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PREPARED UNDER THE DIRECTION OF THE COUNCIL

BY
RICHARD DE ZEEUW
SECRETARY

BY AUTHORITY

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## LETTER OF TRANSMITTAL.

TO HON. WOODBRIDGE N. FERRIS, *Governor of the State of Michigan:*

SIR—I have the honor to submit herewith the XVIth Annual Report of the Michigan Academy of Science for publication in accordance with Section 14 of Act No. 44 of the Public Acts of the Legislature of 1899.

Respectfully,
RICHARD DE ZEEUW,
Secretary.

East Lansing, Michigan, November, 1914,

## FOREWORD.

At the general session of the Michigan Academy of Science held in April, 1913. the members, acting upon the recommendation of the Council, voted to change the time of the annual meeting from the spring to the Friday and Saturday following the last Thurdsay in November. After the general session at which this action was taken, several objections to the fall meeting were brought to the attention of the Council, which met on October 17, 1914. to arrange for the annual session. After considering the objections, the Council voted that it was inexpedient to change the time of meeting, that the next session should be held in the spring of 1915, and that the President and Secretary should canvass the membership for papers and publish a report for 1914 in order that the publication of the annual reports should not be interrupted.

The President and Secretary have followed the instructions of the Council and have arranged in this volume the papers received from the members. The minutes of the meetings, reports of officers, and other business matters usually published in the annual report have been omitted, since the terms of office will be automatically extended to the spring meeting, and the reports cannot properly be published until accepted by the Academy.

Signed,
ALEXANDER G. RUTHVEN,
President.

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The Council consists of the above-named officers and all Resident Past-Presidents.

# PHYSIOGRAPHIC AND MOLLUSCAN SUCCESSION IN LAKE POOLS.

BY H. BURRINGTON BAKER.

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## INTRODUCTION.

The problem under consideration is the physiographic succession in beach pools, which are formed along the shores of larger lakes by wind and current action, and the corresponding ecological succession in the molluscs they contain. Douglas Lake, in Cheboygan County near the northern end of the Southern Peninsula of Michigan, has a number of pools m different stages of formation, and the data given here was mostly collected in that region during the summers of 1911, 1912, and 1913. Less complete studies were also made in Saginaw Bay, off Lake Huron, during the summer of 1908(5), and some mention of these pools will also be made in this paper.

Map 1 is a map of the northern end of the Southern Peninsula of Michigan, showing the situation and the shape of Douglas Lake. The lake was part of the Great Lakes at one of the former glacial lake levels, and has a fauna closely related to the present Lakes Michigan and Huron (6).[1]

[1]The numbers in parentheses refer to the bibliography at the end of the paper.

## PHYSIOGRAPHIC SUCCESSION.

### A. TYPES OF LAKES.

Chart I. Classification of Lakes of Temperate Regions.

| | SMALL LAKES. | LARGER LAKES. | VERY LARGE LAKES. |
|---|---|---|---|
| Shallow lakes. | *Type I.* Small lakes, too shallow for thermocline. Stagnant when frozen; good circulation when not. No abyssal depths. Shores all of protected type. | *Type II.* Larger lakes, too shallow for thermocline. Stagnant when frozen; good circulation when not. No abyssal depths. Shores of both protected and unprotected types; mostly the former. Rarely beach pool formation. | *Type III.* Very large lakes, too shallow for thermocline. Stagnant when frozen; good circulation when not. No abyssal depths. Shores of both protected and unprotected types; mostly the latter. Considerable beach pool formation. |
| Deep lakes. | *Type IV.* Small lakes deep enough for thermocline. Stagnant when frozen, thermocline when not, except spring and fall overturnings. Abyssal depths with periodic warming and aeration. All shores of protected type. | *Type V.* Larger lakes, deep enough for thermocline, which, however, is usually not very sharp (14). Stagnant when frozen, thermocline when not, except spring and fall overturnings. Abyssal depths with periodic warming and aeration. Shores of both protected and unprotected types. Beach pool formation on a small scale. | *Type VI.* Very large lakes, too large for thermocline. Rarely completely frozen; slow circulation. Abyssal depths with slow, but quite constant, warming and aeration. All shores of unprotected types, except in bays, behind spits, etc. Lakes and large pools formed by current and wave action. |

Lakes belong to the general series of physiographic successions known as the lake-pond-swamp series. They tend to form ponds, by being filled in with stream and wave sedimentation and by plant encroachment, while ponds, in turn, become temporary swamps thru the action of similar agencies.

Lakes have often been divided into three main groups based on their adaptation for plankton life (See 8 and 9). These would be: (1 usually small lakes too shallow to have a thermocline; (2) small or larger lakes, deep enough to develop a thermocline; and (3) very large lakes, too large to allow a thermocline. A classification based on the nature of the shores, and consequently on their adaptability for shallow littoral forms would, on the other hand, require a division into two different classes: (1) lakes too small to develop wave and current action to the extent of building sandy, more or less shifting shores; and (2) lakes large enough to prevent, by such action, the fixation of the entire shore by vegetation. The second class would, of course, include all of the lakes that would be able to develop pools to any marked degree.

The relationships of all of the different kinds, for temperate regions, might be expressed about as shown in the accompanying chart (Chart I). Types II, III, V, and VI, as shown in the chart, would be the only ones to develop beach pools to any extent. Rush Lake in Huron County, Michigan, (5), approaches the second type, while Lake St. Clair, between Lakes Huron and Erie, is probably an example of the third. Types V and VI, however, are the ones with which this paper especially deals; Douglas Lake is an example of the former, while the head of Saginaw Bay, off Lake Huron (5), is an example of the latter.

## B. TYPES OF LAKE POOLS.

In these types of lakes, with a portion of the shore-lines shifting and sandy, another form, of the same series of physiographic succession as already mentioned, is illustrated; the ponds, instead of being formed from the entire lake by sedimentation, are cut off from the parent body by sand and gravel barriers, built up by the action of the waves and currents and often also of the ice. There are two types of these pools: those separated mainly by barrier beaches, and those bounded by true bars (10), and it may not be out of place here to include a slight digression into the dynamics of these two classes.

*I. Barrier Beach Types*. Barrier beaches are embankments of sand, etc., thrown up at right angles to the direction of the prevailing strongest winds and usually more or less parallel to the shore. They are built up by the direct action of the waves, combined with the shifting action of the inshore currents; when they connect with the shore at the ends, they enclose small beach pools. On account of this method of formation, they can be raised, by the action of the water alone, only as high as the limit of auction of the largest waves, and from depths no greater than this same limit of action; their height and depth are thus proportionate to the size of the waves, and consequently to the size of the lake in which they are formed. Secondarily wind action may raise the barrier beaches even higher, even building large sand dunes in front of the pools, altho this usually only happens where the surface level of the lake is falling, because only in such cases is enough dry sand exposed. The ice also often helps in building these barrier beaches, and the freezing of the water in the sand allows greater movement of the sand by the wind.

It has sometimes been stated that barrier beaches could only be formed along retreating shore-lines, that is, in lakes, the surface level of which was falling. The maps (maps 3, 4, 5 and 6) show an example of the formation of a beach pool while the surface of the lake was actually rising. It was very evident, to an observer, that this barrier beach was actually pounded up above the surface of the water by the direct action of the waves; in fact, during a heavy storm the barrier beach would actually increase in height while it was being watched. There could be no doubt that the beach could be easily built up while the water remained at the same level. In addition, during the next summer a continued study of the same region was made, and it was found that the formation of the barrier beach was effectually prevented when the surface of the lake fell rapidly, because the line where the waves broke, and where the action was most severe, did not remain long enough in the same place to completely effect its construction. Time and time again during the summer, barrier beaches were started and then abandoned for a line farther out, after which the outwash, that takes place in shallow water between waves, scoured away the partially developed ridge.

A similar abandonment might occur at the time of a rise in surface level, as is shown by the series of maps. Map 4 shows the beginning of a barrier beach, which was later abandoned, and finally destroyed when the rising water caused the line of greatest wave action to move farther inshore. In conclusion, it might be stated that the best conditions for the formation of barrier beach pools appeared to be a fairly constant water level, in very shallow water which deepened very gradually out from the shore, in a lake where large waves were produced during storms.

Along Saginaw Bay (5), this method, combined with wind action, separated long-lived, sand dune pools, which attained a length of nine hundred meters, a width of from fifty to sixty meters, and a depth of not much over a meter; Long Lake on Sand Point was such an example. At Douglas Lake, however, as may partially be seen from the maps, they were usually not more than

fifty meters long and twenty centimeters deep; they were too small to be permanent as their depth was less than the annual variation in the level of the lake. In both cases, on account of the method of formation, they were usually long, narrow and shallow, with their long axes parallel to the shore, and at right angles to the wave action.

*II. Sand Spit Types*. The sand spit or hook, on the other hand, was usually built up more or less parallel to the direction of the currents, which in our small, fresh-water lakes is largely dependent on the direction of the prevailing strongest winds. They were produced by sand being carried out around some point that crossed the path of the current, and then deposited in deeper water; this process was carried on until the spit again connected with the shore and produced a bar. Their size, and the size of the pools and lakes behind them, was not so completely dependent on the size and strength of the waves and currents, and consequently on the size of the lake in which they were produced, as were the barrier beach pools; they could be started in shallow water along the shore and then be built out gradually into deeper water. The time required for their building, however, was directly so dependent. As a result, the sand bar pools were much larger features than the barrier beach pools, it is true that they were much larger in the Great Lakes than in the smaller, inland ones, but this was largely due to the fact that the few thousand years that have elapsed since the glacial retreat from Michigan was far to short a time for the puny currents of these smaller lakes to construct such large bars, as have been produced, for instance, along Lake Michigan, where many of the lakes so separated are larger than Douglas Lake itself. Off several of the points in Douglas Lake were found very evident signs of large bars, which will, in time, separate off lakes of considerable size from the parent body.

