DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 11

ON THE QUATERNARY AND RECENT MOLLUSCA OF THE GREAT BASIN, WITH DESCRIPTIONS OF NEW FORMS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1884

ADVERTISEMENT.

[Bulletin No. 11.]

The publications of the United States Geological Survey are issued in accordance with the statute approved March 3, 1879, which declares that—

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classifications of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

On July 7, 1882, the following joint resolution, referring to all Government publications, was passed by Congress:

"That whenever any document or report shall be ordered printed by Congress, there shall be printed in addition to the number in each case stated, the usual number [1,900] of copies for binding and distribution among those entitled to receive them."

Under these general laws it will be seen that none of the Survey publications are furnished to it for gratuitous distribution. The 3,000 copies of the Annual Report are distributed through the document rooms of Congress. The 1,900 copies of each of the publications are distributed to the officers of the legislative and executive departments and to stated depositories throughout the United States.

Except, therefore, in those cases where an extra number of any publication is supplied to this office by special resolution of Congress, as has been done in the case of the Second, Third, Fourth, and Fifth Annual Reports, or where a number has been ordered for its use by the Secretary of the Interior, as in the case of Williams's Mineral Resources, the Survey has no copies of any of its publications for gratuitous distribution.

ANNUAL REPORTS.

Of the Annual Reports there have been already published:

I. First Annual Report to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Report of the Director of the United States Geological Survey for 1880–'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 61 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881–'82, by J. W. Powell. 1883. 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882–'83, by J. W. Powell. 1884. 8°. xii, 473 pp. 85 pl. and maps.

The Fifth Annual Report is in press.

MONOGRAPHS.

So far as already determined upon, the list of the Monographs is as follows:

I. The Precious Metals, by Clarence King. In preparation.

II. Tertiary History of the Grand Cañon District, with atlas, by Capt. C. E. Dutton. Published.

III. Geology of the Comstock Lode and Washoe District, with atlas, by George F. Becker. Published.

IV. Comstock Mining and Miners, by Eliot Lord. Published.

V. Copper-bearing Rocks of Lake Superior, by Prof. R. D. Irving. Published.

VI. Older Mesozoic Flora of Virginia, by Prof. Wm. M. Fontaine. Published.

VII. Silver-lead Deposits of Eureka, Nevada, by Joseph S. Curtis. Published.

VIII. Paleontology of the Eureka District, Nevada, by Charles D. Walcott. In press.

IX. Brachiopoda and Lamellibranchiata of the Green Marls and Clays of New Jersey, by R. P. Whitfield. In press.

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Geology and Mining Industry of Leadville, with atlas, by S. F. Emmons. In preparation.

Geology of the Eureka Mining District, Nevada, with atlas, by Arnold Hayne. In preparation.

Coal of the United States, by Prof. R. Pumpelly. In preparation.

Iron in the United States, by Prof. R. Pumpelly. In preparation.

Lesser Metals and General Mining Resources, by Prof. R. Pumpelly. In preparation.

Lake Bonneville, by G. K. Gilbert. In preparation.

Dinocerata. A Monograph on an extinct order of Ungulates, by Prof. O. C. Marsh. In preparation.

Sauropoda, by Prof. O. C. Marsh. In preparation.

Stegosauria, by Prof. O. C. Marsh. In preparation.

Of these Monographs, Nos. II, III, IV, V, VI, and VII are now published, viz:

II. Tertiary History of the Grand Cañon District, with atlas, by C. E. Dutton, Capt., U. S. A. 1882. 4°. 264 pp. 42 pl. and atlas of 26 double sheets folio. Price $10.12.

III. Geology of the Comstock Lode and Washoe District, with atlas, by G. F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

V. Copper-bearing Rocks of Lake Superior, by Prof. R. D. Irving. 1883. 4°. xvi, 464 pp. 29 pl. Price $——.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine. 1883. 4°. xix, 128 pp. 54 l. 54 pl. Price $——.

VII. Silver-lead Deposits of Eureka, Nevada, by Joseph S. Curtis, 1884. 4°. xii, 200 pp. 15 pl. Price $——.

Nos. VIII and IX are in press and will soon appear. The others, to which numbers are not assigned, are in preparation.

BULLETINS.

The Bulletins of the Survey will contain such papers relating to the general purpose of its work as do not properly come under the heads of ANNUAL REPORTS or MONOGRAPHS.

Each of these Bulletins will contain but one paper and be complete in itself. They will, however, be numbered in a continuous series, and will in time be united into volumes of convenient size. To facilitate this each Bulletin will have two paginations, one proper to itself and one which belongs to it as part of the volume.

Of this series of Bulletins, Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 are already published:

1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross, with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons. 1883. 8°. 42 pp. 2 pl. Price 10 cents.
2. Gold and Silver Conversion Tables, giving the coining value of Troy ounces of fine metal, &c., by Albert Williams, jr. 1883. 8°. ii, 8 pp. Price 5 cents.
3. On the Fossil Faunas of the Upper Devonian, along the meridian of 76° 30′, from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams. 1884. 8°. 36 pp. Price 5 cents.
4. On Mesozoic Fossils, by Charles A. White. 1884. 8°. 36 pp. 9 pl. Price 5 cents
5. A Dictionary of Altitudes in the United States, compiled by Henry Gannett. 1884. 8°. 325 pp. Price 20 cents.
6. Elevations in the Dominion of Canada, by J. W. Spencer. 1884. 8°. 43 pp. Price 5 cents.
7. Mapoteca Geologica Americana. A catalogue of geological maps of America (North and South), 1752–1881, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.
8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Vanhise. 1884. 8°. 56 pp. Price 10 cents.
9. A Report of the Work Done in the Washington Laboratory during the fiscal year 1883–'84. F. W. Clarke, chief chemist; T. M. Chatard, assistant. 1884. 8°. 40 pp. Price 5 cents.
10. On the Cambrian Faunas of North America. Preliminary studies by Charles Doolittle Walcott. 1884. 8°. 74 pp. Price 5 cents.
11. On the Quaternary and Recent Mollusca of the Great Basin; with Descriptions of New Forms, by R. Ellsworth Call; introduced by a sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert. 1884. 8°. 66 pp. Price 5 cents.

STATISTICAL PAPERS.

A fourth series of publications having special reference to the mineral resources of the United States is contemplated. Of that series the first has been published, viz: Mineral Resources of the United States, by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

Correspondence relating to the publications of the Survey, and all remittances, which must be by postal note or money order, should be addressed to the

DIRECTOR OF THE UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C

WASHINGTON, D. C., *August* 30, 1884.

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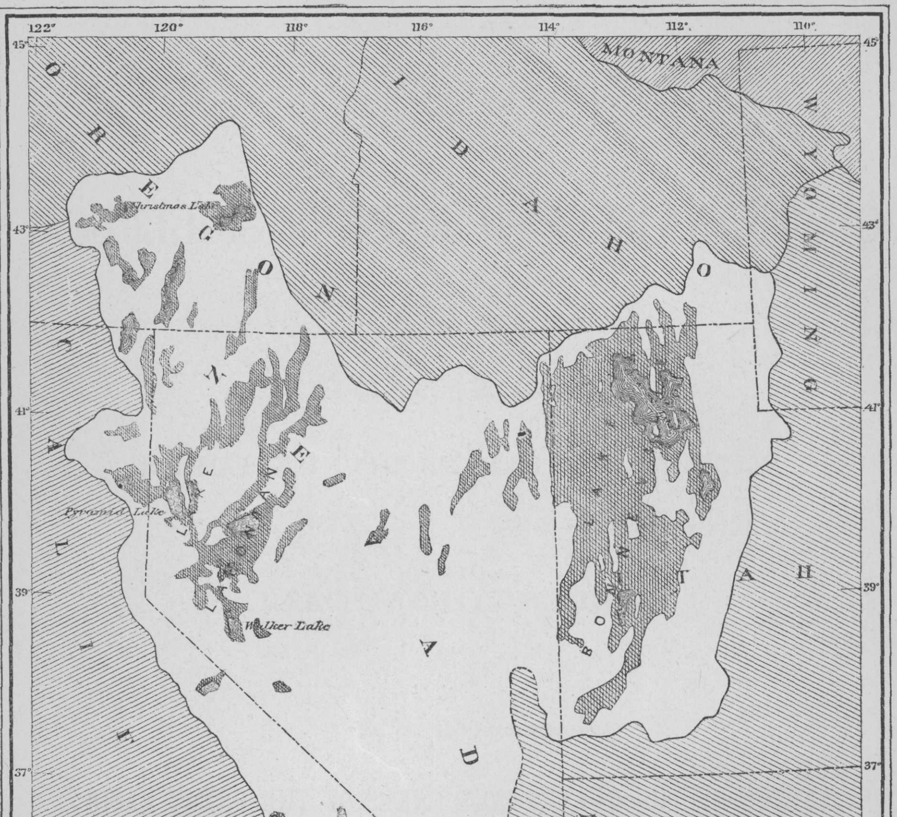

SKETCH MAP OF THE GREAT BASIN

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL DIRECTOR

ON THE

QUATERNARY AND RECENT MOLLUSCA

OF THE

GREAT BASIN

WITH DESCRIPTIONS OF NEW FORMS

BY

R. ELLSWORTH CALL

INTRODUCED BY A

SKETCH OF THE QUATERNARY LAKES OF THE GREAT BASIN

BY

G. K. GILBERT

WASHINGTON
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1884

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ILLUSTRATIONS.

INTRODUCTORY SKETCH OF THE QUATERNARY LAKES OF THE GREAT BASIN.

By G. K. Gilbert.

The biologic investigation reported in this bulletin grew out of an inquiry into the physical history of the Great Basin during the Quaternary. It will be introduced by a brief account of that inquiry, with especial reference to a climatic problem which it was hoped the biologic investigation would aid in solving.

During at least a portion of the Quaternary the desert valleys of the Great Basin contained a system of lakes, in comparison with which the existing lakes of the same region are insignificant. These were incidentally studied by the geologists of the surveys directed by Mr. Clarence King, Capt. George M. Wheeler, and Maj. J. W. Powell, and the outlines of the largest lakes were approximately determined. The present Geological Survey has made them the subject of an independent investigation, to the prosecution of which a corps of geologists was assigned.

The following facts have been ascertained: In the northern portion of the Great Basin there were two large water bodies; the one, Lake Bonneville, covering the Great Salt Lake and Sevier deserts, in western Utah; the other, Lake Lahontan, occupying a group of communicating valleys in western Nevada. Of smaller lakes, twenty-five have been explored, and it is probable that a still larger number remain to be examined. Previous to the epoch of Lake Bonneville its basin appears to have been arid, and the lake history was interrupted by an interval during which the water was greatly diminished, or may even have completely disappeared. There were, therefore, two floods, and corresponding to these there were two series of lacustrine deposits, separated by a zone of unconformity. The lower Bonneville beds are thicker than the upper, whence it is believed that the earlier flood was of longer duration than the later. There was a parallel series of events in the Lahontan Basin. The water rose and fell twice, and the beds deposited during the first rise form a thicker series than those deposited during the second.

This correspondence serves to confirm, and, indeed, practically to establish, the postulate early entertained that the fluctuations of these and other lakes of the region were not merely synchronous but were due to some general cause.

It has been further postulated that the general cause was climatic, and still further that it was identical with the cause of the glacial epoch, whatever that may have been. Such speculation of course implies the fact of a glacial epoch, and that fact is not universally admitted. Nevertheless, the great majority of those who have studied the vestiges of ancient glaciers believe them to have been contemporaneous in different countries, and refer them to some cause of a very general nature.

It is held, moreover, by numerous glacialists that the epoch of ice extension was bipartite, the interval being characterized by conditions comparable with those which now exist; and if this view is well sustained, then the bipartite nature of the lacustrine histories goes far toward establishing the postulate which connects them with the glacial epoch.

With regard to the general nature of the glacial climate there is not a consensus of opinion. It is indeed held by the majority of investigators that the whole earth, or at least the zones including the glaciated areas, were then colder than now, but there is a considerable body of able geologists who maintain the contrary, arguing that an extension of glaciers is rather indicative of a general amelioration of climate. It is believed that the study of the lakes of the Great Basin should throw light upon this problem, and one of the ways in which it might be supposed to contribute to the subject is through a consideration of the faunas of the ancient lakes. If these indicate a lower temperature than now obtains, the view of the majority is to that extent sustained; if they indicate a higher temperature the view of the minority is favored.

With these problems in mind, the fossil shells gathered from the Bonneville and Lahontan strata were placed in the hands of Mr. Call, and he was requested to compare them with existing forms, with a view to ascertaining whether their differences were susceptible of climatic interpretation. Finding the material too meager for the purpose, he afterward visited the region and spent several weeks in the collection of fossil and recent shells. How successful has been his quest, the reader may judge from the facts and inferences set forth in his report. Their discussion from a geologic point of view would here be out of place, but their application will soon be made by Mr. I. C. Russell and by the present writer, who have in preparation monographs on Lake Lahonton and Lake Bonneville.

Before closing, it is proper to explain two special elements of the lacustrine histories to which Mr. Call alludes in his report.

The first of these is embodied in the terms "post-Bonneville," "post-Lahontan," and "semi-fossil." Besides the shells discovered living in existing waters and the shells entombed in the Quaternary strata, there are also great numbers which lie dead and bleached on the surface of the desert at considerable distances from streams or bodies of water. These shells doubtless lived in the ancient lakes after their desiccation had commenced, and before their areas had been so greatly diminished as we now find them. Presumably they represent climatic conditions not greatly removed from those of modern times, but they nevertheless occur at stations which are now absolutely destitute of the conditions essential to their growth. It is to shells of such occurrence that the above-quoted terms are applied.

The second special factor of the lacustrine history is embodied in the tufa deposits of the Lahontan area. These have been critically studied by Mr. Russell, who recognizes three varieties superimposed in the manner indicated by the diagram. The extreme height attained by the Lahontan waters during their first rise was 500 feet above the level of Pyramid Lake. Up to this height are found deposits of "lithoid" tufa. Over the "lithoid" tufa is deposited a distinct variety named "thinolite," but this reaches only one hundred feet above the surface of Pyramid Lake. It rests unconformably upon eroded surfaces of the lithoid tufa, and is chronologically separated from it by an epoch during which the water fell to a lower plane than that marked by Pyramid Lake. The thinolite tufa therefore belongs to the second Lahontan epoch and is synchronous with a portion of the Upper Lahontan beds. After its formation the water rose to its highest level, 530 feet above Pyramid Lake, or 30 feet higher than the first great rise. During this second high stage a third variety of tufa was deposited, the "dendritic," but it failed to attain the height of the lithoid. Its upper limit is 320 feet above Pyramid Lake. Up to the 100-foot contour it rests upon the thinolite tufa. Higher up it is found in contact with lithoid tufa. Lake Lahontan had no outlet; and it is assumed that the salinity of its water varied with expansion and contraction just as that of Great Salt Lake is now known to vary. During the lithoid and dendritic epochs it was presumably a weaker solution than during the thinolite.

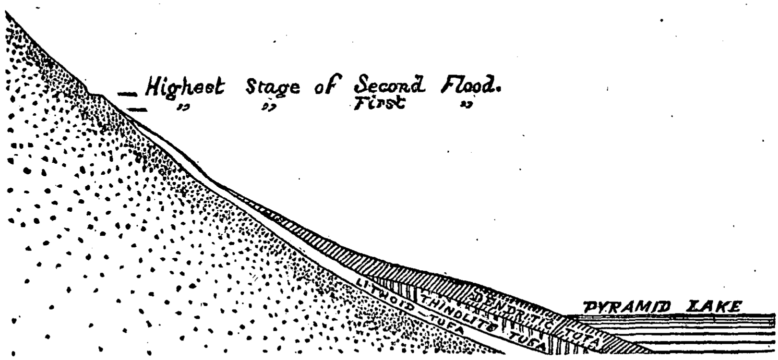

FIG. 1—Diagram showing superposition of tufas.

