connecting Levinhac at the north with Lugan at the south, but there seem to be good reasons for referring to approximately the same horizon some thin and irregular deposits in the southwest corner. The bed, practically single at the south as the Couche de Rulhe, divides near Riou Vieux, the intervals between the lower benches increasing northwardly in the Firmy region, so that in going by the wagon road from Firmy to Cransac, one crosses the whole series from the main bed down. The dips throughout are conformable in the Campagnac system and conformable also to the underlying Auzits. There is every reason to believe that the Campagnac coal covered much of the region south from Riou Vieux, that it underlies the Firmy area and that northward from that area it extended to the eastern border. The conditions observed along the comparatively narrow valley of Riou Mort show that the bed has been removed by erosion there. The presence of Permian in the interior of the basin and its conformability to the Bourran system seems to be a final argument. Permian is present along the eastern border and along the middle of the basin, but is lacking in the intervening space. Its absence is evidence of great erosion by which not only the Permian, but also the underlying deposits, were removed from the southeastern and eastern portions. The relations of the strata throughout indicate that all of the beds, mineral and organic alike, had at one time a much greater extent than now. One cannot be far wrong in estimating the original extent of the Campagnac coal bed as at least 12 square miles, almost all of it on the eastern side of the basin. The thickness of the coal varies, but one is safe in taking it as 35 feet. that being the least reported in any locality where work has been done in recent years and from one half to one third of that observed or reported in localities where work is now in process. Almost the whole of the eastern half of the basin was covered by a coal bed from 10 to 90 feet thick and averaging not far from 35 feet.

The extent of the Bourran bed was greater. It covered the whole of the eastern area, as is shown by the preservation of the Firmy block as well as by the distribution of Permian beds. The Permian covers the Bourran deposits along the central strip, but the Bourran coal crops out on both sides of that strip. The thickness is greatest in the central portion of the basin, but it is still great on the eastern border at Firmy, while at the extreme south, as at the extreme north, it becomes irregular and, though still thick, is broken by many shale partings. On the western side of the syncline south and west from Cransac, it is much thinner than at the eastern outcrop, while at the south on that side, shale partings increase at the expense of the coal. The thinner, irregular beds in the western part of the basin are contemporaneous with some part of the great Bourran bed, and it may be that the bed was practically continuous over the whole basin; but owing to the energetic erosion, evidence to support that suggestion cannot be obtained. One can only take the area as approximately 20 square miles, confined to the eastern two thirds of the basin. The minimum thickness reported is 18 feet; from that it ranges up to more than 100 feet, so that one is not in danger of exaggeration, if he regard the area as covered originally by the equivalent of 35 feet of coal.

The section of the Campagnac coal bed, obtained at the Tramont découverte, closely resembles that of the ordinary bed with underclay and with clay partings throughout; but no such section of the Bourran bed is available, for in the Decazeville découverte, the coal has been faulted and folded within the bed to such an extent that one cannot determine whether or not any of the inclosed clays was continuous, but there is ample underclay. No impressions of *Stigmaria* were seen anywhere, so that neither *Lepidodendron* nor *Sigillaria* contributed materially to formation of the coal.

The sterility of the intervening deposits should not be overlooked. The whole succession above the Bourran coal bed is exposed in the hill between Domergue and Decazeville and no trace of coal was seen anywhere in the section. The interval between the Bourran and the Campagnac is certainly 750 feet along the eastern exposures; the lower portion is shown well at Tramont, fragmentary exposures are numerous along the road from Firmy to Cransac and much of the higher portion is shown north from Decazeville. In this great interval, there are few horizons in which traces of coal occur, and those seem to be local.

In this connection, one must not forget that the series is complete and continuous; that a borehole at Decazeville would pass through the Bourran and Campagnac systems into at least the upper part of the Auzits, seen under the Campagnac coal at a little way east; that the Campagnac rocks continue to the eastern boundary, and that the Campagnac coal bed is far under the Bourran coal bed at the most southerly exposures. In this basin, the coal beds are of independent origin; they do not come together at the border.

ORIGIN OF THE COAL BEDS

The only hypothesis thus far presented to account for the accumulation of coal beds in this basin is that the vegetable matter was brought in by the streams. Bergeron in 1888 announced that the delta theory, newly proposed by Fayol in his brilliant memoir on Commentry, was fully applicable to Decazeville. Bergeron, Jardel and Picandet, in 1900, were more explicit, as they had better knowledge of the conditions. The Soulier-Abiracs coal bed was formed by the Haute Serre stream; the Campagnac bed was formed at the south by accumulation of vegetable matter brought down by the Lugan and Haute Serre, while at the north, the Pont du Bourran stream contributed the needed material; the comparatively unimportant Bourran beds at the west are irregular and indefinite because of their proximity to the entering currents, the fine vegetable materials being carried farther east, there to accumulate beyond disturbing influence of the streams.

The mode in which the coal occurs within the Decazeville is in notable contrast to that observed in the basin of Commentry. Accumulation of coal in important quantity began at a comparatively late time in the history of Commentry, and it was confined to two insignificant areas separated by the barren zone of Montassiégé.[9] But at Decazeville the basin

[9] For explanation of these references to Commentry, see H. Fayol, "Réunion extraordinaire dans l'Allier," Bull. Soc. Géol. de France, 3me. ser., t. 16me., Separate, p. 12; or J. J. Stevenson, "The coal basin of Commentry in central France," Ann. N. Y. Acad. Sci., vol. xix, pp. 161-204, 1909.

was not divided by a main delta deposit, and it maintained its integrity throughout, the area of deposit apparently increasing as time went on. The coal making was not confined to petty areas, but the beds formed practically continuous sheets over a great part of the surface, the Bourran and Campagnac extending to the outlet at Firmy. In Commentry, there is no coal on the delta of the Bourrus brook, the barren zone of Montassiégé, or even on the deltas of the Chamblet and Colombier brooks, as defined by Fayol. Aside from some insignificant patches along the northern border, one finds coal only in the recesses between the Montassiégé and Colombier zones on one side and between Montassiégé and Chamblet on the other. But in the southeast corner of the Decazeville basin, one finds the coal crossing the conjoined deposits of the Longuefort and Haute Serre brooks—and this condition continued there throughout, for the curved outcrops of the Soulier, Campagnac and Bourran beds are shown crossing the area of stream deposit from Haute Serre to Firmy. One must bear in mind that the curved outcrops are no evidence of original form or extent of those beds; they are due to erosion of a fold with strong northward pitch. The distance from Haute Serre to Firmy is about four miles. Farther north, the Campagnac bed crosses the area of deposit as clearly as at the south.

The contrast between Commentry and Decazeville is so great that the delta theory as determined at Commentry would have to be modified in important respects before becoming applicable to Decazeville. The theory, as formulated by Fayol, may be summarized thus:

The coal terrains have great analogies to present deltas; both are composed essentially of materials carried by streams of water; the plant beds of deltas are represented in the coal terrains by combustibles of plant origin. In the coal terrains, as in deltas, the extent of the beds varies from a few square meters to some thousands of square kilometers; the thickness varies from a mere trace to several dozens of meters; the size of the elements from the finest grain to blocks of several cubic meters. At Commentry, a lake surrounded by mountains was in the place now occupied by the Coal Measures. Rain water gradually ate away the surrounding region, dug valleys and carried to the lake pebbles, sand, mud and plants, which finally filled it; these are the materials which constituted the beds of conglomerate, sandstone, shale and coal making up the Coal Measures. The lake of Commentry was nine kilometers long by three wide and its greatest depth was about 800 meters. The distribution of materials depends on their specific gravity or fineness, as well as upon the condition of the water, whether quiet or agitated, into which they are carried. The finer, lighter elements will be carried much farther than the others before reaching the bottom.[10]

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[10] H. Fayol, "Réunion, etc.," pp. 14, 19, 13.

The essential features of the doctrine are that the basin was occupied by a deep lake into which streams brought detritus of all kinds, mineral and vegetable, to be deposited on the bottom in the order of their specific gravity, very fine mineral matter being equivalent in distribution to plant material. An important and attractive feature in Fayol's presentation is the assertion that the coal deposit accumulating on the floor of a basin may be, in its several benches, contemporaneous with deposits at several horizons on the delta slope and thus, though resting on the floor, it may be continuous with a bed which, at the shore, is 1000 feet above the bottom of the basin. This is to explain the shoreward bifurcation of coal beds.

There is no room for difference of opinion respecting the origin and mode of deposit of the inorganic materials in so far as they owe their presence to the transporting power of water; the only question is respecting the origin and mode of deposit of the organic materials now found as coal beds.[11] Unquestionably, the so-called delta theory explains satisfactorily some features of the Decazeville as well as of other basins and, regarded from this viewpoint, it has much to commend it. The flexibility and adaptability of the doctrine in the hands of some of its adherents are thought to be strong arguments in its favor; but these matters are merely secondary. When a hypothesis is presented, the first question to be asked respecting it is, Is it possible? and the second is, Is it probable? To be convinced that this double test is essential at the outset, one need only read some of the old works on cosmogony. Whiston is especially worthy of study, for his work contains not merely a vast accumulation of actual facts, but also a wealth of mathematical demonstration which apparently leaves nothing to be desired. No recorded observation, no known fact, no phenomenon in earth, sea or sky failed as buttress to his elaborate theory respecting the origin of things. That was the panacea for perplexities in cosmogony, and its only defect was that it was based on assumptions. Equally satisfactory as an illustration is the celebrated hypothesis presented by Piazzi-Smyth respecting the great pyramid at Ghizeh, which explained the purpose of every part of that structure so beautifully as to arouse admiration as well as to carry conviction. The only objection to it is that it is based on assumptions which are not true.

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[11] In passing, it may be well to mention a matter of minor importance. The writer was informed several times while in Decazeville that, as the mineral detritus is due necessarily to transport, the natural conclusion would be that the interstratified coal had the same origin. Those who advance this argument seem to regard it as conclusive; but it is not so. Applied to a coral reef inclosed in sandstone or to a sunken swamp covered by sand on the New Jersey or Baltic shore, one would be justified in asserting that since the reef and the swamp are of known *in situ* origin the inclosing sand must also be of *in situ* origin.

One must concede that a hypothesis might be framed which would account satisfactorily for many conditions in a given locality and still be based on an impossibility. Before considering the applicability of the delta theory to Decazeville, one must ascertain whether or not the fundamental conditions demanded by that hypothesis existed in the region under consideration.

The Decazeville basin is very small; the earliest deposits were laid down very soon after the depression was formed, for the rocks belong to one subdivision of the Coal Measures and there is no evidence that rocks of greater age intervene between them and the Archean. The character of the Coal Measures shows that the streams in the earlier period were short and torrential: that even during the greater part of Campagnac deposition they had cut back only a few miles, had not a wide fan of tributaries, but were still more or less torrential and flowed in narrow valleys such as are seen now in and around the basin. They emptied into an at most wholly insignificant body of water, so small that during floods such as have been imagined by some adherents of the transport doctrine everything except coarse stuff would be carried directly to the outlet at Firmy, and the finer materials would be deposited outside of the basin.

Under such conditions, all citation of phenomena observed on deltas of the Mississippi, Nile, Ganges, La Plata or even of the Rhone, would be irrelevant. Streams flowing hundreds or thousands of miles through broad plains and carrying for the most part fine material in their lower reaches, along with trees gathered from immense areas by undermining of banks cannot be utilized to illustrate what a three or even 10 mile torrent, flowing over tough mica schist or microgranulite and inclosed in a narrow valley would or could or might do. Nor may the deposit at the mouth of a petty stream emptying into a pond be compared in any sense with the delta of a vast river. In fact, the term "delta" as applied to the theory seems to have been chosen without full consideration. The writer has not been able to discover in the Montassiégé area of the Commentry basin any evidence of a true delta. The deposit is rather a great dejection cone, largely under water perhaps, with no doubt temporary delta conditions during excessive floods, but during most of the time trenched by only one waterway. It might be well in discussing the conditions to avoid the term delta as not wholly appropriate, and to think instead of broad dejection cones such as one sees in the Rhone valley between Viége and Martigny. At least one of those cones is so much like the earliest Auzits deposit in form and extent as to make not unreasonable the suggestion that the latter began as a subaërial deposit.

Another matter may be noticed in a preliminary way. The delta doctrine in its original form conceives of the coal basin as occupied by a lake of great depth; this no doubt to avoid the difficulty of accounting for the 2500 feet of rock by continental subsidence. But the great original depth of the depression, as shown by Delaunay, is by no means essential to the hypothesis, which without that deserves all the praise which has been lavished upon it for its ingenuity. Lemière has expended much labor and great skill in the effort to determine the forms which the deposits would assume in deep water; but that question does not concern the matter in hand, for there is no evidence whatever to support the suggestion that the basin held a deep lake; such evidence as does exist all indicates that the water area was often small and that it was never deep; that until the end of Campagnac deposition a considerable part of the basin was exposed to subaërial action; even that the Haute Serre deposits may have been begun as a subaërial dejection cone.

The Decazeville basin embraces about 30 square miles; the entering streams, at first short and abrupt, cut back their valleys until in the Bourran time they may have attained a length of 10 miles, sufficient to account for the whole deposit of inorganic detritus. Adding to the surface of the basin itself a strip 10 miles wide, surrounding the depression, the extreme area whose waters found outlet at Firmy would not be more than 350 square miles at the time of greatest extent. In all probability it was much less. The vegetation to supply detritus for the coal beds must have been derived from that area, and the detritus could reach the basin only by way of streams, torrential during a great part of their existence and flowing over tough, resistant rock.

The type of valley through which these streams flowed is familiar in France. The gorge between Eygurande and Bort and that between Allassac and Vigeois on the way to Limoges suffice for illustrations of cutting in the schists. One has only to vary the scale in order to have all the features shown by the Decazeville streams in the several stages of their development.

The work around the basin was confined at first necessarily to corrasion, and erosion made slow progress. But it may be that disintegration of the upland rocks was rapid and afforded material in which vegetation quickly became as luxuriant as at many places between Montluçon and Viviez, within the schist area; that even the walls of the early valleys were covered by a dense growth, such as is seen in close gorges within the same area. One may well imagine this condition, since the Coal Measures flora is taken to be proof of a warm and rather humid climate. One may picture to himself the upland region as covered in great part by a forest, its surface imperfectly drained and its borders indented by short, abrupt streams.

But one is confronted at once by serious difficulty in the effort to apply the doctrine of transport. The Soulier-Abiracs bed rests almost directly on the lowest deposit of the Auzits system; its curved outcrop is from one fourth of a mile to a mile and a half from the schists, so that the coal must have covered much of the space inclosed by that outcrop; it may have been spread over four square miles, or even more, with an average thickness of three feet. While this bed was accumulating, the three streams of Longuefort, Haute Serre and Lugan must have been utterly insignificant. The Campagnac coal bed had an area of at least 12 square miles with an average thickness of 35 feet; the length of the streams, outside of the basin, may have become as much as six miles. The Bourran coal bed was formed when the whole basin was receiving deposits, so that its material must have come wholly from outside, from an area of not more than 300 square miles. One can concede that enough vegetable matter, several times over, was produced on the drainage area to form the coal beds and, at the same time, he would be justified in doubting the possibility of its transference to the basin. Of course, every one knows that small streams at all times carry twigs and leaves and that they carry larger fragments during flood; but that is nothing, for one is concerned here not with patches of carbonaceous matter but with coal accumulations 70 to 100 feet thick.

Rainfall, even when heavy, does little toward shifting the vegetation growing on steep slopes, unless the rock material be loose, in which case landslides may occur; but those are of limited extent, even when greatest. If there be a coating of humus, the effect of the rain is practically nothing. It is unnecessary to go far from Decazeville in search of proof.

At Viviez, two miles away, fumes from the zinc works have destroyed almost all vegetation on the abrupt hillslope alongside; rains have already gashed the face deeply and the cover of disintegrated rock is accumulating at the bottom. The limit of the devastated space is defined sharply; southward from it the vegetable cover remains, and the surface is uninjured. This protective power of humus is familiar. That material accumulates under forest cover everywhere, even on very steep slopes; it absorbs water and then coheres tenaciously. Studies made near New York in the effort to solve the problem of water supply for some towns prove that the humus coating is permanent on exceedingly steep slopes and that water from such slopes is limpid, practically free even from vegetable matter. The hills bounding the gorges below Eygurande and above Allassac have slopes often reaching 30 degrees and sometimes exceeding that angle, while walls in railroad cuts frequently approach the vertical. During the summer of 1910, the rainfall in that portion of France was unusually great, and the numerous showers were almost tropical in violence; water swept down the hillsides in sheets and petty rivulets were converted into torrents. Yet one traveling through those gorges on the railroad could see little trace of destruction—even the plants growing on the walls of cuts were uninjured.

As the Carboniferous climate is supposed to have been tropical or subtropical, reference to conditions observed in the tropics is proper. The writer has had opportunity to examine at close range fully 100 miles of the Venezuelan coast, much of western Trinidad and about 50 miles of the Jamaican coast. The slopes in Venezuela and Trinidad are abrupt, and the strata are often inclined at a high angle. Landslides are not rare, and they always leave a broad scar on the face; but elsewhere the only evidence of heavy rainfall is an occasional gully in yielding rock; the vegetation is practically intact on the steepest slopes. Jamaica illustrates well the relations of rock, rainfall and vegetation. Near Kingston, the rock is a yielding slate on which vegetation can hardly secure a hold; the rainfall is but 30 inches per annum, yet the slopes are gashed. Eastward, where the rock is better, one sees an occasional gully and here and there a landslide; but for the most part the vegetation is very dense. Where trees have been burned off, Guinea grass has taken prompt possession of the surface on even the steepest slopes, giving great spaces of bright green which are notable features of the scenery. During November of 1909, the rainfall in the mountains of the island was excessive, there having been at one locality a fall of 120 inches in eight days, while there were falls of 20 to 30 inches within 24 hours at many others. Banana plantations, with unprotected soil, were washed down the hills and the plants became projectiles with which the flood destroyed vegetation on the lowland; but the cocoanut forests remained almost uninjured and the litter of vegetable débris covering the ground under them was not disturbed. Where the surface was protected by vegetation, the damage was confined to gullies dug by fallen trees pushed forward by the water. These gullies widened in soft material and trees tumbled into the torrent were carried down to the lowland, where they were deposited pêle mêle with mineral detritus over the cultivated area.[12]

It would seem altogether probable that rainfall on slopes along streams could do little toward forming the coal beds of the Decazeville basin. But on the great rolling upland area, drained by the streams and covered by forest growth, the decaying vegetable matter accumulated during a

[12] I am under obligations to Mr. C. Leslie Mais, C. E., of Kingston, for statistics of rainfall in Jamaica, and also for information respecting localities which I could not visit.

long period and formed a thick coating of humus, which, torn off by a mighty flood, might be carried into the basin, there to become coal. It has been suggested many times that such removal would be necessary in order to maintain continued growth of the forest, there being something in humus which is repugnant to trees.

The latter suggestion should be considered first, for it has been urged as showing that the transport doctrine is the necessary explanation of a thick mass like the Bourran bed, almost unbroken by partings. But it is due to a misconception of the conditions. Plants do not find repulsive materials in humus. Almost 150 years ago, De Luc wrote in one of his letters that the old fortifications of Oldenburg, made of material taken from the swamps, were covered with trees showing remarkably luxuriant growth. It is well known that advancing swamps destroy forests by obstructing the drainage, so that the trees are literally drowned by the increasing moisture. There are many plants, among them some trees, which not only endure the moisture, but even thrive in the moist humus; some indeed attain their best estate only when growing in the humus itself. The cedar of the New Jersey swamps, as shown by Cook many years ago, yields its finest wood only where the roots do not reach the subsoil; for where the swamp is shallow and the roots penetrate the underlying beds only inferior wood is produced. The vast thickness of apparently uninterrupted coal in the Bourran bed is in no sense an argument in favor of origin by transport; on the contrary, it may be an important argument against the doctrine as applied to the Decazeville basin.

The floods, upon which some authors lay great stress, could do little along the lines of the streams, even were the valleys as wide at bottom as are those now crossing the basin. It is true that large streams in flood carry houses and logs, but those are, so to speak, only loose materials lifted from open spaces. Transported trees are merely those which have fallen into the water from undermined banks. But along the streams entering the basin, the amount of vegetable matter available for removal could be in only insignificant quantity. The area with abundance of vegetation was mostly in the forested upland region, which is supposed to have been a rolling surface, ill-drained in portions, with broad rather deep swales in which at times the water would collect and flow with increasing force, these conditions being most favorable for accumulation of humus or half-decayed vegetable matter. This humus cover on the upper surfaces could not be affected by the moving waters: the only spaces to be considered are the lower broad hollows falling toward the streams, through which the mass of water would tend to flow rapidly.

One must recognize that the conditions observed in floods of the Seine and Loire are not the same as those probable in the region under consideration. Those rivers rise in the highlands and flow for a long distance through a plain country. Yet there are resemblances and the movements of the water are much the same. The devastation produced by rain-floods is not brought about by the moving water directly, but by the material which is carried, and that is collected by the way. In any case, the water does not come down as a high wave, but with the face rising gradually up stream. No matter how rapid the rise of a rain-flood may be, it is gradual, and only loose materials lying on the surface are gathered up to be carried off. When deep, the water moves slowly below, rapidly above. If the flood pass over a forested plain, its speed is checked in flowing through spaces between the trees, and practically the only injury done is by deposit of mineral material. Even when a flood passes over meadow land bordering the stream the destruction is by burying the soil, as every one knows who has observed the conditions on rivers subject to floods. After a high flood on the Connecticut river, the maize growing on unprotected soil of the "bottoms" had not been washed away; but the rapidly moving water at six feet above the ground had pushed against the spreading tops and had overturned the plants, which lay spread on the surface. The peat bogs existing in many places along the sides of the river have been exposed to floods, great floods, for centuries, but they are intact except along the border, where undercutting of the loose material on which they rest has caused portions to fall into the stream and has made the edge ragged. Kuntze has told the same story about the great peat areas of the La Plata region.

That the running water of floods is not the direct cause of destruction is certain. Every one has observed little islands in streams subject to floods, islands covered with trees, though in flood time these may be submerged for a brief period to the depth of 10 feet or more. The streams issuing from the eastern face of the Rocky Mountains are given to frequent rise of 10 or more feet, the rise being very sudden, yet many of them have wooded islets, most inviting camping places for the inexperienced traveler. Above Vigeois, between Brive and Limoges, the stream has been dammed. Near the head of the pond, the writer saw in 1910 a young tree about eight feet high growing midway in the stream in the cleft of a large rock fragment and only a few inches above the level of the water. That tree had resisted the floods of at least five years, and some of the floods in that torrent must be extremely violent. Unless the stream be loaded with débris, it can do little damage to the flooded area; it will not tear up peat bogs, it will not remove the humus, it will do insignificant injury to a forest.

It is evident that conditions necessary for serious destructive work could not exist in the upland area under consideration. In that area, covered by dense vegetation, the waters would collect slowly in the lower portions; flowing from the humus-covered surface under the forests, they would be almost limpid and with no mineral detritus, carrying only such chance stems as had escaped entanglement while floating through the forest. Even in the broad hollows the flow would be impeded by a dense growth of herbaceous plants, so that rapid movement could be attained only when the water reached the streams; and there alone could a load of detritus be gathered with which to do cutting. There is no conceivable mode whereby vegetable matter growing densely on the upland could be conveyed to the basin.

In this connection another matter requires consideration. The Bourran coal bed, not less than 90 feet thick at Decazeville, is a practically continuous mass, unbroken by persistent clay partings, and it extends with decreasing thickness over much of the basin. No matter which theory of formation be accepted, transport or *in situ*, one must recognize that the accumulation of such a mass would require a great length of time. If one accept the transport theory, a great area is essential as source of supply, and equally a vast period of time. The suggestion that a single flood might provide material for a coal bed, by bringing down vegetable débris which had accumulated during a long period, involves insurmountable difficulties. The total area tributary to the basin could not have exceeded 350 square miles; the material for the Bourran coal bed would require a cover of humus at least 20 feet thick over the whole area, and this would have to be removed by a flood of a type unknown and operating as no flood of modern times acts, for the whole mass from the whole area would have to be brought down. The suggestion, moreover, is not consistent with an argument offered by its author in support of the delta theory, for it demands a thickness of humus which would be fatal to growing plants. In any event, one can readily see that the inpouring of a flood so terrific in extent would churn up the little lake and all light materials would be driven at once to the outlet, to be deposited far outside of the basin.

It is equally difficult to understand how the great bed could be formed by gradual deposit of transported vegetable matter during the vast period of time. One is told that during formation of the sterile deposits, the streams concentrated their attention upon inorganic materials and that during the great floods, they concentrated their attention upon vegetable matter. Such intelligent discrimination on the part of running water is incredible.

One may not appeal here to Fayol's ingenious explanation of conditions observed at Commentry, for those conditions do not exist in the Decazeville basin. In the former basin, the bifurcation of the Grande Couche toward the shoreline is regarded as evidence that while the delta advanced, coal was deposited continuously in the basin beyond, but the deposition was interrupted on the delta slope; so that several thin beds, widely separated at the shore might be one far out in the basin. That explanation is not available for Decazeville, for no such relation exists between the coal beds there, the greatest intervals between them being in the central and eastern parts of the basin.

Whatever may or may not be the worth of the Fayol doctrine respecting the formation of coal beds as applied to other localities, the fact remains that the fundamental requirements of that doctrine do not exist in the Decazeville region. The doctrine is wholly exact when applied to the accumulation of inorganic materials, but one must look elsewhere for an explanation accounting for the accumulation of the coal beds, an explanation consistent with phenomena known to have existed at many periods in the earth's history and known to be existing now. And this is found only in the doctrine of origin *in situ*.

HISTORY OF THE DECAZEVILLE BASIN

In the later portion of the Carboniferous, a triangular block of schist and coarse granite was dropped within the three limiting faults, with its surface sloping gently toward the southeast, thus giving a slight depression, in form of a gaping fault. Midway on the eastern side, near the present village of Firmy, there seems to have been a valley, eroded by a preëxisting stream, and with floor still below that of the depressed area. The vertical displacement, small at first, was sufficient to disturb the drainage, for streams entering from the south evidently originated at this time. Water from all sides escaped through the outlet near Firmy, while detritus was dropped on the borders. The especial line of weakness was along the southeastern side, where subsidence continued until the floor sank beneath the outlet valley and water accumulated to form a pond with an area of several square miles. The little streams carried their loads into the pond, filled it and flowed across the newly made land. The finer materials, spread during flood time over this area, converted it into a muddy flat, of which plants took possession. During extremely slow subsidence, vegetable débris accumulated in the swamp to form the Soulier-Abiracs coal bed. Conditions favoring such growth and accumulation obtained first where the Haute Serre and Lugan deposits were confluent, and thence they extended slowly in each direction.

But the subsidence became more rapid along the eastern border, the land surface sank below the outlet, the pond was formed anew and with gradually increasing area. Evidently the movement was enough to disturb the little streams at the southeast, to render them torrential, so as to sweep out the pebbles, large and small, which had accumulated, as well as to provide a continuing supply. But this condition was of comparatively brief duration, and one finds above the feldspathic conglomerate a recurrence of shales and more or less coarse sandstones. Once more the area is one of muddy flats, but much larger than before. This condition was reached first between the Enne and Riou Mort, where the marshy growth which was to give the Campagnac bed originated. There the streams from north, east and south had dropped their finer materials and thence the marsh expanded, until it reached the border on all sides of the swampy area. Whether or not it extended to the southeast corner cannot be determined. In any case, the subsidence was irregular in that part of the basin; the Haute Serre brook was more or less torrential for considerable periods, and the advance of the Campagnac marsh across its deposits was interrupted several times. The Haute Serre and Longuefort streams covered the swamp again and again with more or less coarse deposits, so that the bifurcation of the bed as it crosses the area of deposit is one of the most interesting features observed in the basin. But this condition had ceased practically at an early period in the history of the Campagnac coal bed. The vest thickness of that bed in the central part of the area and the decreasing thickness in all directions suffice to show that the great marsh had its origin near Cransac. The gentle subsidence was long-continued, permitting the accumulation of more than 100 feet of coal.

One would expect to find that so long a period of comparative quiet was followed by one of rapid and extensive adjustment, and in the basin of Decazeville the expectation is fulfilled. Subsidence, still mostly in the east and south, again brought the swampy surface below water and it was covered with a thin coat of fine detritus. The streams became torrential at the east and south, pushing their loads of coarse material into all portions of the flooded area. The water was always of moderate depth; frequent shale beds show that the streams were often sluggish, while occasional deposits of coal and coaly material are evidence that here and there mud banks reached to the surface and became swamps. But for the most part, conditions were unfavorable to the development of plants, and mineral deposits continued to a maximum thickness of 750 feet, a mass practically devoid of coal.

During this long period the water-covered area expanded, and very possibly some of the deposits in the western portion, assigned by Bergeron, Jardel and Picandet to the Bourran system, may antedate slightly the Grande Couche de Bourran. It is wholly probable that many of the later deposits there are contemporaneous with earlier parts of the Bourran bed. Until the closing stages of the Campagnac system, the western third of the basin had been above water and its rocks had been exposed to subaërial agencies, while the streams draining the western border had carried their water and their loads to the eastern side. But toward the close of Campagnac deposition, the relative conditions were changed; the unstable east side became comparatively stable, while the hitherto stable west side subsided rapidly. While the eastern portion of the basin was becoming an area of mud flats, the western portion became a pond into which streams from that side dropped their coarse materials and the silts were carried eastward to be spread over the emerging land. This condition continued into the Bourran.

When the area between the Enne and Riou Mort, midway in the basin, had been converted into an ill-drained plain, the swamp took possession and advanced thence in all directions, rapidly toward the east, but less rapidly toward the north and the south. The period of very gentle subsidence, following the abrupt change on the west side, was very long, sufficing for the accumulation of at least 100 feet of coal within the original area. The western portion of the basin was filled slowly, and it seems probable that there was little addition to the swamp land in that direction, until late in the formation of the Bourran bed. The irregularities of the swamp border at the west are proved by the clay partings in that direction, especially in the southern prolongation of the bed, where the stream deposits were confluent.

Slow subsidence of the whole block continued long after the accumulation of the Bourran bed. The streams had cut down their channels, and as they flowed over the marsh, they deposited only fine material until a thickness of at least 150 feet had been reached, in marked contrast with conditions succeeding the formation of the Campagnac bed. More rapid adjustment followed, the speed of the streams was increased and the Carboniferous was closed by a deposit of moderately coarse sandstones. There was no return of coal-making conditions. After the deposition of several hundred feet of rock, the land and freshwater features disappeared, and the Permian sea invaded the basin from the south and laid down its beds in practical conformity with the older series below.

The date of andesitic eruption is somewhat uncertain. Bergeron, Jardel and Picandet, who devoted much time to the investigation, seem inclined to believe that the eruptions came at different times. The rock is a notable feature in the northern part of the basin, but it is not confined to that area. Three islets of eruptive rock, in part andesite, are seen north from Lugan, which are in line with an islet of andesite in the northwestern corner, as well as with prongs of an "altered prophyritic rock" projecting from the southern border near Lugan. Cross sections by Bergeron, Jardel and Picandet as well as those by Saint-Martin show that in approaching those islets from the east, the coal is turned up toward the west. Saint-Martin's sections farther north and south, in which the eruptive rocks do not come to the surface, show similar arrangement of the coal beds. Along this line the eruptive rock is newer than the Permian, since that system is involved in the folds. The complicated structure of the basin probably dates from the issue of these rocks; the petty outcrops are only projecting portions of a great mass below, continuous from the southern to the northern part of the basin. For the most part, the local faults and other irregularities of bedding, thought to be due to causes acting during deposit, have resulted merely from movements of softer between harder beds during the final disturbance.

PLATE XIV

FIG. 1.—OUTCROP OF BOURRAN COAL BED AT FIRMY.

FIG. 2.—SOUTHERLY END OF THE DECAZEVILLE DÉCOUVERTE.

The old workings are shown in the background, with fumes due to spontaneous combustion.

Fig. 1

Fig. 2

PLATE XV

FIG. 1.—A "LOCAL FAULT" IN THE EASTERLY WALL OF THE DECAZEVILLE DÉCOUVERTE.

FIG. 2.—THE DOMERGUE DÉCOUVERTE.

Shows effects of spontaneous combustion.

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(*Contributions from the Entomological Laboratory of the Bussey Institution, Harvard University. No. 32*)

THE NORTH AMERICAN ANTS OF THE GENUS CAMPONOTUS *MAYR*

BY WILLIAM MORTON WHEELER

(*Presented by title before the Academy, 14 November, 1910*)

Our North American *Camponoti,* which comprise not only our largest and most conspicuous, but also many of our most abundant ants, were admirably revised in 1893 by Prof. Carlo Emery[1] on the basis of a rather extensive collection received from Mr. Theo. Pergande. So much new material, however, has come to light within the past seventeen years, that it seems advisable again to take account of stock. Emery recorded 28 forms of *Camponotus* from America north of Mexico. These represent 11 species, 9 subspecies and 12 varieties. The present paper records from the same territory 58 forms, representing 21 species, 17 subspecies and 27 varieties. Most of the new forms have been found in western and southwestern Texas and southern Arizona and properly belong to the fauna of northern Mexico. Careful search will undoubtedly bring to light several additional forms in the southwestern states and possibly also in tropical Florida, but I believe that few new forms remain to be discovered in other parts of the Union. I have seen all the recorded forms except two varieties of *C. fallax* (var. *cnemidatus* Emery and var. *paucipilis* Emery), and I have observed most of the species, subspecies and varieties in living colonies.

Ethologically, our *Camponoti* may be divided into two sections, one of which, embracing only the *maculatus* group, contains species that nest in the ground under stones or logs or more rarely in obscure crater nests, whereas the other section embraces all the other groups and contains species that usually nest in dead wood or oak galls. These wood-inhabiting species, however, exhibit considerable diversity of habit.

No genus of ants has a more interesting or significant geographical distribution than *Camponotus*. In North America, only one of the

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[1] Beiträge zur Kenntniss der nordamerikanischen Ameisenfauna. Zool. Jahrb. Abth. f. Syst. VII, pp. 633-682, Taf. 22. 1893.

species ranges over Alaska, British America and the United States, viz: the circumpolar *C. herculeanus*, and of this the variety *whymperi*, which is almost indistinguishable from the north European and Alpine type and is said by Emery to be identical with the Siberian variety, is practically confined to Alaska, British America and to higher elevations in the United States. The variety *noveboracensis* extends across the continent through the northern states and Canada at low elevations; the subspecies *pennsylvanicus* occurs apparently only in the United States and Canada east of the one hundredth meridian and at ordinary elevations, the variety *modoc* only west of the same meridian at higher altitudes. The varieties *mahican* and *ferrugineus* seem to be confined to the northeastern and middle western states. Another species of wide range is the circumpolar *C. fallax*, which is represented by at least 12 subspecies and varieties in the United States and southernmost British America. All the remaining species are decidedly local. The various subspecies and varieties of the *maculatus* group are confined to the western and southern states, the subspecies of *maculatus* occurring only west of the one hundredth meridian, except in Texas, where one of the forms (*sansabeanus*) is found at least as far east as Austin, and in Florida, where there is a subspecies (*tortuganus*) of tropical origin. The southwestern states have a few peculiar species of the *maculatus* group, in all probability of Mexican provenience. These are *C. fumidus, vafer* and *acutirostris*. A tropical species of this group, *C. socius*, is known to occur only in southern Florida, and two members of the *maculatus* group, which are peculiar to North America, viz: *C. castaneus* and its subspecies *americanus*, are confined to the region east of the one hundredth meridian and south of British America. In this region, *americanus* ranges farther north than *castaneus*. A single very constant species of the *herculeanus* group, *C. lævigatus*, is confined to rather high elevations in the Rocky Mts., Coast, Cascade and Sierra Nevada Ranges. The *fallax* group is represented in Arizona and Texas by a few large and handsome species, *C. sayi, texanus* and *schaefferi*, and in California by a small and somewhat aberrant species, *C. hyatti*, with the variety *bakeri*. *C. mina*, subsp. *zuni*, *C. bruesi* and *ulcerosus* are properly Mexican forms of rare and sporadic occurrence in Texas and Arizona. Two tropical species, *C. planatus* and *abdominalis*, enter the United States at two widely separated points, from the West Indies at the tip of Florida and from the "tierra caliente" of Mexico at the mouth of the Rio Grande. *C. planatus* is the same in both these regions, but *abdominalis* is represented by a distinct subspecies (*floridanus*) in Florida and a Mexican subspecies (*transvectus*) in Texas. The species of the subgenus *Colobopsis* seem to be confined to the Gulf

States and the Mississippi Valley, but, as these ants form small colonies and live very secluded lives, their exact distribution cannot be determined at the present time. All four of the forms enumerated in this paper have been taken in Texas. I have seen a single worker minor, which seemed to belong to *C. pylartes*, from southern Illinois.

In the following pages, I have given descriptions of all the forms, except those of the *fallax* and *Colobopsis* groups, which have been described in detail in two papers already published.[2] As our knowledge of the precise distribution of our North American *Camponoti* has been very vague and incomplete heretofore, I may be pardoned for citing all the localities from which I have seen specimens, together with the names of correspondents who have most generously assisted me in collecting material.

The following table will facilitate the identification of the major (maxima) workers.[3]

1. Head of worker major truncated anteriorly; truncated surface circular; intermediate forms (mediæ) between largest and smallest workers lacking or extremely rare. (A) Subgenus *Colobopsis* 54
   Head of worker major not, or at most very obliquely, truncated anteriorly; truncated surface not circular; intermediates nearly always present. (B) Subgenus *Camponotus*......... 2
2. Head rectangular, as broad in front as behind, obliquely truncated in front; each cheek with an irregular longitudinal impression bordered laterally by a crenate ridge........(53) *ulcerosus* sp. nov.
   Head always somewhat narrower in front than behind; cheeks without a longitudinal impression and ridge................ 3
3. Anterior median clypeal margin, with a distinct but narrow notch. 38
   Anterior clypeal margin entire, or at most feebly and broadly excised or sinuate in the middle.......................... 4
4. Clypeus carinate 5
   Clypeus ecarinate, or with a very feeble or blunt carina......... 27
5. Small species, not more than 6–7 mm. long..................... 37
   Large species, averaging more than 8 mm...................... 6
6. Anterior clypeal border produced as an angular lobe, with a sharp point in the middle.................................... 7
   Anterior clypeal border more or less produced as a broad truncated lobe, with rounded or angular lateral corners and straight or feebly excised or sinuate median margin......... 8

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[2] "The American Ants of the Subgenus *Colobopsis*," Bull. Amer. Mus. Nat. Hist., XX, pp. 139-158, 7 figs., 1904; and "The North American Forms of *Camponotus fallax* Nylander," Journ. N. Y. Ent. Soc., XVIII, No. 4, 1910.

[3] The numbers in parentheses preceding the names of the species, subspecies and varieties refer to the descriptions in the text.

7. Tibiæ brown. Length, 12–13 mm........(18) *acutirostris* sp. nov.
Tibiæ black. Length, 15 mm......(19) *acutirostris primipilaris* subsp. nov.
8. Middle and hind tibiæ with a row of graduated bristles on the flexor surface 9
Middle and hind tibiæ without such bristles.................... 21
9. Antennal scapes flattened at the base; tibiæ usually not black.... 10
Antennal scapes not flattened at the base; tibiæ black.......(12) *maculatus ocreatus* Emery.
10. Surface of gaster opaque.................................... 11
Surface of gaster shining.................................... 14
11. Posterior corners of head without yellow spots; thorax dark red or black 12
Posterior corners of head, with yellow spots; thorax yellowish red.........(3) *maculatus vicinus* var. *luteangulus* var. nov.
12. Head ferruginous red; base of gaster, with golden yellow bands. (20) *socius* Roger.
Head black; gaster black, or black with red basal segments...... 13
13. Thorax brownish red or chestnut; gaster often red at the base. (1) *maculatus vicinus* Mayr.
Thorax, with black pro- and mesonotum; gaster not red at base. (2) *maculatus vicinus* var. *plorabilis* var. nov.
14. Antennal scapes not only flattened but slightly lobulate at the base 15
Antennal scapes not lobulate at the base...................... 16
15. Length, 10–13 mm.; head brown in front, black behind; thorax. legs, petiole and at least the base of the gaster light brown or brownish yellow.............(8) *maculatus maccooki* Forel.
Length, 9–11 mm.; black; petiole and base of gaster slightly reddish..................(11) *maculatus bulimosus* subsp. nov.
16. Thorax black like the head and gaster....(F) *maculatus vicinus* var. *infernalis* var. nov.
Thorax red or brownish yellow................................ 17
17. Thorax red 18
Thorax brownish yellow.................................... 19
18. Length, 11–13 mm.; gaster often red at the base...(5) *maculatus vicinus* var. *nitidiventris* Emery.
Length, 8–10 mm.; gaster entirely black...(6) *maculatus vicinus* var. *maritimus* var. nov.
19. Apical half of gaster infuscated......(9) *maculatus sansabeanus* Buckley.
Whole gaster yellow.. 20
20. Head brown or reddish..(4) *maculatus vicinus* var. *semitestaceus* Emery.
Head black........(10) *maculatus sansabeanus* var. *torrefactus* var. nov.
21. Antennal scapes not flattened at the base; tibiæ without long oblique hairs 22

Antennal scapes flattened at the base; tibiæ with long oblique hairs 26

22. Head, thorax and petiole subopaque, ferruginous brown; scapes without short, erect hairs..(13) *maculatus tortuganus* Emery.

Thorax shining, wholly or in part clay yellow; scapes with short, erect hairs 23

23. Mandibles 7-toothed. Length, 8–10 mm...................... 24

Mandibles 5- to 6-toothed. Length, 12–14 mm. (17) *vafer* sp. nov.

24. Head pale yellow, not infuscated behind......(15) *fumidus* var. *fragilis* Pergande.

Head brownish, vertex of head infuscated or black............. 25

25. Occipital border of head yellow or brown.....(14) *fumidus* var. *festinatus* Buckley.

Whole dorsal surface of head dark brown or black.........(16) *fumidus* var. *spurcus* var. nov.

26. Head entirely ferruginous red; cheeks with small foveolæ, without erect hairs........(23) *abdominalis floridanus* Buckley.

Vertex of head dark brown or black, cheeks with deep, elongated foveolæ and erect hairs.......(24) *abdominalis transvectus* sub. sp. nov.

27. Small species, not more than 6 mm. long; head rugose in front. (52) *bruesi* sp. nov.

Large species, at least 8–9 mm. long; head never rugose in front.. 28

28. Antennal scapes, with short erect hairs, body shining, black..(25) *lævigatus* Smith.

Antennal scapes without erect hairs.......................... 29

29. Head small (3.2 x 2.8 mm.); body shining; mandibles 6- to 7-toothed 30

Head large (3.4 x 3.4 mm.); the head and thorax at least opaque or subopaque; mandibles 5-toothed........................ 31

30. Body entirely yellow or reddish yellow.....(21) *castaneus* Latr.

The head at least dark brown or black..........(22) *castaneus americanus* Mayr.

31. Gaster opaque or subopaque.................................. 32

Gaster shining 36

32. Pubescence on gaster short...................................... 33

Pubescence on gaster very long................................ 35

33. Sculpture coarse; hairs and pubescence golden yellow........... 34

Sculpture finer; hairs and pubescence pale yellow or white..(29) *herculeanus pennsylvanicus* var. *mahican* var. nov.

34. Posterior portion of thorax red..(26) *herculeanus* var. *whymperi* Forel.

Whole thorax black.......(27) *herculeanus* var. *modoc* var. nov.

35. Thorax, petiole, gaster and usually also the legs black; pubescence pale yellow or white.......(28) *herculeanus pennsylvanicus* De Geer.

Posterior portion of thorax, petiole, legs and base of gaster reddish yellow; pubescence and pilosity golden yellow......(30) *herculeanus pennsylvanicus* var. *ferrugineus* Fabricius.

36. Gaster black in female and worker..(31) *herculeanus ligniperda* var. *noveboracensis* Fitch.
Gaster deep red in female......(32) *herculeanus ligniperda* var. *rubens* Wheeler.
37. Thorax marginate on the sides and behind; head and thorax ferruginous red..........................(51) *planatus* Roger.
Thorax not marginate; head and thorax black....(50) *mina zuni* subsp. nov.
38. Large species, averaging 10–11 mm.; middle and hind tibiæ with bristles on their flexor surfaces.......................... 39
Small species, averaging 6–8 mm.; middle and hind tibiæ without bristles on their flexor surfaces.......................... 40
39. Entirely yellowish red; clypeal notch rather shallow........(47) *schæfferi* Wheeler.
Head black, thorax and legs red; gaster black, with first segment yellow at the base..................(46) *texanus* Wheeler.
40. Thorax, with a distinct impression at the mesoëpinotal suture... 41
Thorax without a distinct impression at the mesoëpinotal suture. 42
41. Gaster entirely black or dark brown.........(48) *hyatti* Emery.
Basal two-thirds of first gastric segment red....(49) *hyatti* var. *bakeri* Wheeler.
42. Head large, very broad, excised behind; gaster very shining, without pubescence. Length, 8 mm............(45) *sayi* Emery.
Head smaller, narrower; gaster pubescent, less shining; length usually less than 8 mm................................ 43
43. Cheeks and clypeus with elongate, piligerous foveolæ........... 50
Cheeks and clypeus without such foveolæ...................... 44
44. Body black, thorax at most only partially red; average length, 6.5 mm..................(33) *fallax* var. *nearcticus* Emery.
Of a different color.. 45
45. Both head and thorax reddish brown or yellowish red........... 48
Head largely dark brown or black............................ 46
46. Average length, 5.5 mm..................................... 47
Average length, 7 mm.; base of gaster banded with yellow..(36) *fallax* var. *tanquaryi* Wheeler.
47. Thorax dark red, head and gaster black........(34) *fallax* var. *minutus* Emery.
Thorax ivory yellow, spotted with brown, base of gaster often banded with yellow........(35) *fallax* var. *pardus* Wheeler.
48. Average length, 6–6.5 mm................................... 49
Average length, 8 mm..............(38) *fallax rasilis* Wheeler.
49. Gaster yellow at the base........(39) *fallax rasilis* var. *pavidus* Wheeler.
Gaster black throughout.......(37) *fallax* var. *decipiens* Emery.
50. Piligerous foveolæ few on the cheeks, usually absent on the clypeus 51
Both cheeks and clypeus with numerous piligerous foveolæ....... 52
51. Yellowish brown, gaster paler, with brown bands....(40) *fallax subbarbatus* Emery.

Brownish black...(41) *fallax subbarbatus* var. *paucipilis* Emery.

52. Head blackish brown.................................... 53
Head and thorax yellowish red......(42) *fallax discolor* Emery.

53. Thorax blackish....(44) *fallax discolor* var. *cnemidatus* Emery.
Thorax red.........(43) *fallax discolor* var. *clarithorax* Emery.

54. Thorax feebly and evenly arcuate above, without a distinct impression at the mesoëpinotal suture; border of truncated surface of head sharp....(54) *abditus* var. *etiolatus* Wheeler.
Thorax, with a distinct impression at the mesoëpinotal suture; border of truncated surface of head blunt.................. 55

55. Gaster entirely black....................(55) *impressus* Roger.
Gaster banded with yellow at the base......................... 56

56. Thorax and posterior portion of head dark brown..(56) *pylartes* Wheeler.
Head and thorax yellow......(57) *pylartes* var. *hunteri* var. nov.

A. SUBGENUS CAMPONOTUS

I. *Maculatus Group*

1. Camponotus maculatus vicinus Mayr

Camponotus vicinus Mayr, Verh. zool. bot. Ges. Wien, XX, p. 940, ☿, 1870; Forel, Bull. Soc. Vaud. Sci. Nat., (2) XVI, p. 60, ☿, 1879; Dalla Torre, Catalog. Hymen., VII, p. 257, 1893.

C. sylvaticus var. *vicinus* Mayr, Verh. zool. bot. Ges. Wien, XXXVI, p. 422, 1886.

C. maculatus subsp. *vicinus* Emery, Zool. Jahrb. Abth. f. Syst., VII, p. 671, ☿ ♀, 1893; Forel, Biol. Centr. Amer., p. 131, 1899-1900.

Worker major. Length, 11–13 mm.; head, 3.7 x 3.5 mm.; scape, 3.2 mm.; hind tibia, 3.3 mm.

Head, excluding the mandibles, nearly as broad as long, broader behind than in front, with feebly concave posterior and feebly convex lateral borders, convex dorsal and flattened gular surfaces. Mandibles strong, convex, 6-7-toothed. Clypeus carinate, its anterior border moderately produced in the form of a broad flap-like lobe with rounded corners and crenate edge. Frontal carinæ lyrate. Eyes moderately large, flattened. Antennal scapes distinctly flattened at the base and but slightly widened at their tips, which reach a short distance beyond the posterior corners of the head. Thorax robust in front though narrower than the head; pro- and mesonotum slightly flattened; meso- and metapleural regions compressed; in profile, the dorsum is evenly arched, the epinotum with subequal base and declivity, forming at their juncture a rounded, obtuse angle. Petiole with convex anterior and flattened posterior surface and rather blunt border. Gaster of the usual shape. Legs long; middle and hind tibiæ elliptical in cross-section, neither compressed nor grooved.

