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CHARLES D. WALCOTT, DIRECTOR

THE BEAR RIVER FORMATION AND ITS CHARACTERISTIC FAUNA

BY

CHARLES A. WHITE

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WASHINGTON, D. C., *March 20, 1895.*

SIR: I have the honor to transmit herewith the manuscript and illustrations of a paper on the Bear River formation and its characteristic fauna.

Very respectfully,

C. A. WHITE.

Hon. CHARLES D. WALCOTT,

Director of the United States Geological Survey.

OUTLINE OF THIS PAPER.

The object of this bulletin is the correction of an essential error which has long prevailed among geologists concerning the taxonomic position of one of the North American Cretaceous formations; that is, its object is to present a summary of the facts which show the entire separateness from the Laramie formation of that series of nonmarine strata which has heretofore been known as the Bear River Laramie, with which formation the Bear River series of strata has long been confounded. To this end the Bear River series is defined as a distinct formation, stratigraphically, geographically, and paleontologically, and its taxonomic position is stated in detail.

The subject is discussed historically, and with reference to the published results of the work of all the geologists who have written upon it. The work of correcting the error referred to and of properly characterizing the Bear River formation, having been accomplished upon a paleontological basis, all the known fossils of this formation are herein described and figured. Comparisons are also made of its fauna with those of other nonmarine formations of this and other continents, and relevant biological questions are discussed.

THE BEAR RIVER FORMATION AND ITS CHARACTERISTIC FAUNA.

By Charles A. White.

HISTORICAL STATEMENT.

When we consider the geographical extent of that great interior region of North America which has been traversed and reported upon by geologists during the past forty years, the difficulty with which former explorations and investigations were attended, the complex displacements which the strata of great areas in that region have suffered, and the newness of the geological problems which the early investigators encountered there, it is not strange that errors concerning the taxonomy of formations should occasionally have been made. Such errors have, however, been remarkably few, and most of these are justly excusable for the reasons just indicated.

One of the most important errors of the kind referred to is that which relates to the Bear River formation, the position of which, with relation to its associated formations, as has lately been shown, has been erroneously stated, or conceded without question, by every geologist who examined it during a period of twenty years immediately following its discovery. After that time some doubt was entertained as to the correctness of the currently accepted views of its relative position, the most definite of which were those published by myself and presently to be mentioned; but a detailed statement of what now appears to be a correct solution of the problem was first published by Mr. T. W. Stanton in 1892.[1]

Because of the former general acceptance of the error referred to, it became incorporated with American geological literature, and was consequently accepted by the geologists of other parts of the world who have had occasion to discuss formations whose fossil faunas more or less completely resemble those of the Laramie and Bear River formations.

It being the principal object of this bulletin to state further what is now regarded as the true taxonomic position of the Bear River formation, and to publish descriptions and figures of all the known fossil

[1] Am. Jour. Sci., 3d ser., Vol. XLIII, pp. 98-115.

forms which characterize it, the following historical account of the growth and prevalence of opinion concerning it is essential to a proper understanding of the subject.

In the year 1859 Mr. Henry Engelmann, geologist to the United States exploring expedition in charge of Captain Simpson, discovered a series of strata constituting an important section at a locality in southwestern Wyoming, upon the bank, and near the mouth, of Sulphur Creek, a tributary of Bear River. All except one of the members of this section, exclusive of the greatly unconformable overlying Tertiary strata which occur in the same neighborhood, were recognized as of marine origin, and at least one of these was found to be coal-bearing. The nonmarine member of this section was found to contain abundant remains of a molluscan fauna which was quite distinct from any then known in North America. The fact was recognized, however, that this fauna contains specific forms which are similar to certain members of the fauna of the Lignite formation occurring in the French Department of the Mouths of the Rhone, which fauna Matheron had a few years previously published and referred to the Tertiary.

During the fifteen years following the year of their discovery those nonmarine strata in southwestern Wyoming were generally spoken of by geologists as the Bear River estuary beds, because it was generally believed that they were of estuarine origin. Later explorations, however, have revealed their presence at other localities in Wyoming, and at still others in the adjoining part of Idaho, which are so widely separated from one another as to show that the formation has greater geographical extent than may reasonably be expected of a true estuarine deposit. Furthermore, no known fact, other than the evident brackish-water character of the branchiferous members of its fauna, is suggestive of its estuarine origin.

During the time mentioned, also, no one seems to have expressed any doubt of the Tertiary age of these strata, because their fossil fauna, although consisting of species which were then new to science, included types which were at that time regarded by all geologists as characteristic of the Tertiary. This view was supposed to be supported by the stratigraphical relation of these strata to the other members of the same section. That is, they were believed to constitute the latest member of the section in which they were found to occur, and to overlie unmistakably Cretaceous strata; but these facts will be more fully stated further on.

About the year 1876 those nonmarine strata which had been discovered at various and widely separated localities in the great interior region, and which are now properly referred to the Laramie, began to be generally recognized as constituting one great formation, and the nonmarine strata of the Bear River Valley district, herein specially referred to, came to be generally known as the Bear River Laramie. This name was applied to those strata because they were thought to have been contemporaneous in origin with the true Laramie, and to hold the same taxonomic position with relation to other formations, although it was well known that their molluscan fauna is very different from that of the Laramie.

Soon after the recognition of the integrity of the great Laramie formation throughout a great geographical area, and the discovery in its strata of Mesozoic as well as Cenozoic types of fossils, differences of opinion arose among geologists as to whether it is properly assignable to the Tertiary or to the Cretaceous. These differences of opinion had reference also to the Bear River formation, because it was then believed to be a part of the Laramie, but the question thus raised was one of geological age only, and did not extend to the subject of the relation of the Bear River strata to other members of the section in which they were then known to occur.

The first published account of the Bear River strata was given by Messrs. F. B. Meek and Henry Engelmann, jointly, in 1860;[1] and later in the same year Mr. Meek published descriptions of some of the fossils which characterize them.[2] In these publications both authors unhesitatingly assigned the strata in question to the Eocene Tertiary.

No other publication concerning them seems to have appeared until 1869, when Dr. F. V. Hayden inserted a paragraph containing a reference to them in one of his official reports upon another region.[3] In this paragraph he expressed the opinion that they are of Tertiary age, and proposed to include in one and the same group the coal-bearing strata of the Sulphur Creek section, those near Evanston, and those at Coalville, Utah, giving that incongruous assemblage the name Bear River group.[4]

In 1870 Dr. Hayden published a short article containing a minute description, accompanied by figures, of the nonmarine strata originally discovered by Mr. Engelmann, now called the Bear River formation, in which publication he continued to assign them to the Tertiary.[5]

In the same volume, and immediately following the article of Dr. Hayden's just mentioned, Mr. Meek catalogued and described a number of new species of fossils, among which are some that were obtained from the Bear River formation at and near the first discovered locality. These Mr. Meek assigned to the Tertiary without comment or qualification.

In his official report for 1870, Dr. Hayden republished the substance of his article in the Proceedings of the American Philosophical Society, just referred to, in which he again assigned the Bear River formation to the Tertiary, stating its position to be at the top of the Sulphur

[1] Proc. Acad. Nat. Sci. Phila., Vol. XII, pp. 126–131.

[2] Ibid., pp. 308–315.

[3] Prelim. Rept. U. S. Geol. Surv. Colorado and New Mexico, p. 91.

[4] The Bear River group, as proposed by Dr. Hayden, embraced strata now known to belong to three separate formations; I retain the name for those only which pertain to one of them; that is, for those to which the name "Bear River" has been most generally applied.

[5] Proc. Am. Philos. Soc., Vol. XI, pp. 420–425, pl. xii.

Creek section. This volume of reports contains also a chapter by Mr. Meek[1] concerning the fossils which were collected from various formations by Dr. Hayden during the previous year, in which he assigned to the Tertiary all the species that were obtained from the Bear River formation.

In Dr. Hayden's official report for 1871 Mr. Meek again catalogued the fossils from the Bear River formation under the head of Tertiary;[2] and in the same year Mr. T. A. Conrad referred this formation to the Lower Eocene. He seems to have done this solely because of the type-character of its fauna,[3] as he had never visited the region in which it occurs.

In 1872 Mr. Meek, in company with Dr. H. M. Bannister, visited Bear River Valley, and specially studied the section which is exposed along Sulphur Creek, near its mouth, and which, as before mentioned, includes, besides a great thickness of marine strata, those of non-marine origin which have just been mentioned as having been first discovered by Mr. Engelmann. The results of this study were published by Mr. Meek in 1873,[4] in connection with which publication he gave a figure of the section referred to, accompanied by a detailed description of its members. In this publication he continued to catalogue the fossils of the Bear River formation under the head of Tertiary, but in his remarks upon these strata he for the first time expressed some doubt upon this point, and suggested that they might "belong to the Upper Cretaceous." It is evident, however, that he was still of the opinion that their position is at the summit of the Sulphur Creek section, and, therefore, above all the undisputed Cretaceous strata which constitute its other members.

The character of his discussions concerning the paleontology of the Bear River formation in this and in previous publications shows that the doubt referred to was not entertained on account of any evidence afforded by the fossils obtained from those strata, all of which he regarded as of Tertiary types, but he seems to have been influenced by the fact that dinosaurian remains had then for the first time been discovered in strata, now known to belong to the Laramie formation proper, which until then had been by all geologists regarded as of Tertiary age, as also had been the Bear River formation.

Upon the geological sheet of the general atlas of the United States Geological Exploration of the Fortieth Parallel, which shows the district traversed by Bear River, the strata which are now known to be properly referable to the Bear River formation are indicated as belonging to the Laramie, and the areas which they occupy are colored upon that sheet in the same manner as are the true Laramie areas. This atlas was published in 1876, and the geology of the Bear River district

[1] Fourth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., pp. 149-153.
[2] Fifth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., p. 376.
[3] Am. Jour. Sci., 3d ser., Vol. I, pp. 381-383.
[4] Sixth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., pp. 451-454.

represented by it is understood to be the joint work of Messrs. Clarence King and S. F. Emmons.

In his final report, also, Mr. King assigned the Bear River strata in question to the Laramie;[1] and he correlated those of the originally discovered locality, near the mouth of Sulphur Creek, with the uppermost beds of the true Laramie at Black Buttes. Mr. Emmons, also, in his final report, assigned the same strata to the Laramie.[2]

At this time the belief already mentioned had become general; that is, that the Bear River formation, notwithstanding the material difference of its fossil fauna from that of the great formation which then began to be known by the name of Laramie, was contemporaneous with the latter, and that both hold the same relation to overlying and underlying formations. For these and other reasons the Bear River formation began, as already stated, to be known as the Bear River Laramie, the evident object of that special designation being only to indicate a recognition of the faunal difference between it and the great Laramie formation.

The final report of Mr. Engelmann was not published until 1876,[3] sixteen years after he had submitted it to Captain Simpson, and the same length of time after he had published his original report. At the time of the later publication discussion as to the true geological age of the Laramie formation, including the Bear River strata, had become somewhat prevalent, some contending for their Tertiary and some for their Cretaceous age. Apparently influenced by these discussions, Mr. Engelmann, in revising his final report, expressed the belief that the Bear River strata are of Cretaceous age, although in his original article, published jointly with Mr. Meek (loc. cit.), the opinion that they are of Tertiary age is plainly stated, and in the later publication he cites no new fact that might have caused a change of opinion.

Mr. Meek's final report to Captain Simpson on the fossils of the Bear River formation is contained in the same volume with that of Mr. Engelmann (op. cit.), and in his discussion of them he too was disposed to assign them to the Cretaceous, but he nowhere indicates a belief that the taxonomic position of the Bear River formation is not the same as that of the true Laramie. In his last published writing[4] he expressed the same opinion which he had formerly held, namely, that the Bear River strata are equivalent to the Laramie. In this last work of his he also described and figured several of the characteristic species of the Bear River formation.

It was in 1876, also, that Maj. J. W. Powell, who had in the previous year personally examined the geology of the district embracing the lower portion of Sulphur Creek Valley and the adjacent portion of Bear

[1] U. S. Geol. Explor. Fortieth Par., Vol. I, p. 373 and map iii, 1878.
[2] Ibid., Vol. II, p. 327, 1877.
[3] See Simpson's Report on the Great Basin of Utah, pp. 247-336, 1876.
[4] U. S. Geol. Explor. Fortieth Par., Vol. IV, p. 163, 1877.

River Valley, published his views of the Bear River formation.[1] He accepted the conclusions which Mr. Meek had reached concerning the order of superposition of the members of the Sulphur Creek section, and published a verbatim copy of Meek's description of it. In this publication Major Powell treated the Bear River strata as equivalent to his Point of Rocks group, which is equivalent to the Laramie, both of which he assigned to the Cretaceous; but he placed the Bear River strata at the summit of the Sulphur Creek section, as all the other geologists had previously done. In the same volume I described several of the characteristic molluscan species of the Bear River formation.[2]

In certain of my writings which were published in 1877 and 1878 I assigned the strata which I now designate as the Bear River formation, as well as the coal-bearing beds near Evanston, which are also found in Bear River Valley, to the great Laramie formation.[3] Both of these assignments, however, having been erroneous, a part of the conclusions which were reached in their discussion were necessarily erroneous also.

The results of some extended field observations made by myself in Colorado, Utah, and Wyoming were published in 1879.[4] In the part of that publication which relates to the geology of Bear River Valley I expressed the views which I then held concerning the relation to the Laramie formation of the Bear River strata and of the Evanston coal-bearing beds. These views were similar to those expressed in my publications of the two previous years, except that in the later publication I suggested that the Bear River strata are probably older than the Laramie; but I based this opinion upon the fact that the characteristic types of the Bear River fauna are much less like those of any Tertiary, or now living North American, fauna than are those of the Laramie. In 1883[5] I repeated the expression of this opinion as to the greater age of the Bear River strata, but my views were not in either case fully stated.

In 1879 Dr. A. C. Peale twice published results of his examination of the geology of a portion of western Wyoming,[6] in which publications he showed that the Bear River formation has a greater geographical extent than was before known. He found these strata occupying a belt of country of varying width, lying partly in Wyoming and partly in Idaho, and extending northward from the place of their original discovery to the forty-third parallel of north latitude, a distance of about 100 miles. Besides this, he reported the existence of a narrower and shorter belt lying parallel with the other a few miles farther eastward.

Most of the strata throughout the district examined by Dr. Peale, as well as those of the first discovered locality, have been much displaced by orogenic movements, in consequence of which the structural

[1] Geology of the Uinta Mountains, p. 158.

[2] Ibid., pp. 118, 122, 123.

[3] Bull. U. S. Geol. and Geog. Surv. Terr., Vol. III, pp. 607-614. Idem, Vol. IV, pp. 707-724.

[4] Eleventh Ann. Rept. U. S. Geol. and Geog. Surv. Terr., pp. 161-172.

[5] Third Ann. Rept. U. S. Geol. Surv., p. 430.

[6] Eleventh Ann. Rept. U. S. Geol. and Geog. Surv. Terr., pp. 511-644; and map accompanying the Twelfth Ann. Rept. Also, Bull. U. S. Geol. and Geog. Surv. Terr., Vol. V, pp. 195-200.

geology there is often found to be obscure. Doubtless because of this obscurity he failed to see any reason to oppose the then prevalent opinion that the Bear River formation is referable to the Laramie epoch, and reported that formation as overlying a series of strata which he assigned to the Cretaceous, but he admitted that he found no paleontological evidence of their Cretaceous age.

In 1877 and 1878 Prof. Orestes St. John examined the geology of a portion of western Wyoming and the adjacent part of Idaho, his district lying immediately north of the one examined by Dr. Peale, but the results of his work were not published until 1882.[1] In this report he shows that the Bear River strata, which, following the then prevalent custom, he assigned to the Laramie, occupy considerable areas in the district examined by him, one of them being a northward continuation of the principal belt reported on by Dr. Peale. These areas show a northward continuation of the Bear River formation of about 40 miles more than was shown by the results of Dr. Peale's observations, and they seem to mark the extreme northern limit of the formation.

The structural geology of Professor St. John's district is even more obscure than is that of Dr. Peale's, but he seems to have had little difficulty in recognizing the separate identity of the formations which exist there. The difficulty of determining their taxonomy, however, was increased over that of other portions of the Bear River district by the apparent absence of any marine Cretaceous strata associated with the Bear River strata which he found there.

From 1881 to 1885, inclusive, I published several articles in which reference is made to certain of the characteristic fossils of the Bear River formation.[2] In all of those publications, with the partial exception of my review of the nonmarine fossil mollusca, already mentioned, the fossils of that formation are so referred to as to convey the idea of its equivalency to the Laramie.

During the preparation of my review of the North American Cretaceous formations, which was published in 1891,[3] I found it necessary to discuss the Laramie formation in that connection. While reviewing the literature and paleontology of that portion of my subject and con-

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[1] Twelfth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., Part I, pp. 175–269 and map.

[2] The following statement of the titles and places of publication of these articles, in addition to similar references in preceding footnotes, is given for the purpose of making bibliographical reference to the subject of this bulletin as complete as practicable:

Tanganyika shells. Nature, Vol. XXV, pp. 101, 102.

On certain conditions attending the geological descent of some North American types of fresh-water gill-bearing mollusks. Am. Jour. Sci., Vol. XXIII, pp. 382–385.

New molluscan forms from the Laramie and Green River groups, with discussion of some associated forms hitherto known. Proc. U. S. National Museum, Vol. V, pp. 94–99, pls. 3 and 4.

A review of the nonmarine fossil mollusca of North America. Third Ann. Rept. U. S. Geol. Surv., pp. 411–550, pls. 1–32.

Contributions to invertebrate paleontology, No. 4; Fossils of the Laramie group. Twelfth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., Part I, pp. 49–103, pls. 20–30.

The genus Pyrgulifera Meek and its associates and congeners. Am. Jour. Sci., Vol. XXIX, pp. 277–280.

[3] Bull. U. S. Geol. Surv. No. 82.

sidering the statements there made in connection with the results of my personal visits to Bear River Valley, I became more than ever convinced that the Bear River formation is older than the Laramie, and that it would somewhere be found overlain by Cretaceous strata. This opinion I expressed on page 153 of the work referred to.

THE TAXONOMIC POSITION OF THE BEAR RIVER FORMATION.

The considerations mentioned in the last one of the preceding paragraphs seemed to demand an immediate and determined attempt to solve the question of the relative position of the Bear River strata. Therefore, in the field season of 1891 Mr. Stanton accompanied me to the Bear River Valley, and together we reviewed its geology up to the point where my previous investigations had ceased. It being then impracticable for me to continue field work, I left him to pursue the investigations alone, the results of which he embodied in the article already referred to,[1] and his principal conclusions are also stated on the following pages. This article was accompanied by one prepared by myself, which contained a statement of the principal facts mentioned on the preceding pages.[2]

The results of Mr. Stanton's investigations show that the Bear River formation, instead of occupying a position at the top of the North American Upper Cretaceous series, as it was formerly supposed to do, and as does the Laramie formation, lies beneath the greater part, if not the whole, of that series. That is, he has determined its position as beneath the Colorado formation and above that series of Jurassic strata which occurs within a large part of the interior region of North America and which are generally regarded as of Upper Jurassic age. The following table, copied from Mr. Stanton's article before referred to, represents the section as determined by him in the Bear River district. It shows not only the position of each of its members with relation to one another, but also their relation to the complete Upper Cretaceous section of the great Rocky Mountain region:

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[1] Am. Jour. Sci., Vol. XLIII, pp. 98-115, February, 1892.
[2] Ibid., pp. 91-97.

Mr. Stanton's Bear River general section.

Tertiary.	Wasatch.	Conglomerates, coarse sandstones, and shales, with coal at the base.
Cretaceous.	Laramie.	Wanting, or included in the above.
	Montana.	Not positively identified.
	Colorado.	Shales and coal-bearing sandstones. Thickness not less than 2,500 feet.
	Bear River.	Very fossiliferous, argillaceous, and calcareous shale, alternating with thin beds of sandstone.
	Dakota?	Conglomerates and coarse sandstones. Thickness of last two 2,500 to 4,000 feet.
Jurassic.	Belemnites beds.	Thin-bedded sandstones and sandy shales.

The following table shows the equivalency of the members of Meek and Hayden's Upper Missouri Cretaceous section with those which are now generally recognized as constituting the Upper Cretaceous series as it occurs in the great Rocky Mountain region and in the Green River basin, in Wyoming. The names of these members are mentioned in the foregoing table by Mr. Stanton, but the comparison is made in the following table for the convenience of those who are more familiar with the older than with the later names:

Nomenclature of Upper Cretaceous series.

Meek and Hayden's Upper Missouri section.	*Upper Cretaceous section of Rocky Mountain region, etc.*
Judith River beds (Laramie).	Laramie.
Fox Hills group. Fort Pierre group.	Montana.
Niobrara group. Fort Benton group.	Colorado.
Dakota group.	Dakota.
Jurassic.	Jurassic.

Notwithstanding the evident accuracy of Mr. Stanton's determinations as to the relative position of each of the members of the Bear River section, there are still some unsolved questions relating to the exact taxonomic position of the Bear River formation proper and of the unfossiliferous conglomerates and sandstones which underlie it and overlie the Belemnite-bearing Jurassic beds; that is, the following questions may justly be propounded: Is the Bear River formation of later, contemporaneous, or earlier origin than the Dakota formation? If of earlier origin, is it of Upper Cretaceous, Lower Cretaceous, or Jurassic age? Are the conglomerates and sandstones just mentioned of Jurassic age; are they referable to the Dakota formation, or do they represent some formation of intervening age? Discussions of these questions must, of course, have reference to both stratigraphy and paleontology.

Unfortunately, stratigraphical indications upon the subject are confined to the order of superposition of the members of the Bear River section as it has been determined by Mr. Stanton, because all of them, including the unquestioned Jurassic, are apparently strictly conformable with one another, and there is therefore no physical indication of a time hiatus between any of them.

The apparently strict conformity of the conglomerates and sandstones with the Belemnite-bearing, and therefore marine, Jurassic strata, which they overlie, offers at least a suggestion that the former may represent the nonmarine upper division; that is, the "Atlantosaurus beds" of the Jurassic as it is developed in Colorado and Wyoming. This fact as to conformity, however, offers little or no more than a suggestion, because the Dakota formation is equally conformable with the Jurassic wherever contact between them has been observed. Therefore all known indications are quite as much in favor of Mr. Stanton's suggestion of the Dakota age of those sandstones and conglomerates as they are of their Jurassic age. His opinion that they are probably equivalent to the Dakota, also accords with that of the members of the Fortieth Parallel Survey. No direct paleontological aid is available for the solution of this question, because those conglomerates and sandstones have not yet furnished any fossils.

While the Bear River formation is an abundantly fossiliferous one, paleontological indications of its geological age are indefinite for several reasons, among which are the following: No other fossils have been found in it than those which are described and figured in this bulletin, except some imprints of angiospermous leaves, which, although identifiable as such, are too fragmentary for satisfactory illustration. No vertebrate fossils are known to exist in any of its strata, although some scattered cycloid fish scales have been found in immediately overlying shales. Its invertebrate fauna, as a whole, is very different from any other known North American fauna, and, besides this, such of its faunal types as are like those which occur in other North American strata have had a long geological time range. For example, Jurassic nonmarine molluscan remains have been discovered in Colorado and Wyoming[1] which belong to types quite as modern in character as are any of those of the Bear River fauna, and not an inconsiderable part of the types of both the faunas referred to are found among now living mollusca. Therefore, so far as the Bear River fauna is now known, and when it is considered with reference to other North American faunas, it seems to afford very little, if any, intrinsic paleontological evidence as to whether it is of Cretaceous or Jurassic age.

At two localities, however, Mr. Stanton found the few fragmentary imprints of angiospermous leaves just referred to, which, although too imperfect for specific designation, are plainly of the general character of such plant remains as are common in Upper Cretaceous strata, and they are unlike any that are known in either the Lower Cretaceous or the Jurassic strata of North America. This, so far as it goes, may be regarded as an intrinsic paleontological indication of the Upper Cretaceous age of the Bear River formation, and allies it with the Colorado and Montana formations. Furthermore, it is shown on following pages that several of the molluscan members of the Bear River fauna are so closely similar to forms which occur in the Colorado formation as to suggest their specific identity. This still further indicates the affinity of the Bear River formation with the overlying members of the Upper Cretaceous series.

On the other hand, wherever the Dakota and Colorado formations have been found in contact, their strata are not only conformable, but in certain districts their paleontological relation[2] to each other has been found to be quite as intimate as is that of the Bear River formation with the Colorado, which has just been mentioned. Such conditions seem to preclude the probability of the existence of an intermediate series of strata in either case.

This apparent intimacy of relationship of the Colorado formation with both the Dakota and Bear River is suggestive of the contemporaneity of origin of the two latter formations; but we are here met with the fact that the faunal characteristics of the two formations are very different from each other,[3] although both are of nonmarine origin. Therefore, to assume the contemporaneity of origin of the Bear River and Dakota formations is to assume that their discordant aquatic faunas were developed independently and in separate hydrographic basins. This is not improbable, but we have yet no proof of it.

On the other hand, there seems to be no discovered direct proof that the nonmarine Bear River strata do not represent the early part of the Colorado epoch, which is represented by marine strata only in those

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[1]See Bull. U. S. Geol. Surv. No. 29, 1886.

[2]So far as the Dakota formation is concerned, it is the marine portion only that is here referred to, such, for example, as those found in Kansas and Texas. For remarks upon these marine Dakota strata and their fossils see Proc. U. S. Nat. Museum, Vol. XVII, pp. 136–138, 1894.

[3]It is true that a species of Pyrgulifera has lately been discovered in Dakota strata, as will be more fully mentioned on a following page, but it is the difference between the Dakota and Bear River faunas, each as a whole, that is here referred to.

districts where the Dakota formation is distinctly recognizable at its base. An indirect suggestion that the Bear River formation is separate from the Colorado is, however, furnished by the section in Weber Valley, about 30 miles southwestward from the Sulphur Creek section. The Jurassic is distinctly represented in Weber Valley, and the Colorado formation is there apparently complete, even to its base. Between these two formations there are two series of strata, in neither of which have any fossils been found. The lower one of these formations Mr. Stanton regards as equivalent to the conglomerates and sandstones of his Bear River general section, as shown on page 21, and as possibly equivalent to the Dakota formation. The upper one he thinks is probably equivalent to the Bear River formation.[1] If these suggestions shall prove to be correct, they will indicate that the deposition of the Bear River formation was already completed at the beginning of the Colorado epoch, and the fact will also indicate a greater southern extension of the Bear River formation than is now certainly known.

The questions propounded on page 22 are therefore still unanswered or answered only in part; but in view of the facts which I have stated and of Mr. Stanton's determinations, I do not now hesitate to assign the Bear River formation to the Upper Cretaceous, and to designate its position as at or near the base of that series. This assignment also accords with the reputed age of a formation in Hungary[2] whose fauna is more nearly like that of the Bear River formation than any other known.

PROBABLE CAUSES OF FORMER ERRORS CONCERNING TAXONOMIC POSITION, ETC.