## MOLLUSCAN SUCCESSION.

### A. MOLLUSCS OF DOUGLAS LAKE.

The molluscs of Douglas Lake, at least of the southwestern portion where the pools were being formed, entirely consisted of gill-breathing species, or of pulmonates which had become adapted to take water into their lungs and breathe in that way. Even the young of *Physa ancillaria parkcri* (Currier), which lived in water but a few centimeters deep, normally breathed in this way, while the older shells, such as the adults of this same species, were so completely habituated to breathing water that, when placed in small aquaria, they died soon after exhausting the air in the water, without even attempting to come to the surface to breathe; altho when once taught to breathe air, by the simple method of exposing them out of water until the water in their lungs partially evaporated or was otherwise replaced by air, they could be kept in a small dish for several months and would come to the surface regularly like any ordinary, air-breathing form.

The shallow littoral fauna, which was the only portion that directly affected the beach pools, could be divided into five groups according to habitat: (1) the shells of unprotected, sandy shores; (2) the shells of more or less protected, sandy to marly shores; (3) the shells of well-protected, mucky shores; (4) the deep littoral shells that came up into shallow water to breed; and (5) the shells of the submerged vegetation zones.

There follows lists with brief notes of the molluscs in the various groups. In these lists the species are divided into three classes according to size: clams, primary species, and secondary species. The notes on abundance refer to the comparative abundance in the groups; this is done in an attempt to more or less equalize the effect of the size in an attempt to prevent the direct comparison of the abundance of a large form, like a clam, with that of a small form such as, for instance, *Planorbis parvus* Say. A small form, altho very abundant, may not be such a powerful factor in the association as a species less numerous in individuals but of much larger size; it must be, understood, however, that these groups are not meant to express comparative dominance, in the sense that this is used in plant ecology.

The remarks on abundance are purely comparative; figures, however, were obtained for many of the forms by means of a quadrat study, and these will be published in a future report. The following designations are used to express this abundance: very abundant, abundant, quite abundant, very common, common, quite common, frequent, quite infrequent, infrequent, very infrequent, quite rare, rare, very rare.

1. *Shells of the unprotected, sandy shores*. In most places around the south-west end of Douglas Lake, the bottom sloped out gradually to a depth of about a meter, and dropped off more or less suddenly to deep water; along the unprotected, sandy shores, this "step-off" was particularly steep, and sometimes even attained an angle of forty-five degrees. In these places exposed to the more or less direct action of the waves and currents, the sand was constantly shifting under the action of these agents, and all of the shells were quite large burrowing forms; higher plant life was entirely absent.

Clams. (All of the clams of the lake were small, approaching the dwarfed, Great Lakes forms.)

*Lampsilis luteola* (Lam.). Abundant; from about 20 cm. of water out, mainly in about 1 m. of water near the edge of the shelf.

*Anodonta grandis footiana* (Lea). Quite abundant; distribution similar to the preceding species.

*Lampsilis nasuta* (Say). Quite common; distribution similar to the preceding.

Primary species.

*Campeloma decisum* (Say). Abundant close to shore in about 15 to 20 cm. of water, quite abundant at a depth of a meter, and considerably less numerous between these depths.

*Sphaerium acuminatum* (Prime). Infrequent; mostly at a depth of a meter or a little less.

*2. Shells of the more or less protected, sandy to marly shores*. On the northeastern shores of the bays and behind spits, etc., the shores were more protected, especially in the shallower waters. The bottom usually contained more or less marl, which often cemented the sand so as to form a rather firm, superficial layer in shallow water, while it was apt to be considerably softer in deeper water. *Scirpus americanus* usually grew along these shores, with *Scirpus validus* near the edge of the shelf. There was often a zone of *Potamogeton*, etc., along the edge of the shelf, while bunches of *Chara*, etc., were not infrequent in the shallow water of the shelf itself, and *Utricularia cornuta* often formed a sort of a sod in the places where the marl helped to form a firm superficial layer.

Clams.

*Anodonta grandis footiana* (Lea). Common; distribution similar to that along the unprotected shores.

*Lampsilis luteola* (Lam). Frequent; distribution similar to preceding species.

*Anodonta marginata* (Say). Infrequent; found mainly in deep littoral zones; found in shallow water and in more protected situations than the preceding forms.

*Lampsilis nasuta* (Say). Very infrequent; distribution similar to the first two species.

Primary species.

*Campeloma decisum* (Say). Very abundant; distribution similar to that on unprotected shelves, only more abundant thruout.

*Planorbis bicarinatus*, var approaching *portagensis* Baker. Shelf form. Abundant; from a depth of about 15 cm. to near the edge of the shelf. Most abundant in soft bottomed places at a depth of 65 cm., or in places protected by outer bars.

*Sphaerium acuminatum* (Prime). Frequent; thruout the deeper portions of the shelf.

*Planorbis campanulatus smithii* Baker. Infrequent; most numerous in about 40 cm. of water, in places where bottom was soft.

*Lymnaea emarginata*, var. approaching *angulata* (Sowerby). Shelf form. Infrequent; most numerous in about 40 cm. of water in places where there was a superficial crust.

Secondary species.

*Planorbis bicarinatus*, var., juvenile. Juvenile specimens, which were probably both the offspring of the shore form and of the deep littoral varieties, were abundant in similar situations to the adult shore form, altho usually in somewhat shallower water.

*Physa ancillaria parkeri* (Currier), juvenile. Quite abundant; mainly in 5 to 15 cm. of water on pebbles, etc., and on the firmly cemented bottom.

*Lymnaea emarginata angulata* (Sowerby), juvenile. Common in similar situations to the shelf form.

*Planorbis parvus* Say. Common; mostly in protected places in water from 10 to 35 cm. in depth. Most abundant at about 20 cm.

*Valvata tricarinata* (Say), and var. *confusa* Walker. Quite common; in similar situations to the preceding. Most numerous in about 30 cm. of water.

*Amnicola limosa* (Say). Quite infrequent; in similar situations to the preceding.

*Planorbis campanulatus smithii* Baker, juvenile. Infrequent; along with the adults.

*Physa ancillaria*, var. approaching *magnalacustris* Walker. Very infrequent; mostly in about 20 cm. of water. It appeared that some of the offspring of the deep littoral *Physa ancillaria parkeri* remained on the shelf and became this form, as has been mentioned in a former paper in regard to the forms in the outlet of Maple River (6). Air-breathing, juvenile specimens in the laboratory developed into the same form.

*Physa gyrina* Say. Very rare; a single specimen was obtained in 25 cm. of water off Pine Point.[1]

[1]This species, *Planorbis deflectus*, and *Ancylus parallelus* were not examined for the purpose of determining whether they breathed water or air, but it seemed probable that they did the latter, as all of the other pulmonates, including *Planorbis parvus*, appeared to do so.

*Pisidium* sp. Several species of *Pisidia* were obtained in this habitat, but the specimens and records were lost by fire.

3. *Shells of mucky shores*. In the most protected places, the water plants, such as white and yellow water-lilies, potamogetons, wild celery, etc., were much more abundant on the shelf and at the edge of the step-off. In consequence, there was often a considerable deposit of fine muck, and the bottom conditions of these places more closely approached the pools, than did those of the other portions of the shelf. The step-off was much more gradual in these places; often it was hardly noticeable.

Clams.

*Anodonta grandis footiana* (Lea). Frequent; depth distribution similar to that in preceding habitat.

*Lampsilis luteola* (Lam.). Infrequent; ditto preceding.

*Lampsilis nasuta* (Say). Rare; ditto preceding species.

*Strophitus edentulus* (Say). Very rare; one specimen obtained from about 35 cm. of water.

Primary species.

*Campeloma decisum* (Say). Very common; distribution similar to that in preceding habitats.

*Planorbis bicarinatus*, var. approaching *portagensis* Baker. Shelf form. Common; similar in distribution to that in preceding habitat.

*Planorbis campanulatus smithii* Baker. Quite common; distribution similar to that in preceding habitat. More numerous than the preceding species in the most mucky places.

*Lymnaea stagnalis perampla* Walker, young specimens. Frequent; mostly in water about 55 cm. in depth, and in the most mucky places.

*Sphaerium sulcatum* (Lam.). Infrequent; mostly in water about a meter in depth.

Secondary species.

*Planorbis bicarinatus*, var., juvenile. Common; similar in distribution to that in preceding habitat.

*Planorbis campanulatus smithii* Baker, juvenile. Common; in similar places to adults.

*Amnicola limosa* (Say). Frequent; similar in distribution to those of marly shores; especially numerous on sticks and debris.

*Valvata tricarinata* (Say), and var. *confusa* Walker. Quite infrequent; similar in distribution to preceding species.

*Planorbis parvus* Say. Infrequent; similar in distribution to preceding; altho usually in shallower water along with the next form.

*Physa ancillaria parkeri* (Currier), juvenile. Quite rare; similar in distribution to those on marly shores.

*Planorbis deflectus* Say. Very rare; similar in distribution to Planorbis parvus.

4. *Deep littoral shells, which came up into shallow water to breed*. As has already been mentioned in a former paper (6), there were six primary forms which lived in the deep littoral zones of Douglas Lake, but came up on the shelf to breed. These apparently came up in a regular order during the summer and at quite separate times, except in colder summers, like that of 1912, when they came up crowded together in the early part of September, altho apparently in the same order as before.

*Planorbis bicarinatus portagensis* Baker. Bred in great abundance, in similar situations to habitat of shelf form; came up usually in midsummer.

*Lymnaea emarginata angulata* (Sowerby). Bred in abundance, in similar situations to the habitat of the juvenile specimens in group 2; came up in latter part of July, slightly later than the preceding species.

*Physa ancillaria parkeri* (Currier). Appeared common; in water from 10 to 35 cm. in depth, especially in places where there was a firm, marly crust. Most numerous at about 20 cm. Apparently came up in the early part of June.

*Planorbis bicarinatus percarinatus* Walker. Frequent; in similar places and at a similar time to the other variety of *P. bicarinatus*.

*Lymnaea stagnalis perampla* Walker. Frequent; bred in mucky-bottomed and weedy situations. Found in great abundance near the middle of July in the mouth of Bessey Creek in the summer of 1911.

*Planorbis campanulatus smithii* Baker. Quite infrequent; bred mainly along mucky-bottomed shores with the shelf form. The time was difficult to determine as the deep littoral immigrants are difficult to distinguish from the form which inhabited the shelf; apparently it was nearly coincident with that of the varieties of *P. bicarinatus*. This variety was less completely a deep littoral form than were the others; the shelf form was not so noticeably increased in numbers during the immigration.

