THE CHAMPLAIN SEA

EVIDENCE OF ITS DECREASING SALINITY SOUTHWARD AS SHOWN BY THE CHARACTER OF THE FAUNA

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Introduction

Recent collecting in the postglacial banks of the Champlain and St Lawrence valleys has brought out the fact that going southward there is evidence of a marked change in the Pleistocene fauna, similar to that seen in the living fauna of the Baltic sea today. Study of this fauna and comparison with the conditions found in the Baltic and elsewhere has led to the conclusion that the character of this postglacial marine fauna is due in large part at least to decreasing salinity in this direction in the waters of that time.

The normal salt composition of sea water permits the development of a fauna rich in species and genera. A reduction in the salt content of the water produces an impoverished fauna, poor in species, poor in lime, dwarfed in size but often rich in individuals (Shimer, p. 473; Walther, 1919, p. 60).

Marine animals are divided into three groups according to their ability to live in water of various degrees of salinity: (1) *stenohaline types* can not live in water with less than 30 or 35 permille[1] of salt (normal open sea); (2) *euryhaline types* can endure without injury a considerable freshening of the water; they need the salt but not a definite percentage, and will live as long as any salt remains; (3) *brackish-water types* are adapted to a small amount of salt and an increase of the salt content is just as harmful as a reduction of it. The brackish state of water has never been definitely delimited, but probably the upper limit would be a salinity of 2 or 3 permille. The stenohaline forms outnumber the euryhaline and brackish-water forms in all groups (Walther, 1894, p. 6263; Grabau, p. 1044).

Experiments have been undertaken with sea animals (by Beudant; Walther, 1894, p. 63) to determine whether they can be induced to live in gradually freshened water. It was found that if marine mollusks are brought suddenly into fresh water, almost all the species die; but many species can endure the gradual addition of fresh to salt water until eventually the water has become quite fresh.

[1] That is, parts in a thousand.

Among 610 individuals of various marine species which were gradually accustomed to fresh water, only 37 per cent died. Of the same number of the same species which were kept at the same time continuously in salt water, 34 per cent died; so that the mortality in the groups compelled to live in a strange element was only 3 per cent greater. These experiments show that sea animals are not bound to an absolute quantity of salt, but their stenohaline or euryhaline behavior is important in this, that they are able more easily or with more difficulty to adjust the salt content of their tissue to that of the surrounding water. It has been found that nearly related species behave very differently in this respect; one species may die immediately, another live on for several days. Foraminifera live mostly in pure salt water, yet in the estuaries of British rivers there are known 100 species belonging to 44 genera. In brackish sea water, in spite of the simultaneous increase in the lime content, the secretion of lime skeletons is diminished. Species of Foraminifera in the estuaries have shells poor in lime, while the same species secrete coverings rich in lime in the normal salty sea (Walther, 1894, p. 63; 1919, p. 123).

A noted area for studying the influence of a diminished salt content upon the animal life is the Baltic sea, which shows a very striking decrease in salinity eastward and in a large way the responses of the fauna to it. It is more static than estuaries; it lacks the tides which are characteristic of the latter and therefore does not show the pronounced changes from fresh to salt water twice a day. The North sea has the normal marine salinity of 35 permille which decreases steadily going eastward in the Baltic until at the northern end of the Gulf of Bothnia the water is practically fresh. In the Skager Rak the water has a salinity of 34 permille; off Skagen, the northeasternmost point of Denmark, 30 permille; in Kattegat, 22 permille, and 20 permille in Kiel bay. " Throughout the southern part of the Baltic, from the 'Scheren,' at the mouth of the Gulf of Finland, to Bornholm the salinity is from 7 to 8 permille at the surface and does not vary greatly in the depths. For instance, in the deepest part of the Baltic off the Island of Gotland, the salinity is only 12 permille, and in the Bay of Danzig, which shows a yearly average of 7.22 permille at the surface, it is only 11.66 permille (average) at the depth of 105 meters. In the Bay of Riga the salinity is 6 permille, in the southern part of the Gulf of Bothnia it is 4 permille and gradually diminishes until the water is entirely fresh (3 permille at Uleaborg, northern end; Grabau, p. 1045).

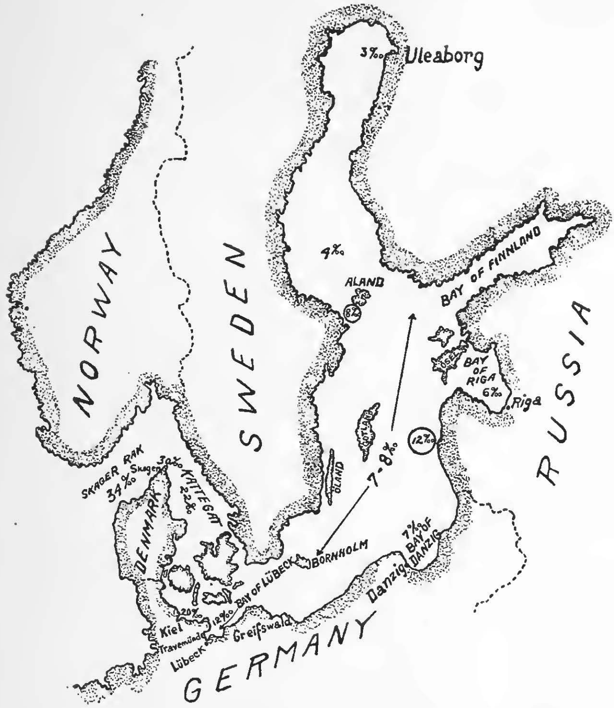


Fig. 1 Sketch map of Baltic showing permillage variations in salinity (after O'Connell, 1916).

Corresponding to these changes in salinity are certain very definite changes in the fauna." (O'Connell, p. 70; see also Grabau and Jacobsen).

As the salinity of the water decreases from that normal for sea water, the fauna changes from one typically marine to one in which only a few marine groups are represented and finally to a fresh-water fauna. Each phylum is affected.

Pouchet and de Guerne (p. 919–21), from a study of dredgings in the Baltic, reported from the Gulf of Finland a *crustacean* fauna made up almost entirely of fresh-water types. One of the types, Bosmina longirostris, shows a great abundance of individuals, for it represented by itself alone three-fourths of the mass of the animals obtained at the various stations. Associated with the fresh-water types is a marine pelagic form, Evadne nordmanni, which occurs more and more frequently in proportion to the increase in the salinity of the water (westward). In descending south the Evadnes tend more and more to replace the Bosminas, but the latter have been found even as far down as Kiel. Another abundant euryhaline crustacean is Podon intermedius. From the point of view of the pelagic fauna, the Gulf of Finland may be compared to a lake broadly opened on the Baltic (salinity of .73 permille at Cronstadt; 2.62 permille at Seskär). Along the extent of Gotland, the marine crustacean fauna is found in the Baltic as far as Kalmar sound between Öland and Sweden. One interesting copepod found is Temora velox, known for a long time as an inhabitant of brackish waters. This species appears to have adapted itself in a special manner to extreme conditions of existence in the Baltic, for it has spread out everywhere there and is so abundant as to play an important part in the nourishment of certain fish.

A change similar to the above has been found among the *Mollusca*. Species of Limnaea, such as L. palustris and pereger, replace the Littorina species. When the salinity of the water is low along the coast the two forms are found living together, and with them is also found a river form, Neritina fluviatilis. Common forms of Planorbis and Bythinia have been enumerated from the Baltic in addition to the Limnaeas and Neritinas. In the Gulf of Bothnia many of the common air-breathing pond snails have habituated themselves to the slightly saline waters of that part of the Baltic (Forbes, p. 90, 231; O'Connell, p. 71).

There is a very rapid decrease eastward in the number of species comprising the whole fauna. Möbius (1872, p. 279; 1873, p. 138) describes the Baltic as being faunistically divided into two basins, a western and an eastern; the former marked by a rich fauna, the latter by a strikingly impoverished one. In his earlier report on the Baltic fauna (1872, p. 277), he gives the total number of observed invertebrate animals as amounting to about 200 species (exclusive of infusorians and crinoids), only one-fifth of which were found in the eastern basin of the Baltic which begins between Rügen and the southern extremity of Sweden. In the later report (1873), this number is increased to 241 species for the western basin (exclusive of infusorians, rhizopods, ostracods) of which 69 have been found in the eastern. The following table (after O'Connell, p. 72) shows the rapid decrease in the species of the Baltic fauna and gives a comparison of that fauna with a normal marine fauna:

Comparative number of species of invertebrates in the Baltic, etc.

Phyla	*Waters around Great Britain*	*Baltic as a whole*	*Bay of Kiel*	*Bay of Travemunde*
	35 permille	78 permille	20 permille	12 permille
Protozoa	69	....	....	....
Porifera	42	7	3	3
Coelenterata	98	28	24	8
Echinodermata	48	6	5	2
Vermes	101	68	50	26
Bryozoa	....	11	8	5
Crustacea	....	50	36	19
Mollusca	682	68	64	40
Tunicata	....	5	4	4
Total	1040	243	194	107

Another striking change has been noted in the character of the Baltic fauna which may likewise be correlated with the variation in salinity. As the stenohaline forms disappear entirely, euryhaline forms become *dwarfed.* Möbius (1873, p. 138) reports dwarfing of worms, and of a copepod, very noticeable even in the short distance from Arendal (Norway coast, on Skager Rak) to Kiel. The dwarfing of fishes has also been noted (*see* O'Connell, p. 72). The animals of the eastern basin are more dwarfed than in the western basin, and the best examples are found among the mollusks, in which group in addition to being dwarfed, the shells become poor in lime.

Mytilus edulis at Kiel attains a length of 8-9 cm; in the eastern basin (for example at Stolpe bank, Gotland and Dalarö) this mollusk reaches a length of only 3-4 cm. In the clayey mud of the sea bottom in various places in the eastern basin are found very many conchiolin coverings of Mytilus edulis and Macoma balthica (groenlandica); often the two brown conchiolin coverings are still bound together by the ligament at the back in complete shell form. This occurrence is readily explained. It has been found in the case of these two species, in the eastern basin, that the lime layers of the shell are extraordinarily thin, and therefore so brittle that they can be easily crushed between the fingers. Because of its thinness, the lime layer of the shells is very soon dissolved after the death of the animal (Möbius 1873, p. 138).

A very noteworthy case of dwarfing is exemplified by Cardium edule, the common European cockle, which has a large, rough, thick shell and thrives best under purely marine conditions. This species "in the North sea, of normal marine salinity, is the size of a small apple; at Stockholm, where the salinity is below 10 permille, the shell in the deeper, more saline water is only as large as a walnut and is even smaller along shore where the water is fresher. At Königsberg, with the decreasing salinity, the size reaches that of a hazelnut, whereas at Reval, it is only the size of a pea" (O'Connell, p. 72). The studies made of the Baltic sea have shown that the fauna of a brackish-water body of the nature of the Baltic is due to a mingling of marine species and fresh-water (river) species which, however, are modified. Only the most euryhaline marine species survive. A very important fact brought out is that, however dwarfed or otherwise modified the species may be, the marine forms of the Baltic are not different specifically from those living in water of normal marine salinity nor do the fresh-water forms differ specifically from those found in the rivers emptying into the Baltic or those in nearby fresh-water bodies (Forbes, p. 90; Pouchet & de Guerne, p. 920, 921).

Examples of dwarfing due to freshening of sea water have been noted elsewhere than in the Baltic. Cardium edule, which is common along the British coast, is found in a dwarfed condition in the brackish waters of the estuaries. The shell is invariably reduced in size, and in addition is thin and with less strongly marked external characters. The cockle of the Greenland estuaries is likewise thin, smooth and almost edentulous; in each valve of the young shells are found rudiments of a single tooth which finally disappear. This species of Cardium is very abundant in the Pliocene (Crag) of Suffolk and Norfolk, but is not now found in Europe (Forbes, p. 213–14; *see* Shimer, p. 474).

Both the Caspian and Black seas have fresher water than the Atlantic ocean, due to the many streams emptying into them. The fauna in each case is typically marine and the species are the same as those in the Atlantic, but in these seas they are practically all dwarfed in size as compared to the Atlantic specimens. Ten species of Cardium are found in the Caspian sea, small, thin, with lateral or central teeth or both suppressed. Often one tooth alone is preserved; at times it acquires a great development and is accompanied by great distortion of the shell on that side. These are all aberrant forms, all related back to Cardium edule. The same is true of the cockles of the Black sea (Forbes, p. 201–2, 211–15; *see* Shimer, p. 473, 474). Among other species dwarfed by brackish water are Mya arenaria and Littorina littorea.