The reader who cares to inform himself more fully in regard to the history of these Quaternary lakes can do so by consulting the following literature:

U. S. Geographical Surveys West of the 100th Meridian. Vol. III,

Geology. Part I. Report upon the Geology of portions of Nevada, Utah, California, and Arizona, examined in the years 1871 and 1872. By G. K. Gilbert. Pp. 88–104.—Part III. Geology of portions of Utah, Nevada, Arizona, and New Mexico, explored and surveyed in 1872 and 1873. By E. E. Howell. Pp. 249–251.

U. S. Geological Exploration of the Fortieth Parallel. Vol. I. Systematic Geology. By Clarence King. Pp. 488–525.

U. S. Geological Survey. Second Annual Report. Contributions to the History of Lake Bonneville. By G. K. Gilbert. Pp. 169–200.

U. S. Geological Survey. Third Annual Report. Sketch of the Geological History of Lake Lahontan; a Quaternary lake of northwestern Nevada. By Israel C. Russell. Pp. 189–235.

U. S. Geological Survey. Fourth Annual Report. A Geological Reconnaissance in Southern Oregon. By Israel C. Russell. Pp. 435–462.

ON THE QUATERNARY AND RECENT MOLLUSCA OF THE GREAT BASIN, WITH DESCRIPTIONS OF NEW FORMS.

By R. Ellsworth Call.

CHAPTER I.

SYSTEMATIC CATALOGUE OF QUATERNARY AND RECENT SHELLS OF THE GREAT BASIN.

The material herein reported upon was derived in part from collections made by the Great Basin Division of the United States Geological Survey and in part from personal collections made under the auspices of the same organization. The material comes from numerous and widely separated localities, and is fairly representative of all the beds of ancient Lakes Lahontan and Bonneville. The first-named area furnishes the greater body of material, and also exhibits the more diverse fauna.

The later beds present three identical forms in common—*Fluminicola fusca* Hald., *Helisoma trivolvis* Say, and *Limnophysa palustris* Müller—no one of which is characteristic of either area. These identical forms represent two distinct families of gasteropods, the first named belonging to the *Rissoidæ*, the others to the *Limnæidæ*. Each of these great families is represented by the characteristic species of each series of lacustrine beds, the *Limnæidæ* being alone characteristically represented in the Lahontan beds, and the *Rissoidæ* alone characteristically represented in the Bonneville beds.

The field treated in this paper is entirely new, and the methods adopted are also new. The results have been put into the form of tables of measurements, and these tables have been used as the basis of graphic representation.

The facies of the shells studied in a measure correspond with differences in size. That is to say, the weight, sculpture, and other taxonomic features were found to vary in almost or quite as marked a degree as the size.

The material upon which the included discussion is based is exhibited in the following catalogue[1]:

LAMELLIBRANCHIATA.

UNIONIDÆ.

Genus MARGARITANA.

Margaritana margaritifera Linn.

This species is circumpolar. It appears over a considerable area of the northeastern United States, Nova Scotia, New Brunswick, Newfoundland, and Quebec. Its western limit in this area is Central Pennsylvania. It reappears in the headwaters of the Missouri River, and thence over all of the western United States, south to Arizona and north to British Columbia. It is somewhat common in streams near Salt Lake City, Utah, and occurs rarely at Elko, Nev., in the Humboldt River. It is far smaller throughout its western range than are its eastern congeners. It has been found fossil at one locality only in the Lahontan area, in the Walker River Cañon, Nevada. Within the Bonneville area it is semi-fossil[2], or post-Bonneville, at numerous localities and notably in Sevier Desert.

Genus ANODONTA.

Anodonta nuttalliana Lea. Observations on *Unio*, Vol. II, 77 (1838). Transactions Am. Phil. Soc., Vol. VI, Pl. 20, Fig. 62 (1838).

Anodonta wahlametensis Lea. Trans. Am. Phil. Soc., Vol. VI, Pl. 20, Fig. 64 (1838). Obs. on *Unio*, Vol. II, 78 (1838).

Anodonta oregonensis Lea. Trans. Am. Phil. Soc., Vol. VI, Pl. 21, Fig. 67 (1883).

Anodonta californiensis Lea. Trans. Am. Phil. Soc., Vol. X, Pl. 25, Fig. 47. Obs. on *Unio*, Vol. V, 42 (1852).

Vide also, Stearns, "On the History and Distribution of the Fresh Water Mussels and the Identity of certain alleged species." Proc. Cal. Acad. Sci., Nov. 20, (1882), p. 4 *et seq.* In this paper a vast array of facts is brought out, together with the necessary data to render the synonymy as here given absolutely certain.

The synonymy here indicated is based upon extensive suites from various localities on the Pacific slope and in the Great Basin. In its various forms the species has a wide distribution through California, Idaho, Oregon, Washington Territory, British Columbia, Vancouver's Island, Nevada, and Utah. Specimens were dredged in Utah Lake in August, 1883. In the Lahontan area it is especially abundant in the Humboldt River, and found sparingly in the Truckee River, Nevada.

[1] The bibliographic references given in connection with this catalogue are such only as are easily accessible; no attempt has been made to furnish a complete bibliography.

[2] The special use of this term is explained on page 10, *ante*.

It is found fossil in middle Lahontan beds at Mill City, Nev., and post-Lahontan beds on the desert east of Carson Lake. In the Bonneville area it has not yet been discovered in Bonneville beds, but abundant post-Bonneville fossils occur on Sevier Desert. It is somewhat common in fresh-water streams near Salt Lake City.

CORBICULIDÆ.

Genus SPHÆRIUM.

Sphærium striatinum Lam.

Cyclas striatina Lam. Animaux sans Vertèbres, Vol. V, p. 560, (1818).
Sphærium striatinum Lam. Smithsonian Misc. Coll. No. 145, p. 37, Fig. 29 (1865).

Widely distributed in the United States and Canada. Found fossil only at Rye Patch, Nev., in Upper Lahontan beds.

Sphærium dentatum Hald.

Cyclas dentatum Hald (Prime), Smithsonian Misc. Coll. No. 145, p. 40, Fig. 32 (1865).

This species was originally described from Oregon, and has a somewhat limited distribution. In the Lahontan area it occurs in Humboldt River, at Elko, and fossil in Upper Lahontan beds at Rye Patch, Nevada. It is a very abundant species in Utah Lake, where it attains a great size. Found as a post-Bonneville semi-fossil in great abundance upon the surface of Sevier Desert; occurs also in dredgings from Great Salt Lake, near the mouth of the Jordan River, whence it was doubtless drifted or floated.

Genus PISIDIUM.

Pisidium ultramontanum Prime. Smithsonian Misc. Coll. No. 145, p. 75, Fig. 85 (Appendix) (1865).

This species is rare and restricted in distribution. The original specimens came from California and Oregon. Found semi-fossil near Button's Ranch, Christmas Lakes, Oregon. As a fossil it occurs (*a*) in estuary of highest Lahontan two miles southeast of Brown's, Nev.; (*b*) section on west side of Truckee River, below Reservation Bridge; and (*c*) in Upper Lahontan beds at Rye Patch, Nevada.

Pisidium compressum Prime. Proc. Bost. Soc. Nat. Hist., Vol. IV, 164 (1851). Smithsonian Misc. Coll. No. 145, p. 64, Fig. 67 (1865).

This species is very widely distributed, ranging from New England to California, and north into Canada. It is everywhere rare. In Lahontan beds it has been found at the base of the bone-beds on the south side of Walker River Cañon, Nevada, below the Narrows. It is there Lower Lahontan. Three specimens, living, were dredged in August, 1883, in Utah Lake.

Pisidium abditum Hald. Proc. Acad. Nat. Sci. Phil., Vol. I, p. 53 (1841). Smithsonian Misc. Coll. No. 145, p. 68, Fig. 72 (1865).

Twenty-seven different specific names are listed in the extensive synonymy credited to this form by Prime in his monograph. Its distribution is so wide and the local conditions to which it is subjected are so various that its extensive synonymy is not remarkable. It has been found, living, in the Bonneville area, at only one locality—City Creek, near Salt Lake City, Utah.

GASTEROPODA.

LIMNÆIDÆ.

Genus HELISOMA.

Helisoma trivolvis Say.

Planorbis trivolvis Say. Nicholson's Encyc., Pl. II, Fig. 2 (1817-18-19). Am. Conch., Pt. VI, Pl. LIV, Fig. 2 (1834).

Helisoma trivolvis Say. Smithsonian Misc. Coll. No. 143, pp. 115-121, Figs. 194-201 (1865).

This species is the most widely distributed form of the genus in North America, and is correspondingly variable. In the Lahontan area it is found fossil only at Rye Patch, Nev., in Upper Lahontan beds, and semi-fossil near Button's Ranch, Christmas Lake, Oregon. Living examples are very abundant at many localities, especially near Wadsworth, Nevada. In the Bonneville area it is less abundant, living. It has been found in Upper Bonneville beds, near Salt Spring Creek, and as a post-Bonneville fossil, on the surface of the Sevier Desert.

Helisoma ammon Gould. Proc. Bost. Soc. Nat. Hist., Vol. V, 129 (1855). Pacific Railroad Reports, Vol V, 331, Pl. XI, Figs. 12-18 (1857). Smithsonian Misc. Coll. No. 143, p. 112, Fig. 187 (1865).

Restricted in distribution to portions of California, Oregon, and Nevada. No specimens have been found in Lahontan beds, but it is abundant as a semi-fossil on the surface of Humboldt Lake Basin near White Plains.

Genus GYRAULUS.

Gyraulus parvus Say.

Planorbis parvus Say. Nicholson's Encyc., Pl. I, Fig. 5 (1817, 1818, 1819).

Gyraulus parvus Say. Smithsonian Misc. Coll. No. 143, p. 139, Figs. 219-221 (1865).

Generally distributed east of the Sierra. Found in Middle Lahontan beds at Mill City, and in Upper Lahontan beds at Rye Patch, Nevada. In the Bonneville Basin it has been found only at one locality—living in a small pond at Fort Douglas, near Salt Lake City.

Gyraulus vermicularis Gould.

Planorbis vermicularis Gould. Proc. Bost. Soc. Nat. Hist., Vol. II, 212 (1847).
Gyraulus vermicularis Gould. Smithsonian Misc. Coll. No. 134, 128, fig. 214 (1865).

The distribution of this form is limited similarly with *Helisoma ammon*, namely, to portions of California, Nevada, and Oregon. The shells submitted are from Button's Ranch, Christmas Lakes, Oregon, and are semi-fossil.

Genus MENETUS.

Menetus opercularis Gould.

Planorbis opercularis Gould. Proc. Bost. Soc. Nat. Hist., Vol. II, p. 212 (1847).
Menetus opercularis Gould. Smithsonian Misc. Coll. No. 143, 125, Figs. 208–209 (1865).

Distribution similar to the last, with the addition of Utah. In the Lahontan area found (*a*) in Upper Lahontan lake beds, above tufa, Rye Patch, Nevada, and (*b*) in an estuary of the highest Lahontan beach, two miles southeast of Brown's, Nevada, of the same age. In the Bonneville area it is not found fossil, but is living in abundance in Warm Spring Lake, near Salt Lake City.

Genus LIMNÆA.

Limnæa stagnalis Linn.

This form, a true *Limnœa*, is circumpolar in distribution, and ranges to high latitudes. It formed the subject of numerous experiments, alluded to below, made by Semper with reference to its powers of endurance of cold and other unusual conditions. Rare specimens were found semi-fossil in the Humboldt sink in the Lahontan area. It abounds, as a semi-fossil, in Sevier Desert, and numerous living examples occur near Salt Lake City, and in Utah Lake at American Fork, in the Bonneville Basin.

Genus LIMNOPHYSA.

Limnophysa palustris Müller.

Helix palustris Müller. *Teste* Rackett, Trans. Linn. Soc., Vol. XIII, 42 (1822).
Limnophysa palustris Müll. Smithsonian Miss. Coll. No. 143, p. 44, Figs. 60–66 (1865).

This form is circumboreal, and consequently exhibits many varieties. It is an abundant post-Lahontan fossil, and ranges downward to Upper Lahontan, in estuary of highest Lahontan beach, near Brown's, Nevada; and to Middle Lahontan in the medial stratified gravels of Mill City, Nevada. It is abundantly distributed, living and semi-fossil, throughout the Bonneville area, and is found fossil in Upper Bonneville beds, near Salt Spring Creek, Utah. It is very common and unusually large on the surface of Sevier Desert.

Limnophysa sumassi Baird. Proc. Zoöl. Soc. London, p. 68, 1863. Smithsonian Misc. Coll. No. 143, p. 43, Figs. 56–58 (1865).

The distribution of this form is restricted to the northwestern United States, and southwestern British America. It is doubtful whether it should be separated specifically from *L. palustris* Müll., with which it presents common taxonomic features. It is found fossil in Upper Lahontan beds at Brown's Station, Nevada. It is rare in the Bonneville area and fossil only at Matlin Pass, in Upper Bonneville beds, above the intermediate beach.

Limnophysa bulimoides Lea. Proc. Am. Phil. Soc., Vol. II, 33 (1841). Smithsonian Misc. Coll. No. 143, 61, Fig. 96 (1865).

This species is very restricted in distribution, being found only in parts of California, Nevada, Oregon, and Washington Territory, and doubtfully credited to Idaho. Found fossil in Alkali Valley, in sand just below Lahontan beds, and semi-fossil at Button's Ranch, Christmas Lakes, Oregon.

Limnophysa bonnevillensis Call.

The description of this form is given below. No living representatives are known. It occurs in Upper Bonneville beds, being abundant at Kelton, and common in Fish Spring Valley and near Willow Springs, Utah.

Limnophysa humilis Say. Jour. Acad. Nat. Sci. Phila., Vol. II, 378 (1822). Smithsonian Misc. Coll. No. 143, p. 63, Figs. 99–109 (1865).

This, another protean limnæid, to which numerous specific names have been applied, ranges through all the eastern United States and west to Nevada, though not yet discovered within the Bonneville Basin. It is found fossil in Upper Lahontan beds at Rye Patch, Nevada.

Genus PHYSA.

Physa gyrina Say. Jour. Acad. Nat. Sci. Phila., Vol. II, 171 (1821). Smithsonian Misc. Coll. No. 143, p. 77, Figs. 130–132 (1865).

Physa elliptica Lea. Trans. Am. Phil. Soc., Vol. V, 115, Pl. XIX, Fig. 83 (1837).

This variety (?) of *Physa heterostropha* Say has not been found west of this area, where it is common. As a fossil it occurs only in Upper Bonneville beds, near Salt Spring Creek, Utah. The variety, to which Mr. Lea gave the name of *elliptica*, is found abundantly and of large size in Warm Spring Lake, near Salt Lake City. The range of the species is great, extending from this area eastward to Maine.

Physa heterostropha Say.

Limnœa heterostropha Say. Nich. Encyc., Pl. I, Fig. 6 (1817–1818–1819).
Physa heterostropha Say. Smithsonian Misc. Coll. No. 143, Figs. 144–152 (1865).

This, one of the earliest described *Physæ* of the United States, presents the greatest geographical range, and furnishes correspondingly numerous varieties. These varieties have been identified with the typical form to the number of thirteen, and there is evidence that a careful study will sensibly increase the synonymy. The species has not been found in the lake beds of either basin, but exists in some abundance as a semi-fossil on the surface of Sevier Desert.

Physa lordi, Baird. Proc. Zoöl. Soc. London, p. 68 (1863). Smithsonian Misc. Coll. No. 143, p. 76, Figs. 125–127 (1865).

This form is rare as a fossil, and has yet to be discovered living in the Bonneville Basin. A few examples have been found upon the surface of the Sevier Desert. The species is widely distributed in British America and in the northern United States, from Michigan westward.

Physa ampullacea Gould.

Physa bullata Gould. Proc. Bost. Soc. Nat. Hist., Vol. V, 128 (1855). Name preoccupied and changed by author *in lit.* to *Physa ampullacea.*

Physa ampullacea Gould. Smithsonian Misc. Coll. No. 143, p. 79, Figs. 134, 135 (1865).