Mandibles and anterior borders of cheeks shining, the former very coarsely striato-punctate; head, thorax and gaster subopaque; head densely shagreened behind, in front very densely and finely punctate or granular, sides also with numerous small rounded foveolæ; sides of clypeus and inner borders of frontal carinæ with a few large piligerous foveolæ. Thorax, petiole and legs more finely, gaster more coarsely and transversely shagreened, also with small transverse foveolæ bearing the pubescence and large piligerous foveolæ across the middle and along the posterior border of each segment.

Hairs and pubescence yellow, the former long, sparse and erect, confined to the mandibles, clypeus, dorsal surface of head, thorax, border of petiole, gula and both dorsal and ventral surfaces of the gaster. Pubescence sparse, especially on the gaster, but very distinct on the posterior portions of the head, thoracic dorsum, scapes and legs. Middle and hind tibiæ with rows of stiff, graduated bristles on their flexor surfaces. There are a few short hairs at the tips of the antennal scapes and at the femoro-tibial articulations.

Head and antennal scapes black; mandibles, clypeus, cheeks and antennal funiculi often tinged with red. Thorax and legs brownish red or chestnut; gaster black, with dull brown posterior segmental margins; base of first segment or the whole of the first and second segments red like the thorax.

Worker minor. Length, 7–8.5 mm.

Head longer than broad, not contracted but rounded behind the eyes, with rather straight, subparallel sides. Clypeus and antennal scapes much like those of the worker major, the scapes reaching nearly half their length beyond the posterior corners of the head. Thorax about as broad as the head, base of the epinotum somewhat longer than the declivity. Petiole subcuneate, with more convex posterior surface and blunter border than in the worker major.

Sculpture, pilosity and color much as in the worker major, but gaster not red at the base.

Female. Length, 14–16 mm.

Head similar to that of the worker major but proportionally longer and narrower behind, with more nearly parallel sides. Thorax about as broad as the head. Epinotum with short, convex base and much longer, steep and slightly concave declivity. Petiole rather high, thick below, compressed anteroposteriorly above, with sharp border. Wings long (16–17 mm.).

Differs from the worker major in sculpture to the extent of having the thorax, gaster, legs and lower lateral borders of the head shining.

Pilosity, pubescence and color much as in the worker major, but the mesonotum, scutellum and metanotum black and the pronotum, pleuræ, tibiæ and femora sometimes infuscated. Gaster frequently red at the base. In some specimens, the whole of the thorax and the legs are very dark brown or black. Wings suffused with brown; veins and stigma light brown.

Male. Length, 8–11 mm.

Head somewhat longer than broad, with large, convex eyes, broader and rounded postocular region and concave cheeks. Clypeus carinate, with broadly rounded anterior border. Mandibles edentate. Antennal scapes slender, terete, not flattened at the base. Thorax robust; epinotum like that of the female. Petiole very low and thick, its upper border transverse, blunt, sometimes with a broad but shallow excision.

Head, thorax and gaster very finely shagreened, shining.

Pilosity much as in the worker; pubescence shorter and much less conspicuous.

Black; mouthparts, funiculi, genitalia, tarsi and articulations of the legs and wings brownish or reddish. Wings colored like those of the female.

This, the typical form of the subspecies *vicinus*, as defined by Emery, is represented in my collection by specimens from the following localities:

California: Alameda, Harris, Humboldt County and Felton, Santa Cruz Mts. (J. C. Bradley); San Jacinto Mts., 6000 ft. (F. Grinnell, Jr.); Mt. Lowe (5000 ft.) and Palmer's Canyon, near Claremont (Wheeler).

Nevada: King's Canyon, Ormsby County (C. F. Baker).

Oregon: Corvallis (Amer. Mus. Nat. Hist.).

Washington: Seattle and Almota (A. L. Melander); Friday Harbor (T. Kincaid); Grand Coulée; Pullman (W. M. Mann).

Idaho: Julietta and Moscow (J. M. Aldrich).

New Mexico: Mera Chaco Canyon (Pepper).

British America: Lardo, Kootenay Lake (J. C. Bradley).

Emery cites this form from Descanso, Calif. Mayr mentions it from Connecticut and Virginia, but this is evidently an error, probably traceable to incorrectly labeled specimens or to confounding the form with the very similarly colored *C. noveboracensis.*

C. vicinus and its varieties live in the soil under stones in rather dry, sunny places. The eggs and young larvæ are of a peculiar salmon-yellow color. The sexual phases seem to occur in the nests at all times of the year.

2. C. maculatus vicinus var. plorabilis var. nov.

Very similar to the typical *vicinus* in sculpture and pilosity, but differing in color. The thorax, petiole and legs of the worker forms are deep red, the pro- and mesonotum of the worker major black, the gaster entirely black, except for the brown posterior segmental margins.

The female is decidedly smaller than that of the typical form (12–13 mm.) and black, with the exception of the antennal funiculi, pleuræ, declivity of epinotum and legs, which are dark red.

The male is indistinguishable from that of the typical form.

I have seen specimens of this variety from the following localities:

California: Pacific Grove (H. Heath).

Nevada: (Amer. Mus. Nat. Hist.).

Washington: Pullman, Kiona, San Juan Island and Ellensburg (W. M. Mann); Seattle.

Idaho: Moscow (J. M. Aldrich).

Apparently the small workers mentioned by Emery from Beckwith, Calif. (5000 ft.) belong to this variety, which at first sight may be confounded with forms of *C. herculeanus* colored like the European type or like the American *C. whymperi*.

3. C. maculatus vicinus var. luteangulus var. nov.

Very similar to the typical *vicinus*, but the thorax of the major and minor workers is paler, of a more yellowish red color and all of the worker forms have a bright yellow spot on each of the posterior corners of the head. The gaster of the largest workers is more or less yellowish red at the base. The surface of the body is a little more shining than in *vicinus* but less so than in the var. *nitidiventris*. Males without varietal characters.

Described from several workers and males taken by C. R. Biederman in Carr Canyon, Huachuca Mts., Arizona, one worker from the Yakima River, Washington, taken by Samuel Henshaw, four workers taken by W. M. Mann on Moscow Mt., Idaho, and three workers from Wawawai, Washington, taken by the same collector.

4. C. maculatus vicinus var. semitestaceus Emery

EMERY, Zool. Jahrb. Abth. f. Syst., VII, p. 672, ☿, 1893.

Described by Emery from a couple of workers from Plummer County, Calif., 5000 ft. (Theo. Pergande), which had the thorax and legs reddish yellow, the head dark ferruginous red, the vertex, mandibles and antennal scapes piceous brown, the gaster clay yellow. Other specimens from Fuller's Mill, San Jacinto, Calif., were still paler, being entirely clay-yellow, with the head partly pale dirty brown. The cheeks bore a few very short bristles, the erect pilosity was more abundant than usual, especially on the gula.

There are in my collection a worker media and a minor from the San Jacinto Mts., Calif. (F. Grinnell, Jr.), referable to this variety. In the media, however, the head and antennal scapes are entirely black and opaque. The worker minor is red throughout, with the top of the head slightly darker.

5. C. maculatus vicinus var. nitidiventris Emery

EMERY, Zool. Jahrb. Abth. f. Syst., VII, p. 672, ☿, 1893.

Differing from the typical *vicinus* in the sculpture of the worker forms, the shagreening of the gaster and often also of the head and thorax being finer and more superficial, so that these parts are shining. The pubescence on the body is also shorter and much less conspicuous, especially on the gaster. There are no erect hairs on the cheeks. The thorax, legs and petiole are yellowish red; in major workers of most colonies, the gaster is black throughout. but in some, it is more or less red or yellowish red at the base. In some specimens which form a transition to the var. *luteangulus*, the posterior corners of the head are rather indistinctly reddish or yellowish. The female *nitidiventris* differs from that of *vicinus* in its more shining head. The male seems to lack varietal characters.

Of this variety, which is common in the western states, I have seen many specimens from the following localities:

Colorado: Salida, Boulder, Florissant, Buena Vista, Colorado City, Colorado Springs, Manitou (Wheeler); Steamboat Springs (T. D. A. Cockerell); Pueblo (Jerome Schmitt); Stout, Ft. Collins and Dixon Canyon (E. G. Titus).

Wyoming: Carbon County (Wortmann).

New Mexico: Romeroville, San Ignacio, Gallinas Canyon, Santa Fe, Raton, Pecos, Silver City, Dripping Spring in Organ Mts. and Las Vegas (T. D. A. Cockerell); Alamogordo (G. v. Krockow); Albuquerque (F. C. Pratt).

Arizona: Coconino Forest, Grand Canyon (Wheeler); Ramsey Canyon, Huachuca Mts. (W. M. Mann and Wheeler).

California: Santa Rosa; Marin County.

Emery cites this variety from Louisiana, but I believe that this must be an error, for, according to my observations, it does not descend, at least to the eastward, much below an altitude of 6000 feet, and is properly an ant of the high plains and slopes of the Rockies. The two California localities above mentioned are represented only by a couple of major workers and these may be rubbed specimens of the true *vicinus*.

6. **C. maculatus vicinus** var. **maritimus** var. nov.

Closely resembling the preceding variety, but of smaller size in all phases except the male. Length of worker major, 8–10 mm.; worker minor, 6–7 mm.; female, 11–12 mm. (wings 12 mm.); male, 9–10 mm. The gaster is entirely black in the worker major and female, or reddish only at the extreme base; the wings of the male are very pale. The female has the head, pro- and mesonotum, scutellum and metanotum black, the remainder of the thorax, the legs and petiole yellowish red, the mandibles, clypeus and antennæ dark red.

California: Pacific Grove and San José (H. Heath); Catalina Island (C. F. Baker).

7. **C. maculatus vicinus** var. **infernalis** var. nov.

This variety is based on several major and minor workers from Las Vegas, N. Mexico (Wheeler); a single worker media from Santa Cruz Mts., Calif. (J. C. Bradley) and three minor workers and two males from Palo Alto, Calif. (W. M. Mann). These all closely resemble the *nitidiventris* in sculpture, but the thorax is black like the head and gaster, the lower pleuræ, the petiole, legs and funiculi dark brown. The clypeus, mandibles and scapes are black.

8. C. maculatus maccooki Forel

C. sylvaticus stirps *maccooki* Forel, Bull. Soc. Vaud. Sci. Nat., (2) XVI, P. 81, p. 69, ☿ ♀ ♂, 1879; *Ibid.*, (2) XX, P. 91, p. 347, 1884.

C. maccooki Dalla Torre, Catalog. Hymen., VII, p. 241, 1893.

C. maculatus subsp. *maccooki* Emery, Zool. Jahrb. Abth. f. Syst., VII, p. 672, Taf. XXII, Fig. 29, ☿, 1893.

Worker major. Length, 10–13 mm.; head, 3.2 x 3 mm.; scape, 2.7 mm.; hind tibia, 3.6 mm.

In structure closely resembling *C. vicinus*, but the antennal scapes are more thickened at their tips, and their bases are not only flattened but dilated to form a small but distinct, rounded lobe on the outer side. Mandibles 5- to 6-toothed. Base and declivity of epinotum subequal. Middle and hind tibiæ elliptical in cross-section, not sulcate.

Sculpture of body as in the var. *nitidiventris*, the sides of the head covered with punctures or small foveolæ as in that form.

Pilosity as in *vicinus*, but pubescence much less developed, being as short and inconspicuous as in *nitidiventris*. There are no hairs on the cheeks. Middle and hind tibiæ with bristly flexor surfaces.

Head, cheeks, clypeus, mandibles and antennæ deep reddish brown or ferruginous; front and vertex black, mouthparts yellowish. Thorax, legs, petiole and gaster sordid light brown or brownish yellow, the gaster usually more or less dark brown at the tip and often transversely banded with fuscous on the more anterior segments, rarely black throughout.

Worker minor. Length, 6–8 mm.

Resembling the worker major in sculpture, pilosity and color, but the head is more shining. The lobular dilation at the base of the antennal scape is small but perceptible.

Female. Length, 12–14 mm.

Resembling the female of *nitidiventris* in sculpture and pilosity; color like that of the major worker, but the mesonotum, scutellum and metanotum are dark brown, the pronotum more or less infuscated. In some specimens the whole gaster is brownish yellow and lighter than the pleuræ and legs; in others it is dark brown at the tip and obscurely transversely banded with brown more anteriorly. Wings suffused with brownish yellow; veins yellow, stigma brownish.

Male. Length, 9 mm.

Very similar to the male of *vicinus* and its varieties. The antennal scapes are flattened, dilated and lobulate at the base.

The types of this subspecies came from the Island of Guadalupe, about 200 miles off the west coast of Lower California. I have seen numerous worker and female specimens but only a single male from the following places in the Pacific States:

California: Palo Alto (H. Heath and W. M. Mann); San José (H. Heath); Alameda and Marin County (Amer. Mus. Nat. Hist.); Ukiah, Mendocino County and Berkeley (J. C. Bradley); Point Loma, San Diego (P. Leonard); Pasadena (Wheeler).

Washington: (Osten Sacken).

Oregon: (Osten Sacken); Corvallis (Amer. Mus. Nat. Hist.).

Emery cites *maccooki* also from Descanso, Calif.

9. C. maculatus sansabeanus Buckley

Formica sansabeana BUCKLEY, Proc. Ent. Soc. Phila., VI, p. 167, ☿ ♀ ♂, 1866.

Camponotus marginatus var. *sansabeana* MAYR, Verh. zool. bot. Ges. Wien, XXXVI, p. 365, 1886; DALLA TORRE, Catalog. Hymen., VII, p. 242, 1893.

C. maculatus subsp. *maccooki* var. *sansabeanus* EMERY, Zool. Jahrb. Abth. f. Syst., VII, p. 672, ☿ ♀, 1893; WHEELER, Trans. Tex. Acad. Sci., IV, Pt. II, No. 2, p. 23, ☿ ♀ ♂, 1902.

Worker major. Length, 9–11 mm.; head, 2.8 x 2.7 mm.; scape, 2.5 mm.; hind tibia, 2.5 mm.

Resembling *maccooki* but stouter, more thick-set, with proportionally larger head and shorter legs. The flattened dilatation at the base of the antennal scape is broader than in *vicinus*, but slightly narrower and less lobulate than in *maccooki*. Clypeal carina blunter, lobe of the anterior border shorter.

Sculpture and pilosity as in *maccooki*, but lower surface of head with more numerous erect hairs. Cheeks with a very few erect hairs arising from somewhat elongated foveolæ. Pubescence very short and sparse.

Color much like that of *maccooki*, but thorax more brownish, basal half of gaster yellow or yellowish brown, apical half and sometimes the whole gaster more infuscated.

Worker minor. Length, 5–7 mm.

Antennal scapes less dilated at the base than in the worker minor of *maccooki*. Cheeks without erect hairs. Color much like that of the worker major.

Female. Length, 12–14 mm.

Head broader than in *maccooki*, especially behind. Surface, especially of the thorax and gaster, very smooth and shining. Pubescence more dilute and inconspicuous than in the worker major. Wings long (12–13 mm.), suffused with yellow; veins and stigma brownish yellow.

Male. Length, 8–9 mm.

Head proportionally shorter than in the male *maccooki*. Cheeks hairy. Antennal funiculi, tarsi and tibiæ yellowish brown; wings less suffused with yellow and paler than in the female; veins and stigma pale yellow.

The types of this form were, in all probability, collected by Buckley in central Texas, where it is rather common, nesting under stones in dry woods. Emery's specimens also came from this region and from Louisiana. I have before me specimens from the following localities:

Texas: Austin, topotypes (Wheeler); Marble Falls (Wheeler); Handley (J. C. Crawford); Leary (W. D. Pierce).

New Mexico: Pecos (T. D. A. Cockerell and M. Grabham).

Arizona: Prescott (Wheeler).

Colorado: Manitou (Wheeler).

Although Emery records *sansabeanus* as a variety of *maccooki*, I believe that it should rank as an independent subspecies of *maculatus*, on account of its smaller size and the different proportions of the head, body and legs in the worker major.

10. C. maculatus sansabeanus var. torrefactus var. nov.

The worker major differs from that of *sansabeanus* in having the whole gaster brownish yellow, like the thorax, petiole and legs. The head is deep red, with the front and vertex black and the posterior corners each with a yellow spot; in the worker minor the head and antennæ are brown, the mandibles darker. The antennal scapes in all the workers are less dilated at the base than in the corresponding phases of *sansabeanus*. The male has the funiculi, tarsi and tibiæ paler, the pleuræ and often the thoracic dorsum and gaster piceous instead of black. The head is very broad, with shorter and less concave cheeks than in the preceding subspecies and varieties, and the anterior portion of the head is conspicuously hairy. The wings are scarcely suffused with yellow, the veins and stigma very pale. I have not seen the female.

Described from numerous workers and males from three colonies, two taken by myself in the Coconino Forest and Indian Garden, Grand Canyon, Arizona, the other by Mr. R. V. Chamberlin at East Mill Creek, Utah.

11. C. maculatus bulimosus subsp. nov.

Worker major. Length, 9–11 mm.; head, 3.2 x 3.2 mm.; scape, 2 mm.; hind tibia, 2.5 mm.

With the stature of *sansabeanus*, but differing in the following particulars: head proportionally larger, as broad as long, with the anterior angles larger and more inflated as in *C. herculeanus*, so that the mandibles appear to be more retracted. Clypeus even less produced, with the median border crenate and slightly pointed in the middle and the carina more distinct. Antennal scapes shorter and much more flattened and dilated at the base, with a small lobe as in *maccooki*, and nearly as broad at the tip as at the base. Thorax thickset, with high, rounded epinotum, the declivity being as long as the base.

Body subopaque; mandibles, legs and venter more shining; surface of head and thorax rather coarsely, gaster more finely and superficially shagreened. Whole head, including the clypeus and front, covered with small punctures, which are more scattered on the posterior corners. Posterolateral borders of clypeus, inner borders of frontal carinæ, the pro- and mesonotum with a few piligerous foveolæ.

Hairs much as in *sansabeanus*, even on the cheeks.

Black; thorax, petiole and base of gaster slightly reddish; insertions and tips of scapes, funiculi and legs deep reddish brown; posterior borders of gastric segments sordid yellowish.

Worker minor. Length, 5–7 mm.

Differing from the minor worker of *sansabeanus* in the shorter and broader head; with more prominent anterior corners, the shorter and basally more dilated antennal scapes.

Body more shining than in the worker major. Pilosity and color as in this phase, but mandibles, clypeus, cheeks and scapes deep red and legs sometimes more yellowish.

Female. Length, 13–15 mm.

Resembling the major worker, but head longer than broad and thorax and gaster more shining. Black; mandibles, funiculi, femora and tibiæ deep reddish brown; venter and sides of two basal gastric segments blotched with brownish yellow; trochanters and tips of coxæ of the same color. Wings strongly tinged with brown; veins and stigma pale brown.

Male. Length, 7–8 mm.

Resembling the male of *sansabcanus*, but the head and thorax somewhat more opaque. Hairs dirty yellow, rather abundant on the cheeks, which are somewhat broader in front than at the eyes. Black; funiculi and tarsi light brown. Wings somewhat paler than in the female.

Described from a number of specimens of all four phases from a single colony found by C. R. Biederman nesting in the ground under a stone at Palmerlee, Arizona, (5500 ft.) and several workers and males taken by W. M. Mann in Ramsey Canyon, Huachuca Mts., (5800 ft.) in the same territory.[4]

This form is readily distinguished by the shape of the head, short antennal scapes and the combination of the characters of the antennæ of *maccooki* with the thickset stature of *sansabeanus* and the coloration of the darkest forms of *vicinus*. It deserves a higher rank than as a mere variety of *sansabeanus*.

12. C. maculatus ocreatus Emery

C. maculatus subsp. *ocreatus* Emery, Zool. Jahrb. Abth. f. Syst., VII, p. 673, ☿, 1893; *Ibid.*, VIII, p. 336, 1894.

C. maculatus race *ocreatus* Pergande, Proc. Calif. Acad. Sci., (2) IV, p. 26, ☿, 1893.

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[4] During November, 1910, I found this ant very common under stones in Miller Canyon, Huachuca Mts., Ariz., between 5000 and 6000 ft.

Worker major and *media*.

"Both in habitus and structure of the head and clypeus this subspecies bears the greatest resemblance to *maccooki* Forel, but differs from this form in its feebler sculpture; the whole head is therefore more shining in the worker major (hardly less shining than in the typical *castaneus*). The scattered punctures on the sides of the head are smaller and less numerous. *The antennal scape is more slender, longer and neither flattened nor dilated at the base.* The color of the three specimens before me (one major and two media workers) is clay-yellow; head, antennal scape, first funicular joint, knees, tibiæ and first tarsal joint black, remainder of tarsi and funiculus brown; in the large worker the thorax is darker, pro- and mesonotum piceous brown; tip of gaster blackish. Epinotum, even in the large workers, with its basal surface nearly twice as long as the declivity; in this respect differing from the subsp. *maccooki* and *vicinus*, which have a much higher epinotum.

"Length of worker major, 12 mm.; head, 3.5 x 3.2 mm.; scape, 3.4 mm.; hind tibia, 4 mm.

"Panamint Mts., California, from Mr. Pergande." (Emery.)

Pergande records this form also from San Luis and San Esteban, Mexico.

I have not seen the worker forms, but I have before me five deälated specimens which I take to represent the female of this subspecies. Four of these are from Palmerlee, Arizona, 6000 ft., (C. R. Biederman) and one from the Huachuca Mts. in the same territory (Dr. H. Skinner). They vary from 14–16 mm. in length. The structure of the antennæ and the coloration of the legs and gaster are as described for the worker, the thorax is brown, with the pro-, meso- and metanotum and scutellum either entirely black or spotted with dark brown. The posterior portion of the head is subopaque and densely shagreened, the remainder of the body very smooth and shining. The clypeus is like that of *maccooki*, the lobe of the anterior border being very short, the carina distinct. There are several large punctures or foveolæ on the clypeus and also on the cheeks where they are somewhat elongated. Pilosity sparse, absent on the cheeks. Pubescence very short and dilute. The middle and hind tibiæ are somewhat triangular in cross-section and grooved on their anterior surfaces, and the series of graduated bristles extends along nearly the whole length of their flexor surfaces.

13. **C. maculatus tortuganus** Emery

C. maculatus subsp. *tortuganus* EMERY, Zool. Jahrb. Abth. f. Syst., VIII, p. 336, ☿, 1894.

Worker major. Length, 9–11 mm.; head, 2.6 x 2.3 mm.; scape, 2.2 mm.; hind tibia, 2.8 mm.

Head rather long and narrow, with very feebly convex sides. Eyes large, moderately convex. Mandibles 7-toothed. Clypeus strongly carinate, the lobe of its anterior border moderately produced, rather narrow, with very faintly sinuous median edge and rounded lateral corners. Frontal carinæ lyrate, rather closely approximated. Antennal scapes terete at the base, neither dilated nor flattened, enlarged towards their tips. Thorax slender, low, evenly arched above in profile; epinotum with the base fully twice as long as the declivity, which is slightly concave. Petiole rather high and narrow, with convex anterior and flattened posterior surface and blunt lateral and upper border. Legs rather long; middle and hind tibiæ triangular in cross-section, with sulcate anterior surface.

Head, thorax and petiole subopaque, very densely and finely shagreened. Mandibles shining, coarsely striato-punctate. Anterior border of cheeks and clypeus shining, cheeks and sides of head with small, elongate punctures or foveolæ; clypeus and inner borders of frontal carinæ, pro- and mesonotum with a few coarse piligerous punctures. Gaster finely and superficially shagreened, shining.

Hairs yellowish, erect, moderately abundant on the dorsal surface, very short and appressed on the antennal scapes and legs; femora with a few long hairs on their flexor surfaces; bristles lacking on the flexor surfaces of the tibiæ. Cheeks without erect hairs, those on the anterior border of the clypeus short and inconspicuous. Funiculi with very minute erect hairs. Pubescence very sparse, short on the head and thorax, somewhat longer on the gaster.

Ferruginous brown; head darker than the thorax, and the upper surface of the latter often darker than the pleuræ. Mandibles and anterior borders of cheeks and clypeus blackish. Scapes infuscated except at the base. Gaster black or dark brown, venter, base of first segment and posterior margins of segments paler. Coxæ and femora yellow, tibiæ and tarsi ferruginous.

Worker minor. Length, 6–7 mm.

Head very long, more than twice as long as broad, excluding the mandibles, somewhat narrowed behind in the occipital region; cheeks long, parallel. Clypeus like that of the worker major. Thorax very slender; base of epinotum more than three times as long as the declivity.

Head, thorax and petiole more shining than in the worker major, paler and more yellowish brown; head somewhat darker, mandibles brown. Gaster and legs colored as in the worker major. Pilosity also similar, but there are no minute erect hairs on the antennal funiculi. Cheeks without foveolæ or only with a few faint elongate punctures.

Female. Length of body, 10–11 mm.; of wings, 11 mm.

Resembling the worker major in sculpture, pilosity and color. Head proportionately longer. Eyes large and convex. Thorax as broad as the head, rather depressed; epinotum with indistinct base and declivity, the former fully as long as the latter. Petiole similar to that of the worker major. Wings suffused with sordid yellow; veins and stigma pale brownish yellow.

Male. Length, 7 mm.

Head through the eyes about as broad as long. Eyes and ocelli very large. Cheeks much shorter than the eyes, straight and parallel. Posterior portion of head broad and rounded. Clypeus subcarinate, with broadly rounded, projecting anterior border. Mandibles narrow, edentate. Antennæ slender, first funicular joint as long as the second, distinctly incrassated. Thorax robust, with low, evenly rounded epinotum; its base and declivity indistinctly differentiated, the former about twice as long as the latter. Petiole longer than high, with a low, thick, transverse node. Gaster and legs slender.

Head and thorax subopaque or somewhat shining, especially the pleuræ and the front of the head, very minutely and indistinctly shagreened; gaster shining.

Hairs yellow, erect, rather long and abundant on the head and gaster, petiole and epinotum, sparse on the remainder of the thorax. Legs and antennæ naked. Pubescence rather long on the gaster, but inconspicuous or absent elsewhere.

Head yellowish brown beneath and behind, with a large dark brown or black spot on the vertex. Antennæ, thorax, petiole and legs brown; gaster dark brown or blackish, with paler posterior margins to the segments; mouthparts and genitalia yellowish. Wings dull whitish, with pale yellow veins and stigma.

Described from a long series of specimens of all four phases belonging to a single colony taken by myself at Miami, Florida. I have also taken this subspecies at Planter on Key Largo, and have specimens from Lake Worth (Jerome Schmitt) in the same State. Emery based the subspecies on a single worker from the Dry Tortugas. This he supposed to be a worker media, but it was undoubtedly a worker major (maxima), since this has a smaller head than our other *Camponoti* of the *maculatus* group. *C. tortuganus* is closely related to the subsp. *lucayanus* Wheeler from the Bahamas, to *C. vafer* and *C. fumidus* var. *festinatus*, but all of these forms have erect hairs on the antennal scapes.

14. C. fumidus Roger var. festinatus Buckley

Formica festinata Buckley, Proc. Ent. Soc. Phila., VI, p. 164, ☿ ♀, 1866.

Camponotus festinatus Dalla Torre, Catalog. Hymen., VII, p. 231, 1893.

C. fumidus var. *pubicornis* Emery, Zool. Jahrb. Abth. f. Syst., VII, p. 670, ☿, 1893.

C. fumidus var. *festinatus* Wheeler, Trans. Tex. Acad. Sci., IV, II, No. 2, p. 22, 1902.

Worker major. Length, 8–10 mm.; head, 3 x 2.6 mm.; scape, 2.6 mm.; hind tibia, 3 mm.

Head rather small, longer than broad, broader behind than in front, with feebly excised posterior border and rather convex sides. Eyes slightly convex. Mandibles 7-toothed. Clypeus carinate, moderately produced in front as a broad flap-shaped lobe, rounded at the sides and slightly sinuate in the middle. Antennal scapes rather long, reaching about one-quarter their length beyond the posterior corners of the head, terete at the base, neither flattened nor dilated. Thorax slender, evenly arched above; base of epinotum fully twice as long as the sloping declivity. Petiole with convex anterior and flattened posterior surface and rather sharp border. Gaster of the usual shape. Legs slender; middle and hind femora scarcely compressed, elliptical in cross-section, not sulcate.

Mandibles shining, sparsely punctate. Head rather coarsely, thorax and gaster more finely shagreened, so that the head, especially in front, is opaque or subopaque, its posterior corners, the thorax and, especially the gaster, more shining. Whole of head, except the spaces between the eyes and the frontal carinæ, covered with sparse, elongate foveolæ, which are deepest and largest on the cheeks, clypeus and front.

Hairs tawny yellow, abundant and erect on all parts of the head and gaster, thoracic dorsum, fore coxæ and petiolar border. Femora with a few scattered erect hairs on their flexor and posterior surfaces; tibiæ with very short slanting hairs; middle and hind pairs without graduated bristles on their flexor surfaces. Antennal scapes with short, erect and delicate hairs, in some specimens abundant, in others very sparse or almost absent. Fringe of hairs on the clypeal border short. Pubescence short and dilute, but distinct on the head, thorax, gaster and antennæ.

Clay-yellow; legs somewhat paler than the body, head more reddish, with the mandibles, cheeks, border of the clypeus, vertex and middle portion of the antennal scapes to a variable extent dark brown or blackish. In some specimens the whole head, except the occipital border, is dark brown. Each gastric segment with a more or less distinct transverse brown band, broadened in the middorsal line.

Worker minor. Length, 6–7 mm.

Head, excluding the mandibles, more than twice as long as broad, distinctly narrowed behind, with long, straight, parallel cheeks. Lobe of clypeus without median sinuosity and with short, sharp, lateral corners. Thorax very low and slender, base of epinotum more than three times as long as the declivity. Petiole in profile conical, with blunt border. Legs and antennæ long and slender.

Head, thorax and gaster moderately shining, very finely shagreened; foveolæ of the head represented only by a few, faint, elongate impressions on the cheeks.

Hairs pale yellow, less abundant than in the worker major. Erect hairs on the antennal scapes shorter and more delicate, lacking on the legs. Pubescence extremely short and dilute, visible only on the gaster and scapes.

Pale clay-yellow throughout; mandibular teeth and edge of clypeus and cheeks brown or black.

Female. Length, 11–14 mm.

Resembling the worker major in sculpture, pilosity and color, but with the head narrower behind and with straighter, more parallel sides. Insertions of wings and anterior edge of scutellum black. Mesonotum immaculate, at most with brownish streaks representing the underlying musculature seen through the thin, yellow integument. Wings tinged with yellow; veins and stigma pale brown.

Male. Length, 6–7 mm.

Head somewhat longer than broad, with rather large eyes and ocelli, rounded and broader behind, with slightly concave, subparallel cheeks which are somewhat shorter than the eyes. Mandibles narrow, edentate. Clypeus carinate, with broadly rounded anterior border. Antennæ slender, first funicular joint incrassated at its tip, nearly as long as the second joint. Thorax robust, epinotum sloping, base not more than half as long as the declivity. Petiole very low and thick, transverse, its upper surface flattened and somewhat impressed in the middle, without a border.

Head and thorax moderately shining, the former subopaque behind; gaster smoother, surface of body very finely shagreened.

Erect hairs pale yellow, rather abundant, covering the thorax as well as the head and gaster, absent on the scapes, cheeks and legs. Femora and tibiæ with minute, appressed hairs.

Brownish yellow; posterodorsal portion of head, scutellum and upper surface of gaster, except the anterior and posterior borders of the segments, dark brown. In some specimens, the whole thorax or only its dorsal surface and the epinotum are light brown.

This variety was first very inadequately described by Buckley from specimens taken in Texas, in all probability near Austin. I have redescribed it from topotypes. It is represented among my material by numerous specimens from the following localities:

Texas: Austin and throughout Travis County (topotypes); San Antonio, New Braunfels, San Angelo, Marble Falls, Kenedy, Brownwood and Terlingua (Wheeler); Laredo (J. F. McClendon); Dimmitt County (Schaupp); Chisos Mts. (O. W. Williams); Abilene (A. W. Morrill); Kerrville (F. C. Pratt); Lampasas (W. D. Hunter).

Arizona: Nogales (Oslar); Huachuca Mts. (H. Skinner and Wheeler).

Mexico: Cuernavaca (Wheeler); Guadalajara (J. F. McClendon).

Worker major specimens, often in the same colony, are extremely variable in the coloration of the head. In general they agree very well with Roger's description of *C. fumidus* from Venezuela, but he does not mention the erect hairs on the antennal scapes. On this account, Emery regarded his specimens, which came from Colorado, as representing a variety, which he called *pubicornis*. As there is no question in my mind concerning the identity of this form with Buckley's *festinatus*, and as long series of specimens from all the localities mentioned above show the erect hairs on the antennal scapes, I believe that I am justified in consigning *pubicornis* to the synonymy.

C. festinatus nests in the ground under stones, logs or dried cow dung in dry sunny pastures. It forms colonies varying from a few to several hundred individuals. It is extremely timid, and, as I have never seen it abroad during the day-time, I infer that it must be either crepuscular or nocturnal. This is also indicated by the very pale coloration of the minor workers.

15. **C. fumidus** var. **fragilis** Pergande

Camponotus fragilis PERGANDE, Proc. Calif. Acad. Sci., (2) IV, p. 26, ☿, 1893; FOREL, Biol. Centr. Amer., III, p. 133, 1899-1900.

C. fumidus var. *fragilis* EMERY, Zool. Jahrb. Abth. f. Syst., VIII, p. 336, 1894.

Differing from *festinatus* only in its paler color. Both worker major and minor are pale, whitish yellow; the former with the mandibles and antennal scapes pale brown and pale brown bands on the gaster. The pilosity is like that of *festinatus*, and the antennal scapes have numerous, very delicate, white, erect hairs. The female and male are unknown.

This variety was originally described from San José del Cabo and San Fernando, Lower California (G. Eisen). I have examined three cotypes. One worker major and one minor which I took at Alamito, Presidio County, Texas, seem to belong to this variety, but the yellow tint of the body is deeper and more like that of *festinatus*. They may represent very pale specimens of this variety.

16. **C. fumidus** var. **spurcus** var. nov.

Differing from *festinatus* in the darker coloration of the workers and female. In all of these phases the body is more sordid yellow; the worker major has the whole dorsal surface of the head dark brown or black, the mandibles deep red, with black borders, the antero-median portion of the clypeus and anterior portion of the front reddish, the antennal scapes, except their extreme base and apex, black, the dorsal surface of the thorax and petiole and the bands on the gaster dark brown. The femora and tibiæ may also be more or less infuscated. In the minor worker, the posterior portion of the head and often also the thoracic dorsum are brown. The female is colored like the worker major, with the mesonotum and scutellum dark brown and subopaque and the bands on the gaster darker and broader than in the female *festinatus*. Tarsi, antennal scapes and funiculi brown. I have not seen the male.

Described from numerous specimens collected by myself in southwestern Texas (Toronto and Paisano Pass, in Brewster County, and at Fort Davis) and a female and worker taken by Oslar in the Huachuca Mts., Arizona. There can be little doubt that in the dry regions of Mexico, western Texas and southern Arizona, both this variety and *fragilis* will be found to be connected with *festinatus* by numerous transitional forms.

17. **C. vafer** sp. nov.

Worker major. Length, 12–14 mm.; head, 3.5 x 3 mm.; scape, 2.8 mm.; hind tibia, 3.2 mm.

With the stature of *vicinus*. Head resembling that of *vicinus* in shape Mandibles 5- to 6-toothed. Eyes rather convex. Clypeus keeled, its anterior border distinctly notched in the middle, with a short, rounded lobe on each side, separated by a rather deep notch or sinuosity from the lateral corner of the sclerite. Antennal scapes slender at the base, neither flattened nor dilated, enlarged towards the tip. Thorax long and slender, low in profile and regularly arched above; epinotum sloping, its base nearly twice as long as the declivity. Petiole rather high and narrow, with feebly convex anterior and posterior surfaces and blunt border. Legs long; middle and hind tibiæ somewhat flattened, triangular in cross-section, grooved on their anterior surfaces.

Shining throughout, head more opaque behind; mandibles coarsely striato-punctate; head densely shagreened and covered with sparse punctures or foveolæ, which are large and elongate on the cheeks, clypeus and front, small and round on the sides. Thorax and gaster very finely and superficially shagreened.

Pilosity yellow, resembling that of *vicinus* but more abundant; mandibles, clypeus, cheeks and sides of head with short, erect hairs; antennal scapes with numerous short, stiff hairs arising from coarse punctures; hairs on the clypeal border short and inconspicuous. Legs with very short, scattered and oblique hairs; flexor surfaces of middle and hind tibiæ without rows of bristles. Pubescence very feebly developed, especially on the thorax and gaster, where it is very short and scattered, somewhat longer and more conspicuous on the posterior portion of the head.

Mandibles and head dark reddish brown or black, clypeus and front usually paler. Antennal scapes dark brown, yellow at the extreme base; funiculi yellow, first joint brown. Thorax clay yellow, sometimes brownish on the pro- and mesonotum. Petiole and legs yellow, tarsi and tibiæ sometimes brownish or reddish. Gaster dark brown, posterior borders of segments and base of first segment clay-yellow.

Worker minor. Length, 8–10 mm.

Head much as in *vicinus*, longer than broad, with parallel sides and rounded posterior border. Clypeus like that of the worker major. Antennæ long and slender. Thorax narrow. Petiole very blunt, almost conical. Legs long and slender.

In sculpture and pilosity very similar to the worker major, even to the foveolæ on the head and the short, erect hairs on the antennal scapes and sides and front of head. Color also similar, but the head is pale brown, the clypeus, cheeks and front yellow and the yellow at the base of the gaster is more extensive, sometimes embracing the whole of the first and much of the second segment.

Female. Length, 14 mm.

Resembling the worker major in sculpture, pilosity and color. Base of epinotum much longer in proportion to the declivity than in *vicinus*. Petiole broader, with more acute border. Wings long (13 mm.), strongly suffused with yellow; veins and stigma brownish yellow.

Described from numerous workers taken by Mr. C. R. Biederman from two large colonies nesting under stones at Palmerlee, Arizona, (5000 and 6000 ft.) and a single female taken by Dr. H. Skinner in the Huachuca Mts. of the same territory.[5]

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[5] I have taken this species in Hunter's Canyon in the same mountains.

This species is evidently rather closely related to both *C. festinatus* and *C. ocreatus*, but is readily distinguished from the former by its greater size, the shape of the clypeus, the coloration, the stiffer hairs on the scape and coarser foveolation of the head, from the latter by the shape of the clypeus, foveolation of the head, coloration of the legs and the presence of erect hairs on the antennal scapes.

18. **C. acutirostris** sp. nov.

Worker major. Length, 12–13 mm.; head, 3.5 x 3.3 mm.; scape, 3 mm.; hind tibia 3.9 mm.

With the stature of *vicinus*, but with a proportionally smaller head, which has rounded, convex cheeks and posterior corners and broadly excised posterior border. Eyes feebly convex, rather large. Mandibles 6-toothed. Clypeus carinate, produced in front as a pointed angle, which is slightly turned up at the tip. Just behind this tip the carina is interrupted for a short distance by a feeble transverse impression. The anterolateral border of the clypeus is deeply sinuate on each side. Frontal area and groove distinct; frontal carinæ feebly lyrate and more approximate than in *vicinus* and *vafer*. Antennal scapes slender and terete at the base, neither flattened nor dilated, slightly enlarged at their distal ends. Thorax narrower than the head and shaped much as in *vicinus*, but the epinotum is more like that of *vafer*, having its basal surface about twice as long as the declivity. Petiole high and rather narrow, with both anterior and posterior surfaces convex, the former more than the latter; border sharp, feebly emarginate in the middle above. Gaster of the usual shape. Legs long; middle and hind tibiæ sulcate on their anterior surfaces and rather triangular in cross section.

Head subopaque, densely shagreened; mandibles, cheeks, gula, sides, frontal area and anterior half of front rather smooth, shining. Mandibles finely and densely striate and coarsely punctate. Cheeks with numerous elongate foveolæ; clypeus, front and vertex with large, more scattered and rounded foveolæ. The punctures on the sides of the head very small and scattered. Thorax subopaque and shagreened like the head; petiole and gaster more finely shagreened, shining.

Hairs yellow, erect, rather short and sparse on the upper surface of the head, thorax and gaster and border of petiole, more numerous on the gula. Marginal hairs of clypeus rather long and prominent. Cheeks with a few short, erect hairs. Femora with a row of long, sparse hairs on their flexor surfaces; tibiæ without hairs on their extensor surfaces, but with a row of stiff graduated bristles along the whole length of their flexor surface. Pubescence very short and dilute, discernible only with difficulty except on the scapes.

Head black; mandibles, clypeus and frontal area deep red; antennal scapes black, with yellow or red bases and tips; funiculi brown or yellow. Thorax and legs yellowish brown; pronotum and, to a less extent, the mesonotum sometimes blackish or dark brown; tibiæ and tarsi light brown. Gaster brown, with yellow posterior borders to the segments; venter and base or whole of first segment yellow.

Worker minor. Length, 7.5–9 mm.

Head longer than broad, with straight parallel sides, postocular portion prolonged and rounded, but distinctly narrowed at the occiput. Clypeus like that of the worker major, but the point in the middle of the anterior margin is more obtuse and less projecting. Antennæ very slender. Thorax through the pronotum about as broad as the head. Epinotum low, with its base twice as long as the declivity into which it passes without a perceptible angle. Petiole thick and rather conical, with blunt, entire lateral and dorsal border.

Sculpture and pilosity much as in the worker major. Cheeks with a few scattered, erect hairs.

Dull yellow; mandibles and cheeks brown; sides and posterior portions of head darker; dorsal surface of gaster, with the exception of the posterior edges of the segments, light brown. Antennal scapes and tarsi brownish.

Female. Length, 13 mm.

Resembling the worker major in sculpture, pilosity and color. Head narrower, with straighter, more nearly parallel sides. Epinotum with convex, rounded base, nearly as long as the declivity. Petiole broad and thick, compressed antero-posteriorly near the margin, which is sharp. Thorax smooth and shining, epinotum opaque and shagreened; scutellum, metanotum and pronotum, except for a large anteromedian blotch, dark brown or black. Wings long (15 mm.), scarcely tinged with yellow near the costal margin; veins brown, stigma blackish.

Male. Length, 10 mm.

Head very small, longer than broad, occipital border straight, not broader than the anterior border and equal to the surface on each side between the posterior orbit and the corresponding end of the occipital border. This surface is not convex, but flat. Cheeks subparallel, straight, not concave. Clypeus with broadly rounded border and reflected edge. Mandibles indistinctly bidentate. Thorax through the insertions of the wings nearly twice as broad as the head, narrowed behind, with the epinotum as long as broad, rounded and sloping in profile, without distinct basal and declivous surfaces. Petiole very low, thick and blunt, as long as high. Gaster, antennæ and legs long and slender.

Mandibles and head subopaque, very finely shagreened; clypeus, cheeks and front with a few coarse punctures. Thorax shagreened like the head, subopaque in front; scutellum, epinotum and gaster smooth, shining, more finely and superficially shagreened.

Hairs pale, short, erect and sparse, most abundant on the gaster, absent on the scapes and tibiæ, present in a single row on the flexor surfaces of the femora.

Black; mandibles, distal portion of antennal scapes, genitalia and tarsi brown; articulations of thorax, gaster and legs whitish. Wings whitish hyaline, with pale yellow veins and brownish stigma.

Described from numerous workers, one female and one male taken from a single colony living in the ground under a stone at Alamogordo in the foot-hills of the Sacramento Mts. of New Mexico (G. von Krockow), and several workers from Box Canyon in the same territory (A. G. Ruthven).

This species is readily distinguished from all our other *Camponoti* by the peculiar shape of the clypeus in the worker and female phases. Its other characters are, however, so much like those of the preceding forms, notably *C. ocreatus* and *vafer*, that it must be included in the *maculatus* group. The resemblance to *ocreatus* is even closer in the following subspecies.

19. **C. acutirostris primipilaris** subsp. nov.

Worker major. Length, 15 mm.

Differing from the worker major of the typical form in its large size, in lacking the deep, elongated foveolæ and erect hairs on the cheeks and in coloration. The whole head, including the scapes and first funicular joint of the antennæ, the tips of the femora, the whole of the tibiæ, the dorsal portions of the pro- and mesonotum, black.

Worker minor. Length, 10–11 mm.

Resembling the worker major in sculpture, pilosity and coloration, but without black on the dorsum of the pro- and mesonotum.

Female. Length, 16–17 mm.

Like the worker major. Pro- and mesonotum, scutellum and metanotum black; pleuræ, epinotum, coxæ, petiole and femora brown; gaster black, first and also the second segment, except its posterior border, yellowish brown. Petiole with the upper border more or less excised in the middle. Wings distinctly suffused with yellow; veins and stigma brown.

Described from a single worker major taken by C. R. Biederman at Palmerlee, Arizona, 5500 ft.); six minor workers and a media taken by W. M. Mann in Ramsey Canyon, Huachuca Mts., Arizona, and three females taken by Dr. H. Skinner at Nogales in the same territory.[6]

This subspecies in the coloration of the antennæ and legs closely resembles *ocreatus*, but it is readily distinguished by its larger size and by its clypeal border which is angular and pointed like that of the typical *acutirostris*.

20. **C. socius** Roger

Roger, Berlin Ent. Zeitschr., VII, p. 140, ☿, 1863; Forel, Bull. Soc. Vaud. Sci. Nat., (2) XVI, p. 74, ☿, 1879; Mayr, Verh. zool. bot. Ges. Wien, XXXVI, p. 422, ♀, 1886; Dalla Torre, Catalog. Hymen., VII, p. 253, 1893; Emery, Zool. Jahrb. Abth. f. Syst., VII, p. 670, 1893.

Worker major. Length, 11–13 mm.; head, 3.3 x 3.2 mm.; scape, 3.5 mm.; hind tibia, 3.5 mm.

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[6] Since the above was written, I have found this subspecies very abundant in various canyons of the Huachuca Mts. It nests under stones at altitudes of between 5000 and 6000 ft.

Head but little longer than broad, broader behind than in front, with slightly excised posterior border and slightly convex cheeks, convex dorsal and flattened gular surface. Eyes moderately large, feebly convex. Mandibles 6-toothed. Clypeus rather indistinctly carinate, its anterior border produced as a broad lobe, rounded on the sides and sinuately excised in the middle. Frontal carinæ lyrate. Antennal scapes flatten d but not dilated at the base, thickened towards the tips, which reach well beyond the posterior corners of the head. Thorax rather robust, in front narrower than the head, laterally compressed behind; in profile with evenly arched dorsum. Epinotum rounded, its base fully twice as long as the sloping declivity. Petiole rather high and narrow, with strongly convex anterior, more feebly convex posterior surface and blunt, rounded margin. Gaster of the usual shape. Legs long, middle and hind tibiæ distinctly flattened.

Mandibles shining, striatopunctate near the teeth, but elsewhere with scattered punctures. Body, femora and antennæ opaque, very minutely and densely punctate, tibiæ somewhat shining. Clypeus and sides of head with small, scattered punctures.

Hairs and pubescence yellow, the former moderately abundant but short, present on the postero-lateral portions of the head but not on the cheeks; on the legs short, scattered and oblique, except on the flexor surfaces of the femora, where there is a row of long erect hairs. Middle and hind tibiæ with a row of rather short, graduated bristles extending nearly their entire length. Scapes without erect hairs. Pubescence short and sparse, distinct only on the dorsum of the gaster.

Ferruginous red; mandibles and scapes darker; anterior border of clypeus and cheeks black. Gaster black, with golden yellow posterior border to each segment, a broad transverse golden band on the first, and another at the base of the second segment.

Worker minor. Length, 7.5–10.5 mm.

Head longer than broad, slightly broader in front than behind, with rounded postocular portion and feebly convex sides. Clypeus more distinctly carinate than in the worker major, broadly rounded in front, with a very faint median notch. Antennal scapes very slightly flattened at their bases. Thorax similar to that of the worker major, but base of epinotum fully three times as long as the declivity. Petiole longer than broad, but higher than long, thick and subconical, with blunt border.

Sculpture, pilosity and color as in the worker major, but mandibles not darker than the remainder of the head, clypeus somewhat yellowish and antennal scapes red like the funiculi.

Female. Length, 15–16 mm.

Pale ferruginous, antennal funiculi, gaster and legs more or less yellowish red, mandibles reddish brown, scutellum, especially near its edges, and the tarsi brown, posterior border of gastric segment and anterior portion of same, excepting the first segment, dark brown. Pilosity as in the worker, but sparser. Head as in the major worker very finely and densely punctate, partly finely shagreened, and in addition, especially on the clypeus and cheeks, with scattered punctures. Mandibles nearly smooth, with scattered punctures.

