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CONTRIBUTIONS TO THE GEOLOGY OF MAINE

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FOREWORD

This publication presents five short reports on various geologic subjects and environments in Maine. Three of the reports have a primary economic significance and all of them provide basic geological data. The purpose of this bulletin and others which are anticipated for the future is to present, at an early date, new ideas and studies on a variety of current programs of the Geological Survey. In this way the profession and industry will be kept current with the progress of geologic work in Maine.

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OUTLINE OF THE GEOLOGY AND MINERALIZATION OF THE SOUTH END OF THE MUNSUNGUN ANTICLINORIUM, PISCATAQUIS COUNTY, MAINE

By Bradford A. Hall[1]

GENERAL GEOLOGY

This report presents an outline of the geology of the south end of the Munsungun Anticlinorium, a name proposed by the author (1964) for the anticlinal belt including the area of this report and trending northeast into the vicinity of Fish River Lake (Boucot, et al, 1960). Rocks in this area range in age from Cambrian(Є) to Early Devonian comprising a section probably more than 40,000 feet thick. The rocks are within the chlorite grade of regional metamorphism and are described by unit in Table 1.

The tectonic history of the area is complex, there being three angular unconformities within the section. In addition, rocks were folded and a regional cleavage developed during the post-Early Devonian (Becraft-Oriskany) Acadian orogeny. A highly penetrative early foliation or cleavage is also present in the undifferentiated Cambrian(Є) rocks but not in rocks of younger age. Post-Middle Ordovician deformation, the Taconic orogeny, and post-Late Silurian deformation, the Salinic disturbance of Boucot (1962), were not intense enough in this area to produce cleavage or metamorphism.

MINERALIZATION

Finely disseminated sulphide, most of which is probably pyrite, is ubiquitous in the more mafic igneous rocks of the Middle Ordovician section and somewhat less so in the more silicic rocks. Middle Ordovician mafic extrusives and intrusives are aslo rich in ilmenite and magnetite.

Pyrite and marcasite are common in the rusty-weathering Cambrian(Є) dark gray slate. In this rock the sulphide is commonly concentrated as knots or crystalline rosettes in the hinges of minor folds. Pyrite, both disseminated and as laminae, is very common in black, graptolitic, silceous mudstone of the Ovm unit and in graptolitic slate at the top of the Ovs unit.

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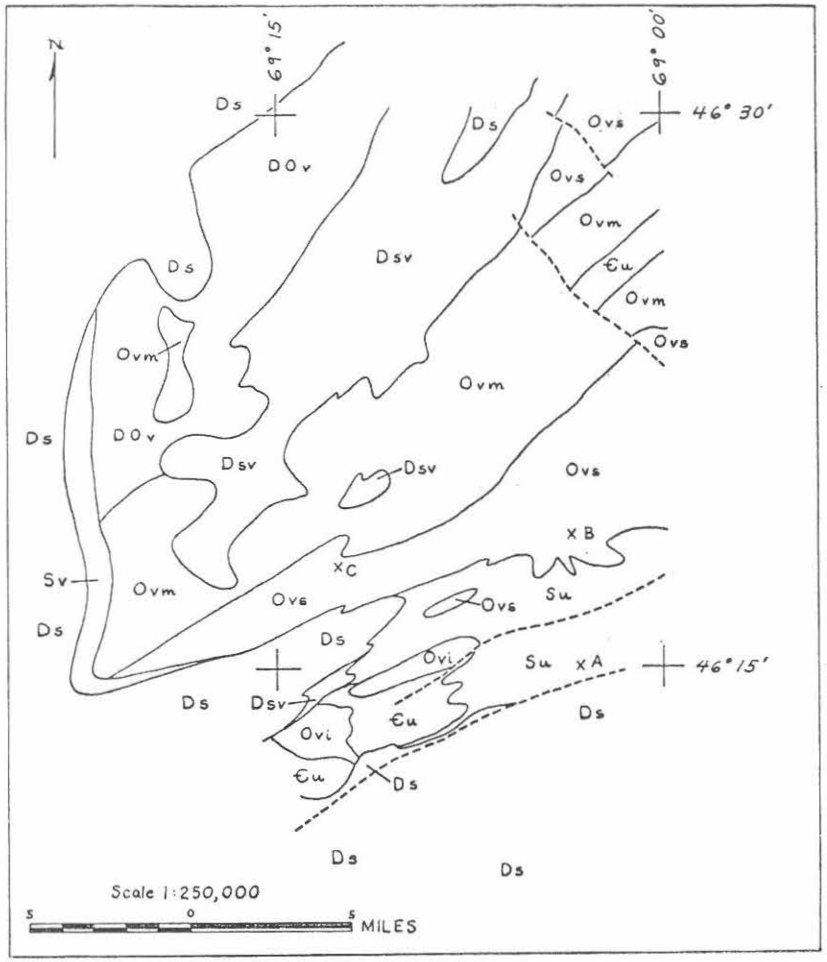

Figure 1. Geologic map of the south end of the Munsungun Anticlinorium. See Figure 2 for legend.

In addition to the above general occurrences of sulphide minerals, mineralization has been noted in three specific localities. These will be described briefly and keyed to the map of Figure 1 by use of letters: A, B, and C. Locality A is at the first falls about 2,000 feet upstream from Third Lake Matagamon on the East Branch of the Penobscot River. Very minor amounts of malachite were seen in flinty Ordovician(?) clasts within a massive Upper Silurian conglomerate. Locality B is about 800 feet upstream from Chandler Pond on the brook flowing from Mathews Pond. Minor amounts of malachite are present

in a thin bed of gray tuff interbedded with red Ordovician siliceous slate and chert. Locality C is about 5,600 feet south of the outlet of Haymock Lake along the gravel road from Chamberlain Lake to Ashland. Massive siderite is found on the east side of the road associated with white-weathering Ordovician siliceous mudstone.

TABLE 1

DESCRIPTION OF ROCK UNITS

CAMBRIAN(?)

Cambrian undifferentiated (€u)

Gray and green phyllite and slate with some siltstone, thin dark limestone interbeds, and blocks of quartz graywacke and calcareous cross-bedded siltstone. Red and green, green, or gray phyllite in the southernmost part of the map area.

MIDDLE ORDOVICIAN

Lower unit (Ovm)

Pillowed basalt, dolerite, siliceous and mafic tuff, slate, and mudstone. Contains slate, graywacke, and conglomerate at the base.

Upper unit (Ovs)

Dolerite and basalt; siliceous white-weathering tuff, agglomerate, and slate; gray, green, and red slate and chert. Dark gray, pyritiferous slate at the top.

Undifferentiated volcanics (Ovi)

Mafic tuff, dolerite, and basalt of probable Middle Ordovician age. Some coarser-grained dolerite probably intrusive.

Devonian-Ordovician volcanics (DOv)

Basalt, rhyolite, trachyte, agglomerate, and white-weathering tuff.

UPPER SILURIAN

Silurian undifferentiated (Su)

Andesitic and rhyolitic volcanics; red, green, and gray lithic conglomerate and sandstone; calcareous siltstone and sandstone, sandstone, and impure limestone.

Silurian volcanics (Sv)

Mafic agglomerate, tuff, and flows. Flows locally pillowed.

LOWER DEVONIAN

Lower unit (Dsv)
Andesitic volcanics, calcareous sedimentary rocks, and conglomerate.

Seboomook formation (Ds)
Interbedded sandstone or siltstone and slate. Laminated two to twelve inch beds of gray siltstone and fine-grained sandstone in the vicinity of Indian Ponds.

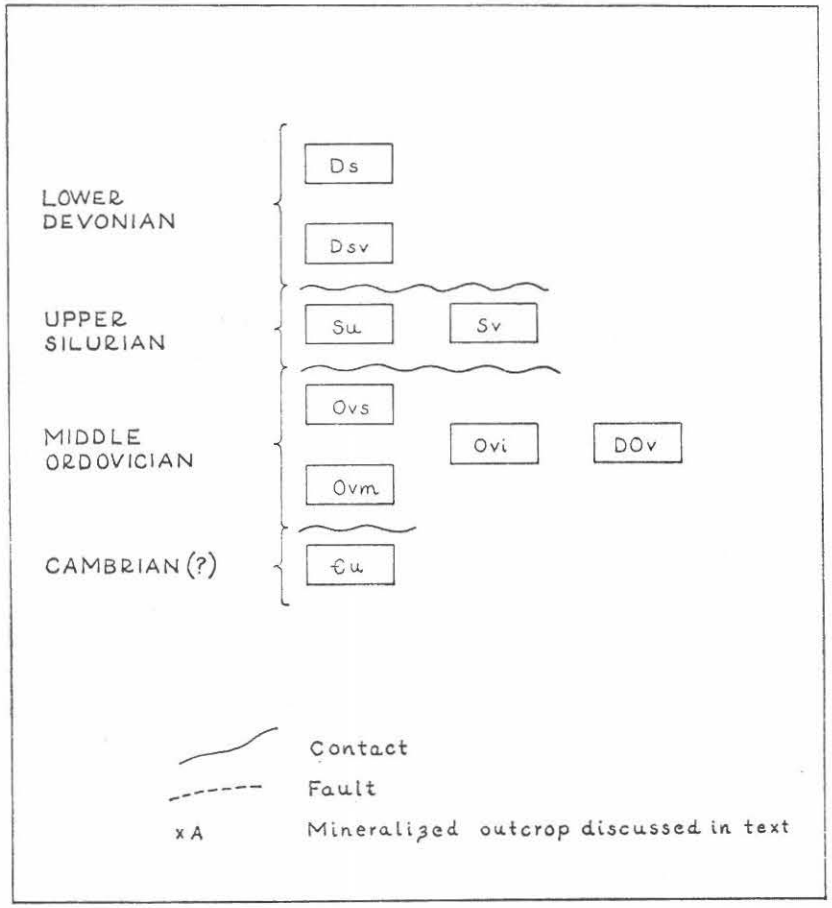

Figure 2. Legend for map of Figure 1. Rock units are described in Table 1.

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DIATOMITE IN MAINE

Frederick M. Beck[1]

INTRODUCTION

Diatomite occurs in many fresh water ponds in Maine. It has been mined sporadically on a small scale from some ponds, and there has been considerable interest shown by companies interested in larger scale operations. This paper will bring together much of the information available from various sources.

Diatomite (diatomaceous earth, infusoria, infusorial earth, siliceous marl) is a deposit composed almost entirely of the tests or "skeletons" of microscopic plant organisms called diatoms. These tests are siliceous and any given bed will contain a wide variety of types. Individual diatom tests are extremely small and are only visible through a microscope. Diatoms have very ornate shapes and a large surface area for their size. This property makes diatomite economically important.

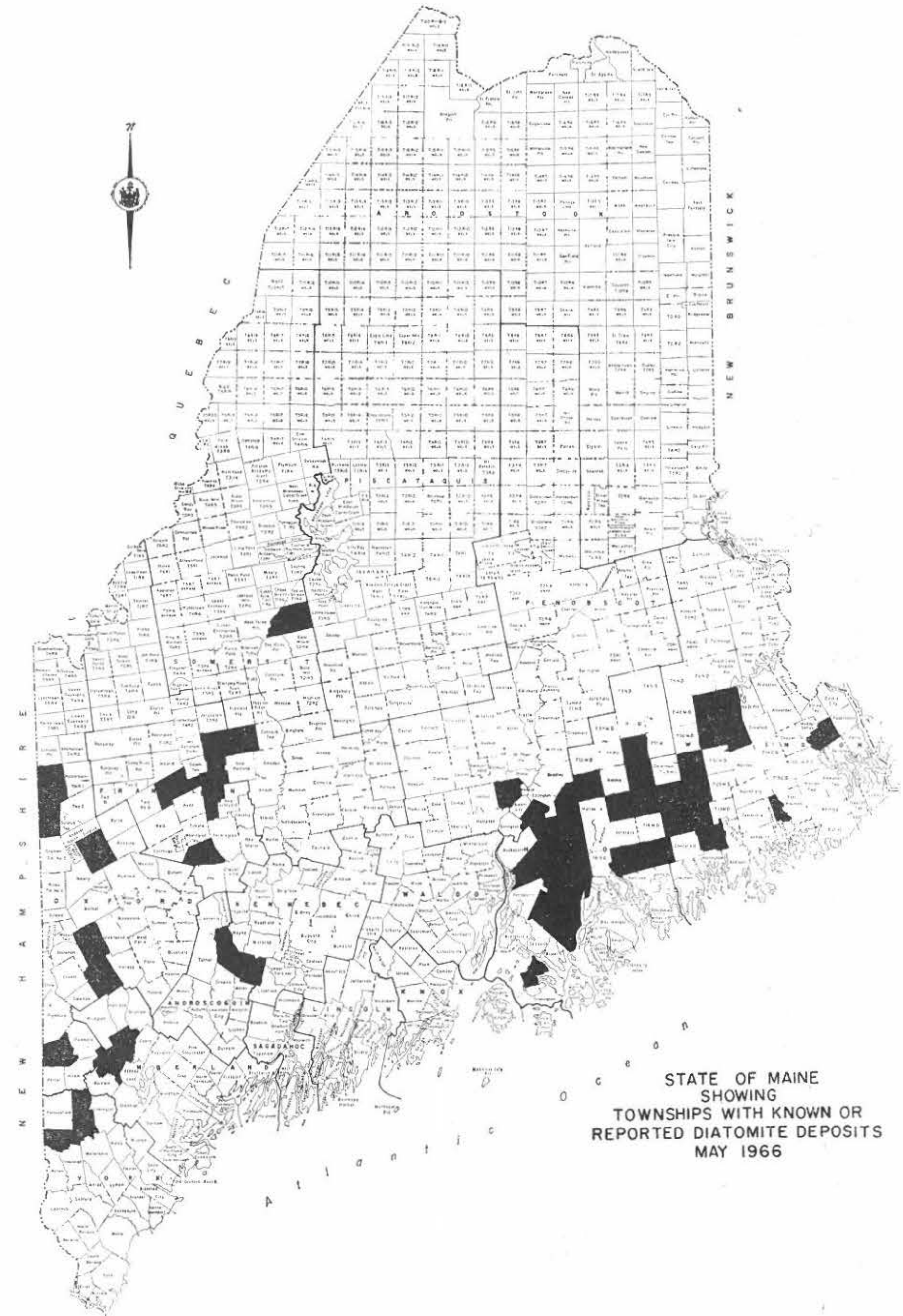
There are literally thousands of uses for diatomite, most of which have to do with filtering, insulation, fillers, and miscellaneous uses including abrasives, absorbants, paints, and soil conditioners. Essentially all United States production is from the western states of California, Nevada, Washington, Arizona, and Oregon. There are a large number of small diatomite occurrences in Maine and the other eastern states. However, these have not yet proven to be of economic value. Their small size has discouraged large investors and the complex technology of preparation and marketing has discouraged smaller companies. The yearly U. S. production of diatomite (1965) is slightly under 500,000 short tons.