Because the views concerning the position of the Bear River formation with relation to other formations which have been controverted upon the preceding pages have been held by so large a number of observers, including some of the ablest of North American geologists, it is proper to offer some explanatory, if not apologetic, suggestions as to the causes of the origin and long continuance of those erroneous views. These causes evidently relate in part to the great disturbance which the Bear River strata have suffered and to other physical conditions, and in part to erroneous preconceived paleontological opinions.

For a long time after the discovery by Mr. Engelmann of the section of strata near the mouth of Sulphur Creek, strata equivalent to those of that part of it which is now known as the Bear River formation were not known to occur elsewhere, and it was upon the examination of this section only that the views referred to were originally formed. All the strata of the Sulphur Creek section are greatly disturbed, a large part

[1] Bull. U. S. Geol. Surv. No. 106, p. 46, 1893.

[2] See Tausch (Leopold von). Ueber die Fauna der nicht-marinen Ablagerungen der oberen Kreide des Csingerthales bei Ajka im Bakony, Ungarn. Abhandl. K.-k. geol. Reichsanstalt, Band XII, No. 1, Wien, 1886.

See also Oppenheim (Paul). Ueber einige Brackwasser- und Binnen-Mollusken aus der Kreide und dem Eocän Ungarns. Zeitschr. Deutsch. geol. Gesell., Band XLIV, Heft 4, Berlin, 1892.

of them standing vertical or nearly so, and others are inclined at various angles. Besides this, they are now known to be traversed by faults which are so much obscured that their character or even their existence was hardly demonstrable before the facts brought out by Mr. Stanton were applied to the study of the strata of that district. Furthermore, the Sulphur Creek section is exposed only within a small neighborhood, where it is closely surrounded by a broad expanse of unconformably overlying Tertiary strata. These Tertiary strata so completely cover the strata which are or originally were continuous with those of the section as to make it impracticable to trace any of the latter continuously more than a short distance.

It is only in the district which extends northward from Sulphur Creek that any other than the original discoveries of Bear River strata have been certainly made. When this district began to be examined the work was necessarily done in a desultory manner, because the geologists who did the work were attached to topographical surveying parties, to whose movements theirs were subordinated. The difficulties of travel were also great, because pack and riding animals were the only means for conveying persons and for transporting supplies. In addition to the disadvantages just mentioned, these geologists were necessarily influenced in their judgment by the published views of those who had previously reported upon the Sulphur Creek section. They found the Bear River and associated formations everywhere nearly or quite as much disturbed as they are at the Sulphur Creek locality, and in their necessarily hasty examinations they did not discover the error that had been made there.

Besides the difficulties imposed by the conditions just mentioned, one of the most important elements in the solution of the question involved seems to be entirely absent from the whole district in which the Bear River formation occurs. That is, the reports which have been made by various geologists upon western Wyoming and adjoining parts of Utah and Idaho indicate that no true Laramie strata exist in any part of the district where those of the Bear River formation occur. Therefore, those observers were all the more ready to accept the Bear River strata as representing the Laramie. Further confusion was caused by erroneous identification of some of the marine Cretaceous strata of the Sulphur Creek section. That is, in the region surrounding the Bear River district the molluscan faunas of the equivalents of the Colorado and Montana formations, respectively, present so many differences from those faunas as they are known farther eastward that the strata of the Sulphur Creek section which are now known to belong to the Colorado formation were believed to belong to the later Montana formation.

Although the greatly disturbed and obscured condition in which the strata of the Bear River and its associated formations were found was the primary cause of the erroneous conclusion as to their order of superposition which was reached by the geologists who first investigated them, it can not be denied that the then prevalent paleontological views are largely responsible for it. That is, none of these investigators seem to have doubted that such types as those which are included in the Bear River fauna are characteristic of, and peculiar to, the Tertiary. The fact also that the Bear River strata are of nonmarine origin evidently had some influence in favor of assigning them to the Tertiary, because at that time little was known of the existence in North America of nonmarine strata earlier than those of Tertiary age. Moreover, they found the Bear River strata occupying a position at one end of the exposure of a series of strata which contain unquestionable marine Cretaceous fossils,[1] and believing these nonmarine strata to be of Tertiary age, they necessarily assumed that they overlie their associates of marine origin.

In the light of all the facts now known, it seems strange that the wide difference between the fauna of the Bear River strata and that of the Laramie did not cause more distrust of the idea which was then entertained that they were of contemporaneous origin, especially because it was this discordance of faunal characteristics which finally suggested to me the investigations that have resulted in assigning the Bear River formation to a much earlier epoch than that of the Laramie.[2] Still, the full extent of the faunal difference referred to was not known to the first investigators of those formations, and the difference which was then known to exist was, they thought, probably due to the division of the waters of the Laramie epoch either into different faunal areas or into different hydrographic basins. It is also just to add that while the principal error which has been discussed on the preceding pages was largely due to erroneous paleontological views, it is equally true that without the aid of paleontology that error could not have been refuted.

Finally, in putting forth this explanation of what is regarded as the true taxonomic position of the Bear River formation, it is proper to say that the conclusion reached is largely based upon the knowledge of facts and principles bearing both directly and indirectly upon this subject which has accumulated since the work of the earlier investigators was accomplished. Besides this, the district occupied by the Bear River formation, which was a wilderness when they began their investigations, is now traversed by two railroads, and all parts of it are readily accessible for study.

GEOGRAPHICAL EXTENT OF THE FORMATION.

Having discussed the separate identity and stratigraphical relations of the Bear River formation, it remains to consider the geographical area which it occupies, or within which its strata are known to occur.

[1]See Mr. Meek's figure of the Sulphur Creek section, Ann. Rept. U. S. Geol. and Geog. Surv. Terr. for 1872, p. 451. Also Mr. Stanton's reproduction of the same, Am. Jour. Sci., Vol. XLIII, p. 102, Feb., 1892.

[2]See Third Ann. Rept. U. S. Geol. Surv., p. 430, 1883; Eleventh Ann. Rept. U. S. Geol. and Geog. Surv. Terr. for 1877, p. 247, 1879; and Bull. U. S. Geol. Surv. No. 82, p. 153, 1891.

Our knowledge of the true limits of this area has hitherto been, and to some extent still is, indefinite or uncertain for three reasons: First, those strata were not until lately fully differentiated from the Laramie; second, among the fossils which have from time to time been obtained in various districts other than that in which the Bear River fauna was originally discovered are some which so closely simulate certain Bear River species that they have been erroneously identified with them, thus giving origin to erroneous reports concerning the geographical extent of the Bear River formation; third, all the smaller, but nevertheless important, details of the geology of the great region in which the Bear River strata are now known to occur have not yet been fully worked out. The first reason has already been discussed, and it is desirable to consider the other two.

The former belief, which has just been indicated, and which was also mentioned by me in a previous publication,[1] that Bear River strata exist in certain districts of eastern and southern Utah, never resulted in the accumulation of such facts as would warrant a definite indication of the outlines of the areas in which they were supposed to occur. This belief was based upon the assumed identity of certain species of fossil shells which from time to time reached the hands of paleontologists from various persons who had visited the districts referred to. A part of these reputed identifications were wholly erroneous, as has been shown by the discovery of essential differences of structure; but in other cases, even when the essential structure of the whole shell is known, the identity is so apparently real that it is difficult or impracticable to prove it otherwise.

The cases of assumed identification which are now certainly known to be erroneous were due to reliance upon the external form of the shells examined, and those cases, concerning which there is still some doubt, were due to a want of strong specific features in the shells of all the members of the genus to which they belong. It will be sufficient for my present purpose to mention one case each of these two kinds.

A case of total error of identification is that of a gasteropod species, of which many specimens were received from different localities in Utah. These shells in outward aspect resemble typical forms of *Pyrgulifera humerosa* even more closely than do some of its unquestionable varieties, and upon this external character alone the identification was based, the interior features not having been then ascertained. Subsequently, however, these shells were found to possess folds upon the columella like those which characterize Admetopsis. This character, of course, not only requires their reference to another species, another genus, and another family, but it indicates a marine instead of a nonmarine origin for the fauna to which it belongs.

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[1] Am. Jour. Sci., 3d ser., Vol. XLIII, p. 97, February, 1892.

A case of still questionable identification is that of a species of Corbicula or Cyrena which, although its essential details of structure are known, it is difficult to describe as different from *Corbicula durkeei.* The doubt here implied whether the shell in question is a Corbicula or a Cyrena is due to the absence or obliteration of transverse striæ upon the lateral teeth of the specimens received. The discrepancy in this case was thought to have been due to obliteration, because those striæ are often obliterated, and are never so conspicuous upon the shells of *Corbicula durkeei* as they usually are upon North American species of Corbicula.

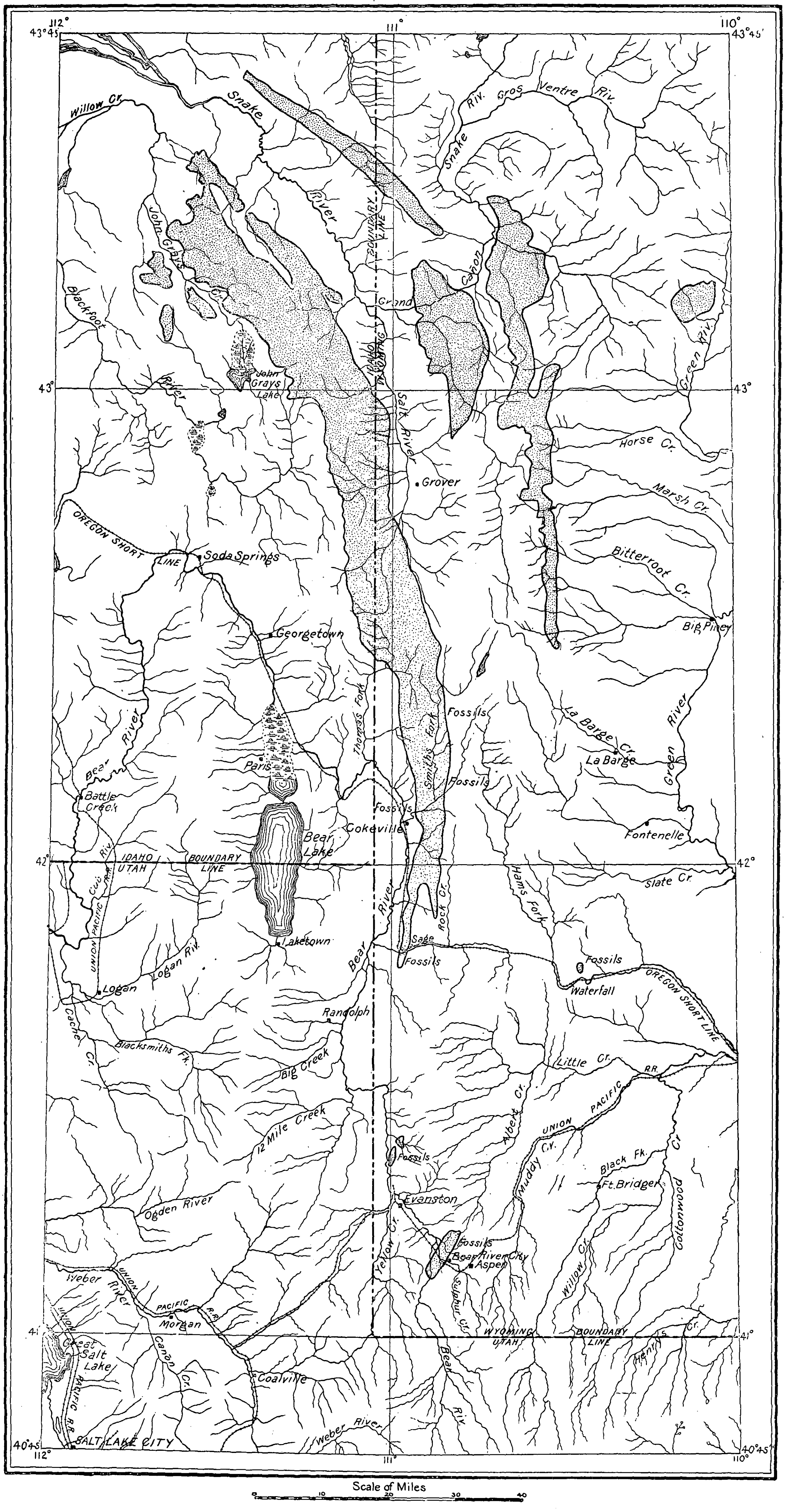
These two species, *Pyrgulifera humerosa* and *Corbicula durkeei*, are two of the most conspicuous and characteristic of the members of the Bear River fauna, and the forms just mentioned, which so closely simulate them, are now known to have been obtained from the Colorado formation and to be members of its marine fauna. Moreover, in the districts where they were found later investigations have failed to reveal the presence of any strata which contain unmistakable members of the Bear River fauna.[1]

In connection with the description on following pages of the species which constitute the Bear River fauna, some suggestions are made as to the possibility that certain of them may have survived into the Colorado epoch, and that in such cases the apparent identity may be real, the Corbiculoid species just referred to being one of them. The forms in question, however, being such as present comparatively few salient specific characteristics, and also such as occur with little variation in formations of different ages, the evidence they furnish is not entirely satisfactory.

In connection with the subject of assumed identification of Bear River species at localities far distant from the district in which they were originally discovered, it is desirable to refer to the fauna of the Dunvegan series of strata which occur in Canada, especially those of the valley of Peace River. Through the kindness of Mr. J. F. Whiteaves, paleontologist to the Geological Survey of Canada, I have been able to compare a small suite of those fossils with the large collections of the Bear River fauna now in the United States National Museum. The species which most resemble members of the Bear River fauna are one each of the following genera: Corbula, Corbicula, Modiola (Brachydontes), and Ostrea.

Some of these Dunvegan specimens of Ostrea are exceedingly like some of those which are found in the Bear River strata. They are also much like some of those found in various other formations, as well as some living forms. The Modiola is very like the *M. multilinigera* of Meek, and consequently very like the form in the Bear River formation

[1] It should be observed that these errors are the result of museum study only of the fossils in question. The same investigators who made them could not have done so if they had then had the opportunity of field work in connection with their paleontological study.



SKETCH MAP SHOWING AREAS OCCUPIED BY BEAR RIVER FORMATION.

to which on a following page I have proposed the conventional name of *M. pealei*.

The Dunvegan Corbicula is quite variable in shape and marginal outline, but some of the specimens are so nearly like those of *C. durkeei* that they would hardly be regarded as specifically different if found associated with genuine specimens of that species in Bear River strata. Other specimens are so closely like those forms of Corbicula or Cyrena which have been mentioned as occurring in the Colorado formation that one can not say how they differ specifically.

Of all the species obtained from the Dunvegan strata the one which most deserves attention in this connection is the Corbula. This is so exceedingly like *C. pyriformis* that if found associated with unquestionable members of the Bear River fauna one would hardly be justified in separating it. Still, in the absence of such association, and in view of the general want of salient features in the shells of Corbula by which the species may be discriminated, I think one is justified in rejecting this Dunvegan form as a specific representative of *C. pyriformis*.

The other species of Dunvegan fossils which were sent me for examination by Mr. Whiteaves belong to the genera Goniobasis, Neritina, Unio, Corbula?, and Mactra?, but none of them is identifiable with any member of the Bear River fauna. I therefore regard the Dunvegan fauna, although allied to that of the Bear River formation, as in no such sense identical with it as would imply a true geological equivalency of the formations respectively containing them. Besides this, the Canadian geologists are disposed to regard the Dunvegan and Belly River series of strata as belonging to one and the same horizon, and the position to which they assign the latter is somewhat later than that which has now been determined for the Bear River formation.

It is evident from the foregoing explanations that the Bear River fauna is not represented as a fauna beyond the limits of the district which is indicated by the accompanying sketch map (Pl. I), and it is probable that no really specific member of it exists beyond those limits.

For the third of the reasons mentioned on page 27 why our knowledge of the area occupied by the Bear River formation has been imperfect, it has not been found practicable to prepare for this bulletin a satisfactory detailed geological map of the district in question. The accompanying sketch map, however, embraces the extreme limits of the district in which the Bear River strata have been certainly recognized, and its shaded portions indicate the areas within which they have been observed or confidently assumed to exist.

These areas are in part copied from map 2 of the Twelfth Annual Report United States Geological and Geographical Survey of the Territories, which is based upon the reports of Dr. A. C. Peale and Prof. O. St. John, and in part from maps 2 and 3 of the atlas of the United States Geological Exploration of the Fortieth Parallel. The outlines of the areas which upon the copied portions of the two Fortieth

Parallel maps are designated Laramie are somewhat modified and restricted upon the sketch copy here presented, to make them accord with observations made by Mr. Stanton and myself. Those which are copied from the map by Dr. Peale and Professor St. John have been largely verified and identified by Mr. Stanton as Bear River areas up to 20 miles north of Cokeville. Northward from that point all the areas which are designated Laramie upon the last-named map are those which are confidently assumed to be occupied by Bear River strata, although the fact of that identity has not yet been verified by collections of fossils from all of them.

The shape, position, and limitation of those shaded areas bear no necessary relation to the limits of the Bear River formation as it was originally deposited. Those original limits have not yet been even approximately determined, and it is not likely that they will ever be much more definitely known. Their present limitation, as it is shown by their respective outlines upon the map (Pl. I), is due to causes which have transpired since their deposition took place. That is, it has been accomplished by the great disturbance which the strata of the whole district have suffered, by the outflow of great masses of volcanic rock, and by the extensive erosion and denudation which followed those events. These areas therefore represent only minor portions of the Bear River formation as it was originally deposited.

While it is evident that this formation as it was originally deposited occupied a larger total area than that which would be indicated by a line merely circumscribing that group of comparatively small irregular areas, we have now no satisfactory evidence that its original limits extended much, if any, beyond the limits of the district which is represented by the accompanying map, and which, for convenience in these discussions, I designate the Bear River district. It is true that a part of the region surrounding the district is occupied by Tertiary sedimentary deposits, and a smaller part by post-Cretaceous lava outflows, either of which would have covered from view any Bear River strata which may have existed there. Still, there are some other localities in the surrounding region at which equivalents of either a part or all of the marine strata of the Sulphur Creek section exist, but no equivalents of the Bear River strata have been paleontologically recognized in association with them, and in most of these cases there is no physical indication of their existence.

One of the most important of these localities is in the valley of Weber River, about 30 miles southwestward from the mouth of Sulphur Creek. Here, as has already been stated on page 24, the marine members of the Sulphur Creek section are well represented, and among them are certain strata which possibly represent the Bear River formation. This question, however, can not be decided without the discovery of its characteristic fossils, and its southern limit may therefore be provisionally supposed to lie somewhere between Sulphur Creek and Weber Valley.

Another important locality at which equivalents of the marine members of the Sulphur Creek section occur is at Flaming Gorge, Green River, and in the district extending east and west from that river along the north flank of the Uinta Mountains. This district embraces the boundary line between Colorado and Wyoming, and is from 50 to 70 miles eastward from the Sulphur Creek section. In this district the full series of strata from the Jurassic to the Laramie formation, inclusive, are exposed in the same order and in the same general condition that they are found to present throughout the Rocky Mountain region, but no trace of the Bear River formation is found among them.

The other exposures of the equivalents of the marine members of the Sulphur Creek section within the region surrounding the Bear River district are few in number, and less complete and important than are those of the two districts just referred to. Still, they are characteristic, but at none of them has any trace of the Bear River fauna been discovered, and no strata have there been recognized that may reasonably be referred to the Bear River formation.

It has already been shown that the supposed identity with members of the Bear River fauna of certain fossil forms found in eastern and southern Utah is fallacious. Furthermore, Mr. Stanton, who has carefully examined the geology of those regions for that purpose, was unable to find there any trace of the Bear River formation, even when representatives of the other members of the Sulphur Creek section were present.

In consideration of all the facts presented in the foregoing paragraphs, it seems quite unlikely that the Bear River formation ever occupied a much, if any, larger area than is represented by the extreme limits of the accompanying sketch map. This geographical isolation of the Bear River formation is still further emphasized by the comparison of its fauna with other North American fossil faunas which is presented on following pages. Its taxonomic isolation is also apparent because of its absence from all known sections of strata which occur beyond the geographical limits which have been designated.

DESCRIPTION OF SPECIES.

MOLLUSCA.

CONCHIFERA.

Family OSTREIDÆ.

Genus OSTREA Linnæus.

OSTREA HAYDENI n. s.

Plate II, figs. 1, 2.

Ostrea ——? White, Eleventh Ann. Rept. U. S. Geol. and Geog. Surv. Terr., p. 242.

Among the collections which from time to time have been obtained from the Bear River formation are numerous examples of a small oyster belonging to the typical section of the genus Ostrea. These are so closely like specimens which have been found in the Colorado, Montana, and Laramie formations, respectively, that it is impracticable to describe them in terms which would not apply nearly or quite as well to those forms. Their resemblance to certain specimens of the young of the living *Ostrea virginica* is also quite as close as it is to the fossil forms just mentioned. For these reasons the propriety of giving a separate specific name to this fossil form might well be questioned, but I have decided to do so because it will add to the convenience of discussing the formation in which the shells occur and the fauna as a whole which characterizes it. The name which I have chosen is given in memory of Dr. F. V. Hayden, whose collections contained the first discovered specimens.

Although several others of the various species which constitute the fauna of the Bear River formation, especially those whose congeners are brackish-water denizens, are found in immediate association with this little oyster, it is usually confined to separate thin layers, which in some cases it almost entirely constitutes. Its geographical distribution, however, has been found to be nearly or quite coextensive with the present known limits of the formation.

The small size of all the discovered specimens, the largest not much exceeding 50^{mm} in length, gives one the impression that they are all immature, but the average size is about the same at all the localities at which they have been discovered, some of which are more than 100 miles apart. The shells are therefore regarded as mature notwithstanding their small size.

The localities at which this form has been found to be more abundant than at any others are 20 miles north of Cokeville, 7 miles north of Evanston, and near the mouth of Sulphur Creek.

Family MYTILIDÆ.

Genus MODIOLA Lamarck.

MODIOLA PEALEI n. s.

Plate II, fig. 3.

Compare *Modiola (Brachydontes) multilinigera* Meek, 1873, Ann. Rept. U. S. Geol. and Geog. Surv. Terr. for 1872, p. 492.

Compare *Volsella (Brachydontes) multilinigera* White, 1880, Twelfth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., p. 18, pl. ii, fig. 3.

Among the collections which have been obtained from the Bear River formation are numerous fragments of a Modiola which in all observable characteristics closely resembles the *M. multilinigera* of Meek, the original specimens of which came from the Colorado formation. Indeed this Bear River form so closely resembles the one just mentioned that it would not be unreasonable to refer them to one and the same species if it were certainly known that the deposition of the Bear River formation was, as it seems to have been, followed immediately by that of the Colorado formation. Because of this doubt and of the imperfection of the Bear River specimens, which is so great as to make it impracticable to clearly diagnose them specifically, I prefer to give them a separate name, as I have done in the case of the oyster with which they are associated. For this purpose I have selected the name of Dr. A. C. Peale, because he was among the first geologists to examine the Bear River formation after its discovery by Mr. Engelmann, and his collections contained the first observed specimens of this form.

Fig. 3 on Pl. II is of a young and imperfect example, somewhat enlarged. The forementioned characteristics of the shell have been observed mostly by means of fragments of larger examples.

Mr. Stanton obtained imperfect specimens of this form at several localities, and its geographical distribution is apparently the same as that of *Ostrea haydeni*.

Family UNIONIDÆ.

Genus UNIO Retzius.

UNIO BELLIPLICATUS Meek.

Plate II, figs. 4, 5, 6.

Unio belliplicatus Meek, 1870, Proc. Am. Philos. Soc., Vol. XI, p. 439.
Unio (Lexopleurus) belliplicatus Meek, 1871, Ann. Rept. U. S. Geol. and Geog. Surv. Terr. for 1870, p. 294.
Unio belliplicatus Meek, 1873, Ann. Rept. U. S. Geol. and Geog. Surv. Terr. for 1872, p. 478.
Unio belliplicatus Meek, 1877, U. S. Geol. Explor. Fortieth Parallel, Vol. IV, p. 165, pl. 16, fig. 4, 4a.
Unio belliplicatus White, 1879, Ann. Rept. U. S. Geol. and Geog. Surv. Terr. for 1877, p. 242.
Unio belliplicatus White, 1883, Third Ann. Rept. U. S. Geol. Surv. p. 430, pl. 6, figs. 1, 2, 3.

The following is Mr. Meek's description of this form, copied from Vol. IV of the reports of the United States Geological Exploration of the Fortieth Parallel, pp. 165–166:

Shell attaining a medium size, transversely subovate, the widest part being a little in advance of the middle, moderately convex, generally less than twice as long as high; anterior margin short, rather regularly rounded; posterior margin obliquely subtruncated, with a more or less convex outline, most prominent below, where it is obtusely subangular or abruptly rounded into the base; dorsal outline nearly straight, or more or less arched; base broad semiovate, being most prominent in advance of the middle, in large specimens generally a little sinuous posteriorly; beaks much depressed, or scarcely rising above the cardinal margin, oblique, and placed near the anterior end, not eroded; hinge moderately long, with cardinal and lateral teeth, so far as known, much as in *U. vetustus*. Surface ornamented by a series of very regular, distinctly defined, and generally simple plications, which commence very small, and closely approximated along the dorsal margin just before the beaks, and after slight curves radiate and descend obliquely toward the posterior basal margin, increasing in breadth and becoming more obtuse as they descend and diverge, and at last in large specimens becoming obsolete before reaching the margins; while another more or less similar series of plications sometimes originates along the cardinal margins behind the beaks, and descends obliquely backward and downward, so as to connect with those of the first-mentioned series along the posterior umbonal slopes at very acute angles, somewhat like we see on species of Goniomya. Marks of growth moderately distinct, becoming sometimes stronger or subimbricating near the margins.

The dimensions of this species were given by Mr. Meek in inches, the approximate metric equivalents of which are: Length, 70^{mm}; height, 38^{mm}; thickness, 20^{mm}. Later collections show that the species is very variable not only in size but in proportional dimensions, some being much more convex and some much shorter than others. This is in part shown by the figures on Pl. II; but other specimens in the collections, which, however, are too imperfect for satisfactory illustration, show the great variations just mentioned.

The plications also vary considerably in character, being much stronger upon the more robust specimens than upon others. In such cases they often occupy a larger part of the anterior surface of the shell than is usual in other cases. It was upon the character of these plications that Mr. Meek at one time proposed to separate this species as the typical representative of a subgenus under the name of Loxopleurus, but this proposition he afterwards abandoned. The peculiar character and direction of these plications constitute a striking feature of this species, but they really consist of a blending of concentric and radiating folds, which, when occurring separately, constitute ordinary features of ornamentation among the Uniones.

This species has a wide geographical distribution in the Bear River formation; but it has been found more abundant at the locality near the mouth of Sulphur Creek than at any others.

UNIO VETUSTUS Meek.

Plate III, figs. 1, 2, 3, 4.