6-toothed. Clypeus not carinate, its anterior border produced as in the worker major and with rounded corners mesial to the excisions. Thorax finely reticulate-rugulose, above moderately shining. Petiole moderately thick, with rounded upper border. Gaster very finely transversely rugulose.

Male. Length, 9 mm.

Head longer than broad; rounded behind; cheeks subparallel, concave, as long as the eyes. Clypeus convex, scarcely carinate, with rounded anterior border. Mandibles edentate. Eyes rather small. Antennæ slender, scapes not flattened at the base, first funicular joint very feebly incrassated, as long as the second. Thorax robust, epinotum rounded, sloping, with subequal base and declivity. Petiole low and thick, upper border sharp, distinctly excised in the middle. Gaster small; legs and antennæ long and slender.

Surface of body shining; head and thorax more coarsely, gaster much more finely and superficially shagreened. Mandibles subopaque, finely punctate.

Pilosity similar to that of the worker, but erect hairs absent on thorax, on legs much shorter and appressed.

Chestnut brown; anterior portion of head, antennæ, legs, articulations of thorax and edges of gastric segments yellowish brown. Wings faintly suffused with yellow; veins and stigma pale yellow.

This species, originally described from Brazil, enters the United States only in southern Florida. The description is drawn from several workers and two males, some of which were taken by the late Rev. Jerome Schmitt at Sanford, while others are labeled simply Florida and belong to the American Museum of Natural History. Forel redescribed the worker from specimens taken at Green Cove Spring by Mrs. Mary Treat. Both Mayr and Emery saw specimens from Florida. The description of the female is translated from Mayr.

21. C. castaneus Latrelle

Formica castanea Latreille, Hist. Nat. Fourm., p. 118, Pl. III, Figs. 11, 12 A. C. and D., ☿ ♀ ♂, 1802.

Formica mellea Say, Bost. Journ. Nat. Hist., I, 3, p. 286, ♂, 1836; Leconte, Writings of Thos. Say, II, p. 731, ♂, 1859.

Camponotus melleus Mayr, Sitzb. Akad. Wiss. Wien, LIII, p. 485, ☿ ♀ ♂, 1866; Forel, Bull. Soc. Vaud. Sci. Nat., XVI, P. 81, p. 60, ☿ ♀ ♂, 1879.

C. castaneus Mayr, Verh. zool. bot. Ges. Wien, XXXVI, p. 420, ☿ ♀ ♂, 1886; Forel, Ann. Soc. Ent. Belg., XXX, p. 141, 1886; Dalla Torre, Catalog. Hymen., VII, p. 224, 1893; Emery, Zool. Jahrb. Abth. f. Syst., VII, p. 673, 1893; Wheeler, Bull. Amer. Mus. Nat. Hist., XXI, p. 402, 1905; Occas. Papers Bost. Soc. Nat. Hist., VII, 7, p. 22, 1906.

Worker major. Length, 9–10 mm.; head, 3.2 x 2.8 mm.; scape, 3 mm.; hind tibia, 3.4 mm.

Head small, but little broader behind than in front, with rounded sides and feebly excised posterior border. Eyes somewhat convex. Mandibles 6- to 7-toothed. Clypeus convex in the middle, ecarinate or bluntly and indistinctly carinate; its anterior border broadly rounded, not produced, sinuate at the sides, with crenate edge. Frontal carinæ lyrate, rather far apart. Frontal area indistinct, extremely small; frontal groove distinct. Antennal scapes rather long, reaching about one-third their length beyond the posterior corners of the head, their bases terete, neither flattened nor dilated, distal ends not incrassated. Thorax slender, laterally compressed, moderately high, in profile rather evenly arched above; epinotum with indistinct base and declivity, the former about twice as long as the latter. Petiole thick, with strongly convex anterior and flattened posterior surface and very blunt, rounded and entire margin. Gaster of the usual form. Legs long; middle and hind tibiæ neither compressed nor sulcate, elliptical in cross section.

Whole body shining, very finely and superficially shagreened, more coarsely on the anterior portions of the head. Mandibles coarsely and uniformly punctate. Cheeks with small, slightly elongated foveolæ, or punctures; sides of clypeus and front feebly punctate.

Hairs yellow, erect and sparse, very short on the mandibles, rather long on the border of the clypeus, absent on the sides and corners of the head and on the legs and scapes, except at the tips of the latter and of the femora. Middle and hind tibiæ with a series of short bristles on the distal half of their flexor surface. Pubescence very short, dilute and indistinct.

Yellow or yellowish red, head and gaster somewhat darker; mandibles, antennal scapes, anterior border of clypeus and cheeks very dark red or blackish; tibiæ and tarsi also sometimes brown or dark red. Gastric segments sometimes obscurely brownish posteriorly. Mandibular teeth black.

Worker minor. Length, 7–8 mm.

Head somewhat less than twice as long as broad, sides subparallel, slightly convex, postocular portion rounded, slightly contracted towards the occipital border. Clypeus similar to that of the worker major, but more truncated in front. Antennæ long and slender, the scapes reaching nearly half their length beyond the posterior corners of the head. Sculpture, pilosity and coloration like that of the worker major.

Female. Length, 13–15 mm.

Closely resembling the worker major, but the head has straighter and less convex sides, the petiole is much compressed anteroposteriorly, with a rather sharp border, which is distinctly notched in the middle above, and the color of the whole body is often deeper and more brownish. Wings long (15 mm.), strongly suffused with yellow; veins and stigma brownish yellow.

Male. Length, 8–9 mm.

Head longer than broad, but little broader behind than in front; cheeks concave, subparallel, about as long as the eyes, which are moderately large. Clypeus convex, but not carinate, with broadly rounded anterior border. Mandibles edentate, rather broad. Thorax robust, epinotum convex, without distinct basal and declivous surfaces. Petiole low, thick, transverse and very blunt above. Gaster, antennæ and legs slender.

Sculpture, pilosity and color like those of the female, but hairs shorter and less conspicuous, absent on the cheeks and thorax, except the epinotum, which bears a few erect hairs. Mandibles scarcely darker than the head; mesonotum often streaked with brown. Wings colored like those of the female.

The types of this species, which is easily recognized by the red color of all the phases, came from the Carolinas and Pennsylvania. I have seen no specimens from British America or from any portion of the Union west of the one hundredth meridian. Mayr's citation of specimens of this or the following subspecies from California, Colorado and New Mexico is very questionable. The material before me represents the following localities:

North Carolina: Belmont (Jerome Schmitt); Raleigh (F. Sherman).

Maryland: Chestertown (H. Viereck); Georgetown, D. C. (E. G. Titus).

Virginia: Ashland (J. F. McClendon).

Florida: (Amer. Mus. Nat. Hist.).

Louisiana: Mansfield (R. C. Howell).

New Jersey: Caldwell (E. T. Cresson): Sea Isle City (H. Viereck); Fort Lee (W. Beutenmueller and Wheeler); Great Notch (Wheeler).

New York: West Farms (J. Angus).

Connecticut: Westville (W. E. Britton).

Massachusetts: Cambridge (Mus. Comp. Zool.).

Indiana: Bass Lake, Hammond and Mount Vernon (W. S. Blatchley).

Although thus widely distributed through the eastern half of the Union, *C. castaneus* seems nowhere to be common except, perhaps, in the South Atlantic states. It forms moderately populous colonies, which nest in the ground under stones in open woods, in the same manner as the species of the *maculatus* group. The workers are very timid and probably nocturnal.

22. C. castaneus americanus Mayr

C. americanus Mayr, Verh. zool. bot. Ges. Wien, XII, p. 661, ☿ ♀, 1862.

C. castaneus Mayr; *Ibid.*, XXXVI, p. 420, 1886; Dalla Torre, Catalog. Hymen., VII, p. 223, 1893.

C. castaneus subsp. *americanus* Emery, Zool. Jahrb. Abth. f. Syst., VII, p. 674, ☿ ♀ ♂, 1893; Wheeler, Bull. Amer. Mus. Nat. Hist., XXI, p. 402, 1905; Occas. Papers Bost. Soc. Nat. Hist., VII, 7, p. 22, 1906.

This subspecies, as Mayr and Emery have observed, is highly variable in color, and this is true of individuals of the same colony. The only features in which it seems always to differ from the typical *castaneus* are the deeper and more elongate foveolæ on the cheeks of the major workers and the coloration of the head, which is black or dark brown in all four phases, with the mandibles, clypeus and cheeks more or less brown or reddish. The thorax, gaster, legs and antennæ of the worker major may be dirty or clay-yellow throughout, but usually the dorsal surface of the thorax, especially of the mesonotum, and a broad transverse band on each gastric segment are light or dark brown. Some specimens have the thorax and gaster piceous, with the thoracic dorsum and gastric bands black; or more rarely the body may be black, with the pronotum, legs and petiole dark red or brown. In the female, the thorax is nearly always black above, the gaster dark brown or with yellow base and pale borders to the segments. The male usually has the thorax, gaster, petiole, legs, antennæ and anterior portions of the head brown or piceous, but specimens are occasionally found with the thorax and gaster black. The wings of the female and male are, as a rule, less suffused with yellow than in the typical *castaneus*.

C. americanus occurs over much the same territory as *castaneus*, but it ranges further north and is much more common. I have seen specimens from the following localities:

New Hampshire: Pelham (Bridwell).

Massachusetts: Weston, Newton and Middlesex Fells, Boston (A. P. Morse); Essex County and Mt. Tom (G. B. King); Sutton (Bost. Soc. Nat. Hist.); Andover (Morse and King); Medford (Dall); Blue Hills, Arnold Arboretum, Boston and Ellisville (Wheeler).

New York: Montgomery; Staten Island (W. T. Davis).

Pennsylvania: Rockville (H. Viereck): Edge Hill (Greene).

New Jersey: Manumuskin, Iona and Da Costa (C. Daecke); Jamesburg and Patterson (W. T. Davis); Halifax, Newfoundland and Lakehurst (Wheeler); Lacy; Fort Lee (W. Beutenmueller).

North Carolina: Black Mts. (W. Beutenmueller); Lake Toxaway (Mrs. A. T. Slosson).

Georgia: Clayton, 2000–3000 ft. (W. T. Davis); Chickamauga.

Florida: Quincy (W. A. Hooker).

Indiana: Wyandotte and Mitchell (W. S. Blatchley)..

Illinois: Rockford (Wheeler).

Missouri: (Forel).

Indian Territory: Ardmore (C. R. Jones).

Oklahoma: Ponca City (A. C. Burrill).

Texas: College Station (F. C. Pratt); Palestine (F. C. Bishopp); Calvert (C. R. Jones).

C. americanus is as variable in color as the typical *castaneus* is constant. As these forms are distinguished merely by the coloring of the head and the foveolation of the cheeks, *americanus* would properly be merely a variety, but I have followed Emery in regarding it as a subspecies, for the reason that I have been quite as unsuccessful as he has been in finding transitions between the two forms.

II. *Abdominalis Group*

23. Camponotus floridanus Buckley

Formica floridana Buckley, Proc. Ent. Soc. Phila., VII, p. 161, ☿, 1866.

Camponotus atriceps stirps *Yankee* Forel, Bull. Soc. Vaud. Sci. Nat., (2) XX, p. 340, ☿, 1884.

C. atriceps var. *floridanus* Mayr, Verh. Zool. bot. ges. Wien, XXXVI, p. 423, ☿ ♀ ♂, 1886.

C. floridanus Dalla Torre, Catalog. Hymen., VII, p. 231, 1893.

C. abdominalis subsp. *floridanus* Emery, Zool. Jahrb. Abth. f. Syst., VII, p. 670, 1893.

Worker major. Length, 8–10 mm.; head, 3.5 x 3.4 mm.; scape, 2.7 mm.; hind tibia, 3 mm.

Head large, nearly as broad as long, broader behind than in front, with broadly excised posterior and convex lateral margins. Eyes flattened. Mandibles 5- to 6-toothed. Antennæ short, scapes flattened at the base but not dilated, enlarged towards their tips, which do not extend beyond the posterior corners of the head. Clypeus carinate, its border produced as a prominent lobe with sharp corners, between which the median edge is angularly excised. Frontal carinæ lyate, rather far apart; frontal area small, triangular; frontal groove distinct. Thorax robust, narrower than the head in front, compressed and more narrowed in the pleural region; in profile rather unevenly arched, with deep pro-mesonotal suture, highest in the mesonotal region; epinotum depressed, sloping, with indistinct and subequal base and declivity. Petiole in profile cuneate, with similar, feebly convex anterior and posterior surfaces; seen from behind, evenly rounded above, with rather blunt border. Legs moderately long and robust; middle and hind tibiæ neither compressed nor sulcate, elliptical in cross section.

Mandibles opaque, very finely striated and sparsely punctate; teeth smooth and shining. Head opaque, very densely and minutely punctate or shagreened. Cheeks with small, scattered foveolæ; clypeus and lateral borders of front with a few large piligerous foveolæ. Thorax, gaster and legs moderately shining, more superficially shagreened.

Hairs coarse, long, fulvous, erect, rather abundant, shorter on the anterior surface of the antennal scapes and on the legs, absent on the cheeks and sides of the head, very short on the mandibles and clypeal border. Pubescence very short and dilute, distinct only on the gaster.

Head ferruginous red; mandibles, antennal scapes and anterior border of cheeks and clypeus darker. Thorax and legs more yellowish red. Gaster black, with the posterior edges of the segments narrowly yellow.

Worker minor. Length, 5.5–7 mm.

Head, excluding the mandibles, about twice as long as broad, with straight, parallel sides and short evenly rounded postocular portion. Eyes rather large and convex. Clypeus like that of the worker major. Antennæ slender, scapes not flattened at the base, reaching about half their length beyond the posterior corners of the head. Thorax low, narrow and evenly arcuate above, epinotum without distinct base and declivity. Petiole like that of the worker major.

Head more shining and sometimes of the same yellowish red color as the thorax and legs. Antennæ dark red throughout. Pilosity as in the worker major.

Female. Length, 13–15 mm.

Head broad, much like that of the worker major. Dorsum of thorax and gaster smoother and more shining. Petiole compressed anteroposteriorly, with sharper border, somewhat notched in the middle above. Color and pilosity as in the worker major, except that the erect hairs are shorter and somewhat sparser, and that in some specimens (probably immature) the mesonotum has three pale brown blotches. Wings long (14 mm.), grayish hyaline, suffused with yellow only near the costal margin; veins and stigma yellowish brown.

Florida: Lake Worth (Jerome Schmitt); Miami and Key Largo (Wheeler); Caloosahatchie River (Heil).

Georgia: St. Mary's (O. Bangs).

This ant is not uncommon in southern Florida, nesting in old stumps and logs. Like the other subspecies of *abdominalis,* which are widely distributed over tropical America, it is very pugnacious. Occasionally it is found nesting in epiphytes in the green-houses of the northern states. I have before me a series of workers taken by Mr. G. von Krockow from a vigorous colony that had been living for some time in one of the hot-houses of the New York Botanical Garden. The male, which I have not seen, is described by Mayr as indistinguishable from that of the typical *abdominalis* of Brazil, and it is probably very much like the male of the subspecies *transvectus* described below.

24. C. abdominalis transvectus subsp. nov.

Worker major. Length, 8–9 mm.

Resembles *floridanus*, but differs in the smaller average size and in the following particulars: foveolæ on the cheeks elongated and deeper; cheeks and sides of head with erect hairs; vertex of head very dark brown or black; hairs somewhat more abundant, especially on the antennal scapes; pubescence longer and more conspicuous. Thorax, legs and gaster colored as in *floridanus.*

Worker minor. Length, 6–7 mm.

Differing from the worker minor of *floridanus* in the same characters as the worker major.

Female. Length, 12 mm.

Resembling the worker major, but with the mesonotum and scutellum blotched with black. Wings as in the female *floridanus.*

Male. Length, 7 mm.

Head through the eyes about as broad as long; cheeks converging somewhat anteriorly, shorter than the eyes. Mandibles rather broad, bidentate. Thorax robust, with rather steep epinotum, its base shorter than the declivity, which is slightly concave. Petiole low and thick, transverse, with blunt margin. Gaster small, legs and antennæ slender.

Surface subopaque, very densely and finely shagreened, gaster shining.

Hairs pale yellow, abundant, shorter than in the minor worker. Cheeks with a few erect hairs. Antennal scapes naked, legs with minute oblique hairs.

Dark brown; mandibles, clypeus, antennæ and gaster black; pleuræ and legs light brown; genitalia, funiculi, tarsi and articulations of legs and thorax yellowish. Wings dull hyaline, with pale yellow veins and stigma.

Described from ten workers, two females and a single male, taken by Mr. J. D. Mitchell at Harlington, Cameron County, Texas, and a single worker taken by the same collector at Brownsville, Texas.

I have described this form as a subspecies, although its exact status is doubtful, owing to the extreme variability of the species, which is in urgent need of revision. The same form, which I took some years ago at Cuernavaca, was identified by Professor Forel as "*C. abdominalis*, new subspecies between *esuriens* F. Smith and *mediopallidus* Forel." I have since received it also from Juanacatlan, Mexico (J. F. McClendon). Other specimens from Tuxpan, sent by the same collector, have the head of the major and minor worker yellowish red like the thorax and legs, and numerous specimens collected at Esquinapa by Mr. J. H. Batty and at Guadalajara by Mr. McClendon have paler heads and no hairs on the sides of the head. These therefore represent a transition to *floridanus*. All the Mexican specimens are larger than the Texan. As Texas is at the extreme edge of the northern range of the species, we may suppose that this smaller average stature of *transvectus* is a sign of depauperation.

III. *Herculeanus Group*

25. **Camponotus lævigatus** F. Smith

Formica lævigata F. Smith, Catalog. Hymenop. Brit. Mus., VI, p. 55, No. 197, ☿ ♀, 1858; Lord, Natur. in Vancouver I. and Brit. Col., II, p. 341, 1866.

Camponotus lævigatus Mayr, Verh. Zool. bot. Ges. Wien, XXXVI, p. 420, ☿ ♀, 1886; Emery, Zool. Jahrb. Abth. f. Syst., VII, p. 671, 1893.

C. levigatus Dalla Torre, Catalog. Hymen., VII, p. 238, 1893.

Worker major. Length, 10–13 mm.; head, 3.4 x 3.4 mm.; scape, 2.7 mm.; hind tibia, 3.2 mm.

Head as broad as long, somewhat broader behind than in front, with very round, convex sides and posterior corners and scarcely excised posterior border. Eyes small, flat. Mandibles convex, 5-toothed. Clypeus short, evenly convex, without a carina, its anterior border not produced, with a shallow, rounded median excision and a slightly deeper and more angular excision on each side. Frontal area obsolete, frontal groove distinct. Antennæ with short scapes, not reaching beyond the posterior corners of the head, neither flattened nor dilated at the base, distinctly enlarged at the tips. Thorax robust and rather high, narrower than the head in front, laterally compressed behind.

evenly arched above in profile, epinotum with subequal base and declivity meeting in a rounded, obtuse angle. Petiole high, compressed anteroposteriorly, with feebly convex anterior and flattened posterior surface; border entire, evenly rounded and rather blunt. Gaster of the usual shape. Legs of moderate length; middle and hind tibiæ neither compressed nor sulcate, elliptical in cross section.

Entire surface smooth and shining; mandibles coarsely striato-punctate.

Head, thorax, scapes and legs covered with scattered, rather small, but deep punctures; intermingled with these on the cheeks, clypeus, front and vertex, there are large but equally scattered punctures or foveolæ, those on the cheeks being elongated. Gaster very finely, transversely shagreened and with scattered, piligerous punctures. Pubescence apparently lacking.

Hairs white or pale yellow, delicate, abundant, short and erect on the body, longest on the gaster. Antennal scapes and legs with numerous short, erect hairs. Flexor surfaces of middle and hind tibiæ with a few short bristles at their distal ends.

Deep black throughout; mandibles, clypeal border and cheeks rarely deep red; tarsi brownish towards their tips; posterior edges of the gastric segments dull brown.

Worker minor. Length, 7–9 mm.

Head similar to that of the worker major, but little longer than broad, with less convex sides, short and broadly rounded behind. Eyes feebly convex. Clypeus subcarinate. Antennal scapes extending about one-third their length beyond the posterior corners of the head. Epinotum and petiole like those of the worker major, but basal surface of the former longer in proportion to the length of the declivity.

Sculpture, pilosity and color as in the worker major.

Female. Length, 13–15 mm.

Very similar to the worker major. Sides of head less convex. Epinotum with flattened base, shorter than the abrupt, concave declivity. Petiole even more compressed anteroposteriorly than in the worker major, with sharper border, narrowed and feebly excised above. Wings long (15 mm.), strongly tinged with brown; veins and stigma brown.

Male. Length, 9–10 mm.

Head, including the eyes, about as broad as long, evenly rounded and broadest behind; cheeks subparallel, slightly concave, about as long as the eyes. Mandibles edentate. Clypeus convex, but scarcely carinate, with broadly rounded, entire anterior border. Ocelli very small. Antennæ long and slender; first funicular joint incrassated distally, a little longer than the second. Thorax robust; epinotum convex, sloping, without distinct basal and declivous surfaces. Petiole thick, rather high, transverse, evenly rounded and blunt, slightly impressed in the middle above. Gaster slender. Legs long, with long tarsal claws and very large empodia.

Surface of body very finely and densely shagreened; mandibles, head, pro- and mesonotum subopaque, remainder of thorax, gaster and legs shining.

Pilosity similar to that of the worker, but less abundant, absent on the scapes and thorax, with the exception of the epinotum. Pubescence very short and dilute, but visible on the head, thorax and gaster.

Black; mandibles, antennal funiculi, tarsi and articulations of the legs brown; wings colored like those of the female.

The types of this species, which is very constant and easily recognized by its deep black color, smooth surface and peculiar pilosity, came from California. I have examined specimens from the following localities:

California: Yosemite, Sierra Nevada, Sierra Valley, San Jacinto Mts., 6000 ft. (F. Grinnel, Jr.); Baldy Peak, San Gabriel Mts. (Brewster, Joos and Crawford); Blue Lake, Humboldt County; Felton, Santa Cruz Mts.; Alta Peak (9500–11,000 ft.), Giant Forest to Marble Fork, Sissons (J. C. Bradley); McCloud and Castle Crag (A. Fenyes).

Washington: Seattle (T. Kincaid); Union City (J. C. Bradley).

Oregon: Corvallis (Amer. Mus. Nat. Hist.).

Montana: Weeksville (S. Henshaw).

Idaho: Moscow Mt. (W. M. Mann), Lewiston and Moscow (J. M. Aldrich).

Colorado: Ute Pass and Cheyenne Canyon (Wheeler); South Boulder Canyon and Sugar Loaf (T. D. A. Cockerell).

Utah: Beaver Canyon (C. Schaeffer).

New Mexico: Santa Fé (on *Populus*), Pecos and Glorieta (T. D. A. Cockerell).

Arizona: (A. P. Morse).

Mexico: Gulf of California (A. Agassiz).

As shown by this list of localities, *C. lævigatus* is a mountain ant peculiar to the high ranges of the western states. It extends into Mexico and also for a short distance into British America (Vancouver Island, according to Lord). I believe that it will rarely be found below an altitude of 6000 ft. I have seen it only at elevations of 7000–8000 ft. in the mountains of Colorado. It forms large colonies which nest in dry stumps or logs after the manner of *C. herculeanus* and its various subspecies and varieties. In behavior it closely resembles the south European *C. vagus*.

Emery mentions three female specimens from Descanso, Calif., which seemed to represent a form allied to but distinct from *lævigatus*. These resembled the females of the *herculeanus* group, but had 6-toothed mandibles and an indistinctly carinate clypeus. The whole head was opaque, densely punctate, with scattered piligerous, shallow foveolæ, and the sides of the head bore short, stiff bristles. The tibiæ had short, oblique hairs; the color was like that of the *C. ligniperda* female. I have not been able to find any specimens answering to this description among my material.

26. C. herculeanus L. var. whymperi Forel

Formica herculanea Lord, Natur. in Vancouver I. and Brit. Col., II, p. 341, 1866.

? *Formica semipunctata* W. Kirby, Fauna Bor. Amer., IV, p. 262, No. 362, ♀, 1837.

? *Camponotus semipunctatus* Mayr, Verh. Zool. bot. Ges. Wien, XIII, p. 401, 1863.

C. herculeanus Forel, Bull. Soc. Vaud. Sci. Nat., (2) XVI, p. 57, 1879, 1881; Provancher, Natur. Canad., XII, 81, p. 354, No. 1, ☿ ♀ ♂, 1881; Faune Ent. Canad. Hymén., p. 597, No. 1, ☿ ♀ ♂, 1883; Addit. Faune Canad. Hymén., p. 231, No. 1, 1887; Dalla Torre, Catalog. Hymen., VII, p. 233, 1893; Emery, Zool. Jahrb. Abth. f. Syst., VII, p. 674, 1893.

C. herculeanus var. *whymperi* Forel, Trans. Ent. Soc. London, p. 699, ☿ ♀, 1902; Bull. Soc. Ent. Belg., XLVIII, p. 152, 1904; Emery, Deutsch. Ent. Zeitschr., p. 184, ☿, 1908; Wheeler, Geol. Survey Mich., p. 328, ☿, 1908.

Worker major. Length, 10–13 mm.; head, 3.5 x 3.5 mm.; scape, 2.7 mm.; hind tibia, 3.3 mm.

Head as broad as long, broader behind than in front, with broadly excised posterior border, rather convex sides and swollen cheeks. Eyes moderately large, flat. Mandibles 5-toothed; convex at the base, flattened or slightly concave on their distal halves. Clypeus evenly convex, not carinate, its anterior border scarcely produced, squarely truncated or feebly excised in the middle, with a deeper excision on each side near the cheeks. Frontal area large, subtriangular; frontal groove distinct. Frontal carinæ lyrate, rather far apart. Antennal scapes rather short, not extending beyond the posterior corners of the head, terete, neither dilated nor flattened at the base, incrassated distally. Thorax robust, rather high, feebly and evenly arcuate above, narrower than the head, laterally compressed behind; epinotum obtusely angular, with subequal base and declivity, the former feebly convex, the latter feebly concave in profile. Petiole high, compressed anteroposteriorly, with convex anterior and nearly flat posterior surface, its border rounded, entire and rather sharp. Gaster of the usual shape, legs moderately long and stout; middle and hind femora neither compressed nor sulcate, elliptical in cross section.

Opaque; very densely and rather coarsely shagreened; mandibles, eyes, anterior portion, sides, lower surface and posterior corners of head more shining. Mandibles coarsely striato-punctate. Whole head covered with sparse, shallow punctures, which are larger, but not elongated, on the cheeks. Upper surface of thorax and gaster with scattered piligerous foveolæ, the latter also with numerous small, often transverse punctures bearing the pubescence.

Hairs brownish yellow, coarse, short and erect, not very abundant; absent on the cheeks and sides of head. Antennal scapes and legs covered with short slanting or appressed hairs. Pubescence very short, dilute, scarcely visible on the thorax, most distinct on the gaster but not concealing the sculpture.

Black; mandibles, anterior border of head, antennæ, legs, petiole, posterior portion of thorax and the base of the first gastric segment, deep red. Posterior borders of gastric segments dark brown. In some specimens, the posterior portions of the thorax, the mandibles, anterior portion of the head, the antennal scapes and femora are black. Middle and hind tibiæ with only a few short bristles at the distal ends of their flexor surfaces.

Worker minor. Length, 6–8 mm.

Head somewhat broader than long, but little broader behind than in front, with feebly convex sides and nearly straight posterior border. Eyes slightly convex, clypeus carinate. Antennal funiculus extending about one-third its length beyond the posterior corners of the head. In other respects like the worker major.

Female. Length, 13–16 mm.

Very much like the worker major. Head with somewhat straighter sides, but broader behind than in front. Eyes larger and more convex. Thorax through the wing-insertions scarcely broader than the head; epinotum with convex base, impressed in the middle; declivity longer and distinctly concave. Petiole more compressed than in the worker major, narrow and high, with rounded, entire and more acute border.

Surface throughout more shining than in the worker, especially the thorax, which is quite glabrous above; epinotum opaque, shagreened. Gaster very finely transversely shagreened and covered with small punctures. Mesonotum and gastric segments also with a few scattered piligerous foveolæ.

Pilosity like that of the worker, but sparser and shorter. Pubescence also shorter and sparser, especially on the gaster.

Black; mandibles, legs, antennæ and often also the epinotum, pleuræ and petiole tinged with red. Wings very long (in large specimens 18 mm.), strongly tinged with brown; veins and stigma yellowish brown.

Male. Length, 9–10 mm.

Head through the eyes about as broad as long; broadly rounded behind; cheeks feebly convex, converging anteriorly, as long as the eyes. Ocelli very small. Mandibles edentate. Clypeus convex in the middle, but scarcely carinate, its anterior border broadly rounded and slightly sinuate in the middle. Thorax robust; epinotum with flattened and subequal base and declivity meeting to form a rounded obtuse angle. Petiole rather high, distinctly compressed anteroposteriorly, with thin, rather acute border, which is deeply excised in the middle above.

Opaque; very finely shagreened; gaster shining.

Hairs and pubescence shorter and sparser than in the worker, especially on the head and thorax. Cheeks without hairs. Short hairs on the legs and antennal scapes appressed and scarcely more than pubescence.

Black; mandibles, antennæ and legs reddish. Wings paler than those of the female; veins and stigma yellow.

Forel based this variety on specimens from Alberta. I have seen a large number of individuals from the following localities:

Alberta: Field, Vermillion Pass and Lake Louise, cotypes (Whymper); Red Deer; Banff (J. C. Bradley).

Alaska: (Dall); Kasiloff Lake, Kenai Peninsula (Berlin Mus.); Koyukuk (W. J. Peters).

British Columbia: Goldstream to Downie Creek, Selkirk Mts. (J. C. Bradley); Golden (W. Wenman); Carbonate River, Moraine Lake, Valley of Ten Peaks, Hector and Emerald Lake (J. C. Bradley).

Saskatchewan: Methy Lake (Kennicott); Farewell (V. A. Armstrong).

Vancouver I.: (U. S. Nat. Mus.).

Quebec: James Bay and Rupert House (Alanson Skinner); Saguenay River (Engelhardt); Montmorency; Amherst Island and Anticosti Island (Samuel Henshaw).

Ontario: Moose Factory (Alanson Skinner); Rat Portage (J. C. Bradley).

Labrador: (A. S. Packard); Cape Charles.

New Brunswick: St. John (Mus. Comp. Zool.).

Newfoundland: East Coast; Cod Roy (L. P. Gratacap).

Nova Scotia: Digby (John Russell); Ship Harbor (Samuel Henshaw).

Oregon: Umatilla (Samuel Henshaw).

Washington: Brinnon, Hoods Canal (J. C. Bradley); Wenass and Spokane (Samuel Henshaw).

Idaho: Moscow (J. M. Aldrich).

Wyoming: Douglas; Laramie (U. S. Nat. Mus.); Carbonate (Wortmann).

Colorado: Pike's Peak, 10,500 ft. (Wheeler); Pike's Peak, half-way house (T. D. A. Cockerell); Cripple Creek, 10,200 ft., Cascade; Florissant, 8500 ft., and Williams Canyon, Manitou, 8000 ft. (Wheeler); Eldora, 8600 ft., and Ward, 9000 ft. (T. D. A. Cockerell); Ft. Collins (E. G. Titus).

New Mexico: Cloudcroft (H. Skinner); Beulah, 8000 ft., and Pecos (T. D. A. Cockerell); Barela Mesa (Miss A. Gohrman); Manzanares (Miss M. Cooper).

Michigan: Isle Royale and Porcupine Mts. (O. McCreary and C. C. Adams); Marquette (M. Downing).

Wisconsin: White Fish Bay, near Milwaukee, in tamarack bog (Wheeler).

Maine: Reeds Isle, Penobscot Bay (A. C. Burrill); South Harpswell (Wheeler): Heald Pond, near Jackman (F. A. Jones).

Vermont: Jay Peak summit, 4018 ft.

New Hampshire: Mt. Washington, 3840 ft. (W. Reiff).

Pennsylvania: St. Vincent (Jerome Schmitt).

I have followed Forel and Emery in placing under the var. *whymperi* all the American ants which were formerly regarded as belonging to the typical *C. herculeanus* of boreal and alpine Europe, but I must admit that the differences which, according to Forel, separate the two forms are very slight, not to say elusive. These differences are merely a somewhat coarser sculpture and slightly longer and more abundant, oblique or suberect hairs on the antennal scapes and tibiæ in the American specimens. After carefully comparing a couple of the cotypes of *whymperi* kindly given me by Professor Forel with many specimens of *C. herculeanus* collected by myself during two summers in the high Alps, I have some doubts as to the validity of *whymperi* as a true variety. Moreover, the specimens I have examined from Newfoundland and Isle Royale, Michigan, have the hairs on the scapes and tibiæ neither longer nor more erect than in European specimens and the differences in sculpture are to me imperceptible. Forel states that the female of *whymperi* measures only 12–13.5 mm. and is therefore smaller than that of the typical *herculeanus*, but I have before me a number of females from British America and the Rocky Mts. which measure 15–16 mm. Emery states that the var. *whymperi* occurs also in Siberia and Mongolia and has therefore included it in the palearctic fauna.

The list of localities given above shows that the true home of *C. whymperi* is British America, Alaska and high elevations in the Rocky Mts. (8000 ft. and over) and White Mts. (3000 ft. and over). When it strays to lower levels, it is found only in cold tamarack bogs (in Wisconsin), coniferous forests (in Maine, Michigan, Oregon and Washington) or in the cold woods of the Alleghanies (in Pennsylvania). It is therefore quite as clearly a boreal or alpine form in America as is the typical *herculeanus* in Europe. Its habits, too, are the same. It forms large colonies nesting in logs and stumps, especially of conifers, and may be regarded as the prototype of our various North American "carpenter ants."

27. C. herculeanus L. var. modoc nom. nov.

C. pennsylvanicus var. *semipunctatus*, Forel (nec Kirby), Bull. Soc. Nat., XVI, p. 57, 1881; Ann. Soc. Ent. Belg., XLVIII, p. 152, 1904.

Worker major and *minor*.

Differing from *whymperi* in sculpture, pilosity and color. The shagreening of the head is coarser, so that it is even more opaque, especially on the sides and posterior corners. The punctures of the gaster are larger and the whole surface rougher and more opaque. Hairs and pubescence golden yellow, the former much as in *whymperi*, except that they are shorter and more appressed on the scapes and tibiæ. The pubescence is much longer and more conspicuous, especially on the upper surface of the gaster, but decidedly shorter than in *pennsylvanicus*. Head, thorax, petiole and gaster black; legs deep red. Coxæ dark brown; antennæ varying from black to dark brown, the funiculus usually somewhat paler than the scape. In the worker media and minor, the mandibles may be tinged with red.

Female.

Closely resembling the worker major in sculpture, color and pilosity. The thorax differs from that of the female *whymperi* in being opaque and densely shagreened, except the scutellum and metanotum, which are smooth and shining. In some specimens, the mesonotum is subopaque, but not as smooth as in *whymperi.*

Male.

Indistinguishable from the male of *whymperi.*

Described from numerous specimens from the following localities:

California: King's River Canyon (H. Heath); Marin County, Fallenleaf Lake, Giant Forest and Alta Meadow Trail (J. C. Bradley); Sierra Nevada (Amer. Mus. Nat. Hist.); Tahoe City (A. Fenyes).

Washington: Umatilla and Klikitat Valley (Samuel Henshaw); Pullman (C. V. Piper); Olympia and Seattle (T. Kincaid); San Juan Island (W. M. Mann); Union City (J. C. Bradley).

Oregon: Corvallis (Amer. Mus. Nat. Hist.).

Nevada: (Amer. Mus. Nat. Hist.).

Idaho: (R. W. Doane); Moscow (J. M. Aldrich).

Colorado: Boulder Canyon (T. D. A. Cockerell).

New Mexico: Upper Ruidoso, 8500 ft. (C. H. T. Townsend); Harvey's Ranch, Las Vegas Range, 9600 ft. (Miss Ruth Raynolds); same range, 10,000 ft. (E. L. Hewitt); James Canyon, near Cloudcroft (A. G. Ruthven).

Utah: Little Willow Canyon (R. V. Chamberlin).

South Dakota: Black Hills (Amer. Mus. of Nat. Hist.).

British Columbia: Alert Bay (H. I. Smith).

I would regard California as the type locality of this form, which seems to be rather constant. The specimens from Utah and South Dakota have paler and somewhat longer pubescence and therefore form a transition to *pennsylvanicus.* All of my specimens, however, show that there is little difficulty in separating this form from *whymperi.* In the northern and western portion of its range, it seems to descend to lower levels than this form, but in the mountains of New Mexico it seems to occur in the same stations.

I do not believe that this is the form described by Kirby as *semipunctatus.* Kirby's description, which evidently refers to a female specimen, is quite worthless. That it refers either to *whymperi* or *pennsylvanicus* seems to be proved by the locality. He says that the specimen was "taken on a journey from New York to Cumberland House." Now

Cumberland House is in Keewatin, and in the region through which he traveled to reach that point, he could only have happened on *whymperi* or *pennsylvanicus,* and as most of his journey lay through British America, it is more probable that he had a specimen of *whymperi.* I believe therefore that Forel is mistaken both in attributing the western form of *herculeanus* above described to *semipunctatus* and in placing it under *pennsylvanicus.* It is clearly more nearly related to *whymperi* and the typical *herculeanus* of Europe.

28. C. herculeanus pennsylvanicus De Geer

Formica Pennsylvanica De Geer, Mém. Serv. Hist. Insect., III, p. 603, No. 4, Pl. 31, Figs. 9-10, ☿ ♀ ♂, 1773; Göze, De Geer, Abh. Gesch. Ins., III, p. 391, No. 4, Pl. 31, Figs. 9-10, ☿ ♀ ♂, 1780; Retzius, Gen. et Spec. Insect., p. 75, No. 332, 1783; Olivier, Encycl. Method. Insect., VI, p. 501, No. 52, 1791; Latreille, Hist. Nat. Fourmis, p. 99, Pl. 2, Fig. 3, 1802; Lepeletier, Hist. Nat. Ins. Hymen., I, p. 213, No. 14, ☿ ♀, 1836; Buckley, Proc. Entom. Soc. Phila., VI, p. 155, ☿ ♀, 1866; Provancher, Natur. Canad., XII, p. 355, No. 2, ☿ ♀, 1881; Faune Ent. Canad. Hymén., p. 598, No. 2, ☿ ♀ ♂, 1883; McCook, Trans. Amer. Ent. Soc., V, p. 277-289, Pl. 2-4, 1876.

? *Formica semipunctata* W. Kirby, Fauna Bor. Amer., IV, p. 262, No. 362, ♀, 1837.

Formica caryæ Fitch, Trans. N. Y. State Agri. Soc., XIV, p. 151, ☿ ♀ ♂, 1854.

Camponotus pennsylvanicus Mayr, Verh. Zool. bot. Ges. Wien, XII, p. 666, No. 24, ☿ ♀, 1862; McCook, Proc. Acad. Nat. Sci. Phila., 1878, p. 15-19; Ann. Mag. Nat. Hist., (5) XIII, p. 419, 1884; *Ibid.*, p. 140, 1879; Ern. André, Spéc. Hymen. Europe, II, Pt. 13, p. 141, 1882; *Ibid.*, Pt. 14, p. 153, No. 3, ☿ ♀, 1882; Dalla Torre, Catalog. Hymen., VII, p. 246, 1893.

C. herculeanus race *pennsylvanicus* Forel, Bull. Soc. Vaud. Sci. Nat., (2) XVI, P. 81, p. 57, 1879.

C. herculeanus var. *pennsylvanicus* Mayr, Verh. Zool. bot. Ges. Wien, XXXVI, p. 420, 1886.

C. herculeanus subsp. *pennsylvanicus* Emery, Zool. Jahrb. Abth. f. Syst., VII, p. 675, 1893; Wheeler, Bull. Amer. Mus. Nat. Hist., XXI, p. 402, 1905; Occas. Papers Bost. Soc. Nat. Hist., VII, 7, p. 23, 1906.

Worker major and *minor.*

Differing from the preceding forms of *herculeanus* in sculpture, pilosity and color. The head and thorax are somewhat less coarsely shagreened and appear therefore more shining. This is especially true of the sides and posterior corners of the head. The gaster is opaque and very coarsely shagreened, with the punctures that bear the pubescence larger and more transversely elongated. The hairs and pubescence are more abundant and longer than in *whymperi* and *modoc* and of a pale yellow or white color. On the gaster, the pubescence is extremely long and takes the form of dense, appressed hairs which conceal the ground surface and give this region of the body an ashy tint and silky luster. In what may be regarded as the typical form of the subspecies, the body, including the posterior margins of the gastric segments is black throughout, with only the antennal funiculi, tarsi and articulations of the legs dark brown or reddish. In many major workers, however, and especially in minor workers, the mandibles, antennal scapes, legs, pleuræ and petiole may vary from very deep to pale red.

Female.

Resembling the worker major, but the whole thorax and gaster are more shining, as in the female *whymperi;* hairs and pubescence shorter than in the worker major, especially on the gaster, which has the pubescence only a little longer and denser than in *whymperi.*

Male.

Indistinguishable from the male of *whymperi;* black throughout, with only the antennal funiculi and tarsi brown. Wings often as deeply tinged with brown as in the female.

I have examined many specimens of this well-known ant from the following localities:

Pennsylvania: North Mts., Bartram's Park, Philadelphia and Lehigh Water Gap (C. Daecke).

New York: Saranac Lake, Big Moose, Oswego, Nassau, Cedar Hill and Keene Valley (N. Y. State Coll.) ; Ithaca (Cornell Univ. Coll.) ; Garrison-on-Hudson (T. D. A. Cockerell) ; Bronxville and Cold Spring Harbor, L. I. (Wheeler) ; Bergen Beach (G. von Krockow) ; West Farms (J. Angus) ; Staten Island (W. T. Davis) ; Turin (Lucy Armstrong).

New Jersey: Caldwell (E. T. Cresson) ; Riverton (H. Viereck) ; Medford and Westville (Phila. Acad. Coll.) ; North Woodbury and Delair (C. Daecke) ; Newfoundland (W. T. Davis) ; Halifax and Fort Lee (Wheeler).

Maine: Mt. Katahdin (Hamlin) ; Bethel (Mus. Comp. Zool.).

New Hampshire: Canobie Lake (G. B. King) ; Exeter (Mus. Comp. Zool.).

Vermont: Jay Peak (A. P. Morse).

Massachusetts: Sherborn, Natick, Winchendon, Palmer, Needham, Wellesley and West Roxbury (A. P. Morse) ; Worcester, Haverhill, Cambridge and Brookline (Mus. Comp. Zool.) ; Boston and Blue Hills (Wheeler) ; Springfield and Essex County (G. B. King) ; Milton (Bost. Soc. Nat. Hist.) ; Warwick (Miss Edmunds) ; Woods Hole (Miss A. Fielde).

Connecticut: Woodmont (Butrick) ; New Haven and Branford (W. E. Britton) ; Colebrook (Wheeler).

Maryland: Chestertown and Pomona (H. Viereck) ; Washington, D. C. (W. V. Warner).

Virginia: Ashland (J. F. McClendon).

North Carolina: Black Mts. (W. Beutenmueller); Lake Toxaway (Mrs. A. T. Slosson).

Georgia: Clayton, 2000–2700 ft. (W. T. Davis).

North Dakota: Ellison (Miller).

South Dakota: Medicine Root, Pine Ridge Ind. Res. (Thompson).

Wisconsin: Milwaukee (Wheeler).

Michigan: Battle Creek.

Illinois: Urbana (Pricer); Mossville (F. Blake); Algonquin (W. A. Nason); Rockford (Wheeler).

Indiana: Arlington and De Long (W. S. Blatchley).

Tennessee: Springdale (C. C. Adams).

Missouri: St. Louis (C. F. Baker).

Kansas: Ottawa (E. G. Titus).

Arkansas: Fort Smith (A. W. Morrill).

Oklahoma: Ponca City (A. C. Burrill).

Texas: Austin (Wheeler); Meridian and Beaumont (W. H. Long); Brownwood (J. C. Crawford); Joaquin, Longview and Lovelady (W. W. Yothers and E. S. Tucker); Victoria (J. D. Mitchell); Calvert (C. R. Jones); Dallas (W. D. Hunter and F. C. Pratt); Palestine (F. C. Bishopp).

Louisiana: Logansport (W. D. Pierce); Shreveport and East Point (F. C. Bishopp); Baton Rouge (W. Newell); Mansfield (W. D. Hunter); Orange (R. C. Howell); Natoches (Cushman and Pierce).

Ontario: Toronto (R. J. Crew).

Quebec: Montreal (T. D. A. Cockerell).

Worker specimens from St. Louis, Missouri, and from some of the Texas localities, notably from the vicinity of Austin, have a pceuliar brown tinge to the body, and the legs and antennæ are much paler than in the typical form of the subspecies, but I have not deemed it advisable to separate them as an independent variety.

From the foregoing list of localities, which might be very easily increased, it will be seen that *C. pennsylvanicus* ranges over southern Canada and the states as far west as Victoria, Texas, and the Pine Ridge Indian Reservation in South Dakota. Unlike *whymperi* and *modoc* it is a lowland form. It is far and away the most abundant *Camponotus* in the North Atlantic states and Middle West, showing a range of adaptability to differences in temperature and humidity second only to that of *Lasius americanus* and *Formica subserica.* On this account, it is the only one of our *Camponoti* that has attracted general attention. It is commonly found nesting in old logs and stumps or in the dead wood of standing trees, but occasionally it nests in old houses. In such places it may do considerable damage by tunneling in beams and rafters and may become a domestic nuisance by visiting the sweet food-stuffs in kitchens and pantries. Its habits were first studied by McCook. Recently Pricer and Miss Edith Buckingham have made many interesting observations on its polymorphism and behavior.

29. **C. herculeanus pennsylvanicus** var. **mahican** nom. nov.

C. herculeano-pennsylvanicus Forel, Bull. Soc. Vaud. Sci. Nat., XVI, P. 81, p. 57, ☿, 1879.

C. herculeanus var. *herculeano-pennsylvanicus* Emery, Mem. R. Acad. Sci. Ist. Bologna, p. 770, 1896.

Worker major and *minor*.

Differing from the typical *pennsylvanicus* only in pilosity and color. The hairs and pubescence are pale yellow as in *pennsylvanicus*, but the pubescence on the gaster is shorter and sparser, though longer than in *modoc*. The legs and petiole are red and the thorax is more or less tinged with the same color, at least on the pleuræ. Posterior borders of gastric segments dull yellow. On the whole, this variety seems to be intermediate between *whymperi* and *pennsylvanicus*.

Described from a number of workers taken in the following localities:

Massachusetts: Cambridge (Mus. Comp. Zool.); Woods Hole (Wheeler).

New Jersey: Englewood (Wheeler).

Forel mentions this form also from the Alleghanies, New York, Illinois and South Carolina.

I have attached this variety to *pennsylvanicus*, because it shows a greater affinity to this form than to the true *herculeanus*, and I have ventured to give it a new name, because the one by which it has been known is not properly a varietal name and is very unwieldy. Whether this form is worthy of recognition as an independent variety cannot be decided without more material than I have been able to examine.

30. **C. herculeanus pennsylvanicus** var. **ferrugineus** Fabr.

Formica ferruginea Fabricius, Suppl. Entom. Syst., p. 279, No. 11-12, ☿ ♀, 1798; Latreille, Hist. Nat. Fourm., p. 94, 1802; Fabricius, Syst. Piez., p. 399, No. 14, 1804; F. Smith, Catalog. Hymen. Brit. Mus., VI, p. 53, No. 187, 1858.

Camponotus ferrugineus Mayr, Verh. Zool. bot. Ges. Wien, XIII, p. 399, 1863.

C. pennsylvanicus var. *ferrugineus* Forel, Bull. Soc. Vaud. Sci. Nat., (2) XVI, P. 81, p. 56, 1879; Emery, Zool. Jahrb. Abth. f. Syst., VII, p. 668, 1893; Dalla Torre, Catalog. Hymen., VII, p. 247, 1893; Wheeler, Bull. Amer. Mus. Nat. Hist., XXI, p. 402, 1905; Occas. Papers Bost. Soc. Nat. Hist., VII, 7, p. 23, 1906.

Worker major and *minor.*

Closely resembling the typical *pennsylvanicus* in sculpture and in the length and abundance of the hairs and pubescence, but differing in color. The hairs and pubescence are bright golden yellow instead of pale yellow or white. Thorax, petiole, coxæ, femora and base of first gastric segment yellowish ferruginous; pronotum and often also the mesonotum black. Antennal scapes black, with yellow tips and insertions; funiculi, mandibles, anterior border of head, tibiæ and tarsi deep red; posterior margins of gastric segments yellow.

Female.

Resembling the worker. Pronotum, mesonotum, except its anterior portion, scutellum and metanotum black. Remainder of thorax, base and sometimes the whole of the first and the base of the second segment yellowish red. Wings rich yellowish brown with resin-yellow veins and stigma. Hairs and pubescence golden yellow, shorter than in the worker, especially on the gaster.