In general, species that live in both normal sea water and in brackish water are smaller in the latter. There are some exceptions to this (Forbes, p. 230; *see* Shimer, p. 474), as, for example, Scrobularia and Mactra solida. These forms have become thoroughly adapted to a brackish water environment, and, moreover, attain their largest size there.

Modifications due to changes in the salt content of water are not confined to invertebrates alone; and while this paper is concerned with invertebrate species only, it is not amiss here to point out a case or two in which a higher group, the fishes, are affected. The dwarfing of fishes in the Baltic has been noted above. Forbes (p. 204) shows that the fishes of the Black sea are very indicative of the estuarine character of its waters. The number of species is remarkably small when compared with those of the Mediterranean; but on the other hand the number of individuals is marvelously great. Lull (p. 172) points out ontogenetic variation dependent upon the chemical content of the water in little fishes known as sticklebacks (Gasterosteus cataphractus). "Those living in salt water have from twenty to thirty bony plates along the back, in brackish water these are reduced to from fifteen to three, while in fresh water there are none at all."

Pleistocene Fossils of the Champlain Sea

Part 1 *Decrease in Species Southward*

A careful list, with localities, has been compiled of the marine Pleistocene invertebrate species collected by the writer and also all those reported by others in various publications; and these have been tabulated to show the distribution of the species from Labrador to the southernmost locality from which they have been collected in the Pleistocene of the Champlain valley.

Table showing distribution of marine Pleistocene invertebrate fossils

Species	Labrador	Anticosti	Rivière-du-Loup	Murray Bay	Quebec and vicinity	Montreal	Ottawa and vicinity	Valcour Is., N. Y.	Port Kent, N. Y.	Burlington, Vt. and vicinity	Willsboro, N. Y.	Port Henry, N. Y. and vicinity	Chimney Point, Vt.	Crown Point, N. Y.	Crown Point Station vicinity, N. Y.
FORAMINIFERA															
Nodosaria laevigata d'Orb.	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...
Lagena sulcata (W. & J.)	...	×	×	×	×	×	...	...	...	...	...	...	...	...	...
Entosolenia globosa Will.	×	×	×	×	×	×	...	...	...	...	...	...	...	...	...
" costata Will.	×	×	×	×	×	×	...	...	...	...	...	...	...	...	...
" marginata Will.	×	×	×	×	×	×	...	...	...	...	...	...	...	...	...
" squamosa Will.	×	×	×	×	×	×	...	...	...	...	...	...	...	...	...
Bulimina presli P. & J.	×	...	×	×	×	×	...	...	...	...	...	...	...	...	...
Polymorphina lactea Adams	×	...	×	×	...	×	...	...	...	...	...	...	...	...	...
Truncatulina lobatula (W. & J.)	×	×	×	...	...	...	...	...	...	...	...	...	...	...	...
Orbulina universa d'Orb.	×	...	×	...	...	×	...	...	...	...	...	...	...	...	...
Globigerina bulloides d'Orb.	...	×	×	...	...	...	...	...	...	...	...	...	...	...	...
Pulvinulina repanda (F. & M.)	×	...	×	×	×	×	...	...	...	...	...	...	...	...	...
Polystomella crispa (Linn.)	×	...	×	×	×	×	×	...	...	...	...	...	...	...	...
Nonionina scapha (F. & M.)	×	×	×	×	×	×	...	...	...	...	...	...	...	...	...
Textularia pygmaea d'Orb.	×	...	×	...	×	...	...	...	...	...	...	...	...	...	...
Cornuspira foliacea (Phil.)	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...
Quinqueloculina seminulum Linn.	×	...	...	...	×	×	...	...	...	...	...	...	...	...	...
Biloculina ringens d'Orb.	×	...	×	×	×	×	...	...	...	...	...	...	...	...	...
Triloculina tricarinata d'Orb.	...	...	×	×	×	...	...	...	...	...	...	...	...	...	...
Rotalina? turgida Wms.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
PORIFERA															
Tethea logani Daw.	...	...	...	...	...	×	×	...	...	...	...	...	...	...	...
Tethea?	...	...	×	...	...	×	...	...	...	×	...	...	...	...	...
ECHINODERMATA															
Ophiacantha spinulosa M. & T.	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...
Solaster (Crossaster) papposa M. & T.	...	...	...	...	...	×	×	...	...	...	...	...	...	...	...
Amphiura sp.	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...
Euryechinus drobachiensis (Müll)	...	...	×	...	×	×	...	...	...	...	...	...	...	...	...
Echinus granularis Say	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
Psolus fabricii Dur. & Kor.	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...
BRYOZOA															
Membranipora catenularia Jam.	×	...	×	...	×	...	...	...	...	...	...	...	...	...	...
" lacroixii Aud.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
" lineata Linn.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
Hippothoa expansa Daw.	...	...	×	...	×	...	...	...	...	...	...	...	...	...	...
Schizoporella hyalina John.	...	...	×	...	×	...	...	...	...	...	...	...	...	...	...
Lepralia pertusa Esper.	×	...	×	...	×	...	...	...	...	...	...	...	...	...	...
" quadricornuta Daw.	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...
" spinifera? Bush	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
" violacea? John.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
" variolosa John.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
" globifera Pack.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
Porella (Lepralia) belli Daw.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
Porella elegantula (d'Orb.)	...	...	×	...	...	...	×	...	...	...	...	...	...	...	...
" compressa Sow.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
Smithia producta (Pack.)	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
" trispinosa (John.)	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
Cribilina punctata? Hass.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
Mucronella peachii John.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
" ventricosa Hass.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
Myriozoum planum Daw.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
" subglaciale d'Orb.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
Tubulipora fimbria Lam.	...	...	×	...	×	...	...	...	...	...	...	...	...	...	...
Idmonea atlantica Forbes	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
Diastopora obelia John.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
Crisia eburnea Ellis	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...
Alecto sp.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
Lichenopora hispida (Flem.)	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
Celleporaria surcularis Pack.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...

Table showing distribution of marine Pleistocene invertebrate fossils (*continued*)

Species	Labrador	Anticosti	Rivière-du-Loup	Murray Bay	Quebec and vicinity	Montreal	Ottawa and vicinity	Valcour Is., N. Y.	Port Kent, N. Y.	Burlington, Vt. and vicinity	Willsboro, N. Y.	Port Henry, N. Y. and vicinity	Chimney Point, Vt.	Crown Point, N. Y.	Crown Point Station vicinity, N. Y.
BRACHIOPODA															
Rhynchonella psittacea Gm.	...	×	×	...	×	×	...	...	...	...	...	...	...	...	...
Terebratella labradorensis Sow.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
" spitzbergensis David	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
LAMELLIBRANCHIATA															
Saxicava rugosa Lam. (= arctica L.)	×	×	×	×	×	×	×	×	×	×	×	×	...	...	...
Panopaea norvegica Speng	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
Mya arenaria Linn	×	×	...	×	×	×	...	×	×	×	...	...	...	...	...
" truncata Linn	×	×	×	...	×	×	...	...	×	...	...	...	...	...	...
Lyonsia arenosa Möll	...	...	×	...	...	×	...	...	...	...	...	...	...	...	...
Macoma groenlandicaBeck (=balthica L.)	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Macoma calcarea Chem.	×	×	×	×	×	×	×	×	×	×	...	...	...	...	...
" inflata Stim	...	...	×	...	...	×	...	...	...	...	...	...	...	...	...
Cyrtodaria siliqua Daud	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
Venericardia borealis Con.	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Astarte laurentiana Lyell	...	...	×	...	×	×	×	×	...	...	...	...	...	...	...
" banksii Leach	×	×	×	...	×	×	×	...	...	...	...	...	...	...	...
" lactea Brod. & Sow.	×	...	×	×	...	...	...	...	...	...	...	...	...	...	...
" arctica Möll	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Cardium islandicum Linn.	...	...	×	×	...	...	...	...	...	...	...	...	...	...	...
" dawsoni Stim.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
" (Serripes) groenlandicum Chem.	×	...	×	×	×	...	...	...	...	...	...	...	...	...	...
Cryptodon gouldii Phil.	...	...	...	...	...	×	...	...	...	×	...	...	...	...	...
Mytilus edulis Linn	×	×	×	...	×	×	×	...	×	×	×	×	...	...	...
Modiola modiolus Linn.	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...
Modiolaria nigra Gray	...	...	×	...	...	×	...	...	...	...	...	...	...	...	...
" corrugata Stim.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
" discors Linn.	...	...	...	...	×	×	...	...	...	...	...	...	...	...	...
Nucula tenuis Mont.	...	...	×	...	...	×	×	...	...	×	...	...	...	...	...
" expansa Reeve	...	...	×	...	...	...	...	...	...	×	...	...	...	...	...
Leda pernula Müll.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
Leda minuta Fabr.	×	...	×	...	...	×	×	...	...	×	...	...	...	...	...
Yoldia arctica Gray	...	...	×	...	×	×	×	...	×	×	×	...	×	...	...
" limatula Say	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
" myalis Couth	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Pecten islandicus Chem.	×	×	×	...	×	...	...	...	×	...	...	...	...	...	...
Ostrea virginiana Lister	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...
GASTROPODA															
Philine lineolata Couth.	...	...	...	...	...	×	×	...	...	...	...	...	...	...	...
Cylichna alba Br wn	...	...	×	...	...	×	×	...	×	...	...	...	...	...	...
" ory a Totten	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...
" nucleola Reeve	...	...	...	...	...	×?	...	...	...	...	...	...	...	...	...
" occulta Migh. & Ad	...	...	...	×	...	×	...	...	...	...	...	...	...	...	...
" striata Brown	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
Haminea solitaria Say	...	...	...	...	...	×	×	...	...	...	...	...	...	...	...
Diaphana debilis Gould	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...
Utriculus pertenuis Migh	...	...	...	...	...	×	...	...	×	...	...	...	...	...	...
Siphono-dentalium virtreum Sars	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...
Amicula emersonii Couth.	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...
Puncturella noachina Linn	...	...	×	...	×	...	...	...	...	...	...	...	...	...	...
Acmaea testudinalis Möll	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Lepeta coeca Möll	×	...	×	...	×	×	...	...	...	...	...	...	...	...	...
Capulus ungaricus Linn	...	...	...	...	×	×	...	...	...	...	...	...	...	...	...
Crepidula fornicata Linn	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...
Margarita helicina Fabr.	...	...	...	×	...	×	...	...	...	...	...	...	...	...	...
" argentata Gould.	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...
" cinerea Couth	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...

Table showing distribution of marine Pleistocene invertebrate fossils (*continued*)

Species	Labrador	Anticosti	Rivière-du-Loup	Murray Bay	Quebec and vicinity	Montreal	Ottawa and vicinity	Valcour Is., N. Y.	Port Kent, N. Y.	Burlington, Vt. and vicinity	Willsboro, N. Y.	Port Henry, N. Y. and vicinity	Chimney Point, Vt.	Crown Point, N. Y.	Crown Point Station vicinity, N. Y.
Cyclostrema costulata Möll						×									
" cutleriana Clark						×									
Turritella erosa Couth	×		×			×									
" reticulata Migh	×														
" acicula Stim	×		×												
Littorina rudis Martin			×												
" palliata Say			×												
Rissoa castanea Möll						×									
" exarata Stim						×									
Cingula jan meyeri Friele						×									
Bela harpularia Couth	×		×	×	×	×									
" elegans Möll				×		×									
" pyramidalis Ström						×									
" turricula Mont			×			×									
" trevelliana Turton	×		×												
" violacea Migh. & Adams						×									
" cancellata Migh. & Adams	×			×											
Natica cl usa Brod. & Sow	×	×	×		×	×									
Lunatia heros Say					×										
" groenlandica Beck		×	×		×	×	×								
Choristes elegans Cpr						×									
Velutina zonata Gould					×	×									
Scalaria groenlandica Perry			×		×										
Acirsa eschrichtü Holb			×		×	×									
Trichotropis borealis Brod. & Sow	×		×			×									
" arctica? Midd						×									
Admete viridula Fabr					×	×	×								
Aporrhais occidentalis Beck	×														
Ptychatractus ligatus (Migh.)						×									
Astyris holbolli Möll			×												
Menistho albula Möll			×												
Buccinum undatum Linn	×	×	×												
" totteni Stim			×												
" cyaneum Brug			×												
" groenlandicum Chem			×												
" tenue Gray			×												
" scalariforme Möll			×												
" ciliatum Fabr			×			×									
" cretaceum Reeve			×												
" glaciale Linn	×	×	×			×									
" plectrum Stim			×												
Tritonofusus krayeri Möll	×		×												
Sipho spitzbergensis Reeve						×									
Neptunea despecta Linn	×		×	×	×	×	×								
Trophon scalariforme Gould	×		×	×		×									
" clathratum Linn		×	×	×		×									
ANNULATA															
Serpula vermicularis Linn			×	×		×	×								
Vermilia serrula Stim			×												
Spiochaetopterus typus Sars	×														
Spirorbis glomerata Müll	×		×												
" vitrea Fabr	×		×	×	×	×									
" borealis Daud			×												
" lucidus Flem			×												
" nautiloides Lam			×												
" carinata Mont			×												
" sinistrorsa Mont			×												
" quadrangularis Stim			×												