Unio vetustus Meek, 1860, Proc. Acad. Nat. Sci. Phila., Vol. VIII, p. 117.
Unio vetustus Meek, 1876, Simpson's Rept. Great Basin of Utah, p. 359, pl. v, figs. 12, a, b.
Unio vetustus Meek, 1877, U. S. Geol. Explor. Fortieth Parallel, Vol. IV, p. 164, pl. 16, figs. 5, a, b, c.
Unio vetustus White, 1883, Third Ann. Rept. U. S. Geol. Surv., p. 430, pl. 7, figs. 1–4.

The following is Mr. Meek's description of this species, as given in Vol. IV of the reports of the United States Geological Exploration of the Fortieth Parallel (loc. cit.):

Shell of about medium size, transversely subovate or subelliptic, the widest part being anteriorly, though young examples are narrower, with dorsal and ventral margins more nearly parallel, rather thin and moderately convex, about twice as long as high; base forming a long semi-elliptic or semi-ovate curve in adult shells, but usually straighter in the young; posterior margin rather narrowly rounded below in large specimens and obliquely truncated in small examples; dorsal margin nearly straight, excepting in large shells, where it is more arched; anterior margin short and rounded; beaks depressed, not eroded, placed near the anterior, very neatly ornamented with small, perfectly regular, concentric ridges and furrows, that generally end abruptly behind at a small, oblique, linear, posterior umbonal ridge extending backward and downward, while midway between this and the cardinal margin there is a second similar ridge; other portions of the surface merely marked with lines of growth, which sometimes assume a subimbricating appearance near the free margins. Hinge of moderate length, with two cardinal teeth in the left valve, the posterior one being larger than the other; lateral teeth long and nearly straight (cardinal teeth of right valve unknown); scars of anterior muscles deep and irregularly pitted.

The dimensions of this species, like those of the preceding one, were given by Mr. Meek in inches, the approximate metric equivalents of which are: Length, 100^{mm}; height, 53^{mm}; thickness, 27^{mm}. This species, however, is very variable in its proportional dimensions as well as in marginal outline. These differences are in part shown by the figures on Pl. III.

The concentric ridges upon the umbones, which are mentioned by Mr. Meek, are in some cases quite as distinct as they are upon *U. belliplicatus* before they diverge as radiating folds. Indeed the surface markings of very young specimens of both species were evidently often closely similar.

Both Mr. Meek and myself at one time thought this form to be identical with one which occurs in the upper part of the Laramie, and with another which occurs in the lower part of the Wasatch formation. These were *U. priscus* Meek and Hayden, from near Fort Union, N. Dak., and *U. mendax* and *U. rectoides* White, from the base of the Wasatch formation in Utah. It is true that these forms are closely similar to *U. vetustus* when the great variation of the latter is taken into consideration, but there are recognizable differences between them. Besides this, *U. vetustus* is now known to belong to a much older stratigraphical horizon than do the other forms mentioned. It is therefore regarded as inexpedient to give them all the same name, even if it were still more difficult to discriminate between them.

The geographical distribution of this species within the Bear River formation is the same as that of *U. belliplicatus*, and they are usually found in intimate association. Both have been found more abundant at the Sulphur Creek locality than elsewhere.

Family CYRENIDÆ.

Genus CORBICULA Megerle.

CORBICULA DURKEEI Meek.

Plate IV, figs. 1, 2, 3, 4.

Cyrena (Corbicula?) durkeei Meek, 1870, Proc. Am. Philos. Soc. Phila., Vol. XI, p. 431.

Corbicula (Veloritina) durkeei Meek, 1872, Ann. Rept. U. S. Geol. and Geog. Surv. Terr. for 1870, p. 294.

Corbicula (Veloritina) durkeei Meek, 1877, U. S. Geol. Explor. Fortieth Parallel, Vol. IV, p. 167, pl. 16, figs. 6, a, b, c, d, e, f, g.

Corbicula (Veloritina) durkeei White, 1883, Third Ann. Rept. U. S. Geol. Surv., p. 437, pl. 8, figs. 8, 9, 10, 11.

The most complete diagnosis of this species given by Mr. Meek occurs in Vol. IV of the reports of the United States Geological Exploration of the Fortieth Parallel, pp. 167–168, which is as follows:

Shell attaining a large size, thick, trigonoid-subcordate, gibbous, oblique, with length exceeding somewhat the height, most convex a little in advance of and above the middle, and cuneate postero-ventrally; posterior dorsal slope long, straight, or slightly convex in outline from the umbones to the angular or subangular posterior basal extremity; basal margin sem-iovate in outline, being most prominent anteriorly; anterior margin short, descending very abruptly from the beaks, with a slightly concave outline above, and rounding regularly into the base below; beaks elevated, gibbous, obliquely incurved, contiguous, and placed about halfway between the middle and the anterior end, or sometimes nearly over the latter; posterior umbonal slopes prominently rounded, with posterior dorsal margins inflected or incurved, so as to form a profound, broad concavity, or sulcus, along their entire length, as the two valves are seen united; lunule in most cases deep, but generally without well-defined margins; ligament short, narrow, and so deeply seated in the broad dorsal concavity as not to be visible in the side view when the valves are united; surface only showing moderately distinct lines of growth; hinge strong; cardinal teeth oblique, excepting the anterior one, which ranges nearly vertically; lateral teeth elongated, and only very minutely striated, or very nearly smooth, the posterior one of the left valve being sometimes mainly formed by the beveling of the inflected edge of the valve instead of standing out at right angles from an erect margin; pallial lines with a short, very shallow sinus, immediately under the ovate, shallow, and oblique scar of the posterior abductor muscle; anterior muscular impression deeper, slightly smaller than the other, and ranging nearly vertically.

As was his custom, Mr. Meek gave the dimensions of this shell in inches, the approximate equivalents of which are: Length, 47^{mm}; height, 39^{mm}; thickness, 28^{mm}.

This species, as was noticed by Mr. Meek in connection with its original publication, and as is shown by the figures on Pl. IV, is very variable in its proportions and marginal outline. Indeed the extremes which in this respect are observable among a large series of specimens are so great that if no intermediate forms were discovered no one would hesitate to assign them to different species. The recognition of this extreme interspecific variation led me to assign to this species some examples of a closely similar shell which were found near the north fork of Virgin River in southern Utah.[1] It has since been ascertained, however, that those specimens came from the lower part of the Colorado formation, and that its faunal associates are of distinctly marine character.

There is another form, possibly belonging to the same southern Utah species, which was obtained from the Colorado formation in the valley of Sulphur Creek near where the strata of the Bear River formation are exposed, and where it was associated with a fully marine fossil fauna. To this form I first gave the name of *Cyrena* (*Veloritina*) *erecta*, but afterwards referred it to the *Cyrena securis* of Meek.[2]

The form obtained from southern Utah was referred to *C. durkeei*, not only because its own characteristics are similar to those of that species, but because some of its associates so closely simulate other Bear River species that I then thought them identical, although they are now known to be different. The form discovered in the valley of Sulphur Creek, while I recognized its close similarity to *Corbicula durkeei*, I regarded as belonging to a different genus and species. I accordingly referred it to the marine genus Cyrena, because I could discover no striation of the lateral teeth, which character is absent in Cyrena and present in all known North American fossil forms of Corbicula, and because the specimens were found as members of a distinctly marine fauna, while the associates of *Corbicula durkeei* are fresh-water and brackish-water forms.

Still, the striation of the lateral teeth of *Corbicula durkeei* is never strongly marked, and it has not been fully demonstrated that those of

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[1] U. S. Geog. Surv. West of the One Hundredth Merid., Vol. IV, p. 207, pl. xxi, fig. 13, 1877.

[2] Eleventh Ann. Rept. U. S. Geol. and Geog. Surv. Terr., p. 289, pl. 3, figs. 2, a, b, c, 1879.

Cyrena securis were not at least indistinctly striate. These facts lead to a suggestion similar to that which was made in the case of *Modiola pealei* on a preceding page. That is, they make it reasonable to inquire whether the forms found in the Colorado formation in southern Utah and in Sulphur Creek Valley in southwestern Wyoming may not have been genetically derived from *Corbicula durkeei* by survival from the brackish waters in which the Bear River formation was deposited into the marine waters of the Colorado formation. This suggestion of course implies that there may have been continuous sedimentation in the production of the Bear River and Colorado formations. This condition has not yet been demonstrated, but it is known that the Colorado formation rests immediately upon the Bear River strata, and no facts are yet known that forbid the supposition that sedimentation was, at least in part, continuous from the former to the latter formation.

Mr. Meek proposed the subgeneric name Veloritina[1] for this shell, and this designation has been generally used by American authors. It will be seen, however, that the characters which he designates as subgeneric are the unusual proportional height of the shell and the depression of the dorsal margin. The interspecific variations which have been mentioned, and which are in part shown by the figures on Pl. IV, are such as to include forms in which these characters are entirely absent. This fact renders of doubtful value any subgeneric designation as regards this species.

It is worthy of remark that although *Corbicula durkeei* is so abundant in the Bear River formation it is the only representative of the family Cyrenidæ that has yet been found in its strata.

This species is one of the most abundant and characteristic of the members of the Bear River fauna. It is particularly plentiful 7 miles north of Evanston, and also near the mouth of Sulphur Creek, but its geographical range is throughout the whole extent of the formation so far as its strata have been examined.

Family CORBULIDÆ.

Genus CORBULA Bruguiere.

CORBULA PYRIFORMIS Meek.

Plate IV, figs. 5, 6, 7, 8, 9.

Corbula (Potamomya) pyriformis Meek, 1860, Proc. Acad. Nat. Sci., Vol. XII, p. 312.

Corbula (Anisorhynchus) pyriformis Meek, 1872, Ann. Rept. U. S. Geol. and Geog. Surv. Terr. for 1871, p. 292.

Corbula (Anisorhynchus) pyriformis Meek, 1876, Simpson's Rept. Great Basin of Utah, p. 361, pl. 5, figs. 9, 10.

Corbula (Anisorhynchus) pyriformis Meek, 1877, U. S. Geol. Explor. Fortieth Parallel, Vol. IV, p. 170, pl. 17, figs. 2, a, b, c, d.

Corbula pyriformis White, 1883, Third Ann. Rept. U. S. Geol. Surv., p. 441, pl. 8, figs. 12–16.

[1] For its diagnosis see U. S. Geol. and Geog. Surv. Terr., Vol., IX, p. 161, 1876.

Mr. Meek's most complete description and discussion of this form is contained in Vol. IV of the reports of the United States Geological Exploration of the Fortieth Parallel, pages 170 to 174. The following is a copy of his description:

Shell attaining a large size, rather thick, oval-subpyriform, nearly equivalve, very gibbous in the central and anterior regions, and much more compressed, narrowed, and produced posteriorly; beaks elevated, nearly equal, incurved, and placed more or less in advance of the middle; anterior side generally truncated obliquely forward above, from the beaks to near the middle, thence rounding abruptly to the base; posterior side much attenuated, and usually slightly truncated at the immediate extremity; dorsal margin generally much concave in outline behind the beaks, and provided with a well-defined marginal carina, extending in each valve from the beaks nearly to the posterior extremity, and between these carinæ with a deeply excavated lanceolate escutcheon; basal margin deeply rounded in the central and anterior region, and more or less sinuous in outline behind the middle; lunule deeply and rather largely impressed, without being always distinctly defined, though it is sometimes margined by a subangular ridge on each side. Surface ornamented with concentric ridges and furrows, most regularly and strongly defined on the umbonal region, and gradually becoming more irregular and less distinct toward the basal margin, or in some cases entirely fading away, so as to leave only the lines of growth over the whole exterior. Hinge with the tooth of the right valve rather thick, prominent, subtrigonal, striated, and a little curved upward; cartilage-pit deep and trigonal; hinge of left valve with pit and cartilage-process, presenting the usual characters; pallial line with apparently a small shallow sinus; posterior muscular impression very faintly marked; anterior muscular impression generally well defined, subovate, attenuated, and curving backward above where they connect with the small scars of the pedal muscles.

This species varies considerably in form as well as in surface-markings. In some specimens the whole surface is nearly smooth or only marked with obscure lines of growth, while in others the most gibbous part of the valves and the umbones are marked with very regular, distinct, concentric ridges and furrows. In still others the ridges and furrows are exceedingly irregular and very strongly marked. There are also more or less marked differences in the elevation of the beaks, the convexity of the anterior region, and the proportional length of the attenuated posterior extremity; yet all of these varieties blend together by such slight shades of difference that it seems impossible to find constant characters by which they can be separated specifically.

This species is an unusually large one for the genus Corbula, besides which it is unusually obese. The length of one of the larger examples is 40^{mm}; height, 29^{mm}; and thickness, 26^{mm}.

Mr. Meek regarded this form as representing a subgenus under Corbula, and he adopted for it Conrad's MS. name, Anisorhynchus;[1] but, as Mr. Meek has himself shown, it possesses no features which properly separate it from true Corbula. It is a conspicuous member of the Bear River fauna, not only because of its large size, but because of its abundance. Its geographical range is throughout the whole known extent of the formation, but it is most abundant at the locality 7 miles north of Evanston and at the one near the mouth of Sulphur Creek.

[1] For Mr. Meek's diagnosis of Anisorhynchus, see U. S. Geol. and Geog. Surv. Terr., Vol. IX, p. 241, 1876.

CORBULA ENGELMANNI Meek.

Plate IV, figs. 10, 11.

Corbula (Potamomya?) engelmanni Meek, 1860, Proc. Acad. Nat. Sci. Phila., Vol. XII, p. 213.
Corbula engelmanni Meek, 1876, Simpson's Rept. Great Basin of Utah, p. 362, pl. 5, figs. 13, a, b.
Corbula (Anisorhynchus?) engelmanni Meek, 1877, U. S. Geol. Explor. Fortieth Parallel, Vol. IV, p. 174, pl. 17, figs. 1, 1a.

All the larger collections of fossils that have been obtained from the Bear River formation contain a greater or less number of specimens of the form to which Mr. Meek gave the name *Corbula engelmanni.* Ever after its first publication, however, he felt much doubt whether it was really distinct from *C. pyriformis*, and I also have been disposed to regard this form as the young of that species, but there are certain facts which still suggest the separate specific identity of *C. engelmanni*, among which are the following: First, the outline of the form to which the name *C. engelmanni* has been applied rarely if ever fully agrees with that of *C. pyriformis* of similar size, as it is indicated by the lines of growth on adult specimens of the latter; second, the strong convexity of the valves and the incurving of the beaks which are characteristic of *C. pyriformis* are not observable on any of the shells which have been referred to *C. engelmanni;* third, no forms have been discovered which in size and shape are intermediate between *C. engelmanni* and *C. pyriformis;* fourth, the form *C. engelmanni* bears a much closer resemblance to the *C. nematophora* Meek of the Colorado formation than it does to *C. pyriformis.*

The last-named fact suggests a genetic survival of the form *C. engelmanni* from the waters in which the Bear River formation was deposited into those of the Colorado formation, the case thus suggested being similar to those which have been suggested on preceding pages for *Ostrea haydeni*, *Modiola pealei*, and *Corbicula durkeei.*

This form generally occupies different layers from those in which *C. pyriformis* prevails, and is frequently found in the same layers with *Unio belliplicatus* and *U. vetustus.* It is widely distributed in the Bear River formation, and is somewhat plentiful at some of the localities, but it is never so abundant as is *C. pyriformis.*

Genus CORBULOMYA Nyst.

CORBULOMYA TAUSCHII n. s.

Plate IV, figs. 12, 13.

Shell of moderate size, generally suboval, but sometimes subtrihedral in marginal outline; front somewhat narrowly rounded; base broadly convex; posterior narrowly rounded but not attenuated nor much extended; dorsal border sloping with little convexity from the umbones to the posterior margin; anterior obliquely truncate; lunule rather large, moderately deep, and margined by a more or less distinct angulation. Surface marked by somewhat distinct lines of growth and by small, irregular, concentric folds. Posterior tooth of the left valve strong, anterior one small, cartilage pit large. Teeth of the right valve unknown.

Length of the largest valve in the collection, which is suboval in marginal outline, 29mm; height, 20mm. Length of another example, which is subtrihedral in marginal outline, 22mm; height, 17mm. The latter example is not referred to this species with entire confidence.

If only the hinge-structure of this shell is considered, it is difficult to say how it differs from typical Corbula; but I refer it to Corbulomya because of its generally suboval marginal outline, its thin test, and its want of the posterior extension or attenuation and of the postero-dorsal carinæ, which usually characterize true Corbula.

The specific name is given in honor of Dr. Leopold von Tausch, of Vienna, who has done so much to make known the Hungarian fossil fauna, which in many respects so much resembles that of the Bear River formation.

This species was discovered at only one locality, which is near Sage Station, in Twin Creek Valley, Wyoming; but it was found associated with several characteristic species of the Bear River fauna.

GASTEROPODA.

Family AURICULIDÆ.

Genus AURICULA Lamarck.

AURICULA NEUMAYRI n. s.

Plate V, fig. 1.

Shell small, subfusiform; spire, short; volutions about six in number, those of the spire convex, the last one large, elongate, and subterete; suture moderately impressed; columella bearing three folds, all of which are prominent, but the middle one strongest and most nearly transverse in direction, the anterior one smallest; outer lip plain, moderately thickened in the adult, but sharp in immature examples. Aperture comparatively narrow and narrowly rounded in front, but ending anteriorly in a sharp angle. Surface marked by lines of growth which are often strong and somewhat irregular.

Length, 12mm; diameter, 5mm.

In its generic characteristics this form so nearly agrees with typical species of Auricula that, although its antiquity is suggestive of a generic difference in the animal, I do not see how the shell can with propriety be referred to any other genus. It is also an interesting fact that the family Auriculidæ is so fully represented in this formation as it is shown to be by the presence of this and the four following species.

The specific name is given in memory of the late Prof. M. Neumayr, of Vienna, whose important works upon the nonmarine fossil fauna of Austria-Hungary are well known.

The geographical range of this species was doubtless coextensive with other members of the fauna, but the only examples yet known are those which Mr. Stanton discovered at the locality 20 miles north of Cokeville, Wyo.

Genus MELAMPUS Montfort.

MELAMPUS CLARKII n. s.

Plate V, figs. 2, 3.

Shell small, subovate or subfusiform; spire short, its apex prominent; volutions five or six in number, those of the spire narrow and convex, that of the apex deflected or reversed; the body volution comprising much the greater part of the bulk of the shell, broadest at its distal part and tapering toward its proximal end; suture impressed and accompanied at its proximal side by a slightly impressed revolving line; aperture narrow, rounded in front and sharply angular behind; outer lip thin; inner lip more or less calloused and bearing three teeth; the upper tooth prominent, narrow, and inclining a little forward; middle tooth also prominent and inclining a little backward; the anterior tooth small and situated near the front of the aperture. Surface smooth or marked by more or less distinct lines of growth.

The largest specimens discovered are from 4 to 6^{mm} in length. They appear to be mature or nearly so, but it is probable that the species attains a greater size than the discovered specimens indicate.

The only specimens discovered were obtained by dissolving in acid the pieces of impure limestone which were obtained by Mr. Stanton 20 miles north of Cokeville, Wyo., where they were associated with *Tortacella haldemani* and several other minute forms herein described.

The specific name is given in honor of Prof. W. B. Clark, of Johns Hopkins University.

It is probable that the animal which constructed the shells here described was not really congeneric with those living forms which are classed under the genus Melampus, but the features presented by these fossil shells are so nearly like those of the shells of living species of Melampus that I am not able to satisfactorily refer it to any other genus. It is evidently congeneric with the *Melampus antignus* of Meek, from the brackish-water Cretaceous deposit near Coalville, Utah.

Genus RHYTOPHORUS Meek.

RHYTOPHORUS PRISCUS Meek.

Plate V, figs. 4, 5.

Melampus priscus Meek, 1860, Proc. Acad. Nat. Sci. Phila., Vol. XII, p. 315.
Rhytophorus priscus Meek, 1872, Ann. Rept. U. S. Geol. and Geog. Surv. Terr., p. 478.
Rhytophorus priscus Meek, 1876, Simpson's Rept. Great Basin of Utah, p. 364, pl. 5, figs. 4, a, b.
Rhytophorus priscus Meek, 1877, U. S. Geol. Explor. Fortieth Parallel, Vol. IV, p. 175, pl. 17, figs. 6, 6a.
Rhytophorus priscus White, 1883, Third Ann. Rept. U. S. Geol. Surv., p. 44, pl. 8, figs. 2, 3.

Although Mr. Meek gave the generic name Rhytophorus to this form in 1872, and it was so used by himself and others during the following years, no diagnosis of the genus was published until 1877, when it appeared in Vol. IV of the reports of the United States Geological Exploration of the Fortieth Parallel, page 175. The same page also contains Mr. Meek's description of the species, as follows:

Shell obovate, about once and a half as long as wide; spire depressed-conical; whorls about five, convex, or faintly subangular; last one large, somewhat shouldered above, and tapering below the middle; suture well defined; surface marked by rather obscure lines of growth, and the small, regular, vertical, or slightly oblique folds, which are distinct on the volutions of the spire, and around the upper edge of the body-whorl, but obsolete on all the surface below this; aperture narrow, angular above, and apparently very narrowly rounded below; outer lip sharp and apparently smooth within; columella provided with one rather strong oblique fold below, and a much smaller, less oblique one about half-way up the aperture.

Length of Mr. Meek's type specimen, 22^{mm}; diameter of the same, 18^{mm}. Some examples, however, which Mr. Stanton found near Sage Station, about 60 miles north of Sulphur Creek, where the species was originally discovered, show that it sometimes reached a much larger size. One of these specimens, when perfect, was not less than 30^{mm} in length.

This species has been found at only the two localities just mentioned, but it is probable that its geographical range was coextensive with the formation.

RHYTOPHORUS MEEKII White.

Plate V, figs. 6, 7.

Rhytophorus meeki White, 1876, Powell's Rept. Geol. Uinta Mts., p. 118.
Rhytophorus meeki White, 1880, Twelfth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., p. 82, pl. 30, figs. 8, a, b.
Rhytophorus meeki White, 1883, Third Ann. Rept. U. S. Geol. Surv., p. 444, pl. 8, figs. 4, 5.

Shell subfusiform; spire moderately extended, its length a little less than one-third the entire length of the shell; volutions about six in number, those of the spire convex, the last one large, elongate, subterete; suture impressed, and upon the proximal side of and near it there is an almost equally impressed revolving narrow furrow which has the appearance of a second suture; posterior fold of the columella well developed; the anterior one small. Surface marked by ordinary lines of growth, and also, upon the spire, by numerous small varices or longitudinal folds which cross the volutions in a direction slightly oblique to the axis of the shell, but nearly parallel to the lines of growth. These varices appear on only the distal portion of the last volution, but they cross the entire exposed portion of the volutions of the spire.

Length of the most perfect of the type specimens, 20^{mm}; diameter, 9^{mm}; but other specimens have a length of about 25^{mm}.

There is some reason to believe that this form is only a variety of *R. priscus* Meek; but the difference between typical examples of the two forms as they have heretofore been recognized is so great that it is still thought inexpedient to place them together.

Typical examples of *R. meeki* have as yet been found only at the locality near the mouth of Sulphur Creek.

Genus TORTACELLA gen. nov.

Shell slender, resembling in outward form that of the genus Acella Haldeman, but, unlike the shells of that genus, it bears two more or less prominent oblique folds upon its columella; outer lip plain, slightly thickened in the adult state; aperture elongate, rounded in front and sharply angular or narrowly subtruncate behind. Type, the *Acella haldemani* of White, which is at present the only species known

TORTACELLA HALDEMANI White.

Plate V, figs. 8, 9, 10, 11, 12.

Acella haldemani White, 1878, Bull. U. S. Geol. and Geog. Surv. Terr, Vol. IV, p. 714.
Acella haldemani White, 1880, Twelfth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., p. 84, pl. 30, figs. 9, a, b.
Acella haldemani White, 1883, Third Ann. Rept. U. S. Geol. Surv., p. 445, pl. 6, figs. 18, 19.

Shell very small and very slender; spire much extended, longer than the aperture; volutions very obliquely coiled, about six in number, those of the spire broadly convex, or with a tendency to become flattened at the middle, the last one comparatively large but not ventricose; aperture elongate and narrow, especially behind, a little obliquely rounded and sometimes slightly expanded at the front, sometimes narrowed at the middle by the slight flattening of the volutions just mentioned. Surface marked by numerous fine raised lines, visible under a lens, which correspond in direction to the lines of growth and which are separated by spaces of about equal width with the lines. The direction of these lines is only slightly oblique to the axis of the shell. Outer lip slightly thickened in adult specimens, the two columellar folds of about equal size, situated near each other at the mid length of the inner lip.

Length of adult example, 6^{mm}; diameter of the last volution, a little less than $1\frac{1}{2}^{mm}$.

All the specimens of this species which the collection contains have been obtained in the condition of chalcedonic pseudomorphs[1] by dissolving in acid pieces of the impure limestone layers in which they, together with many other small shells, were embedded. They have not been discovered in any other condition, and without the aid of the process which has just been mentioned it is not likely that this species would have been discovered. Even by this means it was not until lately discovered that it bears two folds upon the columella and that it therefore does not belong to the genus Acella, to which it was originally assigned.

Family LIMNÆIDÆ.

Genus LIMNÆA Lamarck.

LIMNÆA NITIDULA Meek.

Plate VI, figs. 1, 2, 3.

Melania ? nitidula Meek, 1860, Proc. Acad. Nat. Sci. Phila., Vol. XII, p 314.
Limnæa (Limnophysa) nitidula Meek, 1877, U. S. Geol. Explor. Fortieth Parallel, Vol. IV, p. 181, pl. 17, figs. 5, 5a.
Limnæa (Limnophysa) nitidula White, 1883, Third Ann. Rept. U. S. Geol. Surv., p. 445, pl. 6, figs. 15, 16.

The following is Mr. Meek's description of this species as given in Vol. IV of the reports of the United States Geological Exploration of the Fortieth Parallel, p. 181:

Shell small, ovate-subfusiform; spire conical, moderately elevated; volutions about six and a half, convex, last one forming two-thirds of the entire length; suture well defined; aperture sub-ovate, narrowly rounded below and angular above, scarcely equaling one-half of the length of the shell; columella apparently with only a very small fold, and showing by the side of the inner lip below appearances of a small umbilical indentation. Surface marked by fine, rather obscure lines of growth, with (on some specimens) exceedingly faint traces of microscopical revolving striæ.

Length, 10^{mm}; diameter of the last volution, 5^{mm}.

Ever since the first publication of this species more or less doubt has prevailed as regards its specific and generic characters, the locality and formation from which it was first obtained, and the identity of the type specimens. I have hitherto been somewhat disposed to regard it as identical with the form which is described on a following page under the name of *Charydrobia stachei*, and I should therefore have rejected it from this summary of the fauna of the Bear River formation if it were not that a considerable number of specimens have lately been obtained which conform well to the original description as published by Mr. Meek. The specimens believed to be those which were thus originally used by him are figured on Pl. VI. They are preserved in the collections of the United States National Museum, accompanied by a label in

[1] For an explanation of this condition, see Rept. U. S. Nat. Museum for 1892, p. 265.