5. *Shells of the vegetation zones*. As has already been mentioned, there were considerable areas at the edge of the shelf, especially along the mucky shores, which were taken up by various aquatic plants. These zones only occurred in the protected places.

Primary species.

*Lymnaea stagnalis perampla* Walker, young shells. Quite infrequent.

Secondary species.

*Amnicola limosa* (Say). Very abundant.

*Valvata tricarinata* (Say), and var. *confusa* Walker. Quite common.

*Planorbis parvus* Say. Quite common.

*Ancylus parallelus* Haldeman. Frequent; especially on lily pads.

*Planorbis deflectus* Say. Quite rare.

## B. MOLLUSCS OF LAKE LAGOONS AND POOLS.

### I. BARRIER BEACH TYPES.

*a. Barrier Beach Pools on South Point*. (Map 2, a; maps 3, 4, 5, and 6.) The barrier beach pools of Douglas Lake, as has already been mentioned, were so small that their depth was less than the annual range of the surface level of the lake itself, and so they were built and destroyed each year. On this account, the shells of these pools were simply landlocked forms from the lake itself, and showed no ecological succession of pool forms.

These pools were mainly formed on South Point, on the northeast side of the lake about midway between North and South Fish Tail Bays. They were situated in a place that would have been open to the action of the strongest waves, except for the presence of a large triangular bar of peculiar formation (map 2, 0), which caused the water to be not much more than a meter deep for nearly a mile off shore. For these reasons, there were apparently almost no shelf forms except the clams and *Campeloma decisum*. These lagoons and pools were, however, favorite breeding places for *Lymnaea emarginata angulata*, *Planorbis bicarinatus portagensis* and *P. bicarinatus percarinatus*, and large numbers of these species were landlocked, and subsequently many of them killed, during the summer of 1911. *Physa ancillaria parkeri* must have bred here also, as the juvenile specimens were found, in considerable numbers, during the summers of 1911, and 1913, and to some extent in. 1912. Small specimens approaching *Physa ancillaria magnalacustris* were also obtained.

### II. SAND SPIT TYPES.

On the other hand, the sand spit pools of Douglas Lake, like the barrier beach pools of Saginaw Bay, were major features and often predicated a long life history. Four lagoons and pools, in different stages of completion, were studied; these were, in order of their apparent age: the Pine Point Lagoon, the Hook Point Lagoon, the Swamp Point Lagoon, and the Sedge Point Pool. The situations of these four were more or less similar, in that they all were produced along the north-east side of the lake, the first two and the last along the shore north of North Fish Tail Bay, the last on its south shore. They apparently were produced by the currents that were diverted along the shore of the lake to the east of the triangluar bar already mentioned.

#### a. Description of Different Examples.

*1. The Pine Point Lagoon*. (Map 2, b; map 7). During the summer of 1912, a spit was initiated to the south-east of Pine Point by a heavy storm from the west and south-west; in the summer of 1913, this had developed far enough to partially enclose a small lagoon. This was choked with *Scirpus americanus*, and also contained a few scattered potamogetons, *Eleocharis*, bunches of *Chara*, etc. The bottom was at first of sandy marl, similar to the bottom of the shelf in that portion, but soon

accumulated considerable quantities of debris, muck, etc.

Clams.

*Anodonta grandis footiana* (Lea). Infrequent; a few stray specimens were noticed.

Primary species.

*Campeloma decisum* (Say). Abundant.

*Planorbis bicarinatus*, var. approaching *portagensis* Baker, shelf form.

Abundant.

*Physa ancillaria parkeri* (Currier). Common, during breeding period.

*Lymnaea emarginata angulata* (Sowerby). Frequent; during breeding period.

*Planorbis campanulatus smithii* Baker. Infrequent.

*Lymnaea stagnalis perampla* Walker. Very infrequent; during breeding periods.

Secondary species.

*Planorobis bicarinatus*, var. juvenile. Abundant.

*Physa ancillaria parkeri* (Currier); juvenile. Very common.

*Planorbis parvus* Say. Frequent.

*Lymnaea emarginata angulata* (Sowerby); juvenile. Frequent.

*Amnicola limosa* (Say). Frequent.

*Valvata tricarinata* (Say), and var. *confusa* Walker. Infrequent.

*2. The Hook Point Lagoon*. (Map 2, c; map 8). Inside the inner curve of the sand spit, at the end of Hook Point, was a marshy lagoon in which the water was quite shallow, reaching a depth of 30 cm. The shelf adjacent was mucky bottomed and was covered with patches of white and yellow water-lillies; the lagoon itself was choked with such plants as *Scirpus americanus*, *Hypericum virginicum*, *Dulichium arundinaceum*, *Lobelia cardinalis*, *Eupatorium perfoliatum*, and a few, short-stemmed plants of *Castalia odorata*, while at one end there was a considerable growth of *Myrica gale*.

Primary species.

*Planorbis bicarinatus*, var. approaching *portagensis* Baker; shelf form. Infrequent.

*Campeloma decisum* (Say). Infrequent; young.

*Lymnaea stagnalis perampla* Walker. Very rare; young specimens.

Secondary species.

*Amnicola limosa* (Say). Abundant.

*Planorbis bicarinatus*, var.; juvenile. Quite common.

*"Pisidium*, juvenile, apparently *regulare* Prime."[1] Quite common.

*Planorbis hirsutus* Gould. Quite common.

*Planorbis deflectus* Say. Infrequent; dead shells.

*Musculium securis* (Prime). Infrequent.

*Physa ancillaria parkeri* (Currier); juvenile. Very infrequent.

*Pisidium sargenti* Sterki. One specimen; “not typical."

*3. Swamp Point Lagoon*. (Map 2, d; no separate map). On Swamp Point, the sand spit had surrounded the lagoon to a greater extent than at Hook Point; there was only a channel, a few centimeters deep, connecting it with the main lake in 1911; and this was also filled in by the growing spit during the summer of 1913, so that it was only open during very high water. The bottom of the shelf nearby was more or less mucky and there was a considerable development of the weed zones, which reached very close to shore on account of the exceptional narrowness of the shelf in this portion of the lake. The bottom of the lagoon was also covered with marly muck, but this deposit was thicker and was also mixed with decayed and matted rushes and other plant remains. This lagoon closely approximated a pond, both in fauna and flora. Some of the prominent plants were *Spartina michauxiana*, *Scirpus validus*, *Phragmites communis*, *Scirpus americanus*, *Potentilla palustris*, *Lobelia kalmii*, and *Rosa carolina*.

Primary species.

*Campeloma decisum* (Say). Infrequent; young specimens.

Secondary species.

*Musculium securis* (Prime). Quite common.

*Segmentina crassilabris* Walker. Quite common.

*Lymnaea obrussa* Say. Infrequent; young specimens.

*Pisidium sargenti* Sterki. A few young specimens, "small and slight."

*Planorbis bicarinatus*, var.; juvenile. Rare.

*Planorbis* sp. Rare; juvenile, too young to be identified.

*Physa ancillaria parkeri* (Currier), juvenile. Rare.

[1]The pisidia were indentified by Dr. V. Sterki, and the notes in quotation marks were made by him.

*4. Sedge Point Pool.* (Map 2, e; map 9). At Stony Point, somewhat over a hundred yards west of Sedge Point, a steep, stony bank sloped up directly from the waters edge to a height of from fifteen to twenty feet. This "sea-cliff" showed signs of considerable, recent erosion at the base, while to the east of it a long ridge became apparent; the whole of the latter had apparently been formed as a sand spit from the sand worn away from Stony Point and other places along the shore. Ice had apparently assisted in building this spit.

Behind this ridge were a series of swamps and ponds, beginning with areas of damp, low ground near Stony Point, and terminating in the large pond shown on the map of Sedge Point (Map 9). Beyond Sedge Point, as can be seen from the map, a submerged continuation of the spit extended out towards Pine Point, and this was apparently separating a new pool. The bottom of the shelf on the outer side of this latter portion of the spit was quite sandy and unprotected, but the bottom behind it was covered with a considerable deposit of marl.

The Sedge Point Pool was mucky-bottomed and the water had a reddish tinge, probably due to iron. The center of the pond was free from vegetation, except for a few scattering potamogetons, but around the dege was a more or less complete zone of water plants. This was dominated by *Scirpus validus*, intermixed with water-lilies, along the inner shores, and by *Scirpus americanus* along the outer and eastern edges. In the shallow water, especially along these latter shores, was a thick growth of such plants as *Hypericum virginicum*, *Dulichium arundinaceum*, *Proserpinacea palustris*, *Lobelia cardinalis*, *Eupatorium perfoliatum*, and *Sium cicutaefolium*. At the western end the bottom was very mucky and was dominated by such plants as *Phragmites communis* and *Typha latifolia*. It was in the shallow water around the eastern end, where the mucky layer was least prominent, that most of the shells were found.

Clams.

*Anodonta grandis footiana* (Lea). Very rare; in the central, weedless area.

*Lampsilis nasuta* (Say). Very rare; ditto preceding.

Primary species.

*Lymnaea stagnates appressa* (Say), rarely somewhat approaching *perampla* Walker. Very abundant, but usually not very large. One of the largest measured: altitude 41.9 mm., diameter 21.2 mm., aperture length 23.1 mm.

*Planorbis trivolvis* Say. Infrequent; shells quite small and flat. The largest specimen measured: greater diameter 18.6 mm., lesser diameter 15.5 mm., altitude of aperture 7.1 mm.

*Lymnaea exilis* Lea. Apparently infrequent. The largest specimen obtained measured: altitude 36.7 mm, diameter 11.7 mm., length of aperture 16.7 mm.

*Planorbis campanulatus smithii* Baker. Only dead shells obtained.