While no specimens of this form are known in the Lahontan area, specimens have been used in the included discussion from contiguous localities in the Mono Basin, California. In the Bonneville area the species is a common one, living; this area also marks its most eastern known limit of distribution.

Physa humerosa, Gould.

Proc. Bost. Soc. Nat. Hist., Vol. V, 128 (1855). Smithsonian Misc. Coll. No. 143, 92, Fig. 157 (1865).

Colorado Desert, north to Pyramid Lake, in which it is living. Formerly abundant, judging from the thousands of semi-fossils on the surface of the desert. Known, living, only as above.

Genus Radix.

Radix ampla var. *utahensis* Call.

A few specimens of this form were dredged in Utah Lake in August, 1883, and are described herein. The superficial features would be perhaps insufficient to establish the variety, but the dentition differs from typical *R. ampla* Mighels very materially. The specimens sustain to *R. ampla* a similar relation to that exhibited by *Pompholyx costata* Hemphill, a strongly marked variety of *P. effusa* Lea. The relation which it may genetically sustain to *Polyrhytis kingii* Meek, from the Tertiary of Cache Valley, Utah, is below indicated.

Genus Pompholyx.

Pompholyx effusa Lea. Proc. Acad. Nat. Sci. Phila., Vol. VIII, 80 (1856). Smithsonian Misc. Coll. No. 143, 74, Fig. 119 (1865).

Pompholyx solida, Dall. Ann. Lyc. Nat. Hist. N. Y., Vol. IX, 333-361, Pl. II (1870).

Pompholyx costata, Hemphill. (Ms).

This species, with its varities *P. costata* Hemphill, from the Dalles, Oregon, and *P. solida* Dall, from White Pine, Nev., is the characteristic fossil of the Lahontan beds, and is also highly characteristic in the modern fauna of that area. It is the only fossil found ranging from Lower to Upper Lahontan strata, and occurs at many localities, often in the greatest abundance. It is one of the three forms now living in Pyramid Lake, but of a size far below that which it formerly attained. The principal variant features which it presents are below alluded to.

Genus CARINIFEX.

Carinifex newberryi Lea.

Planorbis newberryi Lea. Proc. Phila. Acad. Nat. Sci., 41 (1858).

Carinifex newberryi Lea. Smithsonian Misc. Coll. No. 143, 74, Figs. 120–122 (1865). Also Stearns, in Proc. Acad. Nat. Sci. Phila., 108–110, Figs. 25–27 (1881).

In distribution this form is restricted to portions of California, Nevada, Utah, and Oregon. In the Lahontan Basin it ranges from the shores of Walker's Lake north to Button's Ranch, Christmas Lakes, Oregon, where it is found semi-fossil. Lahontan fossils have been found only at the south end of Winnemucca Lake, contiguous to Pyramid Lake. In the Bonneville area it was discovered living in Utah Lake. The specimens were rather small, and the peculiar flattening of the apical whorls made it an unusually interesting form. This is the most eastern locality yet reported. It is probably a comparatively recent addition to the fauna of the Bonneville Basin.

Genus ANCYLUS.

Ancylus newberryi Lea. Proc. Phila. Acad. Nat. Sci., 166 (1858). Smithsonian Misc. Coll. No. 143, p. 145, Fig. 244 (1865).

This shell is restricted in its distribution, so far as known, to California and Nevada. It has been found fossil only in Upper Lahontan beds in the white marl at the south end of Winnemucca Lake.

Ancylus, sp. undt.

A single specimen of this form was dredged in Utah Lake, in August, 1883. No opportunity has been presented to complete the identification.

RISSOIDÆ.

Genus AMNICOLA.

Amnicola longinqua Gould. Proc. Bost. Soc. Nat. Hist., Vol. V, 130 (1855). Smithsonian Misc. Coll. No. 144, 87, Fig. 173 (1865).

Described by Dr. Gould from specimens collected during the progress of the Pacific Railroad surveys on the Carson Desert. Until recently no living shells of the species were known; specimens which are referred to this species collected by H. Hemphill, near Lake Point, Utah, are in the Stearns Collection, Smithsonian Institution. It is found fossil in Upper Lahontan beds at south end of Winnemucca Lake, and at Buffalo Springs. Specimens appear to be rare in the Lahontan area.

Amnicola cincinnatiensis Anth.

Paludina cincinnatiensis Anth. Bost. Jour. Nat. Hist., Vol. III, pts. 1, 2, p. 279, Pl. III, Fig. 3 (1840).

Amnicola cincinnatiensis Anth. List of Cincinnati shells (1843). Name changed, but no description.

See the next species.

Amnicola porata Say.

Paludina porata Say. Jour. Acad. Nat. Sci. Phila., Vol. II, 174 (1821).
Amnicola porata Say. Smithsonian Misc. Coll. No. 144, p. 82-83, Fig. 164 (1865).

Both of these forms are abundant fossils in Upper Bonneville beds at various localities. The most abundant shell is the form referred to *Amnicola cincinnatiensis*. Some hesitation has been experienced in adopting the specific name *porata* for the less common form. Neither species is known to be now living in the district included in the Bonneville drainage.

Amnicola dalli Call.

This form, described herein, is somewhat abundant living in a small stream tributary to Pyramid Lake, near the north end, at Symon's Ranch. No fossil specimens of the species have been found.

Genus PYRGULA.

Pyrgula nevadensis Stearns. Proc. Phila. Acad. Nat. Sci., 173. Figure, (1883). Call & Beecher, in American Naturalist, September, 1884, Vol. XVIII, Pp. 851-855. In this paper the dentition is figured.

It is somewhat doubtful whether the generic reference of this form is correct. It appears to be devoid of the canal-like production of the aperture which is almost the sole generic character of *Pyrgula*. The only locality where living forms have been found is Pyramid Lake, Nevada, where it occurs in countless thousands. No examples are known from the Lahontan beds.

Genus FLUMINICOLA.

Fluminicola fusca Hald.

Leptoxis fusca Hald. Monograph of *Leptoxis*, 4, Pl. III, IV, Figs. 83, 84 (1847?).

The distribution of this genus is restricted, and especially is this true of the species here listed. It has been found only in portions of California, Oregon, Nevada, Idaho, and Utah. It occurs fossil in both Upper Lahontan and Upper Bonneville beds, very abundantly in the latter at Kelton and Snowville, Utah, but sparingly in the Lahontan beds at Rye Patch, Nevada. Living forms are common in the Ogden River, and abundant in Utah Lake, Utah.

VALVATIDÆ.

Genus VALVATA.

Valvata virens Tryon. Proc. Acad. Nat. Sci. Phila., 148, Pl. I, Fig. 11 (1863). Smithsonian Misc. Coll. No. 144, p. 15, Fig. 21 (1865).

Restricted in distribution to Oregon, California, Nevada, and Utah. In the Lahontan area this shell occurs somewhat abundantly as an Upper Lahontan fossil. It is an abundant semi-fossil on the surface of Sevier Desert in the Bonneville area.

Valvata sincera var. **utahensis** Call.

This form is another of those found to be so distinct as to require mention as a variety. Its affinities are pointed out below. It is a very abundant shell at the north end of Utah Lake at Lehi.

PULMONATA GEOPHILA.

The collections of fossils made in the Bonneville area have not yet disclosed any land-shells, and but few have been found in the Lahontan basin. These represent but three genera and an equal number of species, none of which are abundant. They must be regarded as an adventitious fauna in the lake beds, washed down from higher land by rains and floods. As living shells they all range beyond the limits of the area.

In this catalogue reference is made only to those that have been found fossil, since our knowledge of the land-shells of the Great Basin is much less complete than that pertaining to the fresh-water mollusca. All forms credited to either the Lahontan or the Bonneville area have, however, been listed in the accompanying synoptical tables.

HELICIDÆ.

Genus VALLONIA.

Vallonia pulchella Müll.

Helix pulchella Müll. Vermes, p. 30. (Title and reference quoted.)

Vallonia minuta Morse. Jour. Portland Soc., Nat. Hist., Vol. I, 21, Figs. 54–56, Pl. VIII, Fig. 57.

Vallonia pulchella, Müll. Smithsonian Mis. Coll. No. 194 p. 157, Figs. 270–272 (1869).

This is a circumboreal species, with wide southern distribution; it also ranges to high altitudes. Fossil specimens have been found in Upper Lahontan beds at Rye Patch, Nevada.

Genus SUCCINEA.

Succinea stretchiana Bland. Annals N. Y. Lyc. Nat. Hist., Vol. VIII, 168, Fig. 16 (1865). Smithsonian Misc. Coll. No. 194, p. 263, Fig. 471 (1869).

Living specimens have been found only in Nevada. The fossil material comes from Upper Lahontan beds at Rye Patch, Nevada.

PUPIDÆ.

Genus PUPILLA.

Pupilla muscorum Linn. *Vide* Pfeiffer, Mon. Hel. Viv. Vol. IV, p. 666. Smithsonian Misc. Coll. No. 194, p. 234, Figs. 397–401 (1869).

This is another circumboreal form, with wide southern range. Fossil only at Rye Patch, Nev., in Upper Lahontan beds.

OSTRACODA.

Among the shells submitted for study occurred many thousands of a minute ostracoid crustacean, only the generic position of which has been made out as follows.

CYPRINIDÆ.

Genus CYPRIS.

Cypris sp. indt.

A minute ostracoid crustacean is mentioned by White[3] as very abundant west of Fairview and at the head of Soldier's Creek, Utah. While he does not positively identify it, he yet thinks it to be identical with *Cypris leidyi* E. & S. The description of that species is not accessible at this time, and it is impossible to state whether the Lahontan forms are identical with the Utah form. Specimens occur abundantly in many localities in Lahontan Lake beds, and range from the surface of the highlands adjacent to the Truckee to and into the lithoid tufa at various points.

In the original description of Lake Bonneville[4] the occurrence of "Cypris?" is mentioned. The specimens are not at hand, but so far as information goes they agree in size and general appearance with those from Lahontan beds, and their specific identity is probable.

In tables I to IV following is given a synopsis of the recent and fossil shells discovered in the area studied.

TABLE I.—*Fossil Lahontan Mollusca.*

Family.	Genus.	Species.	Remarks.
Unionidæ	Margaritana	margaritifera, Linn	North to British Columbia, east to Utah.
	Anodonta	nuttalliana, Lea	To eastern limit of Great Basin.
Corbiculidæ	Sphærium	dentatum, Hald	Occidental.
		striatinum, Lam	Maine to Texas to California.
	Pisidium	ultramontanum, Prm	Restricted.
		compressum, Prm	Rare.
Limnæidæ	Helisoma	trivolvis, Say	Everywhere.
		ammon, Gould	Rare. Var. last?
	Gyraulus	parvus, Say	Common.
		vermicularis, Gould	Oregon, California, Nevada.
	Menetus	opercularis, Gould	
	Limnophysa	palustris, Müll	Common, circumpolar.
		bulimoides, Lea	Restricted.
		——?	Casts. Species undetermined.
		sumassi, Bd	Var. of L. palustris?
		humilis, Say	Common and abundant.
	Pompholyx	effusa, Lea	Only species. Now found living in Pyramid Lake.
	Carinifex	newberryi, Lea	See context.
	Ancylus	newberryi, Lea	Rare.
Rissoidæ	Amnicola	longinqua, Gould	Only known as a fossil in the Lahontan area.
	Pyrgula	nevadensis, Stearns	Genus new to North America.
	Fluminicola	fusca, Hald	Only one specimen found.
Valvatidæ	Valvata	virens, Tryon	Rare.
Helicidæ	Vallonia	pulchella, Müll	Circumboreal.
	Succinea	stretchiana, Bld	Nevada.
Pupidæ	Pupa	muscorum, Linn	Circumboreal.
(7)	(18)	(26)	

[3] United States Geol. and Geog. Sur. West of 100th Meridian, Vol. IV, p. 216.

[4] United States Geol. and Geog. Sur. West of the 100th Meridian, Vol. III, p. 99.

TABLE II.—*Recent Mollusca of the Lahontan Area.*

Family.	Genus.	Species.	Remarks.
Unionidæ	Margaritana	margaritifera, Linn	Humboldt and Truckee Rivers.
	Anodonta	nuttalliana, Lea	Abundant on surface of Carson Desert.
Corbiculidæ	Sphærium	striatinum, Lam	Humboldt River. Abundant.
	Pisidium	compressum, Prime	Humboldt River. Common.
Limnæidæ	Helisoma	corpulentus, Say	Honey Lake. Walker and Quinn Rivers.
		ammon, Gould	Black Rock Desert.
		trivolvis, Say	Common. Abundant at Wadsworth.
		subcrenatus, Say	Honey Lake, California.
	Gyraulus	parvus, Say	Ponds and small streams.
		vermicularis, Gould	Spring south end Pyramid Lake.
	Menetus	opercularis, Gld	Elko. Sloughs Humboldt River.
	Limnophysa	palustris, Müll	Everywhere in ponds. Abundant.
		sumassi, Baird	Honey Lake.
		humilis, Say	Spring, south end Pyramid Lake.
		bulimoides, Lea	Black Rock Desert. Quinn River.
	Limnæa	stagnalis, Linn	Surface of desert. White Plains.
	Physa	gyrina, Say	Common.
		humerosa, Gould	Pyramid Lake. Carson Desert.
		ampullacea, Gould	Honey Lake. Mono Valley.
		heterostropha, Say	Truckee River. Wadsworth.
	Pompholyx	effusa, Lea	Pyramid Lake.
Rissoidæ	Amnicola	dalli, Call	Brook near north end Pyramid Lake.
	Pyrgula	nevadensis, Stearns	Pyramid Lake. Walker's Lake (living?).
Helicidæ	Patula	idahoensis, Newc	*Teste* W. G. Binney.
		strigosa, Gould	Do.
		hemphilli, Newc	Do.
	Zonites	arboreus, Müll	Do.
		viridulus, Mke	Do.
		nitidus, Müll	Do.
	Conulus	fulvus, Drap	East slope Sierra Nevada.
	Vallonia	pulchella, Müll	Var. *costata*.
	Vitrina	pfeifferi, Newc	Sierra Nevada. *Teste* Binney.
	Succinea	sillimani, Bland	Humboldt Lake.
		stretchiana, Bland	Truckee Valley. Wadsworth.
		lineata, W. G. B	*Teste* Binney.
		rusticana, Gould	Do.
Pupidæ	Pupilla	muscorum, Linn	Truckee Valley. Driftwood.
		corpulenta, Morse	*Teste* Binney.
	Leuchocheila	arizonensis, Gabb	Do.
(6)	(21)	(39)	

TABLE III.—*Fossil Bonneville Mollusca.*

[P. B. = Post-Bonneville].