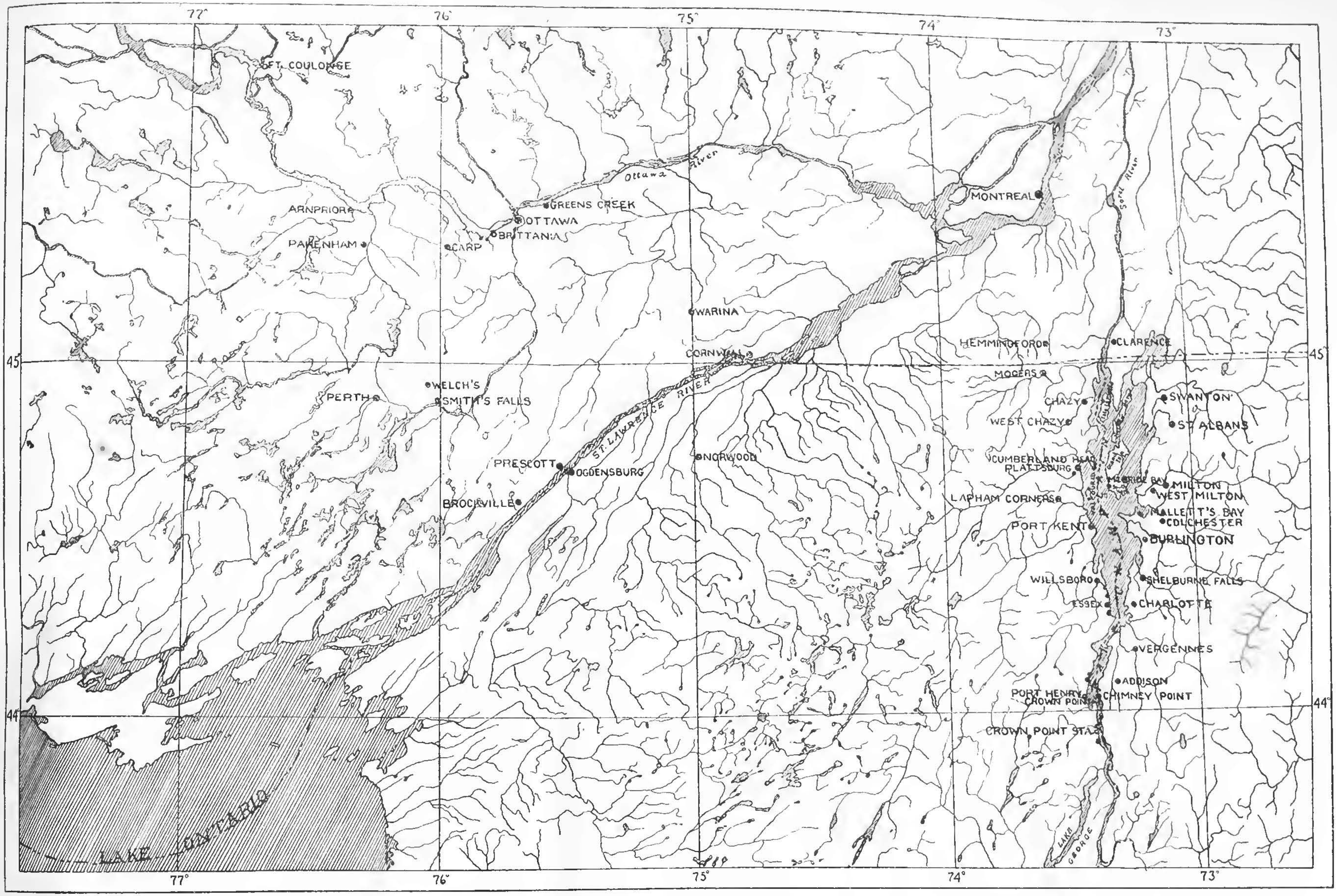
Table showing distribution of marine Pleistocene invertebrate fossils (*concluded*)

Species	Labrador	Anticosti	Rivière-du-Loup	Murray Bay	Quebec and vicinity	Montreal	Ottawa and vicinity	Valcour Is., N. Y.	Port Kent, N. Y.	Burlington, Vt. and vicinity	Willsboro, N. Y.	Port Henry, N. Y. and vicinity	Chimney Point, Vt.	Crown Point, N. Y.	Crown Point Station vicinity, N. Y.
CRUSTACEA															
Balanus hameri Asc.	...	×	×	...	×	×	...	...	...	...	...	...	...	...	...
" porcatus Da Costa	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...
" crenatus Brug.	×	×	×	...	×	×	×	×	×	×	×	...	...	...	...
Eupagurus bernhardus? Fabr.	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
Hyas coarctata Leach	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...

In addition to the species listed in the table there are nine species, each reported only from one locality but not from any of the lower St Lawrence localities: from Ottawa and vicinity, Dentalina sp., Leda pygmaea, Natica affinis, Nereis pelagica; from Port Kent, Tritonium anglicum, T. fornicatum (Emmons, Geol. of N. Y., 2d Dist., 1842, p. 128); from Burlington and vicinity, Yoldia obesa, Y. siliqua, Nucula abyssicola. An old collection of Pleistocene fossils from the Champlain valley in the State Museum contains Rhynchonella psittacea, Mya truncata, Buccinum glaciale, B. ciliatum, B. cyaneum, Balanus hameri; but as no localities were given for these species they can not be used in the lists. The distribution of the total number of species is summarized in the comparative table which follows:

Phyla, etc.	All localities	Labrador to Rivière-du-Loup and Murray Bay	Quebec and vicinity	Montreal	Ottawa and vicinity	Valcour Is.	Port Kent	Burlington and vicinity	Willsboro	Port Henry and vicinity	N. of Chimney Point	Crown Point	Crown Point Station vicinity
Foraminifera	21	18	13	15	2	....	....	....	....	....	....	....	....
Porifera	2	1	....	2	1	....	....	1	....	....	....	....	....
Echinodermata	6	2	1	5	1	....	....	1	....	....	....	....	....
Bryozoa	28	26	5	2	1	....	....	1(?)	....	....	....	....	....
Brachiopoda	3	3	1	1	....	....	....	....	....	....	....	....	....
Mollusca { Lamellibranchiata	37	28	12	18	10	5	8	13(?)	4	3	2	1	1
Mollusca { Gastropoda	68	41	12	40	7	....	4	....	....	....	....	....	....
Annulata	11	11	1	2	2	....	....	....	....	....	....	....	....
Crustacea	5	4	3	2	1	1	1	1	1	....	....	....	....
Total	183	134	48	89	25	6	13	17(?)	5	3	2	1	1

Of the 25 species found at Ottawa and vicinity, 4 (listed above) have not been reported elsewhere; of the other 21 all except 1 (Porella elegantula) occur likewise at Montreal.



Map 1. Map showing localities [•] in the Champlain basin, and a part of Canada, where marine Pleistocene fossils have been found. Scale $\frac{1}{950400}$; approximately 15 miles to the inch.

Ottawa and Vicinity

Dentalina sp.	Nucula tenuis
Polystomella crispa	Astarte banksii
Tethea logani	A. laurentiana
Solaster papposa	Cylichna alba
Porella elegantula	Natica affinis
Saxicava rugosa	Lunatia groenlandica
Mytilus edulis	Neptunea despecta
Macoma groenlandica	Admete viridula
M. calcarea	Haminea solitaria
Yoldia arctica	Philine lineolata
Leda minuta	Serpula vermicularis
L. pygmaea	Balanus crenatus

From Green's creek and Besserer's wharf, Ottawa river, about 8 miles below Ottawa, have been reported Saxicava rugosa, Macoma groenlandica, Yoldia arctica, Leda pygmaea, Nucula tenuis, Solaster papposa and Nereis pelagica. In addition there have been found in the clay nodules at this locality remains of three species of fish: a capelin, Mallotus villosus (abundant); a lump sucker, Cyclopterus; a species of stickleback, Gasterosteus. There have also been found remains of fresh-water plants, several birds, mammals etc., which show that the Leda clay was not far from the shore when clay with drift material was brought down by the rivers. Leda (Yoldia) may occur in moderately deep water; the other fossils suggest shallow water (Coleman, p. 131).

Marine Pleistocene shells have been reported from numerous localities in Canada, some of which are shown on the accompanying map of localities (map 1). The two commonest and most abundant shells reported are Saxicava rugosa and Macoma groenlandica. Brockville, Ont., is the most southern and most inland point at which Pleistocene fossils have been found. At Pakenham Mills, 30 miles southwest of Ottawa, the only marine shell reported is Macoma groenlandica, a species now found farther up in the estuaries than most others (Dawson, 1894, p. 58). The line marking the limit of known marine fossils extends from Brockville through Perth, northwest to Fort Coulonge on the Ottawa river. "Gravels, sands and clays not unlike the marine deposits...occur at various places west of Brockville...and some of them have been searched carefully for fossils, but without success, suggesting that for some cause the marine fauna could not advance into the Ontario basin" (Coleman, p. 134).

In New York State, marine fossils of this period cease in the westward extension before the beds reach Morristown, opposite Brockville. So far, the most western locality from which they have been reported is Ogdensburg. Marine fossils have been found in New York from north to south as follows:

1 *Ogdensburg*

Macoma groenlandica
M. calcarea
Saxicava rugosa
Cylichna alba (?)

2 *Mooers*

Macoma groenlandica
Saxicava rugosa
Yoldia arctica
Balanus sp. (fragments, rare)

3 *Freydenburg's Mills, Saranac R.*

Saxicava rugosa
Macoma groenlandica
Mytilus edulis
Balanus sp.

4 *Cumberland Head, Plattsburg*

Macoma groenlandica
Mya arenaria

5 *Lapham Corners*

Mytilus edulis
Macoma groenlandica

6 *Valcour Is.*

Saxicava rugosa
Macoma groenlandica
Mya arenaria
Astarte laurentiana (rare)
Balanus crenatus

7 *Port Kent*

Saxicava rugosa
Macoma groenlandica
M. calcarea (rare)
Mya arenaria
M. truncata
Mytilus edulis
Yoldia arctica
Pecten islandicus
Cylichna alba (not frequent)
Utriculus pertenuis (rare)
Tritonium anglicum
T. fornicatum
Turritella sp.
Balanus crenatus

8 *Willsboro*

Saxicava rugosa
Macoma groenlandica
Mytilus edulis
Yoldia arctica (rare)
Balanus crenatus

9 *Port Henry (few miles north of)*

Macoma groenlandica
Saxicava rugosa
Mytilus edulis (fragments, rare)

10 *Crown Point*

Macoma groenlandica

11 *Crown Point station (mouth of Putnam Creek, ½ mile north)*

Macoma groenlandica

12 *Crown Point station (2 miles south, along shore)*

Macoma groenlandica

In addition to the places listed above, Macoma groenlandica has been found at Norwood, in the vicinity of Chazy, and at Essex and southward.

In Vermont the greatest number of species have been reported from the vicinity of Burlington, probably because that area has been better searched. The writer has found in the clays about a mile north of Burlington a Balanus crenatus, not hitherto reported from that state, and in the clays just north of Chimney Point Yoldia arctica, not before reported so far south as this. The fossils in Vermont have been found from north to south as follows:

1 McBride Bay, South Hero

Mya arenaria
Macoma groenlandica
Saxicava rugosa

2 Burlington and vicinity

Macoma groenlandica
Saxicava rugosa
Yoldia arctica
Balanus crenatus (rare)

3 Mallett's Bay, north of Burlington

Ophioglypha sarsii
Lepralia sp.
Macoma groenlandica
M. calcarea
Saxicava rugosa
Mya arenaria
Mytilus edulis
Yoldia arctica
Yoldia obesa
Leda minuta
Nucula tenuis
N. expansa
N. abyssicola
Cryptodon gouldii

4 Colchester

Macoma groenlandica
Saxicava rugosa
Mya arenaria
Yoldia obesa
Yoldia siliqua
Tethea sp.

5 Chimney Point

Macoma groenlandica
Yoldia arctica (rare)

In addition, Mytilus edulis has been reported from Isle La Motte, Mya arenaria from Providence island, and Yoldia obesa from St Albans. Shells also have been noted at Swanton, Milton Falls, Milton, West Milton, Chickering Village, Shelburne Falls, Charlotte, Vergennes and Addison, but no lists of species have been given.