OCCURRENCE AND PRESERVATION

Diatoms are aquatic organisms usually referred to the kingdom Protista. They occur in water under all non-toxic conditions of salinity, temperature, and pH. Probably the only requirement for their growth is suitable nutrients, of which soluble silica is the most important. Environmental conditions usually determine which specific forms will exist.

If diatoms are abundant in a pond and settle to the bottom when they die, a deposit of diatomite will begin to form. With stable physical

[1]Maine Geological Survey



conditions this deposit will attain a considerable thickness and without influx of silt and mud the diatomite will remain fairly pure. If the pH of the water does not increase above 5, the siliceous tests will not dissolve readily.

These optimum conditions do not always prevail, however. Contamination of the diatomite by clay, silt, sand, and organic matter is common. Lowering or changing of the pond outlet can erode and destroy bottom sediments. A change in the pH of the water from 5 to 8 increases silica (SiO_2) solubility five fold (Lohman, p. 184). Assuming none of these events befall the diatomite bed, the pond will eventually fill with diatomite. A bog will form and peat will begin accumulating on top of the diatomite. If the bog is drained a meadow results such as Perley's Meadows in Cumberland County. The Maine diatomite occurrences have sometimes been known as sub-peat deposits for this reason.

In Maine the diatomite beds began forming following the retreat of the last continental glacier. Presumably the newly formed kettles, lakes and ponds would have a plentiful supply of glacial flour rich in silica. If the conditions for preservation as mentioned above have been present since that time (10,000-15,000 years), the chances of diatomite accumulation would be good.

HISTORY OF DIATOMITE INTEREST IN MAINE

The earliest reference to Maine diatomite deposits is by Jackson (1837, p. 98) in which he says "Marl is common beneath the peat bogs and, being charged with vegetable juices, is admirably suited for a manure." It is presumed that this reference is to siliceous marl as calcareous marl is not common beneath peat in Maine.

It was not until 1839 that the sub-peat deposits in the United States were recognized as being composed of diatoms (Bailey, 1839, p. 118). Academic interest was greatly stimulated by this discovery and it was mentioned in 1841 (Silliman, p. 176) that sub-peat diatomite already had a wide use as a metal polishing agent. The first specific locality in Maine mentioned in the literature is Newfield, York County. ". . . where it covers many hundred acres, and is five or six feet thick. After burning it is so white and beautiful that it has been fraudulently sold for magnesia alba" (Jackson, 1841, p. 174). In 1861 Hitchcock (p. 285) also mentions Newfield, as well as Limerick, Beddington (Chalk Pond) and Calais as townships containing infusoria beds beneath peat. He alludes to their use as polishing powder. Bailey (1862, p. 397) mentions Bluehill Pond (Noyes Pond); Brownfield; Newfield; Round Lake, Calais; Chalk Pond, Beddington; Adley Pond, Phillips; Bangor; and Chalk Pond, Waterford. He discusses what he considers to be diatomite's most important use, that as a fertilizer. He also mentions the use as a polishing agent and in the manufacture of porcelain. A polishing powder named Tripoli was being prepared from the Bluehill deposit during this period. In 1867 and 1868 Kitton (p. 133, 156, 180; 85, 131) describes the types of diatoms found at Monmouth, Duck Pond (Waterford), Chalk Pond (Albany), and Perley's Meadows.

There is a gap in the record between these early accounts and 1930. The First Annual Report on the Geology of the State of Maine for this year (p. 24) describes a sub-peat deposit at Cornish, Maine, which was currently being worked for polishing powders and heat insulation material. Another deposit near Wilton, Maine, was apparently being worked at this time also. Presumably the diatomite deposits were exploited off and on in a small way during the interval between 1841 and 1930. It has been reported that the Infusorial Earth Company operated to some extent on Noyes Pond (Blue Hill) during the late 1800's and early 1900's. Adley Pond near Phillips was exploited by a silver polish company in the 1930's. There are undoubtedly many other ponds and areas which have been exploited commercially for diatomite during the past 130 years.

The first regional survey made of diatomite occurrences in Maine was made by Allen and Pratt in 1947 and the results were published in 1955. This report included auger tests and size estimates of nine diatomite occurrences.

A considerable amount of exploratory work has been done on several of the ponds in Hancock and Washington Counties during the past eight years by private companies. The work has been directed toward developing sufficient reserves to justify the building of a processing plant. In addition, the Maine Geological Survey recently sponsored a reconnaisance survey of a number of bogs and ponds to determine the presence or absence of diatomite. Several new diatomite occurrences were discovered.

KNOWN AND REPORTED OCCURRENCES

The following list of areas is of all known or reported diatomite occurrences in Maine. It is felt that this list represents only a fraction of the actual number of such occurrences. Future exploration will undoubtedly disclose many more deposits.

Washington County

T. 43 M.D.
Ponds below Monroe Lake
T. 27 E.D.
Clifford Lake
T. 37 M.D.
Second Machias Lake
First Machias Lake
T. 26 E.D.
South Beaverdam Lake
Charlotte
Round Lake
T. 30 M.D.
Lower Cranberry Lake
T. 24 M.D.
The Middle Grounds Heaths
Beddington
Chalk Pond
T. 18 M.D.
Kettles on Blueberry Barren Ridge
Deblois
Denbo Heath Bog
Columbia
Pleasant River Swamp
Duck Ponds
Marshfield
Marks Lake

Hancock County

T. 34 M.D.
West Branch Narraguagus River
T. 28 M.D.
Bracey's Pond
Kettles beside Narraguagus River
Bear Pond
T. 10 S.D.
Shillalah Pond
T. 9 S.D.
Otter Bog
Franklin
Duck Pond
Otis
Lower Springy Pond
Dedham
Hurd Pond
Mitchell Pond
Big Hill Pond
T. 22 M.D.
Rocky Pond
Osborn
Spectacle Pond
Amherst
Half Mile Pond
Debec Pond
Ellsworth
Little Duck Pond
Jesse Bog
Orland
Jesse Bog
Surry
near Surry village
Blue Hill
Noyes Pond
Deer Isle
exact location not known

Man Bog Pond
Hanson Pond
Saulter Pond
Mud Pond

Penobscot County

Bangor
exact location not known
Clifton
Cedar Swamp
Middle Springy Pond
Little Burnt Pond
Upper Springy Pond
Cranberry Pond
Parks Pond
Holden
George Pond

Somerset County

Squaretown
Little Indian Pond
Moxie Gore
Fish Pond
Baker Pond
Mud Pond
Black Brook Pond
Prescott Pond
Lexington
Indian Pond

Franklin County

Kingfield
Hid Pond
Freeman
Gammon Pond
Strong
Taylor Hill Pond
Phillips
Adley Pond
Wilton
Wilton Pond

Oxford County

Magalloway & Upton
Umbagog Lake
Andover
Andover Bog
Albany
Chalk Pond
Waterford
Duck Pond
Brownfield
Bluehill Pond

Cumberland County

Naples
Perley's Meadows

York County

Cornish
Hosac Pond
Limerick
exact location not known

Newfield
exact location not known

Kennebec County

Monmouth
Bog Brook Swamp

Androscoggin County

Leeds
Peat bogs (?)

EXPLORATION

The future of the diatomite industry in Maine depends upon two factors. The first is the development of sufficient reserves; the second is the development of a market.

Those exploring for additional diatomite should take into consideration several factors. First, preservation of the silica depends upon a continuous supply of non-alkaline water. Drainage from granitic areas meets this requirement, and the apparent correlation between granitic outcrops and diatomite distribution in Maine illusrates this. A spring-fed pond would be less subject to silting than one fed from a stream. Diatoms are easily transported and small secondary stream deposits should not be confused with primary pond deposits. Exploration of peat bogs should not be discounted.

Developing a market for diatomite is the more difficult of the problems. The advantage of proximity to eastern markets may be completely offset by the increased preparation costs due to impurities and water saturation. It would seem that if sufficient reserves could be proven, a technique of preparation could be developed which would allow Maine diatomite to be competitive with western diatomite in eastern markets.

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THE OWEN BROOK LIMESTONE PROSPECT

PENOBSCOT COUNTY, MAINE

By

ROBERT G. DOYLE[1]

INTRODUCTION

The Owen Brook limestone prospect is located in the northwest quarter of Township 3, Range 7, Penobscot County, Maine. The Township is managed by Prentiss and Carlisle, Bangor, Maine. Limestone outcrops are distributed in a three square mile area bounded on the east by the East Branch Penobscot River, and on the south by Owen Brook, a minor tributary of the East Branch. Exposures of volcanic rocks on the southeast flank of Deasey Mountain limit the prospect on the west and north (see Fig. 1). The prospect is in an area of hitherto unknown high grade limestone deposits. Because of its location, fairly close to the major agricultural areas in central Aroostook County, this limestone deposit assumes some importance as an agricultural limestone supplier.

This study describes the geologic setting, possible size and estimate of grade of the deposit. The critical problem of accessibility and proximity to a consumption area is also discussed. In presenting this contribution, the writer acknowledges the assistance of Dr. Robert B. Neuman, U. S. Geological Survey, who conducted detailed geologic mapping in the area from 1957-58 and who first reported the deposit (Neuman, 1960). Pavlides, et al., shows the regional geologic relations to the north of the prospect area on a map (p. C-30) accompanying a U. S. Geological Survey Research Study (Pavlides, 1964).

GEOGRAPHY AND ACCESSIBILITY

The deposit lies at the eastern edge of the central Maine uplands; this major physiographic feature is bounded by the swampy lowlands bordering the East Branch Penobscot River. The area is poorly drained low swampy terrain, topographically controlled by hummocky blocks of limestone outcrop. Deasey Mountain, which rises steeply above the swampy lowland, is underlain by resistant mafic volcanics, making a pattern of sharp relief north and west of the limestone.

[1]Maine Geological Survey

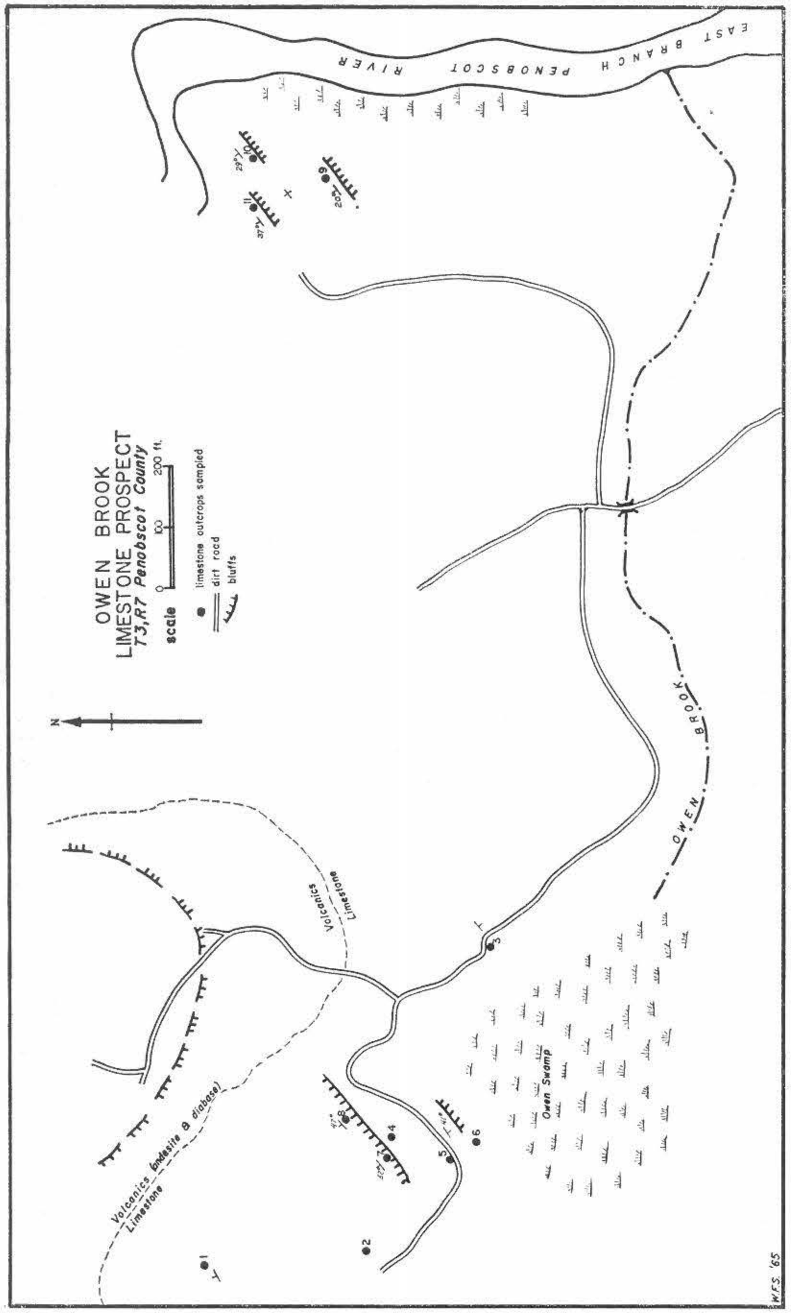

Figure 2. Map showing location and geology of Owen Brook limestone prospect.

Accessibility is limited to a good all weather gravel road from Stacyville, eight miles to the southeast, which passes within one-half mile of the limestone area (see Fig. 1). A local haulage road from the Wassataquoik Stream bridge passes through the property. Both a railroad and a major highway junction are in Stacyville and nearby Sherman. Stacyville is located about 45 miles north of the central Somerset County dairy farming area and 50 miles south of the Aroostook County potato-sugar beet growing areas.