Male.

Differing from the male of *pennsylvanicus* in having the whole of the antennæ and legs, and sometimes also the metasterna, coxæ and ventral portion of the petiole, red or brown. Edges of gastric segments dull yellow. The whole body is densely and coarsely shagreened and the gaster is somewhat more opaque than in *pennsylvanicus.*

Described from numerous specimens taken in the following localities:

Massachusetts: Sherborn (A. P. Morse); Medford (Mus. Comp. Zool.); Boston (Wheeler).

Connecticut: New Haven (Moore and Viereck); Orange and New Canaan (W. E. Britton).

New York: West Farms (J. Angus); Mosholu and Bronxville (Wheeler); Forest Park (G. v. Krockow); Staten Island (W. T. Davis).

New Jersey: Delair (C. Daecke); Camden and Boonton (H. Viereck); Westville (Phila. Acad. Sci.); Fort Lee and Great Notch (Wheeler); Ocean County.

Maryland: Pomona (H. Viereck).

Pennsylvania: Lawndale.

Indiana: Mitchell (W. S. Blatchley).

Illinois: Rockford (Wheeler); Mossville (F. Blake); Urbana (Pricer).

This variety has a much more limited range than *pennsylvanicus*, since it does not extend as far south or north, and seems to be confined to rather low, warm woodlands. It varies so little that it might be regarded as a subspecies. I have been unable to find any specimens that would represent transitions between *ferrugineus* and any of the other forms of *herculeanus.* In certain respects it resembles the Japanese subspecies *obscuripes* Mayr, but this form has much darker legs and in sculpture and pilosity is much like *ligniperda.*

31. **C. herculeanus ligniperda** Latreille var. **noveboracensis** Fitch

Formica novæboracensis Fitch, Trans. N. Y. State Agri. Soc., XIV, p. 52, ☿, 1854.

Camponotus herculeanus race *ligniperdus* var. *pictus* Forel, Bull. Soc. Vaud. Sci. Nat., (2) XVI, P. 81, p. 59, ☿ ♀ ♂, 1879; Ann. Soc. Ent. Belg., XXX, p. 141, ☿ ♀, 1886.

C. herculeanus subsp. *ligniperdus* var. *pictus* Emery, Zool. Jahrb. Abth. f. Syst., VII, p. 674, 1893; Wheeler, Bull. Amer. Mus. Nat. Hist., XXI, p. 402, 1905.

C. ligniperda var. *pictus* Dalla Torre, Catalog. Hymen., VII, p. 240, 1893.

C. herculeanus race *ligniperdus* var. *noveboracensis* Forel, Ann. Soc. Ent. Belg., XLIII, p. 447, 1899.

C. herculeanus ligniperdus var. *noveboracensis* Wheeler, Occas. Papers Bost. Soc. Nat. Hist., VII, 7, p. 23, 1907.

Worker major and *minor*.

Sculpture finer and more superficial than in *whymperi* and *pennsylvanicus*, so that the whole surface of the body and especially the gaster is smoother and more shining. Hairs and pubescence pale yellow or white, sparse and short; the pubescence on the gaster being nearly as short as in *whymperi* and decidedly more dilate; the minute hairs on the scapes and legs more appressed. Head, antennæ and gaster black; thorax, petiole and legs red, the tibiæ and tarsi often somewhat darker. Posterior edges of gastric segments yellowish. In the worker media and minima, the mandibles and sometimes also the clypeus are red.

Female.

Resembling the worker major, but the thorax and gaster very smooth and shining; the latter with shorter hairs and very short and dilute pubescence. Dorsal portion of pronotum, scutellum, metanotum and three more or less distinct longitudinal bands on the mesonotum, black. In some specimens, the whole mesonotum and dorsal portion of the epinotum are black. Extreme base of first gastric segment often red or yellow. In other respects, the color is like that of the worker. Wings strongly tinged with yellowish brown; veins and stigma yellow.

Male.

Indistinguishable from the male of *pennsylvanicus*. Wings somewhat paler than in the female.

Of this variety I have examined specimens from the following localities:

Nova Scotia: Digby (J. Russell); Bedford (W. Reiff).

Maine: West Beach (Mus. Comp. Zool.); South Harpswell (Wheeler).

New Hampshire: Mt. Washington, summit (Mrs. A. T. Slosson and C. S. Bacon); White Mts. (W. F. Fiske); Canobie Lake (G. B. King); Exeter (Mus. Comp. Zool.); Pelham (Bridwell); Hanover (C. M. Weed); Durham.

Vermont: Jay Peak (A. P. Morse).

Massachusetts: Winchendon, Wellesley, Needham and Sherborn (A. P. Morse); Malden, Warwick, Cambridge, Medford and Eastport (Mus. Comp. Zool.); Essex County and Mt. Tom (G. B. King); Lynn (Davis); Boston and Woods Hole (Wheeler).

Rhode Island: Providence (Davis).

Connecticut: New Hartford and Orange (W. E. Britton); Colebrook (Wheeler).

New York: Ithaca (Cornell Univ. Coll.); Keene Valley, Essex County, Oswego, Elizabeth, Karner, Cedar Hill and Saranac Lake (N. Y. State Coll.); Boonville (E. G. Titus).

Pennsylvania: White Haven (J. C. Bradley); North Mts.

Indiana: Pine (W. S. Blatchley).

Michigan: Ann Arbor (J. Dawson).

Illinois: Rockford (Wheeler); Algonquin (W. A. Nason).

Wisconsin: Milwaukee County (Wheeler).

Colorado: Williams Canyon, Manitou (Wheeler).

Washington: Union City (J. C. Bradley).

Oregon: (Amer. Mus. Nat. Hist.).

Although *C. noveboracensis* ranges across the continent from the Atlantic to the Pacific, it is not known to occur further south than Maryland or further north than Nova Scotia. In the Atlantic states, it lives by preference in hilly country, usually at higher elevations than *pennsylvanicus* and *ferrugineus*. To judge from the specimens before me, *noveboracensis* exhibits very little variation in color. The specimens from Washington, however, have the coarse opaque surface of *whymperi* and may be regarded as transitions to this variety.

32. C. herculeanus ligniperda var. rubens Wheeler

C. herculeanus ligniperdus var. *rubens* Wheeler, Psyche, p. 41, ♀ ♂, 1906; Occas. Papers Bost. Soc. Nat. Hist., VII, 7, p. 24, 1906.

This variety differs from *noveboracensis* in having all the gastric segments of the female deep red, except their posterior margins, which are black. The male is indistinguishable from the male of *noveboracensis*. The worker forms are unknown.

Described from two females from Norway, Maine (S. J. Smith); one male and one female from Bethel, Maine (A. M. Edwards) and four females taken in Michigan (Clark).

It is somewhat doubtful whether this form can be maintained as an independent variety. Reëxamination of the type specimens shows that they are very old, and the red color of the gaster in the female may be due to bleaching.

IV. *Fallax Group*

As I have recently published the synonymy and descriptions of the twelve North American subspecies and varieties of *C. fallax* Nyl., which is the type of this group (Journn. N. Y. Ent. Soc., XVIII, No. 4, 1910), I shall here confine myself to listing the various forms, with the states in which they are known to occur.

33. **Camponotus fallax** Nyl. var. **nearcticus** Emery

New York; New Jersey; Pennsylvania; Connecticut; Massachusetts; Rhode Island; Illinois; Wisconsin; Nebraska; Washington; Idaho; Oregon; California; Florida; Texas; Canada.

34. **C. fallax** var. **minutus** Emery

New Jersey; New York; Pennsylvania; Massachusetts; Illinois; Canada; Vancouver.

35. **C. fallax** var. **pardus** Wheeler

New York; New Jersey.

36. **C. fallax** var. **tanquaryi** Wheeler

Illinois.

37. **C. fallax** var. **decipiens** Emery

Indiana; Kansas; Colorado; Utah.

38. **C. fallax rasilis** Wheeler

Texas; Arizona; Louisiana; Florida.

39. **C. fallax rasilis** var. **pavidus** Wheeler

Texas; Louisiana; Florida.

40. **C. fallax subbarbatus** Emery

Maryland; Virginia; New Jersey; Illinois; California.

41. **C. fallax subbarbatus** var. **paucipilis** Emery

Maryland.

42. **C. fallax discolor** Buckley

Texas; Oklahoma; Missouri; Illinois.

43. C. fallax discolor var. clarithorax Emery

California; Illinois; Pennsylvania.

44. C. fallax discolor var. cnemidatus Emery

Maryland.

45. C. sayi Emery

Emery, Zool. Jahrb. Abth. f. Syst., VII, p. 679, Pl. 22, Figs. 27, 28, ☿, 1893.

Worker major. Length, 7–8 mm.; head, 2.5 x 2.4 mm.; scape, 1.7 mm.; hind tibia, 2 mm.

Head large, but little longer than broad, broader behind than in front, with broadly excised posterior margin and prominent posterior corners. Eyes moderately large, feebly convex. Mandibles 5-toothed, convex. Clypeus with very short lateral limbs and subrectangular median portion, which is slightly convex but not carinate, with depressed border and small median notch. Frontal carinæ lyrate, rather far apart. Frontal area subtriangular, broader than long. Frontal groove distinct. Antennal scapes short, not reaching the posterior corners of the head, slender and terete at the base, somewhat thickened distally. Thorax stout and short, narrower than the head, robust in front, narrowed and laterally compressed behind; pro- and mesonotum flattened, in profile moderately arcuate; epinotum with subequal base and declivity meeting to form a distinct though obtuse angle. Petiole high and rather narrow, compressed anteroposteriorly, with convex anterior and flattened posterior surface, its margin entire and rather acute. Legs short, femora stout.

Head and thorax shining, very finely shagreened; cheeks and front with small, round, scattered punctures. Mandibles more coarsely punctate. Gula, sides and posterior corners of head glabrous. Gaster very finely, transversely shagreened, with small, scattered, piligerous punctures, its surface even more shining than the head and thorax.

Hairs white or pale yellow, erect, very sparse; present in a transverse row on the epinotal angle, margin of petiole and in two rows on each gastric segment, one across the middle and the other along the posterior edge. Legs and scapes naked. Pubescence extremely short and dilute, even on the gaster.

Head, antennæ, thorax and legs yellowish red; the head slightly darker; gaster black, with the posterior borders of the segments yellow.

Worker minor. Length, 4.5–6 mm.

Head proportionally longer than in the worker major, with straight and more nearly parallel sides, straight posterior border and rounded posterior corners. Clypeus more convex in front, but not carinate, its anterior border with a minute median notch. Mandibles less convex, eyes more convex than in the worker major. Antennal scapes extending about one-third their length beyond the posterior corners of the head. Thorax less robust; petiole with blunt border.

In sculpture, color and pilosity much like the worker major; head more shining and without small, scattered punctures on the sides and front.

Arizona: Phœnix, cotypes (Th. Pergande); Phœnix and Prescott, running on trunks of cotton-wood trees (Wheeler).

This species, as Emery has remarked, is very similar to *C. fallax discolor*. It is even more like *fallax rasilis*, but the head and thorax are more robust, the head is more excised behind, the clypeal notch smaller, the epinotum more angular and the sculpture is different, the punctures on the sides and front of the head being much smaller and the surface of the head and thorax somewhat more shining. These differences, however, are not very pronounced and it may be necessary, when *sayi* is better known, to reduce it to the rank of a subspecies of *fallax*.

46. **C. texanus** Wheeler

As I have published a detailed description of all four phases of this handsome species (Psyche, 1903, p. 108), it may be passed over here with a few remarks. It is readily distinguished from all the other members of the *fallax* group by its large size (worker major 10–12 mm.), and coloration, the worker major having a black head and gaster, red thorax and legs, a yellow base to the first gastric segment and dark red antennæ. The male differs from all the known males of the *fallax* group in the color of the thorax and legs, which are reddish yellow, with the scutellum, metanotum and three spots on the mesonotum black and the epinotum more or less infuscated.

The types are from Travis County, Texas, and were found nesting in oak logs.

47. **C. schaefferi** Wheeler

The female and worker phases of this species have been described in detail in Journ. N. Y. Ent. Soc., XVII, p. 88, 1909. The worker major is as large as that of *texanus* and measures 9–12 mm., but it is yellowish red throughout with darker mandibles, scapes and anterior border of the head. The mandibles are distinctly flattened distally, and the anterior border of the clypeus is flat and has a broader, shallower notch than in *sayi* and *texanus*, with a small tooth on each side. In these characters and in the sculpture of the head, there is an unmistakable resemblance to the smoother forms of *herculeanus*, such as *ligniperda*. The middle and hind tibiæ have two rows of stiff, graduated bristles on the distal half of their flexor surface. In *texanus*, these bristles are smaller and less numerous and seem to be rather inconstant; in *sayi*, they are lacking. In the worker minor and female of *schaefferi*, which are colored like the worker major, the median excision of the clypeal border is still shallower and even more like that of *herculeanus* and *lævigatus*. The wings of the female are deeply tinged with brown and have resin-yellow veins and stigma. The male is unknown.

The types are from southern Arizona and comprise a media and a minima worker taken by Mr. C. Schaffer at Palmerlee, Cochise County, Ariz., a winged female taken by Mr. E. J. Oslar in the Huachuca Mts. and a long series of females and workers of all sizes taken by Mr. C. R. Biederman in Carr Canyon in the same mountain range from a "nest partly in the ground and partly in rotten wood, six inches deep, at an altitude of 5000 ft."

48. C. hyatti Emery

Emery, Zool. Jahrb. Abth. f. Syst., VII, p. 680, Pl. 22, Figs. 25, 26, ☿, 1893.

"*Worker.* Closely allied to *C. marginatus* [*C. fallax*], but the head with more shining and more nearly parallel sides; posterior corners less rounded, mandibles shining; thorax impressed in the region of the meso-epinotal suture; epinotum with the convex base and concave declivity meeting to form an obtuse angle. Piceous black; mouth, pronotum and legs more or less ferruginous or red. Abdomen black. Length, 3.5–6.5 mm.

"Head of the worker maxima, 1.9 x 1.8 mm.; scape, 1.2 mm.; hind femur, 1.7 mm.; thorax, 2 x 1.3 mm.

"From San Jacinto, California; collected by Mr. Ed. Hyatt; received from Mr. Pergande.

"In habitus very similar to *C. marginatus;* body more thickset. The head in the worker major has more nearly parallel, less convex sides, more concavely excised posterior border, more prominent anterior and posterior corners, the latter being less broadly rounded. In the worker minor the head is somewhat broader than in the minor worker of the same size, the anterior corners somewhat more rounded. The sculpture is very similar to that of the typical *marginatus*, but much more superficial; the impressed punctures much shallower, scarcely visible on the clypeus, smaller on the cheeks; the integument is therefore much more shining. The mandibles are less prominent than in *marginatus*, with more convex outer borders, also 5-toothed, shining, sparsely punctate. The clypeus also has a very short, rounded lobe, with anterior border strongly emarginate in the middle; flat in the worker major, bluntly roof-shaped in the minor. The lobe is less conspicuous in the large worker, owing to the more prominent anterior corners of the head. The thorax is proportionally broader than in *marginatus*, in profile distinctly constricted between the meso- and epinotum; the somewhat convex basal and the distinctly concave declivous surface form together a rounded angle. Seen from above, the pronotum is especially broad and rounded on the sides; the mesonotum is strongly narrowed posteriorly to the mesoëpinotal suture, where the thorax is narrowest; the sides of the epinotum are nearly parallel. The petiolar scale is somewhat broader and thinner than in *marginatus*, its upper margin broadly arched and rather sharp. The sculpture of the thorax and gaster are as in *marginatus*, and the same is true of the pilosity of the whole body.

"The color is variable; usually pitch black; mouth, gula and tibiæ somewhat reddish; prothorax, coxæ, femora and tarsi light red; gaster black, with reddish yellow margins to the segments. Often, especially in minor workers, the pale color is more extensive and the whole insect may be ferruginous red with brownish black gaster."

As I possess only a few small workers (cotypes from Mr. Pergande) of this species, I have translated Emery's original description.

49. C. hyatti Emery var. bakeri Wheeler

WHEELER, Bull. Amer. Mus. Nat. Hist., XX, p. 271, ☿ ♀, 1904.

Worker media. Length, 5.5 mm.

Differing from the typical form in coloration, which is like that of *C. fallax* var. *discolor*, except that the basal two-thirds of the first gastric segment are red, like the head, thorax and appendages. The sculpture is quite as sharp as in *fallax*, and the surfaces of the head and body are quite opaque. The mandibles and cheeks are coarsely punctate. In profile, the thorax is like that of the typical *hyatti*, except that the basal surface of the epinotum has a transverse impression behind.

Female. Length, 7.5–8 mm.

Resembling the female of *C. fallax* var. *discolor*. Head longer than broad, with nearly straight posterior border and prominent posterior angles; cheeks converging in front, distinctly concave. Mandibles 5-toothed. Whole body more shining than in *discolor*, though it is throughout distinctly shagreened. Mandibles, cheeks and front coarsely punctate. Body and appendages yellowish red, teeth of mandibles, anterior border of cheeks and clypeus, scutellum, metanotum, a narrow band across the posterior portions of the first and second gastric segments and the remainder of the gaster, black. Posterior edges of all the gastric segments yellow. There is a more or less distinct brown cloud on the anteromedian and in one specimen also on the lateral surface of the mesonotum. Wings yellowish gray, with brownish yellow veins.

Described from two mediæ and two female specimens taken by Prof. C. F. Baker on Catalina Island, California.

V. *Senex Group*

50. Camponotus mina zuni subsp. nov.

Worker major. Length, 6.5–7 mm.

Head rather small, subrectangular, a little longer than broad and a little broader behind than in front, with slightly excised posterior and feebly convex lateral borders. Eyes rather large, slightly convex. Mandibles 5-toothed, with convex external borders and upper surfaces. Clypeus distinctly carinate, very slightly produced anteriorly as a broadly rounded lobe, with a faint median sinus. Frontal area distinct, triangular, as long as broad. Frontal carinæ strongly lyrate, approximated anteriorly, twice as far apart behind as in front. Frontal groove distinct. Antennæ short; scapes slender and terete at the base, somewhat enlarged towards their tips, which do not extend beyond the posterior corners of the head. Thorax narrower than the head, broader in front than behind, scarcely compressed laterally, in profile feebly arcuate above, the pro- and mesonotum and base of the epinotum subequal, flattened, separated by pronounced sutures; the base of the epinotum somewhat longer than the sloping, straight declivity with which it forms an obtuse angle. Petiole rather high, in profile convex in front, flattened behind, with rather blunt border; seen from behind, narrow below, expanded above, with broadly rounded upper border, feebly notched in the middle. Gaster of the usual shape. Legs rather short, with stout femora; tibiæ without rows of bristles on their flexor surfaces.

Mandibles lustrous or somewhat shining, very finely striated, with scattered, coarse punctures towards their inner borders. Head, thorax and antennæ opaque or subopaque, finely and densely punctate. Cheeks and clypeus also with scattered, somewhat elongated, piligerous foveolæ. Petiole, gaster and legs more shining, rather coarsely and transversely shagreened, with scattered piligerous punctures.

Hairs on the body rather abundant, delicate, short, erect and sordid white; absent on the sides and posterior corners of the head, short and obtuse on the clypeus and cheeks; absent on the scapes, except at their tips. Legs with very short, sparse, oblique hairs; femora with a row of long, erect hairs on their flexor surfaces. Pubescence extremely short and sparse, visible only on the antennal scapes, posterior portion of the head and basal gastric segment.

Color black; mandibles, clypeus, cheeks, antennæ, tibiæ, tarsi and tips of femora ferruginous or dark red.

Worker minor. Length, 4–5 mm.

Head resembles that of the worker major, but is smaller, with straighter sides, more converging anteriorly. Eyes more convex. Antennal scapes reaching about one-third their length beyond the posterior corners of the head. Like the worker major in sculpture, pilosity and color, except that the red coloration of the head is confined to its anterior border. There are no foveolæ on the cheeks and clypeus. The hairs on the body are also shorter and less abundant.

Described from numerous specimens taken by myself on the bark of old mesquite (*Prosopis velutina*) trees at Tucson, Arizona.

This subspecies differs from the typical *mina* first described by Forel from Cape St. Lucas at the tip of Lower California and subsequently redescribed from the same locality as *C. erythropus* by Pergande, in the following characters: The clypeus of the worker major is distinctly carinate, the piligerous foveolæ on the cheeks and clypeus are much smaller, shallower and less abundant, the punctures on the gaster are smaller and sparser, there are no erect hairs and long pubescence on the antennal scapes, except at their extreme tips, none on the sides and posterior corners of the head, and the hairs on the thorax, petiole, gaster and legs are much shorter, more delicate and much less abundant. These differences are shown by comparison of *zuni* with two major worker cotypes of

Pergande's *C. erythropus*, which, as Emery has stated, is merely a synonym of Forel's *mina*.

51. **C. planatus** Roger

C. planatus Roger, Berl. Ent. Zeitschr., VII, p. 148, No. 24, ☿ ♀ ♂, 1863; Dalla Torre, Catalog. Hymen., VII, p. 248, 1893; Forel, Biol. Centr. Amer. Hymen., III, p. 141, 1899-1900.

C. senex stirps *planatus* Forel, Bull. Soc. Vaud. Sci. Nat., (2) XVI, P. 81, p. 97, ☿, 1879; *Ibid.*, (2) XX, P. 91, p. 346, 1884.

C. senex subsp. *planatus* Emery, Mem. R. Accad. Sci. Ist. Bologna, p. 775, 1896.

Worker major. Length, 5–6 mm.

Head small, as broad as long, a little broader behind than in front, with straight posterior and convex lateral borders and rounded anterior corners. Eyes rather large, moderately convex. Mandibles 6-toothed, with convex outer borders and upper surfaces. Clypeus sharply carinate, broadly rounded in front, with the anterior border feebly sinuate in the middle. Frontal area distinct, subtriangular, much broader than long. Frontal carinæ not very strongly lyrate, twice as far apart behind as in front. Frontal groove distinct. Antennæ moderately long; scapes terete at the base, slightly enlarged distally, extending to the posterior corners of the head. Thorax short, a little narrower in front than the head, somewhat broader in front than behind, the dorsal surface evenly arcuate in profile, flattened when seen from above and marginate on each side, where it passes over into the somewhat concave, perpendicular pleural surface. Epinotum with subequal base and declivity, the former slightly convex and square, the latter distinctly concave, the two surfaces meeting with a rather sharp transverse margin. Petiole moderately high, compressed anteroposteriorly, with convex anterior, flattened posterior surface and rather sharp margin; seen from behind, narrow below, expanded above, with broadly rounded border, entire or feebly notched in the middle. Gaster of the usual shape. Legs rather short; tibiæ without bristles on their flexor surfaces.

Opaque throughout, except the mandibles, which are shining, finely striated and coarsely punctate on their lateral and apical surfaces. Head, thorax and gaster densely punctate; legs coarsely shagreened. Cheeks and clypeus with large but rather shallow, somewhat elongated, scattered foveolæ; gaster with coarse, sparse, piligerous punctures.

Hairs very abundant, erect, glistening white; covering the head, thorax, petiole and gaster, especially dense and conspicuous on the epinotum and gaster. Hairs on the legs somewhat shorter and more oblique; on the antennal scapes still shorter and more appressed. Pubescence on the gaster long and dense; much shorter and more dilute on the head and thorax.

Head, thorax, petiole and legs rather dark ferruginous red; mandibles, cheeks, clypeus and often also the antennæ suffused with yellow. Mandibular teeth and gaster black; femora, tibiæ and tarsi often infuscated, except at the articulations.

Worker minor. Length, 3.5–4 mm.

Closely resembling the worker major, but the head smaller and with less convex cheeks and the petiole thicker and blunter.

Female. Length, 6.5–8.5 mm.

Resembling the worker major, especially in the shape of the head. Thorax robust and flattened dorsally. Petiole broader and more compressed than in the worker major. its apical margin sharper and with a rather deep and broad median notch. Hairs much shorter and less glistening than in the worker, though abundant and erect. Wings rather short (7 mm.) ; almost colorless, with pale yellow veins and dark brown stigma.

Male. Length, 4.5–5 mm.

Head slightly longer than broad, with large eyes and ocelli, its posterior border broadly rounded; cheeks subparallel, straight, somewhat shorter than the eyes. Clypeus convex, bluntly carinate, with somewhat projecting, rounded and entire anterior margin. Mandibles edentate. Antennæ very slender, first funicular joint swollen, longer than the second. Thorax robust, with convex, rounded epinotum, without distinct basal and declivous surfaces. Petiole low, thick and transverse, with rather sharp, entire dorsal border. Gaster and legs of the usual conformation.

Whole body subopaque, finely shagreened or punctate.

Pilosity much as in the worker minor, but less abundant. Scapes naked. Cheeks with a few blunt, erect hairs. Hairs on legs short, subappressed, longest and most conspicuous on the gaster. Pubescence apparently absent.

Black; mandibles, mouthparts, tarsi, genitalia and articulations of legs and thorax brownish. Wings like those of the female, but with even paler veins.

Described from numerous specimens of all four phases taken in the following localities:

Florida: Miami, Card's Point and Planter, Key Largo (Wheeler).

Texas: Esperanza Ranch, Brownsville (C. Schaeffer).

This tropical species is widely distributed through Central America, Mexico and Cuba, but enters the United States only at the two points mentioned above, namely, at the southern extremity of Florida and at the mouth of the Rio Grande del Norte. Like the other species of the *senex* group, it forms rather small colonies and is exquisitely arboreal in its habits. On Key Largo and at Card's Point, I found it nesting in epiphytic Tillandsias in mangrove thickets; at Miami I saw a fine colony nesting under a piece of loose bark on the trunk of a living tree.

VI. *Novogranadensis Group*

52. **Camponotus bruesi** sp. nov.

Worker major. Length, about 6 mm.

Head rather small, subrectangular, a little broader behind than in front, with feebly excised posterior border and slightly convex sides; anterior corners lobular and rounded, slightly reflected. In profile the head is obliquely truncated anteriorly, but the truncated surface has rounded lateral borders. Eyes rather large, slightly convex. Clypeus flattened, about one-third again as long as broad, about one-half as broad behind as in front; its anterior border broadly rounded and entire, its lateral and posterior borders also rounded, the former diverging anteriorly. A raised, longitudinal line, most distinct on the posterior portion of the clypeus, represents the carina. Frontal area present only as a minute triangular impression. Frontal carinæ lyrate; frontal groove distinct. Antennal scapes slender and not flattened at the base, enlarged towards their tips, which surpass by about one-sixth their length the posterior corners of the head. Thorax rather long, narrower than the head, broadest in front and gradually narrowed behind, but with the pleuræ scarcely compressed; in profile rather low, arched, with pronotum somewhat flattened, the mesonotum convex and the epinotum depressed and sloping, without distinct basal and declivous surfaces. Petiole high and cuneate in profile, with blunt border; seen from behind, the scale is narrow at the base, gradually expanding above, with broadly rounded, entire border. Gaster of the usual shape. Legs rather long and slender.

Mandibles and head opaque, the former very finely and indistinctly striated, sparsely punctate; teeth smooth and shining. Clypeus and cheeks irregularly rugose and coarsely punctate, remainder of head densely and uniformly punctate. Thorax somewhat shining, densely, but somewhat more superficially punctate than the head; gaster and legs still more shining, transversely shagreened; the upper surface of the gaster also with scattered, piligerous punctures.

Hairs delicate, white, erect; abundant on the thorax, petiole and gaster. Head with a few long hairs on the vertex, sides with short, erect hairs; those on the truncated surface still shorter and appressed. Scapes and legs with short, stiff, oblique hairs, less abundant on the femora, which have a row of longer, erect hairs on their flexor surfaces. Tibiæ without bristles on their flexor surfaces. Pubescence lacking.

Black; mandibles, cheeks, posterior end of clypeus, anterior portion of front, antennæ and tarsi, except the first joint, deep red. Posterior edges of gastric segments brownish.

Worker minor. Length, 4–5 mm.

Differing from the worker major only in the head, which is smaller, not broader than the prothorax, somewhat longer than broad, narrower in front than behind, with straight sides and posterior border. It is not obliquely truncated in front, but has a rather convex, sharply carinate clypeus, with broadly rounded, entire anterior border. Eyes more convex, antennal scapes reaching about half their length beyond the posterior corners of the head. The whole head is uniformly and densely punctate and a little more shining than in the worker major. Cheeks and clypeus with a few scattered foveolæ. Hairs on the dorsal surface of the head more abundant, those on the cheeks more delicate than in the worker major. Mandibles, antennæ and tarsi, except the first joint, deep red; remainder of the body black.

Described from a single worker major and a number of minor workers taken by myself on the trunk of a small desert *Acacia* at Fort Davis, Texas. There are also in my collection three minor workers taken by Mr. C. H. T. Townsend at Cerro Chilicote, Chihuahua, Mexico, and three minor workers collected by Mr. J. F. McClendon at Guadalajara, Mexico.

This species seems to be very closely related to *C. frontalis* Pergande from Tepic, Mexico, but it is decidedly smaller, the clypeus is much broader and more rounded in front, the scapes have no erect hairs and the gaster lacks bluish reflections. Pergande gives no description of the thoracic structure. Another allied Mexican species is *C. andrei* Forel, but this has a more nearly rectangular clypeus, the head is not obliquely truncated in front and is neither rugose nor red in this region. *C. bruesi* shows an unmistakable approach to the species of the subgenus *Colobopsis* through forms like *C. abscisus* Forel of Guatemala and *C. ulcerosus* described below.

VII. *Ulcerosus Group*

53. **Camponotus ulcerosus** sp. nov.

Worker major. Length, 6.5 mm.

Head rather large, subrectangular, a little longer than broad, as broad in front as behind, with nearly straight posterior and very feebly concave, subparallel lateral borders; posterior corners rather angular, anterior corners produced forward as rounded lobes beyond the anterior border of the clypeus and the closed mandibles. In profile the head is high and convex behind, obliquely truncated in front, with flattened gula. The truncated surface is bordered on each side by a coarsely crenate ridge, which runs from the outer edge of the lobe-like anterior corner to a little in front of the eye, where it turns inward and subsides before reaching the frontal carina. This ridge forms the outer boundary of an elongated, irregular and rather deep impression resembling the scar of an ulcer. Eyes rather small, feebly convex. Mandibles apparently 4-toothed, flattened; their outer borders sinuate towards the base. Clypeus flat, ecarinate, trapezoidal, one and one-half times as long as broad, with straight, somewhat crenate anterior border, about twice as long as the posterior border, which is also straight; the sides slightly curved outward and diverging anteriorly. Frontal area distinct, triangular, as long as broad. Frontal carinæ far apart, more approximated and lyrate in front, parallel behind, forming the inner boundaries of rather deep scrobes for the bases of the antennal scapes. Frontal groove distinct. Antennal scapes much curved at the base, slender, but distinctly flattened, enlarged towards their tips, which reach nearly to the posterior corners of the head. Thorax decidedly narrower than the head, rather long, gradually narrowed posteriorly, but with distinctly convex pleuræ; in profile, the dorsum is rather flat, feebly arcuate; epinotum with subequal base and declivity, both slightly concave and meeting at a rounded angle. Petiole high, cuneate in profile, with thick base and narrower summit, and both anterior and posterior surfaces flattened; border obtuse; from behind, the scale is narrow at the base, expanding above, with broadly rounded, entire upper margin. Gaster of the usual shape. Legs slender.

Head opaque; occiput and posterior angles shining; the truncated anterior portion, including the mandibles, clypeus, the portions of the cheeks within the ridges and the anterior portion of the front, uneven and irregularly rugose; remainder of the head covered with dense, uniform punctures and more scattered and rather deep foveolæ, which are slightly elongated on the cheeks outside the ridges. Thorax, petiole, gaster and legs densely punctate, more shining than the anterior portion of the head, less so than its posterior corners. In addition to the dense punctures, the surfaces of these parts are covered with coarse, scattered piligerous punctures.

Hairs glistening white, erect, abundant; longest on the gaster, petiole and thorax, shorter on the head; blunt on the cheeks and sides of the head. Antennæ with short, delicate, erect hairs on the anterior surfaces and tips of the scapes. Hairs on legs sparse, rather long and oblique or suberect. Tibiæ without bristles on their flexor surfaces. Pubescence apparently lacking.

Black; mandibles, clypeus, front and cheeks to a little outside the ridges which bound the truncated surface, yellowish brown; posterior edges of gastric segments, antennæ and tarsi, except the first joint, dark brown, antennal scapes somewhat paler and more reddish towards their bases.

Described from a single specimen taken by Mr. C. Schaeffer at Palmerlee, Huachuca Mts., Arizona.

This remarkable species differs from all our other North American *Camponoti* in the peculiar structure of the head, which shows a decided resemblance to certain species of *Colobopsis* and furnishes additional proof, if it were needed, that this group cannot be defined with sufficient precision to constitute a genus. Except in the structure of the head, *C. ulcerosus* is very closely related to *C. bruesi* and *C. frontalis* Pergande. Indeed, the worker minor of *ulcerosus* must be almost indistinguishable from that of *bruesi*, although it probably differs in having a higher and more angular epinotum.[7]

B. SUBGENUS COLOBOPSIS *MAYR*

As I have given a full description of our North American species of this peculiar subgenus and of their habits in a paper published several years ago,[8] I may here confine myself merely to enumerating the different forms with their synonymy and habitats and to describing a new variety which has come to light more recently.

54. **Camponotus (Colobopsis) abditus** Forel var. **etiolatus** Wheeler

WHEELER, Bull. Amer. Mus. Nat. Hist., XX, p. 150, ☿ ♀ ♂, 1904.

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[7] I recently found two colonies of *C. ulcerosus* in the type locality (Miller and Carr Canyons, Huachuca Mts.). These colonies were nesting in the ground under large stones at altitudes of 5500 and 6000 ft., respectively. The minor worker, which will be described on another occasion, is, as I surmised, very much like that of *C. bruesi.*

[8] "The American Ants of the Subgenus *Colobopsis*," Bull. Amer. Mus. Nat. Hist., XX, pp. 139-158, 7 figs., 1904.

Texas: Austin, in galls of *Holcaspis cinerosa* on *Quercus virginiana* (Wheeler); Victoria and Jackson County, in twigs of *Hicoria pecan* (J. D. Mitchell).

55. C. (C.) impressus Roger

Colobopsis impressa ROGER, Berl. Ent. Zeitg., p. 160, ☿, 1863; MAYR, Verhandl. Zool. bot. Ges. Wien, p. 423, 424, ☿, 1886.

Camponotus impressus DALLA TORRE, Catalog. Hymen., VII, p. 235, 1893.

Camponotus (Colobopsis) impressus EMERY, Ann. Mus. Civ. Genova, XXVII, p. 517, 1889; Zool. Jahrb. Abth. f. Syst., VII, p. 681, ☿, 1893; WHEELER, Bull. Amer. Mus. Nat. Hist., XX, p. 144, ☿ ♀, 1904.

Georgia: (Mayr).

Florida: Lake Worth (Jerome Schmitt); Belleair (Mrs. A. T. Slosson).

Texas: Dallas (Schwarz and Pratt).

Indian Territory: Okmulgee (J. D. Mitchell).

56. C. (C.) pylartes Wheeler

WHEELER, Bull. Amer. Mus. Nat. Hist., XX, p. 147, ☿ ♀, 1904.

Texas: Delvalle, in twigs of *Hicoria myristicæfolia* (*Wheeler*); Victoria (W. D. Hunter); Longview and Liberty (S. S. Tucker).

Louisiana: Shreveport, in spine of *Gleditsia aquatica* (W. D. Hunter).

57. C. (C.) pylartes Wheeler var. hunteri var. nov.

Both the major and minor workers of this form differ from the corresponding phases of the typical *pylartes* in color, the head, thorax, petiole, antennæ, legs and two basal gastric segments being yellow, the head of a little deeper and more reddish, the base of the gaster of a paler tint than the thorax. Tips of the antennal funiculi black. First and second gastric segments with a narrow, transverse, fuscous band near the posterior edge; remaining gastric segments black. In some specimens, the base of the third segment is also pale yellow.

Described from numerous specimens taken by Mr. J. S. Mitchell in twigs of pecan (*Hicoria pecan*) at Victoria, Texas, and sent me by Dr. W. D. Hunter.

POSTSCRIPT

While this paper has been going through the press, I have had an opportunity to collect additional material of *Camponotus* in southern Arizona and California and have succeeded in finding several new forms belonging to the *maculatus* group. Descriptions of these, with the exception of the following interesting subspecies, must be reserved for another occasion.

58. **Camponotus maculatus dumetorum** supsp. nov.

Worker major. Length, 10–13 mm.; head, 3.3 x 3 mm.; scape, 2.5 mm.; hind tibia, 3 mm.

Combining characters of *maccooki* and the typical *vicinus*. Antennal scape not only flattened at the base but dilated to form a lobule which is even larger than that of *maccooki* and often obtusely angular. Body coarsely shagreened; head and thorax subopaque, gaster slightly shining. Clypeus with several large, elongate, piligerous foveolæ; cheeks with more numerous and smaller, elongate foveolæ; remainder of head feebly punctate; frontal region with a few deep, piligerous punctures. Hairs and pubescence as in the typical *vicinus*, yellow, the former absent on the cheeks, erect and abundant on the dorsal and gular surfaces of the head, thoracic dorsum, petiolar border, gaster and flexor surfaces of the femora Pubescence long but sparse, conspicuous on the head, pleuræ, legs and gaster. Head, mandibles, scapes and gaster black; funiculi, legs, thorax, petiole and extreme base of first gastric segment dull brown.

Worker minor. Length, 6–9 mm.

Resembling the worker major, but with the usual differences in the shape of the head, which is often more or less brown like the thorax, especially in front. The lobule at the base of the antennal scape is very large and conspicuous and more angular, so that the scape at this point may be broader than at the tip.

Male. Length, 10–11 mm.

Resembling the male of *vicinus*, but the head is proportionally shorter and broader, the cheeks are more convex and the scapes are flattened and lobulate at the base. The whole head, especially its sides and gular surface, is conspicuously hairy. Pleuræ, gaster and legs also with numerous, but less conspicuous, erect, tawny yellow hairs. Head and thorax opaque, gaster and legs more shining, but the whole surface densely shagreened. Body black; funiculi and tarsi brown; wings suffused with yellow, with yellow veins and stigma.

Described from numerous specimens taken from many colonies in the dry foot-hills of the San Gabriel Range near Pasadena and Claremont, California, up to an altitude of 2,000 feet.

This ant appears to be the dominant insect of the chaparral. It nests in the ground among the bushes, forming flat craters varying from a few inches to a foot in diameter, with a round or, more frequently, elongate entrance. It does not go abroad in the day time, at least during the dry season. The number of its nests in the chaparral is surprising, but it is difficult to study these, except in places where the brush has been burned over or where it has been cleared away to leave fire guards. The workers probably derive their sustenance from the aphids and coccids on the scrub-oaks (*Quercus dumosa*) and other bushes that compose the chaparral.

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MEASUREMENTS OF DAKOTA INDIAN CHILDREN[1]

BY CLARK WISSLER

The measurements here discussed were made by Dr. J. R. Walker, for thirteen years physician in charge at the Pine Ridge Agency, in connection with the regular inspection of children required in the administration of the Indian schools. These include stature, weight and chest measurements of all ages to maturity, for both full and mixed blood individuals. The writer compiled these measurements and presents in the following pages a discussion of the results as compared with those secured for white children under similar conditions. While the number of cases for each age and sex is much less than desirable, it is probable that from no other definite Indian group could so great a number be obtained in the same period of time, this being one of the largest reservations. The number of full bloods is estimated as 5242 and mixed bloods as 1877. Of these, Dr. Walker has 1770 and 1193 measurements respectively. The Indians on Pine Ridge Reservation are chiefly of the Ogallala subdivision of the Teton, with an almost negligible mixture of Cheyenne. The mixed bloods are due to white men marrying Indian women and include in our classification the offspring of all such unions even to the third degree.

So far as we know, no such extended series of measurements have been reported for the children of a single tribe. Mention may be made, however, of some fragmentary series for Indians of the Southwest and Mexico by Dr. Aleš Hrdlička.[2]

As the values of these measurements will depend almost entirely upon the accuracy of the ages given for children, it seems best to take up that point at once. While Dr. Walker and the writer are sure that there is here sufficient accuracy for our purpose, the mere assertion of it will not suffice. For several years, the agency at Pine Ridge has kept a birth record and enforced registration of all births. The registration in day schools, which all children of proper age are required to attend, also serves

[1] Investigation prosecuted with the aid of a grant from the Esther Herrman Research Fund of the New York Academy of Sciences.

[2] Bureau of American Ethnology, Bull. 34.

to perpetuate this record. On the other hand, the Indians themselves maintain a winter-count, or calendar, by which they keep track of their ages and other more important events. With this calendar, Dr. Walker familiarized himself so that parents could be carefully questioned. All this gives the age of the child as to year; but in the determination of the birth month and hence the nearest birthday, there is necessarily greater error than in the case of similar measurements for white children. The mixed blood ages, on the other hand, are almost as accurate as those for whites. Now we may waive all this and pass to the data themselves. It seems scarcely necessary at this late day to state that, as errors of age are likely to be due to guesses and memory lapses and hence accidental, they will have little effect upon the average measurements, but will increase the calculated variability to an appreciable extent. Thus, a comparison of variabilities for Indian and white children may serve as a check on accuracy in age. For the white standard, we may take values calculated for a publication by Professor Franz Boas and the writer, from which Table 4 has been compiled.[3] A comparison with Table 1 shows at a glance that the variabilities for stature and weight are, with few exceptions, less for Indian children; for the mixed blood the same tendency is clear, but of less magnitude. As these differences cannot be accounted for by absolute differences in stature and weight, we are forced to the alternative that either these Indians show an almost abnormal lack of variability in the type, or that the ages and measurements as taken are about as accurate as those made on white children. The former seems unworthy of serious consideration. Of course, it is apparent that these Indian children are less variable than white, but their ages have been given with sufficient accuracy as not to obscure that difference. Further, in giving the age of white children by year, it should not be overlooked that in the group for any year there are children who differ in age almost a full year and that no matter how accurately the ages are known this great difference will tend to conceal differences and disturb the variability. Even in cases where Indians did not give the part of the year of birth correctly, the assignment of the case to the age shown by the year-count would, it is true, give a greater error than where such assignment was made according to the nearest birthday; but the difference would be of degree rather than kind and affect chiefly the variability in the group, as some children would be somewhat too young and some too old.

[3] Report of the U. S. Commissioner of Education for 1904, p. 25. 1905.

Table 1.—*Stature of Indian and Mixed Children.*[4]

	Indian males.			Indian females.			Mixed males.			Mixed females.		
Age.	No.	Av'ge.	Var.	No.	Av'ge.	Var.	No.	Av'ge.	Var.	No.	Av'ge.	Var.
1	1	79.5	......	....	....	......	2	73.0	......	2	......	......
2	1	84.0	......	4	85.5	4.6	1	76.5	......	1	....	......
3	7	98.0	6.9	13	89.4	3.7	4	92 0	1.9	4	91.0	1.8
4	10	103.1	2.8	9	96.7	6.0	5	102.2	2.7	1	....	......
5	18	111.0	5.9	25	108.2	5.7	2	111.5	1.2	12	103.6	7.5
6	37	116.3	4.1	40	114.4	4.6	19	119 1	3.6	26	115.8	3.7
7	71	122.7	4.2	78	121.8	4.5	43	123.0	4.5	43	122.2	6.0
8	85	129.6	5.1	48	127.1	5.8	54	127.4	5.1	53	126.0	5.2
9	71	133.2	4.8	58	134.4	5.8	52	131.2	5.1	52	130.4	6.1
10	66	137.5	6.7	46	137.3	5.2	51	135.9	4.4	55	134.7	7.1
11	76	141.7	6.8	48	140.8	6.4	51	139.3	5.7	45	140.6	6.4
12	70	145.1	7.6	50	147.5	4.8	32	142.4	7.8	60	146.7	5.5
13	72	150.5	5.3	68	152.6	6.1	39	148.5	6.3	44	153.2	6.8
14	70	155.4	6.5	73	156.3	4.7	28	157.8	6.8	49	157.8	6.1
15	68	161.0	5.9	52	160.7	4.1	33	163.6	7.3	39	156.5	5.5
16	58	166.6	5.8	59	162.3	3.2	26	168.9	5.0	56	160.7	5.3
17	55	173.4	5.3	50	161.1	5.1	20	169.8	5.7	47	162.0	5.3
18	30	174.9	5.8	21	164.0	4.3	11	174.4	6.7	24	161 5	2.8
19	13	175.8	5.1	10	161.8	3 5	5	177.9	4.3	8	157.8	7.5
20	....	....	......	....	....	.....	5	172.9	6.2	3	160.0	8.0
Adults.	412	175.7	......	134	160.1	5.2	47	174.4	5.7	42	162.1	4.2

Table 2.—*Weight of Indian and Mixed Children.*

	Indian males.			Indian females.			Mixed males.			Mixed females.		
Age.	No.	Av'ge.	Var.	No.	Av'ge.	Var.	No.	Av'ge.	Var.	No.	Av'ge.	Var.
1	1	....	......	....	....	.....	2	23	......	3	21	......
2	1	....	......	4	29	3.1	1	....	......	1	....	..
3	7	34	5.5	15	32	4.7	4	31	......	4	31	2.5
4	10	43	3.1	8	34	3.2	5	42	2.7	1	....	......
5	18	47	6.3	26	41	5.1	2	50	......	12	39	4.1
6	36	50	5.0	40	47	3.8	21	53	6.2	26	47	4 5
7	70	58	6.1	78	55	6.0	42	57	6.3	42	54	7.7
8	85	64	7.3	48	57	5.1	54	60	8.1	52	58	6.6
9	71	69	6.8	55	65	5.7	50	64	8.2	53	63	7.8
10	65	75	8.7	47	72	7.5	51	74	7.8	55	69	9.0
11	74	80	7.5	45	77	8.3	50	76	9.6	44	76	9.8
12	72	86	9.5	49	86	10.6	30	84	9.0	60	90	14 2
13	68	92	11.1	67	95	13.2	39	88	9.5	41	96	12.0
14	67	102	11.5	68	106	14.3	27	103	14.1	44	105	17.5
15	66	110	13.3	48	119	15.8	32	113	14.7	37	113	14.2
16	59	121	14.1	58	125	12.7	25	128	12.9	52	125	16.3
17	48	132	14.7	46	126	14.5	19	129	14.0	46	130	17.2
18	30	139	11.7	18	136	15.5	11	147	11.4	21	131	11.7
19	12	146	15 0	6	125	9.7	5	147	10.2	8	132	18.3
20	....	....	......	3	144	......	5	144	18.0	2	102	......
Adults.	....	....	......	127.	160	29.1	41	172	21.0	42	150	32.1

[4] Measurements are in centimeters.

TABLE 3.—*Chest Measure in Exhalation, for Indian and Mixed Children.*[5]

Age in yrs.	Indian males.			Mixed males.			Indian females.			Mixed females.		
	Cases.	Av'ge.	Var.	Cases.	Av'ge.	Var.	Cases.	Av'ge.	Var.	Cases.	Av'ge.	Var.
3	7	50.2	1.9	3	51.3	.4	13	51.5	3.1	....	....	......
4	9	55.0	2.9	5	54.4	2.5	9	51.1	3 4	....	....	......
5	16	56.5	3.4	2	56.6	3.1	21	52.7	2.6	10	54.5	2.9
6	25	58.0	2.6	17	58.8	3.0	31	56.7	3 0	13	56.6	3.4
7	46	60.3	2.6	23	59.8	2 7	56	59.7	4.1	26	59.1	4 9
8	43	62.2	2.5	35	59.8	3.4	33	60.4	2.5	38	60.1	2.9
9	33	64.4	2.5	36	62.6	3.0	40	63.4	4 2	40	60.8	4.2
10	41	65.1	3.1	38	64.9	3 5	39	64.1	3.7	42	63.2	4.9
11	38	66.6	3.1	39	65.3	3.6	30	66.8	4.5	33	64.8	5.1
12	29	68.7	3.5	30	66.6	3.7	34	67.8	4.6	46	66.8	4.6
13	32	70.0	4.4	32	67.3	4.4	52	69.8	3.9	38	70.0	4.1
14	31	71.6	2.8	26	73.1	4.7	48	73.7	5.5	33	72.7	6.2
15	31	74.4	3.0	26	73.7	5.1	34	74.9	5.0	35	73.7	4.9
16	31	77.8	3.7	20	78.2	4.6	46	76.6	4.9	48	74.2	5.0
17	32	79.9	4.9	20	77.3	4.3	37	76.9	5.2	32	76.7	5.6
18	31	80.2	4.7	8	82.0	2.9	18	78.0	5.2	23	78.3	6.0
19	12	83.7	5.0	5	82.6	4.0	9	78.3	3.5	9	77.1	4.7
Adults.	179	91.4	5.6	45	90.9	5.3	131	90.2	9.1	43	84.0	8.5

TABLE 4.—*Measurements of White Children.*[6]

Age in yrs.	Stature.						Weight.					
	White males.			White females.			White males.			White females.		
	Cases.	Av'ge.	Var.	Cases.	Av'ge.	Var.	Cases.	Av'ge.	Var.	Cases.	Av'ge.	Var.
6	118	112.9	6.1	104	112.0	4.7	109	45.7	5.5	97	43.8	4.8
7	203	117.9	5.0	143	117.1	5.6	202	49 7	5.9	128	47.9	6.1
8	198	122.8	5 3	146	122.1	5.8	190	54.1	6 4	142	51.9	6.6
9	252	127.8	5.5	174	127.0	5.4	220	59.4	7.3	147	58.0	8.4
10	252	132.9	5.9	215	133 0	6.5	221	65.8	8.5	170	64.1	10.5
11	244	137.4	6.2	233	137.2	6.4	210	71.3	10.3	199	70.0	10.4
12	274	142.6	6.4	252	144.3	7.2	246	78.4	12.2	201	81.0	13.1
13	253	147.9	7.7	213	149.9	6.9	204	86.9	15.7	183	89.7	15.3
14	228	154.6	8.4	164	153.9	7.2	203	98.2	16.5	149	100.6	16.8
15	191	162.0	8.4	147	156.9	5.3	162	113.8	20 8	136	106 2	13.9
16	120	166.0	6.5	107	157.2	6.0	93	122.6	17.1	100	108.7	12.1
17	53	168.6	5.6	69	159.1	5.2	39	132.7	14.9	64	114.6	13.6

[5] Measurements are in centimeters.