Family.	Genus.	Species.	Remarks.
Unionidæ	Anodonta	nuttalliana, Lea	Semi-fossil. Sevier Desert. P. B.
Corbiculidæ	Sphærium	dentatum, Hald	Do.
Limnæidæ	Helisoma	trivolvis, Say	Upper Bonneville.
	Gyraulus	parvus, Say	Semi-fossil. P. B.
	Limnophysa	palustris, Müll	Upper Bonneville.
		sumassi, Baird	Semi-fossil. P. B.
		bonnevillensis, Call	Upper Bonneville.
		desidiosa, Say	Do.
	Limnæa	stagnalis, Linn	Post-Bonneville.
	Physa	heterostropha, Say	Semi-fossil. P. B.
		lordi, Baird	Do.
Rissoidæ	Amnicola	porata, Hald	Upper Bonneville.
		cincinnatiensis, Anth	Do.
	Fluminicola	fusca, Hald	Do.
Valvatidæ	Valvata	sincera, Say, *var.* utahensis, Call.	Post-Bonneville.
Helicidæ	Succinea	lineata, W. G. B	Do.
(6)	(11)	(16)	

TABLE IV.—*Recent Mollusca of the Bonneville Basin.*

Family.	Genus.	Species.	Remarks.
Unionidæ	Marganitana	margaritifera, Linn	Common throughout the basin.
	Anodonta	nuttalliana, Lea	Do.
Corbiculidæ	Sphærium	dentatum, Hald	Lake Utah.
		striatinum, Lam	Sevier River. Streams.
	Pisidium	abditum, Hald	City Creek.
		compressum, Prime	Utah Lake.
Limnæidæ	Helisoma	trivolvis, Say	Numerous localities.
	Gyraulus	parvus, Say	Camp Douglas.
	Menetus	opercularis, Gould	Warm Spring Lake.
	Limnophysa	palustris, Müll	Everywhere.
		sumassi, Baird	Sevier River.
		humilis, Say	Salt Lake City.
		desidiosa, Say	Lehi.
		caperata, Say	Warm Spring Lake.
	Limnæa	stagnalis, Linn	Utah Lake. Warm Spring Lake.
	Radix	ampla, var. utahensis, Call.	Lake Utah.
	Physa	elliptica, Lea	Warm Spring Lake. Var. *P. gyrina.*
		gyrina, Say	Everywhere.
		ampullacea, Gould	Numerous localities.
		heterostropha, Say	Utah Lake.
	Carinifex	newberryi, Lea	Do.
	Ancylus	sp. undt	Do.
Valvatidæ	Valvata	sincera, var. utahensis, Call.	Do.
Rissoidæ	Bythinella	binneyi, Tryon	City Creek. Spring Grouse Valley.
	Fluminicola	fusca, Hald	Utah Lake. Ogden River.
Helicidæ	Patula	striatella, Anth	Wasatch Mts.
		strigosa, Gould	Wasatch Mts. Ogden.
		idahoensis, Newc	Do.
	Hyalina	arborea, Müll	Salt Lake City.
	Conulus	fulvus, Drap	Do.
	Vitrina	pfeifferi, Newc	City Creek Cañon.
	Succinea	lineata, Binney	American Fork.
		sillimani, Bland	Shores of Utah Lake. Lehi.
	Vertigo	ovata, Gould	City Creek Cañon.
(6)	(22)	34	

CHAPTER II.

DISTRIBUTION AND ENVIRONMENT.

GEOGRAPHIC AND CHRONOLOGIC DISTRIBUTION.

While there are certain facts of a physical character which justify the correlation in time of these lacustral beds, there exists no palæontologic evidence of that fact. The fossil mollusca are dissimilar, not only in their generic, but also in their family relations in many instances. The characteristic fossil of Lahontan—*Pompholyx effusa* Lea—is limnæid, while *Amnicola porata* Hald. and *A. cincinnatiensis* Anth., characteristic of the Bonneville beds, belong to the *Rissoidæ.* The first family is inoperculate and pulmonate; the second operculate and pectinibranchiate. Representatives of the genus *Amnicola* are now found common to both areas, but *Pompholyx* has not extended eastward into the Bonneville Basin, so far as known. But a kind of indirect evidence of correlation in time is furnished by increased abundance of fossil shells in those beds which are known to have been contemporaneous in origin with the highest level of each lake, and by their comparative paucity in those beds related to the lower stages. It is believed that this abundance or paucity may be correlated with the successive fluctuations of the lakes, and is dependent on them directly, or on the climatal conditions which caused them. If a valid argument can be based upon arbitrary estimates of the relative abundance of shells in turn based upon absolute abundance of fossils, then that abundance or paucity sustains a significant relation to humidity and to the tufa deposits in the case of Lake Lahontan. Thus, *Pompholyx* occurs sparingly in the lithoid tufa, is not found in thinolite at any point, becomes very abundant during the period of deposition of the dendritic tufa, and is found commonly but not abundantly in Pyramid Lake at the present time. These phenomena suggest a decided relation to humidity and to the varying chemical composition of the waters, which probably changed in nearly or quite the degree that humidity itself varied. Thus the history of *Pompholyx* in its relation to Lake Lahontan is most interesting but problematic. It is latterly associated with *Physa humerosa* Gould, and *Pyrgula nevadensis* Stearns, the only other mollusca now known to be living in that northern remnant of Lahontan—Pyramid Lake. *Pyrgula* has replaced *Pompholyx* in the modern lake, and, indeed, is not known in any Lahontan deposit.

The only other locality where *Pyrgula* is known to occur is in Walker's Lake, but not now in the living state. Since careful collection has failed to reveal the form in Lahontan beds or Lahontan tufas, the hypothesis is justifiable that it has been introduced into each of these lakes since they became independent bodies. The genus is a new addition to the fauna of North America, is found in the mountainous districts of Europe, central Asia, and South America, and has hitherto been known to exist only in pure fresh-water lakes and at considerable altitudes.[5]

The dentition of *Pyrgula* was unknown until its abundant collection in Pyramid Lake, when its description and illustration became possible.

The wide range of *Pompholyx* in Lahontan beds makes possible a valuable comparison of the same species from localities representing stages of the lake widely separated in point of time. Such comparisons as have been instituted show that its history alone will furnish an important addition to hexicology. Specimens taken from the lithoid tufa on Anaho Island, in Pyramid Lake, when compared with those from horizons correlated with the dendritic period present the widest range among individuals. The shells from both localities are higher than Pyramid Lake forms, are much thinner, and the coiling of the whorls is much looser. The lithoid tufa specimens present a large proportion of costate forms, the ratio being as 1 to 2, while in recent specimens the ratio is as 1 to 32. The recent specimens approximate *P. effusa*, var. *solida* Dall, while in sculpture and elevation the earlier and smooth forms of the lithoid tufa approach nearest to the typical *P. effusa* Lea.

The abundance of costate forms in the earlier beds, and their comparative paucity among recent shells, is suggestive of genetic relation to *Vorticifex binneyi* Meek, of Miocene-Tertiary age, from Fossil Hill, Nevada. The existence of a very distinct carina on the body whorl of *Pompholyx* from Anaho Island, and its absence on recent forms, is still again suggestive of the same genetic relation. Lake Bonneville, in its Lake Utah representative, furnishes an allied fact. *Radix ampla*, var. *utahensis*, presents features allying it to *Polyrhytis kingii* Meek, from the Miocene-Tertiary of Cache Valley, Utah. Thus, in each of these great areas are recent forms of like family relations, but belonging to different genera, related respectively to forms nearly congeneric with them, but of Tertiary age. The differences which they present are certainly less specific than those exhibited in the Tertiary species of *Planorbis* from Steinheim, which have recently formed the subject of an elaborate memoir.[6]

The comparative wealth in genera and species of the areas comprised in Lake Lahontan and Bonneville, as well as the differences and identi-

[5] *Pyrgula scalariformis* Wolf is an apparent exception to this statement, but much doubt attaches to the generic reference of the form so named. It was described from the post-Pliocene of Tazewell Co., Ill., in which a genus—*Pomatiopsis*—sustaining a superficial resemblance to *Pyrgula* is known to occur. Moreover, the correlation of species and station, as above indicated, combined with the sole possible stations of the fossil forms, certifies the doubt.

[6] Hyatt, "On the Tertiary Species of Planorbis at Steinheim." Anniversary Memoirs Boston Society of Natural History, 1880.

ties of their fossil and recent mollusca, is succinctly shown in Table V, following:

TABLE V.—*Distribution of Fresh-water Shells.*

Family.	Genus.	Species.	Lahontan.		Bonneville.	
			Recent.	Fossil.	Recent.	Fossil.
Unionidæ	Margaritana	margaritifera, Linn	*	*	*	
	Anodonta	nutalliana, Lea	*	†*	*	†
Corbiculidæ	Sphærium	dentatum, Hald		*	*	†
		striatinum, Lam	*	*	*	
	Pisidium	compressum, Prime	*	*	*	
		abditum, Hald			*	
Limnæidæ	Helisoma	corpulentus, Say	*	†		
		ammon, Gould	*	†		
		trivolvis, Say	*	*		*
		subcrenatus, Carp	*			
	Gyraulus	parvus, Say	*	*	*	†
		vermicularis, Gould	*	*		
	Menetus	opercularis, Gould	*	*	*	
	Limnophysa	palustris, Müll	*	†*	*	†*
		sumassi, Baird	*	*	*	†
		humilis, Say	*	*	*	
		bulimoides, Lea	*	†		
		bonnevillensis, Call				*
	Limnæa	stagnalis, Linn		†	*	†
	Radix	ampla, *var.* Utahensis, Call			*	
	Physa	gyrina, Say	*		*	
		humerosa, Gould	*	†		
		ampullacea, Gould	*		*	
		heterostropha, Say	*		*	†
		elliptica, Lea			*	
		lordi, Baird				†
	Pompholyx	effusa, Lea (vars)	*	†		
	Carinifex	newberryi, Lea		†*	*	
	Ancylus	newberryi, Lea		*		
Rissoidæ	Amnicola	dalli, Call	*			
		longinqua, Gould		*	*	
		porata, Hald				*
		cincinnatiensis, Anth				*
	Fluminicola	fusca, Hald		*	*	†*
	Pyrgula	nevadensis, Stearns	*			
	Bythinella	binneyi, Tryon		*		
Valvatidæ	Valvata	virens, Tryon			*	
		sincera, *var.* utahensis, Call			*	†
(5)	(19)	38	22	*18, †8	22	*6, †10

NOTE.—The asterisk (*) is used simply to indicate the presence of the species in either the recent or the fossil fauna. The dagger (†) is used to indicate semi-fossils. When the same species is found both fossil and semi-fossil, the signs are written together, with the relative abundance indicated by the order of the signs.

In this table only the fresh-water shells are listed. But, comparing Tables I and III, in which land-forms are included, it will be observed that Lahontan furnishes eighteen genera and twenty-six species, comprised in seven families. Bonneville presents eleven genera and sixteen species, distributed among six families. Only six of the sixteen species are Bonneville fossils, but eight others are semi-fossils in the Bonneville area. Of recent forms, as exhibited in Tables II and IV, the genera are equal in number, but are not all common to the two areas, and include all the known land-shells of the respective regions. Moreover, the Lahontan area furnishes an equal number of families and a greater number of species.

Of the thirty-eight species of freshwater shells, twenty-two are living in the Lahontan area, twenty-two in the Bonneville, and thirty in the entire district; twenty-three are known fossil or semi-fossil in the Lahontan area, thirteen in the Bonneville, and twenty-eight in the entire district. The Lahontan area includes of living and fossil twenty-six, the Bonneville twenty-four.

It will at once be noted that the majority of fresh-water forms presented alike by all these five tables belong to the *Limnæidæ*. This family is world-wide in distribution, and exhibits a most remarkable group of genera and subgenera in its various divisions. Of all fresh-water forms the species of *Limnæidæ* have the greatest hypsometric range, extend to the highest latitudes, and best survive certain physical changes, such as droughts, extremes of cold, and, as our investigations in the Great Basin prove, even transitions from fresh to saline waters. In the north temperate regions of America some species—*Limnæa stagnalis*, *Bulimnæa megasoma*, *Limnophysa palustris*, *L. sumassi*, and *Physa lordi*—reach a high degree of perfection and appear to be eminently adapted to that habitat. Some of these—*Limnæa stagnalis* and *Limnophysa palustris*—are circumboreal, and find in these latitudes their metropolis. The identity of other American with European forms is highly probable. Such species as are known to be common to Europe find their southernmost range in the Great Basin.

It is, perhaps, fortunate that this widely distributed family is so amply developed within this area. Its range is such that it here finds an almost infinite variety of station,[7] often an environment structurally uncongenial, temperature ranges which may be either above or below its optimum, but which are comprised within wide limits, and, as might be expected, it presents a range of variation clearly co-ordinate with the physical conditions of its environment. Many of the variant features presented are clearly local or accidental; such, for example, as those which arise from distortion,[8] traumatism, and so forth.

Eliminating these features, and those of kindred character and consequences, there yet remain other characters, such as size, color, thickness, and coiling of whorls, entirely dependent upon causes general in respect both to their range of operation and the effects they produce. Of these, one principal factor is food, in its character and abundance. So far as certain genera of *Limnæidæ* furnish reliable data, their station is largely determined by food opportunities. In another great American family, not represented in the Great Basin—the *Strepomatidæ*—the

[7] "Station," as used herein, is to be understood as immediate and permanent physical environment; "habitat" is used in the sense of geographic distribution.

[8] Distortion is often clearly the result of purely local conditions, but even then varieties may be produced that present established features of a specific value in succeeding generations. The Steinheim *Planorbes*, previously cited, present a case in point. Ingersoll has described (in Annual Report of the Hayden Survey, 1874, p. 402, a distorted form of *Helisoma* (*Planorbis*) to which he gives the name *H. plexata*. The shells, which abounded in places where thrived a species of closely matted aquatic plant, came from a lake of considerable elevation (9,500 feet) in Antelope Park, Colorado. The shell was accommodating its growth to the ever-varying conditions of the pond in which it dwelt. In such a case as this the correlation of aberrant forms with their surroundings is comparatively an easy task.

same law holds true. They abound in the southern United States, in clear rocky mountain streams, in those stations suited to the growth of confervæ, and their habitat is clearly connected therewith. The abundance of a species is, in a restricted sense, a measure of suitable food opportunities; and the abundant shell fauna of the dendritic stage of Lahontan is a witness that fresh-water confervæ—the sole food of *Pompholyx*—flourished in great abundance. The wide range of variation seen in the vast numbers of that form from the Lahontan area, under conditions of abundance that lead to the elimination of food as a factor clearly point to some other potent agent, the effects of which are reremarkably uniform throughout the area.

DEPAUPERATION *versus* SALINITY.

Before passing to a consideration of these factors a further remark upon an anomaly in distribution as regards station is necessary. In both the Lahontan and the Bonneville areas fresh-water species occur in brackish-water stations, accommodating themselves to abnormal conditions. In the Lahontan Basin the forms are found solely, as far as information goes, in lacustrine waters. Walker's Lake, quite fresh as compared with Pyramid Lake, has furnished no living shells whatever; but Pyramid Lake, with $\frac{1}{450}$ of saline matter, abounds in the fresh-water *Pyrgula*, and contains also *Pompholyx* and *Physa*. No bivalves of any kind have yet been found in either salt or brackish water. In the Bonneville area the forms occur in brackish springs, but in none of the salt or brackish lakes so far as known. *Limnophysa* and *Physa* are the sole genera, each represented by a single species. The first of these genera has not yet been found in saline stations in the Lahontan area. On the other hand, neither *Pompholyx* nor *Pyrgula* occurs in either fresh or salt waters in the Bonneville Basin. *Physa* alone is common to the fresh and saline stations of the two areas. When *Pompholices*, of the Lahontan area, from fresh-water stations, are compared with *Pompholices* from saline stations, the forms are seen to differ in some important particulars. Not only do the fresh-water *Pompholices* grow to a much greater size, but they have thinner and lighter shells. The shape of the apertures presents a wider range of variation in the brackish-water forms, and the epidermis is lighter in color. It is believed that these differences have been successfully correlated with the differences of station—saline or fresh water. In the Bonneville area the minimum of saline matter is found in the brackish springs, but the same biologic features are presented.[9] The shells of *Physa* and *Limnophysa* from

[9] Some of these springs have a chemical constitution that varies within wide limits at different times of the year. In the fall they are brackish, but in the spring fresh and sweet. See Stansbury's "Report on Expedition to Great Salt Lake," p. 174. Whether these are mollusk-bearing is unknown.

such stations are much less dense, the lines of growth are fainter and much closer, and the sculpturing is altogether more variable than in specimens derived from fresh-water streams adjacent.

That the power of accommodation possessed by these shells is not unlimited is sufficiently indicated by their uniform absence from salt marshes and from highly saturated saline lakes.