CHART II.—COMPARISON OF BEACH POOLS OF DOUGLAS LAKE.

| | Pine Point L. | Hook Point L. | Swamp Point L. | Sedge Point P. | Temporary swamps. |
|---|---|---|---|---|---|
| Clams. | | | | | |
| *Anodonta grandis footiana* (Lea) | I | | | vR | |
| *Lampsilis nasuta* (Say) | | | | vR | |
| Primary species. | | | | | |
| *Planorbis campanulatus smithii* Baker | I | | | | |
| *Lymnaea emarginata angulata* (Sowerby) | Fb | | | | |
| *Physa ancillaria parkeri* (Currier) | Cb | | | | |
| *Lymnaea stagnalis perampla* Walker | vIb | vRy | | | |
| *Planorbis bicarinatus*, shelf form | A | I | | | |
| *Campeloma decisum* (Say) | A | Iy | Iy | | |
| *Physa ancillaria* Say, var | | | | vR | |
| *Lymnaea stagnalis appressa* (Say) | | | | vA | |
| *Lymnaea exilis* Lea | | | | I | |
| *Planorbis trivolvis* Say | | | | I | |
| *Aplexa hypnorum* (L.) | | | | | qA |
| *Lymnaea palustris* (Mueller) | | | | | Cl |
| Secondary species. | | | | | |
| *Valvata tricarinata* (Say) and *confusa* Walker | I | | | | |
| *Lymnaea emarginata angulata* (Sowerby), juven. | F | | | | |
| *Planorbis parvus* Say | F | | | | |
| *Amnicola limosa* (Say) | F | A | | | |
| *Physa ancillaria parkeri* (Currier), juvenile | vC | vI | R | | |
| *Planorbis bicarinatus*, var., juvenile | A | qC | R | | |
| *Pisidium regulare* Prime? | | qC | | | |
| *Planorbis hirsutus* Gould | | qC | | I | |
| *Planorbis* sp? | | | Rj | | |
| *Pisidium sargenti* Sterki | | vR | vIy | | |
| *Musculium securis* (Prime) | | I | qC | A | |
| *Segmentina crassilabris* Walker | | | qC | vA | |
| *Lymnaea obrussa* Say | | | Iy | vR | |
| *Pisidium variabile* Prime | | | | R | |
| *Sphaerium occidentale* Prime | | | | | vC |
| *Planorbis umbilicatellus* Cockrell | | | | | I |

CHART III.—COMPARISON OF POOLS OF DIFFERENT REGIONS.

| | Sand Point (19). | Stony Island (19). | Near Rush Lake (19). | "Long Lake" (9). | Sedge Pool (13). | Sedge Point Pool. |
|---|---|---|---|---|---|---|
| Clams. | | | | | | |
| *Anodonta grandis footiana* (Lea) | | | | | | vR |
| *Lampsilis nasuta* (Say) | | | | | | vR |
| Primary species. | | | | | | |
| *Planorbis trivolvis* Say | A | A | A | A | A | I |
| *Lymnaea lanceata* (Gould)[1] | C | C | | | | |
| *Lymnaea kirtlandiana* (Lea) | | | | | R | |
| *Lymnaea palustris* (Mueller) | R | | I | | | |
| *Lymnaea exilis* Lea | | | | | | I |
| *Lymnaea stagnalis appreesa* (Say) | | | | | A | vA |
| *Physa gyrina* Say | | | C | | I | |
| *Physa elliptica* Lea | I | | | | | |
| *Physa ancillaria* Say, var | | | | | | R |
| *Aplexa hypnorum* (L.) | I | | I | | | |
| Secondary species. | | | | | | |
| *Musculium securis* (Prime) | A | A | A | A | ? | A |
| *Musculium ryckhaltii* (Norman) | | R | | | | |
| *Musculium truncatum* (Linsley) | I | | | | | |
| *Sphaerium occidentale* Prime | I | | I | | | |
| *Pisidium variabile* Prime | | | | | | I |
| *Segmentina crassilabris* Walker | | | C | | | vA |
| *Segmentina armigera* (Say) | C | | C | | | |
| *Planorbis parvus* Say | I | | | | | |
| *Planorbis deflectus* Say | | I | | | | |
| *Planorbis exacuous* Say | I | | | I | | |
| *Planorbis hirsutus* Gould | | C | | | | I |
| *Planorbis umbilicatellus* Cockerell | | | | | R | |
| *Planorbis crista* (L.) | | R | | | | |
| *Amnicola walkeri* Pilsbry | R | | | | | |
| *Lymnaea obrussa* Say | I | | | | | R |

[1]This was published as *Lymnaea reflexa* Say, and var., in previous papers (4 and 5), but the writer has since come to the conclusion that it was the *Lymnaea lanceata* (Gould) of F. C. Baker (2).

*Physa ancillaria* Say, var. Two specimens were obtained which appeared to be close to this species. They were quite dark brownish horn in color, with a purplish brown callus. The largest example measured: altitude 11.7 mm., diameter 7.3 mm., aperture length 9.3 mm., while a specimen of *Physa ancillaria parkeri*, from the shore of the lake, measured: 12.3 mm., 9.2 mm., 10.5 mm.

Secondary species.

*Segmentina crassilabris* Walker. Extremely abundant.

*Musculium securis* (Prime). Abundant.

*Planorbis hirsutus* Gould.

*Pisidium variabile* Prime. Rare.

*Lymnaea obrussa* Say. Very rare.

b. Comparison of Different Pools.

To bring out more clearly the relationships of these different pools, two charts were prepared: one, (chart 2), comparing the four lagoons and pools of Douglas Lake, while the other (chart 3), the pools of three different regions in northern Michigan. Six pools were shown in this last chart; the first four from Huron County (5), the fifth from Dickinson County (7), and the sixth the Sedge Point Pool of Douglas Lake.

The pools in the first class were the remnants of small, sand-spit lakes on the south side of Sand Point; the fourth was "Long Lake," a barrier beach pool on the north side. The pools on Stony Island were formed on a large sand spit which, in fact, constituted most of the island, but were separated from Saginaw Bay by what appeared to be a barrier beach; they were on the less protected side of the island. On the other hand, the pools near Rush Lake in Huron County, and the sedge pool of Dickinson County, were formed in connection with streams. The first were apparently creek-flat pools; the second was a glacial depression which was close to the Sturgeon River, and certainly drained into the latter, during high water, if it was not flooded by it.

From chart 3, it will be seen that the characteristic pool molluscs of these portions of northern Michigan were: *Planorbis trivolvis* among the larger species, and *Musculium securis* among the smaller ones. The presence of some medium-sized *Lymnaea* was also quite typical; in the Sand Point and. Stony Island pools, *Lymnaea lanceata*, derived from the lagoon formations of Saginaw Bay, was quite common, while in the pools near Rush Lake and in Dickinson County, *Lymnaea palustris*, with varieties, and *Lymnaea kirtlandiana*, respectively, appeared to be the pioneers of the temporary swamp conditions (see chart 4). *Lymnaea exilis* seemed to be the example of this type in the Sedge Point Pool, while both in it and in the sedge pool of Dickinson County, *Lymnaea stagnalis appressa*, a shell more characteristic of larger bodies of water, was very numerous. Another characteristic genus was *Segmentina*, one or the other of the two species being usually present.

It will be noticed that, in this paper and in former papers by the writer, the line between lakes and pools was apparently drawn farther along than by Shelford (13), or by F. C. Baker (1); in fact, the pools of the writer appear to correspond to the senescent stages, at least in the molluscan fauna, of those described by Shelford. The writer did not find, in any of the three regions mentioned, *Planorbis campanulatus* or *Amnicola limosa* in any pool closed off from the parent lake or stream, and the Sedge Point Pool was the only one where clams were found. This partly might have been due to the differences in location; the three regions, described by the present writer, were all considerably north of Chicago, and the colder winters, on account of the greater amount of ice and the resultant stagnancy, might have prevented the life of such forms in the shallow waters of the pool formation. It also might have depended partly on the point of view of the writer; I would have called the senescent pools of Shelford the typical pools, perhaps because, in the more northern regions, the transition stages between the lake and pool, which were most prominent in the latter writer's descriptions, appeared to be passed thru more quickly. Also, the molluscs present in the "senescent" stages were the only ones common to all pools, no matter what their method of formation. The pools of the writer appeared to resemble more closely the prairie pools of Shelford, perhaps because these apparently did not show transition stages connecting them with the larger lakes, and so lacked relict species from those formations.

To return to Douglas Lake, the Pine Point Lagoon had about the same shells as the adjoining, marly bottomed shelf (groups 2 and 4), only, as the bottom was more mucky, a few of the mucky bottomed shelf forms were more numerous (Groups 3 and 4). This was what might have been expected from the youngest lagoon of the series; a year or two was not enough time to develop a divergent fauna or to cause a disappearance of the old one.

The second of the series, in completeness of separation and in age, was the Hook Point Lagoon. Here was found a considerable reduction in the lake forms; the single clam, four of the primary species, and three of the smaller forms had disappeared, while of the remaining ones were less numerous, with the single exception of *Amnicola limosa*, which increased greatly in numbers. This exception may have been due to the fact that the present lagoon was more closely connected with a mucky-bottomed shelf and with the weed zones, while the preceding one was adjacent to a marly-bottomed portion. Two new forms, not including the pisidia on account of the loss of the records of the shelf forms, had appeared in the Hook Point Lagoon, one being common, the other infrequent. The latter of these, *Musculium securis* has already been mentioned as one of the most characteristic pond forms.

In the Swamp Point Lagoon was found a still greater reduction of the lake forms. All of the primary species had disappeared as such, with the exception of *Campeloma decisum*, while two others were sparsely present as juveniles. *Planorbis hirsutus* was not found, but juvenile specimens of a *Planorbis*, too young to be identified, appeared partly to take its place. On the other hand, *Segmentina crassilabris*, another pond species, had appeared.

The Sedge Point Lagoon differed somewhat from the others; judging from its greater size and probably far greater age, it must have been separated from the main lake much more slowly. All of the lake forms had disappeared, with the exception of the two clams, which were rare and had probably persisted on account of the large size of the pond.[1] However, two of the lake shells, *Physa ancillaria parkeri* and *Lymnaea stagnalis perampla* (group 4), were represented by changed varieties, *Physa ancillaria*, var., and *Lymnaea stagnalis appressa*, respectively. In addition, two new, primary

species had appeared, both of them more or less characteristic of ponds; in fact, the first, *Planorbis trivolvis*, already has been cited as the most typical, large form of the ponds of northern Michigan. Among the secondary species, not counting the pisidia, all of the forms that appeared in the other lagoons were present; they were also in greater numbers than in the smaller lagoons, with the single exception of *Lymnaea obrussa* which had fallen off in abundance.