[6] The stature is given in centimeters; the weight, in pounds.

TABLE 5.—*Stature and Weight Correlations for Indian and Mixed Children.*

Age in years.	Indian males.		Indian females.		Mixed males.	
	n.	R.	*n.*	R.	*n.*	R.
7	70	64	61	78	38	64
8	84	70	39	74	53	82
9	70	70	55	46	47	78
10	65	90	40	72	38	58
11	71	90	37	86	50	50
12	82	60	43	95	30	72
13	69	89	68	70	35	46
14	69	61	55	55	21	92
15	66	72	58	28	32	76
16	57	71	58	40	23	62
17	46	97	41	40	..	....

The averages and their calculated variabilities for stature and weight are presented in Tables 1 and 2. As a check on these, we have added chest measurements at exhalation, Table 3. By observation, it appeared that the variability was far less for this measurement than for the full expanded chest, giving us a fair value for another size character. As will be observed, the cases between the ages of six and eighteen are sufficient in number to give an average of fair certainty, but irregularities must be expected. Were there more Indians, the result would be more satisfactory, yet a glance at the tables shows that the regularity of growth from year to year is nearly equal to that for the much larger series of white children. This is conspicuous for the full blood children, of whom we have many more cases than from the mixed blood.

Perhaps the first point of interest is the relation of Indians to whites. Taking the values in Table 4 as the standard stature for whites, we find the following deviations:

Age in years.	Indian males.	Indian females.	Mixed males.	Mixed females.
6	34	24	62	30
7	38	37	51	51
8	68	50	46	39
9	54	74	34	34
10	46	43	30	17
11	43	36	19	34
12	25	32	−2	24
13	26	27	6	23
14	8	24	32	39
15	−10	38	16	−4
16	6	51	29	35
17	48	20	12	29

There can be no doubt that these children are taller than whites of corresponding age. The peculiar breaks are not sufficiently numerous to be taken into consideration, and they appear to be due in part to accidental variation and to differences in the periods of greatest annual increment, to be discussed later. Between mixed blood and full blood, there appears a tendency for the latter to exceed in stature; in the twenty-four possible cases, the mixed bloods exceed in but nine. While it is clear that the differences are small, it is positive that the mixed bloods do not exceed the stature of full bloods.

As a check on the preceding, we have the tables for weight, from which the following deviations from the white standard may be calculated:

Age in years.	Indian males.	Indian females.	Mixed males.	Mixed females.
6	4	3	7	3
7	8	7	7	6
8	10	5	6	6
9	10	7	5	5
10	9	8	8	5
11	9	7	5	6
12	8	5	6	9
13	5	5	1	6
14	4	5	5	4
15	—4	13	—1	7
16	—2	16	5	6
17	—1	9	—4	15

This is consistent with the foregoing, in that these Indian children of all ages are heavier than white children, with the possible exception of a few ages to be discussed later. Again, there are nine cases in which the mixed bloods exceed the weight of full bloods out of a possible twenty-four. Of these nine, four are common to both stature and weight.

Another point of interest is the respective variabilities as shown in these tables. Again taking the white stature as the standard, we have

Age in years.	Indian males.	Indian females.	Mixed males.	Mixed females.
6	—20	— 1	—25	—10
7	— 8	—11	— 5	+14
8	— 2	0	— 2	— 6
9	— 7	+ 4	— 4	+ 7
10	+ 8	—13	—15	+ 6
11	+ 6	0	— 5	0
12	+12	—24	+14	—17
13	—24	— 8	—14	— 1
14	—19	—25	—16	—11
15	—25	—12	—11	+ 2
16	— 6	—28	—15	— 7
17	+ 3	— 1	— 1	+ 1

The predominating negative sign makes it clear that these Indian children are less variable than the whites, and again the mixed bloods fall between the white and full blood standards. As a check upon this difference, we may use the variability values in Table 3 (exhalation). Taking the full bloods as the standard, we find the following differences for the mixed blood children:

Age in years.	Males.	Females.
3	—16	..
4	— 4	..
5	— 3	3
6	4	4
7	1	5
8	9	4
9	5	0
10	4	8
11	5	6
12	2	0
13	0	2
14	19	7
15	21	—1
16	9	1
17	— 6	4
18	—18	8
19	—10	12
Adults..	— 3	—6

The predominating positive values show clearly that even here the variability is greater for the mixed bloods, thus confirming the general tendency of this class to approach the white standard in size relations, in contrast to the full bloods.

Most studies of this kind for white children have concerned themselves with the annual increments and the periods of maximum growth. Our data readily lend themselves to comparison with the results so far attained. Growth is usually estimated by the absolute increments, or the differences between the averages for the respective ages. From our tables we obtain the following for stature:

Age.	Males.			Females.		
	White.	Mixed.	Indian.	White.	Mixed.	Indian.
5–6	..	76	53	..	122	62
6–7	50	39	64	51	64	74
7–8	49	44	69	50	38	53
8–9	50	38	36	49	44	73
9–10	51	47	43	60	43	29
10–11	45	34	42	42	59	35
11–12	52	31	34	71	61	67
12–13	53	61	54	56	65	51
13–14	67	93	49	40	46	37
14–15	74	58	56	30	7	44
15–16	40	53	56	3	42	16
16–17	26	9	68	19	13	11
17–18	..	46	15	..	5	29
18–19	..	35	9	..	..	..

A close inspection of these increments will show that the general trend of all is similar. The same peculiar difference between the growth curve for white girls and that for boys is observable among both Indian and mixed children. For girls, the adolescent period of increased growth reaches its maximum at about the same time for all alike; for boys, the Indians seem to reach it later than the mixed and whites. In case of both mixed bloods and Indians, the pre-adolescent acceleration is more in evidence than among white children. the mixed bloods again falling nearer the white standard. As the number of cases is small, we may check this result by a similar treatment of the values for weight.

Age.	Males.			Females.		
	White.	Mixed.	Indian.	White.	Mixed.	Indian.
5–6	..	3	3	..	8	6
6–7	4	4	8	4	7	8
7–8	6	3	6	4	4	2
8–9	5	4	5	6	5	8
9–10	6	10	6	6	6	7
10–11	6	2	5	6	7	5
11–12	7	8	6	11	14	9
12–13	9	4	6	9	6	9
13–14	11	15	10	11	1	11
14–15	16	10	8	6	8	13
15–16	10	15	11	3	12	6
16–17	11	1	11	6	5	1
17–18	..	18	7	..	1	10

Owing to the expected greater variation in weight, the results are less readily compared, but they seem to agree with the preceding. The general result of measurements of white children is that the periods of maximum increase in stature occur at 13-15 for boys and at 13-14 for girls. Now, our measurements show that for mixed bloods the corresponding periods are 13-15 and 11-13 respectively; for Indians, 15-17 and 13-14. Inspection shows that there is a corresponding range for weight and that it holds equally well in exhalation. As the important point has been made that the period of greatest increment is also the period of maximum variability, we may apply another check to this result. For mixed bloods, the maximum variability for stature occurs at 12-15 and 10-14; among Indians, these are 11-14 and 11-13. For weight, there is corresponding agreement. Further, a glance at the tables will make it clear that the tendency is toward the maximum variability values during these intervals. While the number of cases is small and the irregularities in some values distressing, the general consistencies of the above differences in maximum period gives them considerable probability.

In some recent studies of this character, the method of correlation was used to show that the relation between stature and weight and perhaps other size values also reached its maximum at the period of greatest growth. While the number of cases in our data is scarcely sufficient for satisfactory results, they are, nevertheless, as large as used in some other investigations. Hence, we have made some of the calculations for comparison, Table 5.

For white children the following correlation values may be taken as the standard:

Age.	Males.	Females.
6	86	68
7	78	71
8	69	79
9	72	79
10	83	82
11	88	88
12	81	74
13	74	70
14	87	74
15	81	87
16	71	65
17	56	59

For white boys, the maximum correlation occurs for 10-12; for Indian boys, 10-13; for white girls, 10-11; for Indian girls, 11-12. The mixed blood boys show a peculiar reverse relation; low correlations for 10-13 with the maximum at 8 and 14 respectively. We did not calculate the correlations for mixed females. In general, we find here about the same correlated values for Indian children as for whites, though there is, as elsewhere, a suggestion of later manifestation of maximum growth, which, however, is far from certain with so few cases. The results for the mixed blood are curious and might be set down as accidental, if this group did not show other tendencies to depart from the normal. Thus, it may turn out that erratic values are a characteristic of such a mixture. In contrast to the preceding, the correlation values of the mixed blood do not tend toward an intermediate position with respect to Indian and white standards.

In general, it appears that these Dakota children are taller and heavier than white children as measured and reported: that the mixed blood children stand between the values for the two races, and that while there is a suggestion of a later maximum growth period for the Indian, the difference is not decisive, the probability being that there is no difference in the time periods of growth. The tables, however, suggest a slightly more rapid maturity for Indian children during the 15th and 16th years of life. The variability for these Indian children is less than for white children. It is often said that the children of mixed parents are taller than either parent, but these results are in direct contradiction to that.

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GEOLOGY AND ECONOMICS

By James F. Kemp

Presidential Address, read at the Annual Meeting of the New York Academy of Sciences, December 19, 1910

During the century which has just closed, the various branches of natural science, botany, zoölogy, geology and their relatives, having earlier completed their childhood, attained to the well-rounded development of maturity. Their broad truths were given clear expression; they were widely apprehended, and they became the foundations of various inventions and applications of far-reaching influence upon human welfare. Geology, although closely bound up with agriculture, has, nevertheless, been especially concerned with mining. And justly so, because its contributions to the art of mining have been no more than a filial return, since mining as practised in the middle ages was the parent of geology. Until recent years, geology's services to the industry have been chiefly rendered in spreading sound and reasonable ideas regarding the nature and distribution of the useful minerals; in solving the perplexing structural questions affecting their occurrence, and in facilitating the discovery of new fields.

The problems of the production of the metals and non-metalliferous substances, as we know them to-day, are of quite recent growth. High explosives, efficient engines and pumps, steam shovels and the like are all not so old as many men who are still living. They have so greatly reduced costs that practically a new world has opened to the miner. Not only on the surface or near it has he been able to work, but the depths have become accessible, and where the value of the ore justified the effort, no floods of water have sufficed to keep him out.

These successes, coupled with ever-expanding markets, have until recently directed attention almost wholly toward discovery and production. But the last ten years have brought a further change. We are now less concerned about new discoveries than about the maintenance of old ones. We are not altogether intent on production, but are much given to forecasting and husbanding. From being solely an aid to the miner, the active worker, the producer, geology has become the colleague and helper of the economist, the statistician and the philosopher.

Like all other changes in fundamental points of view, this one has not come with absolute suddenness. As far back as 1879, certain geologists and engineers began to raise and discuss the question of the duration of the Pennsylvania anthracite. In 1894, the late Richard P. Rothwell, long the able editor of the *Engineering and Mining Journal*, gave these coal fields a future of 70–100 years. Thus, for over thirty years, the question of their death has been a very live one. Even earlier, the future of the coal-fields of Great Britain came up for discussion. A parliamentary commission was appointed in 1866 and reported upon the question in 1871. For forty years, anxiety has prevailed regarding the continued production of our petroleum wells, and naturally so. The very means of production of this useful source of heat and light starts a train of thought along the lines of its permanence.

Some ten years ago, the question of our reserves in iron ore began to excite interest. Mr. Andrew Carnegie gave most forcible expression to the feeling of alarm in his rectorial address in 1902, at the University of St. Andrews, Scotland. Mr. Carnegie was known from one end of the world to the other as one of our greatest ironmasters, and his words made a profound impression. In his address, he assigned us only enough first-class ore to last for sixty or seventy years and only enough of the inferior grades for thirty years thereafter. We all trembled for some years with the prospect of seeing our greatest industry in the production of metal disappearing within a century. Many thoughtful people began to wonder what would become of us with its extinction.

I have thought, therefore, that it might be not without interest if we take up this evening the more important of our metals and pass in review some of the fundamental facts of their production, the yield of their ores, the foreign sources, the future probabilities and the effect upon the civilization of our own and other lands which would result from their curtailment. In a word, we may for a time discuss geology and economics.

The iron industry in the United States took its rise in the colonies along the Atlantic seaboard and at the outset was based upon the magnetic ores and brown hematites there occurring. For one hundred and fifty years, its growth was slow. In the decade of the forties and fifties of the past century, it had spread to the Adirondacks and in the fifties began its development in the Lake Superior region. Not until after the close of the Civil War and the resumption of peaceful activities did this great industry manifest its possibilities. With improved facilities of navigation which placed Lake Superior in easy communication with the coal-producing states of Pennsylvania and Ohio, the iron-ore-producing states of Michigan, Wisconsin and later Minnesota, came rapidly into prominence. In somewhat slower growth, Alabama, during the seventies and eighties, gathered headway. At present four fifths of our ore supply comes from the three Lake Superior states and three out of the four fifths from Minnesota alone. Alabama, Tennessee and Georgia together yield one tenth, and the remaining one tenth is divided among a dozen or more other states, of which New York is the leader. Since 1880, the total has increased about sevenfold, and Pennsylvania, then the source of about one quarter the supply, now yields approximately one and one half per cent. Minnesota, now the great source of ore, only entered the lists in 1884 and only began to utilize its present great mines about ten years later.

Thus, in the brief course of thirty years, there have been very great rearrangements, not only in geographical sources of supply, but still more in actual amount of output. In normal, prosperous years, the annual production is somewhat more than fifty million tons of ore.

But there have also been other changes not less striking. In early days and in remote situations, only the richest ores could be mined. Magnetites for example in the lump from the Adirondacks afforded over 60 per cent. metallic iron. Specular hematites from the Lake Superior districts necessarily yielded 65. For some years, no one regarded them with respect if they contained less. Red hematites from Alabama afforded forty-five to fifty. The minor ores near the furnaces were often much lower—but they may be passed over for the moment in emphasizing the larger features. Magnetites in the Adirondacks are now concentrated before shipping, and in instances two and one half to three tons are condensed to one of 65 per cent. tenure. The crude ore carries 33–35 per cent. During the early years of the present decade, the general average yield of Lake Superior shipments fell off about one per cent. per year—so that now the soft ores, so called in contrast with the hard lump specular of earlier days, range somewhat above 50 per cent. Alabama ores, once 45 to 50, now are very uniform at 36 to 37. So far as the brown hematites are concerned, which in the form of lumps, crusts, pipes, etc., are distributed throughout ochres and clays, the percentage of available iron in the crude ore is lowest of all. We wash from eight to ten tons of crude in order to get one ton of concentrates of say 40–45 per cent. in iron, and under favorable circumstances may treat much lower raw materials. Soft magnetites in Pennsylvania, which on the richer outcrops gave 45 to 50 per cent., are now dug in very large amounts with a yield of 43. If we take the total production of ore in the United States and the total production of pig iron, we find the yield in the large way to be about 50 per cent.

In order to gain some idea of the comparative merits of these figures when set alongside the percentages in the ores produced in other lands, a few cases may be cited. Germany, in 1907, produced 27,700,000 tons of ore, exported nearly four millions and imported eight and one half millions. Of the local production, three quarters were obtained from Elsass, Lothringen and Luxemburg, whose percentage in iron ranges between 30 and 40 and is on the whole not very different from Alabama's present percentages of 36–37. Germany's imports, of course, range much above these figures, else the ore could not stand the freight charges from mines in such remote countries as Sweden, Spain and Algiers.

Great Britain produced, in 1907, approximately, 15,000,000 tons, of which about three quarters were the so-called impure carbonates yielding 30–35 per cent. iron. One ninth of the total was red hematite at 50–55. The general average would be somewhat less than that of Alabama. Importations of richer ores, especially from Spain, helped to raise the furnace yield.

France, in 1908, produced 10,087,000 tons, of which 88 per cent. was mined in French Lorraine of the same type as the main German supplies. The ore ranged from 33 to 40 per cent., again not far from the Clinton ores of Alabama. We are justified, therefore, in saying that the largest part of the output of the next three producing countries of the world is about the same as the lowest grade of lump ore, which can be profitably mined under present conditions in the United States. When, therefore, we come to estimate comparative reserves, we must realize that in the Lake Superior region—our greatest producer—we pay no attention to-day to ores, which are, nevertheless, much richer than those of Great Britain and continental Europe.

In the opening sentences, I spoke of the anxiety which was felt a few years ago regarding the reserves upon which the industry would of necessity rely for its future. I mentioned Mr. Carnegie's remarks in 1902 at the University of St. Andrews. But he was not the only one who discussed this question, and now in referring to one or two other forecasts, I think you will have in mind some of the fundamentals which establish a correct point of view.

In 1905, Professor Törnebohm, the eminent and greatly esteemed former director of the Geological Survey of Sweden, assigned to us a reserve of only one billion and sixty millions of tons. Obviously, at an annual production of over fifty millions, this reserve would only last twenty years. The future thus looked still darker than when seen through Mr. Carnegie's spectacles. Much opposition arose at once, however, to Professor Törnebohm's data, because from them had been omitted the red hematites of Alabama, which can be very accurately estimated and which of themselves are thought by competent observers to have at least a half billion tons for the future. Additional modifications must also be introduced when we properly appreciate the downward tendency of workable percentages. The lower the percentage of iron which we require in the product of our mines, the greater the amount of ore which at once becomes available. This is peculiarly true of iron, because of its very wide, general distribution.

In 1907, in anticipation of the International Geological Congress of 1910, which was to be held in Stockholm, the Swedish committee of arrangements began the preparation of a series of estimates of iron reserves in all the countries of the globe. Geologists familiar with local conditions were requested to prepare the figures each for his own country. It fell to the speaker to start the collection of American estimates, and much aid was afforded by several of the largest companies owning reserves. Shortly thereafter, however, the interest in the conservation of natural resources sprang up, and Dr. C. W. Hayes, of the United States Geological Survey, was empowered to use all the resources of this great organization in assembling data on iron. In this way, figures as reliable as can be expected are now available. We learn from them that we may consider three and one half billion tons of fifty per cent. ore as assured in the Lake Superior region. Of this great total of three billions, one hundred millions are in the Mesabi range of Minnesota. At thirty millions of tons per annum, the present output of Minnesota, we have a reserve for a century.

On the other hand, if we drop to 40 per cent. or slightly below, still, however, remaining a few per cent. above the Alabama grade, the drill holes show above depths no greater than those already reached in some mines, two or three hundred billions of tons of siliceous hematites, giving amounts practically inexhaustible.

In the Alabama ore beds, we feel assured of five to six hundred million tons of the grades now utilized, and there may well be twice that number. The conservative estimate would afford enough to last at the present output of that state longer than a century. In addition, there is much reason for thinking that there may be two or three times as much.

Speaking for the country as a whole, we may say that there is an assured and demonstrated supply, at the present rate of output and the present percentage of yield, for about a century. There is, furthermore, a less accurately measured but still very probable addition, when we allow for lower grade but still practicable ores, which will be sufficient to last at present rate of production for fifteen hundred years to come.

If, however, production increases, as indeed it may with a rapidly growing population, and if in this way heavier and heavier drafts are made upon even this great reserve, where shall we look for more? There may be some new discoveries within the United States, but at present it is impossible to speak definitely of them. We may ask if there are other supplies in neighboring lands. To this question we may answer, yes. Along the north shore of Cuba, toward its eastern end and near the sea, three areas of what formerly appeared to be a barren, ferruginous soil have been discovered and tested, so that we now know that there are two to three billions of tons of a very pure iron ore, which, when deprived of the large percentage of water which it contains—a cheap and simple process—will yield from 40 to 45 per cent. iron. This variety of ore already begins to enter our ports, and the deposits will undoubtedly contribute in no unimportant way to the output of our furnaces.

The report of the International Geological Congress has shown further that in Newfoundland there are quite probably more than three billions of tons of red hematite, whose present yield averages 54 per cent. From Brazil, moreover, in the state of Minas Geraes, but pretty well back from the coast and not yet opened up by rail, as estimated by Dr. O. A. Derby, there are from five to six billion tons of 50–70 per cent. ore awaiting the drill and the steam shovel. Ore from Brazil faces a long sea voyage, but the grade is rich, and the ironmasters of this and other countries are looking upon these deposits as well within the possibilities of the future. Ocean freights are kept at very reasonable rates in these later days, and once on a steamship even so low-priced a commodity as iron ore, if of good percentages and cheaply mined, can be taken relatively great distances. This is demonstrated by the shipment this year from the mines of Kiruna, 112 miles within the Polar Circle in Lapland, of 300,000 tons of ore, 113 miles to the Norwegian coast by rail, and over 4,000 miles to Philadelphia by sea, with no great prospect of a return cargo. These shipments also demonstrate that we are not without the range to which European ores may be shipped when exceptionally rich. Some portion of the vast ore body of Kiruna, with its demonstrated 500 millions of tons of 60–69 per cent. ore, will also reach American furnaces.

But even were our actual ores of present grade to become exhausted. iron as a metal would not fail. The basic rocks with their low percentages still remain. The trap-rock of the Palisades contains 7–8 per cent. of metallic iron, a value that is far above the general yield of our copper ores in the red metal.

Iron, therefore, will never fail. It will probably not change in its general relations to modern conditions for a very long time to come, so far as its ores are concerned. We may have greater anxiety about the supplies of coking coals than about the iron ore, but there are always such possibilities of improvements or changes in processes that no one can justly give way to unqualified forebodings.

Copper is the metal generally considered next in importance to iron. It is a very old one in the history of the race. The bronze age, you will recall, preceded the iron age. Prehistoric man in Europe solved the mixed metallurgy of copper and tin before he learned the smelting of iron. Prehistoric man in America found native copper on the shores of Lake Superior and passed it in trade a thousand miles from its home. As a cherished possession, it constituted his ornaments while he lived, and it was buried with him after he had died.

Among the moderns, copper is most extensively employed in brass, but as a conductor of electricity, it finds year by year increasing applications in the purest condition in which the metallurgist can supply it. If at home or in your office you look around your chair or desk, you will be surprised to find how universally employed it is.

Greatly stimulated by the development of electricity in later years, the production of copper has advanced by leaps and bounds. At present, the United States is the heaviest producer, with Spain following next, but yielding only one eighth as much. The United States furnishes over half the total. In 1850, this country yielded 728 tons; in 1900, over 303,000, and in 1908, 471,000. Meantime, in 1850, the price of copper was about 30 cents per pound. Its lowest point in recent years was nine cents in 1894. Its highest, 25 cents, was attained in 1907. We may each of us imagine the variation in the profits of a mining enterprise as between 11 cents a pound and 15 cents, let alone 20 or 25 cents. Mining costs, smelting and freight charges, show no such variation, so that with rising prices profits greatly increase. Indeed, few of the metals have such extraordinary ups and downs as does copper.

In its ores, the yield varies greatly. On Lake Superior, where the native metal is distributed through ancient lava flows in little pellets, leaves and sheets, it has been profitably mined and produced through periods of years, when it constituted but three quarters of one per cent. of the ore. The general run is, however, one per cent. and above. If we recall that in a ton of 2,000 pounds, one per cent. is 20 pounds, and three quarters of one per cent. 15 pounds, and if copper is selling at, say, 13 cents, the mining manager must break down, hoist, concentrate with attendant losses and smelt an ore worth less than two dollars for all the metallic contents which it contains. We can thus gain an idea of the close and economical work required and the ability demanded of a manager. As the price rises, the profits greatly increase, and temporarily idle mines are brought within the widening remunerative zone and are quickened into life. As the price falls, the mines dangerously near the line close down and production ceases. The lowest cost of production claimed is from the low grade and very large ore bodies of the west and is placed at or about eight to nine cents per pound laid down in New York.

In copper ores outside of the Lake Superior region, we usually find the metal in composition with sulphur. The ores as they come from the mine may be rich enough to go directly to the smelter, or they may require concentration before the grade is sufficiently high. The ores which are directly smelted reach the minimum of copper in the Boundary district of British Columbia, but associated gold and silver raise the value per ton above four dollars. Copper ores yielding copper alone were smelted at Ducktown, Tenn., during long campaigns at a little less than 2.5 per cent. In earlier years and in many mining districts, ores as high as 20 per cent. were found, rarely even higher, but they in time were exhausted, and five per cent. would be quite rich for day in and day out averages.

These statements will serve to establish a point of view and likewise afford a standard of comparison. What is the outlook for the future of copper production?

We can not predict copper with the certainty of iron. It seldom appears in bedded deposits which can be measured. In the deep mines, we can not always see ahead for more than a year or two. In some mines, we know from exceptionally complete development of twenty years' supply. But the great advance in copper mining has been the entrance of relatively low-grade ores into the productive field. The wall rocks of ten years ago have become the ores of to-day. Where we find in porphyries or schists copper sulphide disseminated in fine particles or as coatings along crevices and in sufficient richness to yield two to two and one half per cent. throughout very large bodies, it can be mined very cheaply and concentrated in enormous quantities so as to return a safe margin. If the ore lies near the surface, steam shovels make excavation extremely low in cost. The huge pits and open cuts of this type of mine in the West are now among the great sights for the traveler. Mills whose insatiable crushers take as much as eight or ten thousand tons per day are no longer unknown. The drill blocks out the ore long before mining begins, and reserves can be estimated more closely than in the vein mines.

If a mine is called upon to furnish a mill with 2,000 tons per day and we allow 300 working days in the year, 600,000 tons must be supplied per annum. For a life of twenty years, a time practically demanded of such an enterprise to justify the great expense of installation, at least 12,000,000 tons must be shown by the drill before the enterprise can safely begin. If we expect to mine three times this amount per day, we call for three times as much ore. These figures, large as they may seem, are not beyond the estimates of ore bodies as now blocked out in several places in the West, and even with these great demands, twenty years' supply and even more in instances have been demonstrated.

Let us now imagine again a 2,000-ton daily output of say 2.25 per cent. ore, of which the mill saves two thirds, or 30 pounds of copper in the ton. The output in copper per day will be 60,000 pounds, or 30 tons, and for the year 9,000 tons. Should three new companies start up with four or five times this output, 36,000 to 45,000 tons will be added to a yearly supply, which in 1909 was 552,668 tons. We see great need of a growing demand in order that these vast contributions may be absorbed. Yet I have made no unreasonable assumptions nor have I overstepped the practical certainties of the next few years.

How long will our copper hold out? Mines come and go, and for the immediate future there will certainly be no scarcity. Copper does not oxidize as readily as iron and is not lost. The world's stock steadily accumulates. But twenty years is not a long look ahead. Are there new countries which will be producers? Some of the old mines in Europe are now no longer great sources of the metal.

We do know of possibilities in Alaska that will add some contributions. We know of new or recently opened ore bodies in Peru, Bolivia and Chile that promise well. We hear of very large deposits in the southeastern corner of the Congo State, once worked by the ancients, now revived by the moderns and possessing large reserves of 15 per cent. copper ore. The Cape to Cairo railway will give them great impetus. For the immediate future, there is no lack, but if we look fifty years or a century ahead, we can speak with less confidence. In a general way, we may say that probably new discoveries will, for a time at least, more than keep pace with demands. But when we look fifty years into the future we are not so certain. It behooves the producers to use no treatment of an ore except a careful and economical one. If tailings and waste from our mills now contain one third the copper in the original ore, they should be impounded and kept from being washed away by floods, against the possible call of the future. We dare not say that they will never be within the ranges of profitable treatment even though their low percentage places the copper beyond reach to-day. The copper situation is not one to excite anxiety, yet it is also one not to encourage extravagance.

Following copper, we may take up lead and zinc, which are the next metals in amount of production. Of the three, zinc is the least in total tons and in total value. We may gain some idea of the relations from the small table given below, in which zinc is taken as unity and the figures relate to 1908.

	Amount	Value	Price per Pound
Zinc	1.0	1.0	1.0
Lead	1.6	1.45	0.9
Copper	2.46	7.0	2.8

Thus we see that the lead production is one and three fifths that of zinc, and the copper is two and one half times: that the lead is about one and one half times the value of the zinc, and the copper is seven times: and that zinc is worth more per pound than lead and only about one third as much as copper. The red metal is not only produced in greater amount, but is worth more per pound and in the aggregate than both the others taken together.

Among the nations of the world, the United States has become the chief contributor of lead and yields year by year proportions varying from 27 to 33 per cent. of the total. The next country is Spain with about two thirds as much, and Germany follows with three fifths.

In this country, the state of Missouri is the heaviest contributor and is responsible for practically 40 per cent. of the total. Idaho is next with about 32 per cent. and Utah follows with 13 to 14. The western lead all carries silver. The precious metal is an important factor in the value of the product. When we come to forecast the future, it is not possible to see more than a few years in advance or to speak in more than a general way. The miners would be glad to be assured of reserves of ore for a goodly period of years, but it is seldom possible or practicable to demonstrate their presence. Operations necessarily continue with a few years' supply blocked out in advance of the actual mining, and the hope is maintained that more will be found. Very often the expectations prove justified. We may, therefore, in a measure forecast future experience somewhat by the past. In the Missouri lead region, mines have been operated for forty or fifty years, not on so large a scale at the outset as now, but continuously. For some years at least, no change may be anticipated. In Idaho, the lead ores are now known to continue to depths of nearly 2,000 feet beneath the overlying surface and to be holding out without essential change in character. In Missouri, however, the mines never have been very deep, that is over three or four hundred feet, and the compensation comes in wide horizontal extent.

Some of the old time heavy producers have greatly declined. Nevada.

once an extremely important source of lead, is now a comparatively small contributor. Colorado, in former years our chief source, has dropped to only a third of its one-time yield, and yet the total of the country has gone quite steadily on. The fall in the price of silver was a hard blow to the western lead miners and naturally not only cut off their profits but raised the necessary percentage of metal in the ore.

If we look ahead for a century or some such long period, we may not feel assured that production can be maintained at present rates. There may, of course, be new discoveries in lands not as yet fully explored. Being distant from present centers of consumption as they necessarily would be, their entry into the markets would imply higher prices so as to meet the charges of freight.

On the other hand, lead is a metal which oxidizes or changes very slowly. In its applications in the metallic state, it tends thus to accumulate unless lost in use, as in the case of shot and bullets. It is extensively employed in the manufacture of paint, and in this form is of course never recovered. About two per cent. of the entire output is destroyed to give us white and red pigments.

It behooves us on the whole to be careful in the use of lead and to avoid, when possible, its unnecessary sacrifice.

Zinc is a metal of comparatively late introduction into commerce in the large way. Although known for centuries, it has found its chief applications in the last sixty years. There was no zinc mine in the United States until approximately the year 1850, and from the Missouri region whence we now obtain our chief supplies, the really serious contributions began about 1870. Lead, indeed, was mined and prized long before this, but the associated zinc ore was thrown one side on the dumps. In the West, the same experience continued until much later. Zinc was a nuisance in the metallurgical treatment of lead, and even the lead was sought and smelted either because of its own silver contents or because it made possible the treatment of other refractory silver ores. In the metallurgical work, the zinc was volatilized or slagged off and was lost. Indeed, one of our most serious metallurgical problems has been the successful treatment of lead-zinc ores, and many investigators have addressed themselves to its solution. Now that anxiety is beginning to manifest itself regarding zinc supplies for the future, the desire to save it is stronger than ever.

Zinc, however, is a peculiar metal, and because of the exigencies of its treatment, its ores must possess greater richness and greater purity than those of other base metals. Thus in the case of copper, a ten per cent. ore is in later days phenomenally rich, and as it can be smelted in a shaft furnace, the presence of iron or lime or other bases that make fusible slags is an advantage. But zinc ores, perhaps after preliminary roasting, must be reduced and the metal must be volatilized at a high temperature from a small charge in a retort. The presence of fusible bases destroys the retort, and the bases are therefore debarred beyond certain small percentages. Thus it happens that a forty or fifty per cent. zinc ore might be valueless if contaminated by iron or lime beyond a narrow margin. While almost any conceivable mineralogical aggregate that contained ten per cent. of copper would be a very valuable ore, a zinc-bearing aggregate with four or five times as much zinc might be unsalable.

Suppose we compare them from another standpoint. Copper ores, if at all profitable, are worth about so much per unit of copper, that is, so much for each per cent. While there is some variation, yet the contrasts as among three per cent., five per cent. and ten per cent. ores are much the same as the ratio of the per cents to each other. But if we think of a zinc-blende ore or concentrate of 60 per cent. as the standard of richness, a fifty per cent. ore is not worth five sixths as much, nor a forty per cent. ore two thirds. On the contrary, a forty per cent. ore might be entirely unsalable. As the zinc decreases, other deleterious bases take its place, and a worthless mixture soon results. Zinc is in many ways the most peculiar of the metals, and when we come to deal with its profitable treatment analogies with other metals fail.

In 1907, the United States was the chief producer of zinc among the nations, but, as a rule, Germany leads, followed by this country and Belgium in the order named. In later years, our output has varied from 26 to 30 per cent. of the total. As a rule, Germany is 2–4 per cent. in excess of us and Belgium is 4–5 per cent. less.

In America, Missouri is the chief source of zinc. Its production from the mines in 1908 was approximately one half the output of the entire United States. New Jersey follows with somewhat over one quarter the total, while all the rest are much smaller.

The Missouri ores as thus far produced have been obtained from comparatively shallow depths. They extend lengthwise and sometimes laterally to greater dimensions than vertically. While it is not beyond the possibilities that lower lying deposits may be discovered, since zinc ores are found in Arkansas in strata of lower geological position, anticipations of this reserve have not as yet been demonstrated on a large scale. Kansas, Oklahoma and Arkansas, the states neighboring to southwest Missouri, also have some zinc ores, but they are not of great importance; southwestern Wisconsin is a very old mining district and has many small mines, which were earlier worked for lead. They have been revived for zinc in later years and are now an appreciable but not great factor. They may develop somewhat more extensively and may last for a goodly series of years, but the mines are relatively small and are wet, so that exploration does not go very far in advance of mining.

In New Jersey, the future is best forecast of all. For thirty or forty years, there is no occasion of anxiety. Yet thirty or forty years pass quickly, and then we must prepare to look for other sources. To make the zinc-blende of the Rocky Mountain region available, an increase in price is practically necessary, otherwise the metal can not stand the freight charges. There is zinc ore in the west, but to what extent we can not well say. It has been avoided rather than sought in most of our mines. Yet we do note symptoms of attention to it. In Butte, Montana, efforts are being made to concentrate it. Shipments of oxidized ores have been made from New Mexico for some years past. Until recently large amounts of peculiar appearance seem to have been entirely overlooked at Leadville, Colorado. They now promise to be an important resource. A government commission has reported upon the occurrence of the metal in British Columbia in the hopes of utilizing the ores. From Mexico, too, we learn of explorations for zinc. Conditions are changing in the case of this metal, and more and more it is certain to be brought from remoter localities. But when we look a long way ahead, say for a century, we can not feel free from anxiety. This condition of mind is even more prominent in Europe than in America. The waning of the famous old mines near Aix-la-Chapelle and the apprehensions felt regarding other sources have led to a world-wide search. Zinc ores, for example, now reach Hamburg from the Pacific shore of Siberia, and as other discoveries are made, additional points remote from present smelting centers are likely to be shippers, provided that transportation is by water. Nevertheless, all these new conditions call for advances in price, and before many years zinc bids fair to take the upward course.

The precious metals, silver and gold, are the only other two which we may pass in quick review. Silver is a less attractive object of mining than it was twenty years ago, and yet with the improvement of processes of extraction and with the great development of the output of copper and lead in which it is a by-product, the fall in its price of the early nineties has been less disastrous to the amount produced than one might have supposed. Our maximum output was reached in 1892, when it was 63,500,000 ounces, valued at $55,662,500. In the same year, about 1,600,000 ounces of gold were produced, valued at somewhat over thirty-three millions of dollars. In 1908, we are credited with approximately fifty-two and a half million ounces of silver, valued at twenty-eight million dollars. Gold, meantime, with the fall of silver, has advanced to 4,574,340 ounces, valued at $94,560,000.

In the United States, we have now comparatively few distinctively silver mines. Among them Tonapah, Nev., has been chief. Mexico is the particular home of silver, but the remarkable district of Cobalt, Ontario, has given great present importance to Canada. In our own country, we must expect the white metal to share the fortunes of the copper and lead with which it is chiefly produced. As influencing its future, copper is a more serious factor than lead, both for the reason that Missouri lead contains little if any silver, and because western copper ores display greater reserves than do western lead ores. As sources of silver, there were in 1908 no very great differences among Montana (a copper-silver state), Colorado (a silver and lead-silver state) and Nevada (a silver state). Utah (both a lead-silver and a copper-silver state) afforded about five sixths Montana's output; and Idaho (a lead-silver state) about three fourths Montana's;[1] Arizona (a copper-silver state) follows after a long interval, and the others are much smaller.

As an indication of relative magnitudes, while the output of the United States was placed at 52.5 million ounces in 1908, Mexico afforded 72.6 and Canada 22 millions. Australia with 17.3 follows and then Peru with 7.2 millions. A metal with so high a value as silver will stand transportation from remote points, and although the production in one country or another may fluctuate, the world's supplies are not likely to be seriously affected for many years. Silver is largely used in the metallic state, and, being resistant to change, it tends to accumulate. Photography is the most destructive industry to it, and when once employed in this art, it is practically lost.

Gold is mined for itself alone to a far greater degree than is silver. Thus in this country in 1908, almost 93 per cent. of the gold was produced without regard to other metals, and only 7 per cent. was obtained with copper and lead; whereas about 60 per cent. of the silver was produced in association with the base metals. Gold in later years has increased in amount of production beyond all previous experience. The steady and scientific digging and washing of low-grade gravels are, in the long run, more productive than the rich skimmings of the early Califor-

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[1] In ounces they range:

Montana	10,356,200
Colorado	10,150,200
Nevada	9,508,500
Utah	8,451,300
Idaho	7,558,300
Arizona	2,900,000

nia, Australia and Klondike placers. The world's total of 444 millions of dollars in 1908 was in excess of any previous year. The Transvaal furnished the most, nearly 146 millions. The United States followed, with 96 millions; Australasia yielded 72.5; Russia, nearly 40; Mexico, 24.5; Rhodesia, 12.2, and British India, 10.4. All the rest were under 10. The countries mentioned supply about 90 per cent. of the total.

In the United States, 28 per cent. of the gold comes from gravels, and these are the least permanent of the sources of the metal. With their exhaustion, the output will decline. In the deep mines, there are signs of waning output in some districts. In our own country, new districts have come to the front from time to time to give on the whole a steady increase in output for forty years past. So far as the future is concerned, however, the ups and downs of any one or of several countries make slight difference in the world at large. Gold can be readily shipped from point to point, and the place of its production is a comparatively small matter.

Like silver and to an even greater degree, it resists chemical change, so that the world's stock constantly augments. No very important portion is permanently lost in the arts.

Gold and silver are so extensively employed in coinage that they have received more attention at the hands of economists than have any other metals. Gold in later years, with its increasing production, has led to much philosophical speculation. The establishment of it as the monetary standard and the elimination of silver from this position have occasioned some of the most heated political controversies in the history of our country. Into these, a geologist is not competent to enter. We all probably realize from old-time experience how easy it is to become befogged. But the geologist can say that for some years to come the gold production will undoubtedly be maintained. And that while the Klondike and Alaska may wane, Siberia will increase.

We may now briefly summarize the main facts affecting the six metals which have been passed in review. It will then be possible to draw some general conclusions. Of iron ore, there is no lack, nor need any one be apprehensive regarding the supply of this metal, but before very many years have passed, the yield of the ore will have decidedly declined. While the falling off will be gradual, it will undoubtedly tend in the long run toward forty per cent. This change is in itself important, because, unless otherwise neutralized, it will raise the cost of production. It makes necessary the melting of more barren materials in the furnace, so that the consumption of fuel rises with respect to the amount of iron produced. It means also the mining and freighting of an additional burden which yields no return. From whatever point of view we regard it, other things being equal, the cost of production rises. The great reserves of lower grade ore than is at present mined are in the Lake Superior district. They are siliceous ores and will require in smelting the admixture either of limestone or of other iron ores high in the bases. The Clinton ores of Alabama are of this type, and except for the hitherto unfortunate percentages of phosphorus which they might add to Lake Superior ores, they would doubtless make an advantageous mixture with the latter. But the southern ores are remote from the northern. In order to meet them at or near the supplies of fuel, a long railway haul would be necessary. While this is not impossible, it would add to the cost so greatly as to be highly improbable. There is one further consideration. The greater part of our pig iron is used in the manufacture of steel. For this purpose, in the two processes most extensively employed hitherto, we need, respectively, either a very low or a fairly high percentage of phosphorus. If our irons are in between, and like the church at Laodicea, neither hot nor cold, they have been ill-adapted to steel manufacture. Unless the growth of the open-hearth process introduces great changes, the mixture, therefore, of southern basic ores and northern siliceous ones is not altogether promising for this reason.

The greatest cause of apprehension as regards present processes of iron manufacture lies in the supply of coking coal. We have built lofty furnaces, and in their use we place upon the fuel as it progresses downward in the furnace a heavy load of overlying ore and limestone. We need a very strong coke to stand up under the burden. The coals which yield these high-grade cokes are found in a small portion of the total coal-bearing area, and the life of the supply is one of the very serious phases of the present situation. I do not know what the amount of reserves may be.

While these physical and chemical factors operate to increase costs, there is always the possibility of improved processes and of greater efficiency to keep them down. The improvement most frequently in people's minds to-day is the utilization of water powers to generate electricity, which in turn may supply heat. Now, in a blast furnace smelting iron ores, one third the fuel is employed in reducing the iron oxide and two thirds in developing the necessary heat for the reaction. Were we able with water powers to furnish electricity economically and from it derive the necessary heat, we might save two thirds of the present amount of required fuel. We might reduce costs. The remaining one third of the fuel we should always need, but it is possible that poorer grades than high quality coke might answer. The saving would lie, of course, in the difference between the cost of the fuel and the cost of the electric current, provided the latter could be furnished more cheaply than the former.

The water powers in our own country, or at least in the more thickly settled portions of it, have not failed to attract attention, nor have they gone altogether unutilized. The more conveniently situated ones are already harnessed to the dynamos. But in countries like Norway and Sweden, where there are large water powers still available, where there are rich deposits of ore and where coal fails, the applications of electricity to iron smelting are likely to be first worked out successfully. Data may be furnished in the lifetime of many of us which will cast light upon these improvements in their world-wide relations.

The only other apparent possibility of reducing costs lies in the labor charges. Wages at present are not unduly high, and unless the increasing population of the country brings to pass an inevitable struggle for existence, which will cause the greater subdivision of tasks at lower proportionate returns, or unless the general reduction of expenses for subsistence makes lower wages possible, there would seem to be slight prospect of change in this item. In any event, the reductions from this cause can not compensate the falling off in the yield of iron as foretold above.

Suppose iron goes up in cost—other conditions of our daily life remaining the same—transportation and all manufacturing based on machinery would become more expensive, and less freely carried on. Undoubtedly an appreciable pressure would be developed to turn our people back to the rural districts and to tilling the soil for a livelihood. The tendency under the stimulus of manufacturing development has been the other way. The migration of late years has been toward not from the cities. Shall we perhaps find in the long run, in the increasing cost of iron and steel a partial solution of a much vexed problem? Will the cry "back to the soil" receive support in a way not generally anticipated? The question is an interesting one for speculation.

The general inference regarding copper is that the pinch of higher cost of production will be felt sooner than in the case of iron. We have no knowledge of such enduring reserves of copper ores as we have of iron. On the other hand, copper, despite its vast importance, is not the fundamental necessity that is iron. It is used in less quantity in machinery, and its increase in cost would less vitally affect manufacturing industries based on machinery. Advancing cost would cut it out of much ornamental work of inferior esthetic merit. The most serious effect would be found in raising the expenses of service in the applications of electricity. Electrical transportation, telegraphy and telephony would be more expensive than to-day. Unless wireless methods of transmission eliminate copper, or unless some discovery in the domain of physics which we do not now foresee, furnishes a substitute for the omnipresent copper wire of to-day, we may find ourselves face to face with some curtailment in these modern aids to the easy conduct of life's affairs. If, in the course of several centuries, the falling off in supply and the growth in population should raise copper to relatively high figures, we may wonder if a return in a way to the conditions of the middle ages will not result. Will copper then become to a greater degree than now the basis of skilled handiwork? Will the by-gone craftsmanship be revived, and with a lessening total output shall we see an advance in artistic skill? In fact, if the vast development of machinery and the huge output of metallic objects at low cost—a condition so characteristic of to-day—should be checked or curtailed, would not hand-work on more valuable mediums of expression be restored? It is not altogether unreasonable to anticipate fewer objects and higher craft in their production.

The cases of lead and zinc are even more emphatic than that of copper. We have still fewer assured reserves, and the pinch of increasing cost may manifest itself at an earlier date. The two metals are not, however, quite such vital factors in modern life as is copper, and the larger effects would be less apparent. Zinc is a necessary component in the manufacture of brass, the industry which absorbs the greater part of the copper output. A curtailment of either lead or zinc would cause inconvenience but would scarcely occasion fundamental changes.

Silver will be very seriously affected by a decrease in the output of either copper or lead. Gold will feel these changes in an appreciable but far less degree. There will always be sufficient, however, of each of the precious metals for coinage, and beyond this use their applications, except perhaps in photography, concern luxuries rather than fundamental necessities. We can not attribute to them any profound possibilities in their influence upon civilization should the contributions of the mines decline. In the recent past, we have been more apprehensive regarding a too great supply of the precious metals, than regarding one too small.

With the increasing interest in the discussions of the conservation of natural resources, there has been an increasing disposition of the authorities to assume supervisory powers over mining and metallurgical operations. The old-time idea that to the crown, or, as we are accustomed to say, to the state, belongs the mineral wealth of the earth, is experiencing something of a revival. The disposition to restrict the waste of valuable metals or minerals in processes of manufacture is commendable, and after careful demonstration that it is feasible and that it is just to the operating concerns, it may be wisely done. The rejected product of concentrating mills or the "tailings," so called, when provided with appreciable percentages of metals, may well be stored where they can be utilized by future generations, if processes improve so as to make them available. That is to say, they should not be run into rivers or placed where they will be dissipated. The same remark applies to slags from metallurgical works. The moderns, for example, are now working over the lead-bearing slags left by the ancients at the great lead mines of Laurium, Greece. Even the slags of early smelters in the West and in Mexico may again pass through the furnace.

Another question relates to the discovery, location and ownership of mining property. So far as the metals are involved, and with the metals this address has been alone concerned, the valuable discoveries are so few in comparison with the disappointing attempts to develop, that only by encouragement and rather generous conditions will the prospector be enabled to follow his arduous calling. He must be offered large prizes proportionate to the many failures. He must be assured of possession by a very circumspect and conscientious administration, if confidence in the justice of the government is to be maintained. People in the parts of the country where mining for the metals is not carried on hear only of the great successes and little of the innumerable disappointments. Far the largest part of the population thus acquire very distorted views of the real conditions of mining. The interference by the government, other than in the ways which I have mentioned, and in maintaining reasonably safe conditions for the workman, is a matter to be regarded with great caution, lest irreparable injury be done to the large problem of maintaining our future supplies with such new discoveries and developments as may be feasible. The wisest course is to improve the method of establishing and recording titles to new discoveries, and then, except in the matters already mentioned, to let the natural course of business assert itself. The proper share of the state will be obtained through the normal processes of taxation.

The mines for the metals do not, however, present the most important phase of this subject. Coal is a more serious problem, and one demanding more extended treatment than would be justifiable in an address primarily devoted to other themes. One may only express the hope that where cases of dispute arise they may be determined in the courts, according to the established rules of evidence.