GEOLOGY

The Owen Brook prospect is composed of a middle Silurian reef limestone with a reef debris facies, fore reef section and layered back reef members, lying on the south flank of a steeply (?) dipping mafic volcanic mass of Silurian (?) age. Neuman (1960) describes the deposit as a fault slice segment, part of a major transverse fault system which brings middle Ordovician (?) cherty meta-argillites into contact with less altered Silurian rocks of various kinds.

Aeromagnetic data (Brombery, et al., 1963) show a marked magnetic "low" over the prospect indicating that the non-susceptible limestone is deep enough to obscure the effects of a more highly magnetic unit at depth. The limestone itself is highly fossiliferous including many invertabrate phyla of Silurian (?) age. It is light gray to pale buff and gray in color; it weathers white on exposed surfaces. The texture of the back reef (?) portion is roughly bedded and fine grained and occasionally massive. The fore reef and debris zones (?) are characterized by coarse grained agglomeratic texture, lack of bedding and high porosity. Except for medium grain sized calcite recrystallization and slight elongation of the fragments, there is little evidence of metamorphism in the deposit.

The limestone outcrops have a general northwest strike, paralleling the regional trend of the supporting extrusive rocks. Dips are steep, varying from 55° - 75°. Internal structural data were not obtained; thus, minor features are not predictable.

PROSPECT DESCRIPTION

The limestone outcrops examined indicate that there is a physical and chemical homogeneity to the entire deposit, which, even considering the local variation resulting from origin (fore reef, back basin, debris slopes, etc.) allows for a simple calculation of size and value.

A very rough estimate of tonnage indicates approximately 2,500,000 tons of available limestone down to 50 feet below the projected stripping surface. Using 150,000 tons per year of agricultural consumption

TABLE 1

CHEMICAL ANALYSES

	OB1	OB2	OB3	OB4	OB5	OB6	OB7	OB8	OB9	OB10	OB11
SiO_2	3.32	0.62	4.24	1.96	2.50	1.72	6.04	5.22	13.50	8.96	1.16
Al_2O_3	0.72	0.12	0.32	0.42	0.54	0.16	1.06	1.28	1.66	2.34	0.10
Fe_2O_3	0.56	0.16	0.40	0.32	0.40	0.32	0.56	0.56	0.64	1.04	0.24
CaO	52.82	55.33	52.71	54.02	53.52	54.42	50.80	51.10	44.57	48.19	54.93
MgO	0.77	0.59	0.62	0.62	0.96	0.83	1.07	0.88	2.46	1.16	0.60
Loss on Ign.	42.02	43.67	41.70	42.67	42.39	42.94	40.57	40.75	37.26	38.47	43.19
Total	100.21	100.49	99.99	100.01	100.31	100.39	100.10	99.79	100.09	100.16	100.22

Table 1. Chemical analyses of 11 hand samples from Owen Brook Limestone Prospect. (Analyses completed by Dragon Cement Company, Thomaston, Maine.)

in limestone (ignoring other potential uses), and assuming the possibility of a 50% control of the market, a twenty to thirty year supply is assured.

Table 1 indicates the chemical analyses of eleven hand samples which appeared to be representative of the outcrops found. Each sample was finely ground, split, and a composite fraction analyzed. All the localities except O.B. #9 and #10 show very high CaO content, with compatibly low silica and MgO (Table 1). O.B. #9 and #10 may represent a zone of local (thermal?) alteration since these analyses are similar to sample results from low grade metamorphic terrain. Neuman (verbal communication, 1966) indicates that the flanking limestone reefs may be argillaceous in part, giving rise to the anomalous chemical analyses of samples O.B. #9 and #10.

CONCLUSION

The presence of a considerable tonnage of high calcium limestone in the form of a steeply dipping coral reef lying on the southwestern flank of a Silurian volcanic sequence may be of significance as a source of agricultural limestone for the dairy and potato farms of northern and central Maine. It is well located near rail and highways. The grade of the deposit averages 53.00% CaO with low MgO and silica. The possibility of over 2,000,000 tons of limestone of this grade makes this a worthwhile target for further investigation.

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NEW SCOTLAND DEPOSITIONAL HISTORY OF THE BECK POND REGION SOMERSET COUNTY, MAINE

A. J. Boucot[1], Charles Harper[2], and Keith Rhea[3]

INTRODUCTION

In an earlier report (Boucot, Harper, and Rhea, 1959) the geology of the Beck Pond region was described. It may briefly be summarized as consisting of a pre-Ludlow (Late Silurian) age granitic basement complex upon which were deposited the Beck Pond limestone of New Scotland (Upper Gedinnian) age and the penecontemporaneous lower portion of the Seboomook formation, followed by the intrusion of diabase. The available evidence suggests that the Beck Pond limestone was deposited upon a local topographic high during the same time that the lower part of the Seboomook formation was being laid down in an adjacent topographic low. The Seboomook eventually filled up the topographic low and covered the Beck Pond limestone unconformably, although the time interval between the two is relatively insignificant. Despite the small size of the Beck Pond Region, it is significant in any consideration of early Paleozoic geology of the northern Appalachians as it demonstrates the location of original, pre-New Scotland age basement complex topography and the existence of an irregular shoreline of New Scotland age. Neither of these features has been demonstrated previously anywhere in the Appalachians.

The Beck Pond limestone is subdivided into five members. Member one, the northernmost unit, is predominantly coarse, grey-green, quartzose limestone containing a few stromatoporoid biostromes. Member one has distinct bedding and some cross-bedding. Member two, occurring southeast of member one, consists chiefly of stromatoporoid biostromes interlayered with minor amounts of grey-green, quartz-rich limestone containing some coral and stromatoporoid fragments. Member three, to the southeast of member two, is similar to member one and also has distinct bedding and cross-bedding, but differs in containing a large percentage of granitic pebbles and a few cobbles as contrasted with member one, which contains no cobbles and almost no pebbles. Member four is light-colored, granite-boulder

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conglomerate containing boulders up to 15 feet across. The boulders have the same lithology as the basement complex granite exposed to the northwest, and the matrix is grey-green and highly calcareous. Member four is more coarse-grained and less well-sorted than any of the other units. Member five, the most southeasterly unit, is coarse-grained, grey-green, calcareous quartz-conglomerate similar to member four but containing more fossils, which are concentrated in certain layers. In most exposures, the granitic fragments in member five range up to cobble size, rather than to boulder size as in member four. This unit is, for the most part, coarser-grained and more fossiliferous than members one and three and has generally indistinct bedding. Southwest of member five is a dark-colored boulder conglomerate (unit Db?) which consists of granitic boulders and cobbles of basement complex.

The Seboomook formation consists of cyclicly layered argillite and argillaceous, fine-grained sandstone, having a basal granite talus member in one area. The Bear Pond limestone member is in the lower part of the Seboomook in the northern part of the region.

The Beck Pond limestone is generally inclined to the southeast at an angle of about 25 degrees, as are most of the Silurian and Devonian strata on this limb of the Moose River synclinorium. The Silurian and Devonian strata of this region reached their present attitudes during the folding of the Acadian orogeny.

PURPOSE OF THE STUDY

The chief purpose of this study was to determine whether the five members of the Beck Pond limestone form an ascending stratigraphic sequence, with member one at the base and member five at the top, or whether they form a series of laterally intergrading units. This problem receives no help from the abundant fossils as all the fossils are of New Scotland age, like those in the base of the unconformably overlying Seboomook formation and its Bear Pond limestone member.

The secondary problem, which is a corollary of the first, concerns the source area for the granitic boulders concentrated in members four and five, as well as the pebbles and cobbles of granite in members three to five. This granitic debris is lithologically similar to that exposed in the basement complex to the northwest. The basement complex to the northwest would logically form the source area, except for the fact that members one and two contain no cobbles or boulders of

granite and are almost completely devoid of pebbles. This problem necessitates either postulating faulting in post-member two time to create relief to the northwest to provide a source for the granitic debris, or postulating the existence of granite pinnacles in the area presently occupied by member four. The fault hypothesis is unsupported by field evidence. The granite pinnacle hypothesis receives some support from the presence of horizontal beds associated with some of the conglomerate of member four in such a manner that after removal of the regional dip they can be interpreted as original northerly dips on a sloping surface (Figure 11).

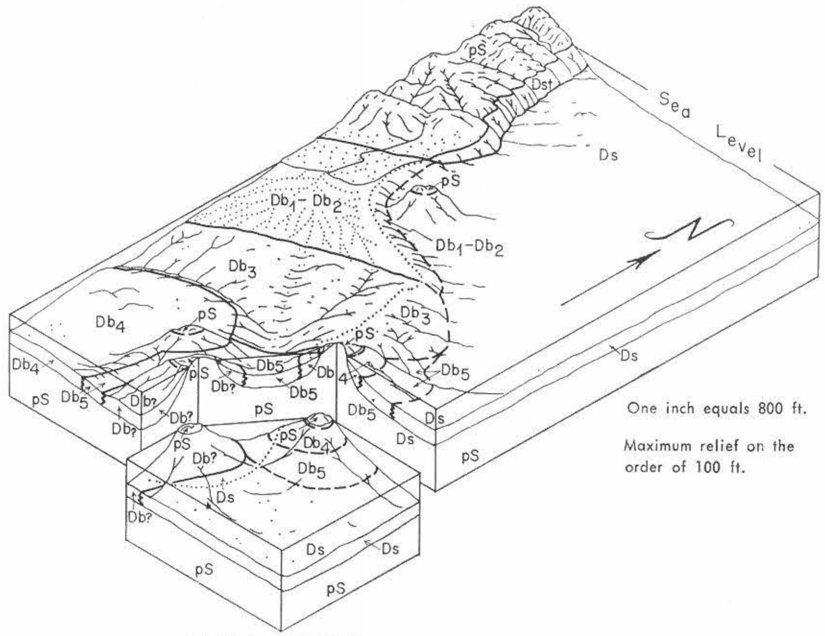
PROCEDURE

After completion of the field studies (Boucot, Harper, and Rhea, 1959) a series of oriented limestone blocks collected by Harper and limestone chip samples collected by Rhea were available for analysis. Harper slabbed the oriented blocks to determine bedding orientation, sorting and angularity of clastic debris, and paleoecologic information. Rhea dissolved the limestone chip samples in hydrochloric acid and studied the insoluble residues. After completion of the laboratory studies the results were synthesized and a revised interpretation of the depositional environment made possible in the light of the additional information.

STUDIES OF ORIENTED SLABS

Oriented samples of the Beck Pond limestone ranging in size from 6 inches to 16 inches in greatest dimension, with the majority of samples between 10 and 14 inches in greatest dimension, were collected during the field work from members 1, 2, 4, and 5. Three samples were obtained from member 1, 15 from member 2, none from member 3, 7 from member 4, and 27 from member 5. In the laboratory four sawed and polished sections, two approximately parallel to the bedding and two approximately perpendicular to the bedding, were made from each sample, and the sections were described in detail. Megascopic estimates of percentages of fossil fragments, granitic pebbles, and matrix were made for each sample. Estimates of fossil and granite pebble size refer to the longest dimension observed on the sawn surfaces.

The laboratory investigation was intended to supplement the field work in determining (1) what fossils are present in the various depositional environments of the Beck Pond limestone, (2) the extent to which these fossils have been broken, transported and reworked, (3)



EXPLANATION

Db? | Db_1-Db_2 | Db_3 | Db_4 | Db_5 | Ds | Dst

Db? Dark colored boulder conglomerate

Db_1-Db_5 Beck Pond limestone members 1–5

Ds Seboomook formation

Dst Light colored boulder conglomerate

pS Pre-Silurian granitic basement

Observed and inferred contacts in the earlier part of Beck Pond time delimiting Beck Pond lithologic facies which interfinger to east with contemporaneous Seboomook lithologies.

Present erosional contact of Seboomook formation ranging stratigraphically from late to Post Beck Pond time.

Figure 11. Diagrammatic restoration of the topographic and lithofacies relationships existing during the deposition of the Beck Pond limestone.

the extent to which they remain in living position, (4) whether the various fossil assemblages constitute life or death assemblages, (5) the distribution of the granitic pebbles, (6) the extent to which the fossils and granite pebbles have been sorted and rounded and (7) bedding orientations.

MEMBER DESCRIPTIONS AND CONCLUSIONS

MEMBER 1

The fossils found in the samples from member 1 included fragments of laminar stromatoporoids, crinoids, brachiopods, and gastropods (*Platyceras*). Although no granitic pebbles or tabulate coral fragments appeared in the samples, a few were found in the outcrops of member 1 during the field work, as were a few stromatoporoid biostromes. The fossils showed no preferred orientations.

The depositional environment of member 1 was one favorable to brachiopods, gastropods, crinoids, and laminar stromatoporoids. A few of the stromatoporoid coenosteums seen in the field were preserved in place. Otherwise the fossils were broken and deposited as fragments, and they may represent death assemblages, the lone exception being a horn coral-stromatoporoid assemblage found in living position (see Plates 2, 3, U.S.G.S. Bull. 1111-A). U.S.G.S. fossil locality 3601-SD is from the northern end of outcrop 22

MEMBER 2

The samples from member 2 are of two kinds. The first consist of parts of large laminar stromatoporoid coenosteums; the second contains 75 percent to 95 percent laminar stromatoporoid fragments in a sandy limestone conglomerate matrix.

Most of the first group of samples appear to be from coenosteums that were either clearly or very probably in living position. The stromatoporoid laminae are convex up and the general trend of the laminae is parallel to the bedding as observed in the field. Some of the samples have interbedded lenses of sandy and fine-grained material less than one centimeter thick in the coenosteum. Others have irregular inclusions of secondary calcite and black foreign material. The lenses contain almost no other fossils—a few brachiopod fragments, crinoid columnals and fragments and stromatoporoid pebbles are present in some of the samples. The fragmentary nature of the fossils other than stromatoporoids suggests that these fossils may represent death assemblages.