The above tables and lists bring out the fact that the number of Pleistocene species is considerably reduced at Ottawa and vicinity, while from Pakenham Mills about 30 miles southwest of Ottawa, not far from the most western limit for *marine* fossils, is reported only Macoma groenlandica. In the Champlain valley the number of species decreases rapidly until at Willsboro, N. Y., only five species are represented.

Emmons (p. 283) states that two species of Pleistocene fossils are found the entire length of Lake Champlain. As a matter of fact only one species, Macoma groenlandica, has been found at the southernmost locality (*see* Woodworth, p. 215). Emmons reports no species south of Crown Point, and I have nowhere found a record of any such southern extension of this fauna; but Prof. John H. Cook in the course of some field work for the State Museum recently (1920) discovered two new localities for Macoma groenlandica, both of them farther south than Crown Point. One locality is along the shore near the mouth of Putnam creek, about one-half of a mile north of Crown Point station; the other is about 2 miles south of Crown Point station, just east of Breeds Hill, and the specimens were not visible in the deposits along the shore, but were dredged from the clay in the lake bottom. This second locality is about 8 miles farther south than the Crown Point area.

Four species extend down the greater part of the Champlain valley. Yoldia arctica found recently, together with Macoma groenlandica, just north of Chimney Point, Vt., has almost as great a range as the latter. Saxicava rugosa and Mytilus edulis were found a few miles north of Port Henry, and have not been found farther south. Only fragments of Mytilus edulis were found and these infrequently, which would indicate that this species was not represented in large numbers as far south as this. Balanus crenatus has not been reported south of Willsboro, nor Mya arenaria south of the Port Kent and Burlington areas. No gastropods occur south of Port Kent, which is the only locality in the Champlain valley from which they have been reported; and only four species have been found here. This does not take account of the three species of Buccinum reported, without locality, from the Champlain valley. The other phyla, Foraminifera, Porifera, Echinodermata, Bryozoa, Brachiopoda and Annulata, are almost without representation in the Champlain area. A specifically unidentified sponge (Tethea sp.) is listed as occurring at Colchester, Vt., and a bryozoan (Lepralia sp.) at Mallett's Bay, Vt. From this latter place one echinoderm also has been reported. Rhynchonella psittacea has been reported from the Champlain valley without a locality and Euryechinus drobachiensis is similarly listed from Vermont; so these citations can have little value in the present problem.[1]

[1] The basin was also open to large marine animals, such as whales and seals (Dawson, 1894, p. 267, 268; Perkins, 1907–8, p. 76, 80, 81, 102).

So far account has been taken only of the occurrence of marine Pleistocene invertebrate fossils. While it is not intended here to place too great weight upon the occurrence of fresh-water fossils, nevertheless, considering the conditions found in the Baltic, the possible significance of the association of marine and fresh-water forms in Pleistocene deposits should not be overlooked. At Clarenceville, an outport of Missisquoi county, Quebec, between the Richelieu river and Missisquoi bay, four species of fresh-water fossils are found in the deposits with *Mya arenaria* and *Macoma groenlandica*. Three of these species, *Unio rectus* Lam., *Unio cardium*? Rafinesque, *Unio ventricosus* Barnes, are represented by large and thick shells better developed than those of the St Lawrence river at present. A species of *Limnaea* also occurs here (Dawson, 1894, p. 58, 238). A similar occurrence of fresh-water fossils has been noted (Ref. cit., p. 238, 245, 246, 248) at Pakenham Mills, in Lanark county, about 30 miles southwest of Ottawa, and about 20 miles east of the western limit of known marine fossils (Coleman, p. 130). A *Sphaerium*? was found here associated with fresh-water bivalves and *Macoma groenlandica*, but the specimens were too imperfect for certain determination. Other species reported from the Saxicava sand and Leda clay of this locality are:

Amnicola limosa (Say)	Valvata tricarinata Say
A. porata (Say)	Planorbis bicarinata Say
Limnaea palustris Müller	P. trivolvis Say
L. elodes? Say	P. parvus Say
Patula (Pyramidula) striatella Anthony	Campeloma decisum Say

From the villages of Avonmore and Monklands, south of Ottawa, Coleman (p. 132) reports fresh-water shells of at least eleven species. At Montreal were found two species of *Limnaea*, *L. umbrosa* Say and *L. caperata* Say (Dawson, 1894, p. 245), and from Mallett's Bay, Vt., (Perkins, 1909–10, p. 55) is reported *Helix (Pyramidula) striatella* found in the Leda clay. In the Montreal and Vermont areas the fresh-water species very probably were carried in by streams. The occurrence of fresh-water fossils together with *Macoma groenlandica* and *Mya arenaria* at Clarenceville is very suggestive of estuarine conditions. The Pakenham Mills area, to which fresh-water fossils are peculiar, is of great interest in this connection. Two of the genera, *Planorbis* and *Limnaea*, and one species, *Limnaea palustris*, which were found adjusted to the slightly saline waters of the upper Baltic, are represented here. It is quite possible that all or part of these forms were carried in by rivers; but the situation of Pakenham Mills near the western limit of known marine fossils is significant and in favor of brackish-water conditions there, and consequent adjustment of the fresh-water forms to this condition. Also, as noted above, the only marine shell found is Macoma groenlandica, which is now found farther up in the estuaries than most others.

There is evidence of freshening of the sea westward. In the region west of the fossiliferous beds, at higher levels, are beachlike deposits of sand and gravel and also stratified clays resembling the Leda clay which are believed by some to be of marine origin, but by others (see Coleman, p. 136, 145) to be of fresh-water origin. Coleman says: " That the old sea level at 350 feet continued into the Ontario basin, and may even have reached its western end seems very probable, and the fact that marine fossils are very abundant east of Brockville, but have never been found to the west, may be accounted for by the narrowing of the lower end of the basin forming a strait not very much wider than the present river and only 100 feet deeper; so that Niagara and the other rivers flowing into Lake Ontario were able to keep the waters fresh, or at least only brackish, in spite of their communication with the enlarged Gulf of Saint Lawrence " (Ref. cit., p. 136).

Part 2 *Dwarfing of Species and Other Modifications*

Dwarf faunas may be divided into two classes: (1) " faunas where the individuals are of smaller size than that to which the species grows under normal conditions; this is the result of an abnormal habitat; (2) faunas where all the individuals are small but of the normal size of the species; in this case some selective action has weeded out all the large and heavy species, leaving a dwarf but not stunted fauna. Dwarf faunas usually include representatives of both classes " (Shimer, p. 490). This, from the data gathered, seems to be true of the Champlain Pleistocene fauna. The dwarfed character of this fauna is well shown by five species: Macoma groenlandica, Saxicava rugosa, Mytilus edulis, Mya arenaria, Yoldia arctica (see plates 1-3). Through the kindness of Doctor Pilsbry, I have obtained for comparison recent specimens of these species, in addition to those in the State Museum.

It is well, perhaps, to give approximately some idea of the numbers of individuals of the different species, upon which comparisons are based. The specimens of Macoma groenlandica collected at Montreal numbered about 225; at Ottawa and vicinity, about 50; at McBride Bay, South Hero, 150; at Cumberland Head, over 300; at Valcour island, over 160; at Lapham Corners, 115; at Port Kent, over 1000; at Burlington and vicinity, over 200; at Willsboro, several hundred; at Essex, over 150; at Port Henry vicinity, over 250; at Chimney Point, about 150; at Crown Point, over 150. The specimens of Yoldia arctica collected at Ottawa and vicinity numbered over 450 (about 375 at Ottawa); at Burlington and vicinity, about 75 (largely fragmentary); at Port Kent, over 350; at Willsboro, about 20; at Chimney Point 12 (fragmentary). The specimens of Saxicava rugosa, collected at Montreal numbered 110; at Ottawa and vicinity (almost entirely Green creek), about 275; at South Hero, 3 (small); at Burlington and vicinity, 7 (fragmentary); at Port Kent, about 300; at Willsboro, about 300. The specimens of Mytilus edulis collected at Lapham Corners numbered several hundreds; at Port Kent, 20+ (fragmentary); at Willsboro, 25+ (fragmentary); at Port Henry, few small fragments. Specimens of Mya arenaria were collected to the number of several hundreds at McBride bay, South Hero, and at Cumberland Head; at Valcour island, about 25+ specimens (largely fragmentary).

Macoma groenlandica is the only species found extending the entire length of Lake Champlain, the most southern occurrence, as noted above, being 2 miles south of Crown Point station. Professor Cook, in reporting the two new occurrences for this species stated that, so far as he could recall, the shells in size and character resembled those from Crown Point. The writer has not, as yet, had any opportunity for studying the shells collected in the vicinity of Crown Point station; and therefore it is the specimens from the Crown Point area, about 8 miles farther north, that are used here for purposes of comparison. The recent shells used in comparison are from the New Jersey and New York coasts. The largest recent shell examined has a length of 33.4 mm and a width of 25.5 mm. The other shells vary from 25 mm to 31.3 mm in length by 19 mm to 26 mm in width. The largest shells found at Montreal were in a fragmentary condition, but in proportion to the measurements of the other shells must have reached a length of 24 mm to 25 mm with a width of 20 mm to 21.5 mm. These very large shells were found to be fewer in number; a large proportion measure from 19 mm to 22.5 mm in length by 16 mm to 20 mm in width. The majority of the shells found, or what might be termed the average shells, are around 17 mm to 18 mm in length by 14 mm to 16.5 mm in width. At Crown Point, the largest shell found had a length of 15 mm and a width of 11.6 mm. The large shells are few and run from a little under 13 mm to 14 mm in length by 10 mm to 11 mm in width. Average specimens measure 10 mm to 12 mm in length by 7 mm to 10 mm in width. These measurements show that at Montreal the largest shells of M. groenlandica found are about the size of the average-sized recent individuals; while the average-sized Montreal specimens run much under this. The largest shells found at Crown Point are less than one-half the size of the largest recent ones and less than three-fifths the size of the largest shells from Montreal. The average Crown Point shells are half, or less, the size of average recent shells, and three-fifths, or slightly over, the size of average Montreal specimens. The Montreal specimens may be regarded as typically marine, and those from Crown Point as dwarfed. Other localities show various gradations between these two points, but there is a general decrease in size southward. (*See* plate 1, figures 6, 7, 8.)

M. groenlandica in the vicinity of Ottawa runs smaller, so far as specimens collected show, than at Montreal. The largest specimens found at Green's creek measured 19.2 mm to 20 mm in length by 14.7 mm to 17.5 mm in width; a number of shells measured from 17.2 mm to 18.3 mm in length by 14.3 mm to 15.6 mm in width; the majority of the shells from here are even smaller, the average running 15.2 mm to 16.5 mm in length by 12 mm to 13.7 mm in width. The average-sized shells here then are 2 mm to 3 mm smaller than at Montreal. At Cumberland Head, near Plattsburg, N. Y., the largest shells, very few in number, run from 17.5 mm to 21 mm in length by 15.4 mm to 16.3 mm in width; medium-sized shells measure 15 mm to 16.7 mm in length by 12.4 mm to 14.3 mm in width; the majority of the shells are smaller yet, ranging in size from 13.8 mm x 12 mm to 14.6 mm x 11.9 mm. At McBride bay, South Hero, Vt., these shells are smaller than at places farther south, except Crown Point and Chimney Point. This may be due to lack of extensive collecting, or perhaps an environment unfavorable to a better development of the shells. The largest shell found measures only 17.5 mm x 14 mm; medium-sized shells measure from 13 mm x 10.5 mm up to 14.3 mm x 12 mm; the majority of the shells have the following measurements or are smaller: 11.5 mm x 10.2 mm up to 13 mm x 10.7 mm. Near Burlington, Vt., and vicinity very few of the large shells were found and these measured from 18.7 mm x 16.5 mm to 22 mm x 17.7 mm. The medium-sized shells running from 17 mm x