The resources in the metals which have been found in the United States have proved so great as to make the industries based upon them a very vital factor in our whole civilization. Great changes in the supply or the cost will inevitably react in the long run upon the opportunities for employment and support and upon the very nature of our national life. While it will be a long time before rearrangements in the case of the most important of the metals, iron, will be manifest, and while they will assert themselves gradually, we are quite certain to face new conditions in copper, lead and zinc at an earlier date. In the end, however, we can perhaps justifiably forecast a future in which agriculture will figure more and more prominently and in which the moral, intellectual and spiritual life of the nation will readjust itself accordingly. Great and concentrated wealth is likely to be less in evidence, materialistic influences less pronounced, and from the vantage ground afforded by the greater comforts and opportunities of modern life as compared with that of a century or a half century past, we may in the distant future look forward to an evolution upon somewhat different lines. Broadly viewed, the national life will probably be increasingly sympathetic with art and with ideals.

R. P. Whitfield

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BIOGRAPHICAL MEMOIR OF ROBERT PARR WHITFIELD

By L. P. Gratacap

Professor R. P. Whitfield was born at Willowvale, New Hartford Township, Oneida Co., New York, on May 27, 1828. His parents came from England, where his father had been engaged at spindle-making for himself. His father possessed very considerable mechanical ability, and from him Professor Whitfield inherited his own marked manipulative skill. His early life was not accompanied by those incentives to the study of nature with which so many naturalists begin their careers, nor did he have any advantages of encouragement either in books or in personal intercourse. In fact, the temperament of his father opposed his occasional indulgence in study and exercised a most unfortunate repressive influence upon the child's natural tastes.

By a lucky chance, such as often determines the tenor of a life, when a very small child, scarcely four years old, a nurse girl ministered in an extraordinary way to the impulses of his nature. This untutored, untrained companion, who filled a humble domestic rôle, frequently took the young Whitfield and the other children out into the fields and woods at Willowvale, a pleasant mill-site five miles southwest of Utica, and turned their attention to the life and habits of wild animals, plants and insects. This girl, as I have heard Professor Whitfield himself designate her, was a "born naturalist"; she was utterly innocent of any book learning, but possessed an intuitive faculty of observation. Every field, each stretch of wood, the fence posts and the quarry stones, the common gravel walk and the flowering wayside were full of delight and wonders to this woman. In the absence of any erudition or any terminology, she supplied both from the flow of her own invention and the stores of her own experience and study. It was a wholesome delighted interest, naïve and spontaneous, and she touched a responsive chord in Whitfield's nature. She knew the various caterpillars, had her own names for them, watched their development into butterflies and taught the children the steps of the wonderful change. The decaying logs of the wood gave up their secrets to her prying and watchful curiosity, the flowers were mentally catalogued and the course of the seasons marked by their unbroken succession from spring to autumn. How deeply this illiterate instruction impressed the young naturalist can be partly inferred from the keen recollection of her tuition in Professor Whitfield's mind seventy years afterwards. It is indeed interesting to note that among other objects of nature which his young instructor brought to the attention of the future paleontologist were the fossil inclosures of the Clinton and Hudson River slates.

When Whitfield was about seven years of age, in the fall of 1835, the family moved to England. Here again the instincts of the naturalist were nourished by the charm and flowering beauty of English lanes and fields. Employed at a place four miles distant from his home, his daily morning and evening walk brought him, at that impressionable age, at the two loveliest periods of the day, into new relations with plants, birds and insects. I have often heard him recall these quiet walks so full of pleasure, the hastening footsteps to work in the morning and the lingering and delayed return at night. Whitfield, at that tender age, was wont to hunt for fossils in a clay bank near his home, where clay for luting retorts was quarried.

The Whitfields returned to America in November of 1841. They went first to Paterson, N. J., thence to central New York to Whitestown, adjoining Utica. It may again be recalled that the efforts of the young Whitfield to make collections and to study animal life were discouraged, sometimes with an unkind violence. The collecting instincts of a naturalist defy repression, and many collections, almost surreptitiously gathered, were preserved in odd bottles and jars in white whiskey, while insects in boxes, impaled on the domestic pin, gave comfort, in stolen moments, to the eager young observer. These collections often met with violent eviction, while from their perishable nature they were more frequently abandoned from necessity. The family later moved to a farm at Osceola, Lewis Co., New York, and the young man became engaged with a Mr. Chubbock in the making of philosophical instruments at Utica. The business of spindle-making was broken up by new inventions, and it was found necessary to abandon it.

Young Whitfield was employed nine years in his new vocation, in the manufacture of philosophical instruments, and his leisure time was devoted to the acquisition of knowledge. He enjoyed, in comparison with most men who attain eminence in science, but slender educational opportunities. His reading had been, in England, limited to the miscellaneous contents of a Sunday School library at Stockport, in which also pedagogical instruction was vouchsafed. This interesting institution was an experiment of some importance. It contained 6210 scholars and over 500 teachers, was non-sectarian and formed practically for a great number of men their only access to the rudiments of education. Here were taught reading, writing, arithmetic and grammar. There were services in the morning and afternoon, and the rest of the day was given up to study. This huge aggregate of scholars was divided up into eight divisions and about sixty classes. From its library, old works on ancient history, the Holy Land and Egypt were obtained by Whitfield, and he reveled in the twice-told tales of departed empires, the sacred land of biblical tradition and the land of the Pharaohs. He often confessed to the thrill of enthusiasm these works awoke in him and his lifelong desire to visit the land of Judea.

At Utica, under broader and more genial auspices, his reading was continued, and he came in contact with scientific men, collectors and learned societies. Here was the Utica Society of Naturalists, which met once a week, and whose members in papers, conferences and through the exhibition of specimens, stimulated each other in a friendly rivalry to explore the natural resources of the adjacent counties.

Professor Whitfield was very successful in his new business. He studied geometrical drawing, read philosophical works, passed from stage to stage in the work, until after eight months he was able to take charge of the entire office and remained practically the foreman until his removal to Albany. He obtained a microscope about this time, and its revelations gave him a new interest in natural history. He became especially interested in entomology, raised broods of larvæ, studied their habits and began a collection of insects. This impulse was strengthened by the advice and encouragement of an uncle who came to America in 1845. He had been a student of insect life in England and belonged to a group of entomological societies known as "fly clubs." This unexpected sympathy renewed and deepened Whitfield's predilection for natural study.

During these years, he became acquainted with Colonel Jewett and thus came in contact with a more representative collection of fossils and shells than any he had previously met, as well as with a larger group of geological books. Then, it seems likely, were laid the beginnings of his interest in paleontology, which finally excluded all other branches of scientific activity. Whitfield worked in Colonel Jewett's cabinet, repaired and labeled his shells, worked over, mounted and arranged his fossils.

Colonel Jewett later became curator of the State Cabinet at Albany, and through this avenue of approach Whitfield met James Hall. Professor Hall was much pleased with Whitfield's perception and intuition with fossils and examined Whitfield's private cabinet. He suggested that Whitfield should work over the Hall cabinet, and for three months

Professor Whitfield was engaged in this work, which resulted in his permanent engagement in July, 1850.

The immediate occasion leading to this radical change of life was the serious illness which Professor Whitfield incurred from metallic poisoning. The constant employment of copper wire in an atmosphere more or less surcharged with floating particles of metal induced a chronic intestinal trouble, which, throughout his life, attacked him periodically with severity. In Albany, the scientific influences were deepened and strengthened, educational facilities increased, and a continuous intercourse with workers and leaders in science began. Nothing could have been more helpful. Meek, Hunt, Logan, Billings, Leslie, Safford, Agassiz, Conrad and Hayden were a few names among the crowd of visitors to Professor Hall's home, and in this multifarious circle, Whitfield's acquaintance with men, facts and literature was greatly extended. Among his new acquaintances, none so beneficently influenced his subsequent career as Professor Newcomb. This well known conchologist took an evident interest in the young student, opened up to him his cabinet of shells, explained the characters of the genera, the limits of species, and distinctly started him on the path of original investigation.

Professor Whitfield soon gave evidence of his morphological instinct. His keen appreciation of form, together with his increasing skill in drawing, made him a most valuable adjunct to the Paleontological Survey of the State and the varied work outside of the State, then engaging the attention of Professor Hall. One of the first drawings, if not the first, made by Professor Whitfield which secured publication was a diagram of *Actinocrinus longirostris* Hall, in the Geology of Iowa, Vol. I, Pt. 2, p. 590. This drawing had some significance. In this drawing, Professor Whitfield elucidated the structure of the crinoid upon a different scheme than any previously employed by Hall, and although De Konick had made use of the same plan, his interpretation was unknown to Whitfield. He showed the radial construction of a crinoid and corrected the misunderstanding of the symmetry of the plates, based on a concentric scheme. Hall adopted this device at once.

Professor Whitfield was now continuously engaged in drawing, the preparations of specimens, comparison of species and the making of critical notes. Meek had preceded Whitfield in this work, and the plates of the Iowa Paleontology and also a large number of those of the third volume of the Survey of New York were his. With him was associated F. J. Swinton. Beyond the Tenth Annual Report of the Regents of the University, the figures appearing in the subsequent reports were almost exclusively Whitfield's, while, with the exception of three plates, all the figures of the Fourth volume of the Paleontology of New York were drawn by his hand.

It is not too much to claim that in a certain indefinable delicacy and perfection of form and shading, these drawings of Professor Whitfield's were unexcelled. Fossils had not previously been treated with such fine discrimination. They almost created a new standard of comparison in fossil portraiture.

Somewhere about 1858, the graptolites of Canada had been put into Professor Hall's hands, and the preparations of the drawings and preliminary studies had been entrusted to Professor Whitfield. This difficult and trying work caused an impairment of vision. Dr. Noyes was consulted, and the hopeless prediction of a loss of eyesight was confidently made. Fortunately this did not occur. At this time, while in consultation as to the condition of his eyes in New York City, Professor Whitfield studied the crustacea to be obtained along the shores of Long and Staten Islands and prepared comparative studies which were usefully incorporated in the diagnosis of *Eurypterus*.

Professor Whitfield at this time studied the Troost crinoids which were placed at Hall's disposal by Agassiz. The results of this study were never published. When the threatened collapse of Professor Whitfield's eyes interrupted his work in Albany, attempts were made to secure provisional draughtsmen, but they seemed unsuccessful.

The Devonian Lamellibranchs came into view, and their separation and preparation for study was the last important work done by Professor Whitfield in connection with the New York Survey. Drawings were made up to *Limopteria*, when Professor Hall proposed a joint authorship. At this time, it was apprehended that Professor Marsh was about to do this work. To forestall this and to secure the results, already important, obtained by Professor Whitfield's examinations, the work was hastened, and Professor Whitfield, almost unaided, completed the outlines and contents of a report to be embodied in the Regents' reports. His time from spring to the fall of 1874 was occupied in this, and it was quite independent work. Professor Hall reviewed the manuscript, shortened and revised it. Then took place the regrettable episode which permanently separated Professor Whitfield from the work of Professor Hall and which in a measure embittered their subsequent relations.

The work on the Lamellibranchs appeared as a pamphlet entitled "Preparatory to New York Geological Survey." It was anonymous, but invited the inevitable inference that Professor Hall had written it. Its distribution ceased upon Professor Whitfield's protest. It is perhaps a difficult question to determine the exact limits of discretion in speaking of such a matter, but this statement is intended to have a significant value in protecting Professor Whitfield's claim to the original work on these fossils and the justice of an association of his name with Professor Hall's in their authorship. Later, as is well known, the Lamellibranchs of the New York Survey appeared as a separate volume. The genera were greatly increased and the species in many instances renamed, but Professor Whitfield's drawings were used and, substantially, his delimitations of many genera and species.

Professor Whitfield, for a few years before his separation from the New York Survey, had been engaged in lecturing at the Troy Polytechnical Institute, in the chair of Applied Geology. The classes were taken on field excursions every spring, and in this way examinations were made of the geology of Northern New York and Northern New Jersey.

In March, 1876, Professor Whitfield resigned his position in Albany and came to the American Museum of Natural History, where he received and installed, with the writer's assistance, the Hall Collection of Fossils and remained the Curator of the Department of Geology until about four months before his death, when he was made Curator Emeritus.

Professor Whitfield's scientific work has been entirely confined to paleontological studies. He possessed a very remarkable memory of form and names and was quick to discover analogies in organic function. His love for nature was very great, and he exhibited to the last day of his life enthusiasm in collecting.

Besides the work on the New York Survey, Professor Whitfield was engaged in work for the Ohio, Wisconsin, New Jersey and the Black Hills Surveys, while papers furnished to journals of science and the series of special studies published in the Bulletin of the American Museum of Natural History complete his life of scientific activity. Before Professor Whitfield left Albany, the plans for a revision of Brachiopoda had been outlined, and a number of preliminary studies completed. In this work, Professor Whitfield made a number of preparations of the brachiopoda, an occupation that led Davidson once to say of him that he and the Rev. Mr. Glass "had probably revealed more of these structures than any other paleontologists." It was Davidson who, in this connection, created the genus *Whitfieldia* from *Meristella tumida* Dalm., a genus which completes the developmental phases of the loop in these brachiopods.

In his convictions relative to the development of life, Professor Whitfield was an evolutionist, though he never emphasized any special views; he believed in the mutability of a species, the inheritance of acquired characters and the modifying influences of environment. His work was, for the most part, systematic. He described a great number of new species, genera and families. His insight into relationships of animal forms was rapid, and his apprehension of generic references usually accurate. The determination of genera from partial, fragmentary remains and internal casts, especially as shown in his work on the Cretaceous and Tertiary formations of New Jersey, was remarkable. Among contributions to science which merit the distinction of being classed as discoveries were his detection of the muscular impressions in "true *Lingula*" in the Trenton Limestone, his observations on the internal appendages of *Atrypa*, his reference of the fossil forms *Dictyophyton* and *Uphantænia* to sponges, his description of a fossil scorpion from the Silurian rocks of America (afterwards made by Scudder the type of the family *Eoscorpionidæ*), his notice of new forms of marine algæ in the Trenton Limestone and description of the occurrence of a *Balanus* from the Marcellus Shale. The long series of papers on systematic paleontology, in which many new genera and species, observations in morphology and correlation, are given, have firmly identified Professor Whitfield's name with American paleontology.

Unostentatious, of a reserved, almost severe demeanor, animated by an intense love of his science, his life was passed peacefully and pleasantly, amid unruffled domestic relations, in unbroken association with the objects of his conscientious and unremitting study.

Professor Whitfield was married at Utica, N. Y., in his twentieth year. His wife died in New York in 1887. Four children were born of this marriage, of whom one, a son, died in youth, and three, two sons and a daughter, survive.

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1890

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Observations on a fossil fish from the Eocene beds of Wyoming. *Ibid.*, III, pp. 117-120, pl. 4. [Describes *Protocatostomus constablei* n. sp. = *Notogoneus osculus* Cope.]

Description of a new genus of inarticulate brachiopodous shell. *Ibid.*, III. pp. 121-122, 8 figs.

Former abundance of the wild pigeon in central and eastern New York. *The Auk*, n. ser., VII, pp. 284-285.

The Fort Cassin rocks and their fauna (supplement to the memoir on the Calciferous formation in the Champlain valley by Professors Brainard and Seely). *Bull. Geol. Soc. Amer.*, I. pp. 514-515.

1891

Observations on some Cretaceous fossils from the Beyrût district of Syria in the collection of the American Museum of Natural History, with descriptions of some new species. *Bull. Amer. Mus. Nat. Hist.*, III, pp. 381-441, pll. 4A-11, 3 figs.

Notes on some fossils from Bolivia, collected by Mr. Arthur F. Wendt, and description of a remarkable new genus and species of brachiopod [*Scaphiocœlia boliviensis*]. *Trans. Amer. Inst. Mining Engineers*, XIX, pp. 104-107, 4 figs.

Contributions to invertebrate palæontology. *Annals N. Y. Acad. Sci.*, V, pp. 505-620, pll. 5-16. Reprinted in *Rep. Geol. Surv. Ohio*, VII, 1893, pp. 407-492, 494, pll. 1-11.

The common edible crab found in fossil in the Hudson River tunnel. *Science*, XVIII, p. 300.

Mastodon remains on New York Island. *Science*, XVIII, p. 342.

1892

Visitors' guide to the geological and palæontological collections in the American Museum of Natural History. 68 pages with 49 text figs. New York, 8°.

Gasteropoda and cephalopoda of the Raritan clays and greensand marls of New Jersey. Monographs U. S. Geol. Surv., XVIII. Washington, 4°. 402 pp. and 50 pll. Also issued with imprint of the Geol. Surv. of New Jersey, with same pagination and plates.

1893

Notice of new Cretaceous fossils from the lower Green Marls of New Jersey. *The Nautilus*, VII, pp. 37-39, pl. 2 (explanation of plate is on pp. 51-52).

New genus and species of burrowing fossil bivalve shell [*Corallidomus concentricus*]. *Rep. Geol. Surv. Ohio*, VII, pp. 492-493, pl. 13, and 1 text fig.

Republication of descriptions of Lower Carboniferous Crinoidea from the Hall collection now in the American Museum of Natural History, with illustrations of the original type specimens not heretofore figured. *Mem. Amer. Mus. Nat. Hist.*, I, pp. 1-37, pll. 1-3.

Republication of descriptions of fossils from the Hall collection in the American Museum of Natural History, from the report of progress for 1861 of the Geological Survey of Wisconsin, by James Hall, with illustrations from the original type specimens not heretofore figured. *Mem. Amer. Mus. Nat. Hist.*, I, pp. 39-74, pll. 4-12.

1894

Mollusca and crustacea of the Miocene formations of New Jersey. *Monographs U. S. Geol. Surv.*, XXIV. Washington, 4°. 195 pp., 24 pll.

On new forms of marine algæ from the Trenton limestone, with observations on *Buthograptus laxus* Hall. *Bull. Amer. Mus. Nat. Hist.*, VI, pp. 351-358, pl. 11.

The food of wild ducks. *The Auk*, n. ser., XI, p. 323.

1895

New forms of marine algæ from the Trenton limestone, with observations on *Buthograptus laxus* Hall. [Abstract of a paper read at the 7th meeting of the Geological Soc. of Amer.] *Science*, n. s., I, p. 67.

1896

Description of a new genus of fossil brachiopod [*Lissopleura*] from the Lower Helderberg limestones. *Bull. Amer. Mus. Nat. Hist.*, VIII, pp. 231-232, figs. 1-5.

Notice and description of new species and a new genus [*Entomocaris*] of Phyllocaridæ. *Ibid.*, VIII, pp. 299-304, pll. 12-14.

1897

Note on the hypostome of *Lichas* (*Terataspis*) *grandis* Hall. *Ibid.*, IX, pp. 45-46, 3 figs.

Descriptions of new species of Silurian fossils from near Fort Cassin and elsewhere on Lake Champlain. *Ibid.*, IX, pp. 177-184, pll. 4, 5.

Descriptions of species of rudistæ from the Cretaceous rocks of Jamaica, W. I., collected and presented by Mr. F. C. Nicholas. *Ibid.*, IX, pp. 185-196, pll. 6-22.

Observations on the genus *Barrettia* Woodward, with descriptions of two new species. *Ibid.*, IX, pp. 233-246, pll. 27-38.

1898

Observations on the genus *Barrettia*. *Proc. Amer. Assoc. Adv. Sci.*, 46th meeting (1897), p. 200. [Abstract.]

Notice of a remarkable specimen of the West India coral *Madrepora palmata*. *Bull. Amer. Mus. Nat. Hist.*, X, pp. 463-464, pl. 24.

Assisted by E. O Hovey: Catalogue of the types and figured specimens in the palæontological collection of the geological department, American Museum of Natural History. Part I. *Bull. Amer. Mus. Nat. Hist.*, XI, pp. iii-vii, 1-72.

1899

Assisted by E. O. Hovey: Catalogue of the types and figured specimens. Part II. *Bull. Amer. Mus. Nat. Hist.*, XI, pp. 73-188.

Observations on some "mud flow" markings on rocks from near Albany, N. Y., now in the American Museum of Natural History, New York. *Ibid.*, XII, pp. 183-187, 3 figs.

Notice of two very large lobsters in the collection of the American Museum of Natural History. *Ibid.*, XII, pp. 191-194, pl. 9.

List of fossils, types, and figured specimens, used in the palæontological work of R. P. Whitfield, showing where they are probably to be found at the present time. *Annals N. Y. Acad. Sci.*, XII, pp. 139-186.

1900

Assisted by E. O. Hovey: Catalogue of types and figured specimens. Part III. *Bull. Amer. Mus. Nat. Hist.*, XI, pp. 189-356.

Observations on and descriptions of Arctic fossils. *Ibid.*, XIII, pp. 19-22, pll. 1, 2.

Description of a new crinoid from Indiana. *Ibid.*, XIII, pp. 23-24, pl. 3.

Note on the principal type specimen of *Mosasaurus maximus* Cope, with illustrations. *Ibid.*, XIII, pp. 25-29, pll. 4, 5.

1901

Assisted by E. O. Hovey: Catalogue of types and figured specimens. Part IV. *Ibid.*, XI, pp. 357-488; Index [to entire volume], pp. 489-500.

Notice of a new sponge from Bermuda and of some other forms from the Bahamas. *Ibid.*, XIV, pp. 47-50, pll. 1-5.

Note on a very fine example of *Helicoceras stevensoni* preserving the outer chamber. *Ibid.*, XIV, p. 219, pll. 29, 30.

Notice of a remarkable case of combination between two different genera of living corals. *Ibid.*, XIV, pp. 221-222, pll. 31, 32.

Some observations on corals from the Bahamas, with description of a new species. *Ibid.*, XIV, pp. 223-224, pll. 33, 34.

1902

Description of a new form of *Myalina* from the Coal Measures of Texas. *Bull. Amer. Mus. Nat. Hist.*, XVI, pp. 63-66, 2 figs.

Observations on and emended description of *Heteroceras simplicostatum* Whitfield. *Ibid.*, XVI, pp. 67-72, pll. 23-27.

Description of a new Teredo-like shell from the Laramie group. *Ibid.*, XVI, pp. 73-76, pll. 28, 29, 1 text fig.

Notice of a new genus of marine algæ fossil in the Niagara shale. *Ibid.*, XVI, pp. 399-400, pl. 53.

1903

Notice of six new species of Unios from the Laramie group. *Bull. Amer. Mus. Nat. Hist.*, XIX, pp. 483-487, pll. 38-40.

Observations on a remarkable specimen of *Halysites* and description of a new species of the genus. *Ibid.*, XIX, pp. 489-490, pll. 41, 42.

1904

Notice of a new genus and species of lower Carboniferous bryozoan. *Bull. Amer. Mus. Nat. Hist.*, XX, p. 469, pl. 11.

Notice of a remarkable case of reproduction of lost parts shown on a fossil crinoid. *Ibid.*, XX, pp. 471-472, pll. 12, 13.

Note on some worm (?) burrows in rocks of the Chemung group of New York. *Ibid.*, XX, pp. 473-474, pl. 14.

1905

Notice of a new crinoid and a new mollusk from the Portage rocks of New York. *Bull. Amer. Mus. Nat. Hist.*, XXI, pp. 17-20, pll. 1-4.

Descriptions of new fossil sponges from the Hamilton group of Indiana. *Ibid.*, XXI, pp. 297-300, pll. 9-11.

Notice of a new species of *Fasciolaria* from the Eocene green marls at Shark River, N. J. *Ibid.*, XXI, pp. 301-303, 2 figs.

1906

Notes on some Jurassic fossils from Franz Josef Land, brought by a member of the Ziegler Exploring Expedition. *Bull. Amer. Mus. Nat. Hist.*, XXII, pp. 131-134, pll. 18, 19.

With E. O. Hovey: Remarks on and descriptions of Jurassic fossils of the Black Hills. *Ibid.*, XXII, pp. 389-402, pll. 42-62.

1907

Notice of an American species of the genus *Hoploparia* McCoy, from the Cretaceous of Montana. *Bull. Amer. Mus. Nat. Hist.*, XXIII, pp. 459-461, pl. 36.

Remarks on and descriptions of new fossil Unionidæ from the Laramie clays of Montana. *Ibid.*, XXIII, pp. 623-628, pll. 38-42.

1908

Notes and observations on Carboniferous fossils and semi-fossil shells, brought home by members of the Peary expedition of 1905-1906. *Bull. Amer. Mus. Nat. Hist.*, XXIV, pp. 51-58, pll. 1-4.

[Annals N. Y. Acad. Sci., Vol. XX, No. 10, Part III, pp. 399–486.
31 March, 1911]

RECORDS OF MEETINGS

OF THE

NEW YORK ACADEMY OF SCIENCES.

January, 1910, to December, 1910.

By Edmund Otis Hovey, *Recording Secretary.*

BUSINESS MEETING.

January 3, 1910.

The Academy met at 8:20 p. m. at the American Museum of Natural History, President Kemp presiding.

Professor **Dean** presented a memorial of Kakichi Mitsukuri, a deceased Honorary Member of the Academy. This has been published in Vol. XIX of the Annals.

On motion, the business meeting was adjourned at 8:34 p. m.

Edmund Otis Hovey,
Recording Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

January 3, 1910.

Section met at 8:35 p. m., Vice-President George F. Kunz presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

George W. Tower, Jr., Geological Notes on Northern Brazil.

Henry S. Washington, Brief Notes on Some of the Geological Aspects of the Province of Bahia, Brazil.

Summary of Papers.

Mr. **Tower** gave an account of an expedition into some little explored territory in connection with studies of deposits of iron, manganese and copper. Remarks were made by Professor J. F. Kemp.

Dr. **Washington** described the features observed on a recent trip to the Province of Bahia. The economic resources of a mineral character were noted, especially manganese, copper, diamond and carbonado. This district is the chief source of this last mineral. Professor Kemp, Dr. Kunz and Mr. Tower joined in the discussion.

The Section then adjourned.

CHARLES P. BERKEY,
Secretary.

SECTION OF BIOLOGY.

JANUARY 10, 1910.

Section met at 8:15 P. M., Roy W. Miner presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Roy W. Miner,	SOME REMARKS ON MYRIAPODS.
Max Morse,	THE ULTRA-MICROSCOPE AND ITS APPLICATION TO THE STUDY OF MICROSCOPICALLY INVISIBLE PARTICLES.
Barnum Brown,	NOTES ON THE RESTORATIONS OF THE CRETACEOUS BIRDS HESPERORNIS AND BAPTORNIS.
Alexander Petrunkevitch,	SOME NEW OR LITTLE KNOWN AMERICAN SPIDERS.

SUMMARY OF PAPERS.

Mr. **Miner** gave an illustrated talk on the Myriapods, dwelling on their classification, evolution and morphology. Handlirsch's theory of the derivation of the Crustacea, Myriapoda and Hexapoda from pro-annelidan stock through trilobite forms was discussed in some detail, special attention being given to the evolution of the ancestral insects (Paleodictyoptera) from the trilobites and their relation to the primitive myriapod stock. All the more typical myriapods were illustrated and their striking anatomical features commented on.

The paper was illustrated with lantern slides.

Mr. **Morse** said in abstract: The ultra-microscope was devised by Zsigmondy and Siedentopf on the principle determined by Tyndall, that if a solution is examined under the microscope by means of horizontal illumination and not by light transmitted through it by the sub-stage mirror, the particles within the solution polarize the light and thereby render them visible as scintillations against a dark background. By means of this instrument, solutions which appear perfectly homogeneous by means of the ordinary microscope are shown to be composed of particles in suspension. Bodies approaching the dimensions of molecules can be made visible. Colloidal solutions have been analyzed by means of the ultra-microscope and shown to be suspensions of particles in a homogeneous medium. Thus, colloidal gold and platinum are resolved into such pseudo-solutions. Albumens fall under this heading, and studies of their nature have shown that they are not homogeneous in solution but are rather fine suspensions. The ultra-microscope as first devised has been modified so as to be adapted to the study of living bacteria. The sub-stage condenser of a microscope is replaced by one where the lens, in place of being bi-convex, is parabolic, and a stop is placed in the centre of the disc so that no direct rays pass to the eye but only those that have been polarized by the bacteria which receive the rays that are sent through them horizontally. The bacterial flora of teeth was shown. Spirochætes and rodforms are seen, and their locomotor organs are made visible.

The paper was illustrated with demonstration of apparatus.

Mr. **Brown** presented a few brief notes from a forthcoming paper, as follows: The anatomy of *Hesperornis* as known from described material was discussed and compared with a skeleton recently mounted in the American Museum. In this specimen, for the first time, a complete tail is known. The swimming pose here chosen is accepted as the one that best represents its aquatic habits and more nearly conforms to the structure of the limbs. The peculiar arrangements of the palate bones in *Hesperornis* and the contemporary *Baptornis* were shown to constitute characters that distinguish them from all known birds. Two new specimens have made possible a paper restoration of *Baptornis* which in some characters is more primitive than *Hesperornis*. The striking features are the complete fibula, heretofore known only in *Archæopteryx,* and a very long tail, of which fourteen vertebræ are preserved. There were at least sixteen. This is complete though reduced in size. The palate bones are like those of *Hesperornis*.

The paper was illustrated with lantern slides.

The Section then adjourned.

L. Hussakof,
Secretary.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

JANUARY 17, 1910.

Section met at 8:15 P. M., Vice-President W. M. Campbell presiding.

The minutes of the last meeting of the Section were read and approved.

Edward Thatcher was duly elected Secretary of the Section.

Professor Campbell then showed a new form of microscope for the examination of metal surfaces of large size, such as a rail in place, a gun barrel or large casting.

The Section then adjourned.

EDWARD J. THATCHER,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

JANUARY 24, 1910.

Section met in conjunction with the American Ethnological Society at 8:15 P. M., Gen. James Grant Wilson presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Franz Boas, THE CHANGES IN THE PHYSICAL CHARACTERISTICS OF THE IMMIGRANTS TO THE UNITED STATES.

The paper embodied some of the results of the speaker's recent investigations under the auspices of the United States Immigration Commission. In the discussion following the lecture, Professor Giddings, Dr. Fishberg and Dr. Tenney took part.

R. S. WOODWORTH,
Secretary.

BUSINESS MEETING.

FEBRUARY 7, 1910.

The Academy met at 8:15 P. M. at the American Museum of Natural History, President Kemp presiding.

The minutes of the last meeting were read and approved.

The following candidates for active membership in the Academy, recommended by Council, were duly elected.

Clarence Roe Gardner, 401 Fifth Avenue,
Edmund B. Southwick, 206 West 83rd Street.

The Recording Secretary then announced the following deaths:

Julius Bien, an active member for 33 years,

Professor Friedrich Kohlrausch, a corresponding member for 11 years,

Edward Mitchell, an active member for 33 years.

The Academy then adjourned.

Edmund Otis Hovey,
Recording Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

February 7, 1910.

The Section met at 8:20 p. m., Vice-President George F. Kunz presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Elvira Wood, On the Phylogeny of Certain Cerithiidæ.

Henry Fairfield Osborn, The Epidermal Covering of Trachodon.

Walter Granger, Tertiary Beds of the Wind River Basin.

W. D. Matthew, Climate and Evolution. Preliminary Observations upon the Geographic Dispersal of Land Animals in its Relation to Progressive Climatic Change.

The Section then adjourned.

Charles P. Berkey,
Secretary.

SECTION OF BIOLOGY.

February 14, 1910.

Section met at 8:15 p. m., Vice-President Charles B. Davenport presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Charles B. Davenport, Variability of Land Snails (Cerion) in the Bahama Islands with its Bearing on the Theory of Geographical Form Chains.

W. K. Gregory, Application of the Quadrate-Incus Theory to the Conditions in Theridont Reptiles and the Genetic Relations of the Latter to the Mammalia.

Summary of Papers.

Dr. **Davenport** said in abstract: Professor Plate has described, in the *Archiv. f. Rassen- und Gesellschaftsbiol.*, Bd. IV, the different forms of a genus of land snails (*Cerion*) from the Bahama Islands; and declares that the *Cerions* of the north coast of New Providence constitute the best known and most known and most manifold example of such a morphologic-geographic "form chain" as the Sarasins describe. Going from the west to the east end of the island, "regular and definitely directed changes" are said to occur "conditioned by the amount of precipitation together with an inner factor—a high responsiveness of the protoplasm." In January, 1910, I collected shells in New Providence from the localities specified by Plate and from several others. I am now attempting to breed them. Meanwhile the evidence seems opposed to Plate's view, since the "western" type is found at various localities in the east alongside of the eastern type. The facts seem to accord better with the view of the immigration into the eastern end of New Providence of snails having the characteristics of *Cerions* from the Eleuthera Island (an immigration facilitated by geographic conditions) and by the formation of varied combinations of characters and pseudo-blends by hybridization.

Dr. Davenport's paper was illustrated with specimens and diagrams.

Mr. **Gregory** said in abstract: Reichert's conclusion that the incus and malleus of mammals represent the vestigial and metamorphosed jaw elements of lower vertebrates, together with the opposing view that these ossicles in the mammalia have been derived directly from the supra- and extra-stapedial cartilages of reptiles, were considered. Exception was taken to Dr. Broom's form of the latter theory, which took the auditory ossicles of the crocodile as a theoretical starting point. All the bones surrounding these elements in the crocodile had evidently undergone certain peculiar specializations and it would be surprising if the auditory ossicles themselves had not also suffered considerable modification in the endeavor to evolve an improved auditory apparatus. The resemblances in the ossicles between crocidile and mammal may therefore be due chiefly to convergent evolution. The modern upholders of the incus-quadrate, malleus-articular theory demand for the ancestral mammal a freely movable quadrate, similar to that of the lizard; but this was because they seem to push too far the biogenetic law. The incus or supposed homologue of the quadrate at present appears in the embryo as a freely movable bone, but this does not prove that it has always been freely movable. These investigators had passed by the theridonts of the Permian and Triassic because in these reptiles the quadrate was fixed at its upper end; but a slight atrophy of the posterior border of the squamosal would have greatly increased the mobility of the quadrate.

Paleontological and embryological evidence showed that the existing joint between the skull and the lower jaws in mammals is a neomorph, probably developed *pari passu* with the atrophy of the quadrate and articular bones. The application of Reichert's theory to the Theriodontia required only that the vestigial quadrate should be freed from its squamosal socket, and secondly that it and the articular should be brought into contact with the stapes or primary auditory rod. But how can we conceive an adaptive, mechanical motive for this extraordinary change? Such seems to be furnished by the embryology of the tympanic chamber of mammals. As is well known, this chamber appears below the ossicles as a diverticulum of the first gill opening. It grows upward and embraces the ossicles, which finally appear to be inside the cavity but are morphologically outside of it, since they never pierce its epithelium. So in the hypothetical pro-mammal the vestigial quadrate and articular on the one hand and the stapedial rod on the other may have been embraced by the up-growing tympanic sack or chamber and finally pressed into contact with each other. The vestigial jaw elements may thus have come to share in the vibrations of the chamber and of the stapes, and thus was initiated their career as accessory auditory ossicles. A somewhat analogous case is the transformation in siluroid fishes of certain vertebral appendages into a chain of ossicles for transmitting vibrations from the air bladder to the internal ear.

Mr. Gregory's paper was illustrated with lantern slides.

The Section then adjourned.

L. HUSSAKOF,
Secretary.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

FEBRUARY 21, 1910.

By permission of the Council, no meeting was held.

EDWARD J. THATCHER,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

FEBRUARY 28, 1910.

Section met at 8:15 P. M., in conjunction with the New York Branch of the American Psychological Association, at the American Museum of Natural History.

The following programme was presented:

H. L. Hollingworth,	Psychological Measurements of the "Pulling Power" of an Advertisement.
Frederic Lyman Wells,	Practise and Individual Differences.
Joseph Jastrow,	The Physiological Support of the Perceptive Processes.
Wendell T. Bush,	The Emancipation of Intelligence in the Study of Philosophy.

Summary of Papers.

Dr. **Hollingworth** discussed the defects of modern methods of "keying" an advertisement and advocated the substitution of psychological tests. The results of an experiment with seventy-five subway advertisements, by the order of merit method, were presented. In coöperation with the New York Advertising Men's League, the keyed results of various kinds of "copy" are being compared with psychological measurements of the same advertisements. The work in progress is directed toward four chief problems: (1) the validity of individual judgments of persuasiveness; (2) the relative strength of the various human instincts as the basis of appeal and conviction; (3) the relative strength of various "effective conceptions"; (4) the practical psychology of color in advertising.

Dr. **Wells** said: In thirty days' practise with five subjects on the number checking test (a form of the A test) and in the Kraepelinian addition test, the general indication seemed to be that the subjects who did well at the start had as much opportunity for further improvement as those who did poorly. This would indicate that in the functions tested, the relative superiority of certain subjects was a manifestation, not of their being nearer the end of the practise curve, but of an inherent ability to profit more by such practise as they had had.

Prof. **Jastrow** said in abstract: The purpose of this paper is to consider a more adequate formulation of the relation between the physiological factor and a complex sensory process in which it participates. A typical instance is found in the visual perception of distance. The conventional statement sets forth that in the presence of a situation requiring judgments of distance, we bring into play the physiological mechanism, testing by the clearness of the retinal image the necessary accommodation; and concominantly throwing into gear the convergence apparatus, and thus tentatively, though quickly, finding the proper adjustments, and, lately, that only when this process is accomplished is the product handed over to the mental elaboration which, utilizing this basis, makes of it a perception of such and such objects at such and such distances. The point of view urged in opposition to this is that while these factors are significant, they are so in almost a reverse order of values. Complex sensory perceptions are so much more psychological that the habit of mind is to jump to an interpretation on the very slightest data and then use the physiological adjustments merely to corroborate the psychological anticipation. The proof for this view is found in the unwillingness of the eyes and indeed their inability, when deprived of a psychological clue and thrown wholly upon physiological support, to obtain any satisfactory judgments at all. In judging the distance of spots of light in a dark room, the greatest diversity appears; and there appears also, just as soon as the least glimmer of light gives any clue to the real situation, the tendency to guess the result and then merely use the physiological processes to check it. Two corollaries from this principle may be said to support it. The one indicates the importance of extreme care in avoiding suggestion, and the other explains why, in complex sensory judgments, we are so prone to illusion. As a working hypothesis for complex judgments, this restatement of the physiological support is not only in itself suggestive but unites a variety of experimental data in a consistent interpretation.

Dr. **Bush** said in abstract: The study of philosophy is still hampered by the claims of problems which are the products of presuppositions which no candid observer is obliged to make but which are remnants from a long tradition. The tradition had its origin in natural conditions characteristic of primitive culture. The resulting metaphysical concepts, since they are not required in order to describe observable facts, but since they do still play a great rôle in philosophy, particularly in the philosophy of religion, are most readily explained as survivals from prehistoric culture. The problems which depend upon taking for granted the authority of these survival-concepts are, accordingly, entirely artificial, and the philosophy whose stock in trade is arguments about these problems is an artificial philosophy. The philosophy which operates with these survival-concepts is monistic idealism, and its two determining ideas are the absolute and consciousness, but systems of philosophy that operate with unverifiable survivals are not the only artificial systems. Systems which exist only to oppose the former derive all their vitality from the existence of their artificial opponent. Accordingly, the various realisms which get their problems from dialectical situations developed by idealism have a subject-matter that is equally unreal. Mythology has been, in the past, an instrument for maintaining very important social relations, but if social progress continues, the time should come when misrepresentations of nature may be appropriately replaced by the laws of facts, the only laws that any ideal whatever can intelligently appeal to. Gifted men are, however, devoting their time and wits to debating questions which would not exist save for the survival of three primitive ideas—God, the soul, the universe. The ideas of God and the universe were united in pantheism to give the idea of the absolute, and from the idea of the soul was derived the concept of mental states which yielded the idealistic conception of consciousness. Modern technical observation does not substantiate any claim to existential validity for these ideas. Their persistence, therefore, in disguised forms, as the presuppositions of problems which men feel obliged to discuss, is a burden for intelligence in the study of philosophy. That part of anthropology which is devoted to the study of origins ought to be the means of liberating many from the perplexities of artificial problems. Disguised theological reminiscence should not continue to be an obstacle to thoroughgoing empiricism.

The Section then adjourned.

R. S. Woodworth,
Secretary.

BUSINESS MEETING.

March 7, 1910.

The Academy met at 8:15 p. m. at the American Museum of Natural History, Vice-President George F. Kunz presiding in the absence of President Kemp.

The minutes of the last business meeting were read and approved.

The following candidate for active membership in the Academy, recommended by Council, was duly elected:

Rev. J. L. Zabriskie, 28 Regent Place, Brooklyn, N. Y.

The Recording Secretary then brought forward an amendment to the Constitution, making the fourth sentence of Article II read, "Corresponding and Honorary Members shall be chosen from among persons who have attained distinction in some branch of science."

On motion, the above amendment, having been proposed in due form at a preceding meeting of the Academy, was unanimously adopted.

The Academy then adjourned.

Edmund Otis Hovey,
Recording Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

March 7, 1910.

Section met at 8:25 p. m., Vice-President George F. Kunz presiding.
The minutes of the last meeting of the Section were read and approved.
The following programme was then offered:

Paul Billingsley, Structure, Origin and Stratigraphic Significance of the Shawangunk Grit.

A. C. Boyle, Jr., Problems Connected with the Occurrence of Gypsum in the Bully Hill and Rising Star Mines, California.

Edwin W. Humphreys and **Alexis A. Julien**, The Preglacial Decay of Schists at Westchester Avenue and Boulevard, Bronx, New York City.

Section then adjourned.

Charles P. Berkey,
Secretary.

SECTION OF BIOLOGY.

March 14, 1910.

Section met at 8:15 p. m., Vice-President Davenport presiding.
The minutes of the last meeting of the Section were read and approved.
The following programme was then offered:

Alexander Petrunkevitch, Relation Between Species and Individual in the Struggle for Existence.

Elvira Wood, A Case of Apparent Reversion Among Gastropods.

Ignaz Matausch, The Preparation of a Museum Anatomical Model.

Summary of Papers.

Dr. **Petrunkevitch** tried to show from examples taken from the groups of spiders and insects that the advantage of the individual is often opposed to the advantage of the species. Structures and habits dangerous to the individual but of use to the species are not uncommon. Their existence proves that the individual is "enslaved" by the species, which condition may be understood only if we consider the individual a mere carrier and protector of the germ. In the evolution of species not the characters of the fittest individual are selected and transmitted to the descendant but those of the fittest to preserve the progeny.

The paper was illustrated with specimens and lantern slides.

Miss **Wood** said in abstract: The ornament of *Potamidopsis tricarinatum* begins as two continuous spirals, passes through a stage with two rows of nodes and interpolates a third row of nodes in the adult. *Potamidopsis trochleare* has three rows of nodes in the young, later loses the median row and has in the adult two continuous spirals. This suggests reversion in the latter species, but in *P. tricarinatum,* the upper spiral disappears before the introduction of the subsutural and median rows of nodes, while in *P. trochleare,* the upper continuous spiral of the adult is developed from the subsutural nodes; hence the two spirals of the adult are not equivalent to the two spirals of the young *P. tricarinatum. P. trochleare* illustrates progressive development resulting in simplification of structures.

Miss Wood's paper was illustrated with specimens and diagrams.

Mr. **Matausch** gave an account of the successive stages in the construction of an anatomical model of a spider for museum exhibition. He exhibited a number of dissected specimens of *Lycosa,* upon which the model is based, as well as a series of wax models which are made preliminary to casting the final model.

The Section then adjourned.

L. Hussakof,
Secretary.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

March 21, 1910.

Section met at 8:15 p. m., Vice-President Campbell presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was offered:

William Campbell, Notes on the Structure of Wrought Iron.

Summary of Paper.

Professor **Campbell,** in the first part of his paper, dealt with the various methods of manufacture: (1) The charcoal, hearth processes; (2) Puddling; (3) Rolling of piled or bushelled scrap. Next, the various uses of wrought iron were discussed and the names and trade-marks of several well-known brands shown, chiefly Swedish iron. Then, by a series of fifty lantern slides, the various structures met within the microscopic examination of wrought iron were set forth and contrasted, both with each other and with those of Bessemer steel. Differences in properties and chemical analyses were mentioned.

The Section then adjourned.

EDWARD J. THATCHER,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

MARCH 28, 1910.

Section met, in conjunction with the American Ethnological Society, at 8:15 P. M., Gen. James Grant Wilson presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was offered:

Paul Radin, SOME PROBLEMS OF WINNEBAGO ETHNOLOGY.
A. A. Goldenweiser, AUSTRALIAN CLAN EXOGAMY.

SUMMARY OF PAPERS.

Dr. **Goldenweiser** contended that exogamy was not a primary but a derivative trait of Australian clans. These are exogamous simply because they are parts of the larger exogamous phratric units. The speaker further illustrated the necessity of taking note of the subjective attitude assumed by the natives towards their marriage regulations. Objectively considered, the systems of many Australian tribes might be regarded as based on endogamic considerations, and from this point of view they have actually been described by a recent observer, Klaatsch.

R. S. WOODWORTH,
Secretary.

BUSINESS MEETING.

APRIL 4, 1910.

The Academy met at 8:20 P. M. at the American Museum of Natural History, President Kemp presiding.

The minutes of the last meeting were read and approved.

The following candidates for active membership, recommended by the Council, were duly elected:

George E. Ashby, 11-13 Cliff Street,
John Hendley Barnhart, N. Y. Botanical Garden,
Edward Bennet Bronson, 10 West 49th Street,
L. Duncan Bulkley, 531 Madison Avenue,
James G. Cannon, 14 Nassau Street,
William J. Cassard, 125 Riverside Drive,
H. A. Cassebeer, Jr., 1095 Steinway Avenue, Steinway, L. I.,
William Childs, Jr., 42 East 14th Street,
Percy Chubb, 5 and 7 S. William Street,
William P. Clyde, 24 State Street,
Robert Collier, 416 West 13th Street,
Maunsell S. Crosby, Rhinebeck, N. Y.,
Carlton C. Curtis, Columbia University,
Theodore L. De Vinne, 300 West 76th Street,
William J. Ehrich, 141 West 74th Street,
Allen W. Evarts, 60 Wall Street,
William H. Farrington, 23 Murray Street,
F. J. Fohs, Lexington, Ky.,
Charles D. Fuller, 139 Greenwich Street,
Lawrence Godkin, 36 West 10th Street,
Frederic G. Goodridge, M. D., 123 East 73rd Street,
Madison Grant, 22 East 49th Street,
James W. Green, Hotel Endicott,
A. M. Guinzburg, 56 West 89th Street,
Mrs. E. H. Harriman, 1 East 69th Street,
F. C. Havemeyer, 113 Wall Street,
Berthold Hochschild, 52 Broadway,
J. E. Hyde, Columbia University,
Miss P. R. Kautz-Eulenburg, 3 West 8th Street,
Nicoll Ludlow, University Club,
Frank Lyman, 82-88 Wall Street,
A. Monae-Lesser, M. D., 16 West 68th Street,
William Fellowes Morgan, Short Hills, N. J.,
John P. Munn, 18 West 58th Street,
Abram G. Nesbitt, Kingston, Pa.,
George Notman, 99 John Street,
John J. Paul, Watertown, Florida,
Albert Plant, 28 East 76th Street,
Selig Rosenbaum, 48 West 85th Street,
A. Rothbarth, 330 West End Avenue,
John H. Sage, Portland, Conn.,

Mrs. Herbert L. Satterlee, 37 East 36th Street,
Dr. L. Schöney, 2460 Seventh Avenue,
Jefferson Seligman, 1 William Street,
William Shillaber, 60 Wall Street,
Louis Morris Starr, 206 Fifth Avenue,
Edward Steinbrugge, Jr., 29 Broadway,
J. M. Stettenheim, 127 West 86th Street,
Theodore N. Vail, 26 Cortlandt Street,
Frederick K. Vreeland, 80th Street and East End Avenue,
W. H. Waite, Greystone, Yonkers, N. Y.,
William I. Walker, 11 Mt. Morris Park West,
William C. Wood, 51 Madison Avenue,

The Recording Secretary then reported the following deaths:

Alexander Agassiz, an honorary member for 23 years,
Rev. J. L. Zabriskie, an active member for 1 month.

The death of Professor Agassiz was referred to the Council Committee with the recommendation that a suitable memorial be prepared.

The Academy then adjourned.

Edmund Otis Hovey,
Recording Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

April 4, 1910.

Section met at 8:30 p. m., Vice-President George F. Kunz presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Dr. **George F. Kunz** reported a find of labradorite from Sonora, Mexico. The mineral is especially clear, like quartz, and very similar to that reported from time to time from other western localities. Dr. Kunz suggested that Sonora may be the original source of all of them.

Several photographic prints made by zircon crystals were also exhibited.

The principal address of the evening was by

John M. Clarke, The Geological Survey of the State of New York.

Summary of Paper.

Dr. **Clarke** called attention to the fact that it was seventy-five years since the then Secretary of State, John A. Dix, proposed a plan for a state survey. Next year, the New York Survey will be able to celebrate seventy-five years of actual continuous existence. He gave a rather detailed and most interesting account of the origin and successive stages of work and progress to the present time. Remarks were made by Professor James F. Kemp, Dr. E. O. Hovey and Dr. George F. Kunz.