Mr. Meek's handwriting, referring them to this species. The examples figured by Mr. Meek in Vol. IV of the reports of the United States Geological Exploration of the Fortieth Parallel, and copied by me in the Third Annual Report of the United States Geological Survey, are unlike these specimens, and unlike any form known to me in the Bear River fauna, and they do not answer to Mr. Meek's description.

This species was originally discovered at the long-known locality near the mouth of Sulphur Creek, but specimens have since been obtained at other localities. Mr. Stanton found some examples of it at the locality 20 miles north of Cokeville, which were embedded in thin layers of impure limestone, from which they were obtained in the condition of chalcedonic pseudomorphs by its solution in acid, in the manner already mentioned.

The distance between that locality and the one at which this form was originally discovered is about 100 miles, which indicates that it has a wide range within the geographical limits of the formation.

Genus PLANORBIS Müller.

Subgenus GYRAULUS Agassiz.

PLANORBIS PRÆCURSORIS n. s.

Plate VI, figs. 4, 5, 6, 7.

Compare with *P.* (*G.*) *militaris* White, Third Ann. Rept. U. S. Geol. Surv., p. 447, pl. 28, figs. 10, 11.

Shell minute, subdiscoidal, the upper side flattened, sometimes slightly convex and sometimes very slightly concave, lower side umbilicate; volutions almost regularly rounded and about four or four and one-half in number; aperture nearly round, only slightly oblique to either the plane or diameter of the coil. Surface marked only by lines of growth.

Diameter of coil of the largest example obtained, 3^{mm}; diameter of aperture, about 1^{mm}.

This little shell is a typical example of the section of the genus Planorbis, to which Agassiz gave the name Gyraulus. It differs from the form which Dr. Hayden found in Jurassic strata at the southwest base of the Black Hills, to which Meek and Hayden gave the name *P.* (*G.*) *veturnus*, in not having a depressed spire and in showing a less rapid increase in the size of the volutions. The *P.* (*G.*) *militaris* White (loc. cit.) which was obtained from the Wasatch formation of Utah more nearly resembles this form than does any other fossil form with which it need be compared, but because there is so much difference in the geological age of the formations from which they respectively come, and because the faunal associates of each are wholly different, the probability of the two forms being specifically identical is not considered.

The presence of this form in the Bear River strata near the mouth of Sulphur Creek has been known for several years, but satisfactory examples of it have only lately been obtained. These were found by Mr. Stanton at the locality 20 miles north of Cokeville, and were obtained by dissolving in acid fragments of the layer of impure limestone, which has been mentioned in connection with the description of *Tortacella haldemani* and other species.

Its presence at localities so widely separated indicates that it had a wide distribution within the geographical limits of the formation in which it occurs.

Family PHYSIDÆ.

Genus PHYSA Draparnaud.

PHYSA USITATA n. s.

Plate VI, figs. 8, 9.

Physa ———? White, 1883, Third Ann. Rept. U. S. Geol. and Geog. Surv. Terr., p. 449, pl. 6, fig. 17.

A collection of fossils which I obtained several years ago from the Bear River strata, near the mouth of Sulphur Creek, contained a single specimen of Physa, of which I afterwards published a figure (loc. cit.), but to which I then thought it inadvisable to apply a separate specific name. The collections which Mr. Stanton made in 1891 contain several other specimens of this form, two of which are figured on Pl. VI. All of these, like the one originally discovered, are imperfect, but they represent a typical species of the genus. Indeed, the proportions and general aspect of this shell are such that it is difficult to say how it differs specifically from certain well-known fossil and living species of Physa. It especially resembles those specimens of the common North American living species *P. gyrina* Say which have a comparatively short spire. Because of this close similarity to published species I have heretofore hesitated to give a separate name to this form, but I do so in this case for the sake of convenience in characterizing and discussing the fauna of the Bear River formation, and because it is presumably different from any published form. It is an interesting fact that this, the oldest species of Physa yet discovered in North America, should so closely resemble forms that are now living upon this continent.

All the discovered specimens of this form have been obtained in the condition of chalcedonic pseudomorphs by dissolving fragments of the embedding limestone in acid, as has been stated in connection with the description of preceding species.

Mr. Stanton's specimens were obtained at the locality 20 miles north of Cokeville, about 100 miles from the place at which the species were originally discovered. This fact indicates that it was generally distributed within the geographical limits of the formation in which it occurs.

Family HELICIDÆ.

Genus HELIX Linnæus.

HELIX? ———?

Plate VI, fig. 13.

Among the numerous small silicified shells obtained by dissolving in acid fragments of the fossiliferous limestone layer which Mr. Stanton discovered at the locality 20 miles north of Cokeville, Wyo., is a single small specimen which seems to be referable to some one of the sections into which the original genus Helix has been divided. The specimen is too incomplete for satisfactory diagnosis, and it is mentioned and figured here only for the purpose of giving as full a statement as possible of the fauna of the Bear River formation. It resembles the form which Dr. Stache has referred with doubt to the *H. cretacea* of von Tausch.[1]

Genus TORNATELLINA Beck.

TORNATELLINA? ISOCLINA n. s.

Plate VI, figs. 14, 15.

Shell short, narrowly umbilicate, but the umbilicus often nearly or quite covered by a thin layer of callus, subfusiform or subglobose; spire short, its sides nearly straight; apex acute; volutions about seven in number, convex, the last one extending considerably forward at the aperture, rounded on the anterior side, from which it is narrowly rounded into the small umbilicus; aperture moderately large, but because of the imperfection of the specimens its shape is not fully known; outer lip plain; inner lip with a thin layer of callus, and upon the body of the shell at the inner side of the aperture there is a single, slightly raised, angular, revolving ridge, which extends backward within the shell and forward upon the inner lip, but it is hardly visible when the outer lip is complete; suture impressed. Surface marked by ordinary lines of growth.

The length of the largest example obtained was, when perfect, about 10^{mm}; diameter of the last volution, $7\frac{1}{2}^{mm}$.

It is doubtful whether this shell really belongs to the genus Tornatellina, but its characteristics, so far as they are observable, agree more nearly with those of that genus than with those of any other shell known to me.

Mr. Stanton found the only known examples at the locality 20 miles north of Cokeville, Wyo. They are in the condition of chalcedonic pseudomorphs, and were obtained by dissolving in acid fragments of the thin layers of impure limestone containing them.

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[1] See Abhandl. K.-k. geol. Reichsanstalt, Wien, Band XIII, p. 167, pl. 4, fig. 30, 1889.

Family NERITIDÆ.

Genus NERITINA Lamarck.

NERITINA NATICIFORMIS White.

Plate VI, figs. 10, 11, 12.

Neritina naticiformis White, 1878, Bull. U. S. Geol. and Geog. Surv. Terr., Vol., IV, p. 715.
Neritina naticiformis White, 1880, Twelfth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., p. 89, pl. 30, figs. 3, a, b.
Neritina naticiformis White, 1883, Third Ann. Rept. U. S. Geol. Surv., p. 430, pl. 7, figs. 5, 6.

Shell small, young examples subglobose and resembling Natica in general aspect, but adult examples expanded and subovoid in outline; spire moderately prominent; volutions four and a half or five in number, convex, a little more narrowly rounded at the posterior than at the anterior side, those of the spire rounded into the depressed suture, the last one in adult shells very large, the expansion being greatest in front; inner lip of moderate breadth, flat or slightly concave, its inner margin moderately sharp, slightly concave, toothless; outer lip thin; aperture large, suboval. Surface plain or marked by faint, fine, close-set, revolving lines, visible only under a good lens.

Antero-posterior diameter, 11^{mm}; transverse diameter, 8^{mm}.

This species was originally described (loc. cit.) from young examples, and the description was therefore not quite accurate. The examples used in the foregoing description were brought by Mr. Stanton from the locality 20 miles north of Cokeville, in Wyoming. They have been obtained in the condition of chalcedonic pseudomorphs by dissolving fragments of the embedding limestone in acid in the manner already mentioned in connection with the description of other species.

It has been found only at the locality just mentioned and at the one near the mouth of Sulphur Creek, but these two localities being 100 miles apart, it is reasonable to suppose that its dispersion was nearly or quite equal to the geographical limits of the formation in which it occurs.

NERITINA STANTONI n. s.

Plate VI, figs. 16, 17, 18.

Shell small, spire slightly elevated or sometimes nearly flat; volutions about four in number, flattened upon the distal side and broadly rounded upon the proximal side. The place of meeting of the two sides, which is the periphery of the shell, is more or less angular, and in typical examples is marked by a small revolving carina, which is sharp and prominent upon all the volutions, but it becomes obsolete near the outer lip of adult examples. Upon some examples evidently belonging to this species the carina is obsolete upon all parts, but the subangularity at that part of such shells, together with their general characteristics, leaves no reasonable doubt that they, too, belong to this species. Inner lip not very broad, plain; aperture moderately expanded, broadly truncate posteriorly and somewhat narrowly rounded in front; outer lip thin. Surface marked by distinct lines of growth, and upon one of the examples two broad revolving bands of color-marking is still preserved.

Antero-posterior diameter of the largest example discovered, 9^{mm}; transverse diameter, 6^{mm}.

This species was found by Mr. Stanton in the thin layer of impure limestone at the locality 20 miles north of Cokeville, in Wyoming, where it was associated with *N. naticiformis* and other forms, which were obtained by dissolving fragments of the limestone in acid. He also obtained it in the ordinary condition from the locality near Sage Station, in the valley of Twin Creek.

Family MELANIIDÆ.

Genus PACHYMELANIA gen. nov.

Shell elongate, compact; test strong or more or less massive, which is largely owing to the deposit of callus upon the inner surface; volutions moderately convex or flattened, marked by longitudinal varices or revolving lines or by both, and both may be strong or obsolete, the last volution not inflated; suture distinct; aperture subovate, its posterior angle, which would otherwise be acute, is usually made obtuse by the deposit of callus, but the callus is not protuberant nor very thick; anterior portion of the aperture extended and rounded, outer lip sinuous, slightly thickened; inner lip covered with a layer of callus of moderate and nearly uniform thickness; columella arcuate.

These shells resemble the Cerithiidæ in aspect, but they are excluded from that family by the absence of any notch or canal in any part of the aperture. They differ from Melanopsis in this respect and in wanting a protuberance of callus upon the inner lip, although they somewhat resemble some forms of that genus in other respects. The character of the anterior portion of the last volution is much like that of Goniobasis Lea, to which genus both Mr. Meek and myself have referred it in former publications, but it differs from that genus in the moderate massiveness of the test and in a general habitus which is readily observable but difficultly describable. None of the species yet known shows any tendency to the production of spines or even of strong nodes. Type, the *Goniobasis cleburni* of White.

The only American species which I at present certainly refer to this genus are those which are described in the following paragraphs, all of which are members of the fauna of the Bear River formation. Few European fossil forms seem to be cogeneric with these, but it is probable that at least a part of the species published by Dr. G. Stache and

Dr. L. von Tausch and referred by them to Goniobasis are properly referable to this genus.[1] The characteristics of the living *Melania* (*Sermyla*) *admirabilis* Smith from Lake Tanganyika, in Africa, very closely resemble those of Pachymelania; but the test of that species appears to be less massive than is that of typical forms of this genus, and its aperture is not so much produced in front. The fact of such a resemblance is, however, an interesting one, because the African species is there associated with Pyrgulifera, as Pachymelania is thus associated in the Bear River formation.

PACHYMELANIA CLEBURNI White.

Plate VII, figs. 1, 2, 3.

Goniobasis cleburni White, 1876, Powell's Rept. Geol. Uinta Mts., p. 122.

Goniobasis cleburni White, 1880, Twelfth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., p. 91, pl. 30, figs. 4, a, b, c, d.

Goniobasis cleburni White, 1883, Third Ann. Rept. U. S. Geol. Surv., p. 460, pl. 6, figs. 4, 5, 6.

Shell moderately large, tapering regularly from the apex, the sides of the spire being gently convex; volutions of adult shells ten or more in number, regularly increasing in size, the sides of those of the spire gently convex or nearly flat, the anterior half of the last volution broadly convex; aperture obliquely subovate in outline. Surface of the spire marked by numerous strong, slightly curved longitudinal ridges or varices, slightly stronger at the middle than at the ends, which extend from suture to suture in a direction a little oblique to the axis of the shell. Surface of the anterior side of the last volution marked by coarse, slightly raised revolving lines, and traces of smaller revolving lines are sometimes seen upon the spire, but these are seldom strong enough to crenulate the varices. The varices usually become obsolete near the aperture of adult shells, and in some cases they are obsolete upon one or more of the last volutions of the spire.

This species was first discovered at the locality near the mouth of Sulphur Creek, but it has been found at most of the localities at which fossils of the fauna of the Bear River formation have been obtained. Its distribution may therefore be regarded as equal to the geographical extent of the formation.

PACHYMELANIA CHRYSALIS Meek.

Plate VII, figs. 6, 7. Compare also with 8, 12, 13.

Goniobasis chrysalis Meek, 1871, Ann. Rept. U. S. Geol. and Geog. Surv. Terr. for 1870, p. 316.

Goniobasis chrysalis White, 1880, Twelfth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., p. 91, pl. 30, figs. 6, a, b.

Goniobasis chrysalis White, 1883, Third Ann. Rept. U. S. Geol. Surv., p. 460, pl. 6, figs. 13, 14.

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[1] See Abhandl. K.-k. geol. Reichsanstalt, Wien, Band XIII, Heft I, 1889. Also idem, Band XII, No. 1, 1886.

The following is Mr. Meek's original description of this species (loc. cit.):

Shell generally almost cylindrical below the middle, but more abruptly tapering above, volutions six or seven, flattened, with the upper margin thickened, last one not angular, and scarcely larger than the next above it; suture well defined.

Surface ornamented by distinct vertical costæ, often ranged nearly in the same line all the way up the spire; these are partly interrupted by an effort to form three, or rarely four, obscure revolving lines or ridges, the upper of which is larger and more prominent than the others, which character, with the slightly enlarged upper ends of the vertical costæ, causes the thickened appearance of the upper margins of the volutions; several other slender and more distinct revolving lines also occur on the under side of the last turn. Aperture somewhat rhombic-ovate.

Mr. Meek's specimens were all small, and at the locality where the species was first discovered no other than small specimens have been found. He gives the length as about 17^{mm}; diameter, 5^{mm}. Among the collections which were brought by Mr. Stanton from other localities, however, are specimens evidently belonging to this species which when perfect were not less than 25^{mm} in length. The longer and more slender specimens are sometimes bent or distorted.

This form is generally found associated with *P. cleburni* and *C. chrysalloidea*, and its distribution seems to be throughout the whole geographical extent of the formation.

PACHYMELANIA CHRYSALLOIDEA White.

Plate VII, figs. 4, 5.

Goniobasis chrysalloidea White, 1876, Powell's Rept. Geol. Uinta Mts., p. 123.

Goniobasis chrysalloidea White, 1880, Twelfth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., p. 92, pl. 30, figs. 5, a, b.

Goniobasis chrysalloidea White, 1883, Third Ann. Rept. U. S. Geol. Surv., p. 462, pl. 6, figs. 11, 12.

Shell of medium size, gradually tapering from the last volution to the apex; volutions about seven or eight, those of the spire slightly convex, the last one broadly rounded to the anterior end; suture impressed, the apparent impression being increased by the projecting fold of the distal border of each volution, which is appressed against the next preceding one. Surface marked by more or less distinct longitudinal, slightly bent ridges or varices, which are crossed by several revolving lines that appear only on the ridges, and not between them, giving the ridges a knotted or crenulated appearance; anterior surface of the last volution also marked by distinct raised revolving lines.

Length of the most perfect of the original type specimens, 28^{mm}; diameter of the last volution, 9^{mm}; but some specimens since obtained are somewhat more slender.

This species is closely related to both *G. cleburni* and *G. chrysalis*, with both of which forms it is associated. It differs from the latter in its much larger size, much greater apical angle, straighter sides of the spire, and in the details of its ornamentation. It differs from *G. cleburni* in its smaller size, the more distinct crenulation of its longitudinal varices or folds, and in possessing the revolving fold-like projection of the distal border of its volutions which has been mentioned in the description.

The locality at the mouth of Sulphur Creek and the one 7 miles north of Evanston are the only localities that have yet furnished recognized specimens of this species, and all of the specimens are in an imperfect condition.

PACHYMELANIA TURRICULA n. s.

Plate VII, figs. 14, 15.

Shell rather small and slender; apex acute; sides of the spire nearly straight; volutions of the spire moderately convex and marked by numerous longitudinal varices which have a tendency to range themselves in continuous lines; the ends of the varices of the one volution not quite reaching those of the next preceding and succeeding volutions gives the shell the appearance of having an unusually deep suture; the anterior volutions of the spire are marked by four depressed revolving lines, giving the varices a crenulated appearance, but these lines are obsolete or absent on the smaller volutions. The surface of the anterior part of the last volution is marked by four or five raised revolving lines, which diminish in strength toward the axis.

The largest and best specimen discovered is imperfect at the proximal end, and its full length is therefore unknown; it probably reached a length of 16^{mm} and a diameter of 6^{mm} at the last volution. This form somewhat resembles the young of *P. cleburni*, but it differs conspicuously in having a smaller apical angle and in having its sides straight along its entire length. Its longitudinal varices are also much more generally disposed in continuous lines.

Mr. Stanton obtained this species at the locality near the mouth of Sulphur Creek and at the one near Sage Station.

There are many specimens referable to Pachymelania in the collections obtained from the Bear River formation, mostly small examples, which one finds it difficult to assign to any of the species just described because of the recognizable interspecific variation in the case of all of them. This fact, together with the remarkable variation of the associated *Pyrgulifera humerosa* which is to be pointed out on following pages, suggests the possibility that some of the forms of Pachymelania just described are only varieties of some of the others, but so far as these forms are now known they all seem to be worthy of full specific recognition. One of the varieties referred to, found by Mr. Stanton at the locality near Sage Station, in the valley of Twin Creek, probably represents a variety of *P. chrysalis*, but the specimens are so constant in their characteristic differences from that form that I have hesitated to refer them to it. This variety is well represented by figs. 12 and 13, on Pl. VII.

PACHYMELANIA? MACILENTA White.

Plate VII, fig 9. Compare also with 10, 11.

Goniobasis macilenta White, 1880, Twelfth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., p. 93, pl. 30, figs. 10, a.

Goniobasis macilenta White, 1883, Third Ann. Rept. U. S. Geol. Surv., p. 462, pl. 6, fig. 12.

Shell comparatively small, slender; test thinner than is usual with typical species of Pachymelania; sides of the spire straight or slightly concave; volutions ten or more in number, uniformly increasing in size, the distal border of each so appressed against the next preceding one that their flattened sides form the continuous surface of the straight sides of the shell. Surface marked by the linear suture and by lines of growth which are gently sinuous and have a general direction approximately corresponding to the axis of the shell. Near the distal border of each volution there is usually to be observed in well-preserved examples a more or less distinct revolving impressed line which simulates a second suture.

Numerous examples of this species have been discovered, but they are all more or less broken and imperfectly preserved. The shape of the aperture is therefore known only by the outline of the volutions and the direction and character of the lines of growth which are observable upon the volutions. All of these characters are consistent with those which distinguish Pachymelania.

Most of the specimens discovered are small, the largest indicating that adult examples reached a length of 25^{mm} and a diameter of 7^{mm} for the last volution. The principal reason for doubt that this shell belongs to Pachymelania is the comparative thinness of the test. In this respect it more nearly resembles Goniobasis, to which genus I have hitherto referred it. A chalcedonic pseudomorph of a young shell which I refer to this species shows that the minute apical volutions were distinctly convex, but that they became flattened before the shell had reached a millimeter in length. The columella of this example, not being distinctly arcuate, suggests its relation to Eulimella, but there is no indication of a reversal, or even of distortion, of the apical volutions. It is probable that figs. 10 and 11 on Pl. VII represent another species, but I am not now able to satisfactorily diagnose them as specifically different from *P.? macilenta.*

This species was first discovered at the locality near the mouth of Sulphur Creek, but it has since been found at most of the localities which have furnished fossils of the Bear River fauna. It therefore appears to have as great a geographical distribution as has any other member of that fauna.

Genus PYRGULIFERA Meek.

This genus has been the subject of so much discussion and the only known American representatives of it are so characteristic of the Bear River formation that it is thought advisable to give Mr. Meek's generic diagnosis here and to discuss the genus and its geographical distribution and chronological range more at length on following pages. The following is the diagnosis as published by Mr. Meek in Vol. IV of the reports of the United States Geological Exploration of the Fortieth Parallel, page 176, but it requires some modification to admit certain forms since properly referred to this genus; such, for example, as those upon which the shouldering of the volutions and the strong surface features mentioned by Mr. Meek are not well developed:

> Shell subovate, thick, imperforate; spire produced, turreted; volutions angular, shouldered, and nodular above; surface typically, with vertical ridges and revolving markings; aperture subovate, faintly sinuous, but not notched or distinctly angular below; outer lip prominent in outline below the middle, retreating at the base, and subsinuous at the termination of the shoulder of the body-volution above; peristome continuous; inner lip a little callous below, and thickened all the way up, but without a protuberant callus above, sometimes with a shallow umbilical furrow along its outer margin below.

With the single exception to be mentioned further on, neither this nor any nearly related genus is yet known in North America beyond the limits of the Bear River formation. All the other known species of Pyrgulifera are mentioned on following pages under the general head of "The geographical and time range of Pyrgulifera."

PYRGULIFERA HUMEROSA Meek.

Plate VIII, figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and Plate IX, figs. 4, 5, 6, 7, 8.

Melania humerosa Meek, 1860, Proc. Acad. Sci. Phila., Vol. XII, p. 313.
Pyrgulifera humerosa Meek, 1872, Ann. Rept. U. S. Geol. and Geog. Surv. Terr. for 1871, p. 376 (no description).
Pyrgulifera humerosa Meek, 1876, Simpson's Rept. Great Basin of Utah, p. 363, pl. 5, figs. 6, a, b, c.
Pyrgulifera humerosa Meek, 1877, U. S. Geol. Explor. Fortieth Parallel, Vol. IV, p. 176, pl. 17, figs. 19, 19a, and woodcut.
Pyrgulifera humerosa White, 1882, Nature, Vol. XXV, p. 101.
Pyrgulifera humerosa White, 1882, Proc. U. S. Nat. Museum, Vol. V, p. 98, pl. 3, figs. 10, 11, 12.
Pyrgulifera humerosa White, 1883, Third Ann. Rept. U. S. Geol. Surv., p. 460, pl. 6, figs. 4, 5, 6.
Pyrgulifera humerosa Tausch, 1884, Sitzungsber. K. Akad. Wiss., Band XC, p. 60, Pl. I, figs. 1-3.
Pyrgulifera humerosa White, 1885, Am. Jour. Sci., Vol. XXIX (2), p. 278.
Pyrgulifera humerosa Tausch, 1886, Abhandl. K.-k. geol. Reichsanstalt, Band XII, p. 4.

The following is the specific description published by Mr. Meek on pages 176–177 of Vol. IV of the reports of the United States Geological Exploration of the Fortieth Parallel:

Shell attaining a rather large size, moderately solid, ovate-subfusiform; spire prominent, distinctly turreted; volutions five and a half to about seven, angular and strongly shouldered, the upper surface being flattened or a little concave, with usually a slight outward slope from the suture to the angle or shoulder, where it meets the vertical outer surface nearly at right angles; last or body-volution large, or generally composing about two-thirds the entire bulk and length of the shell; suture well defined by the prominence and angularity of the volutions, but not channeled. Surface of each turn ornamented by about ten to fifteen rather strong, vertical, or slightly oblique folds, or costæ, each of which terminates in a small, nodular projection at the shoulder above, so as sometimes to impart a subcoronate appearance to the same, while they all become nearly or quite obsolete below the middle of the body-volution; vertical costæ crossed by smaller, but quite distinct revolving, raised lines, or small ridges, some four to six of which may be counted on the outer surface of each turn of the spire, and about ten on the body-volution, where they increase in size downward; upper flattened surface of the volutions generally only marked by the moderately distinct lines of growth seen below; aperture obliquely rhombic-subovate, being higher than wide, rounded subrectangular above, and narrowed and more or less angular, with a slight sinus or notch at the connection of the outer and inner lips near the middle below; columella arcuate; inner lip, in mature specimens, rather thick all the way up, but more so below, where it is somewhat reflected and margined by a slight, revolving, umbilical furrow, with usually an angular outer margin; outer lip sharp, prominent near the middle, and retreating below and at the angle of the whorls above.

The length of Mr. Meek's principal type specimen, which is one of the largest yet discovered, is 41^{mm}; breadth of its last volution, 23^{mm}. There is, however, much difference in size and proportions among the multitude of specimens that have been collected.

Mr. Meek's description applies completely to his type specimen and to much the greater part of the many hundreds of specimens which have been discovered in the Bear River formation. A few of these, however, show such variations of form and ornamentation that no one would hesitate to assign them to different species if they were not associated with intermediate forms and by them more or less closely connected with the great mass of typical forms. Figs. 1 to 10 on Pl. VIII represent what may be regarded as typical forms, and figs. 4 to 8 on Pl. IX represent some of the varieties referred to.

The greatest amount of variation that has been observed is found among the specimens collected by Mr. Stanton at the Cokeville locality, where most of the specimens figured on Pl. IX which show material variation were obtained. The variation consists mainly in the modification of surface features and ornamentation, but there is also some variation of general shape. The coincidence of the two kinds of variation is, however, only exceptional.

Figs. 1, 2, and 3 on Pl. IX represent a form which differs so much from all the others that I have thought it expedient to give it the separate specific name which heads the following description. I do this more as a matter of convenience than because of any belief that there is in the Bear River formation more than one true species of Pyrgulifera. That is, it is evident that all the varieties just referred to, including the one last mentioned as well as the typical forms of *P. humerosa*, were intimately associated with one another while living; and I think it is also evident that they all freely interbred. If this was the case, each form was not only potentially but actually ancestral to representatives of all the other forms, and therefore, according to my understanding of the character and limitation of a species, all these forms are properly included in one specific group.

No member of the Bear River fauna is more conspicuous than is *Pyrgulifera humerosa*. Its geographical distribution is throughout the known extent of the formation, but it has been found especially abundant at the locality near the mouth of Sulphur Creek and at the one 7 miles north of Evanston, in southwestern Wyoming.

PYRGULIFERA STANTONI n. s.

Plate IX, figs. 1, 2, 3.

Among the specimens obtained at the Cokeville locality by Mr. Stanton are some examples of Pyrgulifera which have already been referred to as differing so much from typical forms of *P. humerosa* that I think it expedient for geological, but not necessarily for biological, purposes to give them a separate name. The principal difference between these specimens and typical examples of *P. humerosa* is their greater elongation, less distinct shouldering of the volutions, the somewhat greater prominence of the longitudinal varices, and less distinctness of the revolving lines. Typical examples of *P. humerosa*, as well as the other varieties referred to in connection with the description of that species, were found associated in the same layers with this form, and few examples have been discovered which may be regarded as intermediate between them.