The second group of samples contains such an abundance of laminar stromatoporoid pebbles that the source for the pebbles may have been very close to their place of deposition. Such a source could well have been the biostromes that are interbedded with the layers from which

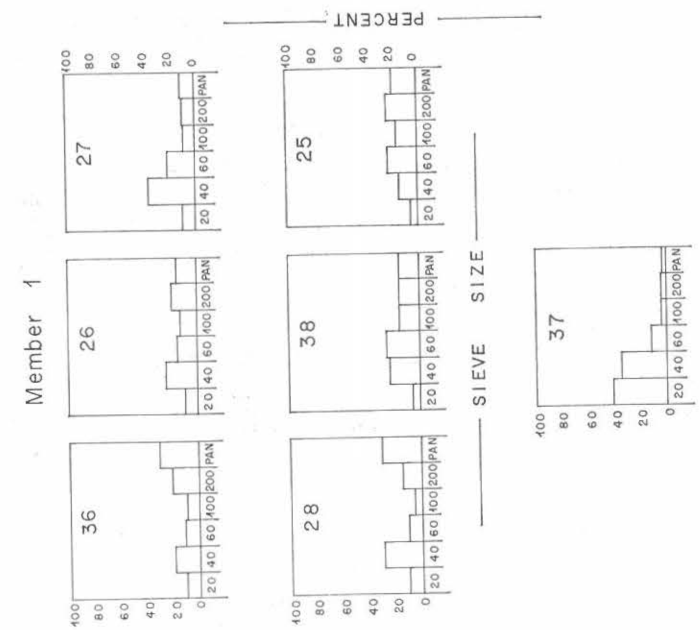


Figure 1a-g. Weight percent of insolubles versus sieve size, member 1.
[Sample numbers – 36, 26, etc.]

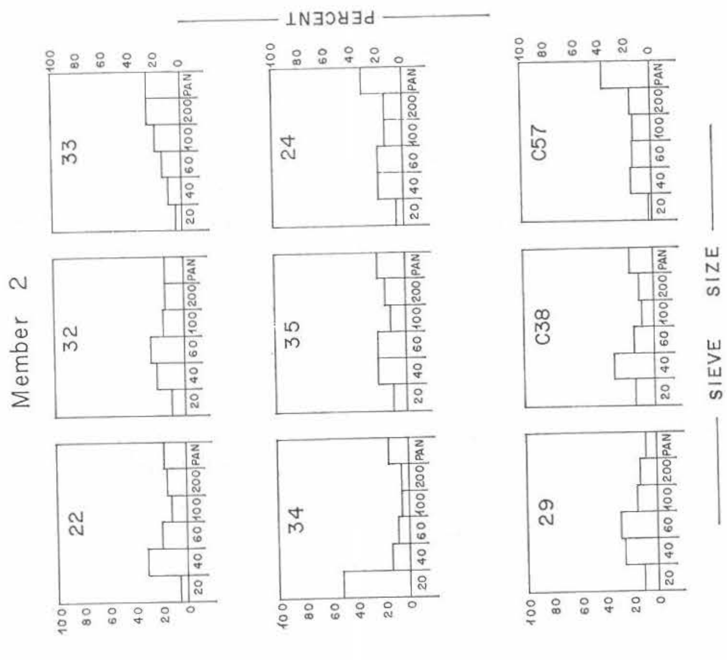


Figure 2a-i. Weight percent of insolubles versus sieve size, member 2.
[Sample numbers – 22, 32, etc.]

these samples were taken. Crinoid columnal fragments are locally abundant; brachiopod and gastropod fragments are rare. Tabulate corals are not present in the samples, but a few were observed in the field.

The depositional environment of member 2 provided an area alternately favorable for the formation of laminar stromatoporoid coenosteums and sandy limestone conglomerate. There was probably enough current action to break off fragments of the coenosteums, round them to some degree, and redeposit them nearly in place. The current action was also sufficient to fragment the crinoids.

Although a few granite pebbles were found in member 2 during the field work, none appeared in the samples. Granitic pebbles are very rare in members 1 and 2 and relatively abundant in 3 together with a few granite cobbles, in contrast with the large numbers of granite pebbles, cobbles, and boulders present in members 4 and 5. U.S.G.S. fossil locality 3600-SD is from the central portion of outcrop 22.

MEMBER 3

Member 3 consists of grey quartzose sandy limestone, grey quartzose sandy limestone conglomerate, and calcareous sandstone containing some stromatoporoid fragments and a few crinoid columnals and granite cobbles and pebbles. The stromatoporoid fragments and crinoid columnals are the only fossils found in member 3. No samples were obtained from this member.

MEMBER 4

The samples from member 4 contained fragments of laminar stromatoporoids, tabulate corals (*Favosites*), brachiopods, crinoids, and gastropods, as well as sub-angular granite pebbles, in a sandy limestone, clayey limestone, or limy sandstone matrix. No horn corals were found in the samples from member 4, and only one outcrop of member 4 was found from the field work to contain horn corals. The samples showed a correlation between the size of the fossil fragments and the size of the granitic pebbles. Where the granitic pebbles are large, the fossil fragments are large, and where the granitic pebbles are small, the fossil fragments are small. This size sorting indicates at least some transportation and winnowing, as does the fragmental nature of the fossils.

The depositional environment of member 4 appears to have been favorable for tabulate corals, brachiopods, gastropods and crinoids.

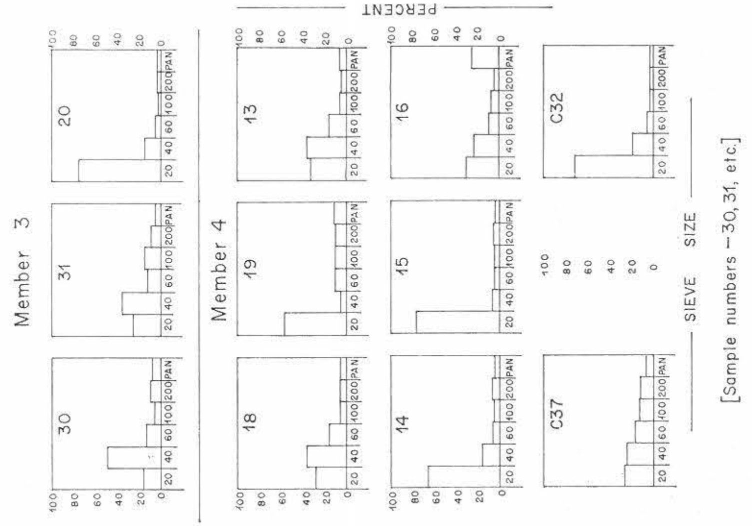


Figure 3a-k. Weight percent of insolubles versus sieve size, members 3 & 4.

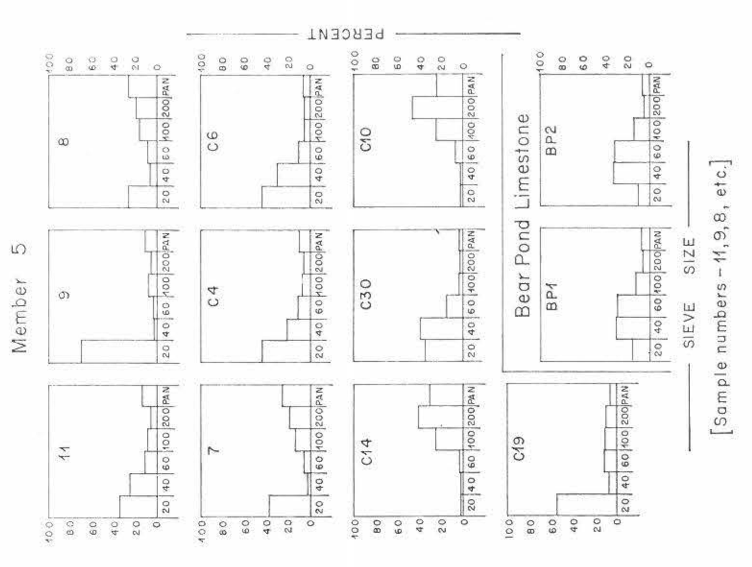


Figure 4a-l. Weight percent of insolubles versus sieve size, member 5 and Bear Pond Limestone.

These were not preserved in situ as life assemblages, however, but were broken up and preserved as fragments. The laminar stromatoporoid fragments could have come from coenosteums present in this environment, or they could have been derived from members 1 and 2. The fragmental nature of the fossils indicates that they probably represent a death assemblage.

In addition to granite pebbles such as were found in the samples, many granitic cobbles and boulders ranging up to 12 to 15 feet across and perhaps larger were observed from member 4 during the field work.

MEMBER 5

The samples from member 5 contain laminar stromatoporoids, tabulate corals, horn corals, brachiopods, and crinoids, as well as granitic pebbles, in a matrix of sandy limestone, limy quartzose sandstone, or fine-grained limestone. The stromatoporoids and most of the tabulate corals occur as somewhat rounded fragments, indicating they have been worked over and possibly transported. Large tabulate corals (*Favosites* colonies), from 6 inches to 10 inches in greatest dimension, show some rounding on the edges. They are not in living position, as is shown by their orientation with respect to the bedding. The horn corals, which are rare, show no evident preferred orientation. The crinoid columnals occur as broken fragments and are deposited more abundantly in some parts of the member than in others. With the exception of two articulated shells, the brachiopods are preserved as disarticulated shells and shell fragments, indicating that they were worked over by currents and transported before deposition. The shells are more often found with the convex side up and, like the crinoid columnals, are more abundant in certain parts of the member than others.

The granitic pebbles and fossil pebbles show some sorting with respect to size. As in member 4, large granitic pebbles are found with large fossil fragments and small granitic pebbles are found with small fossil fragments. This sorting indicates that the granitic pebbles and fossil pebbles have both undergone some transportation.

The general fragmental nature of the fossils suggests that they represent a death assemblage. One stromatoporoid pebble contained two horn corals incorporated in its laminae. This particular association represents a life assemblage similar to that found *in situ* in member 2.

The source of member 5 contained brachiopods, laminar stromatoporoids, tabulate corals, horn corals and crinoids. Current action was sufficient to remove these organisms from their living position and to break them up, work them over, and deposit them as fragments. There is no field evidence that laminar stromatoporoid biostromes are present in member 5, and the stromatoporoid fragments present in the member were possibly derived from nearby relatively quiet environments in other members, rather than from coenosteums living in member 5.

With few exceptions the granitic fragments from member 5 observed during the field work range up to pebble size or to cobble size in contrast to those found in member 4, which range up to boulder size.

DISCUSSION OF ORIENTED SLAB SAMPLES BY OUTCROP

MEMBER 1

Outcrop 28

Outcrop 28 is the only outcrop of member 1 which was sampled, and the discussion of member 1 in the section on "Depositional History" is based on this outcrop. The stromatoporoid fragments are angular to sub-rounded and constitute about 55 percent of the samples. Crinoid stem fragments, *Platyceras* fragments, and brachiopod fragments each constitute 1 percent of the samples. Although a few horn corals, tabulate corals, and granitic pebbles were found at Outcrop 28 during the field work, none were found in the samples.

MEMBER 2

Outcrop 18

One sample from Outcrop 18 consists of part of a large stromatoporoid coenosteum. The coenosteum consists of curved laminae alternating light and dark grey in color and from 1 mm to 1 cm thick, with a few interbedded lenses of sandy and fine grained limestone less than 1 mm thick and one lens 1 cm thick. The curvature of the stromatoporoid laminae is not very great. The laminae are convex upward. As the sample consists almost entirely of stromatoporoid laminae parallel to bedding and curved convex upward, we may infer that the coenosteum sampled is oriented in living position. Laminar stromatoporoids suggest relatively non-turbulent bottom conditions.

The remaining samples from Outcrop 18 consist almost wholly of angular to sub-angular stromatoporoid fragments. There are no other fossils present in the samples, and they contain no granitic pebbles. The great abundance of these stromatoporoid pebbles indicates that they must have come from a source which was very close to their place of deposition and very likely from interbedded biostromes including those seen in the field at Outcrop 18.

Outcrop 22

Four of the samples from Outcrop 22 are parts of large stromatoporoid coenosteums. These consist of alternating light and dark grey stromatoporoid laminae which are parallel, undulating, and convex upwards, somewhat irregular in shape and from less than 1 mm to 5 mm thick (most are between 1 and 3 mm thick). Some of these coenosteum samples contain a few small irregular inclusions of secondary calcite and also a minor amount of irregular inclusions of black foreign matter. Two of the samples contain interbedded lenses of grey to black limy mud containing sand-size calcite grains some of which are fragments of crinoid stems; one of these samples also contained randomly oriented 1 to 2 mm brachiopod fragments. One of the coenosteum samples contains horn corals which are preserved whole and lie between the stromatoporoid laminae. This intimate association of horn corals and stromatoporoid laminae indicates that they represent a life assemblage. The samples indicate that the coenosteums are remarkably devoid of inclusions of other fauna. In three of the coenosteum samples the laminae are gently undulating and are to a first approximation planar. In the remaining coenosteum sample the laminae are undulating with a much greater curvature and thicken and thin much more than in the first three, but the general trend of the laminae is parallel to the bedding. In all of the coenosteum samples the stromatoporoid laminae are conformable to the bedding as ascertained at Outcrop 22 from the field work and are convex upwards, indicating that the coenosteums sampled have almost certainly been preserved in the growth position. In one of the samples the stromatoporoid laminae are intricately interbedded with many limy mud lenses, indicating that the coenosteum of which this is a sample is in the growth position. In another, wedge-shaped pockets of limy mud fill depressions between adjacent dome-shaped portions of a coenosteum and are enclosed by overlying laminae of the coenosteum above. These indicate that the coenosteum is oriented upright with respect to the bedding plane ascertained at outcrop 22 during the field work and thus confirm the conclusion that the coenosteum is in living position. In a third, interbedded mud layers are laminated parallel to the laminae in a coenosteum, also strongly suggesting that the coenosteum is in living position.

The remaining samples from Outcrop 22 consist of 75 percent to 95 percent rounded to sub-angular spheroidal to edgewise stromatoporoid fragments in a sandy limestone matrix. Crinoid stem fragments, brachiopod fragments, gastropod fragments and horn corals are present in these samples in minor amounts. No tabulate corals or granitic pebbles are found. As in Outcrop 18, the great abundance of stromatoporoid pebbles in these samples indicates that these pebbles must have come from a source which was very close to their place of deposition and very probably from interbedded biostromes such as those observed in the field at Outcrop 22, from which some of the samples for Outcrop 22 were taken.