A vote of thanks was given by the Section in acknowledgment of Dr. Clarke's entertaining and instructive address.

The Section then adjourned.

Charles P. Berkey,
Secretary.

SECTION OF BIOLOGY.

April 11, 1910.

Section met at 8:15 p. m., Mr. Roy W. Miner presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Roy W. Miner, Collecting Invertebrates in the Woods Hole Region.

Summary of Paper.

Mr. **Miner** gave an account of his collecting experiences during the summer of 1910 in the Woods Hole region. The methods and results of a dredging expedition were first outlined, and then the speaker gave an account of the habits of some of the more interesting and typical invertebrates found in the vicinity of Buzzard Bay and Vineyard Sound, dwelling especially on the Annulata. The address was illustrated with colored lantern slides of the living animals.

The Section then adjourned.

W. K. Gregory,
Secretary pro tem.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

April 18, 1910.

By permission of Council, no meeting was held.

Edward J. Thatcher,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

April 25, 1910.

The Section met in conjunction with the New York Branch of the American Psychological Association. The afternoon session was held at 4 p. m. at the Psychological Laboratory, Schermerhorn Hall, Columbia University, where the following programme was offered:

J. V. Breitwieser, The Attention Wave.
B. R. Simpson, Correlation of Mental Abilities.
Henry H. Goddard, Development of the Sense of Form in Feeble-Minded Children.
Will S. Monroe, Indications of Incipient Fatigue.

The evening session was held at 8:15 p. m. at the American Museum of Natural History, the following programme being offered:

J. McKeen Cattell, The Measurement of Psychological Merit.
Joseph Jastrow, Recent Applications of the Stereoscopic Principle.
James E. Lough, Experiments in Stereoscopic Vision.
W. P. Montague, Life as Potential Energy.

R. S. Woodworth,
Secretary.

BUSINESS MEETING.

May 2, 1910.

The Academy met at 8:20 p. m., at the American Museum of Natural History, Vice-President Campbell presiding in the absence of President Kemp.

The minutes of the last meeting of the Section were read and approved.

The following candidates for election to active membership in the Academy, recommended by the Council, were duly elected:

Eugene M. Berard, 43 Cedar Street,
W. B. Bourn, Ski Farm, Burlingame, Calif.,
William T. Davis, 146 Stuyvesant Place, New Brighton, S. I.,
James J. Frederich, M. D., 480 East 179th Street,
Albert C. Goodwin, 1070 Bushwick Avenue, Brooklyn, N. Y.,
Edward Griffith, 66 Pine Street,
H. W. Guernsey, 230 West 59th Street,

George W. Hodges, 37 Wall Street,
Frederic H. Humphreys, Morristown, N. J.,
Mrs. William E. Iselin, 745 Fifth Avenue,
Philip M. Lydig, 38 East 52nd Street,
Charles R. McNeil, 39 West 42nd Street,
George F. Norton, 71 Broadway,
Mrs. William C. Osborn, 40 East 36th Street,
Jacob Rossbach, 1 West 86th Street,
Adelbert J. Smith, 15 William Street,
Frank Morse Smith, 149 Seventh Avenue, Brooklyn, N. Y.,
James Streat, 62 Leonard Street,
Mrs. J. A. Vanderpoel, 22 Gramercy Park,
Mrs. Woerishoffer, 11 East 45th Street.

The Recording Secretary reported the following deaths:

Robert Parr Whitfield, Curator of Geology and Invertebrate Paleontology at the American Museum of Natural History from 1877 to 1909, inclusive, and Curator Emeritus of the Department since 1 January, 1910, died 6 April, 1910, at Troy, N. Y. Professor Whitfield had been an active member of the Academy since 1879, and in the early years of his residence in this city, he took much interest in its work. He was a vice-president from 1894-1895 and a Fellow of the Academy. A paleontologist of the old school, a keen observer of form, a wonderfully skillful draughtsman, an assiduous describer of species, his influence was for many years great in his chosen specialty, and his impress upon paleontologic science is permanent.

Rutherford Stuyvesant, an active member for 42 years and a Fellow of the Academy for 1 year.

On motion, the death of Professor Whitfield was referred to the Committee on Members with the recommendation that a suitable memorial be prepared.

The Recording Secretary read a letter from Professor Viktor von Lang sending greetings and acknowledging the receipt of his appointment as delegate to represent the Academy at the semi-centenary of the foundation of the Verein zur Verbreitung naturwissenschaftlicher Kenntnisse of Vienna.

The Academy then adjourned.

Edmund Otis Hovey,
Recording Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

May 2, 1910.

Section met at 8:30 p. m., Vice-President George F. Kunz presiding.

The minutes of the last meeting of the Section were read and approved.

Arrangements were made for a joint meeting with the geologists and mineralogists of the neighboring region for this last meeting of the year. The regular formal session of the Section was preceded by a field meeting. A party of 38 assembled at the Eagle Hotel in Kingston, N. Y., the evening of April 30. A conference was then held at which the general geology of the Rondout region was presented by Dr. Rudolph Ruedemann and Mr. Hartnagel of the New York State Survey, Professor Charles Schuchert of Yale University, Dr. E. O. Hovey of the American Museum of Natural History, Professor D. W. Johnson of Harvard University and Professor A. W. Grabau and Dr. Charles P. Berkey of Columbia University.

The next day was spent in studying the Helderberg series at Kingston and in making a cross section of the ridge at the old cement mines. Later in the afternoon the party divided, one section going with Professor Grabau to study the fauna of certain formations more fully, and the other section following Dr. Berkey to High Falls to see the stream gorge at that point and the excellent exposures of High Fall shale, Binnewater sandstone and Shawangunk conglomerate, all of which are additional to the formations seen in the morning at Kingston.

Another conference was held in the evening which was participated in by most of the visiting geologists. Several of the more obscure questions were discussed at this session in which considerable difference of opinion was developed.

On the morning of May 2, the whole party went to Browns Station in the margin of the Catskills to see the Ashokan Dam and other work being done at the reservoir site by the New York City Board of Water Supply as part of the Catskill water system. Mr. J. S. Langthorn, Division Engineer, in charge of a division of this work, kindly took the party over the most interesting portions of the field, among which were the 50-foot trench being cut into the Sherburne sandstone, one of the large dikes and the Ashokan Dam itself.

At noon the party left Kingston for New York City, where, at 4 o'clock, a short meeting was held in the rooms of the Department of Geology of Columbia University with the following papers:

A. A. Julien, THE GENESIS OF ANTIGORITE.
Victor Ziegler, THE RAVENSWOOD GRANODIORITE.
Charles P. Berkey, GLACIAL MODIFICATION OF THE CHANNELS ABOUT NEW YORK.

At 8:30 in the evening, the regular session of the Section of Geology and Mineralogy was held in the Academy room at the American Museum of Natural History, Vice-President George F. Kunz presiding.

The following programme was offered:

Douglas W. Johnson, THE ORIGIN OF THE YOSEMITE VALLEY.
James F. Kemp, A SPHEROIDAL BASIC DIKE FROM ARKANSAS.
A. W. Grabau, RELATION OF MIDDLE AND UPPER SILURIC IN THE EASTERN UNITED STATES.

The following paper was read by title:

Clarence N. Fenner, THE WATCHUNG BASALT AND THE PARAGENESIS OF ITS ZEOLITES AND OTHER SECONDARY MINERALS.

SUMMARY OF PAPERS.

Professor **Johnson** discussed the gradients of the tributary streams and showed that the present valley bottoms are 2200 to 2400 feet deeper than would be expected from their behavior. The conclusion reached from all sources of evidence is that the result is due to overdeepening by glacial ice.

Professor **Kemp** showed several specimens, and the type of dike was compared to others of spheroidal habit from different localities.

Professor **Grabau** showed a series of typical geological sections in explanation of the correlation proposed.

The Section then adjourned.

CHARLES P. BERKEY,
Secretary.

SECTION OF BIOLOGY.

MAY 9, 1910.

Section met at 8:15 P. M., Professor Bashford Dean presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

W. K. Gregory, NOTES ON THE INSECTIVORE GENUS *Tupaia* AND ITS ALLIES.
Henry E. Crampton, FOURTH JOURNEY OF EXPLORATION IN THE SOUTH SEAS.

Summary of Papers.

Mr. **Gregory** said in abstract: In 1904, Dr. W. D. Mathew interpreted the characters of many Eocene mammals of various orders as pointing to a common stem form of arboreal habits and structure. The oriental insectivore *Tupaia* and its little known Bornean ally *Ptilocercus lowii,* serve to illustrate these characters in still living forms. They have a divergent but not yet opposable thumb and great toe, their habits are chiefly arboreal and the diet insectivorous-frugivorous. *Tupaia* retains many skeletal features that were characteristic of Eocene unguiculates, *e. g.,* long humerus and femur, humerus with entepicondylar foramen, femur with third trochanter, radius and ulna and tibia and fibula separate, flexible carpus and tarsus, semiplantigrade, five-toed manus and pes with divergent digit I, free central carpi, astragalus without trochlear keels and with a rounded head, vertebral formula C. 7, D. 13, L. 6 or 7, S. 3, Cd. 23-26—and many others. Other features distinctly foreshadow the primate type, *e. g.,* relatively large brain case, broad forehead, large, posteriorly closed orbits and especially the structural details of the auditory bulla and ossicles, dentition and astragalus. In *Ptilocercus,* the skull and dentition is even more distinctly lemuroid, but the rest of the skeleton is unknown. It is of course possible that these lemuroid characters are entirely due to convergent evolution, but the provisional conclusion is that the Tupaiidæ are descended from the Insectivore stock that gave rise to the primates. Attention was called to the resemblances between *Ptilocercus* and the lower jaw from the Bridger Eocene described by Matthew as *Entomolestes grangeri.* The only differences are such as frequently separate more generalized forms from their descendants.

The paper was illustrated with lantern slides and specimens.

Professor **Crampton** gave a brief account of the new results obtained in the course of a journey of seven months' duration among the Society, Cook, New Zealand, Tongan, Samoan, Fiji and Hawaiian Islands. The organisms forming the material of investigations were terrestrial snails of the genus *Partula,* a strictly Pacific group. The species differ when a comparison is made of forms occurring in neighboring but isolated valleys of one island, in different islands of the same group and in different groups of islands. The uniform principle of distribution summarizing the observed facts is that the degree of geographic proximity of any two comparable regions is correlated with the degree of biological differentiation of their species.

Professor Crampton also gave a description of two active volcanoes, namely, Savaii in Samoa and Kilauea in Hawaii. Other older islands of volcanic nature were brought into relation with these examples, as later stages in the production of deeply-furrowed land masses like Tahiti, where conditions are such that isolated valley stations are found to be the homes of separate colonies of snails. Regarding the relation of such islands to other weathered peaks like Borabora, to coral atolls and to islands of uplifted coral limestone like many examples in the Cook and Tonga groups, the Darwin-Dana doctrine was contrasted with the view of Agassiz. It was pointed out that the phenomena of distribution in the case of species of *Partula* gave unquestioned support to the Darwin-Dana doctrine of a major process of subsidence, although secondary sporadic examples of the reverse process of uplift may be demonstrated at different points of the South Pacific Ocean.

The paper was illustrated with lantern slides and specimens.

The Section then adjourned.

William K. Gregory,
Secretary pro tem.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

May 16, 1910.

The Section met at 8:15 p. m., Vice-President W. Campbell, presiding.

The minutes of the last meeting of the Section were read and approved.

The programme for the evening consisted of the following public lecture:

S. A. Mitchell, The Return of Halley's Comet.

Edward J. Thatcher,
Secretary.

BUSINESS MEETING.

October 3, 1910.

The Academy met at 8:15 p. m. at the American Museum of Natural History, Vice-President George F. Kunz presiding.

On motion, the business meeting was adjourned to October 17, 1910.

Charles P. Berkey,
Secretary pro tem.

[Annals N. Y. Academy of Sciences, Vol. XX, pp. 420a-420b.]
[Omitted by error from its proper place. Please insert.]

BUSINESS MEETING.

May 23, 1910.

The Academy met at 5 p. m., at the American Museum of Natural History, President James F. Kemp presiding.

The minutes of the last meeting were read and approved.

The following candidates for election as active members, recommended by the Council, were duly elected:

Miss M. C. Bishop, 9 East 84th Street,
Charles Lyman Brinsmade, 166 Columbia Heights, Brooklyn,
Mrs. M. E. Dwight, 31 Mt. Morris Park West,
Richard E. Follett, Pittsfield, Mass.,
Karl Hutter, 241 Lafayette Street,
J. A. Lindbo, St. Edward, Nebraska,
Dr. William N. Polk, 7 East 84th Street.

On motion, the President, Recording Secretary and Treasurer were given power to elect to membership in the Academy persons applying during the vacation season for membership under the circular authorized at the meeting of 7 February and approved by the Council.

The following communication was then read:

Wallace Goold Levison, The Character of Comets.[1]

My present hypothesis of the character of comets is that they are allied to foci of radiant matter, and that the train corresponds to the cathode beam in a Crookes tube. As the latter is confined within and surrounded by the glass vessel while the former is developed in unlimited vacuous space, it is not surprising that they may differ in some details. It seems to me that the polyfurcation of comets' tails is effected by the sun or planets acting as great magnets; just as the cathode beam in a Crookes tube may be similarly divided by an artificial magnet into streamers closely resembling those of multiple-tailed comets.[2]

While in some details as to their spectra, comets differ somewhat from the ordinary cathode phenomena as yet noted, probably for the reason

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[1] Manuscript received by the Editor 16 May, 1910.

[2] This hypothesis I have described in more detail and illustrated with comparative photographs of comets and cathode beams in the following publications:

Papers of the American Astronomical Society, No. 2, p. 54, 1887.
Prospectus Bkln. Inst. Arts and Sci. for 1894-5, p. 18. 1894.
Yearbook Bkln. Inst. Arts and Sci. for 1895-6, p. 120. 1896.
Trans. New York Acad. Sci., Volume XV, p. 156, 1895-1896.
Scientific American, Volume LXXV, No. 10, p. 303, Sept. 5, 1896.

above explained, or more likely because no special effort has been made to reproduce them experimentally under suitable conditions, I anticipate that they will eventually prove to be of similar origin.

If the comet's train be a beam of radiant matter, the following phenomena might attend upon the earth's transit through it: (1.) Being composed of negatively charged electrons (the smallest conceivable particles of matter), each with a long, free path or collectively at comparatively great distances apart, it must consist of highly attenuated material such as Faraday and Crookes regarded as a fourth state of matter. (2.) It could exist only in a near vacuum and, therefore, impinging against our atmosphere, it could only penetrate its superficial and highly rarefied exterior. There it might develop a slight phosphorescence, but as this would occur on the lighted side of our planet, it would be invisible to us. The beam would thereby however become arrested or would terminate. (3.) During the earth's immersion in the comet's train, those of us near the center of its night or dark side would see it passing on all sides as a faintly luminous cylinder, extending above us into space, but modified perhaps by perspective to an apparently coronal form like an aurora. To those of us near the terrestrial horizon beyond the area locally illuminated by sunrise or sunset, it might appear brighter than to those nearer the night center. (4.) The behavior of the comet's train would, however, perhaps depend upon its direction with respect to the magnetic axis or polarity of the earth. In certain directions, it would possibly or even probably be repelled by the earth's magnetism wholly to one side so that we should escape it altogether. (5.) Whether deflected or not, it might occasion terrestrial magnetic perturbations as does the aurora. (6.) If not deflected by the pressure of its impact, it might disturb the equilibrium of the atmosphere and so commingle the upper and lower air as to produce a reduced temperature.

Whether there is in this hypothesis anything inconsistent with the assumption that comets' trains may consist of any kind of matter indicated apparently by spectroscopic records, or of associated meteoric particles projected simultaneously by the pressure of light, has yet to be demonstrated, if possible. Their development in unlimited vacuous space seems to involve a condition beyond experimental provision. It is of interest in this connection that certain kinds of solid matter glow with a vivid phosphorescence under the cathode rays and give a line spectrum very similar to that of the substance indicated when in the condition of an incandescent gas or vapor.

According to this hypothesis, little effect need apparently be anticipated upon the earth from Halley's comet, in case its train is traversed well away from its head.

SECTION OF GEOLOGY AND MINERALOGY.

October 3, 1910.

The Section met at 8:20 p. m., Vice-President George F. Kunz presiding.

The minutes of the last meeting of the Section were read and approved.

Before proceeding to the regular programme of the evening, Dr. George F. Kunz presented some of the results of explorations conducted by the commission investigating choice of site for the proposed Hudson River bridge. Dr. Kunz reported that rock foundations are wanting, except on the present river margins, a condition that would seem to require a span of such extraordinary length that it is a question whether it should be attempted at all. It is his opinion that the bridge plan will finally be abandoned in favor of tunnels, several of which could be constructed for the cost of one bridge. Furthermore, they could be so placed that the several tunnels would accommodate different sections of the city and together be of greater service than the bridge.

The following programme was then offered:

G. S. Rogers, Original Gneissoid Structure in the Cortlandt Series.

Jesse E. Hyde, Some Structural Modifications of the Inwood Limestone.

Charles P. Berkey, Additional Notes on the Interbedded Limestone in the Fordham Gneiss of New York City.

George H. Girty, New Species of Fossils from the Thaynes Limestone of Utah.

George H. Girty, Description of some new Genera and Species of Carboniferous Fossils from the La-fayetteville Shale of Arkansas.

Summary of Papers.

Mr. **Rogers** gave the results of his own observations in field work and illustrated his remarks by lantern slides. Remarks on the similarity of these occurrences to those of the Scandinavian Peninsula were made by Professor J. F. Kemp.

Mr. **Hyde** called attention to the evidence of dynamic results of a differential nature in different layers of the Inwood near Spuyten Duyvil

Creek. The more brittle bands or layers are broken, and the purer adjacent matter has "flowed" in, accomplishing a stretching of the whole mass. The discussion was illustrated with specimens. Remarks were made on the meaning of these characters by Dr. C. P. Berkey.

Dr. **Berkey's** paper dealt with the newer discoveries of interbedded limestone layers, which were described briefly, and special attention was called to the evidence of such occurrences in the recent lower east side deep boring explorations. This facies of the Fordham gneiss series is now well established for southeastern New York.

Dr. **Girty's** papers were read by title.

The Section then adjourned.

Charles P. Berkey,
Secretary.

SECTION OF BIOLOGY.

October 10, 1910.

Section met at 8:15 p. m., Vice-President Chas. B. Davenport presiding.

The minutes of the last meeting of the Section were read and approved.

The meeting was devoted to a series of informal reports by members of the Section on their summer's work.

L. Hussakof,
Secretary.

BUSINESS MEETING.

October 17, 1910.

The Academy met at 8:15 p. m., at the American Museum of Natural History, President Kemp presiding.

The minutes of the meeting of May 23 were read and approved.

The following candidates for active membership, recommended by the Council, were duly elected:

David R. Abercrombie, 311 Broadway,
Oakes Ames, North Easton, Mass.,
Mrs. William H. Bliss, 6 East 65th Street,
Frederick A. Camp, 32 West 129th Street,
José Edward Chaves, 31 East 49th Street,
G. Warrington Curtis, Southampton, N. Y.,
David T. Davis, 55 Liberty Street,
C. Stuart Gager, Central Museum, Brooklyn,

Charles J. Harrah, 27 East 64th Street,
J. C. Havemeyer, 58 Lamartine Avenue, Yonkers, N. Y.,
Miss Amelia B. Hollenback, 460 Washington Avenue, Brooklyn,
Alfred R. Hoyt, 934 Fifth Avenue,
Jacob Hasslacher, 100 William Street,
Dr. V. H. Jackson, 240 Lenox Avenue,
J. Herbert Johnstone, 18 Washington Square,
Francis G. Landon, 29 Broadway,
M. Lichtenstein, 401 West End Avenue,
J. M. McCarthy, 40 Wall Street,
Dr. Henry S. Oppenheimer, 11 East 43rd Street,
Veryl Preston, 136 East 64th Street,
Lycurgus Relkoyer, Montevedio, Minn.,
Mrs. Emilie B. Risley, 1 West 72nd Street,
John A. Roebling, Bernardsville, N. J.,
Basil W. Rowe, 71 Broadway,
Dean Sage, 49 Wall Street,
Robert Scoville, 62 Cedar Street,
Dr. Louis L. Seaman, 247 Fifth Avenue,
Miss Ellen J. Stone, 34 East 50th Street,
Charles Strauss, 141 Broadway,
Frederick Strauss, 1 William Street,
Miss P. Caroline Swords, 48 East 67th Street,
Mrs. B. B. Tuttle, Naugatuck, Conn.,
Chas.-E. A. Winslow, American Museum of Natural History,
Henry H. Wotherspoon, 46 West 127th Street.

The Academy then adjourned.

Edmund Otis Hovey,
Recording Secretary.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

October 17, 1910.

Section met at 8:25 p. m., Vice-President Wm. Campbell presiding.

The minutes of the last two meetings of the Section were read and approved.

The following programme was then offered:

C. C. Trowbridge, The Direction Sense in Birds and Animals from the Standpoint of Physics.

W. Campbell, The Microscopic Examination of some Faulty Railroad Material.

Summary of Papers.

Dr. **Trowbridge** first of all discussed the various theories which have been given to explain this direction sense, especially in birds, and showed how they were untenable from the standpoint of physics. Then he set forth his own theory, which for want of a better name he called the pylex triangulation theory, and explained its principles.

Dr. **Campbell,** in his paper, took several examples of failures of railroad material from wrought iron to rail steel, and by means of the microstructure he demonstrated the cause of failure. First of all, the various constituents met with were described, and the methods of distinguishing them were explained. Then, by numerous lantern slides and specimens, the structure of faulty material was contrasted with that of good. Lastly, he explained why rails of older manufacture had apparently given better service than some of modern make.

The Section then adjourned.

Edward J. Thatcher,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

October 24, 1910.

The Section met in conjunction with the American Ethnological Society, at 8:15 p. m., Gen. James Grant Wilson presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Robert H. Lowie, Ceremonial Organizations of the Crow Indians.

Summary of Paper.

Dr. **Lowie** said in abstract: The societies of the Crow at present comprise purely social clubs, without any religious features and without any adoption ceremony; the Medicine Pipe organization, and the several Tobacco societies, all of which are of a sacred character and can be entered only upon formal adoption. The military societies of the Crow, which are no longer in existence, rather resembled the social clubs, for religious features were practically lacking. There was no adoption ceremony, no sacred origin myths, and they were to a certain extent mutual benefit associations like the clubs of to-day.

R. S. Woodworth,
Secretary.

BUSINESS MEETING.

November 7, 1910.

The Academy met at 8:15 p. m., at the American Museum of Natural History, President James F. Kemp presiding.

The minutes of the last meeting were read and approved.

The following candidates for election as active members, recommended by the Council, were duly elected:

Frederick Billings, 279 Madison Avenue,
Benedict J. Greenhut, 36 West 72nd Street,
Theodore R. Hoyt, 72 Gold Street,
Nathaniel Cushing Nash, 10 Post Office Square, Boston, Mass.,
Lawrence E. Sexton, 34 Pine Street,
W. A. Taylor, 18 East 66th Street,
Robert M. Thompson, 43 Exchange Place,
Chas. Willis Ward, Lovells, Crawford County, Mich.,
John J. Watson, Jr., 390 West End Avenue.

The Recording Secretary announced from the Council that, through the generosity of one of the members of the Academy, a seismographic station was to be established at the American Museum of Natural History, the instruments pertaining thereto to be and remain the property of the Academy.

The Academy then adjourned.

Edmund Otis Hovey,
Recording Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

November 7, 1910.

The Section met at 8:20 p. m., Vice-President George F. Kunz presiding.

The minutes of the last meeting of the Section were read and approved.

After the reading of the minutes, Professor Stevenson moved that the present officers of the Section be nominated as candidates for another term and that nominations be closed. Professor J. F. Kemp put the motion, which was carried, and Dr. George F. Kunz was declared the nominee for Vice-President and Chairman of the Section, and Dr. Charles P. Berkey was declared the nominee for Secretary of the Section.

The following programme was then offered:

J. F. Kemp, THE ELEVENTH INTERNATIONAL GEOLOGICAL CONGRESS AT STOCKHOLM, JULY AND AUGUST, 1910.

J. J. Stevenson, THE COAL BASIN OF DECAZEVILLE, FRANCE.

E. O. Hovey, SOME OBSERVATIONS ON THE YOSEMITE VALLEY.

SUMMARY OF PAPER.

Professor **Kemp** gave an account of the several excursions preceding the Congress, and a summary of the topics and papers presented at the regular sessions was read. The chief feature of the Eleventh Congress was the preparation of a series of monographs on the iron ore reserves of the world. Professor Kemp is the author of those on the iron reserves of the United States, the Philippines, Central America, the West Indies and several of the South American countries. Many of the features of special interest in Sweden and Norway were described, and several lantern views were shown in illustration.

Professor **Stevenson** gave an instructive account and discussion of the structure and origin of the coals of Decazeville. It is his opinion that they have been formed by peat bog growth instead of transported vegetation, as the French geologists have held.

Dr. **Hovey's** description was based upon a trip made during the summer. A magnificent set of lantern views was shown to illustrate the different features.

The Section then adjourned.

CHARLES P. BERKEY,
Secretary.

SECTION OF BIOLOGY.

NOVEMBER 14, 1910.

Section met at 8:15 P. M., Dr. Alexander Petrunkevitch presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Raymond C. Osburn, THE EFFECTS OF EXPOSURE ON THE GILL FILAMENTS OF FISHES.

Alexander Petrunkevitch, COURTSHIP IN TARANTULAS.

W. M. Wheeler, THE NORTH AMERICAN ANTS OF THE GENUS *Camponotus mayr.*

SUMMARY OF PAPERS.

Dr. **Osburn** said in abstract: Salmonoid fishes hatched and reared under artificial conditions frequently show a malformation of one or both of the gill covers, as a result of which the gill filaments are exposed. This condition has been observed in many hatcheries, the percentages sometimes being as high as twenty per cent. The deformity in the fishes studied is produced by the rolling in of the operculum. 486 yearling silver salmon reared in the New York Aquarium were examined with the following results: Normal, 397; right opercle short, 44; left opercle short, 27; both opercles short, 18; percentage of abnormality, 18.31. On examination under the microscope, the exposed filaments are found to be quite abnormal. The epithelium, instead of being composed of thin flattened cells, is greatly thickened, consisting of cuboid or columnar cells, and in some cases several layers of the cells are found. The secondary laminæ, in which respiration for the most part takes place, are often reduced or wanting, and the blood capillaries are not fully developed. The hypertrophy of the epithelium, while it undoubtedly protects the filaments against abrasion, must at the same time seriously interfere with their function in respiration. The cause of the deformity of the opercle is unknown. Fish culturists have noted its appearance very early in fry, but whether it is congenital or is induced by crowding or by other untoward conditions in the hatching trays, further observations must decide.

Dr. **Petrunkevitch** said in abstract: The instincts of the male tarantulas change suddenly at the period of maturity. From a creature with domestic habits, he develops into a vagabond. Disregarding personal danger, he constructs a spermweb into which he throws out his sperm and pumps it then into both of his palpi. In the search for the female, he is entirely dependent upon his sense of touch, his sense of sight being entirely inadequate for the purpose. The courtship is therefore very short and consists in beating the female with his front legs. The danger of being hit by the fangs of the excited female is prevented by catching them with the hooks on the front legs. The coitus lasts not longer than one-half minute, after which the spiders cautiously separate. A few weeks later the males die, apparently a natural death.

Professor Charles B. Davenport, Chairman of the Section, was renominated for the Chairmanship for 1911.

Dr. L. Hussakof, Secretary of the Section, was renominated and re-elected for 1911.

The meeting then adjourned.

L. HUSSAKOF,
Secretary.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

November 21, 1910.

Section met at 8:15 p. m., Vice-President Wm. Campbell presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Charles Conrad Sleffel, The Waste Wax Process of Casting Bronze.

Summary of Paper.

Mr. **Sleffel** explained the process in detail from the artist's model to the finished and colored casting, showing that the ancient process differed but slightly from the modern. The lecture was illustrated by actual models and castings, also by lantern slides.

Two letters of request for grants from the Esther Herrman Research Fund were read, one from Prof. C. C. Trowbridge, The sense of direction in birds and animals. The other from Prof. W. Campbell as to the micro-structure of metals. These letters were approved and referred to the Council.

The Section then adjourned.

Edward J. Thatcher,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

November 28, 1910.

Section met in conjunction with the New York Branch of the American Psychological Association at 4 p. m. at Columbia University.

The following programme was offered:

F. Lyman Wells, Practise Effects in Free Association.
H. L. Hollingsworth, Drowsiness.
Clyde Furst, Mental Hygiene.

The evening programme was taken up at the American Museum of Natural History at 8:15 o'clock as follows:

D. S. Miller, Subjectifying the Objective.
F. J. E. Woodbridge, Secondary Qualities.
Robert H. Lowie, A Forgotten Pragmatist, Ludwig Feuerbach.

Summary of Papers.

Dr. **Wells** said in abstract: When subjects are practised in the free association test through a long series of different words each day, there normally appears a decrease in the association time that may be as high as forty per cent. This practise effect consists essentially in bringing down the long times of a series to the approximate level of the few words showing the shortest time at the beginning of practise. It is an overcoming of the resistances originally present in the majority of responses. It is very striking that the practise of this test, where the given situation is essentially different in each observation, is not markedly less than in other psychological tests where the situations are the same or but slightly different, as in the addition or the number checking tests. Besides this practise effect in the reaction time, it also appears that there are certain changes in the character of the responses; they tend to become more specific, but also more superficial, and less determined by the influence of so-called emotional "complexes."

Dr. **Hollingworth** reported an attempt to study the hitherto inadequately explored transition state between waking and sleeping. Two observers have for two years recorded hallucinations occurring during the drowsy state, and typical cases are reported. Their examination discloses several clearly-defined principles or tendencies, the exposition of which seems to constitute a fairly true though perhaps only partially complete analysis of the state of drowsiness.

1. Transformation of imagery type. Imagery modes ordinarily vague and feeble become dominant and vivid, even tending to replace customary imagery habits. Thus H—who is predominantly auditory and motor in type and can only with difficulty summon up visual images of even the most moderate vividness—has, in the drowsy state, visual experiences which constantly startly him by their clearness. I—to whom visual imagery is a common habit, but who, in her waking consciousness, can not understand what kinesthetic imagery is like—tends, in the drowsy state, to relive motor experiences almost exclusively.

2. Substitution of three types, sensory, perseverative, and ideal. Within the drowsiness fusion a present impression, a perseverative tendency, or even a pure memory element often substitutes itself for some other datum whose rôle it fills in the perceived composition of the hallucination.

3. Fluid association on a sensory basis, with removal of constraining mental sets and controls, leading to bizarre analogies, naïve statements, and unusual verbal juxtapositions.

4. Isolation. Association trains may develop when the drowsy state is extended over a long period of time, and show the same behavior as to the "flash-light" perceptual or ideational states in drowsiness proper, the essential thing being the release of all intellectual inhibition.

5. Grandeur and vastness characterize the simpler perceptual complications as well as the more developed thought processes.

6. Amnesia for processes and events occurring during the drowsy state comes quickly.

7. Absence of special symbolism, except in so far as the hallucination reflects the recent experiences or occupations and hence, perhaps, the fundamental interests of the observer.

Summary. The drowsiness hallucination seems to be a "flash-light" perceptual fusion or complication, and is further characterized by transformation of imagery type; sensory, perseverative, and ideal substitution; fluid association on a sensory basis; and by isolation of association trains when they develop; and it is accompanied by tendencies toward grandeur and vastness, by rapidly ensuing amnesia, and by absence of symbolism.

Mr. **Furst** gave a collection of items from biography and autobiography selected so as to illustrate the ways in which such material may suggest fruitful fields and methods for psychological study. Thus, in the field of mental hygiene, individual equipment for sensation, and individual habits of confinement or exercise, food and sleep, and individual habits of work appear to have an adjustable relation to youth and age, to climate, season, and weather, and to weekly and daily rhythms of efficiency. Similarly, environment, appliances, habit and variety, freedom and restraint, society and solitude may be, at least partially, controlled in their effect upon mental attitudes, interests, aims, and ideals as these, in turn, are related to mental spontaneity and efficiency. Study of mental action and reaction may thus be directed toward a definite selection of stimulus and a deliberate adoption of methods of work that will enhance both the welfare of the mental mechanism and the quality of its product.

Mr. **Miller** said in abstract: It has been maintained that the meaning of the proposition "it ought to be" can never be expressed by any proposition about human feelings, preferences, approvals, or the like; that there is something objective and absolute in the ethical proposition which is missing in the psychological form. But there is an exactly analogous relation between subjective and objective statement in a long list of cases other than the ethical. Thus we make objective statements about what is comic, and their absoluteness is lost when we only state propositions about human feelings of amusement. The whole column of correlatives would run as follows: obligation—approval, the comic—amusement, the beautiful—esthetic pleasure, value—desire, the strange—surprise, the sublime—awe, probability—expectation, "up and down"—certain feelings of effort and relaxation, etc. In each of these cases the one term has an objective and absolute character which is missed in the other, the other making a psychological and personal reference which is absent from the first; the meaning of the first can not be translated, without change, into the second. This fact is, however, fully explicable, and must needs be so because the person subject to the feelings does not in his primary experience psychologize upon himself or class what he feels as his own feeling.

Why in all these cases does the objective come by reflective people to be subjectified? And in what does subjectifying consist? The objective in such cases is subjectified simply because it is found to vary of necessity with the life and organism of the person experiencing it; and in this very fact and in nothing else consists its subjectivity.

Dr. **Woodbridge** said in abstract: The usual question suggested by the mention of secondary qualities is that of their existential status, namely, in what context may they be said to possess reality or to exist? The discussion of this question does not appear to have been profitable in the history of thought. It has moreover tended to divert attention from more important considerations.

Since secondary qualities do exist in the context of experience, one may ask what function they there serve. In answer to this question it may be pointed out that they serve as the means of identifying different efficiencies. Their importance, for instance, in chemical analysis and in the use of the spectrum is evident. It is to be noted that while they are the indices of efficiency, so to speak, no efficiency is assigned to them directly. Their methodological value appears to be thus their value as signs. Furthermore, the existence of secondary qualities appears to be bound up with the specific differentiation of the nervous system in the direction of sense organs. Indeed, it appears impossible to assign any other function to the development of sense organs and a coördinating nervous system than that of securing reaction of the organisms to its environment by means of a specialization in view of the operation of secondary qualities. Bringing together, then, the considerations based upon the methodological value of secondary qualities and those based upon the significance of secondary qualities in the development of the sense organs and the nervous system, it would appear that reaction to secondary qualities as stimuli would afford both a criterion for the existence of consciousness and a definition of consciousness itself. In the life of an organism such reactions would serve as indications of the general connectedness of its surroundings.

Dr. **Lowie** said in abstract: While it is commonly assumed that Germany lags behind in the development of pragmatic philosophy, the speaker contended that the theoretical principles of pragmatism have been long ago defended by Ernst Mach, while a humanistic conception of philosophy, joined with a conception of truth identical with that of Schiller and James, was postulated by Ludwig Feuerbach nearly seventy years ago. As modern pragmatism is primarily a protest against neo-Hegelism, so Feuerbach's philosophy meant a secession from the older Hegelian school. Like James, Feuerbach insisted that philosophy must be based on the totality of human nature as opposed to its exclusively rational components. As an empiricist and nominalist, Feuerbach taught the primacy of the concrete as compared with the abstract. His refusal to abstract from the given totality of human nature prevented him from holding the materialistic views erroneously ascribed to him. He considered reality and thought as incommensurate, and accordingly rejected all systems as artificially cramping the contents of experience. In the treatment of his special problem, the philosophy of religion, Feuerbach pursues a method strikingly similar to that of James and Schiller in their critique of "pure truth" and of Mach in his critique of the Ding an sich: the divine is recognized as based on human traits mystified and set up as non-human by the religious consciousness. Feuerbach's atheism in no way contravenes his pragmatism; for it is based not on the metaphysical question of the existence of the deity, but on the purely practical question whether religion has "worked" satisfactorily. This Feuerbach denies, considering religion an obstacle to social and political progress; but this difference from James and Schiller is merely a difference in the interpretation of historical data and only emphasizes his insistence on pragmatic standards.

The meeting then adjourned.

R. S. Woodworth,
Secretary.

BUSINESS MEETING.

December 5, 1910.

The Academy met at 8:15 P. M. at the American Museum of Natural History, President Kemp presiding.

The minutes of the last meeting were read and approved.

The following candidates for election as active members, recommended by the Council, were duly elected:

J. R. Healy, West 118th Street,

F. Lyman Wells, Columbia University.

The Recording Secretary presented the following overture from the Section of Geology and Mineralogy of the Brooklyn Institute of Arts and Sciences:

The officers of the Brooklyn Institute of Arts and Sciences, Department of Geology, desire the New York Academy of Sciences to appoint a committee of three to act with a similar committee that has already been appointed by the Department of Geology of the Brooklyn Institute of Arts and Sciences in considering the advisability of some action being taken jointly by the New York Academy of Sciences and the Brooklyn Institute and such other scientific bodies as they can associate with them to induce the New York State officials to prepare and publish a series of volumes that shall comprise a complete treatise on the geology of the State of New York, as developed by public researches, together with a bibliography inclusive of all available records to date. As the geology of the State of New York is scattered through an immense number of pamphlets and papers, it is thought desirable that the whole matter should be worked up and digested into a complete treatise.

On motion, the President was authorized and requested to appoint a committee of three, including himself as chairman, to confer with the similar committee from the Brooklyn Institute and report back to the Academy. The committee then was constructed as follows: Messrs. James F. Kemp, J. J. Stevenson and E. O. Hovey.

The Academy then adjourned.

Edmund Otis Hovey,
Recording Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

December 5, 1910.

The Section met at 8:30 p. m., Vice-President George F. Kunz presiding.

The minutes of the last meeting of the Section were read and approved.

The Secretary presented the application of Mr. J. E. Hyde for a grant from the funds of the Academy in support of certain field investigations of a physiographic nature. To questions, Mr. Hyde replied that the results were to be published in the Annals of the Academy. A motion was passed, approving the application for the sum of $100.00. This recommendation was transmitted with the original application to the Council of the Academy.

The following programme was then offered:

J. E. Hyde and **Charles P. Berkey**, Original Ice Structures Indicated by Corresponding Structures in Unconsolidated Sands and Gravels of the Drift on Manhattan Island.

J. E. Woodman, Structure of the Meguma Series of Nova Scotia.

Summary of Papers.

Mr. **Hyde's** paper was given with the aid of lantern slides and was followed by a brief discussion by Dr. Berkey. It was pointed out that a complicated lot of structures are preserved under conditions that point to very different behavior at some former time. There is brecciation, faulting, bending, oversteepening and other phenomena that seem to implicate former incorporation in the ice sheet and the development of differential movements while frozen and suffering deformation with the rest of the ice mass.

Professor **Woodman** illustrated his talk with many charts and maps and gave an instructive account of the results of detailed field work in Nova Scotia.

Dr. **George F. Kunz** announced the discovery of a new gem district at Mount Bitz, in Madagascar. The gems occur in a pegmatite vein carrying, among other rare minerals, a pink beryl. It is a cæsium beryl of remarkable rose-red color and capable of furnishing beautiful gem stones. The name Morganite is proposed for this gem.

The Section then adjourned.

Charles P. Berkey,
Secretary.

SECTION OF BIOLOGY.

December 12, 1910.

Section met at 8:15 p. m., Mr. Roy W. Miner presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

G. G. Scott, The Effect of Changes in Water Density on the Blood of Fishes.

Roy W. Miner, Marine Ecology and its Representation in a Museum.

Ignaz Matausch, Exhibition of Models of Membracidæ.

Summary of Papers.

Mr. **Scott** said in abstract: When salt water fishes are placed in fresh water, they gain in weight. Investigation of the blood shows that there is a decrease in number of corpuscles per cu. mm. and that the specific gravity of the blood decreases. Tests with the Beckmann apparatus shows that the freezing point of the blood of such fishes is higher than that of normal blood. If the fishes are placed in a solution of sea water plus sea salt, the corpuscles count is increased, the specific gravity of the blood is greater and the freezing point of the blood is depressed. A chemical examination of the chlorides of the blood of normal fish as compared with the chlorides of fishes kept in fresh water shows that the loss of chlorides in case of the fishes experimented on is greater than the mere dilution of the blood by the endosmosis of water would account for. Hence, under the abnormal conditions to which the fish is subjected, the gills become permeable to salts. The osmotic pressure of the blood is thus profoundly changed. That these changes reach the tissues is indicated by investigations now going on. The death of the fish which usually accompanies such sudden transitions as are employed in these experiments is possibly caused by conditions set up similar to those in such diseases as dropsy. It is hoped that further investigations being carried on at present will clear up this question.

Mr. **Miner** described the chief associations of marine animals to be found between the tides or just below the lower tide limits along the north Atlantic coast, with especial reference to the annulates and molluscs and the fauna of wharf piles in the Woods Hole region and the north shore of Long Island. The methods of collecting and the chief steps for preserving data, observations, etc., for museum ecological groups were then briefly outlined. The speaker then spoke of the problems connected with constructing and installing groups and models of invertebrates in a museum. Colored slides were shown both of the living invertebrates and their habitat and also of the models and groups in course of construction and as completed at the American Museum. The speaker concluded by exhibiting two sketch-models prepared to take in the field under his direction by Messrs. Matausch and Shimotori of the museum staff as preliminary studies for the Annulate and Pile Fauna Groups which are in course of construction in the American Museum.

Mr. **Matausch** exhibited a series of six enlarged models in wax which he had prepared for the American Museum of Natural History, as well as a series of 23 colored drawings and a collection of typical specimens which had been sent him by Professor F. Silvestri, of Portici, Italy. The *Membracidæ,* or tree-hoppers, are among the most interesting of insects. Very little is yet known concerning the life histories of these forms, a subject to which the speaker said he had devoted considerable attention. They are remarkable for the extraordinary variation in the form of the prothorax. In order to make an enlarged model, it is necessary to dismember the insect and to prepare drawings of the different parts to a selected scale. The separate parts are then copied in clay; plaster moulds are then prepared and casts made in wax. These are then finished, the details put in and the whole put together and colored.

The Section then adjourned.

L. Hussakof,
Secretary.

ANNUAL MEETING.

December 19, 1910.

The Academy met for the Annual Meeting on Monday, December 19, 1910, at 8:50 p. m., at the Hotel Endicott, at the close of the annual dinner, President Kemp in the chair.

The minutes of the last Annual Meeting, December 20, 1909, were read and approved.

Reports were presented by the Recording Secretary, the Corresponding Secretary, the Librarian and the Editor, all of which, on motion, were ordered received and placed on file. They are published herewith. On motion, a vote of appreciation was extended to the Recording Secretary on account of the work done by him during the year which resulted in the gratifying increase of membership experienced by the Academy.

The Recording Secretary read the detailed report of the Treasurer, showing a net cash balance of $3,259.74 on hand at the close of business, November 30, 1910. On motion, this report was received and referred to the Finance Committee for audit.

The following candidates for honorary membership and fellowship, recommended by Council, were duly elected:

Honorary Members.

Prof. Dr. Theodor Boveri, University, Wurzburg, Germany, presented by Prof. E. B. Wilson.

Sir Francis Galton, Kings College, London, England, presented by Prof. J. McKeen Cattell.

Fellows.

J. H. Barnhart, M. D., Botanical Garden,
Wendel T. Bush, Brooklyn, N. Y.,
Carlton C. Curtis, Ph. D., Columbia University,
B. E. Dahlgren, D. M. D., Field Museum, Chicago, Ill.,
W. T. Davis, M. A. A., New Brighton, N. Y.,

C. Stuart Gager, Ph. D., Brooklyn, N. Y.,
R. H. Lowie, Ph. D., American Museum of Natural History,
Raymond C. Osburn, Ph. D., New York Aquarium and Barnard College,
Edmund B. Southwick, Ph. D., Department of Parks,
Edward J. Thatcher, Teachers College,
C.-E. A. Winslow, M. S., American Museum of Natural History and City College.

The Academy then proceeded to the election of officers for the year 1911, Professors C. P. Berkey and C. C. Curtis having been appointed tellers. The ballots prepared by the Council in accordance with the By-Laws were distributed, and after the votes had been counted, the following officers were declared unanimously elected, the requisite number of votes having been cast by members of the Academy entitled to vote:

President, Franz Boas.

Vice-Presidents. George F. Kunz (Section of Geology and Mineralogy), Chas. B. Davenport (Section of Biology), William Campbell (Section of Astronomy, Physics and Chemistry), R. S. Woodworth (Section of Anthropology and Psychology).

Recording Secretary, Edmund Otis Hovey.

Corresponding Secretary, Hermon Carey Bumpus.

Treasurer, Emerson McMillin.

Librarian, Ralph W. Tower.

Editor, Edmund Otis Hovey.

Councilors (to serve 3 years), C. C. Trowbridge, Thomas Hunt Morgan.

Finance Committee, Charles F. Cox, George F. Kunz, Frederic S. Lee.

At the close of the elections, Professor James F. Kemp, the retiring President, delivered his Presidential address upon the subject "Geology and Economics." This address has been published as pages 365-384 of this volume.

After a vote of thanks to the retiring President, which was offered with felicitous remarks by former President N. L. Britton, the Academy adjourned.

Edmund Otis Hovey,
Secretary.

REPORT OF THE RECORDING SECRETARY.

During the year 1910, the Academy held 9 business meetings and 27 sectional meetings, at which 71 stated papers were presented on the following subjects:

Geology, 20 papers; Biology, 13 papers; Ornithology, 1 paper; Paleontology, 2 papers; Ethnology, 3 papers; Psychology, 24 papers; Physics, 7 papers; Astronomy, 1 paper.

Three public lectures by noted home and foreign scientists have been given at the Museum to the members of the Academy and the Affiliated Societies and their friends. These lectures were as follows:

"With Peary in the Arctic." By Donald B. MacMillan, a member of Peary's North Polar Expedition.

"The Geological Survey of the State of New York." By John M. Clarke, State Geologist of New York.

"Halley's Comet." By Samuel A. Mitchell of Columbia University.

At the present time, the membership of the Academy includes 538 Active Members, 17 of whom are Associate Active Members, 131 Fellows, 90 Life Members and 13 Patrons. The election of 11 Fellows is pending. There have been 10 deaths during the year, 18 resignations have become effective and 2 names have been transferred to the list of Non-Resident Members. The new members elected during the year number 131, 6 of whom have not yet completed their membership. As the membership of the Academy a year ago was 437, there has been a net gain of 101 during the year 1910. Announcement is made with regret of the loss by death of the following members:

M. H. Beers, Active Member for 12 years,
Julius Bien, Active Member for 35 years,
E. H. Harriman, Active Member for 6 years,
John S. Huyler, Active Member for 6 years,
Edward Mitchell, Active Member for 25 years,
Rutherford Stuyvesant, Active Member for 43 years,
A. H. Wellington, Active Member for 4 years,
R. P. Whitfield, Active Member for 32 years,
F. H. Wiggin, Active Member for 13 years,
J. L. Zabriskie, Active Member for 1 month.

Respectfully submitted,

EDMUND OTIS HOVEY,
Recording Secretary.

REPORT OF THE CORRESPONDING SECRETARY.

We have lost by death during the past year the following Honorary Members:

Alexander Agassiz, elected in 1887,
William James, elected in 1901,

and the following Corresponding Members:

Frederich Kohlrausch, elected in 1899,
William H. Niles, elected in 1881,
George B. Post, elected in 1888,
C. O. Whitman, elected in 1898.

There are at present upon our rolls 48 Honorary Members and 136 Corresponding Members.

Respectfully submitted,

HERMON C. BUMPUS,
Corresponding Secretary.

REPORT OF THE LIBRARIAN.

The library of the New York Academy of Sciences has received during the year ending December, 1910, through exchange and donation, 294 volumes, 26 separata and 1762 numbers. The Institut National Genevois has presented us with 13 volumes of its Mémoires dating from 1854 to 1883, and the Société d'Histoire Naturelle de Toulouse has presented 26 volumes of its Bulletin for the years 1876-1893. Special acknowledgments are herewith made to these two societies for their generosity and assistance in supplying much needed lacunæ.

The library may be consulted by members and the public between the hours of 9:30 A. M. and 5 P. M. daily, and it is desired that the members assist in further extending its use.

Respectfully submitted,

RALPH W. TOWER,
Librarian.

REPORT OF THE EDITOR.

The Editor reports that during the past fiscal year there were issued No. 6 completing Part I, Nos. 7-11 forming Part II and No. 12 forming Part III of Volume XIX; and of Volume XX, No. 1 forming Part I and Nos. 2-4 of Part II. We have, furthermore, two articles in press and one in manuscript to complete Part II, while Part III will be devoted to the address of the retiring President, memorials of deceased members, the records of the Recording Secretary for 1910 and the index to the volume.