CHART IV.—COMPARISON OF TEMPORARY SWAMPS OF DIFFERENT REGIONS.

| | Sand dune swamps (18). | Rich, clay swamps (18). | Burnt, tamarack S. (14). | McKinnon Brook Flats (15). | Douglas Lake Region. |
|---|---|---|---|---|---|
| Primary species. | | | | | |
| *Lymnaea palustris* (Mueller) | vA | vA | | | Cl |
| *Lymnaea kirtlandiana* (Lea), var | | | | vA | |
| *Aplexa hypnorum* (L.) | A | A | qAd | qC | qA |
| *Physa gyrina* Say | | qC | | qC | |
| *Pgyrina, var. hildrethiana* (Lea) | | I | | | |
| *Physa elliptica* Lea | I | | | | |
| *Physa heterostropha* Say | | | | Rj | |
| Secondary species. | | | | | |
| *Sphaerium occidentale* Prime | A | A | | A | A |
| *Musculium truncatum* (Lindsley) | qA | qA | | | |
| *Musculium partumeium* (Say) | I | I | | | |
| *Pisidium roperi* Sterki | | | vAd | I | |
| *Planorbis parvus* Say | C | C | Ad | C | |
| *Planorbis parvus walkeri* Vanatta | | R | | | |
| *Planorbis umbilicatellus* Gould | R | R | | | I |
| *Planorbis exacuous* Say | | | | A | |
| *Segmentina crassilabris* Walker | | C | | | |
| *Lymnaea obrussa peninsulae* (Walker) | | | Id | | |
| *Lymnaea sp?* | | Rj | | | |

[1]It is well within the limits of possibility that these were introduced artificially, by students or by fishermen.

## III. TEMPORARY SWAMPS.

### a. Description of Swamps.

On Grapevine and Hook Points were found remnants of old ponds which had become temporary swamps, mainly thru the deposit of humus by the water plants and the surrounding forest trees. These were mostly small and rather barren, and were dry during a large proportion of the summer. Another swamp was reported from near the north shore of North Fish Tail Bay, which appeared from the description to be richer; here *Lymnaea palustris* was said to be quite abundant, but the writer was never able to find the place. There were also some larger swamps along the flats of Bessey Creek, at the other end of the lake, but these appeared very similar to those first mentioned. *Lymnaea palustris* was also found along the Maple River, the outlet of Douglas Lake.

There were also many other small hollows thruout the burnt-over, poplar and second growth regions around Douglas Lake, most notably behind the first sand ridge along the south-east shore; this latter might be regarded as a barrier beach formation secondarily increased by wind blown sand. These were similar to the hollows in the sand dunes of Huron County (5), which almost always contained little temporary swamps. These places around Douglas Lake may have contained similar swamps before the fires; in fact, *Nemopanthus mucronata*, a bog plant, was found growing in one of these dry hollows, and a burnt, bleached specimen of *Succinea retusa* was picked up in another. However, the fire had burnt out the mosses, leaves and humus and had destroyed the shading shrubs and trees, all of which formerly prevented rapid absorption and evaporation of the water, so that finally the pervious, sandy soil sucked up the rain almost as fast as it fell. A similar destruction was more apparent in Dickinson County, Michigan, on similar soil (7); hollows, which contained no water in the summer after the disastrous fires of 1908, were still choked with the scorched trunks of the dead tamaracks, etc., and still contained large numbers of dead and partially burnt, aquatic shells.

Primary species.

*Aplexa hypnorum* (L). Quite abundant.

*Succinea retusa* Lea. Quite abundant; semi-amphibious.

*Lymnaea palustris* (Mueller). Common; local.

Secondary species.

*Sphaerium occidentale* Prime. Very common.

*Zonitoides nitida* (Mueller). Frequent; semi-amphibious.

*Planorbis umbilicatellus* Cockerell. Infrequent.

### b. Discussion of Swamp Forms.

In Chart IV, the temporary swamps of the same three regions in northern Michigan have been listed, and their molluscan faunas tabulated, after the manner of those of the permanent ponds. The first two pools were in Huron County, the second two in Dickinson County, the fifth in the present region. The first were temporary swamps formed between the sand dunes of Sand Point, the second the richer, forest swamps of the flat, clay-soiled regions around Rush Lake (5). The third was a burnt-over tamarack swamp, which differed considerably from the other swamps, and was listed, in this connection, to call further attention to the destruction of temporary swamps by fire, a matter which has already been discussed. The characteristic shell of such tamarack swamps appeared to be *Pisidium roperi*. The fourth of swamps were those formed on the mud flats of McKinnon Brook, a small stream, which flowed out of the clay moraines thru the sandy, outwash regions.

It will be seen from this chart that *Aplexa hypnorum* was the most characteristic of the large molluscs, as *Sphaerium occidentale* was of the smaller. Two medium-sized species of *Lymnaea* also appeared to be connected with this habitat: *Lymnaea palustris* in Huron County and around Douglas Lake, and *Lymnaea kirtlandiana*, var., in Dickinson County. In addition, small planorbices seemed to be present quite universally, while *Musculium truncatum* and, to a lesser degree, *Musculium partumeium* were important swamp forms in Huron County. (Compare 3, Station XXI).

The temporary swamps around Douglas Lake seemed to be quite typical in regard to their molluscan fauna; two of the most typical forms were quite numerous, while a third appeared to be common locally, and the small planorbices were represented by *Planorbis umbilicatellus*. They were quite barren, however, and only contained these widely distributed forms, while the other swamps listed contained some accessory species; this was most noticeable in the rich, hardwood swamps around Rush Lake.

SUMMARY.

a. Environmental Differences Between Lakes, Pools and Swamps.

There seemed to be seven main factors that differentiated the various stages of this form of the lake-pond-swamp series, and these were all largely dependent on the size, depth and amount of protection of these bodies of water. The seven factors were: (1) the amount of wave action, and the "roughness" of the water, (2) the comparative extent of the shallow littoral conditions, as compared to the remainder of the body of water, (3) the constancy in amount of water, (4) the isolation, (5) the amount and character of the vegetation, (6) the temperature, and (7) the proportion between the surface and the entire volume of the body of water. Some of these factors were reflected by marked adaptations in the molluscs; the effects of others would have to be determined by closer observation and experiment.

*I. The Amount of Wave Action.* The lakes naturally developed much larger waves than did the ponds and swamps; Douglas Lake sometimes was disturbed by waves six feet in height between trough and crest, while the pools and swamps were mostly smooth or were affected by small ripples. The lagoons, however, altho much less disturbed than the open lake or the unprotected shores, were much more open to wave action than were the enclosed pools.

In this connection, two adaptations were noticeable among the molluscan forms of the lake, in contrast to the pools and swamps: (1) the prominence of burrowing forms in the lake, and (2) the adaptations of the lake molluscs for breathing water. Group 1, of the lake, has already been described as consisting entirely of rather large burrowing forms, and, while their relative prominence fell off with increasing protection, they were present in Groups 2 and 3 at certain depths. The varieties of *Planorbis bicarinatus* and *Planorbis campanulatus smithii* were also semi-burrowing in habit. This fauna became inconspicuous in the lagoons and usually disappeared in the pools, altho the Sedge Point Pool contained two clams; it was entirely absent in the temporary swamps.

The second of these factors was even more prominent. All of the shells of Douglas Lake breathed water (with the possible exceptions already noted), while all of the forms of the Sedge Point Pools, with the exception of the *Sphaeridae* and the two, rare clams were air breathers, as were also the forms of the temporary swamps with the exception of *Sphaerium occidentale*. The pulmonates of the Pine Point and Hook Point Lagoons appeared to breathe water like those of the lake, but those of the Swamp Point Lagoon were air-breathers as far as could be examined. The comparative infrequency of the gill-breathing forms in the pools might have been partly due to the next factor to be taken up, but it certainly seemed probable that the water-breathing adaptations of the larger pulmonates in the lake was forced on them by their inability to take air unless the surface of the water was comparatively smooth. The six, deep littoral forms of group 4 were all peculiar varieties, as has been mentioned in a previous paper (6), with their basal whorls considerably enlarged, apparently to allow for the increased capacity of their lungs which was correlated with this habit of filling them with water. Two of them, *Physa ancillaria parkeri* parked and *Lymnaea stagnalis perampla*, as has already been mentioned, had changed in Sedge Point Pool to the more slender, air-breathing forms, *Physa ancillaria*, var., and *Lymnaea stagnalis appressa*, respectively.

*II. Comparative Extent of Shallow Littoral Conditions.* In most places in Douglas Lake, the shallow littoral zone formed only a narrow shelf fringing the shore, while in the pools and swamps there were no other conditions present. This resulted in two important differential effects on the lake fauna: (1) the free immigration of the deep water forms of the lake, and (2) the fact that the shallow littoral forms were not completely dependent on the water above them for food and air.

The shelf of the lake was open to the immigration of the deep water forms, and the opposite was also true, and the migrations of the deep littoral forms of group 4 certainly showed to what extent competition between the inhabitants of the different zones was possible. On the other hand, the food and air supply of the shelf was added to constantly by the contributions of the wind-developed currents which brought the plankton and air in from the entire surface of the lake, while the pool and swamps forms were completely dependent on the water above them for these necessities. This lack of aeration by change in the water might have been one of the factors that caused the predominance of air-breathing forms in the pools altho its influences must have been largely counterbalanced by other methods of aeration. It certainly seemed as if the food supply must have had a strong effect in the elimination of the larger species from the latter habitats. It would take a rather large pool, for instance, to supply enough food for a self-reproducing body of clams, and they certainly would not be anywhere near so abundant as in the same area on the shelf.

*III. Constancy in Amount of Water*. The lake had practically a constant water supply, but in the pools the amount of water was subject to great variation, while in the swamps comparative dessication was the dominant feature during much of the time. As a result, the pool forms had to be more able to resist change in the amount of water with its attendant dilution and concentration of the mineral content and other substances. In addition, the shells of the swamps needed adaptations for the resistance of drought, and these were found to be present. All of the shells of the swamps were able to live for some time out of water, either burrowed in the mud or up on the water plants, with an epiphragm closing the aperture.