The type specimens of *P. stantoni* are represented by figs. 1 and 2. Fig. 3 represents a form which, while it is here referred to *P. stantoni*, seems to be intermediate between them and the more elongate examples of *P. humerosa*.

Family RISSOIDÆ.

Genus HYDROBIA Hartmann.

HYDROBIA OCCULTA n. s.

Plate X, figs. 12, 13.

Shell very small, elongate, minutely perforate at the base; apex slightly obtuse; volutions six or seven in number, rounded, those of the anterior half of the shell a little more oblique to its axis than are those of the posterior half; suture impressed; aperture subovate, extended in front by the obliquity of the last volution. Surface marked only by lines of growth.

Length, 3^{mm}; breadth of last volution, 1^{mm}.

Several examples of this little shell, like those of several of the other species which are described in this bulletin, were discovered in the condition of chalcedonic pseudomorphs among the débris resulting from an acid solution of fragments of impure limestone found by Mr. Stanton at the locality 20 miles north of Cokeville. It seems to be properly referable to Hydrobia, but the apical angle of the spire is less than is usual with species of that genus, and the apex is also a little more obtuse.

Genus BYTHINELLA Moquin-Tandon.

BYTHINELLA LATENTIS n. s.

Plate X, figs. 10, 11.

Shell very small, moderately elongate, its sides gently convex, base imperforate; volutions five in number, convex; suture impressed; surface marked only by lines of growth; aperture not much expanded, subcircular or suboval in outline, obtusely angular posteriorly.

Length, hardly reaching 3^{mm}; diameter of the last volution, 1^{mm}, or a little less.

This little shell was found associated with the preceding species, and was obtained from its embedding limestone matrix in the same manner. It has been found at no other locality than the one 20 miles north of Cokeville, and if they had not been changed from their original condition to that of chalcedonic pseudomorphs it is not likely that they would ever have been discovered.

Genus CHARYDROBIA Stache.

CHARYDROBIA STACHEI n. s.

Plate X, figs. 7, 8, 9.

Shell large for a species of this genus, subfusiform; volutions about six in number, regularly convex; aperture subovate in outline, narrowly rounded in front, narrow and subangular behind; umbilical fissure more or less distinct. Surface plain.

Length of the largest example discovered, 13^{mm}; breadth of the last volution of the same, $6\frac{1}{2}^{mm}$.

Specimens of this shell, like those of several others already described, were obtained in the condition of chalcedonic pseudomorphs by dissolving in acid the fragments of impure limestone in which they were imbedded. This form has been by some collectors confounded with *Limnæa nitidula*, but it is distinctly different from that species, and there seems to be no good reason to doubt that it is properly referable to the genus Charydrobia Stache. Indeed it bears a close resemblance to the type of that genus, *C. characearum*, as figured by Stache on Pl. V, Abhandlungen der K.-k. geologischen Reichsanstalt, Band XIII.

This species has been found only at the locality near the mouth of Sulphur Creek and at the one 20 miles north of Cokeville. It is probable, however, that it had a general distribution in the Bear River formation.

Family VIVIPARIDÆ.

Genus VIVIPARUS Montfort.

VIVIPARUS COUESI White.

Plate X, fig. 1.

Campeloma ———? Meek, 1877, U. S. Geol. Explor. Fortieth Parallel, Vol. IV, p. 181, pl. 17, figs. 15, 15a.
Viviparus couesi White, 1878, Bull. U. S. Geol. and Geog. Surv. Terr., Vol. IV, p. 717.
Viviparus couesi White, 1880, Twelfth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., p. 99, pl. 30, fig. 1, a.
Viviparus couesi White, 1883, Third Ann. Rept. U. S. Geol. Surv., p. 467, pl. 8, fig. 1.

Shell very large when fully adult; volutions six or seven, convex, the distal side, of the last one especially, abruptly rounded to the suture, giving it a somewhat shouldered aspect there, while the outer side is broadly convex and sloping gently forward and inward; suture deeply impressed, the apparent depth being increased by the great convexity of the volutions. Surface marked by the ordinary lines of growth, no revolving marks of any kind having been detected. The lines of growth indicate that the margin of the outer lip is nearly straight, as is usual with all species of this genus, this feature being one of those which distinguish shells of this genus from those of Campeloma. Inner lip somewhat thickened by callous and reflexed at the proximal or anterior end, but not covering the umbilical fissure there, which is moderately large. The precise shape of the aperture is unknown, but the outline of the volutions shows that it was subovate.

No perfect examples have been discovered, but the largest one yet obtained would, if perfect, measure about 65^{mm} in length; full width of body volution, 38^{mm}.

The apical portion of a specimen of this species was described and figured (loc. cit.) by Mr. Meek under the generic name of Campeloma, but he gave it no specific name. His specimen, however, like the type specimen figured on Pl. X, shows by its nonsinuous lines of growth that it had the straight outer lip of Viviparus and not a sinuous one like Campeloma.

Mr. Meek's specimen came from the locality near the mouth of Sulphur Creek. The type specimen figured on Pl. X came from the locality 7 miles north of Evanston. The species has not been certainly identified at any other locality.

Genus CAMPELOMA Rafinesque.

CAMPELOMA MACROSPIRA Meek.

Plate X, figs. 2, 3.

Melantho (*Campeloma*) *macrospira* Meek, 1873, Ann. Rept. U. S. Geol. and Geog. Surv. Terr. for 1872, p. 478.
Campeloma macrospira Meek, 1877, U. S. Geol. Explor. Fortieth Parallel, Vol. IV, p. 179, pl. 17, figs. 17, a, b.
Campeloma macrospira White, 1880, Twelfth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., p. 102, pl. 30, figs. 2, a.
Campeloma macrospira White, 1883, Third Ann. Rept. U. S. Geol. Surv., p. 469, pl. 8, figs. 6, 7.

The following is Mr. Meek's description of this form as published by him in 1877 (loc. cit.):

Shell ovate, of medium size; volutions about five or six, convex, increasing rather gradually in size and without revolving ridges or angularities; spire moderately prominent, conical, and not eroded at the apex; suture distinct, in consequence of the convexity of the volutions; surface with fine, obscure, slightly sigmoid lines of growth; aperture ovate; inner lip somewhat thickened below.

The length of Mr. Meek's type specimen, which is figured on Pl. X, is 44^{mm}; breadth of the last volution of the same, 28^{mm}.

Specimens of this species have been found at most of the localities at which the Bear River formation has been recognized, and its geographical distribution was apparently equal to that of the formation.

Genus LIOPLAX Troschel.

LIOPLAX? ENDLICHI White.

Plate X, figs. 4, 5.

Goniobasis endlichi White, 1878, Bull. U. S. Geol. and Geog. Surv. Terr., Vol. IV, p. 716.
Goniobasis endlichi White, 1880, Twelfth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., p. 92, pl. 30, figs. 7, a, b, c.
Goniobasis (*Lioplax?*) *endlichi* White, 1883, Third Ann. Rept. U. S. Geol. Surv., p. 463, pl. 7, figs. 7, 8.

Shell moderately elongate-conical, sides of the spire straight, or slightly concave; volutions six or seven in number, convex, the larger ones showing an obsolete angularity at the middle; suture well defined and appearing unusually deep, because of the prominent convexity of the volutions; aperture subovate in outline, its distal end angular, its front somewhat narrowly rounded; outer lip apparently sharp; inner lip with a thin reflected callus which is more developed anteriorly than posteriorly. Surface marked by fine distinct lines, which give it a cancellated appearance under a lens. A few of the revolving lines are stronger than the others, and these are observable without the aid of a lens.

Length, about 22^{mm}; diameter of the last volution, 11^{mm}.

This form has been found only at the locality 7 miles north of Evanston, Wyo. It was evidently not an abundant species, but it is distinctly different from any other recognized member of the Bear River fauna. There is, however, reason to doubt that the extent of variation to which the surface markings were subject were as great as has been indicated in former publications. The foregoing description may therefore be regarded as applying only to the specimens which are represented on Pl. X by figs. 4 and 5. Two imperfect examples were found associated with those which in the publication quoted at the head of this description I have referred to this species and figured in connection with the others, but I am not quite satisfied as to their specific identity with *Lioplax? endlichi*. One of these doubtful specimens is represented by fig. 6. The revolving raised lines upon these doubtful specimens are much stronger than they are upon the typical examples, but the fine revolving and longitudinal lines the presence of which the lens reveals are of the same character in both cases. This fact makes me hesitate to separate them under different specific names, although I think it possible that this may be made necessary by future discoveries.

This species is evidently referable to the family Viviparidæ, and its sinuous outer lip suggests its affinity with Campeloma, but in the subangular character of its volutions and the presence of revolving markings, as well as in general aspect, it resembles the *Lioplax subcarinata* of Say, a species now living in North American fluviatile waters. These features have suggested its reference to that genus, although nothing is known of its most distinctive shell feature, the structure of the operculum.

MOLLUSCOIDEA.

It is hardly to be expected that the Molluscoida would be represented in a nonmarine fauna like that of the Bear River formation, but some traces of a Bryozoan form have been found attached to shells of *Corbula pyriformis* which were obtained at the Sulphur Creek locality. They are too imperfect for description, or even for satisfactory determination, but they probably belong to the genus Membranipora of Blainville.

ANNULOSA.

CRUSTACEA.

The residue resulting from an acid solution of the pieces of impure limestone which were obtained by Mr. Stanton from near Cokeville, Wyo., and which have been already several times mentioned in connection with the foregoing descriptions, was found to contain numerous specimens of silicified shells of Ostracoda. A quantity of this residue was sent for examination to Prof. T. Rupert Jones, of London, whose exhaustive studies of these minute crustaceans are everywhere known, and he found it to contain an unexpectedly large number of forms, These proved to be of so much interest that he has published an illustrated article concerning them in the London Geological Magazine.[1]

In this collection of Bear River Ostracoda Professor Jones has recognized twelve species and seven genera, of which the following is a list:

Cypris purbeckensis E. Forbes.
Cypridea tuberculata Sowerby, var. wyomingensis.
Potamocypris affinis, n. s.
Matacypris consobrina n. s.
M. subcordata n. s.
M. cuneiformis n. s.
M. simplex n. s.
Cythere monticula n. s.
Cytheridea truncata n. s.
C. tenuis n. s.
Cytherideis æqualis n. s.
C. impressa n. s.

The unusually large number of both genera and species thus represented and the wide geographical and considerable chronological range assigned to some of them by Professor Jones make it desirable that all the recognized forms of this Bear River Ostracoda fauna should be represented in this bulletin. They are therefore all figured on Pl. XI, the figures all being copies from Professor Jones's original publication, but it is not thought necessary to republish specific descriptions of the several forms.

It will be seen by the foregoing list that all except two of these forms are described by Professor Jones as new. One of these two he regards as a variety of *Cypridea tuberculata* Sowerby, and the other as identical with *Cypris purbeckensis* E. Forbes, both species having been originally described from the Purbeck division of the English Jurassic. It is an interesting fact that the fresh-water Jurassic fauna of Colorado[2] contains a species of Cypris which Professor Jones refers doubtfully to *C. purbeckensis*, and that *Metacypris consobrina* and *M. subovata* of the Bear River fauna are closely related to *M. forbesii* as it occurs in the Colorado Jurassic. Others of these Bear River Ostracoda, however, are related to members of later faunas.

Professor Jones observes that nearly all these Bear River Ostracoda represent either fresh-water or estuarine forms, but that two or three of them represent marine forms. This fact is not really discordant with the nonmarine character of the associated mollusca. Some of the species of the latter class have living representatives which are capable of thriving in waters of full marine saltness as well as in those which are much less saline, and it is not unreasonable to suppose that those Ostracoda were capable of thriving under similar differences of condition of habitat.

PLANT REMAINS.

Certain of the Bear River strata contain an admixture of much carbonaceous matter, and in some of them impure lignite has been found. This matter having been of vegetal origin, it is presumable that an abundant flora existed contemporaneously with the deposition of the

[1] See Geol. Mag., new ser., Decade III, Vol. X, pp. 385-391, pl. xv, London, 1893.
[2] See Bull. U. S. Geol. Surv. No. 29, p. 24, 1886.

formation, but it is nevertheless true that plant remains in a classifiable condition are extremely rare in its strata. The only remains of this kind yet discovered are some minute Chara fruits and the few fragmentary imprints of dicotyledonous leaves which are mentioned on page 22. Although the latter are too imperfect for satisfactory description and illustration, there can be no question of their dicotyledonous character, nor can there be any doubt that they represent an abundant flora. The Chara fruits have been studied and published by Prof. F. H. Knowlton,[1] the following being a copy of his description:

CHARA STANTONI Knowlton.

Plate X, figs. 14, 15, 16.

"Fruit (Sporostegium), oblong-elliptical in general outline, slightly smaller at the apex, obtuse, nearly one-fifth longer than wide; length, 0.63^{mm}; diameter, 0.48^{mm}. Number of spirals as observed in side view, eight or nine; cells furrowed, separated by thin, low, projecting ridges."

BIOLOGICAL DISCUSSION.

The existence of remains of great vertebrate faunas during all the other known epochs of the Mesozoic era makes it certain that important faunas of that kind existed contemporaneously with the deposition of the Bear River formation. Indeed, that such a fauna existed in the immediate vicinity of, and in part within, the body of water in which its deposition took place may be legitimately inferred, but up to the present time no vertebrate remains are known to have been discovered in any strata that are certainly referable to this formation. Therefore all further reference to a vertebrate fauna must be omitted from a biological discussion of the Bear River formation on this occasion.

That an abundant flora, mainly dicotyledonous, existed during the Dakota epoch is well known, and if, as the evidence now seems to indicate, the Dakota epoch preceded the Bear River epoch, we may assume that an equally important flora existed while the Bear River formation was in process of deposition. Indeed such an assumption would be hardly less rational if it should yet appear that the Bear River is older than the Dakota formation. Still, we have only the indefinite evidence of the existence of a Bear River flora that has been mentioned on a preceding page. That is, besides the comparatively large amount of carbonaceous matter which certain of the Bear River strata contain, all the plant remains yet discovered in any of them are a few fragmentary imprints of leaves and a few Chara fruits. Therefore, while we can not doubt that a great and varied flora existed during the Bear River epoch, and within the Bear River district, we can not now discuss its existence as an ascertained biological fact.

[1] Botanical Gazette, Vol. XVIII, pp. 141-142, Bloomington, Ind., 1893.

This necessary exclusion of vertebrates and plants leaves only the invertebrate fauna to be considered in a biological discussion of the Bear River formation. This invertebrate fauna, so far as it is yet known, is represented concisely by the following classified list of the species, all of which are described and figured on the plates accompanying this bulletin:

The invertebrate fauna of the Bear River formation.

MOLLUSCA.

CONCHIFERA.

Family OSTREIDÆ.

Genus OSTREA Linnæus.

Ostrea haydeni White.

Family MYTILIDÆ.

Genus MODIOLA Lamarck.

Modiola pealei W.

Family UNIONIDÆ.

Genus UNIO Retzius.

Unio belliplicatus Meek.
U. vetustus M.

Family CYRENIDÆ.

Genus CORBICULA Megerle.

Corbicula durkeei M.

Family CORBULIDÆ.

Genus CORBULA Bruguiere.

Corbula pyriformis M.
C. engelmanni M.

Genus CORBULOMYA Nyst.

Corbulomya tauschii W.

GASTEROPODA.

Family AURICULIDÆ.

Genus AURICULA Lamarck.

Auricula neumayri W.

Genus MELAMPUS Montfort.

Melampus clarkii W.

Genus RHYTOPHORUS Meek.

Rhytophorus priscus M.
R. meekii W.

Genus TORTACELLA White.

Tortacella haldemani W.

Family LIMNÆIDÆ.

Genus LIMNÆA Lamarck.

Limnæa nitidula M.

Genus PLANORBIS Müller.

Planorbis (Gyraulus) præcursoris W.

Family PHYSIDÆ.

Genus PHYSA Draparnaud.

Physa usitata W.

Family HELICIDÆ.

Genus HELIX Linnæus.

Helix? ——?

Genus TORNATELLINA Beck.

Tornatellina? isoclina White.

Family NERITIDÆ.

Genus NERITINA Lamarck.

Neritina naticiformis W.
N. stantoni W.

Family MELANIIDÆ.

Genus PACHYMELANIA White.

Pachymelania cleburni W.
P. chrysalis Meek.
P. chrysalloidea W.
P. turricula W.
P? macilenta W.

Genus PYRGULIFERA Meek.

Pyrgulifera humerosa Meek.
P. stantoni W.

Family RISSOIDÆ.

Genus HYDROBIA Hartmann.

Hydrobia occulta White.

Genus BYTHINELLA Moquin-Tandon.

Bythinella latentis W.

Genus CHARYDROBIA Stache.

Charydrobia stachei W.

Family VIVIPARIDÆ.

Genus VIVIPARUS Montfort.

Viviparus couesi W.

Genus CAMPELOMA Rafinesque.

Campeloma macrospira M.

Genus LIOPLAX Troschel.

Lioplax? endlichi W.

MOLLUSCOIDEA.

Genus MEMBRANIPORA Blainville.

Membranipora? ——?

ANNULOSA.

CRUSTACEA.[1]

When one finds it necessary to compare different fossil faunas with one another, it is desirable to know as definitely as practicable whether in each case the fauna is a full one; in other words, it is desirable to know whether all the forms of which a given fauna under investigation was originally composed are probably represented by discovered fossil remains. It has just been shown that the Bear River fauna includes no known vertebrates, and the foregoing list shows that, with the

[1] See the list of the Bear River Ostracoda on page 62.

exception of the Ostracoda just mentioned, its known invertebrate fauna consists wholly of mollusca.

Examining this list with reference to the known general character and composition of living faunas, we do not observe any necessarily material discrepancy among the branchiferous forms, nor any among those of either the littoral or the palustral pulmoniferous forms; that is, these divisions of the mollusca are often no more fully represented among living nonmarine faunas than they are in the foregoing list. There are, however, no specimens among all the collections that have yet been made from the Bear River strata which can with entire confidence be referred to the land pulmoniferous mollusca, and only two species have been discovered which are provisionally so referred.

It should be borne in mind, in this connection, that remains of land mollusca can reach sedimentary entombment only by accidental transportation, while remains of aquatic mollusca have generally been entombed where they lived. Therefore it is probable that the land mollusca were well represented in the district surrounding the waters in which the Bear River formation was deposited. Still, the forementioned discrepancy among the collections of Bear River fossils exists, and it will be further referred to or indicated in following discussions. It will also in part be shown by a comparison of the foregoing list with the lists of other faunas which are given on following pages.

The foregoing statements make it apparent that in discussing the fauna of the Bear River formation we are not only practically confined to the mollusca, but we are confined to a certain few families. Furthermore, applying the accepted criteria of past aqueous conditions, we find that all these molluscan forms fall into the nonmarine category; that is, they are forms the living congeners of which are denizens of either brackish water or fresh water or of the land, there being no representatives among them of forms that now live exclusively in marine waters.

It is clearly apparent, from an examination of the important and somewhat numerous collections of the Bear River molluscan fossils which have been brought to the National Museum, that forms which represent all the varieties of habitat just referred to, including remains of both branchiferous and pulmoniferous mollusca, are intimately commingled in at least a part of the Bear River strata. This fact is especially apparent to the geologist who has himself collected the fossils of that formation. The collector of fossils from the Bear River formation also observes that the layers which contain *Ostrea haydeni* contain comparatively few other forms, and that such purely fresh-water forms as Unio, Viviparus, etc., are rarely, if ever, commingled with them. It is true, however, that some of the forms which are found in intimate association with the Ostrea are also found in similar association with those which we call purely fresh-water forms; but this is taken to indicate that the associate forms referred to were capable of thriving in both saline and fresh waters, while the Ostrea could exist only in saline waters, and the Unio, Viviparus, etc., only in fresh waters.[1]

This apparently, and in part really, incongruous commingling of the fossil remains which constitute the Bear River molluscan fauna is of special interest in connection with its study, and the probable causes of it have also a general relation to the possible geographical dispersion of specific and generic molluscan forms, which subject also will in part be discussed on following pages.

The remarks which I propose to make upon both these subjects will be better understood by some explanatory references to certain of the principles and criteria upon which they are based and which are tacitly understood by geologists, although they are rarely enunciated in their writings.

In discussing the evidence of past aqueous conditions, which by comparison with present conditions are known to have attended the production of the various sedimentary formations of the earth, it has become customary among geologists to apply the term nonmarine to those bodies of water which are either fresh or less saline than are the oceans and the seas which directly and freely communicate with them. It has also become customary to apply the same term to the fossil faunas which present inherent evidence of having existed in such bodies of water, as well as to the formations which were deposited in them. In some cases the entire aquatic fauna whose remains are found to characterize a given nonmarine formation is composed of such forms as plainly indicate that the waters in which they lived and in which that formation was deposited were wholly fresh. In other cases the fossil remains indicate that the waters were more or less saline, and in still others there is a commingling, or an association, of forms which are properly regarded as characteristic of fresh and saline waters, respectively. Reference is here made especially to the mollusca, because it is with the remains of those animals more than with remains of any others that the geologist has to deal in his investigations of the distinguishing characteristics of nonmarine formations.

The remarks here offered are also restricted to such nonmarine deposits as have been laid down in more or less broad bodies of water, those which may have been deposited in fluviatile waters not being at present considered. A large proportion of the now living denizens of fresh waters inhabit rivers and streams, and such was doubtless the case in former geological epochs; but fluviatile deposits are so extremely rare among geological formations that little reference need be made to them in discussing those of nonmarine origin.

In the case of formations which are unhesitatingly referred to a fresh-water origin all the contained fossil remains of branchiferous mollusca

[1] The frequent association of specimens of Pyrgulifera and Pachymelania with *Ostrea haydeni* suggests that these Melanians lived congenially with the Ostrea. A similar association of Melania with Ostrea and Anomia has been observed in the Laramie formation.

are those which pertained to forms whose living congeners are incapable of thriving in waters containing an appreciable amount of salt; but among the faunas of other nonmarine formations there is usually a greater or less number of forms whose living congeners are capable of adapting themselves to both brackish and fresh waters. Furthermore, certain forms, such as Ostrea and Anomia, for example, are not unfrequently found among nonmarine faunas, although all known living members of these families are, and doubtless all their members always have been, incapable of permanent existence in waters which do not contain an appreciable amount of salt, while they are capable of thriving as well in waters of full marine saltness as they are in brackish waters.

It is the branchiferous mollusca that have been particularly referred to in the preceding paragraphs. These, of course, require constant aqueous submergence, and, as a rule, their remains were immediately entombed in the sediments of the waters in which they lived, those sediments having constituted the strata in which their remains are found. It is usually the case, however, that a nonmarine fossil fauna contains a greater or less proportion of the remains of pulmoniferous mollusca, including those of terrestrial, as well as those of littoral and palustral, habitat. Fossil remains of all, or a part, of these three kinds of pulmoniferous mollusca are so generally found commingled with those of the various kinds of branchiferous mollusca that, as a rule, one expects to find more or less of such remains in every nonmarine formation.

The littoral pulmoniferous mollusca here referred to are such forms as the Auriculidæ, for example, which live in the shallows, or within reach of the spray, of saline waters only, and it is a significant fact that fossil congeners of these mollusca have been found only in association with other evidence than that afforded by the structure of their shells that the deposits containing them were, at least in part, laid down in brackish waters. Those referred to as palustral pulmoniferous mollusca are such forms as the Physidæ and Limnæidæ, for example, which live in the shallow fresh waters of ponds and marshy shores. No explanation as to the conditions of habitat of land mollusca is deemed necessary, but it may be remarked that the sedimentary entombment of their remains was always more or less accidental.

Applying these general statements to the Bear River formation, we do it with reference to that commingling of remains of fresh-water and brackish-water branchiferous, and of littoral and palustral pulmoniferous, mollusca which has just been referred to and which was more definitely stated in a previous paragraph. The very large proportion of the members of the Bear River molluscan fauna, which indicates a brackish-water habitat, and the general distribution of those forms throughout the whole formation, leave no room for reasonable doubt that it was deposited in a brackish-water lake or sea which was more or less completely cut off from open marine waters. One therefore naturally desires to inquire what were the conditions under which the commingling was accomplished.

Such an inquiry is appropriate not only in the case of the Bear River formation, but equally so in the case of many other nonmarine formations, as may readily be seen by the commingling of fresh-water and brackish-water forms in their respective fossil faunas. The great Laramie formation, with which the Bear River formation was formerly confounded, presents a case of this kind which is all the more remarkable because of the great geographical extent of the area which it occupies. Unfortunately, however, our present knowledge of the subject is so meager that such an inquiry can result in little more than a few suggestions.

Such a commingling of molluscan remains as is observed in the case of the Bear River fauna may imply, first, that they were accidentally brought together; second, that the species which they represent lived together in one and the same congenial habitat; or, third, that fresh and brackish waters periodically alternated upon certain portions of the great aqueous area within which the formation was deposited.

We may, as already intimated, properly assume that many of these Bear River species were capable of living in waters of varying degrees of saltness, and therefore that a large proportion of the whole fauna lived and thrived together, and consequently that their remains were entombed together. We may also assume that by the action of winds, or of inflowing or other currents, the shells of pulmoniferous mollusca were frequently drifted out into the open waters, where they sank and became intombed among the shells of gill-bearing forms.

We can not, however, assume that such branchiferous forms as *Ostrea haydeni* on the one hand and *Unio belliplicatus*, *U. vetustus*, and *Viviparus couesii* on the other were capable of living and thriving together. Therefore any promiscuous commingling of such categories of forms as these must have been accidental, but we must assume that their respective prevalence in alternating layers has been the result of alternation of saline and fresh waters—that is, an alternation of congenial conditions for each—within certain portions of the great aqueous area in which the formation was deposited.

If there were any evidence that the shells of the fresh-water branchiferous members of the Bear River fauna were drifted to the places of their entombment, the question as to the cause of their commingling with the brackish-water forms would be a simple one, but these shells are too heavy to have been drifted by any current that would not have produced in the sedimentary deposits ample evidence of its action, and no such evidence has yet been discovered. Moreover, the conditions of their entombment and preservation, together with their general distribution throughout the formation, present as good evidence that the mollusca which they represent lived and died where their remains are found as there is in the case of the brackish-water forms.

The general character of the Bear River molluscan fauna indicates that the average saltness of the body of water in which it lived, although variable in different parts, as already mentioned, was practically the same from the beginning to the end of the epoch. A supply of fresh water to the Bear River sea of course came from surface drainage, but what was the source of its supply of salt and how that general average was maintained we can only conjecture. It may have been that a sufficient amount of salt was retained from the marine waters which prevailed over the same area during the preceding epoch, and that this was sufficiently supplemented by surface drainage and evaporation to balance the loss by outflow, or it may have been that supplies of salt came by periodical incursion of waters from an adjacent marine area; but we have no conclusive evidence on any of these points.