Respectfully submitted,

EDMUND OTIS HOVEY,
Editor.

REPORT OF THE TREASURER.

RECEIPTS.

DECEMBER 1, 1909–NOVEMBER 30, 1910.

Cash on hand, December 1, 1909		$1,737.69
Income from investments:		
Interest on mortgages on New York City real estate	$886.00	
Interest on railroad and other bonds	1,120.00	
Interest on bank balances	67.53	
		2,073.53
Life membership fees		2,400.00
Active membership dues, 1907	$60.00	
" " " 1908	80.00	
" " " 1909	175.00	
" " " 1910	3,680.00	
" " " 1911	70.00	
		4,065.00
Associate membership dues, 1910		42.00
Sales of publications		276.36
Annual dinner and meeting, Contributions toward		130.00
Esther Herrman Research Fund, Return of grant		200.00
Permanent Fund, Gift to		10.00
Collection of checks		.20
Total		$10,934.78

DISBURSEMENTS.

DECEMBER 1, 1909–NOVEMBER 30, 1910.

Publication on account of Annals	$2,262.37
Recording Secretary's expenses, including publication of *Bulletin*	1,057.75
Recording Secretary's and Editor's allowance	1,200.00
Esther Herrman Research Fund (Grants)	550.00
Lecture Committee	100.00
Headquarters Committee	8.48
Expenses of Membership Committee	237.35
Expenses of annual meeting and dinner, 1909	140.26
Expenses of Section of Geology	8.48

Expenses of Section of Anthropology	$10.00
General expenses	117.75
Purchase of bonds (investment)	1,960.00
Interest charge on bonds purchased	22.50
Collection of check	.10
Cash on hand	3,259.74
Total	$10.934.78

BALANCE SHEET, NOVEMBER 30, 1910.

Investments	$38,562.50	Permanent Fund	$22,512.57
Cash on hand	3,259.74	Publication Fund	3,000.00
		Audubon Fund	2,500.00
		Building Fund	10,400.00
		Newberry Fund	1,046.25
		Income of Permanent Fund	560.00
		Income of Publication Fund	000.00
		Income of Audubon Fund	75.00
		Income of Building Fund	1,126.96
		Income of Newberry Fund	299.01
		General Income	302.45
	$41.822.24		$41,822.24

Examined and found to be correct,

CHAS. F. COX,
GEORGE F. KUNZ,
FREDERIC S. LEE,
Auditing Committee.

THE ORGANIZATION OF THE NEW YORK ACADEMY OF SCIENCES

THE ORIGINAL CHARTER

AN ACT TO INCORPORATE THE

LYCEUM OF NATURAL HISTORY IN THE CITY OF NEW YORK

Passed April 20, 1818

Whereas, The members of the Lyceum of Natural History have petitioned for an act of incorporation, and the Legislature, impressed with the importance of the study of Natural History, as connected with the wants, the comforts and the happiness of mankind, and conceiving it their duty to encourage all laudable attempts to promote the progress of science in this State—therefore,

1. *Be it enacted by the People of the State of New York represented in Senate and Assembly,* That Samuel L. Mitchill, Casper W. Eddy, Frederick C. Schaeffer, Nathaniel Paulding, William Cooper, Benjamin P. Kissam, John Torrey, William Cumberland, D'Jurco V. Knevels, James Clements and James Pierce, and such other persons as now are, and may from time to time become members, shall be, and hereby are constituted a body corporate and politic, by the name of Lyceum of Natural History in the City of New York, and that by that name they shall have perpetual succession, and shall be persons capable of suing and being sued, pleaded and being impleaded, answering and being answered unto, defending and being defended, in all courts and places whatsoever; and may have a common seal, with power to alter the same from time to time; and shall be capable of purchasing, taking, holding, and enjoying to them and their successors, any real estate in fee simple or otherwise, and any goods, chattels, and personal estate, and of selling, leasing, or otherwise disposing of said real or personal estate, or any part thereof, at their will and pleasure: *Provided always,* that the clear annual value or income of such real or personal estate shall not exceed the sum of five thousand dollars: *Provided,* however, that the funds of the said Corporation shall be used and appropriated to the promotion of the objects stated in the preamble to this act, and those only.

2. *And be it further enacted,* That the said Society shall from time to time, forever hereafter, have power to make, constitute, ordain, and establish such by-laws and regulations as they shall judge proper, for the elec-

tion of their officers; for prescribing their respective functions, and the mode of discharging the same; for the admission of new members; for the government of the officers and members thereof; for collecting annual contributions from the members towards the funds thereof; for regulating the times and places of meeting of the said Society; for suspending or expelling such members as shall neglect or refuse to comply with the by-laws or regulations, and for the managing or directing the affairs and concerns of the said Society: *Provided* such by-laws and regulations be not repugnant to the Constitution and laws of this State or of the United States.

3. *And be it further enacted,* That the officers of the said Society shall consist of a President and two Vice-Presidents, a Corresponding Secretary, a Recording Secretary, a Treasurer, and five Curators, and such other officers as the Society may judge necessary; who shall be annually chosen, and who shall continue in office for one year, or until others be elected in their stead; that if the annual election shall not be held at any of the days for that purpose appointed, it shall be lawful to make such election at any other day; and that five members of the said Society, assembling at the place and time designated for that purpose by any by-law or regulation of the Society, shall constitute a legal meeting thereof.

4. *And be it further enacted,* That Samuel L. Mitchill shall be the President; Casper W. Eddy the First Vice-President; Frederick C. Schaeffer the Second Vice-President; Nathaniel Paulding, Corresponding Secretary; William Cooper, Recording Secretary; Benjamin P. Kissam, Treasurer, and John Torrey, William Cumberland, D'Jurco V. Knevels, James Clements, and James Pierce, Curators; severally to be the first officers of the said Corporation, who shall hold their respective offices until the twenty-third day of February next, and until others shall be chosen in their places.

5. *And be it further enacted,* That the present Constitution of the said Association shall, after passing of this Act, continue to be the Constitution thereof; and that no alteration shall be made therein, unless by a vote to that effect of three-fourths of the resident members, and upon the request in writing of one-third of such resident members, and submitted at least one month before any vote shall be taken thereupon.

State of New York, Secretary's Office.

I CERTIFY the preceding to be a true copy of an original Act of the Legislature of this State, on file in this Office.

ARCH'D CAMPBELL,
Dep. Sec'y.

ALBANY, *April* 29, 1818.

ORDER OF COURT

ORDER OF THE SUPREME COURT OF THE STATE OF NEW YORK
TO CHANGE THE NAME OF

THE LYCEUM OF NATURAL HISTORY IN THE CITY OF NEW YORK

TO

THE NEW YORK ACADEMY OF SCIENCES

WHEREAS, in pursuance of the vote and proceedings of this Corporation to change the corporate name thereof from "The Lyceum of Natural History in the City of New York" to "The New York Academy of Sciences," which vote and proceedings appear to record, an application has been made in behalf of said Corporation to the Supreme Court of the State of New York to legalize and authorize such change, according to the statute in such case provided, by Chittenden & Hubbard, acting as the attorneys of the Corporation, and the said Supreme Court, on the 5th day of January, 1876, made the following order upon such application in the premises, viz:

At a special term of the Supreme Court of the State of New York, held at the Chambers thereof, in the County Court House, in the City of New York, the 5th day of January, 1876:

Present—HON. GEO. C. BARRETT, *Justice*.

In the matter of the application of the Lyceum of Natural History in the City of New York to authorize it to assume the corporate name of the New York Academy of Sciences.

On reading and filing the petition of the Lyceum of Natural History in the City of New York, duly verified by John S. Newberry, the President and chief officer of said Corporation, to authorize it to assume the corporate name of the New York Academy of Sciences, duly setting forth the grounds of said application, and on reading and filing the affidavit of Geo. W. Quackenbush, showing that notice of such application had been duly published for six weeks in the State paper, to wit, *The Albany Evening Journal,* and the affidavit of David S. Owen, showing that notice of such application has also been duly published in the proper newspaper of the County of New York, in which county said Corporation had its business office, to wit, in *The Daily Register,* by which it appears to my satisfaction that such notice has been so published, and on reading and filing the affidavits of Robert H. Browne and J. S. Newberry, thereunto annexed, by which it appears to my satisfaction that the application is made in pursuance of a resolution of the managers of said Corporation to that end named, and there appearing to me to be no reasonable objection to said Corporation so changing its name as prayed in said petition: Now on motion of Grosvenor S. Hubbard, of Counsel for Petitioner, it is

Ordered, That the Lyceum of Natural History in the City of New York be and is hereby authorized to assume the corporate name of The New York Academy of Sciences.

Indorsed: Filed January 5, 1876,

A copy.

Wm. Walsh, *Clerk.*

Resolution of The Academy, *accepting the order of the Court, passed February* 21, 1876

And whereas, The order hath been published as therein required, and all the proceedings necessary to carry out the same have been had, Therefore:

Resolved, That the foregoing order be and the same is hereby accepted and adopted by this Corporation, and that in conformity therewith the corporate name thereof, from and after the adoption of the vote and resolution herein above referred to, be and the same is hereby declared to be

THE NEW YORK ACADEMY OF SCIENCES

THE AMENDED CHARTER

March 19, 1902

Chapter 181 of the Laws of 1902

An Act to amend chapter one hundred and ninety-seven of the laws of eighteen hundred and eighteen, entitled "An act to incorporate the Lyceum of Natural History in the City of New York," a Corporation now known as The New York Academy of Sciences and to extend the powers of said Corporation.

(Became a law March 19, 1902, with the approval of the Governor. Passed, three-fifths being present.)

The People of the State of New York, represented in Senate and Assembly, do enact as follows:

Section I. The Corporation incorporated by chapter one hundred and ninety-seven of the laws of eighteen hundred and eighteen, entitled "An act to incorporate the Lyceum of Natural History in the City of New York," and formerly known by that name, but now known as The New York Academy of Sciences through change of name pursuant to order made by the supreme court at the city and county of New York, on January fifth, eighteen hundred and seventy-six, is hereby authorized and empowered to raise money for, and to erect and maintain, a building in the city of New York for its use, and in which also at its option other scientific societies may be admitted and have their headquarters upon such terms as said Corporation may make with them, portions of which building may be also rented out by said Corporation for any lawful uses for the purposes of obtaining income for the maintenance of such building and for the promotion of the objects of the Corporation; to establish, own, equip, and administer a public library, and a museum having especial reference to scientific subjects; to publish communications, transactions, scientific works, and periodicals; to give scientific instruction by lectures or otherwise; to encourage the advancement of scientific research and discovery, by gifts of money, prizes, or other assistance thereto. The building, or rooms, of said Corporation in the city of New York used exclusively for library or scientific purposes shall be subject to the provisions and be entitled to the benefits of subdivision seven of section four of chapter nine hundred and eight of the laws of eighteen hundred and ninety-six, as amended.

Section II. The said Corporation shall from time to time forever hereafter have power to make, constitute, ordain, and establish such by-laws and regulations as it shall judge proper for the election of its officers; for prescribing their respective functions, and the mode of discharging the same; for the admission of new members; for the government of officers and members thereof; for collecting dues and contributions towards the funds thereof; for regulating the times and places of meeting of said Corporation; for suspending or expelling such members as shall neglect or refuse to comply with the by-laws or regulations, and for managing or directing the affairs or concerns of the said Corporation: and may from time to time alter or modify its constitution, by-laws, rules, and regulations.

SECTION III. The officers of the said Corporation shall consist of a president and two or more vice-presidents, a corresponding secretary, a recording secretary, a treasurer, and such other officers as the Corporation may judge necessary; who shall be chosen in the manner and for the terms prescribed by the constitution of the said Corporation.

SECTION IV. The present constitution of the said Corporation shall, after the passage of this act, continue to be the constitution thereof until amended as herein provided. Such constitution as may be adopted by a vote of not less than three-quarters of such resident members and fellows of the said New York Academy of Sciences as shall be present at a meeting thereof, called by the Recording Secretary for that purpose, within forty days after the passage of this act, by written notice duly mailed, postage prepaid, and addressed to each fellow and resident member at least ten days before such meeting, at his last known place of residence, with street and number when known, which meeting shall be held within three months after the passage of this act, shall be thereafter the constitution of the said New York Academy of Sciences, subject to alteration or amendment in the manner provided by such constitution.

SECTION V. The said Corporation shall have power to consolidate, to unite, to co-operate, or to ally itself with any other society or association in the city of New York organized for the promotion of the knowledge or the study of any science, or of research therein, and for this purpose to receive, hold, and administer real and personal property for the uses of such consolidation, union, co-operation, or alliance subject to such terms and regulations as may be agreed upon with such associations or societies.

SECTION VI. This act shall take effect immediately.

STATE OF NEW YORK,

OFFICE OF THE SECRETARY OF STATE.

I have compared the preceding with the original law on file in this office, and do hereby certify that the same is a correct transcript therefrom, and the whole of said original law.

Given under my hand and the seal of office of the Secretary of State, at the city of Albany, this eighth day of April, in the year one thousand nine hundred and two.

JOHN T. MCDONOUGH,
Secretary of State.

CONSTITUTION

Adopted, April 24, 1902, and Amended at Subsequent Times

Article I. The name of this Corporation shall be The New York Academy of Sciences. Its object shall be the advancement and diffusion of scientific knowledge, and the center of its activities shall be in the City of New York.

Article II. The Academy shall consist of five classes of members, namely: Active Members, Fellows, Associate Members, Corresponding Members and Honorary Members. Active Members shall be the members of the Corporation who live in or near the City of New York, or who, having removed to a distance, desire to retain their connection with the Academy. Fellows shall be chosen from the Active Members in virtue of their scientific attainments. Corresponding and Honorary Members shall be chosen from among persons who have attained distinction in some branch of science. The number of Corresponding Members shall not exceed two hundred, and the number of Honorary Members shall not exceed fifty.

Article III. None but Fellows and Active Members who have paid their dues up to and including the last fiscal year shall be entitled to vote or to hold office in the Academy.

Article IV. The officers of the Academy shall be a President, as many Vice-Presidents as there are sections of the Academy, a Corresponding Secretary, a Recording Secretary, a Treasurer, a Librarian, an Editor, six elected Councilors and one additional Councilor from each allied society or association. The annual election shall be held on the third Monday in December, the officers then chosen to take office at the first meeting in January following.

There shall also be elected at the same time a Finance Committee of three.

Article V. The officers named in Article IV shall constitute a Council, which shall be the executive body of the Academy with general control over its affairs, including the power to fill *ad interim* any vacancies that may occur in the offices. Past Presidents of the Academy shall be *ex-officio* members of the Council.

Article VI. Societies organized for the study of any branch of science may become allied with the New York Academy of Sciences by consent of the Council. Members of allied societies may become Active Members of the Academy by paying the Academy's annual fee, but as members of an allied society they shall be Associate Members with the rights and privileges of other Associate Members, except the receipt of its publications. Each allied society shall have the right to delegate one of its members, who is also an Active Member of the Academy, to the Council of the Academy, and such delegate shall have all the rights and privileges of other Councilors.

ARTICLE VII. The President and Vice-Presidents shall not be eligible to more than one re-election until three years after retiring from office; the Secretaries and Treasurer shall be eligible to re-election without limitation. The President, Vice-Presidents and Secretaries shall be Fellows. The terms of office of elected Councilors shall be three years, and these officers shall be so grouped that two, at least one of whom shall be a Fellow, shall be elected and two retired each year. Councilors shall not be eligible to re-election until after the expiration of one year.

ARTICLE VIII. The election of officers shall be by ballot, and the candidates having the greatest number of votes shall be declared duly elected.

ARTICLE IX. Ten members, the majority of whom shall be Fellows, shall form a quorum at any meeting of the Academy at which business is transacted.

ARTICLE X. The Academy shall establish by-laws, and may amend them from time to time as therein provided.

ARTICLE XI. This Constitution may be amended by a vote of not less than three fourths of the fellows and three fourths of the active members present and voting at a regular business meeting of the Academy, provided that such amendment shall be publicly submitted in writing at the preceding business meeting, and provided also that the Recording Secretary shall send a notice of the proposed amendment at least ten days before the meeting, at which a vote shall be taken, to each Fellow and Active Member entitled to vote.

BY-LAWS

AS ADOPTED, OCTOBER 6, 1902, AND AMENDED AT SUBSEQUENT TIMES

CHAPTER I.

OFFICERS

1. *President.* It shall be the duty of the President to preside at the business and special meetings of the Academy: he shall exercise the customary duties of a presiding officer.

2. *Vice-Presidents.* In the absence of the President, the senior Vice-President, in order of Fellowship, shall act as the presiding officer.

3. *Corresponding Secretary.* The Corresponding Secretary shall keep a corrected list of the Honorary and Corresponding Members, their titles and addresses, and shall conduct all correspondence with them. He shall make a report at the Annual Meeting.

4. *Recording Secretary.* The Recording Secretary shall keep the minutes of the Academy proceedings; he shall have charge of all documents belonging to the Academy, and of its corporate seal, which he shall affix and attest as directed by the Council; he shall keep a corrected list of the Active Members and Fellows, and shall send them announcements of the Meetings of the Academy; he shall notify all Members and Fellows of their election, and committees of their appointment; he shall give notice to the Treasurer and to the Council of matters requiring their action, and shall bring before the Academy business presented by the Council. He shall make a report at the Annual Meeting.

5. *Treasurer.* The Treasurer shall have charge, under the direction of the Council, of all moneys belonging to the Academy, and of their investment. He shall receive all fees, dues and contributions to the Academy, and any income that may accrue from property or investment; he shall report to the Council at its last meeting before the Annual Meeting the names of members in arrears; he shall keep the property of the Academy insured, and shall pay all debts against the Academy the discharge of which shall be ordered by the Council. He shall report to the Council from time to time the state of the finances, and at the Annual Meeting shall report to the Academy the receipts and expenditures for the entire year.

6. *Librarian.* The Librarian shall have charge of the library, under the general direction of the Library Committee of the Council, and shall conduct all correspondence respecting exchanges of the Academy. He shall make a report on the condition of the library at the Annual Meeting.

7. *Editor.* The editor shall have charge of the publications of the Academy, under the general direction of the Publication Committee of the Council. He shall make a report on the condition of the publications at the Annual Meeting.

Chapter II

COUNCIL

1. *Meetings.* The Council shall meet once a month, or at the call of the President. It shall have general charge of the affairs of the Academy.

2. *Quorum.* Five members of the Council shall constitute a quorum.

3. *Officers.* The President, Vice-Presidents and Recording Secretary of the Academy shall hold the same offices in the Council.

4. *Committees.* The Standing Committees of the Council shall be: (1) an Executive Committee consisting of the President, Treasurer, and Recording Secretary; (2) a Committee on Publication; (3) a Committee on the Library, and such other committees as from time to time shall be authorized by the Council. The action of these committees shall be subject to revision by the Council.

Chapter III

FINANCE COMMITTEE

The Finance Committee of the Academy shall audit the Annual Report of the Treasurer, and shall report on financial questions whenever called upon to do so by the Council.

Chapter IV

ELECTIONS

1. *Active Members.* (*a*) Active Members shall be nominated in writing to the Council by at least two active Members or Fellows. If approved by the Council, they may be elected at the succeeding business meeting.

(*b*) Any Active Member who, having removed to a distance from the city of New York, shall nevertheless express a desire to retain his connection with the Academy, may be placed by vote of the Council on a list of Non-resident Members. Such members shall relinquish the full privileges and obligations of Active Members. (*Vide* Chapters V and X.)

2. *Associate Members.* Workers in science may be elected to Associate Membership for a period of two years in the manner prescribed for Active Members. They shall not have the power to vote and shall not be eligible to election as Fellows, but may receive the publications. At any time subsequent to their election they may assume the full privileges of Active Members by paying the dues of such Members.

3. *Fellows, Corresponding Members and Honorary Members.* Nominations for Fellows, Corresponding Members and Honorary Members may be made in writing either to the Recording Secretary or to the Council at its meeting prior to the Annual Meeting. If approved by the Council, the nominees shall then be balloted for at the Annual Meeting.

4. *Officers.* Nominations for Officers, with the exception of Vice-Presidents, may be sent in writing to the Recording Secretary, with the name of the proposer, at any time not less than thirty days before the Annual Meeting. Each section of the Academy shall nominate a candi-

date for Vice-President, who, on election, shall be Chairman of the section; the names of such nominees shall be sent to the Recording Secretary properly certified by the sectional secretaries, not less than thirty days before the Annual Meeting. The Council shall then prepare a list which shall be the regular ticket. This list shall be mailed to each Active Member and Fellow at least one week before the Annual Meeting. But any Active Member or Fellow entitled to vote shall be entitled to prepare and vote another ticket.

Chapter V

DUES

1. *Dues.* The annual dues of Active Members and Fellows shall be $10, payable in advance at the time of the Annual Meeting; but new members elected after May 1, shall pay $5 for the remainder of the fiscal year.

The annual dues of elected Associate Members shall be $3, payable in advance at the time of the Annual Meeting.

Non-resident Members shall be exempt from dues, so long as they shall relinquish the privileges of Active Membership. (*Vide* Chapter X.)

2. *Members in Arrears.* If any Active Member or Fellow whose dues remain unpaid for more than one year, shall neglect or refuse to pay the same within three months after notification by the Treasurer, his name may be erased from the rolls by vote of the Council. Upon payment of his arrears, however, such person may be restored to Active Membership or Fellowship by vote of the Council.

3. *Renewal of Membership.* Any Active Member or Fellow who shall resign because of removal to a distance from the City of New York, or any Non-resident Member, may be restored by vote of the Council to Active Membership or Fellowship at any time upon application.

Chapter VI

PATRONS, DONORS AND LIFE MEMBERS

1. *Patrons.* Any person contributing at one time $1000 to the general funds of the Academy shall be a Patron and, on election by the Council, shall enjoy all the privileges of Active Members.

2. *Donors.* Any person contributing $50 or more annually to the general funds of the Academy shall be termed a Donor and, on election by the Council, shall enjoy all the privileges of Active Members.

3. *Life Members.* Any Active Member or Fellow contributing at one

time $100 to the general funds of the Academy shall be a Life Member and shall thereafter be exempt from annual dues; and any Active Member or Fellow who has paid annual dues for twenty-five years or more may, upon his written request, be made a life member and be exempt from further payment of dues.

Chapter VII

SECTIONS

1. *Sections.* Sections devoted to special branches of Science may be established or discontinued by the Academy on the recommendation of the Council. The present sections of the Academy are the Section of Astronomy, Physics and Chemistry, the Section of Biology, the Section of Geology and Mineralogy and the Section of Anthropology and Psychology.

2. *Organization.* Each section of the Academy shall have a Chairman and a Secretary, who shall have charge of the meetings of their Section. The regular election of these officers shall take place at the October or November meeting of the section, the officers then chosen to take office at the first meeting in January following.

3. *Affiliation.* Members of scientific societies affiliated with the Academy, and members of the Scientific Alliance, or men of science introduced by members of the Academy, may attend the meetings and present papers under the general regulations of the Academy.

Chapter VIII

MEETINGS

1. *Business Meetings.* Business meetings of the Academy shall be held on the first Monday of each month from October to May inclusive.

2. *Sectional Meetings.* Sectional meetings shall be held on Monday evenings from October to May inclusive, and at such other times as the Council may determine. The sectional meeting shall follow the business meeting when both occur on the same evening.

3. *Annual Meeting.* The Annual Meeting shall be held on the third Monday in December.

4. *Special Meetings.* A special meeting may be called by the Council, provided one week's notice be sent to each Active Member and Fellow, stating the object of such meeting.

Chapter IX

ORDER OF BUSINESS

1. *Business Meetings.* The following shall be the order of procedure at business meetings:

    1. Minutes of the previous business meeting.
    2. Report of the Council.
    3. Reports of Committees.
    4. Elections.
    5. Other business.

2. *Sectional Meetings.* The following shall be the order of procedure at sectional meetings:

    1. Minutes of the preceding meeting of the section.
    2. Presentation and discussion of papers.
    3. Other scientific business.

3. *Annual Meetings.* The following shall be the order of procedure at Annual Meetings:

    1. Annual reports of the Corresponding Secretary, Recording Secretary, Treasurer, Librarian, and Editor.
    2. Election of Honorary Members, Corresponding Members, and Fellows.
    3. Election of officers for the ensuing year.
    4. Annual address of the retiring President.

Chapter X

PUBLICATIONS

1. *Publications.* The established publications of the Academy shall be the *Annals* and the *Memoirs.* They shall be issued by the Editor under the supervision of the Committee on Publications.

2. *Distribution.* One copy of all publications shall be sent to each Patron, Life Member, Active Member and Fellow, *provided,* that upon enquiry by the Editor such Members or Fellows shall signify their desire to receive them.

3. *Publication Fund.* Contributions may be received for the publication fund, and the income thereof shall be applied toward defraying the expenses of the scientific publications of the Academy.

Chapter XI

GENERAL PROVISIONS

1. *Debts.* No debts shall be incurred on behalf of the Academy, unless authorized by the Council.

2. *Bills.* All bills submitted to the Council must be certified as to correctness by the officers incurring them.

3. *Investments.* All the permanent funds of the Academy shall be invested in United States or in New York State securities or in first mortgages on real estate, provided they shall not exceed sixty-five per cent. of the value of the property, or in first mortgage bonds of corporations which have paid dividends continuously on their common stock for a period of not less than five years. All income from patron's fees, life membership fees and donor's fees shall be added to the permanent fund.

4. *Expulsion, etc.* Any Member or Fellow may be censured, suspended or expelled, for violation of the Constitution or By-Laws, or for any offence deemed sufficient, by a vote of three fourths of the Members and three fourths of the Fellows present at any business meeting, provided such action shall have been recommended by the Council at a previous business meeting, and also, that one month's notice of such recommendation and of the offence charged shall have been given the Member accused.

5. *Changes in By-Laws.* No alteration shall be made in these By-Laws unless it shall have been submitted publicly in writing at a business meeting, shall have been entered on the Minutes with the names of the Members or Fellows proposing it, and shall be adopted by two-thirds of the Members and Fellows present and voting at a subsequent business meeting.

MEMBERSHIP OF THE

NEW YORK ACADEMY OF SCIENCES

HONORARY MEMBERS

31 December, 1910

Elected.

1898. Arthur Auwers, Berlin, Germany.
1889. Charles Barrois, Lille, France.
1907. William Bateson, Cambridge, England.
1910. Theodor Boveri, Würzburg, Germany.
1901. Charles Vernon Boys, London, England.
1904. W. C. Brögger, Christiana, Norway.
1899. Sir George Howard Darwin, Cambridge, England.
1876. W. Boyd Dawkins, Manchester, England.
1902. Sir James Dewar, Cambridge, England.
1901. Emil Fischer, Berlin, Germany.
1910. Sir Francis Galton, London, England.
1876. Sir Archibald Geikie, Haslemere, Surrey, England.
1901. James Geikie, Edinburgh, Scotland.
1898. Sir David Gill, London, England.
1909. K. F. Göbel, Munich, Germany.
1889. George Lincoln Goodale, Cambridge, Mass.
1909. Paul von Groth, Munich, Germany.
1894. Ernst Häckel, Jena, Germany.
1899. Julius Hann, Vienna, Austria.
1898. George W. Hill, West Nyack, N. Y.
1907. Sir Joseph D. Hooker, Kew, England.
1896. Ambrosius A. W. Hubrecht, Utrecht, Netherlands.
1901. William James, Cambridge, Mass.
1896. Felix Klein, Göttingen, Germany.
1909. Alfred Lacroix, Paris, France.
1876. Viktor von Lang, Vienna, Austria.
1898. E. Ray Lankester, London, England.
1880. Sir Norman Lockyer, London, England.
1900. Franz Leydig, Tauber, Germany.
1898. Fridtjof Nansen, Christiana, Norway.
1908. Wilhelm Ostwald, Gross-Bothen, Germany.

ELECTED.

1898. ALBRECHT PENCK, Berlin, Germany.
1898. WILHELM PFEFFER, Leipzig, Germany.
1900. EDWARD CHARLES PICKERING, Cambridge, Mass.
1900. JULES HENRI POINCARÉ, Paris, France.
1901. Sir WILLIAM RAMSAY, London, England.
1899. Lord RAYLEIGH, Witham, Essex, England.
1898. HANS H. REUSCH, Christiana, Norway.
1887. Sir HENRY ENFIELD ROSCOE, London, England.
1887. HEINRICH ROSENBUSCH, Heidelberg, Germany.
1904. KARL VON DEN STEINEN, Berlin, Germany.
1904. G. JOHNSTONE STONEY, London, England.
1908. EDUARD STRASBURGER, Bonn, Germany.
1896. JOSEPH JOHN THOMSON, Cambridge, England.
1900. EDWARD BURNETT TYLOR, Oxford, England.
1904. HUGO DE VRIES, Amsterdam, Netherlands.
1907. JAMES WARD, Cambridge, England.
1909. AUGUST WEISSMANN, Freiburg, Germany.
1904. WILHELM WUNDT, Leipzig, Germany.
1904. FERDINAND ZIRKEL, Leipzig, Germany.

CORRESPONDING MEMBERS

31 DECEMBER, 1910

1883. CHARLES CONRAD ABBOTT, Trenton, N. J.
1898. FRANK D. ADAMS, Montreal, Canada.
1891. JOSÉ G. AGUILERA, Mexico City, Mexico.
1890. WILLIAM DEWITT ALEXANDER, Honolulu, Hawaii.
1899. C. W. ANDREWS, London, England.
1876. JOHN HOWARD APPLETON, Providence, R. I.
1899. J. G. BAKER, Kew, England.
1898. ISAAC BAGLEY BALFOUR, Edinburgh, Scotland.
1878. ALEXANDER GRAHAM BELL, Washington, D. C.
1867. EDWARD L. BERTHOUD, Golden, Colo.
1897. HERBERT BOLTON, Bristol, England.
1899. G. A. BOULENGER, London, England.
1874. T. S. BRANDEGEE, San Diego, Calif.
1884. JOHN C. BRANNER, Stanford University, Calif.
1894. BOHUSLAV BRAUNER, Prague, Bohemia.
1874. WILLIAM BREWSTER, Cambridge, Mass.
1876. GEORGE JARVIS BRUSH, New Haven, Conn.

ELECTED.

1898. T. C. CHAMBERLIN, Chicago, Ill.
1876. FRANK WIGGLESWORTH CLARKE, Washington, D. C.
1891. L. CLERC, Ekaterinburg, Russia.
1877. THEODORE B. COMSTOCK, Los Angeles, Calif.
1868. M. C. COOKE, London, England.
1876. H. B. CORNWALL, Princeton, N. J.
1880. CHARLES B. CORY, Boston, Mass.
1877. JOSEPH CRAWFORD, Philadelphia, Pa.
1866. HERMANN CREDNER, Leipzig, Germany.
1895. HENRY P. CUSHING, Cleveland, O.
1879. T. NELSON DALE, Pittsfield, Mass.
1870. WILLIAM HEALEY DALL, Washington, D. C.
1885. EDWARD SALISBURY DANA, New Haven, Conn.
1898. WILLIAM M. DAVIS, Cambridge, Mass.
1894. RUTHVEN DEANE, Chicago, Ill.
1899. CHARLES DÉPERET, Lyons, France.
1890. ORVILLE A. DERBY, Rio de Janeiro, Brazil.
1899. LOUIS DOLLO, Brussels, Belgium.
1876. HENRY W. ELLIOTT, Lakewood, O.
1880. JOHN B. ELLIOTT, New Orleans, La.
1869. FRANCIS E. ENGELHARDT, Syracuse, N. Y.
1879. HERMAN LEROY FAIRCHILD, Rochester, N. Y.
1879. FRIEDRICH BERNHARD FITTICA, Marburg, Germany.
1885. LAZARUS FLETCHER, London, England.
1899. EBERHARD FRAAS, Stuttgart, Germany.
1879. REINHOLD FRITZGARTNER, Tegucigalpa, Honduras.
1870. GROVE K. GILBERT, Washington, D. C.
1858. THEODORE NICHOLAS GILL, Washington, D. C.
1865. CHARLES A. GOESSMAN, Amherst, Mass.
1888. FRANK AUSTIN GOOCH, New Haven, Conn.
1868. C. R. GREENLEAF, San Francisco, Calif.
1883. MARQUIS ANTONIO DE GREGORIO, Palermo, Sicily.
1869. R. J. LECHMERE GUPPY, Trinidad, British West Indies.
1898. GEORGE E. HALE, Mt. Wilson, Calif.
1882. BARON ERNST VON HESSE-WARTEGG, Lucerne, Switzerland
1867. C. H. HITCHCOCK, Honolulu, H. I.
1900. WILLIAM HENRY HOLMES, Washington, D. C.
1890. H. D. HOSKOLD, Buenos Ayres, Argentine Republic.
1896. J. P. IDDINGS, Brinklow, Md.
1875. MALVERN W. ILES, Dubuque, Ia.

ELECTED.

1899. OTTO JÄCKEL, Greifswald, Germany.
1876. DAVID STARR JORDAN, Stanford University, Calif.
1876. GEORGE A. KOENIG, Houghton, Mich.
1888. BARON R. KUKI, Tokyo, Japan.
1876. JOHN W. LANGLEY, Cleveland, O.
1876. S. A. LATTIMORE, Rochester, N. Y.
1894. WILLIAM LIBBEY, Princeton, N. J.
1899. ARCHIBALD LIVERSIDGE, London, England.
1876. GEORGE MACLOSKIE, Princeton, N. J.
1876. JOHN WILLIAM MALLET, Charlottesville, Va.
1891. CHARLES RIBORG MANN, Chicago, Ill.
1867. GEORGE F. MATTHEW, St. John, N. B., Canada.
1874. CHARLES JOHNSON MAYNARD, West Newton, Mass.
1874. THEODORE LUQUEER MEAD, Oviedo, Fla.
1888. SETH E. MEEK, Chicago, Ill.
1892. J. DE MENDIZÁBAL-TAMBORREL, Mexico City, Mexico.
1874. CLINTON HART MERRIAM, Washington, D. C.
1898. MANSFIELD MERRIAM, South Bethlehem, Pa.
1890. A. B. MEYER, Berlin, Germany.
1878. CHARLES SEDGWICK MINOT, Boston, Mass.
1876. WILLIAM GILBERT MIXTER, New Haven, Conn.
1890. RICHARD MOLDENKE, Watchung, N. J.
1895. C. LLOYD MORGAN, Bristol, England.
1864. EDWARD S. MORSE, Salem, Mass.
1898. GEORGE MURRAY, London, England.
——. EUGEN NETTO, Giessen, Germany.
1866. ALFRED NEWTON, Cambridge, England.
1897. FRANCIS C. NICHOLAS, New York, N. Y.
1882. HENRY ALFRED ALFORD NICHOLLS, Dominica, B. W. I.
1881. WILLIAM H. NILES, Boston, Mass.
1880. EDWARD J. NOLAN, Philadelphia, Pa.
1879. FREDERICK A. OBER, Hackensack, N. J.
1876. JOHN M. ORDWAY, New Orleans, La.
1900. GEORGE HOWARD PARKER, Cambridge, Mass.
1876. STEPHEN F. PECKHAM, New York, N. Y.
1888. GEORGE E. POST, Beirût, Syria.
1894. EDWARD BAGNALL POULTON, Oxford, England.
1877. FREDERICK PRIME, Philadelphia, Pa.
1868. RAPHAEL PUMPELLY, Newport, R. I.
1876. B. ALEX. RANDALL, Philadelphia, Pa.

Elected.

1876. Ira Remsen, Baltimore, Md.
1874. Robert Ridgway, Washington, D. C.
1886. William L. Robb, Troy, N. Y.
1876. Samuel P. Sadtler, Philadelphia, Pa.
1899. D. Max Schlosser, Munich, Germany.
1867. Paul Schweitzer, Columbia, Mo.
1898. W. B. Scott, Princeton, N. J.
1876. Samuel H. Scudder, Cambridge, Mass.
1894. W. T. Sedgwick, Boston, Mass.
1876. Andrew Sherwood, Portland, Ore.
1883. J. Ward Smith, Newark, N. J.
1895. Charles H. Smyth, Jr., Princeton, N. J.
1890. J. Selden Spencer, Tarrytown, N. Y.
1896. Robert Stearns, Los Angeles, Calif.
1890. Walter LeConte Stevens, Lexington, Va.
1876. Francis H. Storer, Boston, Mass.
1885. Rajah Sourindro Mohun Tagore, Calcutta, India.
1893. J. P. Thomson, Brisbane, Queensland, Australia.
1899. R. H. Traquair, Colinton, Scotland.
1877. John Trowbridge, Cambridge, Mass.
1876. D. K. Tuttle, Philadelphia, Pa.
1871. Henri Van Heurck, Antwerp, Belgium.
1900. Charles R. Van Hise, Madison, Wis.
1867. Addison Emery Verrill, New Haven, Conn.
1890. Anthony Wayne Vogdes, San Diego, Calif.
1898. Charles Doolittle Walcott, Washington, D. C.
1876. Leonard Waldo, New York, N. Y.
1900. Sho Watasé, Tokyo, Japan.
1897. Stuart Weller, Chicago, Ill.
1874. I. C. White, Morgantown, W. Va.
1898. C. O. Whitman, Woods Holl, Mass.
1898. Henry Shaler Williams, Ithaca, N. Y.
1898. N. H. Winchell, Minneapolis, Minn.
1866. Horatio C. Wood, Philadelphia, Pa.
1899. A. Smith Woodward, London, England.
1876. Arthur Williams Wright, New Haven, Conn.
1876. Harry Crècy Yarrow, Washington, D. C.

ACTIVE MEMBERS

1910

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Allen, James Lane
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Anderson, A. J. C.
*Andrews, Roy C.
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Astor, John Jacob
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*Beebe, C. William
Beers, M. H.[1]
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van Beuren, F. T.
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Bishop, Miss Mary C.
Bishop, Samuel H.
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*†Bliss, Prof. Charles B.
†Blumenthal, George
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Brinsmade, Charles Lyman
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Bristol, Jno. I. D.
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Brown, T. Quincy
*Brownell, Silas B.
Bulkley, L. Duncan
*Bumpus, Prof. H. C., Ph.D.
Burr, Winthrop
*Bush, Wendell T.

[1] Deceased.

*Byrnes, Miss Esther F., Ph.D.
*Calkins, Prof. Gary N., Ph.D.
Camp, Frederick A.
*Campbell, Prof. William, Ph.D.
*Campbell, Prof. William M.
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Chubb, Percy
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†Collord, George W.
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de Coppet, E. J.
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Curtis, G. Warrington
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Davies, William G.
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Davis, David T.
*†Davis, William T.
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Eno, William Phelps
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Field, William B. Osgood
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*Flexner, Simon, M.D.
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Follett, Richard E.
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de Forest, Robert W.
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Goodridge, Frederick G.
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§Gould, George J.
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Hammond, James B.
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Hasslacher, Jacob
Haupt, Louis, M.D.
Havemeyer, F. C., Jr.
Havemeyer, J. C.
Havemeyer, William F.
Healy, J. R.
*Hering, Prof. Daniel W.
§Herrman, Mrs. Esther
*Herter, Christian A., M.D.[1]
Hess, Selmar
Hewlett, Walter J.
Higginson, James J.
*Hill, Robert T.
Hirsch, Charles S.
*Hitchcock, Miss F. R. M., Ph.D.
Hochschild, Berthold
Hodges, George W.
Hodenpyl, Anton G.
Hollenback, Miss Amelia B.
*Hollick, Arthur, Ph.D.
†Holt, Henry
†Hopkins, George B.
*Hornaday, William T., Sc.D.
Hotchkiss, Henry D.
*†Hovey, Edmund Otis, Ph.D.
*Howe, Prof. Henry M.
*Howe, Marshall A., Ph.D.
†Hoyt, A. W.
†Hoyt, Theodore R.
†Hubbard, Thomas H.

[1] Deceased.

Hubbard, Walter C.
Hughes, Hon. Charles E.
Humphreys, Edwin W.
Humphreys, Frederic H.
†Huntington, Archer M.
*Hussakof, Louis, Ph. D.
Hustace, Francis
Huyler, John S.[1]
†Hutter, Karl
†Hyde, B. Talbot B.
Hyde, E. Francis
†Hyde, Frederic E., M.D.
Hyde, Henry St. John
Hyde, Jesse E.
†Iles, George
*Irving, Prof. John D.
von Isakovics, Alois
Iselin, Mrs. William E.
†Jackson, V. H.
*Jacobi, Abram, M.D.
James, F. Wilton
†Jarvie, James N.
Jennings, Robert E.
†Johnson, J. Herbert
Jones, Dwight A.
*§Julien, Alexis A., Ph.D.
Kahn, Otto H.
Kautz-Eulenburg, Miss P. R.
*†Kemp, Prof. James F., A.B., E.M.
†Keppler, Rudolph
†Kessler, George A.
Kinney, Morris
Kohlman, Charles
*Kunz, George F., M.A., Ph.D.
†Lamb, Osborn R.
Lambert, Adrian V. S., M.D.
Landon, Francis G.
Langdon, Woodbury G.
Langeloth, J.
*Langmann, Gustav, M.D.
Lawrence, Amos E.
Lawrence, John B.
†Lawton, James M.
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*Lee, Prof. Frederic S., Ph.D.
*§Levison, Wallace Goold
Levy, Emanuel
Lichtenstein, M.
Lichtenstein, Paul
Lieb, J. W., Jr.
Lindbo, J. A.
*Linville, H. R., Ph.D.
†Loeb, James
*Loeb, Prof. Morris, Ph.D.
Lounsberry, R. P.
†Low, Hon. Seth, LL.D.
*Lowie, Robert H., Ph.D.
*Lucas, F. A., Ph. D.
Ludlow, Nicoll
*Luquer, Prof. Lea McI.
*Lusk, Prof. Graham, M.D.
Lydig, Philip M.
Lyman, Frank
Lyon, Ralph
McCarthy, J. M.
†McCook, Col. J. J.
*†McMillin, Emerson
McNeil, Charles R.
MacArthur, Arthur F.
*MacDougall, Prof. Robert
Macy, Miss Mary Sutton, M.D.
†Macy, V. Everit
Mager, F. Robert
Mann, W. D.
Marble, Manton
Marcou, John B.
Marling, Alfred E.
†Marshall, Louis
Marston, E. S.
†Martin, Bradley

[1] Deceased.

*†Martin, Prof. Daniel S.
*Martin, T. Commerford
*†Matthew, W. D., Ph.D.
Maxwell, Francis T.
§Mead, Walter H.
Meigs, Titus B.
Mellen, C. S.
*Meltzer, S. J., M.D.
*Merrill, Frederick J. H., Ph.D.
Metz, Herman A.
Milburn, J. G.
de Milhau, Louis J.
Miller, George N., M. D.
*†Miner, Roy Waldo
Mitchell, Arthur M.
Morewood, George B.
Monae-Lesser, A., M.D.
Morgan, J. Pierpont
*Morgan, Prof. Thomas H.
Morgan, William Fellowes
Morris, Lewis R., M.D.
Munn, John P.
†Nesbit, Abram G.
†Nash, Nathaniel C.
†Nimick, Mrs. A. K.
Norton, George F.
Notman, George
Oakes, Francis J.
Ochs, Adolph S.
Oettinger, P. J., M.D.
*†Ogilvie, Miss Ida H., Ph.D.
†Olcott, E. E.
Olmsted, Mrs. Charles T.
Oppenheimer, Henry S.
*†Osborn, Prof. H. F., Sc.D., LL.D.
*Osburn, Raymond C., Ph. D.
Osborn, William C.
†Osborn, Mrs. William C.
†Owen, Miss Juliette A.
Owens, W. W.
Paddock, Eugene H.
†Parish, Henry
*Parker, Prof. Herschel C.
Parsons, Mrs. Edwin
*Parsons, John E.
†Patton, John
Paul, John J.
Pedersen, F. M., M.D.
*Pellew, Prof. C. E., Ph.D.
Pennington, William
†Perkins, William H.
Perry, Charles J.
*Peterson, Frederick, M.D.
*Petrunkevitch, Alexander, Ph.D.
Pettigrew, David L.
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Phipps, Henry
Phoenix, Lloyd
Pickhardt, Carl
Pierce, Henry Clay
*Pitkin, Lucius, Ph.D.
Plant, Albert
Planten, John R.
Polk, Dr. W. M.
*Pollard, Charles L., Ph.D.
*Poor, Prof. Charles L.
Porter, Eugene H.
Post, Abram S.
*Post, C. A.
*Post, George B.
Preston, Veryl
*Prince, Prof. John Dyneley
Pritchett, Pres. Henry S.
Proctor, George H.
*Pupin, Prof. M. I., Ph.D.
†Pyne, M. Taylor
Quackenbos, Prof. J. D., M.D.
Richardson, Frederick A.
*†Ricketts, Prof. P. de P., Ph.D
Riederer, Ludwig
Riker, Samuel

Risley, Mrs. Emilie B.
Robb, Hon. J. Hampden
Robert, Samuel
Roberts, C. H.
†Roebling, John A.
Rogers, E. L.
Rosenbaum, Selig
Rossbach, Jacob
Rothbarth, A.
Rowe, Basil W.
†de Rubio, H. A. C.
*Rusby, Prof. Henry H., M.D.
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Sage, John H.
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†Schermerhorn, F. A.
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†Schott, Charles M., Jr.
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Scoville, Robert
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Seligman, Jefferson
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Shillaber, William
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*Smith, Ernest E., M.D., Ph.D.
Smith, Frank Morse
*Smith, Prof. John B.
Snow, Elbridge G.
*Southwick, Edmund B., Ph.D.
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*Starr, Prof. M. Allen
Stefánsson, V.
Steinbrugge, Edward, Jr.
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Stettenheim, J. M.
*Stevens, George T., M.D.
*†Stevenson, Prof. John J., LL.D.
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†Stone, Miss Ellen J.
Stokes, J. G. Phelps
Strauss, Charles
Strauss, Frederick
Strauss, Isidor
†Streat, James
Sturgis, Mrs. Elizabeth M.
†Swords, P. Caroline
Taggart, Rush
*†Tatlock, John, Jr.
Taylor, George
Taylor, W. A.
Taylor, William H.
†Terry, James
Tesla, Nikola
*Thatcher, Edward J., Jr.
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Thaw, Benjamin
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Thompson, Lewis S.
†Thompson, Robert M.
*Thompson, Prof. W. Gilman
Thompson, Walter
*Thorndike, Prof. Edward L.
Thorne, Samuel
*Tower, R. W., Ph.D.

*Townsend, Charles H., Sc.D.
Tows, C. D.
*Trowbridge, Prof. C. C.
Tuckerman, Alfred, Ph.D.
Tuttle, Mrs. B. B.
Ullmann, E. S.
†Vail, Theo. N.
Vanderpoel, Mrs. J. A.
†Van Slyck, George W.
†Van Wyck, Robert A.
Vreeland, Frederick K.
*†Waller, Prof. Elwyn, Ph.D.
Walker, William I.
Warburg, F. N.
Warburg, Paul M.
Ward, Artemas
†Ward, Charles Willis
Ward, John Gilbert
Warner, Charles St. John
Warren, Charles Elliott
*Washington, Henry S., Ph.D.
Waterbury, J. I.
Watson, John J., Jr.
†Weir, Col. John
Wellington, Aaron H.
Wells, F. Lyman
Wheeler, H. L.
*White, Horace
*†Whitfield, Prof. R. P.[1]
Wicke, William
Williams, R. H.
Wills, Charles T.
*Wilson, Prof. E. B., Ph.D., LL.D.
Wilson, Henry R.
Wilson, J. H.
Wilson, Miss M. B., M.D.
*Winslow, Prof. Charles-E. A.
*Wissler, Clark, Ph.D.
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Wood, Mrs. Cynthia A.
Wood, William C.
*Woodbridge, Prof. F. J. E.
*Woodhull, Prof. John F., Ph.D.
*Woodman, Prof. J. Edmund
*Woodward, Prof. R. S.
*Woodworth, Prof. R. S.
Wotherspoon, Henry H.
Younglove, John, M.D.
Zabriskie, George
Zabriskie, Rev. J. L.[1]

ASSOCIATE MEMBERS

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Dublin, L. J.
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Gordon, Clarence E.
Hunter, George W.
Johnson, Julius M.
Kellicott, W. E., Ph.D.
McGregor, James Howard
Montague, W. P., Ph.D.
Northup, Dwight
Rogers, G. Sherburne
Stevenson, A. E.
Wood, Miss Elvira
Ziegler, Victor

[1] Deceased.

NON-RESIDENT MEMBERS.

*Abbe, Dr. Cleveland
Buchner, Edward F.
Burnett, Douglass
Davis, William H.
English, George L.
Finlay, Prof. G. I.
Frankland, Frederick W.
Hoffman, S. V.
Kendig, Amos B.
*Lloyd, Prof. F. E.
*Mayer, Dr. A. G.
*Pratt, Dr. J. H.
*Ries, Prof. H.
Reuter, L. H.
*Sumner, Dr. F. B.
*van Ingen, Prof. G.
*Wheeler, Wm. Morton

GENERAL INDEX TO VOLUME XX

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