In the cases of *Lymnaea palustris* and *Aplexa hypnorum*, the egg-masses must have been able to resist even greater dessication, as the bottoms of pools, which had

been dry for some time, were dug up without the discovery of any living shells, and yet the juvenile shells appeared in great numbers during the next rainy season. Specimens of the *Sphaerium occidentale* were also found, in which the animals were all dead, but the damp decaying bodies contained numbers of living, juvenile specimens, protected within the shells of the viviparous parents. Experimental data, on the abilities of different molluscs and their eggs to resist dessication and stagnancy of the water, would be very interesting and important in this connection.

*IV. Isolation.* Lakes are usually connected with other lakes and with large streams by at least temporary streams, and can receive their fauna in this way; Douglas Lake was no exception in this regard (6). The pools and swamps, on the other hand, were usually more completely isolated from other similar habitats. The ponds, it is true, could receive some of their fauna from or thru the parent lake before complete separation from it, but it was often very difficult to find signs of how this would be accomplished; the nearest specimens of *Planorbis trivolvis* to those of the Sedge Point Pool were found in the mouth of a brook three miles away, and these latter were totally different in form and appearance. A single specimen of *Physa gyrina* in group 2, and another of *Strophitus edentulus* in group 3, showed how stray specimens might often be found at a considerable distance from their associates of the same species, and the pools might have been largely populated by similar wandering migrants.

The temporary swamps present a still more difficult problem. The shells in them were found nowhere else around the lake, and they were not connected with each other or with the lake even by temporary streams. It must have been that their comparative tolerance of dessication enabled them, or their eggs, to be carried easily, by birds, etc., from pool to pool.

*V. The Vegetation*. The swamps and pools usually contained a greater amount of vegetation than did any portion of the lakes with the exception of the weed zones, and it was also of a different character. This, of course, had a marked effect or the deposition of humus and on the amount of humic acids in the water. However, the effects of this were not especially brought out.

*VI. The Temperature*. During the summer, the temperature of the pool was considerably higher than those of the littoral zones of the lake, and must have been lower in winter. This was especially true of the beach pools, exposed to the direct sun on the treeless, sandy beaches. This must have had a considerable effect on the shells themselves, and on their food supply.

*VII. Proportion between Area of Surface and Total Volume*. The larger area of the surface of the pools, in proportion to the total amount of water, was in very marked contrast to that of the lake; this strongly effected the preceding factor, and also allowed greater aeration and also greater evaporation in the former habitats. The greater evaporation apparently resulted in high mineral content; the iron deposits of beach pools were apt to be quite prominent and must have been attended by higher concentration of other materials, altho this was not especially tested.

b. Conclusion.

In conclusion, it might be remarked that the beach pools of Douglas Lake gave a marked example of animal succession. As the waves and currents built up the spits and bars, the environment changed, and along this differentiation came changes in the molluscan fauna. The fauna, however, had little effect on these initial metamorphoses, but after the separation, and during it, there must have been considerable competition between the old and the new forms. In addition, they must have become considerable factors in the small pools, by changing the gaseous and organic content, etc. In this succession, the larger species of the lake habitats appeared to-be the first to go, while the secondary forms appeared to be the pioneers. Part of this latter, apparent succession may have been due, however, to the large size of the climax pool as compared with the lagoons.

Despite the considerable effects of the animals on their environment, the physical factors were the main causes of the change from lake to pool, while the vegetation appeared to be the main factor in the change from pool to temporary swamp. Animal ecology, even as compared to plant ecology, seemed to be much more the study of habitats than of associations.

Colorado College, Nov., 1914.

KEY TO MAPS AND CHARTS.

*Chart. I. Classification of Lakes of Temperate Regions,*
*Chart II. Comparison of Beach Pools of Douglas Lake.*
*Chart III. Comparison of Pools of Different Regions.*
*Chart IV. Comparison of Temporary Swamps of Different Regions.*

ABREVIATIONS USED IN CHARTS.

| | | | |
|---|---|---|---|
| A | abundant. | q | quite. |
| b | breeding, only. | R | rare. |
| C | common. | v | very. |
| d | dead. | y | young. |
| F | frequent. | The numbers refer to the numbers of the habitats given in former papers (5, 7). | |
| I | infrequent. | | |
| j | juvenile. | | |
| l | local. | | |

*Map 1. Map of the Northern End of the Southern Peninsula of Michigan, showing Beaches of Glacial Lakes Algonquin and Nipissing.*[1]

The cross-hatched portions show what was land during the time of the Algonquin highest beach level; the highest Nipissing beach is represented by the line just inside the present lake shore and surrounding Mullet, Burt and Crooked Lakes. The figures in the different lakes are their approximate heights above sea-level. The large squares represent the townships, or areas six miles square. (Reproduced from 6).

[1]The data for this map were taken from the large map accompanying (11), from (12), and from corrections kindly made by Mr. Leverett from his field notes.

*Map 2. Douglas Lake.*

| | | | |
|---|---|---|---|
| a | barrier beach pools. | h | North Fish Tail Bay. |
| b | Pine Point. | j | South Fish Tail Bay. |
| c | Hook Point. | k | Grapevine Point. |
| d | Swamp Point. | l | head of Carp Creek. |
| e | Sedge Point. | m | Maple River. |
| f | South Point. | n | Bessey Creek. |
| g | Stony Point. | o | outer edge of triangular bar. |

*Maps 3, 4, 5 and 6. Barrier Beach Formation.*

Four successive maps made of the same region in the summer of 1912, surveyed on July 22, July 30, August 16, and September 5, respectively. All four maps made on the scale; the oblong area inside of the two cross-lines in maps 5 and 6 represent the entire area of maps 3 and 4. (Size 25 by 30 m.) Cross-hatched areas represent land. Contour interval, showing depths of water, 5 cm. *st* and dotted lines represent stony-bottomed areas; *r*, a rock; the remainder of the bottom was sandy. Numbers represent depths in cm.

*Map 7. Pine Point Lagoon;* made July 29, 1912.

Contour interval, showing depths of water, 5 cm. Squares, shown only on land, 5 m. each way. This map shows the lagoon just after it was formed; in 1913 the spit was one-third longer and more completely surrounded the pond.

*Map. 8. Hook Point;* made August 20, 1912.

Contour interval, showing depths of water, 20 cm., out to 1 m. in depth, beyond which it is 1 m.; the latter only shown in depression behind outer spit, in the upper, left hand corner of the map. Squares, shown only on land, 25 m. each way. *H. P. L.*, Hook Point Lagoon. Dashes indicate distribution of *Scirpus americanus*.

*Map 9. Sedge Point and Sedge Point Pool;* made August 1, 1912.

Contour interval, showing depths of water, 10 cm., out to depth of 1 m.; no contours shown beyond that depth; 10 cm. contour omitted, except in pool. Squares, shown only on land, 25 m. each way. Dashes indicated distribution of *Scirpus americanus*; dots of *Scirpus validus*. Broken line indicates margin of trees. The line inside the shore-line represents the high water mark for that year, about 20 cm. above level when map was drawn. *S. P. P.;* Sedge Point Pool.