It is to be regretted that no data bearing on comparative salinity of springs and lakes in which mollusks have been taken living exists. They would surely have proven important aids in this discussion. The tables which follow are such as compare forms taken from fresh water with those known to come from stations of varying degree of salinity.[10] They are useful in establishing the obvious relation existing between the size of the various specimens and their environment. But, assuming that the various degrees of salinity presented by the springs, from fresh-water to that of a percentage incompatible with the life of any limnæid, has been presented by Lake Lahontan since its beginning until now, the ratio of salinity has been and is a variable; as the lake levels rose and fell so did the variable decrease or increase in value. This variable presumably found a biologic expression in the abundance of shell life, as has been above indicated in the case of *Pompholyx*, during the different tufa-forming periods of the lake. Table VI, based upon material from a fresh-water station and from Pyramid Lake, together with its graphic form in Plate II, Diagram I, shows this variable in living *Pompholyx* biologically expressed in difference of size.

TABLE VI.—*Pompholyx effusa* Lea.

Number.	Pyramid Lake.		White Pine.	
	Height.	Breadth.	Height.	Breadth.
	mm.	*mm.*	*mm.*	*mm.*
1	4.50	5.40	5.60	6.60
2	4.44	5.20	6.76	8.30
3	4.44	4.86	7.00	8.40
4	4.50	5.00		
5	5.00	5.50		
6	5.78	6.00		
7	4.60	5.50		
8	5.22	5.32		
9	5.12	5.20		
10	5.40	5.74		
11	4.44	5.50		
Average	4.86−	5.38+	6.45+	7.76+

[10] The discussion of this factor, salinity, is conspicuously incomplete. It could not be rendered complete in the absence of salinity determinations for the various stations classed as "saline" and "brackish." The following list of salinites is pertinent but partial: Walker's Lake, Nevada, .9618 grams per liter, the average of two analyses by Prof. F. W. Clarke; Pyramid Lake, average of four analyses by Clarke, 2.2463 grams per liter; Great Salt Lake (1868), 118.60 grams per liter (O. D. Allen); Little Gull Lake, in the Mono Valley, California, and Church Lake, near Salt Lake City, Utah, fresh. Pyramid and Walker's Lakes are herein classed as brackish. Salinity is used throughout this discussion, in the absence of an adequate specific term, in the sense of general chemical constitution. The determinations above given include only sodium chloride.

The value of this table would, probably, have been enhanced by a greater number of specimens from the White Pine locality, but, as usually happens, unless the collector use especial care, only the largest and most easily discoverable forms appear, and these were adults. The ratio of heights of the White Pine specimens to the same dimension of Pyramid Lake specimens is $\frac{6.45}{4.86}$, and for breadth $\frac{7.76}{5.38}$, a result clearly connected with station. Both localities present that form known as *Pompholyx effusa*, var. *solida* Dall, but not differing in well-marked particulars from the typical *P. effusa* Lea.

In Table VII are presented a series of measurements of this same species from localities which have been correlated with three different stages of water in Lahontan, in each of which the ratio of salinity differed. Plate II, Diagram II, is based upon this table. During the period of the deposition of the beds at White Terrace the most noticeable effect of environment is expressed in a height of shell which is certainly anomalous. Joined to this, as its consequent, is a far greater convexity of whorl than is shown by any specimens from beds deposited before or since.

TABLE VII.—*Pompholyx effusa* Lea.

Number.	Anaho Island.		White Terrace.		Pyramid Lake.	
	Height.	Breadth.	Height.	Breadth.	Height.	Breadth.
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
1	4.20	5.20	8.08	5.00	4.10	5.32
2	3.50	4.44	8.10	6.40	5.86	6.28
3	3.96	5.16	7.40	5.50	6.36	5.84
4	3.76	4.36	6.64	5.00	5.50	7.04
5	4.62	6.16	8.90	5.50	5.36	6.66
6	3.68	4.86	6.80	4.86	6.50	7.40
7	3.28	4.92	8.50	5.28	5.88	6.60
8	4.24	5.44	7.36	5.40	7.36	6.10
9	3.50	5.50	6.86	5.00	5.98	7.10
10	2.88	4.30	7.32	5.00	5.68	6.62
11			7.00	5.10	5.70	6.98
12			5.50	4.42	5.26	5.82
13			6.50	4.50	5.60	6.80
14					7.70	3.36
15					5.22	6.32
16					5.34	6.42
17					5.28	6.72
18					5.12	6.04
19					4.10	5.56
20					5.48	6.66
21					5.00	6.30
22					4.88	5.82
23					5.14	6.16
24					5.30	6.18
25					6.00	7.04
Average	3.76+	5.23+	7.30	5.15	5.43−	6.28+

Evidence of a similar character is presented by Table VIII, graphically represented in Plate III, Diagram I. The measurements in this instance are based upon specimens of *Carinifex* from two localities, the deposits of which, though derived from different lakes, were both late Quaternary and may have been contemporaneous. Those from the south end of Winnemucca Lake are from beds deposited at approximately the same date as the lake beds at White Terrace, the locality used in the construction of Table VII. Those from Christmas Lake were found on the surface of a plain in company with the bones of extinct mammals. The ratio of size for the Winnemucca fossils, as compared with the Oregon shells, is, for height $\frac{10.26}{8.79}$, and for breadth $\frac{11.58}{10.03}$.

TABLE VIII.—*Carinifex newberryi* Lea.

Number.	Winnemucca Lake (fossil).		Christmas Lake.	
	Height.	Breadth.	Height.	Breadth.
	mm.	*mm.*	*mm.*	*mm.*
1	8.54	10.50	8.53	10.20
2	11.50	11.68	8.00	10.48
3	11.28	11.78	7.50	9.32
4	10.10	13.10	9.50	10.10
5	11.22	12.76	9.00	11.00
6	10.18	11.74	10.30	10.10
7	9.00	9.50	9.30	9.30
8			8.50	10.52
9			8.50	9.24
Average	10.26	11.58	8.79+	10.03

In the Bonneville Basin similar results are exhibited by the measurements of shells obtained from brackish springs. In some cases comparisons have been instituted between shells collected in contiguous areas, thus insuring equal climatal conditions, but in other cases between shells from regions more remote. Thus in Table IX, upon which is based Plate III, Diagram II, specimens found fossil, lying upon the surface of the desert east of south Carson Lake, Nevada, are compared with specimens of the same species from Warm Spring Lake, Utah. The ratio of size is nearly as 1 to 2; but, as will appear below, the Utah specimens were specially favored by another factor, of climatal nature. The smallest of the Warm Spring Lake specimens is far above the largest of the Carson Desert forms.

TABLE IX.—*Helisoma trivolvis* Say.

Number.	Carson Lake Desert.		Warm Spring Lake.	
	Height.	Breadth.	Height.	Breadth.
	mm.	*mm.*	*mm.*	*mm.*
1	7.00	13.00	11.00	21.10
2	6.90	12.20	10.80	19.80
3	8.24	15.58	11.30	25.10
4	7.32	11.64	11.00	20.26
5	6.50	7.12	10.44	21.84
6	6.84	14.60	10.82	20.00
7	7.50	9.60	10.64	19.00
8	6.56	12.86	11.24	21.12
9	5.90	11.00	10.32	22.08
10	5.88	9.60	11.54	19.80
11	6.10	11.00	12.38	25.38
12	6.20	11.70	11.50	25.76
13			10.88	17.60
14			10.74	22.00
15			10.50	25.50
16			10.16	19.64
17			10.94	21.60
18			11.50	22.20
19			11.08	23.10
20			10.26	21.42
21			11.06	24.00
22			11.96	25.90
Average	6.74+	11.66−	11.00+	21.87+

No lakes of the Bonneville area, except those entirely fresh, are known to be mollusk-bearing. Moreover, there have been found no fossil shells ranging in point of time, throughout the Bonneville beds upon which to base any conclusion, as in the case of Lahontan, concerning the effect of any degree of salinity upon them, if they existed. But a similar line of corroborative evidence is presented by the shells from brackish springs. Upon such material have been based Tables X and XI, and Plate IV, Diagrams I and II. Here again, in the case of Warm Spring Lake, the climatal factor is brought out prominently. In these tables are exhibited similar results, seen by comparing the averages in the case of two new genera not known in the saline waters of the Lahontan area, but subjected to environmental conditions similar to those of *Pompholyx*. The physiologic effects of the similar stations are identical.

TABLE X.—*Limnophysa palustris* Müll.

Number.	Honey Lake.		Warm Spa Lake.		Brackish Springs (Promontory).	
	Length.	Breadth.	Length.	Breadth.	Length.	Breadth.
	m. m.	*m. m.*	*m. m.*	*m. m.*	*m. m.*	*m. m.*
1	29.50	9.90	18.50	7.32	16.50	7.30
2	28.20	9.50	23.04	9.14	25.46	10.74
3	24.80	9.80	24.08	10.06	19.00	7.72
4	23.16	9.80	19.00	9.54	22.12	9.50
5	26.50	11.20	27.16	11.64	21.10	8.40
6	25.70	10.22	26.50	11.58	18.90	8.70
7	25.20	10.90	25.20	11.60	22.36	8.80
8	25.12	9.90	26.80	11.32	26.10	10.12
9	24.50	9.80	29.00	11.70	16.80	7.60
10	30.40	11.50	28.04	12.16	14.34	6.94
11	19.70	8.70	28.48	12.40	16.86	7.08
12	23.20	10.00	23.38	9.64	16.34	7.42
13	26.00	9.60	27.00	11.92	15.50	6.70
14	17.80	7.12	24.50	10.48	19.06	9.00
15	17.00	7.50	26.50	11.40	19.00	8.20
16	21.00	8.30	20.40	8.24	22.30	8.92
17	19.50	7.10	25.70	11.30	22.24	9.20
18	20.50	8.52	23.70	10.06	15.60	6.68
19			29.24	12.24	18.78	8.04
20			25.70	9.44	16.32	8.72
21			26.10	10.56	21.44	10.00
22			27.52	11.76	19.28	9.22
23			29.42	11.50	21.88	9.50
24			29.88	12.04	25.62	10.90
25			33.10	13.50		
Average	23.28+	9.38+	25.82+	10.92+	19.40+	8.50+

TABLE XI.—*Physa gyrina* Say.

Number.	Salt Lake City (ponds).		Promontory (Brackish Springs).	
	Length.	Breadth.	Length.	Breadth.
	mm.	*mm.*	*mm.*	*mm.*
1	18.96	9.86	13.30	6.30
2	20.32	11.58	14.24	7.48
3	19.00	10.42	15.00	6.88
4	19.24	10.50	14.32	6.74
5	16.50	9.12	17.60	8.52
6	16.34	9.70	16.12	7.70
7	18.50	10.50	16.00	7.64

TABLE XI.—*Physa gyrina* Say—Continued.

Number.	Salt Lake City (ponds).		Promontory (Brackish Springs).	
	Length.	Breadth.	Length.	Breadth.
	mm.	*mm.*	*mm.*	*mm.*
8	16.28	9.50	14.74	7.20
9	19.26	10.90	13.64	7.00
10	17.80	9.88	13.00	6.16
11	22.70	13.26	18.08	9.04
12	18.24	11.00	18.74	8.38
13	19.00	11.16	13.84	6.62
14			17.34	8.40
15			17.94	8.60
16			18.44	8.00
17			20.64	9.14
18			18.96	9.40
19			20.70	9.48
20			21.20	9.12
21			21.82	9.74
22			18.76	9.16
23			17.28	7.88
24			14.42	7.04
25			16.80	7.40
26			15.60	7.50
27			15.82	7.10
28			16.32	7.00
29			13.80	6.88
30			18.56	8.16
31			20.70	8.88
32			18.50	9.30
33			15.60	7.46
34			16.20	7.20
35			20.50	9.50
36			21.84	9.50
37			17.32	7.30
38			15.80	6.80
39			15.50	7.78
Average	18.55—	10.57—	16.69	7.90

Briefly summarized the results of the measurements are as follows.

First, the size (linear) of *Pompholyx effusa* in brackish water (Pyramid Lake) is to its size in fresh water (White Pine) as 72 to 100. The size of *Limnophysa palustris* in brackish springs (Promontory) is to its size in fresh water (Honey Lake) as 85 to 100. The size of *Physa gyrina* in brackish springs (Promontory) is to its size in fresh ponds (Salt Lake City) as 84 to 100. Brackish water is thus correlated with depauperation.

Second, comparing *Pompholyx effusa* from Anaho Island (Lower Lahontan), White Terrace (Upper Lahontan), and White Pine (recent), the ratio of size is 63: 88: 100. The size ratio for *Helisoma trivolvis* from Carson Desert (semi-fossil) and Warm Spring Lake (recent) is 56: 100, but this is affected by the exceptional warmth of the latter locality. As a check recent specimens of *Limnophysa palustris* from Honey Lake and Warm Spring Lake are compared, yielding a size ratio 89: 100. Depauperation is thus correlated with the Quaternary conditions.

The physiologic effects of sudden introduction of marine mollusks into fresh water, or of fresh-water forms into strongly saline waters, are familiar. The result in either case is the death of the shells so treated.

But the shock produced by sudden transfer may be measurably avoided by a gradual change in the salinity or freshness of the water.

On this point Beudant long since conducted some valuable experiments, the results of which have been tabulated, as follows, by Semper:[11]

TABLE XII.—*Experiments with Fresh-water Mollusca.*

Names of species.	Number in the first instance, on May 1.	Number on July 15.		Number on October 15.	
		In fresh water.	In salt water of 2 per cent.	In fresh water.	In salt water of 4 per cent. after 17 days.
Limnæa stagnalis	30	21	23	16	13
Limnæa auricularis	30	19	17	14	11
Limnæa palustris	50	33	27	22	19
Physa fontinalis	50	28	27	17	21
Planorbis corneus	30	22	19	15	13
Planorbis carinatus	50	24	31	19	16
Planorbis vortex	50	37	39	26	22
Ancylus lacustris	50	39	33	28	25
Paludina vivipara	30	23	24	21	11
Paludina tentaculata	50	38	35	31	17
Paludina obtusa	60	42	39	37	30
Neritina fluviatilis	50	37	31	26	9
Unio pictorum	20	17	13	8	....
Anodonta cygnea	15	11	10	7	....
Cyclas cornea	40	32	25	18	....

TABLE XIII.—*Experiments with Marine Mollusca.*

Names of species.	Number in the first instance, on January 1.	Number on June 1.		Number on September 15.	
		In sea water.	In half fresh water.	In sea water.	In quite fresh water after fifteen days.
Patella vulgata	30	23	21	16	15
Turbo neritoides	50	39	37	22	25
Purpura lapillus	30	28	26	19	17
Arca barbata	30	23	22	17	18
Venus maculata	30	26	23	18	15
Cardium edule	30	25	21	17	15
Ostrea edulis	15	15	13	14	11
Mytilus edulis	30	30	30	30	30
Balanus striatus	21	19	21	18	19
Fissurella unciposa	30	21	18	14	....
Haliotis tuberculata	15	13	11	5	....
Buccinum undatum	20	17	13	11	....
Tellina incarnata	30	24	21	13	....
Pecten varius	20	19	7	11	....
Chama lazarus	10	9	5	3	....

In the first place, experiments were conducted with reference to the physiologic effect of sudden transition from fresh to salt water. Subsequently, at Marseilles, the reverse experiment was tried, and numer-

[11] *Vide* Animal Life, 1881, p. 439.

ous specimens of Mediterranean mollusca were suddenly transferred to fresh water. In both cases the experiments were repeatedly varied, until finally the results set forth in these tables were exhibited. It is, however, to be observed that marked increase in salinity eventually produced, in some instances, a result similar to sudden transfer. At the end of the experiments none of the fresh-water Lamellibranchiata were living, while the *Limnæidæ* were, on the whole, well represented. The experiments began on May 1 and terminated October 15. At the commencement 340 specimens of various limnæid genera were placed in fresh water, the salinity of which was gradually increased from 0 to 4 per cent. There were then living 140 individuals, or little more than 41 per cent. of the whole. Of the 15 species, belonging to as many genera, of marine shells with which he subsequently experimented, commencing with January 1 and concluding September 15 following, 6 had no survivor after 15 days in water which was quite fresh. Of the whole number of specimens, 391, little more than 42 per cent., 165, were living. One genus—*Mytilus*—represented by 30 individuals, had survived in undiminished numbers. Its power of endurance is seen, consequently, to be unusually great.