Outcrop 26

One sample which was part of a coenosteum was obtained from Outcrop 26. The internal structure was so obscure that little could be ascertained from it.

Outcrop 27

One sample was obtained from Outcrop 27 which consists primarily of part of a large stromatoporoid coenosteum. The coenosteum consists of light and dark grey stromatoporoid laminae. The laminae are interbedded with a few very irregular sandy and clayey limestone layers, which contain a few crinoid stem fragments. The more sandy interbedded layers have sub-angular stromatoporoid pebbles from sand size to 1 inch across. The structure of the coenosteum is somewhat obscure. The laminae are undulating with the undulations convex upwards. The stromatoporoid coenosteum is definitely in the growth position, as part of the coenosteum was seen overlying and interbedded with clayey and sandy limestone layers.

MEMBER 3

No outcrops of member 3 were sampled.

MEMBER 4

Outcrop 1

The samples from Outcrop 1 contain granitic pebbles and fragments of stromatoporoids, *Favosites*, crinoids, and one gastropod in a sandy limestone or fine-grained limestone matrix. Although no horn corals were found in the samples from Outcrop 1 or from any of the other samples from member 4, a few horn corals were observed at Outcrop 1 in the field. No crinoid stems were observed in the field at Outcrop 1. The stromatoporoid fragments are sub-rounded and constitute 1 percent of the samples. The *Favosites*

fragments are sub-angular and constitute 15 percent of the samples. The crinoid stem fragments are sub-angular to sub-rounded and constitute 25 percent of the samples. The granitic pebbles are sub-angular and constitute 2 percent of the samples.

Outcrop 2

The samples from Outcrop 2 consist of granitic pebbles and fragments of stromatoporoids, *Favosites*, brachiopods, and crinoids in a sandy limestone or limy quartzose sandstone matrix. The stromatoporoid fragments are sub-rounded and edgewise and constitute 8 percent of the samples. The *Favosites* fragments are sub-rounded and constitute less than 1 percent of the samples, as do the brachiopod fragments. The crinoid stem fragments constitute 4 percent of the samples. Sub-angular granitic pebbles constitute 1 percent of the samples.

Outcrop 11

The samples from Outcrop 11 consist of granitic pebbles and fragments of stromatoporoids, *Favosites*, and crinoids in a limy quartzose sandstone matrix. Although a few brachiopods were observed in the field at Outcrop 11, none were found in the samples. The stromatoporoid fragments are sub-angular and constitute 20 percent of the samples. The *Favosites* are sub-angular and constitute 30 percent of the samples. The granitic pebbles are sub-angular to sub-rounded and constitute 25 percent of the samples. The crinoid stem fragments constitute 1 percent of the samples.

Outcrop 16

The one sample taken from Outcrop 16 consists of sub-angular fragments of stromatoporoids (5 percent), sub-rounded fragments of *Favosites* (3 percent) and crinoid stem fragments (2 percent) in a limy quartzose sandstone matrix. No crinoid fragments were found from the field work for Outcrop 16.

MEMBER 5

Outcrop 10

The samples from Outcrop 10 consist of stromatoporoids, tabulate corals (*Favosites*), horn corals, brachiopods, gastropods (*Platyceras*), and crinoids, together with granitic pebbles in a sandy limestone matrix. The stromatoporoid fragments are sub-angular to rounded and range from sand-size to 2 inches across and constitute, in general, from 10 to 20 percent of the samples. Four large tabulate corals (*Favosites* colonies) slightly rounded on the edges but otherwise apparently whole and from 6 to 10 inches in greatest dimension are present in the samples. These are not in living position as is shown by their orientation with respect to the bedding and by their abnormal orientations in the samples. Except for the four large *Favosites* colonies mentioned above, the tabulate coral fossils are sub-angular to rounded *Favosites* fragments which range from 1/4 inch to 3 inches across and constitute about 20 percent of the samples. The horn corals show no definite rounding but are probably fragmental to at least some degree. They constitute only a few percent of the samples in which they are present. The brachiopods are disarticulated or fragmental and constitute one percent or less of the samples in which they are found (U.S.G.S. locality 3499-SD). The granitic pebbles are angular to sub-angular, from 1/4 inch to 1 1/2 inches across and constitute, in general, about 5 percent of the samples. The fossils show no preferred orientation, except in samples 1 and 8, where they are oriented sub-parallel to each other. The granitic pebbles and fossil fragments exhibit some sorting with respect to size. Where the granitic pebbles are large the fossil fragments are large, and where the granitic pebbles are small the fossil fragments are small.

Outcrop 9

The samples from Outcrop 9 consist of fragments of stromatoporoids, tabulate corals (*Favosites*), horn corals, brachiopods, and crinoids, together with granitic pebbles in a sandy limestone matrix. The stromatoporoid fragments are sub-rounded to rounded and constitute about 2 percent of the samples. The *Favosites* fragments are sub-rounded and constitute about 2 percent of the samples. The brachiopod fragments and crinoid stem fragments each constitute about 1 percent of the samples. The granitic pebbles are sub-angular and constitute 1 percent of the samples. The general size of the stromatoporoid and coral fragments and of the granitic pebbles is much smaller than those from Outcrop 10. The samples from Outcrop 9 are much less fossiliferous and contain fewer granitic pebbles than those from Outcrop 10. Crinoid debris is rare in the samples from Outcrop 9. Although large, essentially whole *Favosites* colonies were found at Outcrop 9 during the field work, none were found in the samples. A few well rounded granitic pebbles were found at Outcrop 9 during the field work, and it is seen from the samples that a few sub-angular pebbles 1/4 inch to 1/2 inch across are also present

at this outcrop. The fossil fragments and granitic pebbles are sub-parallel in some of the samples. The majority of the brachiopod fragments are oriented convex upward. The granitic pebbles and fossil fragments exhibit some sorting with respect to size. Where the granitic pebbles are large the fossil fragments are large, and where the granitic pebbles are small the fossil fragments are small.

Outcrops 7 and 8

The samples from Outcrops 7 and 8 consist of fossil fragments of the same types and in the same size ranges as those from Outcrop 9, together with a few small granitic pebbles in a sandy limestone matrix. The fossil fragments are oriented sub-parallel to each other in one sample. The stromatoporoid fragments are sub-angular to rounded and constitute about 15 percent of the samples. The *Favosites* fragments are sub-angular to rounded and constitute about 3 percent of the samples. The crinoid stem fragments, the brachiopod fragments and the horn corals each constitute about 1 percent of the samples. The granitic pebbles are sub-angular to sub-rounded and constitute about 6 percent of the samples.

Outcrops 3 and 4

The samples from Outcrops 3 and 4 consist of fossil fragments of the same types, and in the same size ranges as those from Outcrop 9, and also a few articulated brachiopods together with a few small granitic pebbles in a matrix of limy quartzose sandstone, fine-grained limestone, or sandy limestone. The samples with fine-grained limestone contain no granitic pebbles. The stromatoporoid fragments are sub-angular to sub-rounded and constitute about 15 percent of the samples. The *Favosites* fragments are sub-angular to sub-rounded and constitute about 2 percent of the samples. The horn corals constitute less than 1 percent of the samples. The crinoid stems and brachiopod fragments each constitute about 2 percent of the samples. The granitic pebbles are sub-angular and constitute about 3 percent of the samples. In certain of the samples the sorting is poor. In others sorting is good, with the fossil fragments and granitic pebbles lying very nearly in the same size range.

LABORATORY-DETERMINED BEDDING ATTITUDES

Due to the bouldery nature of the southern members of the Beck Pond limestone, there was some question about the reliability of bedding attitudes determined in the field. Therefore, it was decided that oriented slabs collected for paleoecologic and lithologic analysis would also be studied to determine whether bedding information derived in the laboratory was similar to that measured in the field.

MEMBER 1

OUTCROP 28

Sample 44—No preferred orientation.

Sample 56—No preferred orientation.

Sample 57—No preferred orientation.

MEMBER 2

OUTCROP 18

Sample 38—Stromatoporoid in living position with lamellae convex upward.

Sample 40—No preferred orientation.

Sample 41—Fragment not in living position (stromatoporoid lamellae convex downward).

Sample 42—No preferred orientation.

OUTCROP 22 (N. 60° E., 35° S. observed in field)

Sample 45—Oriented stromatoporoid fragments (N. 45° E., 45° S.) in living position, other fossils not oriented.

Sample 46—Oriented stromatoporoid fragments (N. 45° E., 45° S.) in living position, other fossils not oriented.

Sample 47—Stromatoporoid lamellae convex upward (N. 80° E., 20° S.) in living position.

Sample 48—Oriented stromatoporoid fragments in living position (N. 70° E., 40° S.), other fossils not oriented.

Sample 50—Stromatoporoid lamellae convex upward (N. 80° E., 30° S.) in living position.

Sample 51—Stromatoporoid lamellae convex upward (N. 45° E., 20° S.) in living position.

Sample 52—Stromatoporoid lamellae convex upward (N. 50° E., 50° S.) in living position.

Sample 53—Oriented stromatoporoid fragments (N. 60° E., 20° S.) in living position.

OUTCROP 27

Sample 55—Stromatoporoid lamellae convex upward (no trend) in living position.

MEMBER 4

OUTCROP 1

Sample 24—No preferred orientation.

OUTCROP 2 (Horizontal bedding observed in field)

Sample 23—Oriented, flat-sided stromatoporoid fragments (Horizontal).

OUTCROP 11

Sample 32—No preferred orientation.

OUTCROP 16

Sample 37—No preferred orientation.

MEMBER 5

OUTCROP 3

Sample 22—No preferred orientation.

Sample 26—No preferred orientation.

Sample 27—No preferred orientation.

Sample 30—No preferred orientation.

Sample 31—No preferred orientation.

OUTCROP 4

Sample 28—No preferred orientation.

Sample 29—Subparrallel fossils and partially calcite-filled brachiopod (Horizontal) give top direction.

OUTCROP 7

Sample 15—No preferred orientation.

Sample 16—No preferred orientation.

Sample 17—No preferred orientation.

Sample 18—No preferred orientation.

Sample 19—No preferred orientation.

OUTCROP 8

Sample 14—No preferred orientation.

OUTCROP 9 (E.-W., 50° S.)

Sample 9—Oriented, convex upward shell fragments (N. 45° E., 45° S.) give top direction.

Sample 10—No preferred orientation.

Sample 11—Oriented, convex upward shells (N. 50° E., 45° S.) give top direction.

Sample 12—No preferred orientation.

Sample 13—Sandy and shaly laminae (N. 65° E., 35° S.).

OUTCROP 10 (E.-W., 35° S.)

Sample 1—No preferred orientation.

Sample 2—No preferred orientation.

Sample 3—No preferred orientation.

Sample 4—No preferred orientation.

Sample 5—No preferred orientation.

Sample 6—No preferred orientation.

Sample 7—No preferred orientation.

Sample 8—No preferred orientation.

The above tabulated information shows that the field- and laboratory-determined bedding attitudes are consistent for member two, possibly consisent for member four although poor sampling precludes certainty, and widely divergent in strike for member 5. For member 5 it is likely that the laboratory-determined bedding attitudes are more reliable than those from the field as the partially calcite filled brachiopods should be very trustworthy as levels.

PALEOECOLOGY

All five members of the Beck Pond limestone are characterized by death assemblages, except for members 1 and 2 which also contain undisturbed coral-stromatoporoid life assemblages. The tetracorals and brachiopods of member 1 differ from those of member 5 (Table 1),

TABLE 1

FAUNA OF THE BECK POND AND BEAR POND LIMESTONES

	Member five		Member two	Member one	Bear
	SD-3499	SD-3497	SD-3600	SD-3601	Pond
Brachiopods					
Orthostrophia cf. O. *strophomenoides*	x				x
Levenea sp.	x				x
Dicaelosia sp.	x				
Dalejina sp.	x				x
Sieberella n. sp.	x				
Camarotoechia sp				x	
"*Camarotoechia*" *alveata*	x				
Sphaerirhynchia sp. 2	x				
Sphaerirhynchia sp. 3				x	
Eatonia cf. *E. medialis*	x				
Atrypa "*reticularis*"	x				
Coelospira cf. *C. virginia*	x				
Macropleura cf. *M. macropleura*	x				x
Howellella cf. *H. cyclopterus*	x				x
Kozlowskiellina (*Megakozlowskiella*) sp.	x	x		x	x
Meristella? sp.	x				x
Leptaena "*rhomboidalis*"	x	x		x	x
Leptostrophia? sp.	x				
Leptaenisca sp.	x				
Nanothyris cf. *N. subglobosa*			x	x	
Plicoplasia sp.					?
Schuchertella sp.					x
Ostracodes					
Mesomphalus sp.	x				
Tubulibairdia sp.	x				x
Large smooth Ostracodes					
Kloedenia n. sp.					x
Myomphalus sp.					x
Janusella sp. cf. *J. subtumida*					x
Strepulites sp.					x
bythocyprid *n. gen. et. sp.*					x
n. gen. et. sp.					x
Gastropods					
Platyostoma ventricosum	x		x		x
Corals					
Amplexiphyllum nanum	x				
Briantelasma mainense	x				
Lyrielasma annulatum	x (rare)			x	
Tryplasma rhopalium	x			x (rare)	
Favosites sp.	x				

The ostracodes were identified by Dr. Jean Berdan. The corals were identified by Dr. W. A. Oliver, Jr. (in U.S.G.S. Bull. 1111A, 1960, except for his identification of *Stereolasma* sp., *Alveolites* sp., "possibly *Briantelasma* sp." and "small zaphrentoid" in the Bear Pond limestone.)

indicating the presence of different biotopes within a short distance of each other. The death assemblages in members 1, 2, and 3, together with the life assemblages in members 1 and 2, are characterized by an overwhelming abundance of stromatoporoidal material as well as a greater abundance in the bioclastic fraction; 60 percent or more in member 1, 90 percent or more in member 2, versus 3 percent to 60 percent in member 4 and 33 percent to 71 percent in member five.

The absence of laminar stromatoporoids in living position in members four and five, together with their abundance in the other members, and high correlation between the size of both stromatoporoid and granitic pebbles and cobbles suggests that the stromatoporoids in these two members were transported from points of origin elsewhere.