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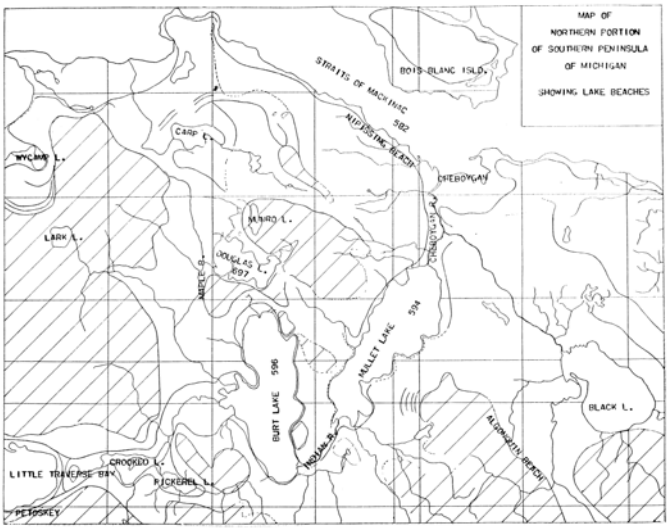
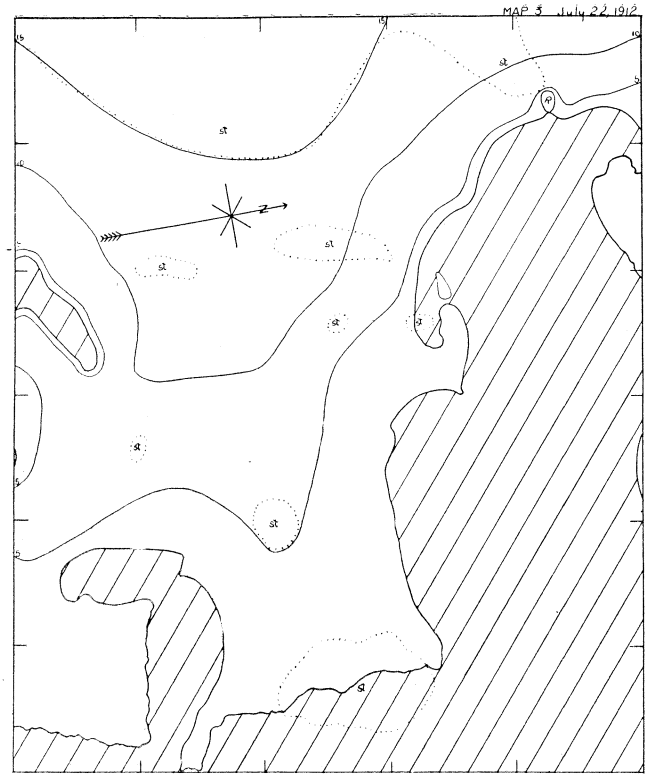
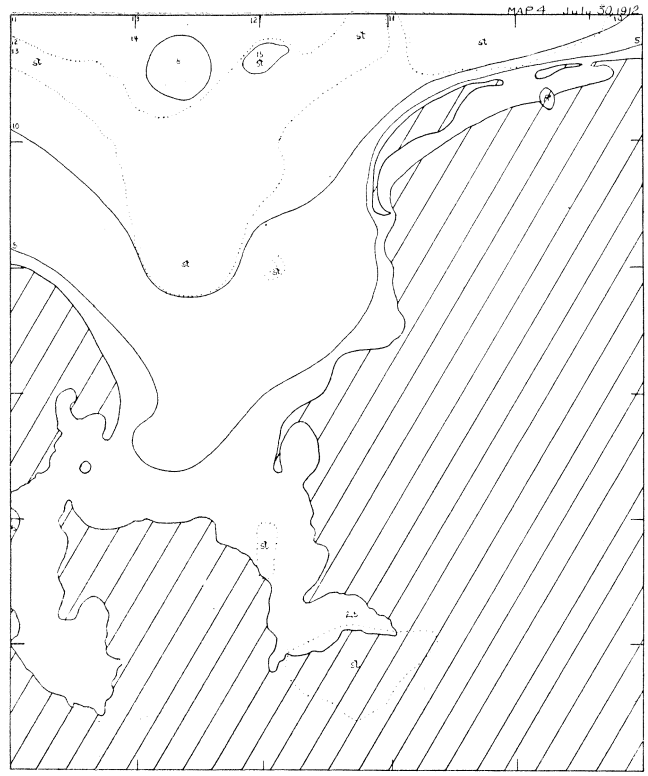
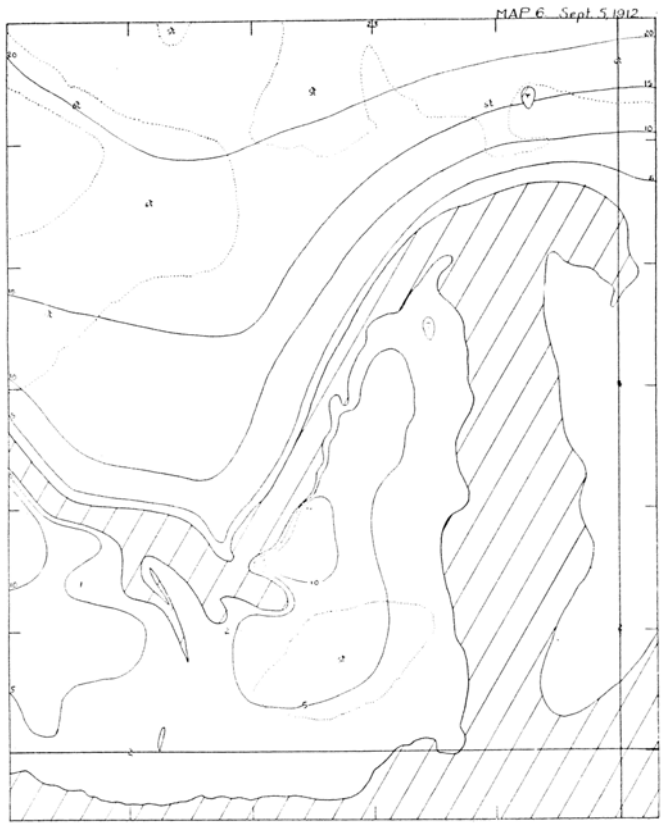

MAP OF
NORTHERN PORTION
OF SOUTHERN PENINSULA
OF MICHIGAN
SHOWING LAKE BEACHES
BOIS BLANC ISLD.
STRAITS OF MACKINAC
582
ALPENA BEACH
CHEBOYGAN
CARP L.
WYCAMP L.
LARK L.
MANIO L.
DOUGLAS L.
597
NEBLE R.
CHEBOYGAN R.
MALLET LAKE
594
BURT LAKE
596
INDIAN R.
BLACK L.
ALPENA BEACH
CROOKED L.
LITTLE TRAVERSE BAY
PICKEREL L.
PETOSKEY

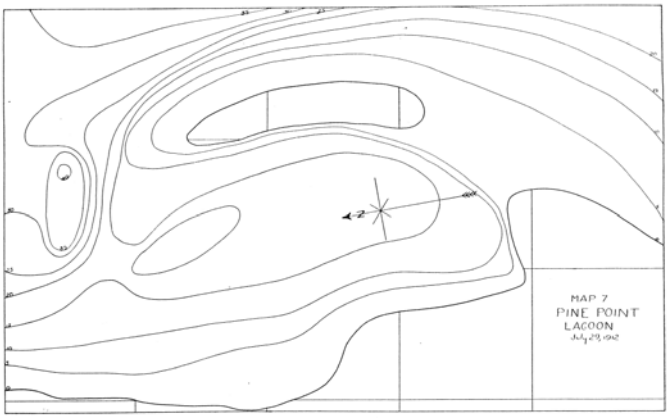
MAP 2.
DOUGLAS LAKE
ONE MILE

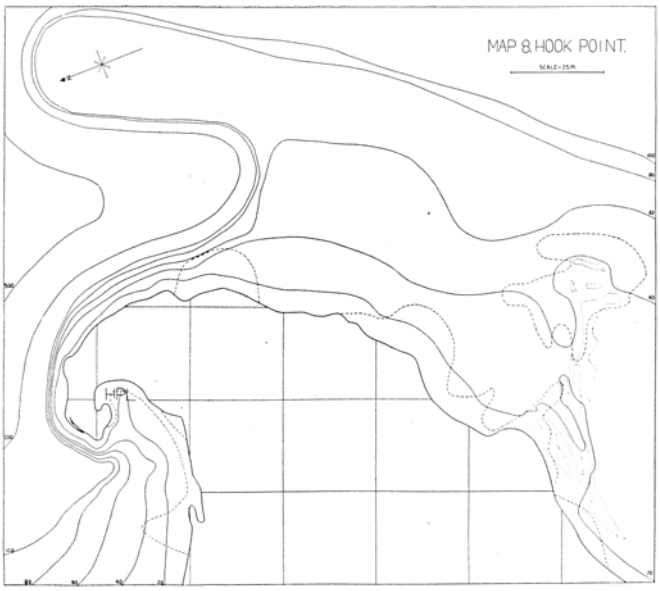

MAP 3 July 22, 1912

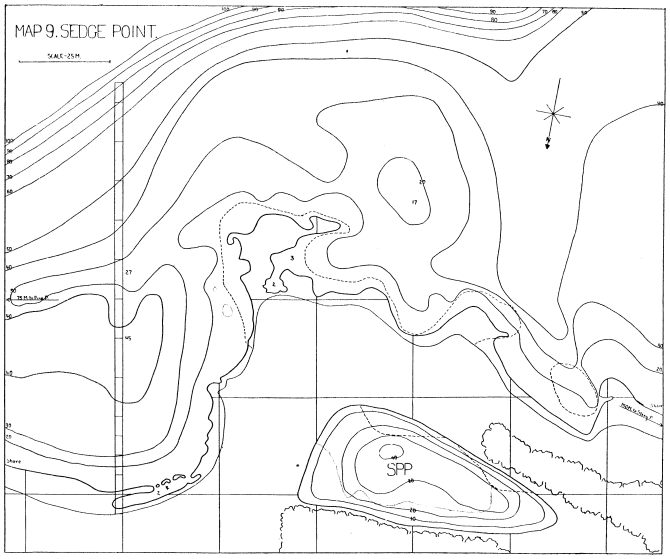

MAP 4 July 30, 1912

MAP 5 Aug. 16, 1912


MAP 6 Sept. 5, 1912


MAP 7
PINE POINT
LAGOON
July 29, 1912


MAP 8 HOOK POINT.
HPL


MAP 9. SEDGE POINT.
SPP

## ORIGIN OF CONTINENTAL FORMS, V.

HOWARD B. BAKER.

One of the most important objections to the theory of the post-Cretaceous separation of mass from the earth as I have developed it in preceding papers before this section, is based upon the relative values of the coastal margins of the continents and the submerged continental borders.

Fisher, 1882, referred only to the very broadest geographical features and did not concern himself with the submarine border. Pickering, 1907, also used very general features, but he supposed that comparisons must deal with the submerged continental margins. In contrast with their methods, I have not only compared continental margins in considerable detail, but my whole development of the theory is built up primarily upon the form of coastal margins as actually represented upon the globe.

Against this method the criticism arises that the position of the strand is not a permanent feature, that it is ever varying. Very slight crustal movements must suffice greatly to change the outlines of land and sea. Both erosion and sedimentation are constantly at work; it would seem to many that nothing is more unstable or less reliable, for such a purpose, than the fleeting picture which the map presents of the present-day relations of land and sea. As contrasted with the strand line, the submarine margin of the continental plateau is held to be the real margin. The ocean basins, so called, are said to be slightly over-full. The hundred fathom contour is regarded as about the brink of the real oceanic depressions of the globe.

It is objected that any comparisons of opposite coasts, which may or may not match each other's curves, must be made on the basis of this real continental margin and that coastal evidence must be thrown out as inadmissible. What is there to be said in reply?

The first point to be made in reply is that this objection gives preference to the *a priori* method over the analytical. To investigate coastal curves as actually charted is to study at first hand facts which are as much beyond denial as those connected with the submerged margin. If opposite coasts match together that geological fact demands explanation and is not to be brushed aside merely because in the light of previous conclusions the reason for the fact is not at once apparent. And, I may add, it is no more proper to attribute coastal parallelisms to chance than to assign to slaty cleavage or rock stratification the same fickle origin. And yet, are there not even today and even in the ranks of geologists a few who attempt in some such way to remove from discussion the, to them, unwelcome fact that coasts are fractured margins and the fractures fit together?

We might suppose that the hundred fathom contour or some other would be more reliable for times as remote as the end of the Mesozoic than the zero contour which is the strand, but can that be proved? Quite the contrary.

The second point is that the proper use of the coast lines necessarily makes provision for the submerged areas.

The coasts are not straight, they are made up of curves, and when we place them parallel with each other the major curves are concentric. It is very noticeable that the coastal curves are not parallel, i. e., concentric, when crowded to contact. There is for each pair of coasts one distance, and of course only one, by which they are separated when their curves are concentric. This distance is easily determined by experiment. Between North America and Africa it averages 200 to 300 miles, between Africa and South America it is about 300 miles. There are a few places, as between the Brazilian coast and that of upper Guinea where the distance is so small as to be almost negligible.