That there were the numerous alternations of fresh and saline areas in various parts of the Bear River sea which have been mentioned, and that these alternations occurred at intervals during the whole epoch of its existence, is sufficiently obvious. The long duration of that epoch is indicated by the aggregate thickness of the Bear River formation, which is about 3,000 feet. It is also obvious that the influx of river freshets is not sufficient to explain these alternations of fresh with brackish waters, because in the strata containing the fresh-water forms there are no sufficient physical indications that such freshets occurred. Besides this, the condition of those fossils and of the strata in which they occur is such as to indicate that a fresh-water fauna became established in certain parts of the Bear River sea and thrived there until the congeniality of its habitat was destroyed or it was shifted to other parts by the afflux of saline water. It is natural to infer that the main portion of such a body of water as was the Bear River sea was at all times too saline for fresh-water mollusks to thrive in, and to assume that such mollusks found a congenial habitat only along certain portions of its borders.[1]

Such a shifting of conditions of habitat as has just been mentioned was necessarily due to shifting physical conditions, chief among which were probably changes in the surrounding drainage system and in the bottom and shore-line of the Bear River sea.

THE BEAR RIVER FAUNA COMPARED WITH OTHER AMERICAN FOSSIL FAUNAS.

It has been shown that the Bear River fauna, so far as it is known, consists wholly of invertebrates, and that with the exception of some Ostracod crustaceans they are all mollusks. For the present purpose there is no necessity for comparing this invertebrate fauna with much the larger part of the fossil faunas of North America further than to

[1] Observations hitherto made of the Bear River formation do not forbid such an assumption, but both fresh-water and brackish-water forms have been found so distributed throughout the broad Laramie formation as seemingly to forbid the assumption that the former lived only along the borders of the Laramie sea.

demonstrate the fact of its nonmarine origin. Besides this, nonmarine fossils are of such rare occurrence in Paleozoic formations that comparisons of the Bear River fauna must necessarily be confined to the known Mesozoic and Cenozoic faunas. It will be sufficient for the present purpose to compare it with that of the Laramie formation, those of the Wasatch, Green River, and Bridger formations collectively, that of the Dakota formation, and that of the upper part of the Jurassic as it is known in Colorado and Wyoming, beginning with the fauna of the last-named strata.

The fresh-water Jurassic invertebrates of Colorado and Wyoming.[1]

MOLLUSCA.

CONCHIFERA.

Family UNIONIDÆ.

Genus UNIO Retzius.

Unio felchii White.
U. toxonotus W.
U. macropisthus W.
U. iridoides W.
U. lapilloides W.
U. stewardi W.

GASTEROPODA.

Family LIMNÆIDÆ.

Genus LIMNÆA Lamarck.

Limnæa ativuncula W.
L. consortis W.
L.? accelerata W.

Genus PLANORBIS Müller.

Planorbis veturnus Meek and Hayden?

Genus VORTICIFEX Meek.

Vorticifex stearnsii W.

Family VALVATIDÆ.

Genus VALVATA Müller.

Valvata scabrida M. and H.?

CRUSTACEA.

OSTRACODA.

Metacypris forbesii Jones.
Metacypris ——— ?
Darwinula leguminella Forbes.
Cypris purbeckensis? F.
Cypris ———?
Cypris ———?

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[1] This list is compiled from Bulletin No. 29 of the U. S. Geological Survey. The following species, which are included with Jurassic forms in that bulletin, are omitted from this list because they came from a more northern region, and it is not yet certain that they really came from the Jurassic: *Unio nucalis* Meek and Hayden, *Viviparus gilli* M. and H., *Lioplacodes veternus* M. and H., and *Neritina nebrascensis* M. and H. These omissions, however, will not affect the comparisons of this fauna with that of the Bear River formation which are made in this bulletin.

Upon examination of the foregoing list of Jurassic mollusca two significant facts are apparent: First, they are all of such forms as are without hesitation referred to a fresh-water habitat; second, although they are specifically distinct from any others, they are all closely related to species which occur in several other fresh-water formations of later age as well as to fresh-water species which are now living. These facts, together with the absence from the Jurassic fauna of brackish-water molluscan forms, which is shown by the foregoing list, and the further fact that it is mainly such forms as were capable of living in brackish water that characterize the Bear River fauna, render a comparison of the two faunas of comparatively little value for present purposes.

The foregoing remarks apply to the mollusca, but there is an interesting relationship between the Ostracoda of the Bear River formation and those of the Jurassic strata of Colorado and Wyoming. The character of this relationship may be seen by comparing the closing entries of the preceding list with the list of the Bear River Ostracoda on page 62, and also by comparing the figures of the latter on Pl. XI of this bulletin with those of the former on Pl. IV of Bulletin No. 29 of the United States Geological Survey.

This relationship of the Bear River Ostracoda to those of the fresh-water Jurassic of Colorado is very interesting, because certain of the forms in each case are respectively similar, and because no similar forms are yet known in any other of the North American formations. It is hardly probable, however, that much important geological information will be derived from these facts, especially in view of the extreme rarity of the Ostracoda in all the known North American faunas of the later formations. Indeed, they are so rare in those formations that it has not been thought necessary to enumerate them in the following lists.

The known invertebrate fauna of the Dakota formation is so meager that only a limited comparison between it and that of the Bear River fauna can be made; but the fact that the Dakota formation is the only one besides the Bear River which contains a species referable to Pyrgulifera makes such a comparison desirable. I have elsewhere shown that of the invertebrate fossils which have been published as having been obtained from the Dakota formation, a part are plainly remains of denizens of marine waters, and that the others are remains of denizens of either brackish or fresh waters.[1]

No member of the Bear River fauna being regarded as indicating a marine habitat, the names of only the fresh-water and brackish-water species of the Dakota invertebrates are given in the following list:

[1]See "Notes on the invertebrate fauna of the Dakota formation, with descriptions of new molluscan forms." Ann. Rept. U. S. National Museum for 1892, pp. 131-138 and one plate.

Invertebrate fauna of the Dakota formation.

MOLLUSCA.

CONCHIFERA.

Family UNIONIDÆ.

Genus MARGARITANA Schumacher.

Margaritana nebrascensis Meek.

Genus UNIO Retzius.

Unio barbouri White.
U. ——— ? W.

Family CORBICULIDÆ.

Genus CORBICULA Mühlfeldt.

Cyrena [Corbicula?] dakotaensis Meek and Hayden.

Family CORBULIDÆ.

Genus CORBULA Bruguiere.

Corbula hicksii W.

GASTEROPODA.

Family CERIPHASIIDÆ.

Genus GONIOBASIS Lea.

Goniobasis jeffersonensis W.
G. ——— ? W.

Family MELANIIDÆ.

Genus PYRGULIFERA Meek.

Pyrgulifera meekii W.

Family VIVIPARIDÆ.

Genus VIVIPARUS Montfort.

Viviparus hicksii W.

Although, with the exception of Margaritana, all the genera of the foregoing list of Dakota species are represented in the Bear River fauna, the Dakota fauna as a whole is not such as to suggest the equivalency of the two formations. There are, however, two significant facts to be observed in this connection. First, there is stratigraphical evidence that there is no great difference in the geological age of the Bear River and Dakota formations; second, in America only these two formations are known to contain remains of Pyrgulifera.

The next nonmarine fauna in ascending chronological order with which the Bear River fauna may be compared is that of the Upper Cretaceous Dunvegan series of Canada, the fauna of which has been briefly discussed on pages 28 and 29. It was there shown that the character of the fauna, although it includes some molluscan forms which are closely related to certain members of the Bear River fauna, is not such as to indicate an identity of the formations which respectively contain those faunas. Besides this, the Dunvegan fauna is not yet known to contain any of the molluscan genera which are especially characteristic of the Bear River fauna.

It is not thought necessary to compare the Bear River fauna with that of the Belly River series of Canada, because of the close faunal relationship of that series with the Laramie formation.

The fauna with which, above those of all other North American formations, it is desirable to compare the Bear River fauna is that of the great Laramie formation, this being the one with which the Bear River formation has long been confounded. The following is a list of the invertebrate species which are now assigned to the Laramie fauna proper. It is given here for comparison with that of the Bear River fauna, which is given on pages 64 and 65.

Invertebrate fauna of the Laramie formation.[1]

MOLLUSCA.

CONCHIFERA.

Family OSTREIDÆ.

Genus OSTREA Linnæus.

Ostrea glabra Meek and Hayden.
O. subtrigonalis Evans and Shumard.

Family ANOMIIDÆ.

Genus ANOMIA Linnæus.

Anomia micronema Meek.
A. gryphorhynchus M.

Family MYTILIDÆ.

Genus MODIOLA Lamarck.

Modiola (Brachydontes) regularis White.
M. (B.) laticostata W.

Family UNIONIDÆ.

Genus ANODONTA Cuvier.

Anodonta parallela W.
A. propatoris W.

Genus UNIO Retzius.

Unio aldrichi W.
U. brachyopisthus W.
U. couesii W.
U. cryptorhynchus W.
U. danæ M. and H.
U. deweyanus M. and H.
U. endlichi W.
U. goniambononatus W.
U. gonionotus W.
U. holmesianus W.
U. primævus W.
U. priscus M. and H.

[1] In compiling this list I have, of course, omitted the species which belong to the Bear River fauna, all of which were formerly referred to the Laramie. The following species were also formerly referred to the Laramie, but I have omitted them from this list because I now understand them to belong to the overlying Wasatch formation, in the list of which they will appear on a following page: *Unio mendax* White, *Pisidium saginatum* W., *Macrocyclis spatiosa* Meek and Hayden, *Helix* (*Spatula?*) *sepulta* W., *H.* (*Triodopsis?*) *evanstonensis* W., *Hydrobia recta* W., and *H. utahensis* W.

U. proavitus White.
U. propheticus W.
U. senectus W.
U. subspatulatus Meek.

Family CYRENIDÆ.

Genus SPHÆRIUM Scopoli.

Sphærium formosum Meek and Hayden.
S. planum M. and H.
S. recticardinale M. and H.
S. subellipticum M. and H.

Genus CORBICULA Mergerle.

Corbicula augheyi W.
C. berthoudi W.
C. cardiniæformis W.
C. cleburni W.
C. cytheriformis M. and H.
C. fracta M.
C. macropistha W.
C. nebrascensis M. and H.
C. obesa W.
C. occidentalis M. and H.
C. planumbonata M.
C. subelliptica M. and H.
C. umbonella M.

Family CORBULIDÆ.

Genus CORBULA Bruguiere.

Corbula subtrigonalis M. and H.
C. undifera M.

GASTEROPODA.

Family LIMNÆIDÆ.[1]

Genus LIMNÆA Lamarck.

Limnæa (Pleurolimnæa) tenuicarinata M.

Genus PLANORBIS Müller.

Planorbis amplexus M. and H.
P. convolutus M. and H.
P. kanabensis W.
P. planoconvexus M. and H.

Family PHYSIDÆ.

Genus PHYSA Draparnaud.

Physa copei W.
P. felix W.
P. kanabensis W.

Genus BULINUS Adanson.

Bulinus atavus W.
B. longiusculus M. and H.
B. rhomboideus M. and H.
B. subelongatus M. and H.

[1]No representative of the Auriculidæ, which family is so well represented in the Bear River fauna, has been found in the Laramie formation. Therefore this list begins with the Limnæidæ.

Family ANCYLIDÆ.

Genus ACROLOXUS Beck.

Acroloxus minutus Meek and Hayden.

Family VITRINIDÆ.

Genus VITRINA Draparnaud.

Vitrina? obliqua M. and H.

Genus HYALINA Agassiz.

Hyalina? occidentalis M. and H.

Family HELICIDÆ.

Genus HELIX Linnæus.

Helix (Strobilia?) kanabensis White.
H. vetustus M. and H.

Genus THAUMASTUS Albers.

Thaumastus limnæiformis M. and H.

Genus COLUMNA Perry.

Columna teres M. and H.
C. vermicula M. and H.

Family NERITIDÆ.

Neritina (Velatella) baptista W.
N. bruneri W.
N. volvilineata W.

Family CERITHIIDÆ.

Genus CERITHIDEA Swainson.

Cerithidea nebrascensis M. and H.

Family MELANIIDÆ.

Genus MELANIA Lamarck.

Melania insculpta Meek.
M. wyomingensis M.

Genus MELANOPSIS Ferussac.

Melanopsis americana W.

Family CERIPHASIIDÆ.

Genus GONIOBASIS Lea.

Goniobasis convexa M. and H.
G. gracilenta M. and H.
G. invenusta M. and H.
G. omitta M. and H.
G. nebrascensis M. and H.
G. sublævis M. and H.
G. tenuicarinata M. and H.

Genus CASSIOPELLA White.

Cassiopella turricula W.

Family RISSOIDÆ.

Genus HYDROBIA Hartmann.

Hydrobia anthonyi M. and H.
H. eulimoides M.
H. subconica M.
H. warrenana M. and H.

Genus MICROPYRGUS M.

Micropyrgus minutulus Meek and Hayden.

Family VIVIPARIDÆ.

Genus VIVIPARUS Montfort

Viviparus conradi M. and H.
V. leai M. and H.
V. leidyi M. and H.
V. peculiaris M. and H.
V. plicapressus White.
V. prudentius W.
V. raynoldsianus M. and H.
V. vetustus M. and H.
V. trochiformis M. and H.
V. ionicus W.
V. panguitchensis W.

Genus TULOTOMA Haldeman.

Tulotoma thompsoni W.

Genus CAMPELOMA Rafinesque.

Campeloma multilineata M. and H.
C. multistriata M. and H.
C. producta W.
C. vetula M. and H.

Family VALVATIDÆ.

Genus VALVATA Müller.

Valvata montanaensis Meek.
V. parvula M. and H.
V. subumbilicata M. and H.

ANNULOSA.

INSECTA.

Corydalites fecundum Scudder.[1]

It will be seen that with the exception of some insect egg masses the Laramie invertebrate fauna as represented by the foregoing list consists entirely of molluscan remains. Doubtless some such fresh-water and brackish-water crustaceans as are known to have existed in late Cretaceous and early Tertiary time lived in the Laramie sea, and the discovery of remains of the Ostracoda especially might have been expected, but no such remains have yet been discovered. In comparing the Laramie fauna with the Bear River fauna, so far as both are now known, we are therefore confined to the mollusca.

Beginning this comparison with the Conchifera, we find a good degree of similarity so far as genera and families are concerned, and no striking contrast between them is observed except as regards the number of species which represent certain of the genera, Unio and Corbicula, for example, and the absence of Anomia from all the Bear River collec-

[1] These remains consist only of egg masses.

tions, while that genus prevails in the Laramie. The only types among the Bear River Conchifera which need be contrasted with any of those of the Laramie are those which are represented by *Unio belliplicatus* and *Corbula pyriformis*, respectively. This contrast, however, is one only, or mainly, of unusual size and obesity in the case of the Corbula, and of external ornamentation in the case of the Unio.

The contrast between the Bear River and Laramie faunas is much greater as regards the Gasteropoda. Upon beginning a comparison of the members of this class of the Mollusca, as represented by the Bear River and Laramie faunas, we are met by the entire absence of the Auriculidæ from the Laramie fauna, although that family is represented in the Bear River fauna by five species and four genera. This contrast is still more conspicuous because two of those genera are yet known only in the Bear River fauna.

The pulmoniferous mollusca are much more fully and variously represented in the Laramie fauna than they are in the Bear River fauna. This is especially the case with those of land habitat, the paucity of whose remains in the Bear River fauna has already been pointed out. The suggestion has also been made that this paucity was due to a want of favorable conditions for the preservation of their remains in the Bear River sediments. Whatever may have been the facts in this case, the few pulmoniferous mollusca whose remains have been discovered in the Bear River strata were of such a character as to be not inconsistent with such a fauna as that of the Laramie. Therefore the observable contrast between the Bear River and Laramie faunas, as regards the pulmoniferous mollusca exclusive of the Auriculidæ, is one of fullness and paucity of representation rather than of diversity of types.

The two Bear River species of the Neritidæ, and two of the three Laramie species belonging to that family, differ too little in generic characteristics from other Cretaceous, Tertiary, and living forms to attract particular attention, but one of the Laramie species, *Neritina* (*Velatella*) *baptista*, belongs to an extinct subgenus. This subgenus is not yet known to occur in the Bear River fauna, but it is found in that of the immediately overlying Colorado formation, and it probably existed somewhere during the Bear River epoch.

As regards faunal types, the most conspicuous contrast between the Laramie and Bear River faunas is observable in the family Melaniidæ. In the Laramie fauna the genera Melania, Goniobasis, Cassiopella, and Melanopsis are represented, but no representative of any of those genera is known in the Bear River fauna.[1] In the latter fauna, as it is now known, the family Melaniidæ is represented by only two genera, Pyrgulifera and Pachymelania, neither of which genera is known to occur in any other North American fauna. The conspicuous contrast

[1] It is true that some authors have referred certain forms to Melanopsis which are congeneric with *Pyrgulifera humerosa*, and that I have formerly referred those Bear River species to Goniobasis which I now assign to Pachymelania, but the true generic characteristics of those forms are shown on preceding pages of this bulletin.

between the Laramie and Bear River faunas which is thus presented by the Melaniidæ is made still more conspicuous by the abundance of individual shells of the different species of those genera in the Bear River strata, and by the fact that those species are among the most characteristic members of the Bear River fauna.

The remaining members of the Laramie fauna to be compared with the Bear River fauna are all branchiferous gasteropods. They belong to genera which occur also in the Bear River fauna or to closely allied genera. Therefore this part of the Laramie fauna does not present a strong contrast to the Bear River fauna, except as regards the greater number of Laramie species, especially of the Viviparidæ. These correspondencies between the Laramie and Bear River faunas are not, however, of such a character as necessarily to suggest the geological equivalency of the formations containing them; and besides this, the contrasts which have been mentioned are inconsistent with such equivalency.

The Wasatch, Green River, and Bridger formations come next in geological age to the Laramie among North American nonmarine formations, and they are by all geologists referred to the Eocene. All three of these formations are so intimately connected with one another, both by faunal similarity and the ranging of certain species from one to another, that for the present purpose the molluscan faunas of all of them will be represented together in the following list. It will also be seen by the footnotes accompanying the list that certain of the fresh-water Laramie species range up into the lowest of these three formations.

The Molluscan fauna of the Wasatch, Green River, and Bridger formations.

CONCHIFERA.

Family UNIONIDÆ.

Genus UNIO Retzius.

Unio clinopisthus White.
U. haydeni Meek.
U. mendax W.
U. rectoides W.
U. shoshonensis W.
U. tellinoides Hall.
U. washakiensis M.

Family CYRENIDÆ.

Genus SPHÆRIUM Scopoli.

Sphærium formosum Meek and Hayden.[1]

Genus PISIDIUM Pfeiffer.

Pisidium saginatum W.

[1]Survival from the Laramie epoch.

GASTEROPODA.

Family LIMNÆIDÆ.

Genus LIMNÆA Lamarck.

Limnæa minuscula White.
L. similis Meek.
L. vetusta M.

Genus PLANORBIS Müller.

Planorbis æqualis W.
P. cirratus W.
P. convolutus Meek and Hayden.[1]
P. militaris W.
P. spectabilis M.
P. utahensis M.

Family PHYSIDÆ.

Genus PHYSA Draparnaud.

Physa bridgerensis M.
P. bullatula W.
P. kanabensis W.[1]
P. pleuromatis W.

Genus BULINUS Adanson.

Bulinus atavus W.[1]

Family ANCYLIDÆ.

Genus ACROLOXUS Beck.

Acroloxus actinophorus W.

Family VITRINIDÆ.

Genus MACROCYCLIS Beck.

Macrocyclis spatiosa M. and H.

Family HELICIDÆ.

Genus HELIX Linnæus.

Helix (Triodopsis?) evanstonensis W.
H. (Arianta?) riparia W.
H. (Aglaia?) peripheria W.
H. (Patula?) sepulta W.
H. veterna M. and H.

Family PUPIDÆ.

Genus PUPA Lamarck.

Pupa leidyi M.
P. arenula W.
P. atavuncula W.
P. incolata W.

Family SUCCINIDÆ.

Genus SUCCINEA Draparnaud.

Succinea papillispira W.

Family CERIPHASIIDÆ.

Genus GONIOBASIS Lea.

Goniobasis filifera W.
G. nebrascensis M. and H.[1]
G. tenera Hall.
G. tenuicarinata M. and H.[1]

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[1] Survival from the Laramie epoch.

Family RISSOIDÆ.

Genus HYDROBIA Hartmann.

Hydrobia recta White.
H. utahensis W.

Genus BYTHINELLA Moquin-Tandon.

Bythinella gregaria Meek.

Genus MICROPYRGUS Meek.

Micropyrgus minutulus Meek and Hayden.[1]

Family VIVIPARIDÆ.

Genus VIVIPARUS Montfort.

Viviparus nanus W.
V. paludinæformis Hall.
V. trochiformis M. and H.[1]
V. wyomingensis M.

The foregoing list of Eocene nonmarine mollusca lainly shows that any comparison of the fauna which it represents with the Bear River fauna must be mainly one of contrast; and the contrast is all the greater because of the absence from this later fauna of any other than purely fresh-water forms. It is also apparent that this fauna is not only closely related to the fresh water and land portion of the Laramie fauna by a considerable number of specifically identical forms, but it is also closely related to the living fresh-water and land molluscan fauna of North America by the generic identity of a very large majority of its members. On the contrary, the Bear River fauna contains only half a dozen forms that can be regarded as closely related to any of the species enumerated in the foregoing list, these being in part palustral pulmoniferous and in part fresh-water branchiferous mollusca. Geologically such a comparison has the effect of showing that the Bear River fauna, which was originally assigned to the Tertiary, is conspicuously different from any North American Tertiary fauna.

In making a general comparison of the Bear River fauna with the other nonmarine fossil faunas of North America, as represented by the three foregoing lists and the remarks which accompany them, it is desirable to recall attention to those features of the Bear River fauna by which it differs conspicuously from all the others. Reference is here especially made to the Auriculidæ and Melaniidæ, because it is the members of these two families that give the Bear River fauna its most distinctive character. This faunal character is all the more conspicuous because, of the six genera which represent those two families, only two of them are known in any other North American fauna, either fossil or recent. To the geological investigator this faunal character of the Bear River formation is physically conspicuous, because of the comparative abundance of the shells of some of the species belonging to the two families just mentioned.

[1] Survival from the Laramie epoch.

In view of the similarities and contrasts between such faunas as have been discussed in the preceding paragraphs, one is naturally led to an inquiry as to their causes. It is not to be expected that all such inquiries can be satisfactorily answered, but the following facts and suggestions are deemed worthy of consideration.

Marine waters have been of world-wide extent ever since life began to exist in them, and interruptions of their physical continuity during the whole course of geological time have never been more than partial or local. It is therefore easy to comprehend how unbroken genetic lines of descent may have occurred in marine waters throughout the whole range of geological time. It is, however, much more difficult to understand how such lines of descent could have been preserved in the case of nonmarine faunas, especially those of their fresh-water branchiferous members, because a change to dry land or to a saline condition of habitat would have been fatal to them. This difficulty is increased when we take into consideration the fact that fresh-water molluscan faunas similar to those now living have abounded ever since the earlier epochs of Mesozoic time, and that many of them contain forms so closely like members of living faunas that it is often impracticable to clearly diagnose them as specifically different. Equally embarrassing is the further fact that the greater part of the ancient ichthyic types which have survived to the present day are found among fresh-water fishes.

In view of numerous facts brought out by paleontological investigation, there seems to be no room for reasonable doubt that in the course of geological time many forms have been developed independently, or along separate genetic lines, the fossil remains of which present no features by which they can be satisfactorily assigned to separate genera; and it is even conceivable that some of the admitted fossil species have had a similarly independent origin. As a rule, however, I think it necessary to assume that closely similar fossil faunas, or important divisions of the same, have a more or less close genetic relationship, notwithstanding the frequent difficulty of understanding how such a relationship could have been maintained.

In a former publication[1] I have suggested that genetic lines of descent of fresh-water branchiferous animals could have been, and in most cases probably were, preserved by means of the persistence of rivers from epoch to epoch of geological time, thus securing a continuance of congenial aquatic habitat through a series of geological epochs; that is, in the process of time lakes inhabited by branchiferous fresh-water faunas naturally became drained by the corrasive deepening of the channels of their outlets, but those faunas found a congenial habitat in the resulting fluviatile waters, which debouched either into other lacustrine waters or more or less directly into the sea.

This theory of the manner of genetic descent of fresh-water faunas seems to apply well to the fresh-water and land portion of the Laramie

[1] Third Ann. Rept. U. S. Geol. Surv., pp. 75-80, 1883.

molluscan fauna, and also to the whole fauna of the Wasatch, Green River, and Bridger formations as represented by the foregoing list. The collective fauna of the three last-named formations shows an intimate relationship to the Laramie fauna, not only by a general similarity of types but by identity of certain of the species. It is therefore natural to infer that the fauna of these Eocene formations was, at least in part, derived by direct genetic descent from the earlier Laramie fauna.

Furthermore, because so large a part of the generic and subgeneric, as well as more general, types of fresh-water and land mollusca of those Eocene formations, and also of the Laramie, are identical with forms which are now living in the great area drained by the Mississippi River system, it is equally natural to infer that the latter were derived by direct descent from their Eocene and Laramie congeners; that is, it is assumed that the fluvial perpetuation of the outlet or outlets of the Laramie sea conveyed its fresh-water fauna in part to the Eocene lakes and in part retained it in fluviatile waters, some of which are flowing to-day as a part of the Mississippi drainage system. This view also finds support in abundant geological evidence that after the Laramie epoch no marine waters prevailed over that great interior portion of the continent in which the formations referred to occur.

It is much more difficult to understand how the Laramie sea may have obtained its fresh-water fauna than how its distinctive types may have been genetically perpetuated; and it is equally difficult to understand how genetic lines of descent could have been so perpetuated from those Jurassic and Bear River faunas, which are represented by the foregoing lists, as to connect with the faunas of subsequent epochs, or with those of the present time. Although we necessarily assume that a part of such lines have been maintained continuously, each through the whole or a part of those geological epochs, it is evident that others of them would have become diverged from the main lines of succession and destroyed by some of those physical changes which marked the successive epochs.

In view of the facts which have been set forth on the preceding pages, I think we may reasonably as sume that one of those divergent lines terminated in the Bear River fauna; that is, at the close of the Bear River epoch the area which its nonmarine waters had occupied having become overspread by the marine waters in which the Colorado formation was deposited, it is not probable that any fluvial outlet of the former nonmarine waters was perpetuated, and there was therefore no provisional habitat in which the Bear River fauna might have been preserved. It was probably in this way that the distinguishing types of that fauna became extinct, together with others of its members which were not so specially characteristic of it.

It was suggested on preceding pages that certain members of the Bear River fauna which were more able than others to live in strongly saline waters survived in the succeeding marine waters of the Colorado formation. This may really have been the case, but such a fact would not necessarily affect the suggestion that the typical Bear River forms, which were doubtless unable to thrive in waters of full marine saltness, were extinguished in the manner indicated.