Notwithstanding several months intervened between the beginning and end of Beudant's experiments, it remains to be noted that these conditions were produced by him within a period which, compared to the time required to produce in Lake Lahontan exactly equivalent conditions, was infinitesimally small. The artificial introduction of small quantities of salt, or of salt water, in order to induce desired changes in environment, could proceed with something like regularity, but in the great body of water composing Lahontan or Bonneville, the same result could be reached only through evaporation, a process extending through long periods of time, during which climatal changes frequently intervened to freshen the gradually contracting lake. The full biologic expression of these changes could, therefore, only be sought in generations widely separated in point of time. During their march each succeeding generation must have acquired something of the power of resistance developed by its ancestry. But whatever of vital force was abstracted from the general organism to offer protective aid to the maintenance of life, as against the new unfavorable element in environment, must have deprived some other specialized organs of full power to exercise their functions. With this transfer of vital energy, we believe, came its biologic expression—depauperation.

The final result of Beudant's experiments, in which he had marine and fresh-water mollusca living together in fresh water, was a condition which held true for certain portions of the ancient Laramie Sea of North America. From strata of Laramie age are described many marine and fresh-water species so associated as to necessitate the conclusion that they were co-existent. In these beds are found several species of *Unionidæ* genetically related to various species now found in the

Mississippi Basin.[12] *Unio* is very susceptible to changes in environment, and appears to respond to them with extreme rapidity. Nevertheless, certain species live in brackish water, as seen in the Brisbane River, in eastern Australia, where *Unio* is found in stations the freshness of which is solely dependent upon the heights and times of tides. In the Livonian Gulf, *Cyclas*, *Unio*, and *Anodonta* live associated with *Tellina* and *Venus*. Many species of *Neritina* inhabit alike brackish and salt water, especially in the Philippines.[13] In the Laramie strata are found examples of the *Strepomatidæ*, the specimens ranking under the genus *Goniobasis*, now exclusively confined to waters entirely fresh, and not found in waters close to the sea, even when abounding in the upper portions of many Atlantic rivers. While a full discussion of these and allied facts is here impracticable, sufficient data are presented to justify the hypothesis that increase in salinity finds a biologic expression (*a*) in depauperation, (*b*) in lessened abundance, and (*c*) in extinction when the water becomes briny.

DEPAUPERATION *versus* TEMPERATURE.

There is a second factor entering into the solution of the problem presented by the fossils studied. This second factor, like the first, is a variable, but, unlike the first, reaches its extremes in far less periods of time. This factor is temperature. Gilbert has shown[14] that Lake Bonneville is the expression of a climatal episode consisting of two humid maxima, and, reasoning by analogy, has correlated its varying stages with a variable precipitation intimately connected with the temperature changes of the Quaternary and its great ice-fields. In Lahontan a similar history is exhibited by the investigations of Russell,[15] and if the Lahontan tufa epochs have been correctly correlated with humidity epochs, it is also expressed by the varying abundance of *Pompholyx*, as above indicated. In Bonneville no series of fossils, correlated with its varying stages, have been found, the characteristic fossils, *Amnicola porata* and *A. cincinnatiensis*, being found only in beds of Upper Bonneville age, and are not known to be living within the area.

The minimum temperature to which certain limnæid forms may be subjected, and survive, is remarkable. *Limnæa stagnalis* has been actually frozen, but revived again on increase of temperature. A similar condition, or a nearly similar one, is annually produced in shallow ponds and ditches within the more northern United States, but every spring

[12] See White on "Antiquity of certain Subordinate Types of Fresh-water and Land Mollusca." Am. Jour. Sci., 1880, Vol. XX, 44.

See also "Non-marine Fossil Mollusca of North America." Third Ann. Report U. S. Geological Survey, pp. 472–477, 1881–'82. Also issued separately.

[13] *Vide* Animal Life, Semper, pp. 434–435, for authorities.

[14] In Second Annual Report of the U. S. Geological Survey, "Contributions to the History of Lake Bonneville."

[15] Third Annual Report U. S. Geological Survey, "On Lake Lahontan," pp. 195–235.

they again teem with the old shells of the preceding years. It is matter of common observation, despite the pulmonate character of the family, to see *Physa* and *Limnophysa* crawling upon the bottom of ponds wholly frozen over.[16] The principal effect of a lowering of temperature is complete or partial loss of power of assimilation, expressed by checks in growth. The lowest thermometric range compatible with assimilation in *Limnæa stagnalis* was found by Semper[17] to be 12° C. Chill-coma results whenever the temperature falls below a certain critical point, which varies considerably for different forms. The optimum temperature range for most fresh-water mollusca is small, but greater for the *Limnæidæ* than for any other family. The biologic expression of this law over wide latitudes is obvious in the varying abundance and size of the different forms; and analogy warrants the assumption that it holds true for hypsometric distribution also. But it is not necessary to depend altogether on analogy, for there have been placed in my hands series of shells from springs of wide range of temperature and also from lakes and ponds of varying altitudes. Table XIV, together with Plate V, Diagram I, is based upon shells from localities of widely varying altitudes.

TABLE XIV.—*Physa ampullacea* Gould.

Number.	Little Gull Lake.		Church Lake.	
	Length.	Breadth.	Length.	Breadth.
	mm.	*mm.*	*mm.*	*mm.*
1	11.44	6.40	14.18	9.16
2	12.50	9.10	16.16	10.60
3	11.82	7.00	18.08	11.58
4	12.20	8.00	17.34	10.62
5	13.72	8.88	16.22	10.60
6	13.22	9.20	15.00	10.24
7	10.30	6.36	14.34	9.44
8	13.00	9.32	14.80	10.96
9	12.60	8.62	15.50	10.50
10	13.76	8.50	14.96	9.24
11	16.10	10.20	12.62	8.80
12	15.00	9.44	16.40	10.70
13			13.38	8.58
14			14.00	9.18
15			13.60	9.24
16			12.06	8.12
17			14.72	8.98
18			16.20	10.04
Average	12.97	8.45	14.98	9.81

Planorbis, *Limnophysa*, and *Physa*, from Little Gull and Parker's Lakes in the Mono Basin, California, at an elevation of from 7,000 to 7,500 feet, present variant features clearly connected with station. The shells are exceedingly light and fragile, and below the normal size of fully

[16] The writer has also collected living *Unio ventricosus*, *U. luteolus*, and *U. rubiginosus* in the Des Moines River, Iowa, at Des Moines, in January, 1882. They were taken from shallow water over a bar, the ice reaching nearly to the bottom.

[17] *Loc. cit.*, p. 108.

developed adults.[18] Parker's Lake is especially cold, because snow-fed; but since the most extensive series come from Little Gull Lake, measurements based upon specimens from it are alone presented. Compared with the same species from Church Lake, near Salt Lake City, Utah, with an altitude of about 4,300 feet, the average size is seen to be much less. The ratio of lengths is $\frac{14.98}{12.97}$, and the ratio of widths $\frac{9.81}{8.45}$. Referring again to Tables IX and X, pages 33 and 34, containing the measurements for *Helisoma trivolvis* and *Limnophysa palustris*, additional evidence of a kindred nature is exhibited. In the case of the Warm Spring Lake specimens, particularly, is to be seen the effect of a higher temperature, for the annual mean of a small lake fed by warm springs must be always quite above the minimum essential for assimilation. The process of growth, under such favorable conditions, is either extended over greater periods of time or proceeds more rapidly during its continuance. This would appear to be almost the sole explanation of the gigantic proportions exhibited by the Warm Spring Lake specimens.

A similar effect has been noticed in *Goniobasis carinifera* and *Goniobasis bella*, both being species which abound in the brooks and springs of the northern portions of Georgia and Alabama. Often, within a few feet of each other—the one station a spring, the other a brook—the difference in size is marked. Some observations made by Mr. T. H. Aldrich, in north Alabama, seem to indicate that in springs this genus does not hibernate as it does in brooks and rivers. The only assignable reason appears to be that the mean temperature of such springs does not widely vary.[19]

In only one instance has it been possible to make comparative measurements of fossils from the Bonneville area; but in that case they are based upon a species now existing under circumstances quite different from those which probably completed the environment of the fossils while living. Table XVI, upon which is based Plate V, Diagram II, presents the results. The fossils are of Upper Bonneville age, and from beds correlated with a high stage of water, and hence of increased precipitation, the climatologic bearing of which has been above noted. The mean annual temperature of Utah Lake must be somewhat higher than that of the snow-fed Ogden River; and, moreover, the lake presents the additional favorable feature of quiet water. The average of the Ogden River specimens is below that of those from the lake, while the fossils fall below both, though the fossils must have enjoyed prac-

[18] To what extent this is due to the sum of unequal conditions—*e. g.*, atmospheric pressure combined with lower temperature—it is impossible to state. Whether such low organisms would respond, noticeably, to differences of barometric pressure, is doubtful. Decrease of temperature is positively known to cause depauperation in some forms, and is here assumed to be the chief factor.

[19] On this point there is very little known. So, too, of the shell fauna of thermal springs. The existing data, which appear to have been exhausted by Dr. A. C. Peale (in the Twelfth Annual Report of the Hayden Survey, pt. ii, pp. 358, 359), bear mainly upon vegetable forms, and in no case upon shells.

tically the same favorable conditions of volume, quietness, and food as do now their recent congeners in the lake.

TABLE XVI.—*Fluminicola fusca* Haldeman.

Number.	Utah Lake.		Ogden River.		Bonneville fossils.	
	Length.	Breadth.	Length.	Breadth.	Length.	Breadth.
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
1	12.50	8.10	10.30	6.60	8.10	5.50
2	11.30	7.64	9.36	7.00	9.94	6.62
3	10.50	6.40	9.00	6.62	9.00	5.56
4	11.72	7.14	8.76	7.10	7.96	6.50
5	10.10	7.00	9.84	6.68	7.58	5.40
6	10.22	6.90	9.80	6.54	7.80	6.20
7	10.00	7.24	9.86	7.10	9.50	6.40
8	9.70	6.52	10.82	6.90	8.34	5.22
9	10.50	6.52	8.68	6.00	7.94	5.50
10	11.50	8.00	8.70	5.64	8.20	5.32
11	9.52	7.00	9.54	6.80	8.10	5.08
12	9.70	6.72	8.64	5.68	8.50	5.56
13	12.00	7.80	8.12	5.82	7.60	5.00
14	10.24	6.50	8.94	6.16	8.36	5.70
15	10.80	8.00	9.60	6.50	8.44	5.60
16	10.50	6.70	8.34	6.36	9.10	5.50
17	11.90	8.20	8.70	5.60	8.08	5.28
18	11.00	7.70	8.64	6.16	7.82	5.40
19	....	....	8.90	6.40	7.72	5.38
20	....	....	9.88	6.30	8.00	5.34
21	....	....	9.78	7.18	8.30	6.10
22	....	....	9.56	6.30	8.06	5.56
23	....	....	8.80	6.00	7.24	4.98
24	....	....	9.26	6.12	8.30	5.54
25	....	....	9.04	6.00	7.46	5.32
Average	10.76+	7.21+	9.24	6.38	8.23	5.50

HYPSOMETRIC DISTRIBUTION.

Hypsometric distribution has received from conchologists much less attention than it apparently deserves. Within small areas, comparatively, there are presented by hypsometry those various physical conditions that must otherwise be sought through several degrees of latitude. In this connection no extended careful investigations have been made to ascertain the physical conditions of the extreme heights at which some of our mollusca have been found. But, reasoning from analogy with plants and insects, the minimum of favorable conditions should obtain at great heights, and indeed that general fact is sufficiently indicated by the paucity of genera, species, and individuals at high stations. In France, however, an attempt in this direction has been made by Fischer.[20] He discovers that the terrestrial mollusca of the Pyrenees and Alps, following the analogy of plants, thrive best at certain heights, and each species extends to an altitude beyond the upper limit of which it does not usually pass. The accompanying Table XVII is based upon his

[20] *Comptes Rendus.* Tome 81, p. 624-626, 1875.

results, in which the names of the zones as he originally applied them are retained:

TABLE XVII.—*Hypsometric Distribution of European Mollusca.*[21]

Zones.	Pyrénées. Name.	No. of genera.	No. of species.	Alps. Name.	No. of genera.	No. of species.
I ZONE.	*Basses vallées. Limite supérieure, 1,000 mètres.—Zone de l'Helix carthusiana.* *Helix carthusiana*, H. variabilis, *Cyclostoma elegans* .... Mollusques fluviatiles: Neritina, Physa, Planorbis, Valvata, Paludina, Bithynia, Sphærium, Unio, Anodonta	2 9	3	*Basses vallées. Limite supérieure, 1,000 mètres.—Zone de l'Helix carthusiana.* Succinea putris, S. oblonga, *Helix carthusiana*, H. fruticum, H. personata, *Cyclostoma elegans* .... Mollusques fluviatiles: Physa, Planorbis, Paludina, Bithynia, Sphærium, Unio, Anodonta	3 7	6 ......
II ZONE.	*De 1,000 à 1,200 mètres.—Zone de l'Helix aspersa.* Limax maximus, *Succinea arenaria*, Helix aspersa, *H. lapicida*, Pupa farinesi, P. umbilicata	4	6	*De 1,000 à 1,200 mètres.—Zone de l'Helix obvoluta.* *Succinea arenaria*, Helix obvoluta, H. montana, H. incarnata.	2	4
III ZONE.	*De 1,200 à 1,500 mètres—Zone de l'Helix limbata.* Limax marginatus, Zonites cellarius, *Z. fulvus*, Helix limbata, *H. hispida*, Bulimus obscurus, Clausilia abietina	5	7	*De 1,200 à 1,500 mètres.—Zone de l'Helix fontenillei.* Zonites crystallinus, *Helix ericetorum*, H. fontenillei, *H. lapicida*, H. pulchella	2	5
IV ZONE.	*De 1,500 à 2,000 mètres.—Zone de l'Helix nemoralis.* Arion empiricorum, Limax agrestis, var. sylvatica, Helix nemoralis, *H. rupestris*, *H. ericetorum*, *H. rotundata*, *Clausilia dubia*, Pupa marginata, Pupa megacheilos, Pomatia partioti .... Mollusques fluviatiles: Ancylus fluviatilis, var. capuloidea	6 1	10 1	*De 1,500 à 2,000 mètres.—Zone de l'Helix sylvatica.* *Zonites fulvus*, Helix sylvatica, *H. rupestris*, *H. rotundata*, H. ruderata, *H. hispida*, H. ciliata, H. edentula, H. holosericea, H. alpina, H. pomatia, *Clausilia dubia*	3	12
V ZONE.	*De 2,000 à 2,500 mètres.—Zone de l'Helix carascalensis.* Helix carascalensis, H. rubigena. Mollusques fluviatiles: Limnæa limosa var. glacialis	1 1	2 1	*De 2,000 à 2,500 mètres.—Zone de l'Helix glacialis.* Vitrina glacialis, V. pellucida, V. nivalis, Zonites petronella, Helix glacialis, H. zonata, H. arbustorum var. alpestris......	3	7

[21] This table is a modification of that employed by Fischer, *loc. cit.* Species common to each area are indicated by *italics*.

The comparatively low altitude at which certain fresh-water genera occur is suggestive to students of Quaternary geology, and, indeed, of older strata in which *Unio*, *Anodonta*, and *Sphærium* occur, as indicating a probable low elevation for the waters in which they lived. To what extent this inference is applicable to the Laramie beds would be a worthy object of inquiry. The high altitudes at which representatives of the *Limnæidæ* occurred, being found in the highest zone in the Pyrenees, is exactly paralleled in the Rocky Mountains and the Sierra Nevada, within the limits of the United States, and in Lake Titicaca and some other bodies of fresh water at great heights in the Andes.

Among land shells in North America the representatives of extreme hypsometric range are *Pupa alticola* and *Vallonia pulchella*—the last being circumpolar.