One reason why the submerged border is not to be relied upon is that it is rapidly changing.

Whereas denudation proceeds on all exposed surfaces, marine deposition is confined for the most part to a narrow strip about the borders, and in this relatively small sedimentary area the rate of building up must be many times the rate at which the general continental surface is being lowered. Not only this, but owing to the irregular distribution of rivers and currents sedimentation is of necessity most irregular. These factors are at work constantly modifying the depth contours near the land and working always in the direction of heterogeneity so that after the lapse of any considerable geological time it is not to be supposed that the hundred fathom depth will retain its former contours.

The indications of severe denudation in northern America and Europe during Tertiary time, culminating in the exceptional conditions of the glacial epoch, point to the oceans of similar latitudes as areas of even greater sedimentary blanketing, and the inference appears to be well borne out by the bathymetrical chart. There is a greater area within the hundred fathom curve to the east and south of Newfoundland than is occupied by that island itself. From Cape Hatteras northeast the hundred fathom line runs, excepting inlets, at an increasing distance from the shore. Upon the opposite side of the ocean, beginning near the deep in the southern part of the Bay of Biscay, the line keeps well out to the west around Ireland and the islands of the Scottish coast, bending east and south and reaching the coast of southern Norway after including nearly the whole of the North Sea.

The 2000 fathom area in the North Atlantic is noticeably restricted, being encroached upon from the west and the north and broken in the middle by the Dolphin Ridge. North of the fiftieth parallel there is little 2000 fathom water and what there is diminishes to the northwestward and northeastward with converging boundaries, these prolongations hinting of the division of the ocean to the west of Greenland and east of Iceland.

The 1000 fathom outline is likewise considerably restricted. One finger pointing up in Davis Strait, a second to the west of Iceland, and a third and fourth between Iceland and Ireland.

For all these depths the Atlantic is thus seen to shoal out as we proceed toward the north and toward the land. All these contours are inseparably connected with the present major distributions of land and sea, and yet they show individuality, each from the others. It is as if all had been profoundly altered, but by no means equally, in short as if the North Atlantic were in course of irregular filling up, which it is, of course, the process accelerating with latitude, and the natural inference is that we are viewing the effects which the rigors of northern climate have had in the tearing down of land and the transporting of materials. That the evidences of heavy sedimentation are here observed at such great distances from land is very likely attributable to transport by floating ice. How much of the alteration of the bottom must be set down to crustal movement is a question unanswered; even the Dolphin Ridge, too far separated as it is from land by deep areas to have been built up by out washed sediments, may in part represent crustal materials left when the Atlantic rent opened, instead of being wholly the result of upheaval of the ocean floor.

Clearly, in these contours of the northern ocean bottom we are confronted with changes of profound significance and to single out any particular depth curve and apply it as a test of interpretations reaching back to the dawn of Tertiary time would be improper.

The Gulf of Mexico receives the silt from an area approximately four times its own and its filling up mast be correspondingly rapid. When the Great Lakes emptied by way of the Mississippi river the drainage area was considerably greater, probably five times that of the Gulf, and yet, the evidences of filling are nowhere near what they are about the borders of the North Atlantic. There is still a small 2000 fathom area left in the western part and the 1000 fathom outline includes perhaps a half of the whole.

There is just one feature in connection with these depths in the Gulf that I wish to mention particularly and that is the relation of Florida to the coast of Yucatan and Honduras. It will be recalled that in the replacement of middle America I place the peninsula of Yucatan to the west of that of Florida with a gap between about as wide as the latter peninsula. Reference to the bathymetrical charts discloses the 100 fathom curve about that distance from the west coast of Florida, but on the east coast of Yucatan it is close inshore and the bottom drops rapidly clear down to 2300 fathoms (2.6 miles). Here is a case where it would seem that the west Florida shoal corresponds to the missing area, and the deep off the Yucatan coast would harmonize with the scheme of matching together. But after all this is a mere approximation; the depths involved are not great enough and moreover we no sooner begin such comparisons than we find insuperable obstacles to their continuance elsewhere. Just as in the matching together of Africa and the Americas we find too little land at the borders and have to leave spaces between, so here in the attempted use of the submarine contours, 100 fathoms or greater, we find too much and have to lap them by, sometimes more, sometimes less. But this difference is vital—in the one case we have coast lines to guide us, in the other there are no guides whatever.

Of all South America the greater part of the disintegrated material is dumped upon the eastern coast to the north of the Amazon and the south of La Plata. Along this coast the submarine border must be changing both rapidly and irregularly and where a given depth still maintains a fairly regular distance from the shore, as is doubtless true over great stretches in spite of undoubted disturbing agencies, that fact may require special explanation.

Touching next upon vertical crustal movements, it is to be observed that for purposes of movement the submarine margin is inseparable from the rest of the continental structure. Any vertical movements which may effect the strand may also affect the hundred fathom depth although, as Shaler[1] pointed out, the changes may possibly be in opposite directions under the sea and upon the land. Under the theory advanced by Chamberlin and Salisbury[2], Shaler's concept of sinking sea bottom is extended to imply pressure towards the continents, shearing and deformation with creeping of the soft sediments of the continental shelf. The evidence which is being presented in the present series of papers was not available when this theory was promulgated and will perhaps in time lead to profitable reconsideration. In any case it is apparent that if the permanence of the coast lines be questionable on the score of vertical movement the submarine border contours are no less so.

[1]Shaler, N. S., "On the Nature of the Movements Involved in the Changes of Level of Shore Lines." Proc. Boston Soc. Nat. Hist. vol. xii, 1868-69, pp. 128-136.

[2]Chamberlain and Salisbury, "Geology" 1906 vol. iii, pp. 526-530.

Marine encroachment by the action of waves and tides in tearing down the land structure is doubtless a real force tending toward change of outline and while its action is localized to the actual strand and marginal shallows the resulting deposition is spread over a considerable area so that this factor presumably changes the coastal outline faster than it does the hundred fathom curve. The importance of this change for the present inquiry is quite problematical, but it would seem, both *a priori* and in view of the coastal parallelisms observed, that whatever its mean rate and whatever its local variations this kind of marine encroachment has acted over long stretches of coast with such a fair degree of uniformity that the major relations have remained from the time of fracture to the present day.

It seems reasonable to suppose that the edges of the continental shelf, submerged to the depth of a hundred fathoms or thereabouts, formerly represented the edges

of the elevated plateaus left by the disruption of the crust at the end of the Cretaceous period.

If the Tertiary or even only the Pliocene, opened with the oceans very low the processes of erosion must have been extremely active upon the heights and most active of all at the edges. The edges of all the lands being precipitous would naturally crumble and break down rapidly. Sea cliffs two or three miles high could not long endure, the continental borders would speedily be rounded down. And the material removed would pile up at the bottom. Thus a more or less gentle slope would be established from the general ocean bottom up to the ever-receding brink of the continental plateau. The general land surface meanwhile, would be lowered, as it is always subject to the erosive forces, but less rapidly than at the borders because of lower gradient.

I infer from evidence previously presented that at least one cause of the Pleistocene Glacial Epoch was high altitude of land above sea level and that such relative elevation was world wide in its occurrence. Also that its duration exceeded that of the glaciation which it helped to bring about. Chamberlin and Salisbury[1] speak of the Pliocene with the Pleistocene as together constituting, except for the presence and effects of the ice, “a single period of great land relief and oceanic restriction."

This condition of high relief extended over the period when the great rivers were cutting down deep gorges in their progress toward the reduction of the general land level to that of the then low sea. During this time the marginal slopes, at first theoretically vertical, were being lowered to gentle grades simultaneously about all lands and if at any time we could have traced their crests upon a map we should doubtless have found them maintaining fairly well their parallelism with the original fractured margins of which they were but modifications All curves would be moved inland concentrically, the convexities of coast made smaller, the concavities larger.

In view of the evidence indicative of such a former general state of high relief of the lands, and considering the huge gorges which were carved by the rivers flowing to the sea, some of which are still traceable upon the submerged shelf, it would seem that there must have been ample time for the crests to have moved inland in some places to great distances. And still a certain degree of uniformity might be maintained over long stretches.

[1]Geology, vol. iii, 1906, p. 327.

Suppose now, succeeding upon such a stage of high relief, a rise of sea level until the basins are slightly over-full. No matter where upon the coastal slope the new strand formed it would be roughly parallel to the original torn outline because its plane would intersect a slope derived from that. The brink or crest contour having moved inland, all slopes having been merged into one another, that crest might be drowned to a depth of a hundred fathoms or to some other depth. On the seaward side of this the slope would be more or less rapid, on the land side gentle. The curves of the new coast line would tend to remain roughly parallel to the original brink.

Then comes sedimentation. The submerged slopes receive the materials washed down from the land. Sediments from large areas are deposited on small, making up in thickness what they lose in area. The inevitable result must be the alteration of the submerged contours out of proportion to the changes produced on the lands by the removal of the transported materials. Ultimately we must expect the hundred fathom curve to be so changed that it cannot at all be taken as representing, what it once did, an approximation to the original torn outline. But the coast line might continue longer to retain its ancient parallelisms.

In matching together two such coasts we should be struck at once with the concentricity of the greater curves, for these curves would be derived from the former crests moved inland. And is this not exactly what we find upon the globe today? And would not the distances, center to center of given land masses, be quite as rigidly prescribed as if we were dealing with freshly torn edges? It seems that such would be the case.

To sum up then, in reply to the challenge of the use of the coastlines, we may emphasize the following points:

1. The preference for the hundred fathom or other submarine curve is based upon *a priori* grounds as opposed to the analytical study of observed facts. It puts a premium on prejudice.

2. Speaking generally, the proper use of the coast lines necessarily provides for the submerged margin.

3. The submerged contours are highly changeable and unreliable because of sedimentary alteration.

4. The submerged contours are fully as objectionable on the score of vertical crustal movements as are the coast lines.

5. Change of coast lines by encroachment of waves and tides varies in detail but seems to be fairly uniform over greater marginal features.

6. A hypothetical rise of sea level in the less remote geological past (close of the Pleistocene) would be compatible with the observed facts.