14.8 mm to 17.7 mm x 14.6 mm are not abundant; the majority of the shells have the following measurements or are smaller: 14.7 mm x 12.8 mm up to 16.8 mm x 15 mm. Macoma groenlandica is not very abundant at Valcour island. The specimens collected here, in general, run smaller than those of the previous locality, but the predominating sizes at Valcour island run somewhat larger than the predominating sizes at Burlington and vicinity. The largest shells are few in number measuring 18.4 mm x 15.8 mm up to 18.8 mm x 16.3 mm and 19 mm x 15.1 mm. The medium-sized shells, 16 mm x 13.3 mm to 17.5 mm x 14 mm are fairly abundant; but the most numerous shells are smaller than this, giving the measurements 15 mm x 13 mm to 15.5 mm x 13.7 mm and 15.8 mm x 13.2 mm. At Lapham Corners, while the shells average about the same, the largest-sized shells are more abundant: 18 mm x 14.7 mm and 19 mm x 15 mm up to 22 mm x 19.3 mm; the medium-sized shells vary from 16.2 mm x 14 mm to 17.5 mm x 15.3 m; but the majority of the shells collected at this locality run as follows and smaller: 14 mm x 12.7 mm to 15.7 mm x 13 mm. M. groenlandica was found at Port Kent in much larger numbers than at any other locality, the largest proportion of the shells varying from 12.4 mm x 10.4 mm to 13.7 mm x 11.5 mm and 14.7 mm x 11 mm. The medium-sized shells measure from 15.2 mm x 13.7 mm to 17 mm x 14.7 mm; while the largest shells reach the size of 18 mm x 15 mm to 22 mm x 19.4 mm. At Willsboro, a short distance south, the shells were very abundant, but no shells were found so large as the largest size found at Port Kent; but the medium and average-sized shells run about the same. The largest shells vary from 17.2 mm x 13.7 mm up to 19 mm x 16.6 mm and 19.2 mm x 15.8 mm; the medium-sized shells vary from 14 mm x 11.3 mm to 15.7 mm x 13.5 mm and 16.7 mm x 13 mm; the majority of the shells average smaller than this and give the measurements: 12 mm x 9.5 mm to 14 mm x 10 mm. Although Essex is only a few miles south of Willsboro, from this point for several miles southward along the lake shore the shells average smaller and thinner, if anything. The majority of the shells vary from 13 mm x 11.8 mm to 15 mm x 12.5 mm; the medium-sized shells, which are much fewer in number, vary from 14.5 mm x 13 mm to 16 mm x 13 mm; while the few largest-sized shells show the measurements: 16.7 mm x 14.2 mm to 18.8 mm x 16.5 mm. The shells found a few miles north of Port Henry and just north of Chimney Point, Vt., while very small for the species, still run markedly larger than the Crown Point specimens. At the locality north of Port Henry only a very few (six) of the largest-sized shells were found and these vary from 18.2 mm x 13.7 mm to 21 mm x

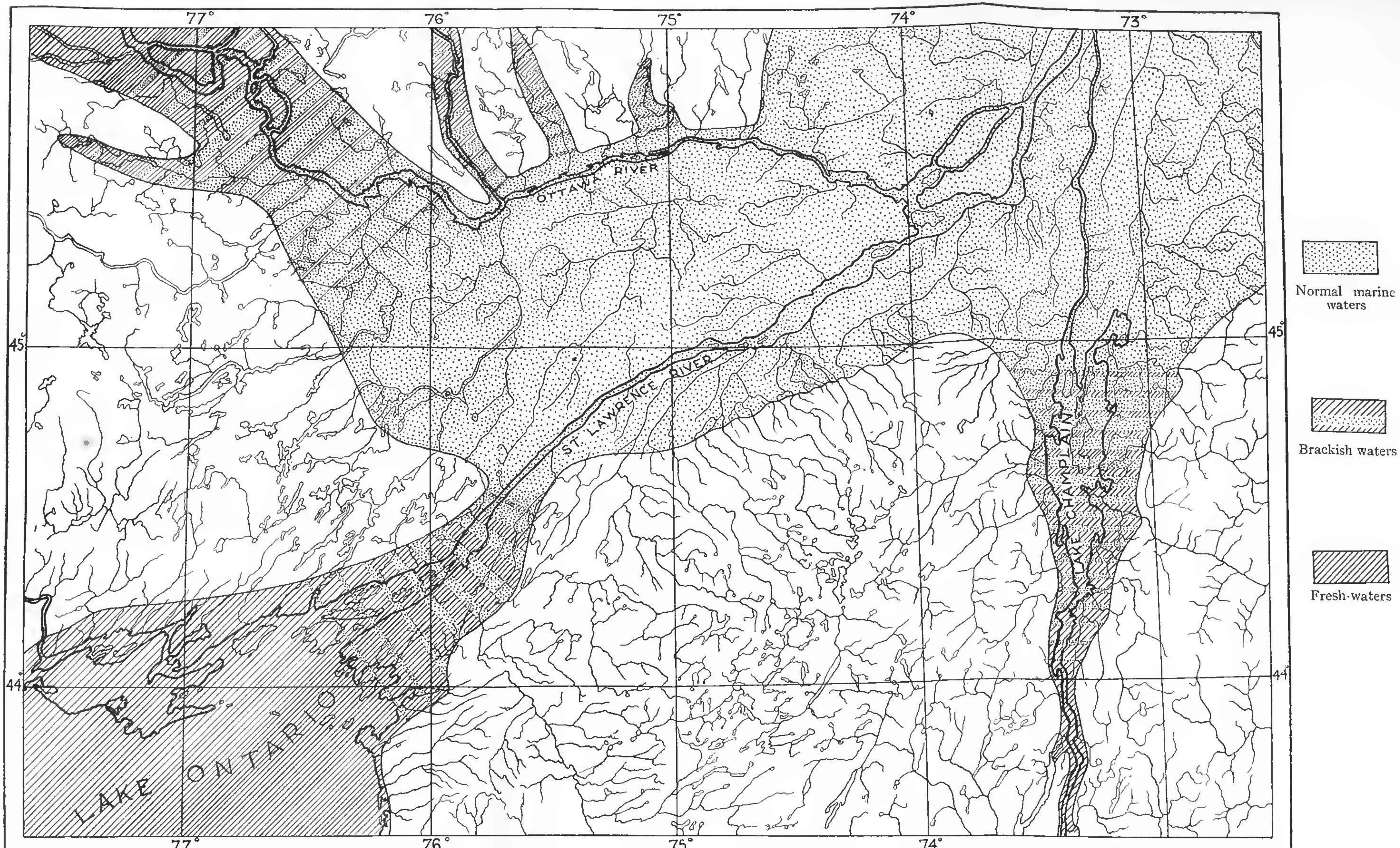
17.8 mm. Here there are two sizes about equally abundant: one size varying from 16 mm x 12.4 mm to 17.5 mm x 13.8 mm and the other, from 13.4 mm x 10.8 mm to 15.8 mm x 12.5 mm. None of the very large specimens was found in the vicinity of Chimney Point. One specimen was found measuring 17.2 mm x 14 mm. The large specimens found vary from 14 mm x 10.8 mm to 14.7 mm x 11.6 mm and 14.8 mm x 11.3 mm; average specimens vary from 12.1 mm x 10 mm to 13.5 mm x 10.8 mm and 13.7 mm x 10.1 mm; but the majority of the shells run smaller, measuring 10 mm x 8.2 mm to 11.6 mm x 9.2 mm.

Yoldia arctica has been found almost as far south as Macoma groenlandica. It has been collected at fewer localities and in smaller numbers than the latter; but it nevertheless shows the same gradual decrease in size southward. Just north of Chimney Point, the most southern locality for the species, the occurrence is very rare, so that few specimens were collected; seven fragmentary shells (four of them half shells) were found and pieces of five other half shells. So far as measurements can be made these shells vary from 8.7 mm x 5.5 mm to 9.5 mm x 6.1 mm and 9 mm x 6.4 mm. Comparison of shells from this locality with recent shells and those from the Montreal section can be made only approximately because of the small number to judge from. All the shells found run small, and since those found farther north run as small or smaller, the small size of the Chimney Point shells I think may be accepted without question. I am rather inclined to believe that a larger series of shells from this place would show that those in our possession are an expression of the larger sizes of the shell and that the average individual runs smaller. Typical adult recent forms of Yoldia arctica vary from 19.5 mm x 12 mm to 20.7 mm x 14 mm; at Montreal typical adult shells were found varying from 17.2 mm x 11.2 mm to 19.3 mm x 11.8 mm and 19.2 mm x 11.9 mm. Approximately, then, the Chimney Point shells are less than one-half the size of the recent shells and about one-half the size of the Montreal specimens. (*See* plate 2, figures 4, 5, 6.)

Yoldia arctica was collected in largest numbers at Ottawa and Port Kent, N. Y., and is apparently more abundant at the latter place. At Willsboro this species was rare in occurrence, though not so infrequent as at Chimney Point. The largest individuals here vary from 9 mm x 5.6 mm to 9.8 mm x 6.3 mm, while the average specimens measure from 7.1 mm x 4.6 mm to 8.8 mm x 5.7 mm. The average specimens vary from a little over one-third to less than one-half the size of the recent specimens and from one-half (or more) to less than one-half the size of the Montreal specimens. The Port Kent and Burlington localities are the most northerly ones at which Yoldia arctica has been collected in the Champlain area. The largest specimens at Port Kent vary from 10 mm x 7 mm to 12 mm x 8 mm; the averaged-sized specimens vary from 6. 7 mm x 4.5 mm to 8.5 mm x 5.4 mm and 8 mm x 6 mm. The majority of the specimens are included in the smaller sizes measuring 7 mm in length and slightly under. The largest specimens then are a little above one-half to three-fifths or more the size of the recent and Montreal specimens, while the average-sized specimens are well under one-half, and even one-third, their size. Of the specimens found at Burlington and vicinity, the largest number were found around Mallett's Bay, but the species was not found to be very abundant anywhere in this area. A larger number of specimens would be necessary to make any more than an approximate comparison with the Port Kent material; but so far as observations go the average specimens of this material run as small as, and perhaps smaller than, those from Port Kent. The large-sized specimens are few in number and vary from 9.8 mm x 6 mm to 13.9 mm x 8 mm. The average-sized specimens (the majority) vary from 5.8 mm x 4 mm to 8.2 mm x 5 mm, but only a few reach the upper limit of size. In the vicinity of Ottawa the specimens in general run smaller than at Montreal, the largest having been collected at Ottawa. The largest specimens here attain the size of 16.4 mm x 9 mm to 19 mm x 11 mm, but the majority of the specimens vary in length from 13 mm to 15 mm and in width from 8 mm to 9 mm. At Green's creek along the Ottawa river, several miles below Ottawa, and at Britannia, a few miles above, all the specimens found were much smaller; but specimens were not found in these localities in sufficient numbers to permit comparisons.

Saxicava rugosa and Mytilus edulis were both found just a few miles north of Port Henry, but Mytilus only in small fragments and these very infrequent, so it is rather impossible to make any conjectures as to the size of the individuals of that species at this locality. Recent specimens of Saxicava rugosa from Barden bay, Greenland, range from a size of 34.6 mm x 18.8 mm to 41 mm x 20 mm. Macoma groenlandica was found to be by far the most abundant species in the Port Henry area; while S. rugosa was found to be rare. Less than twenty specimens were collected here, the largest found measuring 22 mm x 11.5 mm and the others ranging from 18.4 mm x 10 mm to 21 mm x 10.3 mm. The Port Henry area was very carefully searched; and, while the number of specimens collected is not sufficient to make hard and fast comparisons, I believe they may be regarded as typical of the area. They are a little over one-half the size of the recent specimens, and are very considerably smaller than the average Montreal shells, which in addition are very much thicker. The largest Montreal specimen measured 37 mm x 17.1 mm; average large specimens range from 31 mm x 16 mm to 34 mm x 21 mm; a large proportion of the material shows measurements from 22 mm x 14 mm to 27 mm x 16 mm. The Port Henry material therefore runs about the size of the smaller Montreal specimens, though even the very small specimens from the Montreal area have very heavy shells. (*See* plate 1, figures 1–5.)