The same conditions and results should not be sought within areas bounded by isotherms which may approximately represent the maximum or minimum temperatures between which, for any given species, the process of assimilation is continued, for no such inference can be safely drawn from isothermal lines, inasmuch as they mark the mean of often great extremes, either of which would prove fatal to many classes of mollusks and affect all. The mean of temperature does not primarily affect animal life, but great variations and extremes do sensibly modify it. Thus, the transverse irregularly distant lines or ridges in many mollusks, called lines of growth, indicate the cessation and subsequent recommencement of the process of assimilation—a physiologic function dependent very greatly upon climate. In our climate most shells, land and fresh water alike, hibernate during the lower temperature of winter, the period of harmful minimum temperature. Immediately following hibernation comes a period of most rapid assimilation and consequently of growth. This alternation continues during the life of the individual. But in stations where the water is below the optimum temperature, as in Little Gull Lake, Parker's Lake, and other similarly elevated bodies of water, much of the shell-forming energy is diverted to other uses, and there results a shell of great comparative lightness, akin to that seen in shells from stations deficient in calcic carbonate. The constant recurrence of this feature in shells obtained from such stations justifies the hypothesis that here depauperation is the consequent of a temperature below the optimum.

CONCLUSIONS.

Briefly summarized, the results reached by this study of the fossil and recent shells of the Great Basin are—

(1) That the recent and the fossil mollusca are predominantly limnæid, a biologic expression of climate.

(2) That (*a*) the fossil fauna is more variable than the recent; (*b*) in the Lahontan area being characteristically limnæid (represented by *Pompholyx effusa*), and (*c*) in the Bonneville area rissoid (represented by *Amnicola porata* and *A. cincinnatiensis*).

(3) That increase in salinity finds a biologic expression (*a*) in depauperation, (*b*) in lessened abundance, and (*c*) in extinction when the waters become briny.

(4) That the oscillations of the lakes are coupled with (*a*) varying abundance, and (*b*) with varying size of shells, as a biologic expression of climate.

CHAPTER III.

DESCRIPTIONS OF NEW FORMS.

VALVATIDÆ.

Genus VALVATA Müller.

Valvata sincera var. **utahensis** var. nov.

(Plate VI, Figs. 1-3.)

Testa operculata, anguste umbilicata, conica, striatula, nitida, subpellucida, apice corneo-fulva, infra albida; spira obtuse elevata, apice plana; sutura perimpressa; anfr. 4, regulariter accrescentes, summi uni-carinati, carina in anfr. inferiore evanescente, ultimo anfr. per-rotundato, ½ longitudinis testæ formanante; apertura circularis, postice subangulata; peristoma simplex, ad proximum anfr. callo tenuissimo juncta; intus albida.

Habitat.—Lake Utah, Utah.

Long., 4.80^{mm}; lat., 3.20^{mm}.

Shell operculate, narrowly umbilicate, conical, with minute transverse striæ, shining, somewhat pellucid, yellowish horn color at apex, white below; spire obtusely elevated, flattened at tip; suture well impressed; whorls four, convex, regularly increasing, the uppermost ones with a single well-marked carina, which becomes obsolete on the last whorl; last whorl equals one-half the whole length of the shell; aperture circular slightly angled posteriorly; peristome simple, continuous, joined to the next whorl above by a very slight calcareous deposit; within white.

Operculum light horn color, corneus, spirally multi-volute, slightly produced posteriorly to conform to the shape of the aperture. Dentition unpublished.

Length, 4.80^{mm}; breadth, 3.20^{mm}.

This form was dredged in August, 1883, in great numbers in Utah Lake, near Lehi, not far from the head of the River Jordan. It is intermediate between *Valvata sincera* Say and *V. virens* Tryon. From the first it differs in the uni-carinate upper whorls, in being more elevated, in possessing a very much smaller umbilicus, and in its greater size.

From the second it differs in color, size, carination, and form of aperture. It resembles, in some respects, *V. unicarinata*, De Kay (=*V. tricarinata* Say), but differs in size, ornamentation, and form of aperture. Specimens may be seen in the Smithsonian Institution, in the New York State Museum of Natural History, and in the private collections of Beecher, Stearns, Dall, Aldrich, and the writer.

RISSOIDÆ.

Genus AMNICOLA Gould & Haldeman.

Amnicola dalli sp. nov.

(Plate VI, Figs. 4–6.)

Testa anguste umbilicata, obtuse conica, nitida, leviter striata, fusca vel virido-cornea; anfr. 4, convexi, lente accrescentes; sutura regulariter impressa, sub-profunda; apertura ad basim rotundata, postice subangulata, intus cæruleo-albida; peristoma simplex, acutum, marginibus crasso callo junctis; margo columellaris subreflexus.

Long., 3.50^{mm}; lat., 2.30^{mm}.

Habitat.—Mountain streams, Nevada.

Shell narrowly umbilicate, obtusely conical, shining, slightly striated, brown or greenish horn color; whorls four, convex, gradually increasing in size; suture regularly impressed, somewhat deep; aperture rounded before, somewhat angular behind, bluish white within; lip simple, sharp, margins joined by a thick callous, columella rather reflexed.

Length, 3.50^{mm}; lat., 2.30^{mm}.

For the diagnosis of the lingual dentition I am indebted to Mr. Charles E. Beecher, who has prepared the following description and illustrations:

"Jaw thin, membranaceous.

"Odontophore 1.10^{mm} long, .13^{mm} wide. In a full-grown example the odontophore has 94 transverse rows of teeth, with the formula 3 —1 —3.

"Rhachidian tooth short and broad, with the inferior lateral angles produced. Cusp with seven denticles, of which the central one is the largest. The anterior lateral faces are each furnished with a short strong conical denticle, and the adjacent lateral margin of the tooth is thickened and slightly produced. Formula for rhachidian tooth $=\frac{3+1+3}{1+1}$.

"Body of intermediate tooth quadrate; infero-interior angle somewhat produced; furnished with a large bullation, into which the infero-interior angle of the succeeding tooth appears to fit as if for articulation. Peduncle long and straight. Cusp with seven strong angular denticles, arranged according to the formula 2+1+4.

"Body of the first lateral tooth elongate-triangular, oblique to the direction of the broad peduncle. Cusp inflected and carrying twenty-three slender denticles.

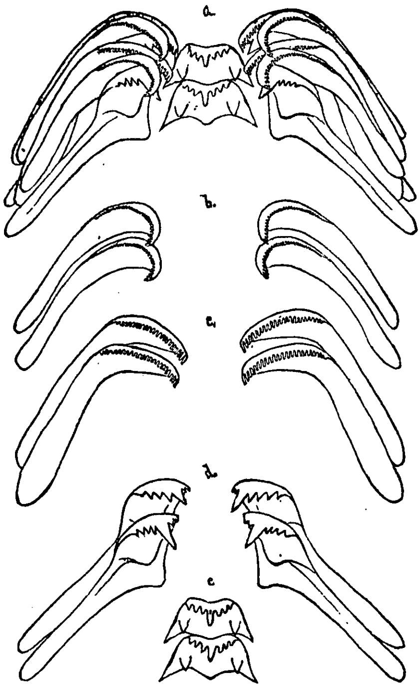

FIG. 2.—Lingual dentition of *Amnicola dalli*, Call × 400.—Beecher.

a.—Two of the transverse rows of the odontophore, showing the normal position of the teeth. The teeth are considered as opaque.
Analysis. b.—Outer laterals. *c.*—First laterals. *d.*—Intermediate teeth. *e.*—Rachidian teeth.

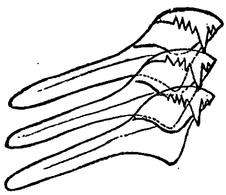

FIG. 3.—Intermediate teeth (× 400) showing mode of articulation.—Beecher.

"Outer lateral tooth hamate, with no marked distinction between the body and peduncle. Free extremity incurved and bearing thirty-four minute denticles. The denticle formula is, therefore—

$$34 - 23 - 7 - \frac{3+1+3}{1+1} - 7 - 23 - 34.$$

"The apparent articulation of the intermediate teeth, as described above, was observed in a fragment of an odontophore which presented a lateral aspect under the microscope. It is not known that this feature has ever been noted in any other species, although it very probably occurs in many which have foraminated or bullate teeth. This disposition of the teeth would allow great flexion of the odontophore without their displacement."

This quite distinct form was collected in considerable numbers at Symon's Stage Station, near the foot of Pyramid Lake, Nevada. Its nearest congener is *A. porata* Say, from which it differs in elevation, sculpturing, and dentition. Since this last character is the one of chief importance, the description of the dentition is here given. Comparing the denticle formulæ of the two forms, thus:

A. porata.

$$30-18-5-\frac{3+1+3}{4+4}-5-18-30,$$ [22]

A. dalli.

$$34-23-7-\frac{3+1+3}{1+1}-7-23-34,$$

the dissimilarity is strongly marked. Specimens may be seen in numerous private collections and in the cabinets of the Smithsonian Institution and the New York State Museum of Natural History.

LIMNÆIDÆ.

Genus Radix Montfort.

Radix ampla, var. **utahensis**, var. nov.

(Plate VI, Figs. 7–9.)

Testa globosa, sub-umbilicata, irregulariter costata, corneo-albida, sub-pellucida; spira parvula, conica; anfr. 4–4½, convexi, supra valde-plani, rapide accrescentes, ultimo inflato, cum transversis costatis perspicatis minutissime corrugatisque; sutura sub-profunda, regulariter impressa; apertura elongato-ovata, effusa, intus margarita-alba; labrum simplex, marginibus callo junctis; columella reflexiuscula, antice recta.

Long. 13.40^{mm}; lat. 7.10^{mm}.

Aper. long. 9.00^{mm}; aper. lat. 5.90^{mm}.

Habitat, Lake Utah, Lehi, Utah.

Shell globose, somewhat umbilicated, irregularly costate, light horn color, nearly pellucid; spire rather small, conical; whorls four to four and one-half, convex, somewhat flattened above, giving rather a shouldered appearance to the whorls, rapidly increasing in size, the last whorl being inflated, with numerous rather marked transverse costæ, minutely wrinkled; suture somewhat deep, regularly impressed; aperture elongately ovate, effuse, approaching patulous, pearly white within; outer lip simple, the margin connected by a slight calcareous deposit; columella somewhat twisted, but straight in front. Dentition

[22]After Stimpson, Smithsonian Misc. Coll. No. 201, p. 14, Fig. 6; also *ibid.*, No. 144, p. 80, Fig. 158.

unpublished. Length of largest specimen 16.82^{mm}; breadth 8.88^{mm}. The average of nine specimens gave a length of 13.40^{mm}, breadth 7.10^{mm}, with about the same ratio for corresponding measurements of aperture. Utah Lake, near Lehi, Utah.

This is a rare form in Utah Lake, its only locality so far as known. Its nearest affinity is indicated in the nomenclature adopted. In the preceding chapters its relation to *Polyrhytis kingii* Meek, has been noted. It was associated with abundant specimens of the *Valvata* herein described, and with *Fluminicola fusca* Hald., and *Sphærium dentatum* Hald. Specimens may be seen as above.

Genus LYMNOPHYSA Fitzinger.

Limnophysa bonnevillensis, sp. nov.

(Plate VI, Figs 10–13.)

Testa umbilicata, elongata, ventricosa vel bullata, solidula, obsolete striata, minutissime reticulata, in anfr. infra suturam ultimo longitudinaliter obsolete costulato; spira elevata, acuta; sutura perimpressa; anfr. 4–4½, per-convexi, ultimo ¾ longitudinis testæ adæquante et subito accresente, ventricosa, basi subexpanso; columella subplicata, leviter callosa, regulariter arcuata; columella peristomateque continuatis; peristoma simplex, marginibus callo crasso junctis; apertura late-ovalis, ½ totius longitudinis æquans, satis obliqua, postice angulosa.

Species fossilis, Bonneville Lake beds, Utah. Quaternary.

Shell umbilicated, elongate, ventricose or bullate, somewhat solid, faintly striate and very minutely reticulated, below the suture the last whorl bearing faint longitudinal ridges or costæ; spire elevated, acute; suture deeply impressed; whorls 4 to 4½, very much rounded, sometimes tending to geniculation above, the last whorl equal to three-fourths the whole length of the shell, rapidly increasing in size, much swollen, somewhat expanded at base; columella somewhat plicate, slightly callous, regularly arcuate; columella and peristome continuous; peristome simple, margins joined by a heavy callous which is continuous and so reflexed as to partially close the umbilicus; aperture broadly ovate, often patulous, equal to one-half the entire length of the shell, oblique, angled slightly behind.

Fossil, Quaternary. Bonneville Lake beds, Kelton, Utah.

The four largest specimens of the many in the collections give the following dimensions:

Specimen.	Length.	Breadth.
	mm.	*mm.*
1	15.00	7.80
2	11.00	5.80
3	9.40	5.20
4	18.50	6.00

This shell resembles depauperate examples of *L. sumassi*, Baird (var. *P. palustris* Müller), but differs in not presenting a decussate surface, and in the columella being less strongly plicate. The greater number of specimens are somewhat malleated, though occasionally quite smooth specimens occur which approach nearest to *L. desidiosa* Say. Many present a patulous aperture, in which respect they resemble specimens of the genus *Radix* rather than true *Limnophysa*. The general outline of the specimens is that of *L. adelinæ* Tryon. Collected abundantly by Mr. G. K. Gilbert, in Upper Bonneville beds, at Kelton, Utah.

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PLATE II.

Each conventional sign represents a shell, and its position represents the dimensions of the shell. The lengths are found by reading from below upwards; the breadths by reading from left to right. The marginal numbers represent millimeters.

The average of the given series is represented by the closed conventional sign.

DIAGRAM 1.

Based upon Table VI, page 31. *Pompholyx effusa* Lea.

The circles represent specimens from Pyramid Lake, Nevada; the squares specimens from White Pine, Nevada.

DIAGRAM 2.

Based upon Table VII, page 32. *Pompholyx effusa* Lea.

The circles represent fossil shells from the gray tufa, Anaho Island, Pyramid Lake, Nevada; the squares fossil shells from the marl at White Terrace; and the triangles represent living shells from Pyramid Lake, Nevada.

DIAGRAM I.

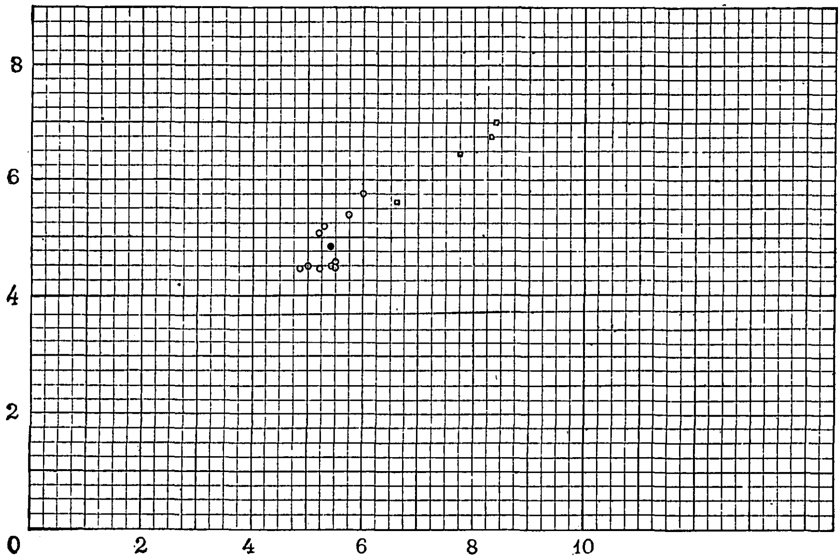
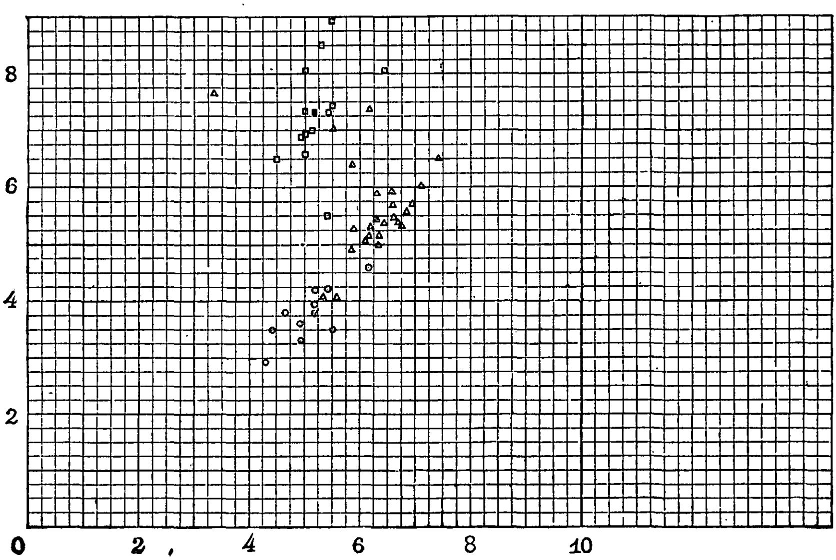


DIAGRAM II.