The coprophagous gastropod *Platyceras* and crinoidal debris are present in variable abundance in all the death assemblages, but not in the coral-stromatoporoidal life assemblage, which suggests that *Platyceras* and crinoids were elements in the non-stromatoporoidal biocoenoses.

The distinctive brachiopod and tetracoral assemblages of members one and five indicate the presence of at least two distinct biotopes. Almost all of the brachiopods of member one are still articulated, whereas those of member five are almost entirely disarticulated. When the abundance of rounded granitic debris in member 5 is considered together with the high correlation between bioclastic fragment size and granitic fragment size, it is clear that the brachiopod-tetracoral biotope of member 5 was characterized by much rougher water than that of member 1. The relatively small number of brachiopod and coral genera from member 1 as contrasted with member 5 also emphasizes the distinctiveness of the two biotopes.

Members 1 and 2 contain a coral-laminar stromatoporoid life assemblage in living position, whereas they are absent in members 3 to 5. The less abundant stromatoporoidal debris in members 3 to 5, whose dimensions correlate very well with those of the associated granitic debris may have been broken from biostromes living in members 1 and 2.

In summary, it appears that at least two biotopes are present: a brachiopod-tetracoral-laminar stromatoporoid biotope in relatively quiet water in members 1 and 2, and a brachiopod-tetracoral biotope in relatively rough water in member 5.

INSOLUBLE RESIDUES FROM THE BECK POND AND BEAR POND LIMESTONES

PROCEDURE

Forty- to fifty-gram samples (see Boucot, Harper, and Rhea 1959, p. 30-31) were dissolved in concentrated hydrochloric acid. The average weight per cent of insoluble residue for each member was determined by summing the weight per cent of all samples from that member and averaging. The per cent mineral composition of the residue was estimated by eye for each sample.

The size fractions retained by the No. 200 sieve size and by the pan sieve size were not examined for angularity or composition because of the small grain size.

All of the weight per cents and the average estimated feldspar contents were plotted on histograms which were interpreted in relation to grain angularity, residue compositions, paleontological studies, and the field data.

SUMMARY OF RESULTS

The coarser size fractions (those retained by sieve Nos. 20, 40, 60, and 100) of the Beck Pond insolubles were found to be mineralogically very similar from member to member. All of the Beck Pond member residues contain 90 to 99 per cent clear quartz and white to light grey feldspar. Minor amounts of muscovite, biotite, pyrite, and chlorite (?) are also found in each member. All grains of sand size or smaller are angular to sub-angular.

The histograms of the weight per cent of insolubles versus sieve size for members 1 and 2 show that these members are poorly sorted. Member 2 is comparatively low in weight per cent of insolubles. The histograms of members 3 and 4 show that their sieved fractions are well-sorted, with the concentration of the insolubles lying in the coarsest size fractions. Member 5 is moderately sorted, again with the concentration in the coarsest fraction. The Bear Pond insolubles were moderately sorted with the concentration in sieve Nos. 40 and 60.

BEAR POND LIMESTONE

The coarse fractions (20, 40, 60, 100) of the Bear Pond residues contain over 95 percent clear quartz and white feldspar (sodic plagi-

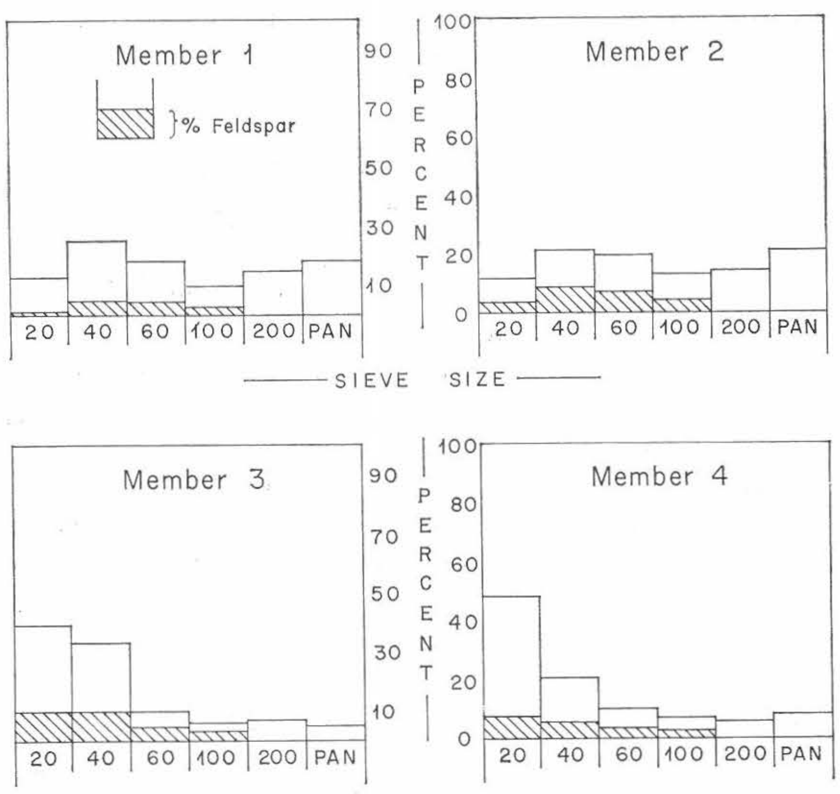


Figure 5a-d. Average weight percent of insolubles versus sieve size.

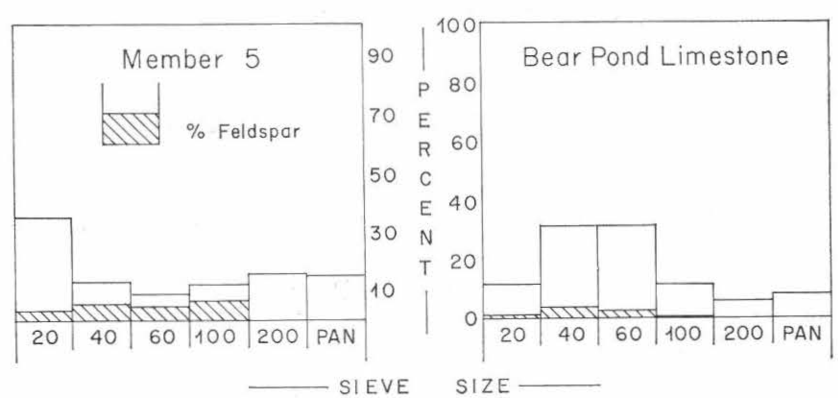


Figure 6a-b. Average weight percent of insolubles versus sieve size.

oclase or orthoclase?) with some dark-colored granitic pebbles (less than 5 percent), muscovite (less than 1 percent), and silicified (?) coral fragments (less than 1 percent). The feldspar in the Bear Pond residues appears to be much whiter than the feldspar in the Beck Pond, and the Bear Pond fine fractions are dark grey to black whereas the Beck Pond fine fractions are a much lighter grey. The average feldspar content in the Bear Pond residues is less than half that in any of the Beck Pond members (Figures 5 and 6), and the sorting is

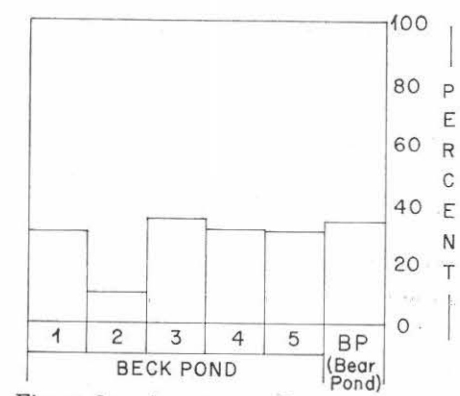


Figure 6c. Average weight percent of insolubles, members 1-5 and Bear Pond Limestone.

moderate to good with a single mode centered between the No. 40 and No. 60 sieve sizes. In sorting and feldspar content, the Bear Pond member is most similar to Beck Pond member 1 (Figures 5 and 6).

The insolubles of the Bear Pond member may have been derived from a different phase of the granitic source of the Beck Pond insolubles, or they may have been derived from one or more separate sources. The apparent variation between the Beck Pond and Bear Pond feldspars and clays may be the result of variations in the weathering of the sediment before, during, or after deposition, or the variations may be the result of different source areas.

BECK POND LIMESTONE

GENERAL CHARACTERISTICS

All of the members of the Beck Pond limestone have several characteristics in common:

1. all grains of sand size or smaller are angular to sub-angular

2. the mineral composition of the coarser grained residues (sieve numbers 20 through 100) is 90 to 99 percent clear quartz and white to gray feldspar (plagioclase?)

3. minerals found in the residues in minor amounts (less than 5 percent and generally less than one percent) include, in order of decreasing importance, muscovite, biotite (partially or completely altered), pyrite (euhedral crystals), and a forest-green mineral (chlorite?).

The relative amounts of feldspar present in the coarse sieve fractions of each member do not vary significantly from member to member, and the variations noted may be explained partially by errors in the sample analyses or by different lengths of time of exposure to weathering processes. The variations in the amount of feldspar in each sieve fraction for each member are given on Figures 5 and 6.

SORTING VARIATIONS

The insolubles of member 5 are moderately sorted, with a principal mode centered on the No. 20 sieve fraction and possibly a small secondary mode centered on the No. 200 sieve fraction (Figure 6). Field evidence (Boucot, Harper, and Rhea, 1959, p. 10-12) shows poor sorting of the coarser debris. The poor sorting of the debris above the No. 20 sieve size is evidenced by the range in grain size from coarse sand in members 4 and 5 to boulders up to 2 feet across in member 5 and up to 15 feet across in member 4.

The insolubles of member 4 are well sorted, with one distinct mode on the No. 20 sieve fraction (Figure 5). The field evidence (Boucot, Harper, and Rhea, 1959, p. 12-15) shows that the size fractions larger than the No. 20 sieve size are poorly sorted.

The member 3 insolubles are well-sorted, the highest weight percents falling in the No. 20 and No. 40 sieve sizes (Figure 5). The granitic pebbles in members 3, 4, and 5 are sub-angular to subrounded.

The insolubles of member 2 are poorly sorted, with one small mode on the No. 40 sieve size and one on the pan, or clay size fraction (Figure 5).

The insolubles of member 1 show moderate to poor sorting; they have one principal mode on the No. 40 sieve fraction, and a smaller secondary mode on the pan, or clay size fraction (Figure 5).

TABLE 2.

A Comparison Between the First and Second Weight-Percent Analyses of the Insolubles of the Beck Pond Limestone

Equivalent Sample Numbers		Weight % of Insolubles			
Field Samples[1]	Renumbered Samples[2]	1st Analysis[3]	2nd Analysis[4]	Outcrop Numbers[5]	Member
BP1	—	—	33.9		Bear Pond
BP2	—	—	33.5	42	Bear Pond
11	8	24.9	26.1	3 & 4	5
9	7	44.3	51.4	7	5
8	6	25.8	30.2	8	5
7	5	30.1	29.5	9	5
C4	—	—	19.1	10S	5
C6	—	—	35.2	10N	5
C14	—	—	25.5	8	5
C30	—	—	30.1	3	5
C10	—	—	19.4	9	5
C19	—	—	40.8	7	5
18	—	—	38.2	1	4
19	—	—	19.0	1	4
13	9	48.2	38.3	2E	4**
14	10	47.9	51.5	2Ectr	4**
15	11	29.2	35.8	2Wctr	4**
16	12	41.0	4.1	2W	4**
C37	—	—	40.1	16	4
C32	—	—	22.3	11	4
30	—	—	31.4	22S	3
31	22	32.7	32.7	22S	3
20	13	78.7	36.7	18S	3
22	15	17.9	15.7	18N	2
32	23	6.0	6.0	22S	2
33	24	6.8	5.7	22Sctr	2
34	25	13.2	13.5	22Nctr	2
35	26	6.9	7.6	22N	2
24	16	15.7	19.4	23	2
29	21	21.6	22.1	24-27	2
C38	—	—	1.9	18N	2
C57	—	—	2.7	24	2
36	27	7.8	8.7	22N	1**
26	18	24.3	31.1	28N	1
27	19	39.2	40.9	28ctr	1
28	20	32.2	37.1	28S	1
38	28	21.2	19.9	32	1
25	17	13.7	23.1	33	1
37	—	—	57.6	34	1

1 These sample numbers used in Figures 1-6.
2 These sample numbers used in Boucot, Harper and Rhea, 1959, Table 1, p. 33.
3 Analysis description given in Boucot, Harper, and Rhea, 1959, p. 30-33.
4 Analysis description given in this paper.
5 N,S,E, and W refer to the north, south, etc., ends of the outcrops; ctr means center of outcrop.
** Note error in Boucot, Harper, and Rhea, 1959, Table 1, p. 33 (see Errata at end of this paper).

Many or all of the secondary modes which occur in the histograms may result from one or two possible causes. First, these secondary modes may be caused entirely by the choice of sieve sizes used in the analysis. If more sieves of varying screen openings in the finer ranges had been used, the modes might have been eliminated. Or possibly the secondary modes may be the result of a secondary source area that could have contributed only very fine-grained material to the deposit. Either of these two possibilities could cause a mode in the finer-grained sieve size.

DEPOSITIONAL HISTORY

Both field and laboratory investigations of the Beck Pond limestone indicate that all its five members consist of a combination of locally produced bioclastic material and locally derived basement complex granitic debris. The similarity in mineral composition between the insoluble portion of the Beck Pond limestone and the underlying basement complex (Boucot, Harper and Rhea, 1959, p. 20-21) suggests that the insolubles were entirely derived from the adjacent basement. The principal compositional difference between the local granitic basement complex and the insolubles is the reduction in feldspar content from about 60 percent in the granitic basement to about 20 percent to 30 percent in the insolubles. This reduction may have been caused by decomposition of feldspar into clay minerals or by disintegration into fine silt and clay size particles which were swept away from the topographically high area of deposition of the coarser fractions. The rock types characterizing the five members reflect marked differences in their depositional environments. Members one and two were deposited under relatively quiet water conditions, whereas members four and five were deposited under relatively turbulent conditions. Member three appears to have been deposited under conditions intermediate between those affecting the other four members.