Localities in the Champlain valley between these two areas show intermediate-sized specimens. At Willsboro the specimens tend to be chunky, short and broad. Only a few are at all large and the majority run rather small. Out of about three hundred specimens only four of the largest sizes were found and these range from only 25.5 mm x 12.8 mm to 28 mm x 13.5 mm. Average large specimens, about ten out of the whole number, vary from 22 mm x 10.8 mm to 23 mm x 12.8 mm; but the majority of the specimens measure as follows and smaller: 17.8 mm x 10 mm to 19.5 mm x 11.6 mm and 20.5 mm x 11.4 mm. At Port Kent, in about the same number of specimens, the shells run slightly larger. The largest sizes, though few in number, are more numerous than in the Port Henry area and range from 25 mm x 12 mm or 13 mm to 29 mm x 14.5 mm. The average large specimens vary from 22 mm x 13.7 mm and 22.6 mm x 11.6 mm to 23 mm x 12.6 mm and 24.8 mm x 11 mm; but the majority of the shells run smaller: 18.4 mm x 11.7 mm to 21.7 mm x 11.6 mm. In this last group belong also shells which run longer, but are much narrower. This variation in the shape of the shells in the same locality will be discussed later. At Valcour island the larger sizes are more abundant and the shells are much heavier again, approaching the condition found in the Montreal area. The species is more abundant here than in any of the other localities and the specimens collected are the largest found in the Champlain valley. The largest specimens range from 28 mm x 17 mm and 29.5 mm x 14 mm to 34.5 mm x 15.5 mm; the average specimens, and the most abundant, measure 22 mm x 11.2 mm to 27.8 mm x 14.3 mm and 28 mm x 13.5 mm. A large portion of the specimens are under 25 mm in length, varying from 20 mm to 25 mm. In the vicinity of Burlington fragments of a few specimens were found, insufficient for comparison; at McBride Bay, South Hero, only three small specimens were found. Valcour island, therefore, is the most northern locality in the Champlain area at which specimens were found in numbers



Map 2 Map of the Champlain sea showing the relative salinity of the different parts. Based upon maps by Coleman and Mather for Canada, Woodworth and Fairchild for New York (see bibliography). Boundaries in Canada more or less generalized and only approximately correct. Scale $\frac{1}{950400}$; approximately 15 miles to the inch.

sufficient for making comparisons. In the Canadian area, in addition to the Montreal material, specimens were collected at Ottawa and vicinity. At Ottawa only a few small specimens were found, decidedly not typical; but at Green's creek, along the Ottawa river, 8 miles below Ottawa, more typical material was found, though not in great abundance. The shells found range from average-sized specimens with a length of 15 mm and width of 7 mm to the largest-sized specimen with a length of 25 mm and width of 13.8 mm, giving measurements well under those for Montreal.

Mytilus edulis was found only in small numbers south of Lapham Corners; and this is the most northern locality in the Champlain area from which the writer has shells for comparison. Specimens collected here number up to several hundreds. The largest specimens range from 38 mm x 20 mm to 45 mm x 20 mm and 43 mm x 25 mm. Sizes varying from 33 mm x 17 mm to 41 mm x 18 mm are abundant, but a large part are smaller. The larger specimens in the case of this species are used for comparison, because I have only the larger, representative recent forms and in some localities only enough specimens have been found to make such a comparison. Recent forms from the New York coast range from 68 mm x 32.1 mm to 77.5 mm x 35.2 mm; from Cape May, 68 mm x 29.7 mm to 76.4 mm x 35.3 mm. Specimens from Gay Head, of "average adult size for the locality and station" run somewhat smaller than those from the two preceding localities. The largest specimen at hand measures 68.3 mm x 30.7 mm. The larger Lapham Corners specimens run one-half to three-fifths and less the size of the largest recent specimens. No specimens have been obtained from the Montreal area. A specimen figured in "Geology of Canada" for 1863 (page 963) measures 40 mm x 20.5 mm, but I should regard this as small for the area. (*See* plate 2, figures 1–3.)

Farther south, at Port Kent, only about a dozen specimens at all complete were found. The largest specimens measure 52 (?) mm x 27 mm and 46 mm x 22 mm; the rest of the specimens range from 32.5 mm x 18.5 mm to 43.7 mm x 27 mm. The largest specimens run about three-fifths the size of the largest recent specimens; most of the other specimens run one-half, and less, that size. At Willsboro, a short distance farther south, the shells are heavier than at Port Kent and, particularly, Lapham Corners. I think this is due to the fact that the limy layer has been dissolved away to a large extent in the specimens from the last-named places. As noted above, at Port Henry only small fragments were found, and these of rare occurrence. At Willsboro, compared with Saxicava rugosa and Macoma groenlandica, this species is relatively rare. Only a few shells are anywhere near perfect, and the larger shells are so broken that measurements can be only approximate or not taken at all. The largest specimens must have had a length of 45 mm to 52 mm and greatest width of 23 mm to 26 mm. The rest of the specimens (not more than twenty-five collected in all, besides the fragments) range from 31.8 mm x 19.5 mm to 43 mm x 23 mm, the majority running under 40 mm in length. The specimens in general run from under one-half to about three-fifths the size of the recent specimens, with the exception of the two or three largest specimens. With the small number of specimens from this locality, it is difficult to make comparisons; but the material seems in general to run about the same as that from Port Kent and Lapham Corners.

Mya arenaria, like Mytilus edulis, has been found in only a few localities, but the Pleistocene specimens from the Champlain area are so pronouncedly smaller and thinner than the recent and Montreal Pleistocene specimens that they deserve consideration here. Recent specimens from the New York coast and Portland, Maine, range from 76 mm x 45.2 mm to 89 mm x 51.2 mm. Specimens from the shore of the bay at Ocean City run considerably smaller, those used in comparison ranging from 64.2 mm x 39.5 mm to 69.6 mm x 42.2 mm. A large number of fragments were found at Montreal, but no whole specimens. The fragments show that the specimens were fully as heavy and must have been comparable in size to the typical, adult recent specimens. In " Geology of Canada " for 1863 (page 963) is figured a specimen from the Montreal area measuring 85 mm x 50 mm, almost the size of the largest recent specimen here used (*see* plate 3).

Pleistocene specimens of this species were collected at Cumberland Head (near Plattsburg); McBride bay, South Hero; and Valcour island. The two largest specimens out of a collection of several hundred specimens from Cumberland Head, measure 52 mm x 35 mm and 50 mm x 31 mm. Other specimens range from 37 mm x 25 mm to 44 mm x 30 mm. The majority of specimens have a length of 40 mm or less, though quite a number range between 40 mm and 44 mm in length. The South Hero specimens are smaller, if anything, than those from Cumberland Head. The largest specimen in the collection of several hundred from this area measures 52 mm x 33 mm. Typical specimens range from 31.3 mm x 18 mm to 44 mm x 29 mm, the larger number measuring less than 40 mm in length. This species is much less abundant at Valcour island. Much of the material collected is fragmentary and comparisons can be made on only about twenty-five specimens. The largest found measures 42 mm x 27.5 mm. One fragmentary specimen, if complete, might be a little larger than this specimen, but there is not enough difference to count in the general run. Other specimens measured range from 33 mm x 20.3 mm to 41 mm x 34.8 mm; and the fragmentary specimens seem to run about the same size. I should say that in general the Valcour island material runs about the same as the South Hero material, with perhaps a smaller representation of the larger-sized specimens. From the above measurements it is seen that the Valcour specimens run one-half, and less, the size of the recent specimens; in the South Hero material, the largest specimen is about three-fifths the size of the largest recent specimen, and a large part of the average material is about one-half the size of recent specimens. At Cumberland Head the relations stand much the same, though the larger specimens here are more abundant.

There is one other species, Cylichna alba, which occurs in a dwarfed form in the Champlain valley. This species has been found only at Port Kent, and even there is relatively infrequent. About 115 specimens were found during the course of several days' collecting, all running much smaller than the Canadian specimens. The largest Port Kent shells are about one-half the size of those from Canada, the majority, however, are much smaller, ranging from two-fifths down to one-third the size of Canadian forms. (*See* plate 2, figures 8, 9.)

Just as it is found in the Baltic, so here, together with the dwarfing of species goes a decreasing thickness of shell. The little Cylichna alba, just discussed, has a very thin shell, so thin that even in working the specimens out of the sand with the point of a small knife-blade many were broken. Of the other shells, Yoldia arctica, Macoma groenlandica and Mya arenaria perhaps show the most noticeable changes. Yoldia arctica, through the Champlain area, from Port Kent southward, shows the same characteristics as Cylichna alba. The shells are of a paperlike thickness and very easily broken in collecting. For this reason most of those collected at Chimney Point, Vt., the most southern locality, are in a fragmentary condition. Even the smaller specimens of Macoma groenlandica from the Montreal area are stoutly built and not easily crushed. Though there are slight variations in some localities, in general there is a gradual decrease in thickness of the shells of this species going southward, until at Crown Point even the largest shells are very easily crushed into numerous pieces between the fingers. At Cumberland Head and South Hero the shells of Mya arenaria particularly were found in quantity and suggested a mass of broken eggshells, a resemblance which is further carried out by their extreme thinness and brittle character. The thinness of the shells of this species at these localities is in striking contrast to the specimens from Montreal and recent specimens. The Montreal specimens are somewhat heavier even than the recent individuals and are three or four times as heavy as the specimens from the Champlain area, measuring even up to 2.6 mm, 3.5 mm, or even 4 mm, in thickness at the thickest part of the shell. Saxicava rugosa shows extremely heavy shells, even among the smaller sizes, from the Montreal area (*see* plate 1, figures 4, 5). Some of them are much heavier than the recent forms from Barden bay, Greenland, but in general this species seems to have been less affected than the others as regards thickness of shell. Saxicava rugosa near Pebble Beach, south shore of Valcour island, is so abundant that shells can be collected by the hundreds in a very short time. Here the shells tend to run rather heavy, the largest ones approaching the Montreal specimens, which in their heaviest expression have a thickness of 2 mm to 2.5 mm and almost 3 mm in the thickest part of the shell. At Port Kent and southward the shells run thinner again, having their thinnest expression in the few specimens found a few miles north of Port Henry. Here the thickness of the largest specimens is no more than .5 mm. There is not sufficient data to make similar comparisons for the specimens of Mytilus edulis found in the various localities.

Walther (1920, p. 210) points out that brackish-water conditions are indicated also by insignificant constancy of form. This is shown to some degree by Macoma groenlandica and Saxicava rugosa, where the shells may be longer and narrower, or shorter and wider than normal or show gradations between these two forms. In Yoldia arctica from the Champlain area the modified form of the shell is very noticeable, as shown by figure 7, plate 2. In the recent forms and those from the Montreal and Ottawa areas, there is a pronounced posterior extension or wing, with subacute tip. The specimens from the Champlain area, Port Kent and southward, possess this posterior wing, but it is shorter and blunter, giving a squarish appearance to the posterior end of the shell; in a large proportion of the shells, the wing is so blunted at the tip that it is hardly recognizable as such. There are all gradations between these two types of forms, and except for these gradations the extreme forms of the Champlain area are so different from the typical form from the vicinity of Montreal and Ottawa that one would be inclined to regard them as belonging to another species.

Pleistocene Fauna of the Hudson Valley and its Significance

No fossils have been reported from the Pleistocene deposits of the Hudson valley south of Croton Point, either from the New York or New Jersey shores. The clays of the Hackensack region, New Jersey, might be attributed either to marine or lacustrine origin (Salisbury, p. 195, 200). The absence of fossils seems to be against the hypothesis of a bay of salt water. However, it is thought probable (ibid., p. 198) that such connections as the bay had with the ocean were perhaps outlets rather than inlets and the discharge of fresh water into the bay after the ice had left New Jersey must have been great. Under these conditions the waters of the bay may not have been salt, or at least not normally salt, which would account for the absence of marine life.

The most northern point at which Pleistocene fossils have been reported from the Hudson valley is at Storm King, 50 miles above New York (Shimer, p. 488, 489). The specimens were found in drilling a series of holes across the Hudson bed and belong to only two species, Mulinia lateralis (Say), of which hundreds of specimens were collected, and Trivia trivittata Say, of which there were but few specimens collected. The fossils were found 620 feet out in the river from the Storm King shore, 40 feet below the bed of the river, which is about 120 feet below the present river or sea level at that point. Shimer describes this as a dwarf fauna which in the abundance of Mulinia lateralis suggests Pleistoceen age. He points out that the Hudson today is brackish at Storm King and as far north as Poughkeepsie and that heavier sea water might still come up in sufficient amount to furnish a marine habitat even under quite fresh surface conditions; but that it was not ascertained whether there are any marine forms in the present bed of the stream. Fairchild (1919, p. 16) states that salt-water organisms pass up the Hudson only to the Highlands.

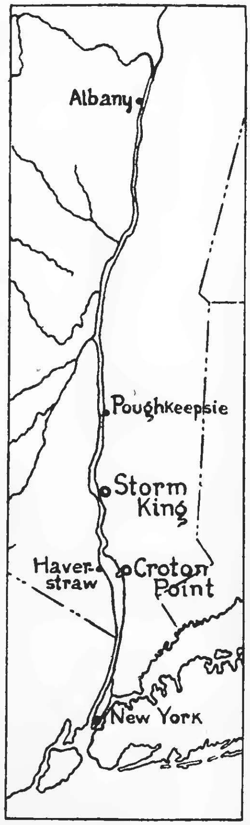


Fig. 2 Sketch map of Hudson river valley showing localities [o] where marine Pleistocene fossils were found.