While the foregoing suggestions as to the fate of those typical forms are evidently rational, and probably indicate the true course of events in that case, no observations hitherto made warrant any definite suggestion as to their ancestry. This lack of suggestive information emphasizes the fact that the fauna which they characterize is unique among the North American fossil faunas.

THE GEOGRAPHICAL AND TIME RANGE OF PYRGULIFERA.

It has been shown on preceding pages that the Bear River fauna, as a whole, is unique among North American fossil faunas, and also that those of its members which especially and conspicuously characterize it are so different from any of the members of other North American faunas that one is hardly justified in offering any suggestions as to their ancestry or progeny; and little can be suggested concerning their more remote faunal relationship.

The most conspicuous generic type among these characteristic members of the Bear River fauna is Pyrgulifera, and peculiar interest attaches to this genus because of the remarkable cases of both geographical and chronological isolation which it presents in the different parts of the world where it is known. In North America this genus has not only the extremely limited time range which has been explained, but, with the exception of a single specimen, evidently referable to this genus, which was lately discovered in Dakota strata in Nebraska, its known geographical distribution is confined to a comparatively narrow belt of country which does not exceed 150 miles in length. This genus is also known to occur in several of the nonmarine fossil faunas of Europe, and to be represented by living species in Africa, but beyond this it is not known to have a representative in any other fauna, nor in any other parts of the world.

The species constituting the European faunas in which Pyrgulifera occurs have been published by various authors and at various times and places, but a good summary of them, so far as the needs of the present discussion are concerned, may be obtained from the publications of M. Philippe Matheron,[1] Prof. Dr. Paul Oppenheim,[2] and Dr. Leopold von Tausch,[3] especially the latter.

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[1]Catalogue méthodique et descriptif des corps organisés fossiles du départment des Bouches-du-Rhône et lieux circonvoisins, Marseille, 1842.

[2]Ueber einige Brackwasser- und Binnen-Mollusken aus der Kreide und dem Eocän Ungarns. Zeitschr. Deutsch. geol. Gesell., Band XLIV, Heft 4, Berlin, 1892.

[3]1. Ueber die Fauna der nicht-marinen Ablagerungen der oberen Kreide des Csingerthales bei Ajka im Bakony (Veszprimer Comitat, Ungarn); und über einige Conchylien der Gosaumergel von Aigen bei Saltzburg. Abhandl. K.-k. geol. Reichsanstalt, Band XII, No. 1, pp. 1-30, pls. i-iii, Wien, 1886

2. Ueber einige Conchylien aus dem Tanganyika-See und deren fossile Verwandte. Sitzungsber K. Akad. Wiss., Abtheil. I, Juli Heft, Wien, 1884.

3. Ueber die Fossilien von St. Briz in Südsteiermark. Verhandl. K.-k. geol. Reichsanstalt, No. 9 Wien, 1888.

The European nonmarine faunas referred to occur respectively in the following formations: The Lignitic formation of southern France, the coal-bearing Upper Cretaceous strata near Ajka in western Hungary, the nonmarine portion of the Gosau formation of the northeastern Alps, the St. Briz deposit in southern Styria, and in probable equivalents of certain of those formations in other parts of Europe. Ten species of Pyrgulifera are recognized by Dr. von Tausch and Professor Oppenheim among those faunas. The following list shows the names by which they designate them:

Pyrgulifera acinosa Zekeli.	P. humerosa Meek.
P. ajkaensis Tausch.	P. lyra Matheron.
P. armata Matheron.	P. pichleri Hoernes.
P. glabra Hantken.	P. rickeri Tausch.
P. gradata Rolle.	P. striata Tausch.

Although the faunas just mentioned, each as a whole, are quite different from one another, Dr. von Tausch has shown that certain of the species of Pyrgulifera range from one formation to another. For example, he has shown that *Pyrgulifera pichleri* and *P. acinosa* are found associated together in both the Gosau and Ajka formations, and also that both *P. armata* and *P. lyra* occur together in the Ajka formations as well as in the Lignitic formation of southern France, where they were originally discovered by Matheron.

The discovery of a form in the Ajka formation which can not be distinguished from typical examples of *Pyrgulifera humerosa*, the most characteristic species of the Bear River formation, is very remarkable. It is sufficiently difficult to understand how Pyrgulifera, or any other nonmarine genus of branchiferous mollusca, could have become so dispersed from one genetic center as to occupy isolated areas on separate continents, but it is still more difficult to believe that the North American *P. humerosa* represents the European form ancestrally, or vice versa. I am therefore inclined to believe that, notwithstanding the apparent identity of the Ajka and Bear River forms, they originated independently.

Still, such a distribution and commingling of species as Dr. von Tausch has shown to occur in Europe is usually accepted by geologists as indicating a more or less direct genetic relationship between the faunas which respectively contain them, and consequently as indicating at least an approximate contemporaneity of origin for the formations which those faunas characterize. It is consistent with these views to regard the Ajka, Gosau, and French Lignitic formations as having been at least approximately contemporaneous in their origin. There being no reason to doubt the Upper Cretaceous age of the Ajka and Gosau formations, this view of the question requires the reference of the Lignitic formation of southern France to the same age, notwithstanding its original reference to the Tertiary. In short, with only one exception, there seems to be no reason to doubt the Upper Cretaceous age of any of the European strata which contain the remains of any of the known species of Pyrgulifera.

The exception referred to is that of the St. Briz deposit in southern Styria, in which is found the *Pyrgulifera gradata* of Rolle. Although some geologists have entertained doubts as to the true age of the St. Briz deposit, several important facts favor its reference to the base of the Tertiary, to which horizon both Dr. Tausch and Professor Oppenheim refer them. Admitting the Tertiary age of this deposit, the time range of Pyrgulifera in Europe, although somewhat longer than it is known to have been in America, seems to have been confined to the upper part of the Upper Cretaceous and the base of the Tertiary.

Briefly summarizing the foregoing statements concerning the geographical and time range of the genus Pyrgulifera, we observe that it is at present known to occur only in North America, Europe, and Africa, and that its earliest appearance is not known to have been earlier than the Upper Cretaceous period.

In North America it is known only in one formation, which belongs at or near the base of the Upper Cretaceous. This formation is found only in the interior portion of the continent, where it occupies a comparatively small area.

In Europe it is found only in the southern portion of the continent, and its time range is apparently from near the middle of the Upper Cretaceous to the base of the Tertiary, inclusive.

In Africa it is known only by living forms, which have yet been found only in Lake Tanganyika.[1]

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[1] The following publications contain discussions of the molluscan fauna of Lake Tanganyika:
Proc. Zool. Soc. London for 1879, p. 348; for 1880, p. 344; for 1881, pp. 276, 558.
Annals Mag. Nat. Hist., 5th ser., Vol. VI, p. 425, London, 1880.
Jour. de conch., Paris, for 1881, pp. 105, 277.
Nature, Vol. XXV, pp. 101-102, 218, 1881.
Proc. U. S. Nat. Mus., Vol. V (for 1882), pp. 94-99, 1883.
Am. Jour. Sci., 3d ser., Vol. XXIX, pp. 277-280, 1885.
Sitzungsb. K. Akad. Wiss. Abtheil I, Juli Heft, Wien, 1884.

PLATE II.

PLATE II.

OSTREA HAYDENI (p. 32).

Fig. 1. Lower valve; exterior view.
Fig. 2. Upper valve; interior view.

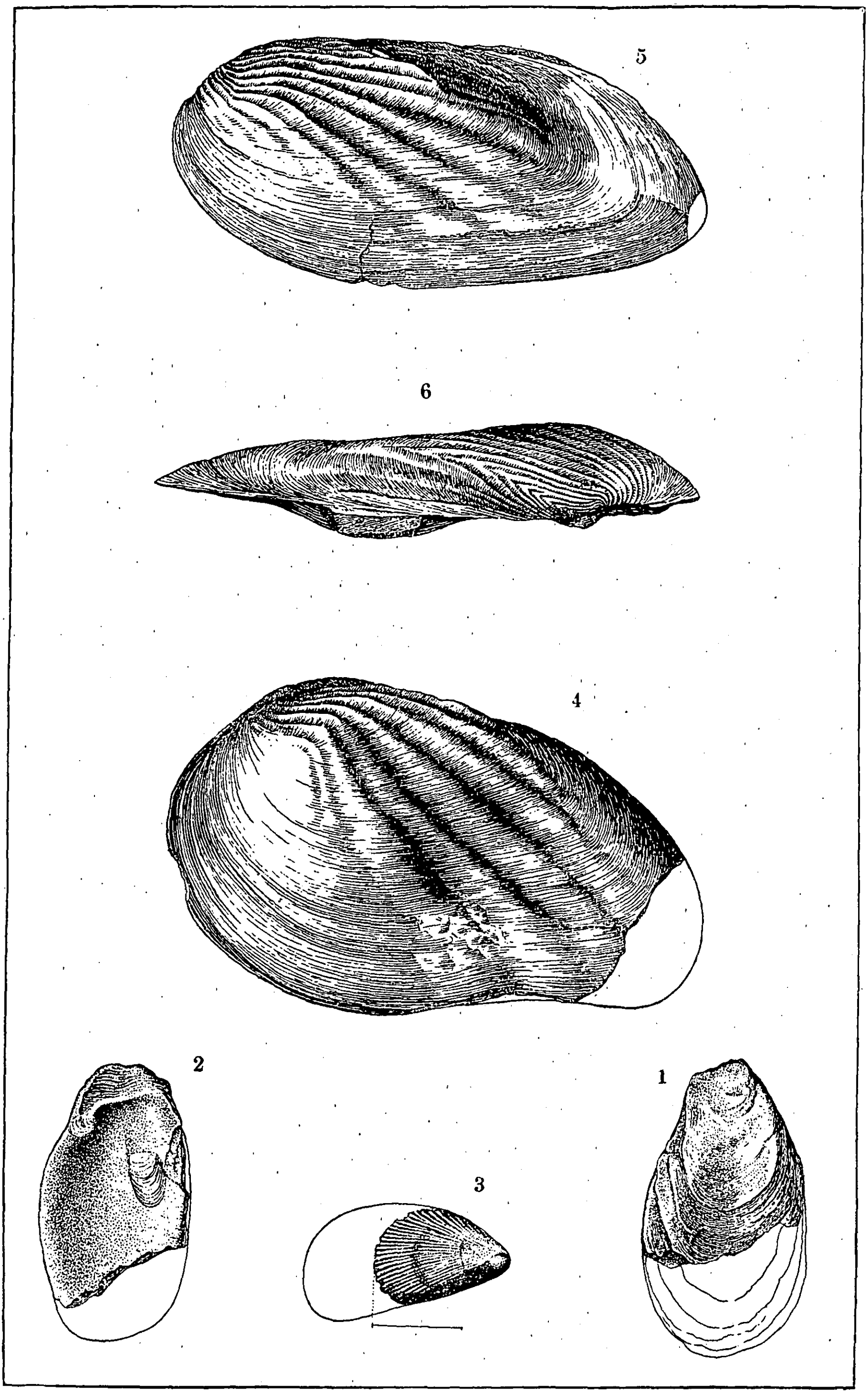
MODIOLA PEALEI (p. 33).

Fig. 3. Imperfect right valve.

UNIO BELLIPLICATUS (p. 34).

Fig. 4. Left valve of usual form.
Fig. 5. Another left valve, more elongate.
Fig. 6. Dorsal view of a left valve.

All natural size.



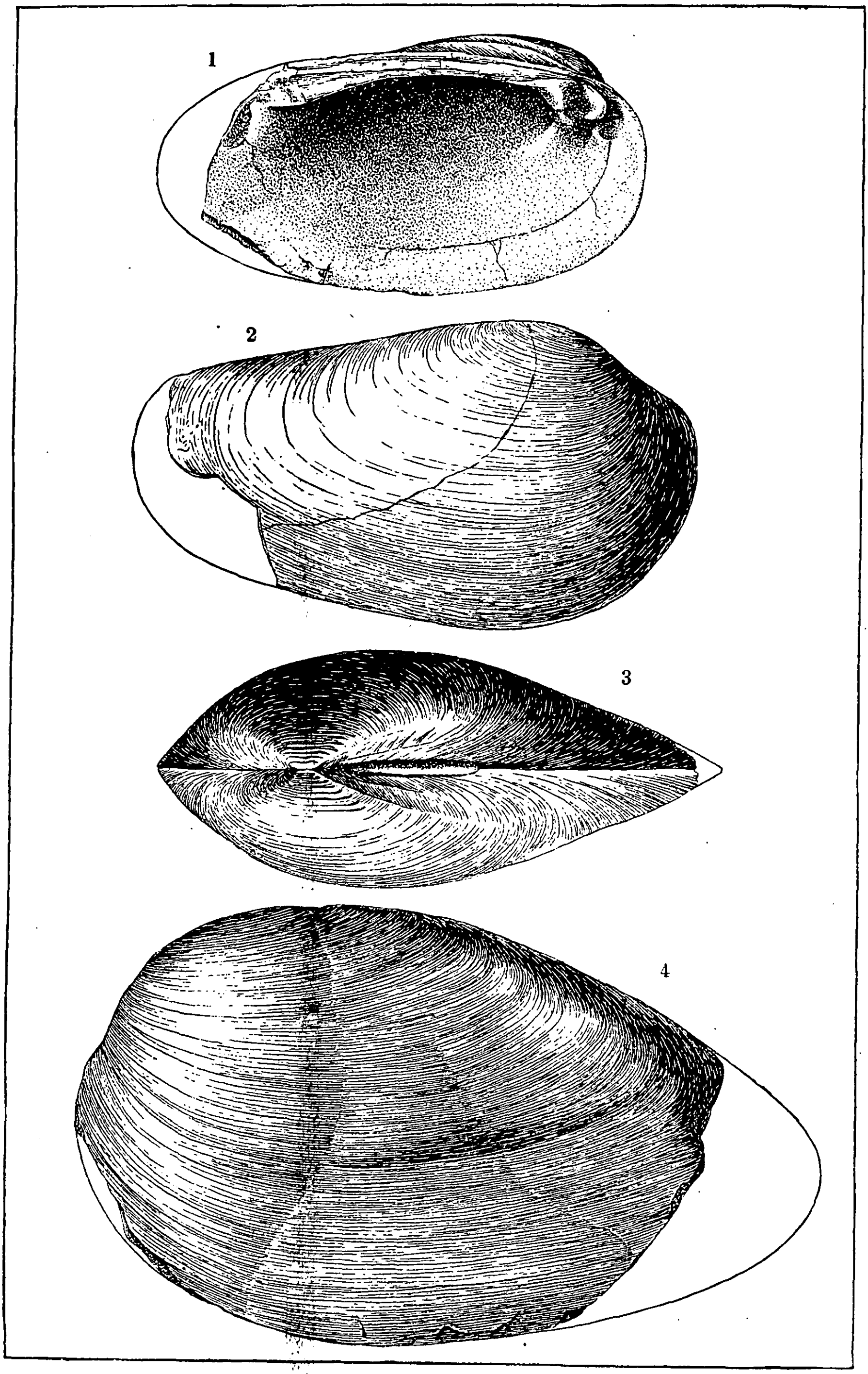
OSTREIDÆ, MYTILIDÆ, AND UNIONIDÆ.

PLATE III.

PLATE III.

UNIO VETUSTUS (p. 35).

Fig. 1. Interior view of a left valve.
Fig. 2. Exterior view of a right valve.
Fig. 3. Dorsal view.
Fig. 4. Exterior view of a large, broad left valve.
All natural size.



UNIONIDÆ.

PLATE IV.

PLATE IV.

CORBICULA DURKEEI (p. 36).

Figs. 1, 2. Lateral views.
Fig. 3. Front view.
Fig. 4. Dorsal view.

CORBULA PYRIFORMIS (p. 38).

Figs. 5, 6, 7. Lateral, dorsal, and front views, respectively, of a typical example.
Fig. 8. Interior view of a right valve.
Fig. 9. Interior view of a left valve.

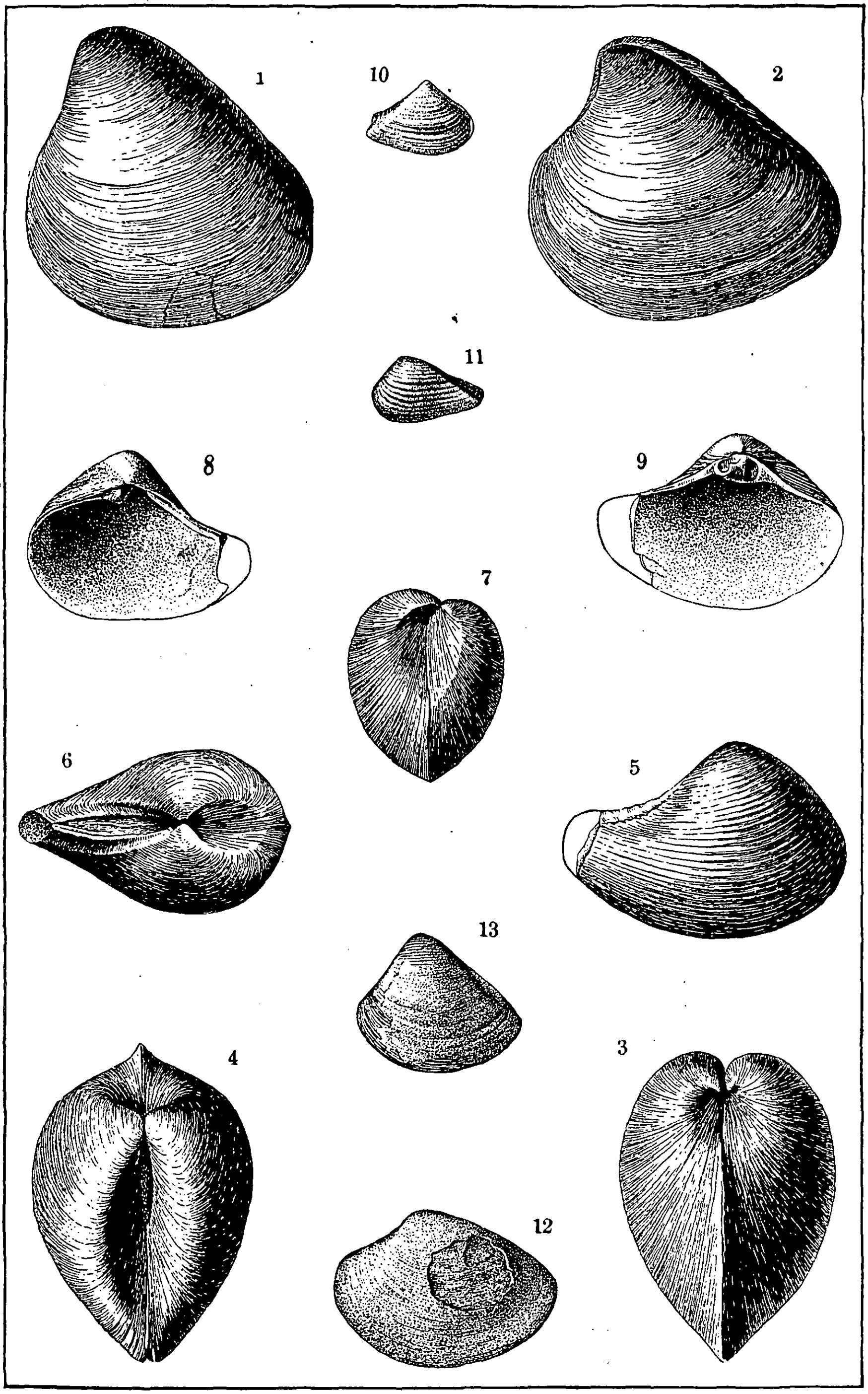
CORBULA ENGELMANNI (p. 40).

Fig. 10. Lateral view of a right valve.
Fig. 11. Lateral view of a left valve.

CORBULOMYA TAUSCHII (p. 40).

Fig. 12. Lateral view of the left valve of the type specimen.
Fig. 13. Similar view of a left valve, probably belonging to this species.

All of natural size.



CYRENIDÆ AND CORBULIDÆ.

PLATE V.

PLATE V.

AURICULA NEUMAYRI (p. 41).

Fig. 1. Apertural view; enlarged.

MELAMPUS CLARKII (p. 42).

Fig. 2. Apertural view; enlarged.
Fig. 3. Similar view of an imperfect specimen; enlarged.

RHYTOPHORUS PRISCUS (p. 43).

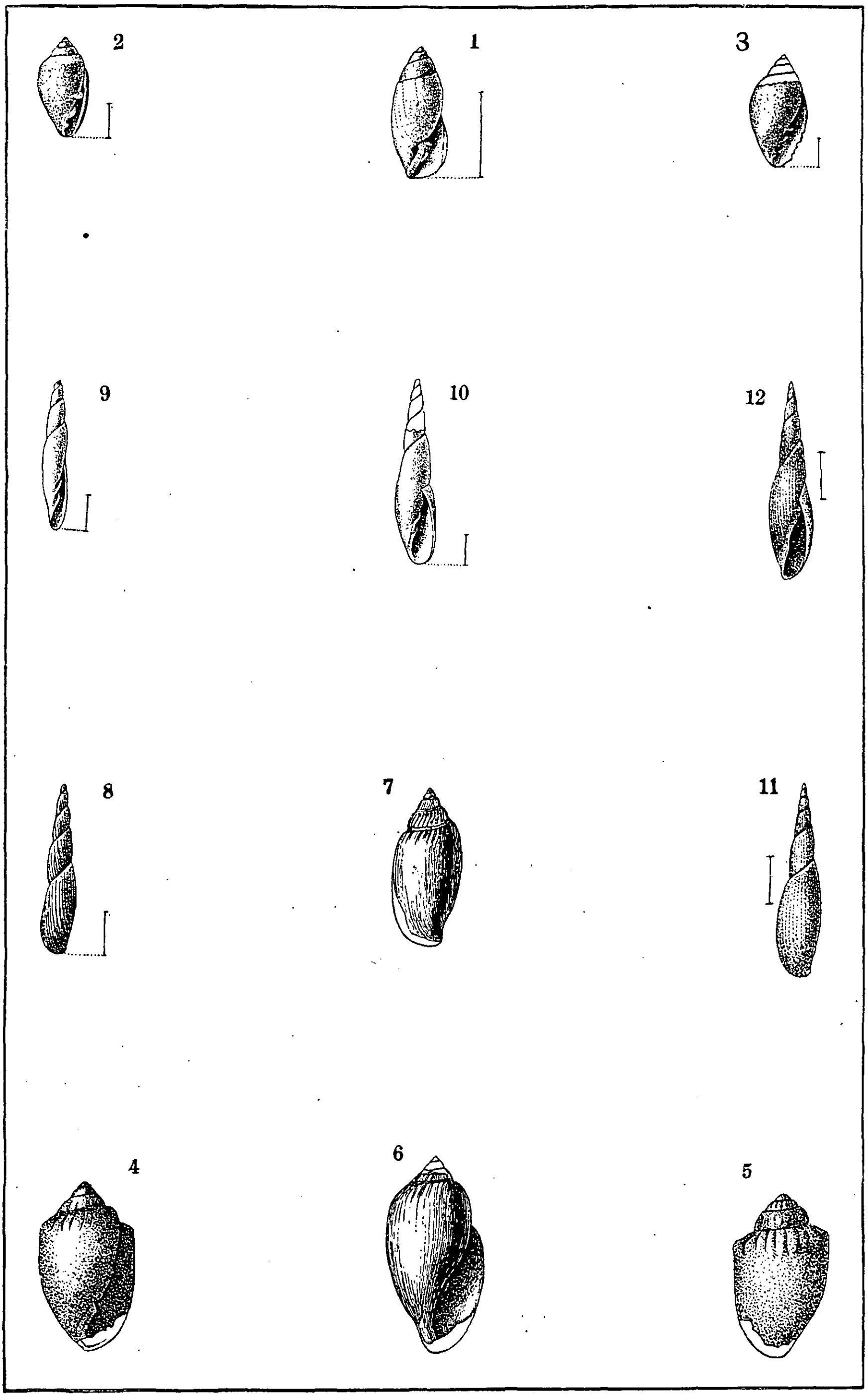
Fig. 4. Apertural view; natural size (after Meek).
Fig. 5. Opposite view of the same specimen (after Meek).

RHYTOPHORUS MEEKII (p. 43).

Fig. 6. Apertural view of a large specimen; natural size.
Fig. 7. Opposite view of another example; natural size.

TORTACELLA HALDEMANI (p. 44).

Fig. 8. Lateral view of a typical example; enlarged.
Fig. 9. Apertural view of a more slender example; enlarged.
Fig. 10. Apertural view of an imperfect example; enlarged.
Figs. 11, 12. Copies of the figures originally published, but which did not show the columella folds.



AURICULIDÆ.

PLATE VI.

PLATE VI.

LIMNÆA NITIDULA (p. 45).

Figs. 1, 2. Copies of Mr. Meek's unpublished figures; enlarged.
Fig. 3. Apertural view of one of Mr. Meek's type specimens; natural size.

PLANORBIS (GYRAULUS) PRÆCURSORIS (p. 46).

Figs. 4, 5. Apical views.
Fig. 6. Umbilical view.
Fig. 7. Peripheral view, showing aperture.
All enlarged.

PHYSA USITATA (p. 47).

Fig. 8. Lateral view of a type specimen.
Fig. 9. Lateral view of another type specimen, partially crushed.
Both natural size.

NERITINA NATICIFORMIS (p. 49).

Figs. 10, 11. Upper and under views of separate examples; natural size.
Fig. 12. Lateral view of one of the original type specimens; much enlarged.

HELIX? ——? (p. 48).