Lithologic and biologic evidence suggests that member two was deposited in the most quiet water of the five members. Member two contains the lowest percentage of insoluble material of the five members (Fig. 6c) and these insolubles are bimodally distributed (Figs. 5a and 5b) with modes centering about R-40 mesh and pan, indicating conditions conducive to the deposition of relatively large amounts of fine-grained sediment and poor sorting. Member 2 is the only member characterized by an abundant, relatively undisturbed life assemblage, which consists of laminar stromatoporoids and tetracorals (member

one contains only a few laminar stromatoporoid bioherms) and it contains virtually no pebbles of basement complex granite. Interbedded with stromatoporoid biostromes of member two are a few arenaceous limestones and arenaceous, stromatoporoidal-crinoidal conglomerates similar to those making up the bulk of member one.

The abundant arenaceous limestones and conglomerates in member one reflect more turbulent conditions than reflected by the stromatoporoid biostromes of member two, although the stromatoporoid conglomerate was probably derived almost *in situ,* presumably by the break up of biostromal material. However, the absence of abundant pebbles of granitic basement complex indicates quieter conditions than prevailed in the depositional environments represented by members three to five. The complete disarticulation of the crinoidal debris and the abundance of stromatoporoidal debris provide an index of the amount of turbulence. The complete disarticulation of the crinoids indicates a relatively low rate of sedimentation as well as a certain degree of turbulence. Member one contains some articulated brachiopods, indicating relatively little disturbance prior to burial.

Members three to five were deposited under relatively turbulent conditions as reflected by the greater percentage of retained 20 mesh material (Figs. 5c, 5d, 6a); the presence of larger amounts of granitic pebbles and cobbles in all three members, of large boulders (up to 15 feet in diameter) in member four, and moderate size boulders in member five (up to two feet in diameter); the high correlation that exists between the dimensions of granitic and bioclastic debris; the disarticulated condition of the brachiopods in member five; and the rounded condition of tabulate coral and stromatoporoidal fragments.

The presence of granitic boulders up to 15 feet in diameter in member four, together with cobbles and smaller boulders in members three and five poses the problem of the boulder source area. The bedding attitudes in the five members are consistently to the southeast, which would at first suggest the presence of a simple ascending sequence from member one at the base to member five at the top. However, the presence of boulders in the southern members immediately raises the problem of how to explain the absence of such boulders in members one and two, as well as the corollary problems of why the largest boulders are concentrated in member four. It is necessary, if a simple stratigraphic concept is maintained, to postulate the creation of local basement complex relief sufficient to provide large boulders to the southern members after member two time. As it appears unlikely that the boulders were transported very far, this relief could be accounted for by postulating either a normal fault to the northwest (Fig. 7) or to the southeast (Fig. 8). In the case of the northwest fault it is necessary to infer the removal of all remnants of members one and two from the upthrown block by erosion prior to the deposition of the granite talus member of the Seboomook formation. In the case of the southeastern fault it is necessary to postulate erosion of the granite block on the southeast sufficient to permit it to be covered by the Seboomook formation.

An alternative to the fault hypothesis for supplying boulders to the southern members is to postulate that pinnacles of the pre-Beck Pond age basement rocks (Figs. 9, 10, 11) were present adjacent to the area of deposition of member four and the dark-colored boulder conglomerate (unit Db?), and that these pinnacles were sufficiently worn down by the end of Beck Pond time to be covered by the adjacent Seboomook formation. This interpretation implies that the five members are essentially contemporaneous facies deposited upon a local topographic high of basement complex in which member four was deposited under rough water conditions adjacent to a basement complex pinnacle or pinnacles, member five under rough water conditions a short distance away from the basement complex pinnacles as evidenced by the smaller dimensions of the boulders, member three under rough water conditions and also a short distance away from the basement complex pinnacles as evidenced by the presence of cobbles, and finally members one and two under relatively quiet water conditions further away from the granite pinnacles.

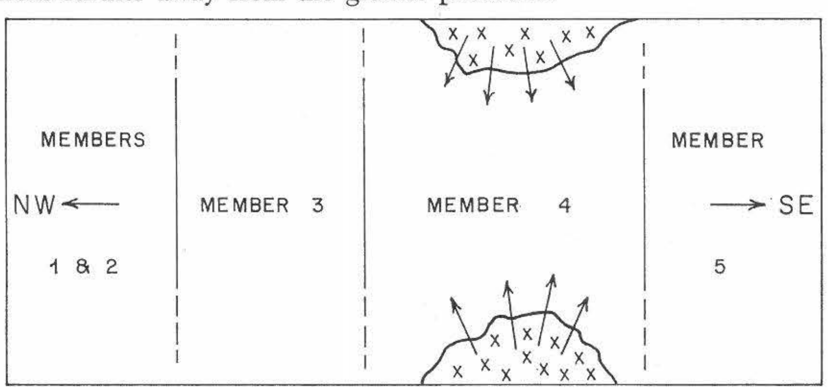


Figure 10. Generalized plan view illustrating the assumption that the changes in lithology represent facies changes and that the source was situated in, or on the flanks of, member 4. The source may have consisted of several pre-existing knobs of basement complex and may have been subsequently buried by the sediments of the Seboomook formation.

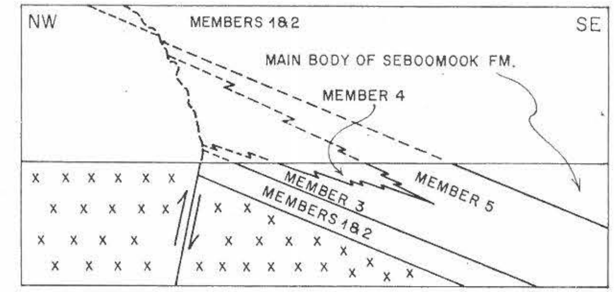


Figure 7. Cross-section illustrating the assumption that a northern fault created relief adequate to supply the clastic debris found in members 3 to 5. The fault would be of post-member 2 age and might have occurred contemporaneously with the deposition of member 3 and part of member 4.

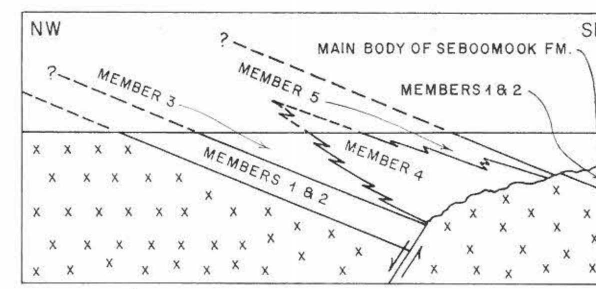


Figure 8. Cross-section illustrating the assumption that a southern fault created relief adequate to supply the clastic debris found in members 3 to 5. The fault would be of post-member 2 age and might have occurred contemporaneously with the deposition of member 3 and part of member 4.

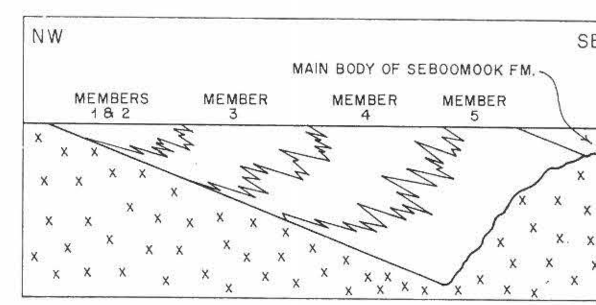


Figure 9. Generalized cross-section illustrating the assumption that the changes in lithology represent facies changes and that the source was a pre-existing buried knob of basement complex.

The postulation of pre-existing granite pinnacles receives some support from bedding attitude observations observed both in the field and in the laboratory. Throughout the area of Beck Pond limestone there is a general southeasterly dip. However, adjacent to both the dark-colored boulder conglomerate (unit Db?) and outcrop 40 (member four) widely divergent bedding attitudes have been observed (see map in Boucot, Harper, and Rhea, 1959). From outcrop 4 (member five) a horizontal bedding determination was made in the laboratory and from outcrop 2 (member four) a horizontal bedding determination was made in both the field and laboratory. If corrections are made for the general southeasterly inclination of the Beck Pond limestone, then these two exposures adjacent to the dark-colored boulder conglomerate can be inferred to have had an original dip of about 25°-35° N. adjacent to a pinnacle of dark-colored granite. The northwesterly dip observed at outcrop 40 (member four) is also consistent with the presence of an original dip away from a pinnacle of granite.

The granite pinnacle hypothesis also helps to explain the presence of quieter water conditions in members one and two, as well as the absence of boulders in member three. These three members could have been relatively protected from extremely turbulent conditions by a series of granite pinnacles to the south, away from the basement complex land area.

The presence of New Scotland age fossils, both in the basal beds of the Seboomook and in the Bear Pond member, which are essentially contemporaneous with those in the Beck Pond limestone suggests that mud and silt of the Seboomook formation were being deposited to the east and southeast of the topographic feature upon which the bioclastic and granitic debris of the Beck Pond limestone was being deposited. The presence of the granite talus member of the Seboomook to the north of the eastern margin of the Beck Pond limestone suggests the presence of an area of relatively high relief as contrasted with that upon which member one was deposited. The presence of a small area of basement complex granite surrounded by Seboomook formation, to the east of both the Beck Pond limestone and the main body of the basement complex, is most easily explained by assuming the presence of a granite pinnacle, east of the topographic high upon which the Beck Pond limestone was deposited, which was gradually overwhelmed by the Seboomook formation.

From the above discussion it can be seen that the granitic boulders in the southern members can be explained either on the basis of the

presence of pre-Beck Pond age granite pinnacles or of post-member 2 normal faulting of pre-Seboomook age. Regardless of which of these alternatives is correct, it is clear that the presence of marked basement complex topography is necessary, and that this topography was eventually covered by the sediment of the encroaching lower, New Scotland age portion of the Seboomook formation.

The presence of transported stromatoporoidal debris in the southern three members together with the high correlation existing between size of stromatoporoidal fragments and granite fragments suggests that the stromatoporoidal debris was derived from the fragmentation and transportation of biostromes elsewhere rather than complete fragmentation of biostromes in members three to five. This conclusion in turn suggests that member two or a similar nearby, unexposed unit may have been deposited at a slightly higher topographic level than members three to five (to account for the transportation of stromatoporoidal boulders to the southeast without any reciprocal transport of granite cobbles or boulders to the northwest). Moreover the brachiopod fauna of member five has not been observed in members one or two.

The general similarity between the Bear Pond limestone member of the Seboomook formation and the southern three members of the Beck Pond limestone suggests deposition under similar conditions. It is possible that the Bear Pond limestone represents a repetition of a similar topographic situation, still of New Scotland age, at a slightly later interval.

APPENDIX A

DESCRIPTIONS OF SAMPLES FROM ORIENTED SLABS

MEMBER 1

Outcrop 28:

Sample 44.

1. sub-angular stromatoporoid fragments up to 1″ across—74%
2. crinoid stem fragments up to 3 mm across—1%
3. sandy limestone matrix—25%

Sample 56.

1. angular stromatoporoid fragments up to 4″ across—60%
2. *Platyceras* fragments—2%
3. clayey limestone matrix—38%

Sample 57.

1. sub-rounded stromatoporoid fragments up to 4″ across—25%
2. crinoid stem fragments up to 3 mm across—5%
3. brachiopod fragments up to 1″ across—2%
4. *Platyceras* fragments—1%
5. fine grained limestone matrix—67%

MEMBER 2

OUTCROP 18:

Sample 38. Sample consists of part of a large stromatoporoid coenosteum.

Sample 40.

1. angular to sub-angular stromatoporoid fragments from sand size up to 2″ across—90%
2. sandy limestone matrix—10%

Sample 41. Sample 41 consists of part of a stromatoporoid coenosteum fragment composed of alternating light and dark grey laminae a few millimeters thick which for the most part are not very distinct. The laminae are convex downward with respect to the bedding plane (which is E.-W., 25° S. at this outcrop from the field work), indicating that the sample is not in place but is part of a stromatoporoid fragment.

Sample 42.

1. sub-angular stromatoporoid fragments up to 2″ across—75%
2. sandy limestone matrix—25%

OUTCROP 22:

Sample 45.

1. rounded to sub-rounded stromatoporoid fragments—75%
2. crinoid stem fragments—3%
3. gastropods (*Platyceras*)—1%
4. sandy limestone matrix—21%

Sample 46.

1. rounded to sub-rounded stromatoporoid pebbles up to 2½″ across—73%
2. crinoid stem fragments—4%
3. gastropods (*Platyceras*)—1%
4. brachiopod fragments—1%
5. sandy limestone matrix—21%

Sample 47. Sample is part of a large stromatoporoid coenosteum and consists mainly of alternating light and dark grey stromatoporoid laminae about 1 mm thick which are convex upward, undulating, and irregular in shape, though the curvature of the undulations is not great (Fig. 6). They are to a first approximation planar and sub-parallel. The laminae surround horn corals which are preserved essentially whole and lie between the stromatoporoid laminae of the coenosteum. This close association of horn corals and stromatoporoid laminae indicates that they represent a life assemblage. No other fossils are associated with the coenosteum.

Sample 48.

1. sub-angular stromatoporoid fragments up to 1″ across—80%
2. crinoid stem fragments up to 2 mm across—1%
3. horn corals about ¼″ in diameter—3%
4. sandy limestone matrix—16%

Sample 49.

1. sub-angular stromatoporoid fragments—74%
2. crinoid stem fragments up to 2 mm across—1%
3. limy sandstone matrix with angular well sorted coarse sand grains—25%

Sample 50. Sample consists of more or less parallel, alternating light and dark grey laminae about ½ mm to 2 mm thick which are undulating and convex upward as in sample 47. There are a few small irregular inclusions of secondary calcite and also a minor amount of black foreign matter in the coenosteum.

Sample 51.

Sample consists of a portion of a stromatoporoid coenosteum which consists of alternating light and dark gray undulating laminae 1 mm to 5 mm thick. The lower quarter of the sample consists of strongly undulating laminae which are convex upward. The upper three-quarters of the sample consists of a basal layer in which the laminae are gently undulating, overlain by a layer in which the laminae are strongly undulating, convex upward, and form wide domes separated by narrow depressions. The laminae are wider on the crests of the domes than on the flanks. The laminae have a much greater curvature and thicken and thin much more in this portion than in samples 47, 50, and 52. Wedge-shaped pockets of limy mud with 1 to

2 mm randomly oriented brachiopod fragments and sand-size angular calcite grains fill the depressions between adjacent domes and are enclosed by overlying stromatoporoid laminae above. These indicate top and bottom of the coenosteum and show that it is oriented upright with respect to the bedding plane as ascertained at outcrop 22 during the field work. There are also a few irregular-shaped inclusions of secondary calcite and a few irregular-shaped inclusions of unidentified black material. Although the laminae are irregular in shape they exhibit a general trend.