The two species found at Storm King live at present off the New England and New Jersey coasts, in normal marine or but slightly freshened water; and in these localities are considerably larger than the Pleistocene specimens. An average size for specimens of Trivia trivittata off the Massachusetts coast is two-thirds of an inch long by one-third of an inch greatest diameter; an average-sized fossil specimen is three-eighths of an inch long by a greatest diameter of three sixteenth of an inch. An average specimen of Mulinia lateralis from the New England coast has a length of nine-tenths of an inch and a width of six-tenths of an inch. One of the larger of the fossil specimens measured five-sixteenths of an inch by one-fourth of an inch. Shimer further points out: "The young shells off the coast are small, thin, with margins subequally rounded and beaks inconspicuous and nearly touching each other; this description applies to all of the Hudson River specimens. It does not seem probable, however, though possible, that so many shells could be gathered at random as was done by the drill without getting some adults. The more probable explanations seems to be that these fossil individuals were living in an unfavorable environment, a water less than normally saline, and through a constant sapping of vitality, were not able to attain large size" (p. 489). Recently a few specimens of Mulinia lateralis were collected at Croton Point about 20 miles south of Storm King. The largest one measured 11.9 mm x 8.5 mm (i. e. about seven and one-half sixteenths of an inch long); a smaller specimen measured 7.1 mm x 5.3 mm (i. e. about four and one-half sixteenths of an inch long). The larger specimens from Storm King run somewhat smaller than the largest specimen from Croton Point, as one might expect in waters of decreasing salinity; but the latter is still only about one-half the size of average recent forms, under normal conditions.

In the sandy layers at Croton Point, a few feet above the water's edge, occurs a bed of oysters (Ostrea virginiana Lister), similar to the thick Saxicava beds found in some localities in the Champlain area and Canada. In one place the bed reaches a thickness of about 30 inches, but it quickly thins out and varies from 12 and 14 inches to about 6 inches; following around the point to the shore on the north side only a thin line of shells is found. It has been popularly assumed that this bed of oysters represents an Indian shell heap. Prof. A. W. Grabau, I understand, some years ago, in a paper which I have not been able to locate, describes this occurrence of oyster shells as an oyster bed rather than a shell heap[1]; and the evidence which I have collected seems to indicate the

[1] Woodworth (p. 187) after an examination of this oyster bed concluded that the shells were in a talus and derived from an old shell heap at the top of the bluff.

same thing. Some of the oysters in this bed are of very large size, but the majority of the shells belong to young forms, and there are a large number of very young forms, "baby" oysters. Also associated with the oyster shells are a number of other marine species of shells: Mya arenaria Linn., Modiola demissus (Dill.), Mulinia lateralis (Say), and Alectrion (Nassa) obsoleta (Say). Balanus crenatus Brug. was collected here; but as that form occurs on the oyster shells, it is of no importance in this connection. I have discussed this bed of shells found at Croton Point with the State Archeologist, Arthur C. Parker, and he believes that the conditions found there warrant the assumption that the occurrence is an oyster bed.

Of the marine forms collected at Croton Point, all but the oysters are in too small numbers or too fragmentary to make comparisons as to size with typical marine forms. Mulinia lateralis we have discussed above as larger than the specimens from Storm King and smaller than the recent shore forms. The oysters occur in very large sizes and the largest specimens are quite massive; but this is a euryhaline form which thrives in water with diminished salt content (Walther, 1920, p. 210).

A number of fresh-water gastropods were found to be of rather frequent occurrence in the oyster beds. They are Polygyra hirsuta (Say), Polygyra fraudulenta (Pilsbry), Eyrgomphala alternata (Say) and Planorbis sp?. These species undoubtedly were carried in by streams.

Ries (p. 594, pl. 14) reports sponge spicules from Croton Point; also five species of fresh-water diatoms. At Croton landing a number of impressions were found in the blue clay which were identified as worm tracks by Professor Hall.

The Pleistocene fauna of the Hudson valley; as far as present knowledge goes, is very small; but I am of the belief that, with this problem in mind, more information can be obtained through further work along these lines. The present evidence, however, seems to lead to the same conclusions as were drawn for the Champlain area. The waters of the Pleistocene Hudson estuary were so freshened in going northward that (1) only a few marine forms were able to advance into these waters at all; (2) so far as present knowledge goes, only two species reached as far up as Storm King, 50 miles above New York, and none has been reported north of this locality; (3) the two species found at Storm King represent a dwarf fauna, one of them, Mulinia lateralis, occurring in a dwarfed condition (less so, however) at Croton Point about 20 miles farther south.

Experiment in the laboratory and observation in the field (information of Dr Raynor Lidén and Dr Ernest Anters) have shown that clay deposited in fresh water shows a laminated character that is not found in similar deposits laid down in very brackish or salt water. The Pleistocene clays in the vicinity of Albany and northward show this laminated character very beautifully, and it has been found in the clays of the Hudson valley extending as far south as Haverstraw (Ries, p. 577). This condition of the clays verifies what has already been indicated by the absence of marine fossils: that the Pleistocene waters of the Hudson valley were fresh or practically fresh north of Storm King. In contrast to this, nowhere in the Champlain area where marine fossils were found was this peculiar laminated character noted, which fact, together with the distribution and character of the fossils of this area, indicates that the Champlain sea extended in a brackish condition, gradually freshened, to the vicinity of Crown Point station and that south of this area its waters were practically fresh.

Summary

This study of collections made in the Champlain and St Lawrence valleys has led to the conclusion that the character of the Champlain Pleistocene fauna is due in large part at least to decreasing salinity southward in the waters of that time.

The first part of this paper is given up to a discussion of conditions found in the Baltic sea and other freshened bodies of water. The Baltic sea shows a very striking decrease in salinity eastward and in a large way the responses of the fauna to it. As the salinity of the water decreases from that normal for sea water, the fauna changes from one typically marine to one in which only a few marine groups are represented and finally to a fresh-water fauna. Each phylum is affected. The decrease in number of species eastward is very rapid; the Baltic has been described as being faunistically divided into two basins, a western and an eastern, the former marked by a rich fauna, the latter by a strikingly impoverished one. Another striking change in the Baltic fauna is the dwarfing of the euryhaline forms. This has been noted among the worms, crustaceans, fishes, but the best examples are found among the mollusks, notably *Mytilus edulis* and *Cardium edule*. In addition to being dwarfed the shells become poor in lime, as exemplified by *Mytilus edulis* and *Macoma balthica* (*groenlandica*). Examples of dwarfing and decrease in thickness of the shells (in the case of mollusks) due to freshening of sea water have also been noted in the British estuaries, and in the Black and Caspian seas.

A careful list, with localities, has been compiled of the Pleistocene invertebrate species collected and reported and these have been tabulated to show the distribution of the species from the sea (Labrador) to the southernmost locality (Crown Point station) from which they have been collected in the Champlain area. The total number of Pleistocene species reported from all localities is 183. Of this number, 89 have been collected from the vicinity of Montreal and 25 from Ottawa and vicinity. So far as reported, only 32 of the total number of species entered the Champlain area, and of this number 7 are listed without localities. At Port Kent, about 40 miles north of the Crown Point area, only 13 species occur; from Burlington and vicinity, on the Vermont side, are reported 17 (—) species. There is a rapid decrease in species from this point southward: at Willsboro only 5 species occur (Saxicava rugosa, Macoma groenlandica, Mytilus edulis, Yoldia arctica, Balanus crenatus); a few miles north of Port Henry, 3 species (Macoma groenlandica, Saxicava rugosa, Mytilus edulis); just north of Chimney Point, Vt, 2 species (Macoma groenlandica, Yoldia arctica); at Crown Point, 1 species (Macoma groenlandica).

By comparison of specimens of the Pleistocene species of the Champlain area and Canada with recent representatives it has been found that the Champlain fauna is a dwarf fauna, the dwarfed character being well shown by 5 species: Macoma groenlandica, Saxicava rugosa, Mytilus edulis, Mya arenaria and Yoldia arctica. In general, representatives of all these species show a gradual decrease in size southward. For example, in the case of Macoma groenlandica, which extends farther south in the Champlain area than any other species the largest shells from Crown Point are less than half the size of the largest recent ones and less than three-fifths the size of the largest shells from the Montreal area. The average Crown Point shells are half, or less, the size of average recent shells and three-fifths, or slightly over, the size of average Montreal specimens. Another species, Cylichna alba, occurs in a dwarfed form in the Champlain valley, but has only been found at Port Kent and is there relatively infrequent.

Just as it is found in the Baltic, so here, along with the dwarfing of species goes a decreasing thickness of shell. This is seen best in Cylichna alba, Yoldia arctica, Macoma groenlandica and Mya arenaria, but is also well shown in Mytilus edulis and Saxicava rugosa.

The variability in form noted by Walther as characteristic of a fauna living under brackish-water conditions is shown in the various Champlain localities to some degree by Macoma groenlandica and Saxicava rugosa; very strikingly by Yoldia arctica.

The Pleistocene fauna of the Hudson valley is briefly considered, but the data are meager. The evidence obtained, however, seems to lead to conclusions similar to those arrived at for the Champlain area. The waters of the Pleistocene Hudson estuary were so freshened going northward that (1) only a few marine forms were able to advance into these waters at all; (2) so far as present knowledge goes only two species reached as far up as Storm King, 50 miles above New York, and none has been reported north of this locality; (3) the two species found at Storm King represent a dwarf fauna, one of them, Mulinia lateralis, occurring in a dwarfed condition (less so, however) at Croton Point about 20 miles farther south.

It is recognized that clay deposited in fresh water shows a laminated character not found in similar deposits in very brackish or salt water. The laminated character of the Hudson Valley clays, seen as far south as Haverstraw, and the absence of this peculiar laminated character in any of the localities in the Champlain area where marine fossils were found, verifies what has already been indicated by the distribution and character of the faunas of these areas: (1) that the Pleistocene waters of the Hudson valley were fresh, or practically fresh, north of Storm King; (2) that the Champlain sea extended in a brackish condition to Crown Point and that south of this area its waters were fresh or practically fresh.

Bibliography

1 **Ami, Henri M.** Additional Notes on the Geology and Paleontology of Ottawa and Its Environs. Ottawa Naturalist, 1892, 6:75

2 **Baldwin, S. Prentiss.** Pleistocene History of the Champlain Valley. Amer. Geol., 1895, 13:170–84

3 **Coleman, A. P.** Marine and Freshwater Beaches of Ontario. Bul. Geol. Soc. Amer., 1901, 12:129–46

4 **Dawson, Sir J. William.** The Canadian Ice Age, Montreal, 1894, particularly, p. 58, 209–69

5 **Emmons, Ebenezer.** Geology of New York. Surv. 2d Geol. Dist., 1842, p. 128, 283–85

6 **Fairchild, H. L.** Postglacial Marine Waters in Vermont. Rep't Vt State Geol. for 1915–16, p. 3–6

7 ———. Pleistocene Marine Submergence of the Hudson, Champlain and St Lawrence Valleys, N. Y. State Mus. Bul. 209–210, 1919

8 **Forbes, Edward.** Natural History of the European Seas. London, 1859, p. 88–90, 171, 201–15, 230, 231

9 **Grabau, A. W.** Principles of Stratigraphy, New York, 1913, p. 1044–45, 1066–69

10 **Jacobsen, O.** Ueber den Salzgehat des Ostseewassers. Jahresbericht der Commission zur wissenschaftlichen Untersuchung der deutschen Meere in Kiel für das Jahr 1871. 1873, 1:37–52

11 **Logan, *Sir* William E.** Geology of Canada. 1863, p. 915–28, 963, 964

12 **Lull, R. S.** Organic Evolution. 1917, p. 172

13 **Mather, Kirtley F.** The Champlain Sea in the Lake Ontario Basin. Jour. of Geol. 1917, 25:542–54

14 **Möbius, Karl.** Die faunistischen Untersuchungen in der Ostsee im Jahre 1871, auf der Expedition S. M. S. Pommerania. Der Zoologische Garten. Zeitschrift für Beobachtung, Pflege und Zucht der Thiere, 1872, 13:276–80

15 ———. Die wirbellosen Thiere der Ostsee. Jahresbericht der Commission zur wissenschaftlichen Untersuchung der deutschen Meere in Kiel für das Jahr 1871. 1873, p. 97–144

16 **O'Connell, Marjorie.** The Habitat of the Eurypterida. Bul. Buff. Soc. Nat. Sci., 1916, 11:70–73

17 **Perkins, G. H.** 6th Report of the Vermont State Geologist for 1907–8. The Pleistocene, p. 255, 256

18 ———. 7th Report of the Vermont State Geologist for 1909–10. The Pleistocene, p. 55

19 ———. A General Account of the Geology of the Green Mountain Region. 8th Report of the Vermont State Geologist for 1911–12. Pleistocene, p. 35–56

20 **Pouchet, G. & de Guerne, J.** Sur la faune pélagique de la mer Baltique et du golfe de Finlande. Comptes Rendus Hebdomadaires des Séances de l'Academie des Sciences. 1885, 100:919–21

21 **Ries, Heinrich.** Clays of New York. N. Y. State Mus. Bul. 35, 1900, p. 572–95

22 **Salisbury, R. D.** Glacial Geology of New Jersey. Geol. Surv. N. J., 1902, 5:195–200

23 **Shimer, H. W.** Dwarf Faunas. Amer. Nat., 1908, 42:472–90

24 **Walther, Johannes.** Einleitung in die Geologie als historische Wissenschaft I. Theil: Bionomie des Meeres. Jena 1893–94, p. 62–65

25 ———. Allgemeine Palaeontologie. Geologische Fragen in biologischer Betrachtung. I Teil: Die Fossilien als Einschlüsse der Gexteine; II Teil: Die Vorgänge des Lebens in der Vorzeit. 1919–20, p. 60, 123–216, 210

26 **Woodworth, J. B.** Ancient Water Levels of the Champlain and Hudson Valleys. N. Y. State Mus. Bul. 84, 1905, p. 206–16

EXPLANATION OF PLATES

PLATE I

Saxicava rugosa Lam. (= *arctica* L.)