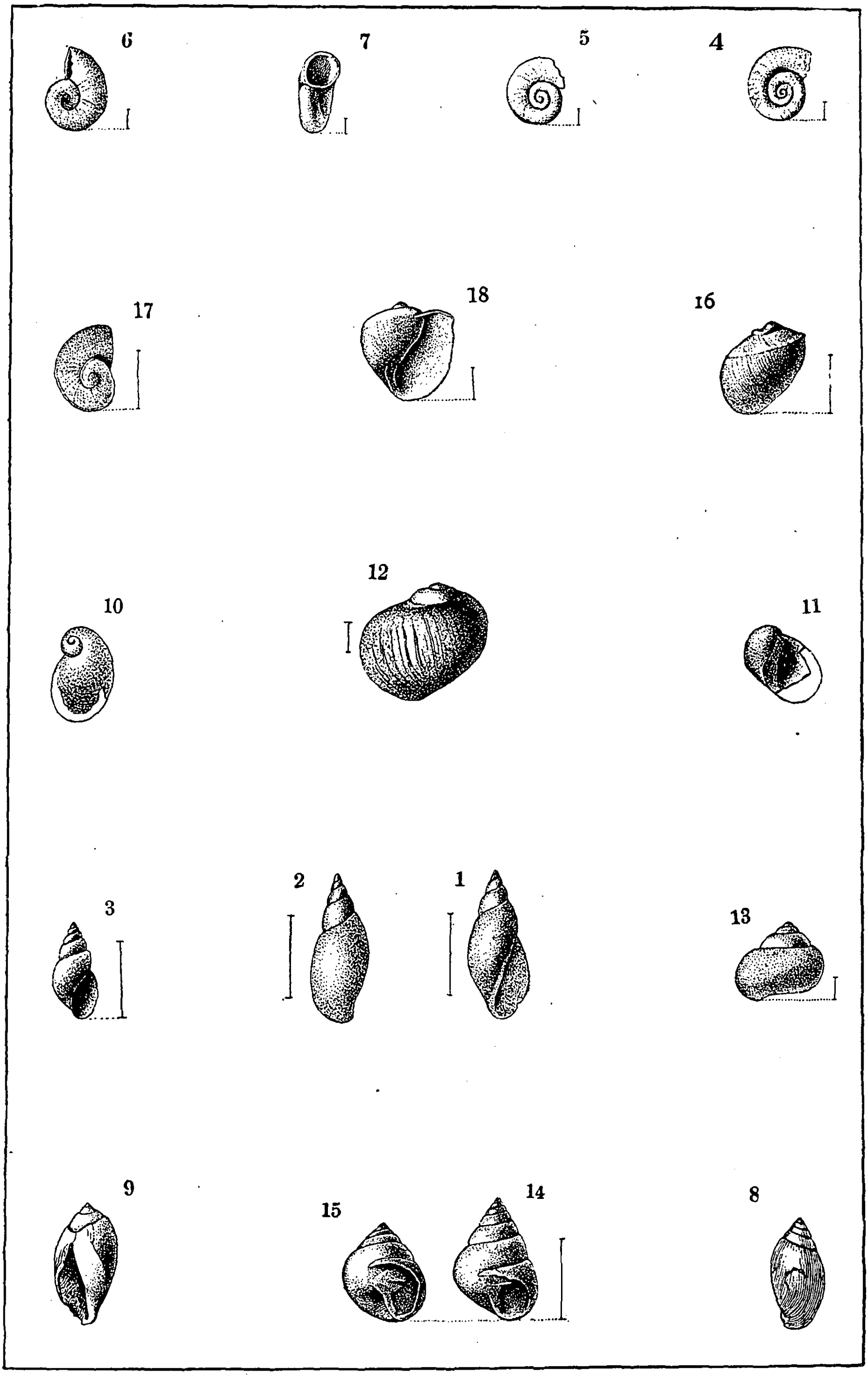
Fig. 13. Lateral view of the only discovered example; much enlarged.

TORNATELLINA? ISOCLINA (p 48).

Fig. 14. Lateral view of the type specimen; enlarged.
Fig. 15. Foreshortened view of the same specimen, showing the small umbilicus.

NERITINA STANTONI (p. 49).

Fig. 16. Lateral view of an adult example; enlarged.
Fig. 17. Apical view of the same, showing that the specimen has been slightly compressed.
Fig. 18. Lateral view of a young example; much enlarged.



LIMNEIDÆ, PHYSIDÆ, NERITIDÆ AND HELICIDÆ (?).

PLATE VII.

PLATE VII.

PACHYMELANIA CLEBURNI (p. 51).

Figs. 1, 2. Lateral views of typical examples; natural size.
Fig. 3. Similar views of an example showing obsolescence of longitudinal varices.

PACHYMELANIA CHRYSALLOIDEA (p. 52).

Figs. 4, 5. Lateral views of the type specimens; natural size.

PACHYMELANIA CHRYSALIS (p. 51).

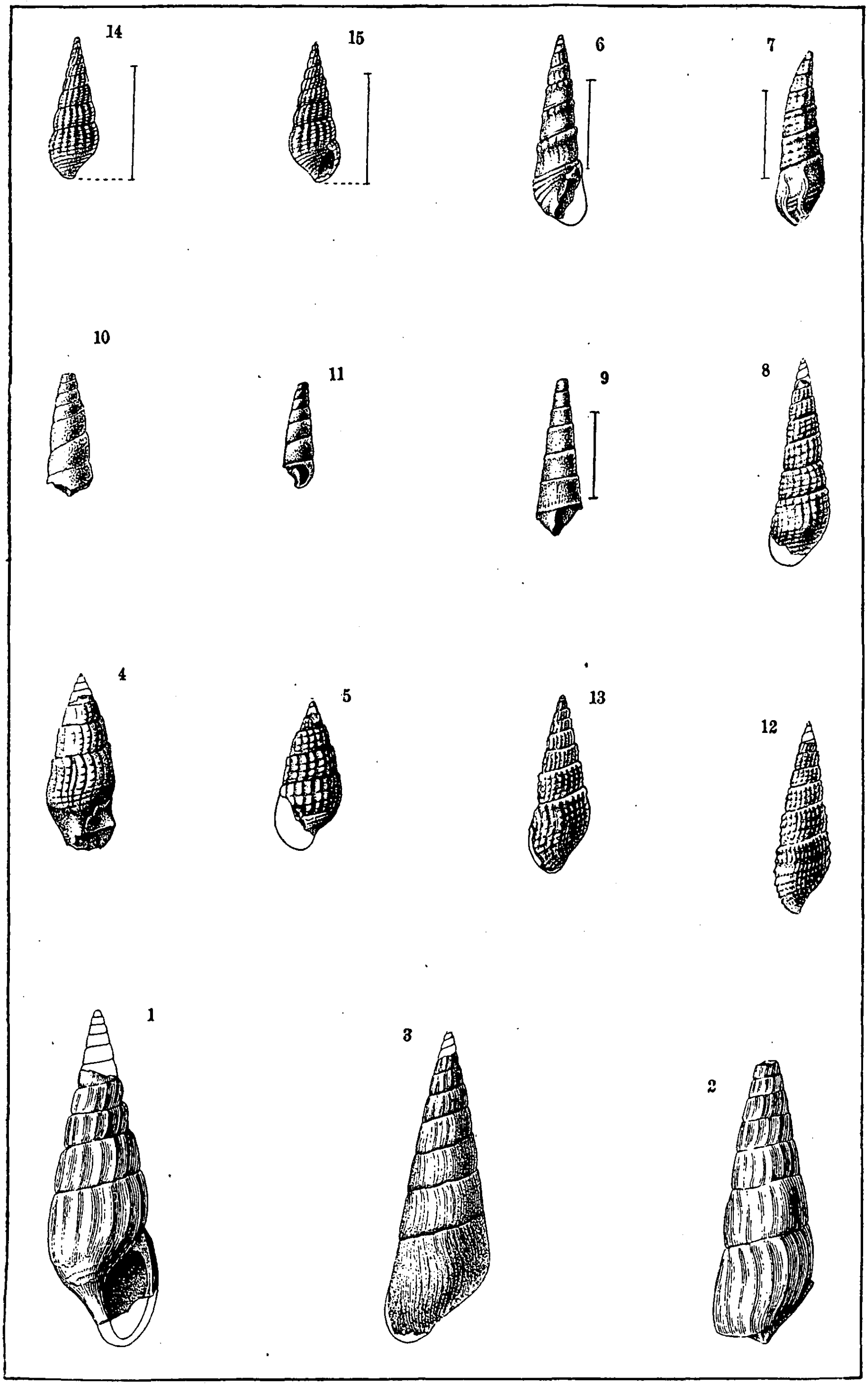
Figs. 6, 7. Lateral views of typical examples; enlarged.
Figs. 8, 12, 13. Possibly varieties; natural size.

PACHYMELANIA? MACILENTA (p. 54).

Fig. 9. Lateral view of type specimen; enlarged.
Figs. 10, 11. Possibly varieties; natural size.

PACHYMELANIA TURRICULA (p. 53).

Figs. 14, 15. Lateral views of the type specimen; enlarged.



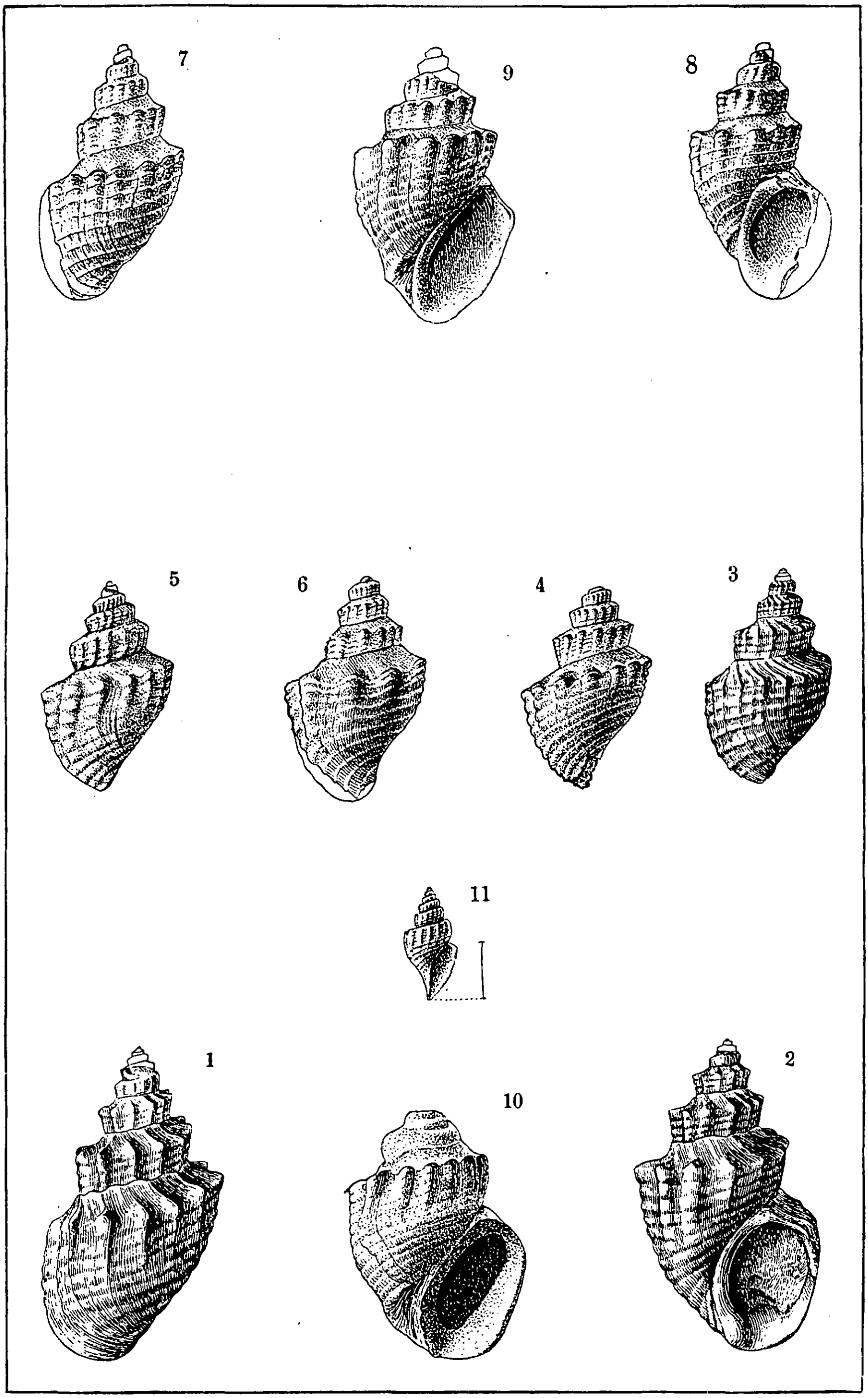
MELANIIDÆ.

PLATE VIII.

PLATE VIII.

PYRGULIFERA HUMEROSA (p. 55).

Figs. 1, 2. Lateral views of Mr. Meek's type specimen.
Figs. 3, 4, 5, 6. Lateral views of typical forms.
Figs. 7, 8. Lateral views of an unusually elongate example.
Figs. 9, 10. Two examples showing an umbilicate fissure.
Fig. 11. A very young example; enlarged.
All natural size.



MELANIIDÆ.

PLATE IX.

PLATE IX.

PYRGULIFERA STANTONI (p. 57).

Figs. 1, 2. Lateral views of typical examples.
Fig. 3. A similar view of another example.

PYRGULIFERA HUMEROSA (p. 55).

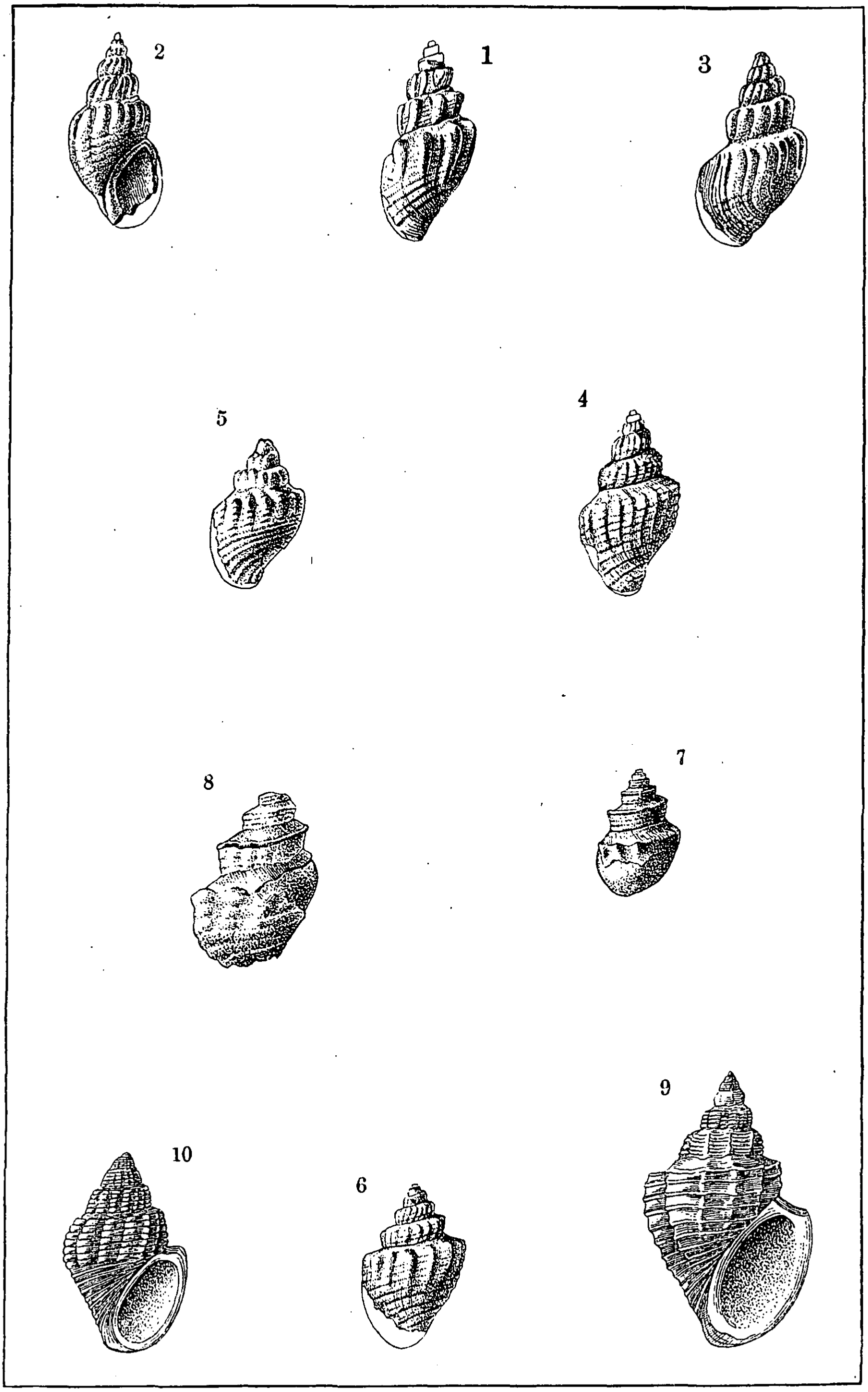
Fig. 4. Lateral view of an example having the volutions more than usually rounded and the nodules obsolete.
Fig. 5. Lateral view of another example showing a somewhat similar rounding of the volutions of the spire.
Fig. 6. Another example having a prominent shoulder to the volutions, but only a slight development of nodules.
Figs. 7, 8. Two examples showing absence of longitudinal varices and a continuous carina at the humeral angle.

PYRGULIFERA (PARAMELANIA) DAMONI.

Fig. 9. A copy of Mr. Smith's original figure. (For comparison.)

PRYGULIFERA (PARAMELANIA) CRASSIANGULATA.

Fig. 10. A copy of Mr. Smith's original figure. (For comparison.)
All of natural size.



MELANIIDÆ.

PLATE X.

PLATE X.

VIVIPARUS COUESI (p. 59).

Fig. 1. Lateral view of the type specimen; natural size.

CAMPELOMA MACROSPIRA (p. 60).

Figs. 2, 3. Lateral views of the type specimen; natural size.

LIOPLAX? ENDLICHI (p. 60).

Figs. 4, 5. Lateral views of the two type specimens.
Fig. 6. Lateral view of the apical portion of a specimen possibly belonging to this species.
All natural size.

CHARYDROBIA STACHEI (p. 58).

Fig. 7. Apertural view of a typical example.
Figs. 8, 9. Lateral views of two other examples.
All enlarged.

BYTHINELLA LATENTIS (p. 58).

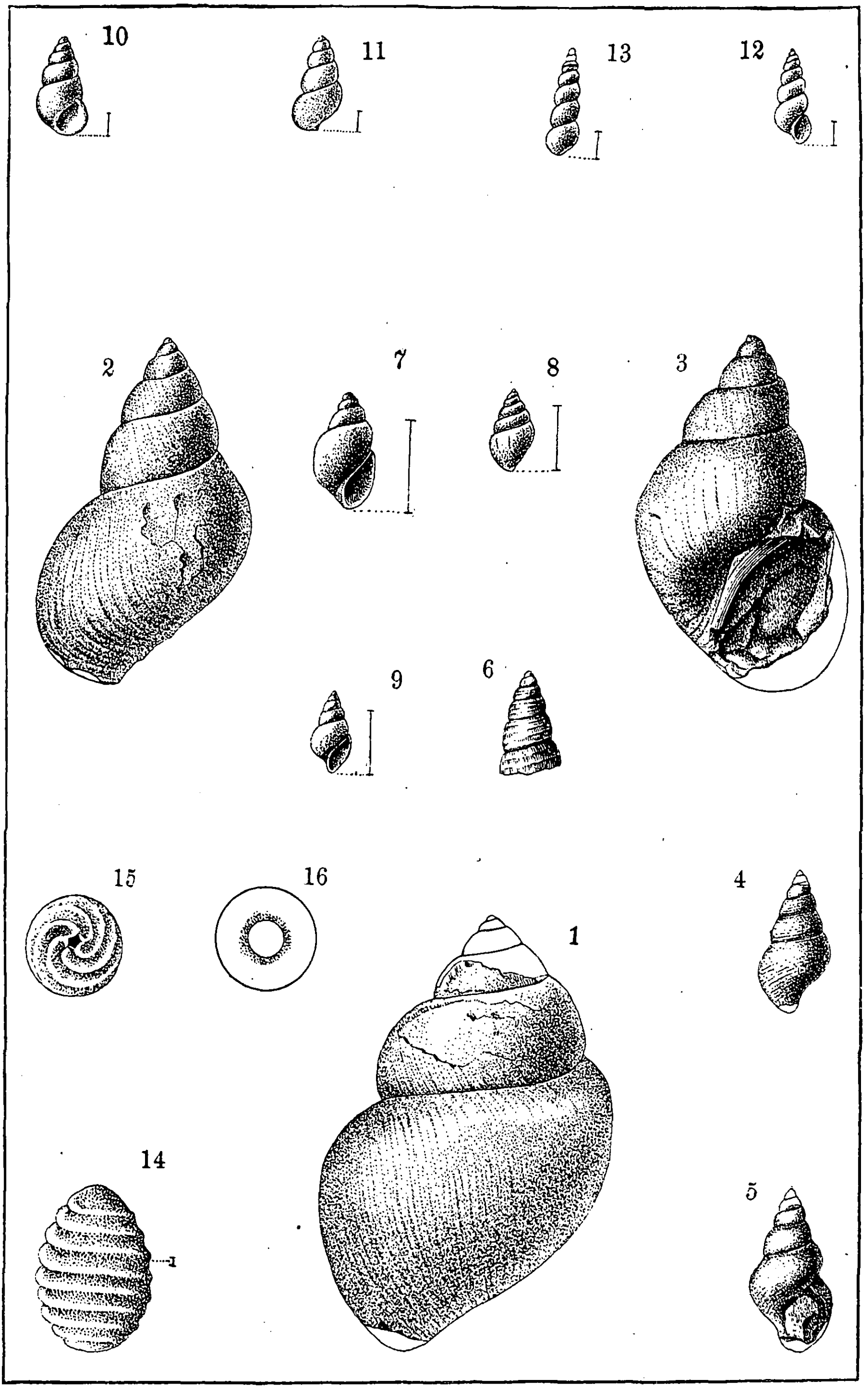
Figs. 10, 11. Lateral views of the type specimens; much enlarged.

HYDROBIA OCCULTA (p. 57).

Figs. 12, 13. Lateral views of the type specimens; much enlarged.

CHARA STANTONI (p. 63).

Fig. 14. Lateral view of a nutlet.
Fig. 15. Basal view of the same.
Fig. 16. Transverse section.
All greatly enlarged.



VIVIPARIDÆ, RISSOIDÆ, AND CHARA.

PLATE XI.

PLATE XI.

METACYPRIS CONSOBRINA (p. 62).

Fig. 1. *a*, Carapace, left valve shown; *b*, edge view; *c*, end view.

METACYPRIS SUBCORDATA (p. 62).

Fig. 2. *a*, Left valve shown; *b*, edge view; *c*, end view.

METACYPRIS CUNEIFORMIS (p. 62).

Fig. 3. *a*, Right valve shown; *b*, edge view; *c*, end view.

CYTHERIDEA TRUNCATA (p. 62).

Fig. 4. *a*, Left valve shown; *b*, ventral edge.

CYPRIDEA TUBERCULATA VAR. WYOMINGENSIS (p. 62).

Fig. 5. *a*, Right valve shown; *b*, ventral edge.
Fig. 6. *a*, Left valve shown; *b*, ventral edge.

CYTHERIDEA TENUIS (p. 62).

Fig. 7. *a*, Left valve shown; *b*, edge view.

POTAMOCYPRIS AFFINIS (p. 62).

Fig. 8. *a*, Right valve shown; *b*, ventral edge.

METACYPRIS SIMPLEX (p. 62).

Fig. 9. *a*, Right valve shown; *b*, edge view; *c*, end view.

CYPRIS PURBECKENSIS (p. 62).

Fig. 10. *a*, Carapace, right valve shown; *b*, edge view.

CYTHERIDEIS ÆQUALIS (p. 62).

Fig. 11. *a*, Carapace, left valve shown; *b*, edge view.

CYTHERIDEIS IMPRESSA (p. 62).

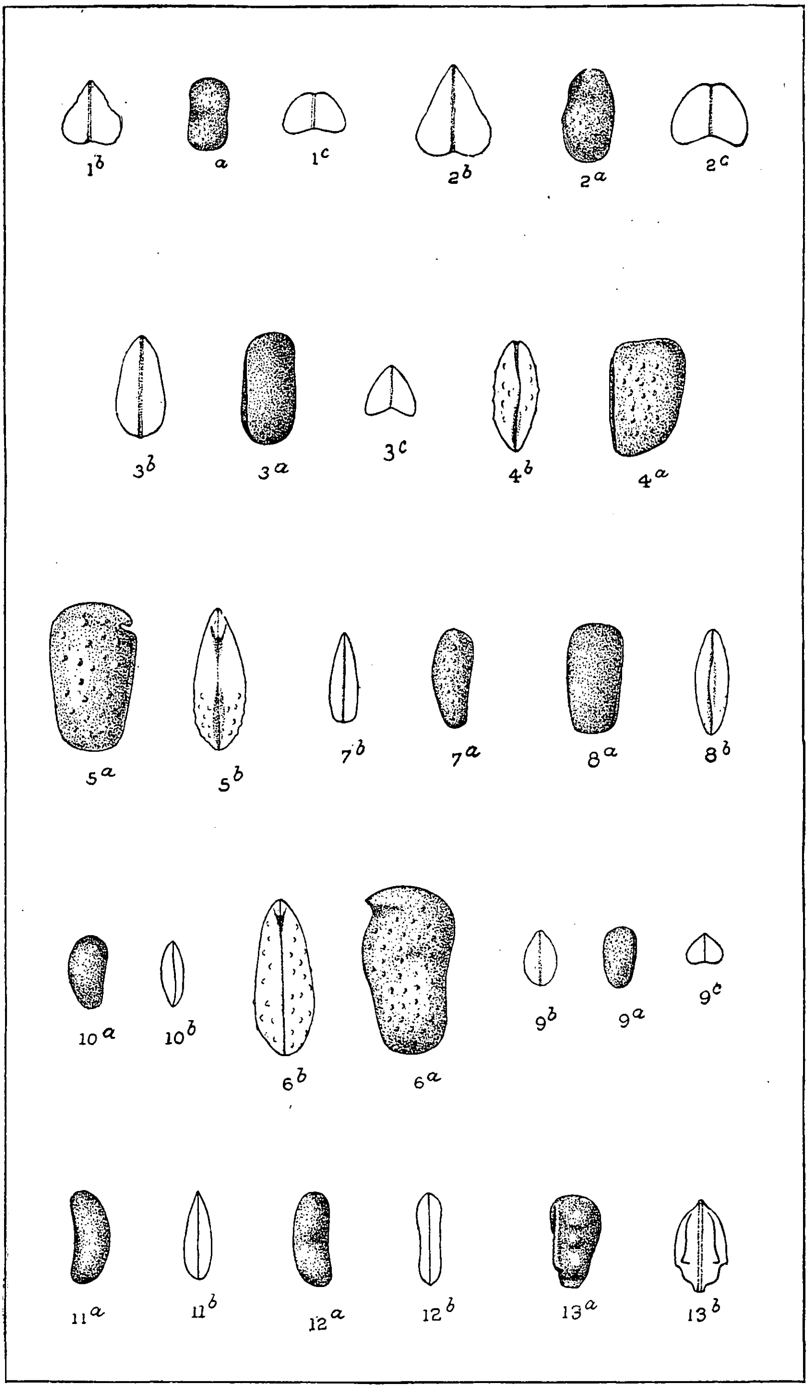
Fig. 12. *a*, Right valve shown; *b*, edge view.

CYTHERE MONTICULA (p. 62).

Fig. 13. *a*, Left valve shown; *b*, edge view.

Figures and explanations copied from Professor Jones's original publication: Geol. Mag., new ser., Decade III, Vol. X, pp. 385–391, pl. xv, London, 1893.

All figures enlarged 20 diameters.


1b
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1c
2b
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8b
10a
10b
6b
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9b
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13a
13b

OSTRACODA.

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