COMPARATIVE DIMENSIONS OF POMPHOLYX EFFUSA

PLATE III.

Each conventional sign represents a shell. The lengths are found by reading from below upwards; the breadths, by reading from left to right. The marginal numbers represent millimeters.

The average of the given series is represented by the closed conventional sign.

DIAGRAM 1.

Based upon Table VIII, page 32. *Carinifex newberryi* Lea.

The circles indicate fossil specimens from the south end of Winnemucca Lake, Nevada; the squares represent semi-fossil shells from Christmas Lakes, Oregon.

DIAGRAM 2.

Based upon Table IX, page 33. *Helisoma trivolvis* Say.

The circles indicate shells from Warm Spring Lake, Utah; the squares, semi-fossils from Carson Desert, Nevada.

DIAGRAM I.

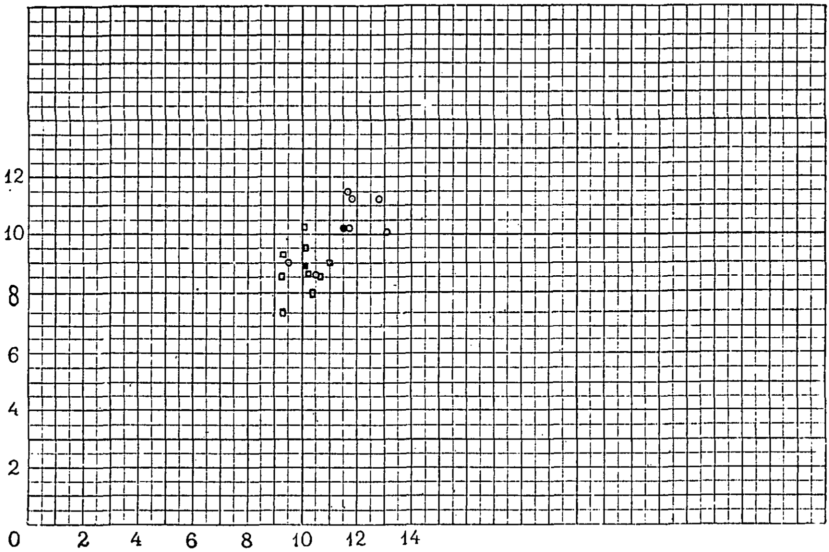
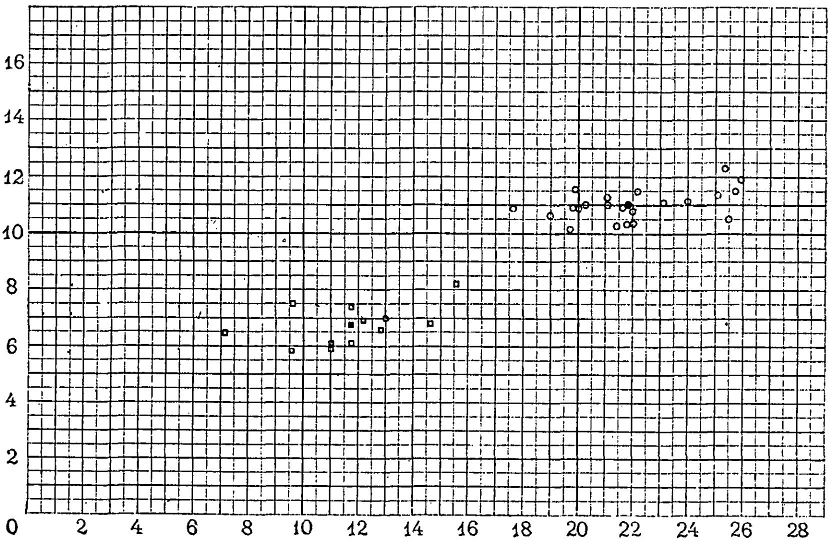


DIAGRAM II.



COMPARATIVE DIMENSIONS OF SHELLS

Plate IV.

Each conventional sign represents a shell. The lengths are found by reading from below upwards; the breadths, by reading from left to right. The marginal numbers represent millimeters.

The average of the given series is represented by the closed conventional sign.

DIAGRAM 1.

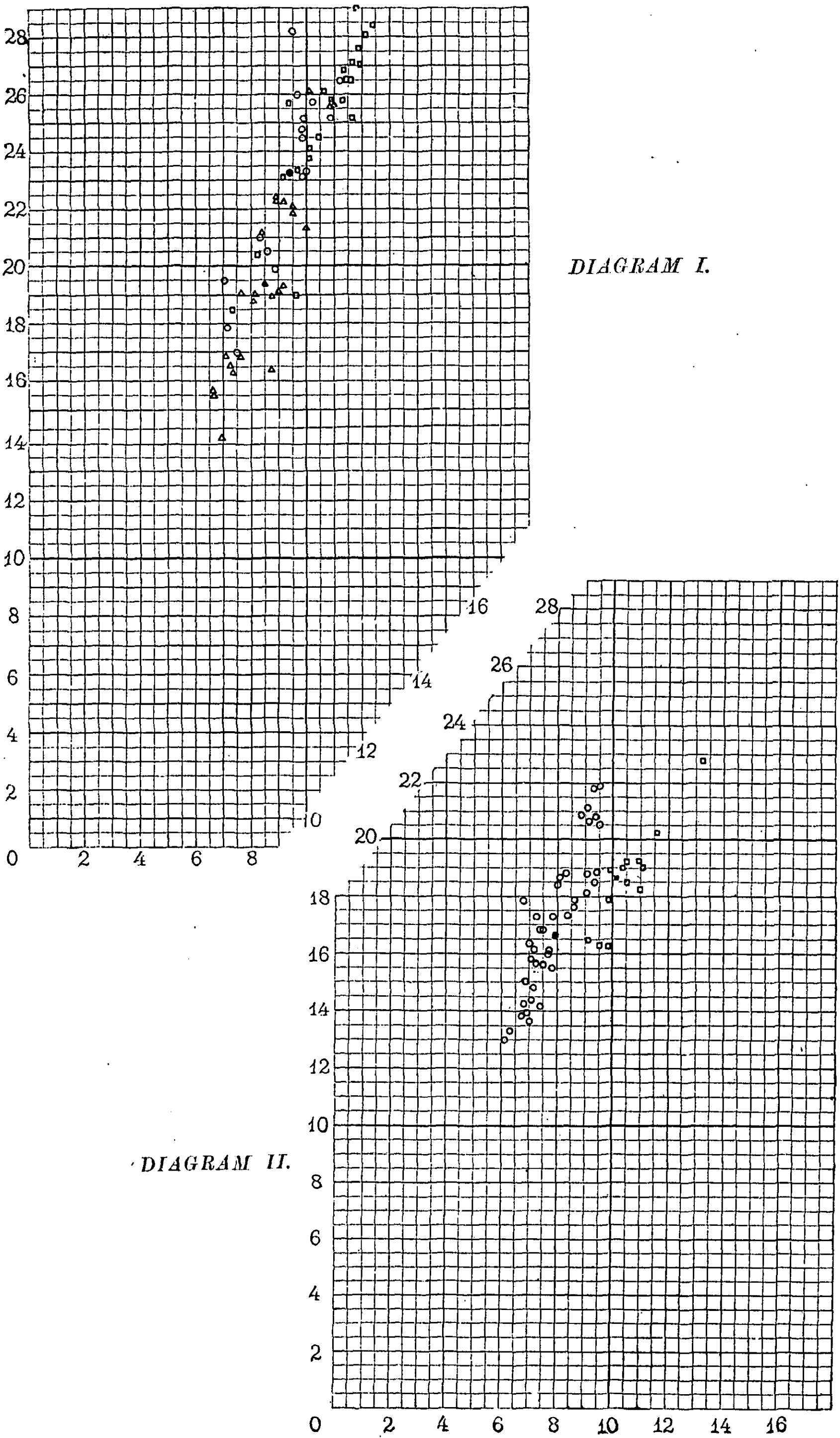
Based upon Table X, page 34. *Limnophysa palustris* Müll.

The circles represent specimens from Honey Lake, California; the squares, shells from Warm Spring Lake, Utah; and the triangles, specimens from brackish springs, Promontory, Utah.

DIAGRAM 2.

Based upon Table XI, pages 34 and 35. *Physa gyrina* Say.

The circles represent shells from brackish springs, Promontory, Utah; the squares, specimens from fresh-water ponds at Salt Lake City, Utah.



COMPARATIVE DIMENSIONS OF SHELLS FROM FRESH AND BRACKISH STATIONS

Plate V.

Each conventional sign represents a shell. The lengths are found by reading from below upwards; the breadths, by reading from left to right. The marginal numbers represent millimeters.

The average of the given series is represented by the closed conventional sign.

Diagram 1.

Based upon Table XIV, page 39. *Physa ampullacea* Gould.

The circles represent shells from Little Gull Lake, California; the squares represent shells from Church Lake, near Salt Lake City, Utah.

Diagram 2.

Based upon Table XVI, page 41. *Fluminicola fusca* Hald.

The circles represent fossils from Kelton, Utah; the squares, shells from Ogden River; and the triangles, specimens from Utah Lake, Utah.

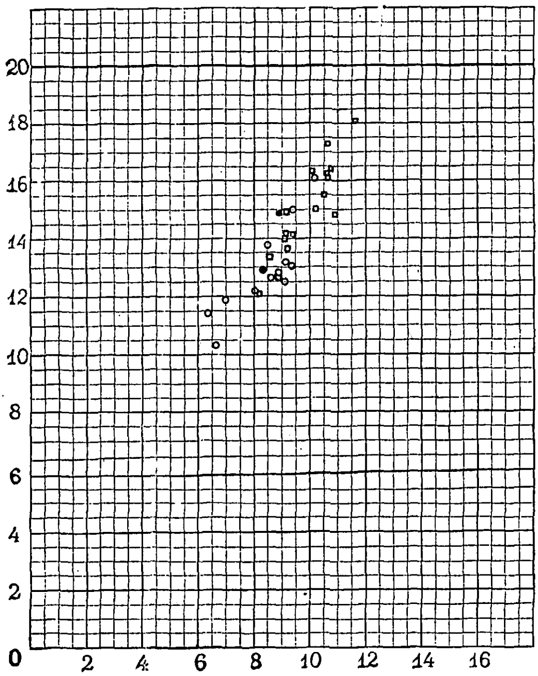


DIAGRAM I.

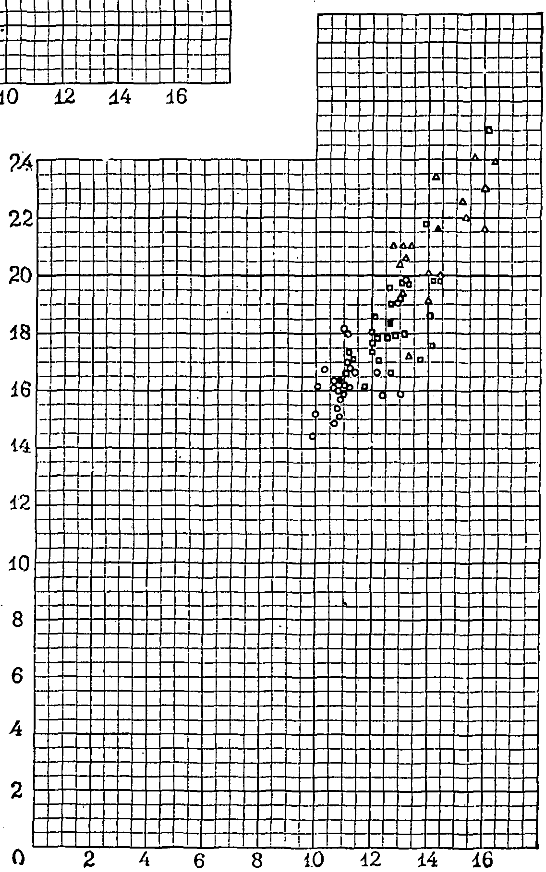
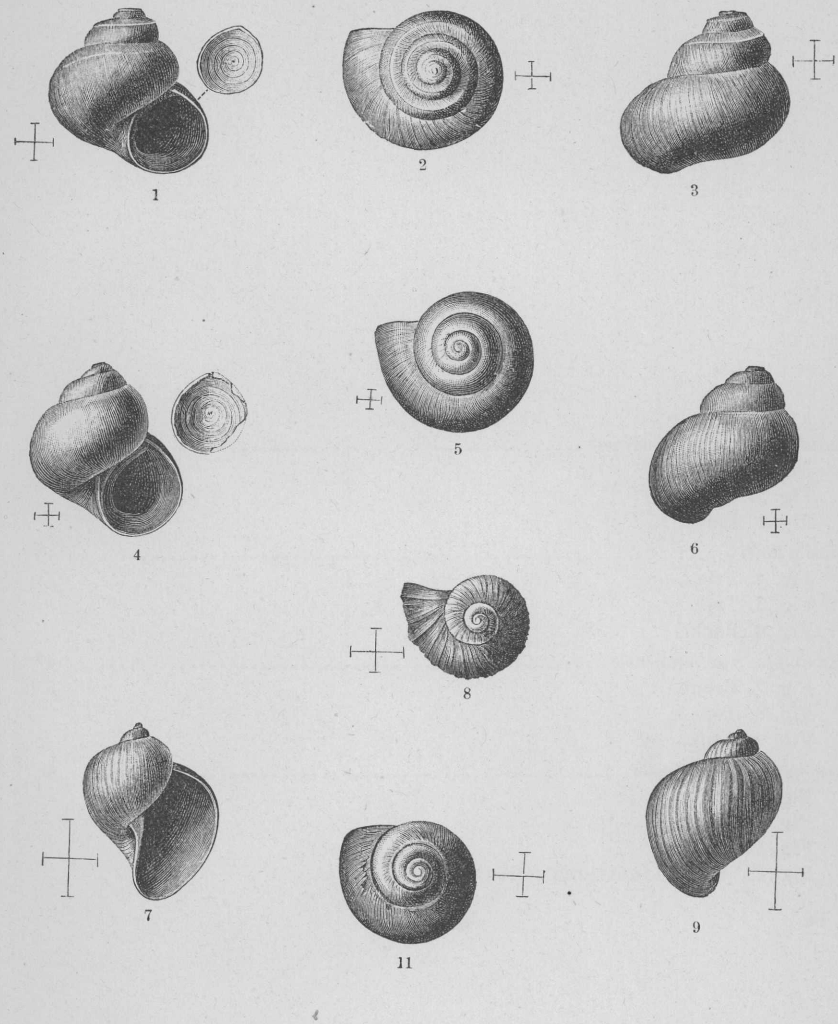


DIAGRAM II.

COMPARATIVE DIMENSIONS OF SHELLS

Plate VI.



RECENT AND QUATERNARY MOLLUSCA.