Fig. 1 Recent specimen (right valve) from Barden bay, Greenland.

Fig. 2 Outlines of right valves showing comparison in size of the largest Pleistocene specimens from various localities in Canada and New York with one of the largest recent specimens. *a*, recent, Barden bay; *b*, Montreal; *c*, Valcour island; *d*, Port Kent; *e*, Willsboro; *f*, Ottawa vicinity; *g*, few miles north of Port Henry.

Fig. 3 Similar outlines of average-sized specimens showing comparison with a medium-sized recent form. *a*, recent, Barden bay; *b*, Montreal; *c*, Valcour island; *d*, Port Kent (Ottawa and vicinity about the same); *e*, Willsboro.

Fig. 4, 5 Two specimens from Montreal showing the remarkable thickness of the shells. Both valves are weathered.

Macoma groenlandica Beck (= *balthica* L.)

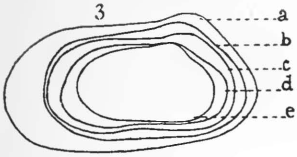
Fig. 6 Recent specimen (left valve) from the New York coast.

Fig. 7 Outlines of left valves showing comparison in size of the largest Pleistocene specimens from various localities in Canada and New York with one of the largest recent specimens. *a*, recent, South Amboy, N. J.; *b*, Montreal; *c*, Port Kent (Burlington vicinity and Lapham Corners practically the same); *d*, Cumberland Head (Port Henry practically the same); *e*, Willsboro (Valcour island and Essex practically the same); *f*, Chimney Point; *g*, Crown Point.

Fig. 8 Similar outlines of average-sized specimens. *a*, recent, Cape May, N. J.; *b*, Montreal; *c*, Valcour island (Burlington and Lapham Corners about the same); *d*, Cumberland Head; *e*, Port Kent (Willsboro, Essex, Port Henry practically the same); *f*, Chimney Point; *g*, Crown Point.

PLATE 1

3



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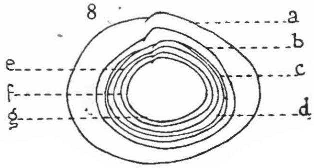

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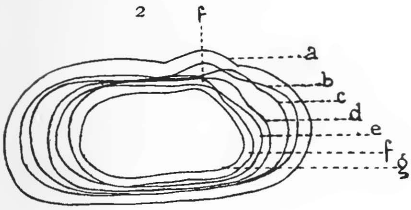

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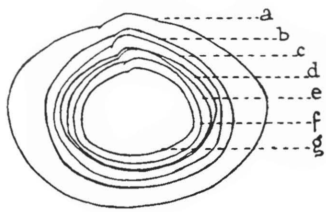

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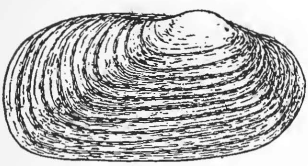

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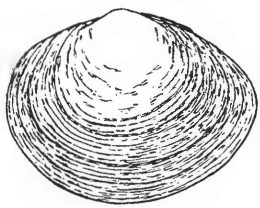

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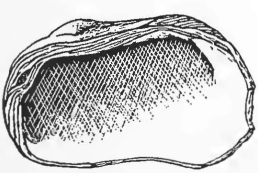

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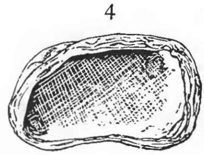

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PLATE 2

Mytilus edulis Linn.

Fig. 1 Recent specimen (left valve) from Cape May, N. J.

Fig. 2 Outlines of left valves showing comparison in size of the largest Pleistocene specimens from localities in New York with one of the largest recent specimens. *a*, recent, Cape May, N. J.; *b*, Lapham Corners; *c*, Port Kent.

Fig. 3 Similar outlines of average-sized specimens. *a*, recent New York coast; *b*, recent, Gay Head, Martha's Vineyard, Mass.; *c*, Lapham Corners; *d*, Port Kent (Willsboro about the same).

Yoldia arctica Gray

Fig. 4 Right valve of a large-sized recent specimen.

Fig. 5 Outlines of right valves showing comparison in size of the largest Pleistocene specimens from localities in Canada and New York with one of the largest recent specimens. *a*, recent; *b*, Montreal; *c*, Ottawa; *d*, Burlington; *e*, Port Kent; *f*, Willsboro; *g*, Chimney Point.

Fig. 6 Similar outlines of medium-sized valves. *a*, recent; *b*, Canada (Montreal); *c*, Port Kent; *d*, Port Kent (majority of specimens). Port Kent material is taken as typical of the Champlain specimens, because there are larger numbers to judge from.

Fig. 7 Outline of right valves showing variation in shape of Pleistocene specimens. *a*, Ottawa; *b*, *c*, *d*, Port Kent. *a* and *d* represent the two extremes.

Cylichna alba Brown

Fig. 8 Pleistocene specimen from Canada (Dawson, Can. Ice Age, p. 244).

Fig. 9 Outlines showing comparison in size of Canadian and Port Kent specimens. *a*, Canadian specimen; *b*, one of the largest Port Kent specimens; *c*, specimen representing the size of the majority of Port Kent forms.

PLATE 2

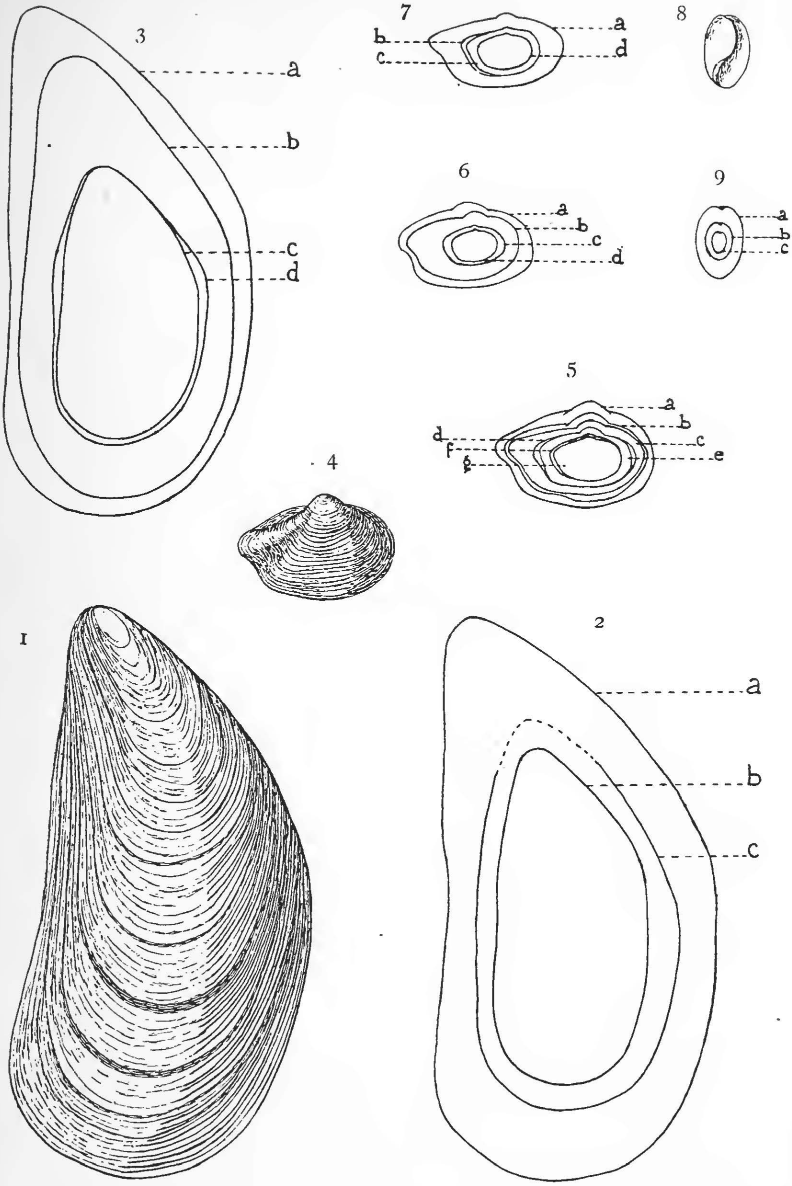

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PLATE 3

Mya arenaria Linn.

Fig. 1 Recent specimen (left valve) from the New York coast.

Fig. 2 Outlines of left valves showing comparison in size of the largest Pleistocene specimens from localities in Canada and New York with one of the largest recent specimens. *a*, recent, New York coast; *b*, Canada (Geol. Can. 1863, p. 963); *c*, Cumberland Head; *d*, McBride bay; *e*, Valcour island.

PLATE 3

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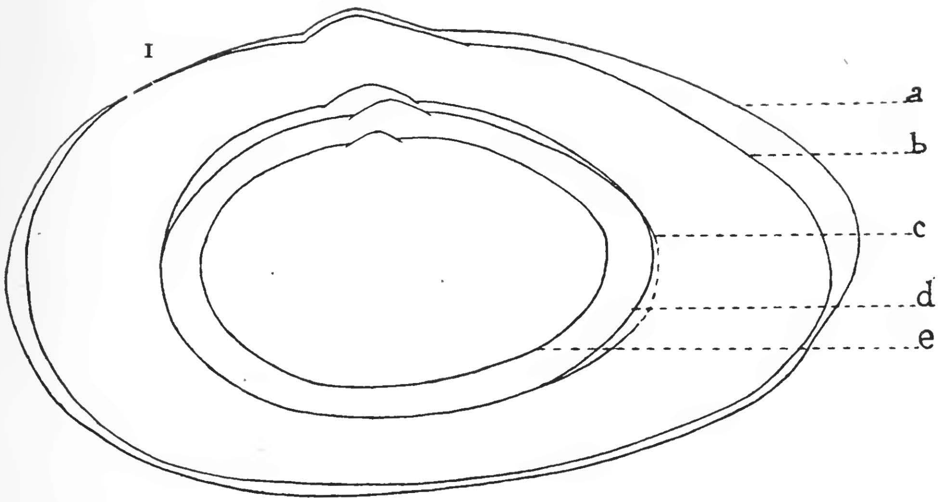

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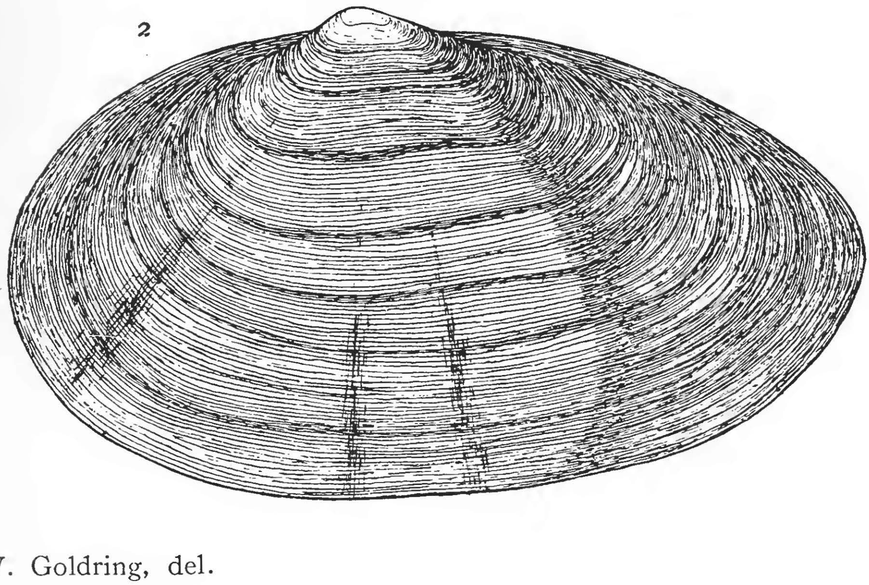

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