Sample 52.
Sample consists of alternating stromatoporoid laminae up to 3 mm thick interbedded with many black limy mud lenses containing sand-size calcite fragments, some of which are fragments of crinoid stems. There are also a few irregular inclusions about 1 cm thick of secondary calcite. The laminae are gently undulating and convex upward. The fact that the laminae are intricately interbedded with the limy mud lenses and are convex upward suggests that the coenosteum is oriented in living position. The stromatoporoid laminae were built on top of the layers of limy mud. New laminae were added on top of the old and the laminae were at intervals partly covered by limy mud. Samples 50, 51, and 52 are remarkably devoid of inclusions of fossils of other marine fauna in the coenosteum.

Sample 53.
1. rounded to sub-rounded, spheroidal to edgewise stromatoporoid fragments ranging from sand size to 2″ across—94%
2. crinoid stem fragments—2%
3. small horn corals—2%
4. sandy limestone matrix—2%

OUTCROP 26:

Sample 54. Sample consists of part of a large stromatoporoid coenosteum.

OUTCROP 27:

Sample 55. Sample consists of part of a large stromatoporoid coenosteum interbedded with limy mud layers which contain crinoid stem fragments and are in part laminated. The laminae in the mud layers are parallel to the laminae in an adjacent

part of the stromatoporoid, indicating that the coenosteum is probably in living position.

MEMBER 4

OUTCROP 1:

Sample 24.
1. sub-angular to sub-rounded crinoid stem fragments up to ¼″ in diameter—50%
2. sub-rounded stromatoporoid pebbles up to ½″ across—3%
3. one 1½″ gastropod fragment
4. sub-angular granite pebbles from sand size to ½″ across 3%
5. fine grained limestone matrix—44%

Sample 25.
1. sub-angular *Favosites* fragments up to 1½″ across—25%
2. crinoid stem fragments up to 1 cm in diameter—2%
3. sandy limestone matrix—73%

OUTCROP 2:

Sample 21.
1. crinoid stem fragments—5%
2. limy quartzose sandstone matrix—95%

Sample 23.
1. sub-angular to sub-rounded edgewise stromatoporoid fragments up to 1½″ across—15%
2. sub-rounded *Favosites* fragments up to 1″ across—1%
3. brachiopod shell fragments—1%
4. crinoid stem fragments 1 mm to 1 cm in diameter—3%
5. sub-angular granite pebbles up to ½″ across—2%
6. sandy limestone matrix—78%

OUTCROP 11:

Sample 32.
1. sub-angular stromatoporoid fragments up to 2″ across—25%
2. sub-rounded granite pebbles about 1″ across—25%
3. limy quartzose sandstone matrix—50%

Sample 33.
1. sub-angular stromatoporoid fragments up to 1″ across—20%
2. sub-angular *Favosites* fragments up to 2″ across—60%

3. sub-angular granite pebbles ¼″ to ½″ across—2%
4. limy quartzose sandstone matrix—18%

Outcrop 16:

Sample 37.
1. sub-angular stromatoporoid fragments less than 1″ across —5%
2. sub-rounded *Favosites* fragments about ½″ across—3%
3. crinoid stem fragments up to 5 mm across—2%
4. limy quartzose sandstone matrix—90%

MEMBER 5

Outcrop 3:

Sample 20.
1. crinoid stem fragments up to 5 mm across—5%
2. limy quartzose sandstone matrix—95%

Sample 22.
1. sub-angular stromatoporoid fragments up to 2″ across—15%
2. brachiopod shell fragments about 1½″ across—2%
3. limy sandstone matrix—19%

Sample 26.
1. sub-angular *Favosites* pebbles up to 1″ across—3%
2. crinoid stem fragments up to 3 mm across—2%
3. a few ¾″ sub-angular granite pebbles—3%
4. limy quartzose sandstone matrix—92%

Sample 27.
1. sub-rounded *Favosites* fragments about ¾″ across—2%
2. crinoid stem fragments—1%
3. limy quartzose sandstone matrix—97%

Sample 30.
1. sub-rounded stromatoporoid fragments from sand size to 1½″ across—30%
2. disarticulated brachiopod shells—1%
3. crinoid stem fragments up to 5 mm across—1%
4. sub-angular granite pebbles ¼″ to ¾″ across—3%
5. limy quartzose sandstone matrix—65%

Sample 31.
1. sub-angular to sub-rounded stromatoporoid fragments from sand size to 2″ across—40%

2. sub-rounded *Favosites* fragments about 1″ across—10%
3. disarticulated brachiopod shell fragments up to 1½″ across —3%
4. sub-angular granite fragments ¼″ to 1″ across—3%
5. crinoid stem fragments—2%
6. clayey limestone matrix—42%

Outcrop 4:

Sample 28.
1. silty and clayey limestone matrix—95%
2. horn corals ¼″ in diameter—1%
3. crinoid stem fragments—3%
4. brachiopod fragments up to 1½″ across—1%

Sample 29.
1. sub-angular stromatoporoid fragments from sand size to 1″ across—5%
2. articulated and disarticulated brachiopod shells—5%
3. crinoid stem fragments about 5 mm across—2%
4. sandy limestone matrix—88%

Outcrop 7:

Sample 15.
1. sub-rounded stromatoporoid fragments ½″ in average size —10%
2. sub-rounded tabulate coral fragments ½″ in average size —10%
3. brachiopod fragments and disarticulated shells—3%
4. sub-angular granite pebbles from ¼″ to 1″ across—5%
5. silty limestone matrix—72%

Sample 16.
1. crinoid stem fragments—3%
2. brachiopod fragments ½″ to ¼″ across—1%
3. rounded stromatoporoid pebbles ¼″ across—3%
4. sub-rounded granite pebbles ¼″ across—1%
5. sandy limestone matrix—92%

Sample 17.
1. rounded to sub-angular tabulate coral fragments ½″ to ¼″ across—5%
2. rounded to sub-angular stromatoporoid fragments ½″ to ¼″ across—8%

3. disarticulated brachiopod fragments—1%
4. crinoid stem fragments—2%
5. granite pebbles ¼″ across—1%
6. sandy limestone matrix—83%

Sample 18.
1. horn corals about 1″ across—15%
2. stromatoporoid fragments about 1″ across—15%
3. one sub-rounded stromatoporoid fragment about 3″ across —20%
4. sub-angular granite pebbles ¼″ to ¾″ across—5%
5. silty limestone matrix—45%

Sample 19.
1. sub-angular granite pebbles ¼″ across—25%
2. sub-angular stromatoporoid fragments up to 1″ across—10%
3. brachiopod fragments about ½″ across—5%
4. sandy limestone matrix—60%

OUTCROP 8:

Sample 14.
1. brachiopod fragments (*Kozlowskiellina*) up to 1″ across —3%
2. stromatoporoid fragments about ½″ across—5%
3. tabulate coral fragments ½″ across—2%
4. crinoid stem fragments—1%
5. horn corals up to 1″ in diameter—3%
6. one ¼″ granite pebble
7. silty limestone matrix—86%

OUTCROP 9:

Sample 9.
1. *Favosites* fragments ¼″ to ½″ across—5%
2. stromatoporoid fragments ¼″ to ½″ across—2%
3. disarticulated brachiopod shells and shell fragments up to ½″ across—5%
4. crinoid stem fragments—1%
5. sandy limestone matrix—87%

Sample 10.
1. crinoid stem fragments up to 2 mm in diameter—2%
2. disarticulated shell fragments up to ½″ across—1%
3. silty limestone matrix—97%

Sample 11.
1. rounded to sub-rounded stromatoporoid fragments ¼″ to 1″ across—8%
2. sub-rounded *Favosites* fragments up to 1″ across—2%
3. disarticulated brachiopod shells and shell fragments up to 1″ across—3%
4. crinoid stem fragments from 1 mm to 1 cm across—1%
5. sub-angular granite pebbles ¼″ to ½″ across—2%
6. sandy limestone matrix—84%

Sample 12.
1. brachiopod fragments up to 1″ across—3%
2. stromatoporoid fragments up to 1½″ across, mostly in the ½″ to ¼″ range—3%
3. *Favosites* fragments up to ½″ across—2%
4. crinoid stem fragments—1%
5. one sub-angular granite pebble ⅜″ across—1%
6. sandy limestone matrix—90%

Sample 13.
1. disarticulated brachiopod shells and shell fragments up to 1″ across—2%
2. rounded stromatoporoid fragments up to ½″ across—2%
3. crinoid stem fragments—1%
4. sub-angular granite pebbles up to ⅜″ across—1%
5. sandy limestone matrix—50%
6. one fine grained clayey limestone layer which contains no fossils—44%

OUTCROP 10:

Sample 1.
1. two *Favosites* colonies, each about 6″ long, rounded on the edges but otherwise apparently whole, and rounded *Favosites* fragments up to 1″ across—25%
2. sub-angular stromatoporoid fragments up to 2″ across—10%
3. horn corals—2%
4. disarticulated brachiopod shell fragments—1%
5. sub-angular granite pebbles up to 1½″ across, with average size about 1″—10%
6. sandy limestone matrix—52%

Sample 2.
1. one large *Favosites* colony (3″ x 10″ x 8″) rounded on the edges—94%

2. rounded *Favosites* fragments ½″ to 1″ across—2%
3. brachiopod fragments—1%
4. sub-angular granite pebbles up to ¾″ across—1%
5. sandy limestone matrix—2%

Sample 3.
1. one large *Favosites* colony similar to those above—92%
2. sub-angular *Favosites* fragments up to 1″ across—2%
3. brachiopod fragments—1%
4. sub-angular granite pebbles about ½″ across—1%
5. sandy limestone matrix—4%

Sample 4.
1. rounded *Favosites* fragments ¼″ to 1″ across—10%
2. sub-angular to rounded stromatoporoid fragments 1/16″ to 1″ across—15%
3. horn corals—less than 1%
4. crinoid stem fragments 1 mm to 1 cm in diameter—15%
5. sub-angular granite pebbles ½″ to ¼″ across—5%
6. sandy limestone matrix—55%

Sample 5.
1. sub-rounded to rounded stromatoporoid fragments up to 2″ across—20%
2. sub-rounded to rounded *Favosites* fragments up to 1¼″ across—15%
3. crinoid stem fragments 1 mm to 1 cm in diameter—7%
4. horn corals—2%
5. *Platyceras* fragments—1%
6. sub-angular granite pebbles ½″ to 1″ across—5%
7. sandy limestone matrix—50%

Sample 6.
1. sub-angular stromatoporoid pebbles, from sand size up to 1½″ across—15%
2. horn corals—2%
3. crinoid stem fragments about 2 mm in diameter—3%
4. brachiopod fragments—less than 1%
5. angular to sub-angular granite pebbles, ¼″ to 1″ across —5%
6. sandy limestone matrix—75%

Sample 7.
1. sub-rounded *Favosites* fragments 1″ to 3″ across—24%

2. sub-angular stromatoporoid fragments from sand size to 1″ across—10%
3. crinoid stem fragments 1 mm to 1 cm in diameter—1%
4. sub-angular granite fragments ¼″ to 1″ across—5%
5. sandy limestone matrix—60%

Sample 8.
1. rounded *Favosites* fragments about 1″ across—25%
2. sub-angular stromatoporoid fragments from sand size to 2″ across—35%
3. crinoid stem fragments 1 mm to 1 cm in diameter—10%
4. horn corals—4%
5. brachiopod shell fragments—1%
6. angular to sub-angular granite pebbles ¼″ to 1″ across —10%
7. sandy limestone matrix—15%

Errata for Boucot, Harper, and Rhea, 1959

1. Page 3, LIST OF ILLUSTRATIONS:

   Lines 8 through 10 of the description of Figure 3 should read: Stromatoporoid and tabulate coral fragments and a few horn corals form some of the pebbles. Most of the larger cobbles and boulders appear to be of the same granite . . .

2. Page 33, TABLE 1:

   a) Samples 9, 10, 11, and 12 should be listed as samples of member 4 instead of member 5.

   b) Sample 27 should be listed with member 1 instead of member 2.

SILURIAN SUBAQUEOUS SLIDE CONGLOMERATE, ADDISON, MAINE

Richard A. Gilman[1]

ABSTRACT

Conglomeratic sediments in the vicinity of Addison, Maine, have been studied to determine their origin and stratigraphic relationships. On the basis of texture, composition, and associated varved siltstones, it is suggested that the conglomerates were formed by the subaqueous sliding of nearshore gravels into fine sediments in the deeper portions of the sedimentary basin. The roundstones are predominantly volcanic in origin, although cobbles of granite and quartzite are occasionally found.

There are several layers of conglomerate interbedded with siltstones and perhaps with volcanic rocks. The conglomerates rest on top of the Ellsworth schist and are believed to represent the basal units of the overlying Middle Silurian volcanic and sedimentary rocks.

INTRODUCTION

The stratified rocks of the southeastern Maine coast (Fig. 1) consist of the Ellsworth schist, (equivalent to the schist of Columbia Falls as shown by Dogget (1930) and Gilman (1961)) and interlayered volcanic and sedimentary rocks of Middle Silurian age, into which the Bays-of-Maine igneous complex (Chapman, 1962) was intruded in Devonian (?) time. This paper is concerned with conglomerates exposed in the vicinity of Addison which are interpreted as the basal units of the Silurian section resting unconformably on the Ellsworth schist.

The writer has studied in detail the metamorphic rocks in the area shown on the geologic map (Fig. 2). These consist of over 7,000 feet of poorly bedded and contorted feldspathic schists and fine-grained, weakly foliated amphibolites. On the basis of composition and texture, it is believed that these represent water-laid andesitic tuffs which were recrystallized during low grade regional metamorphism and later modified by thermal metamorphism associated with the emplacement of the Bays-of-Maine igneous complex.

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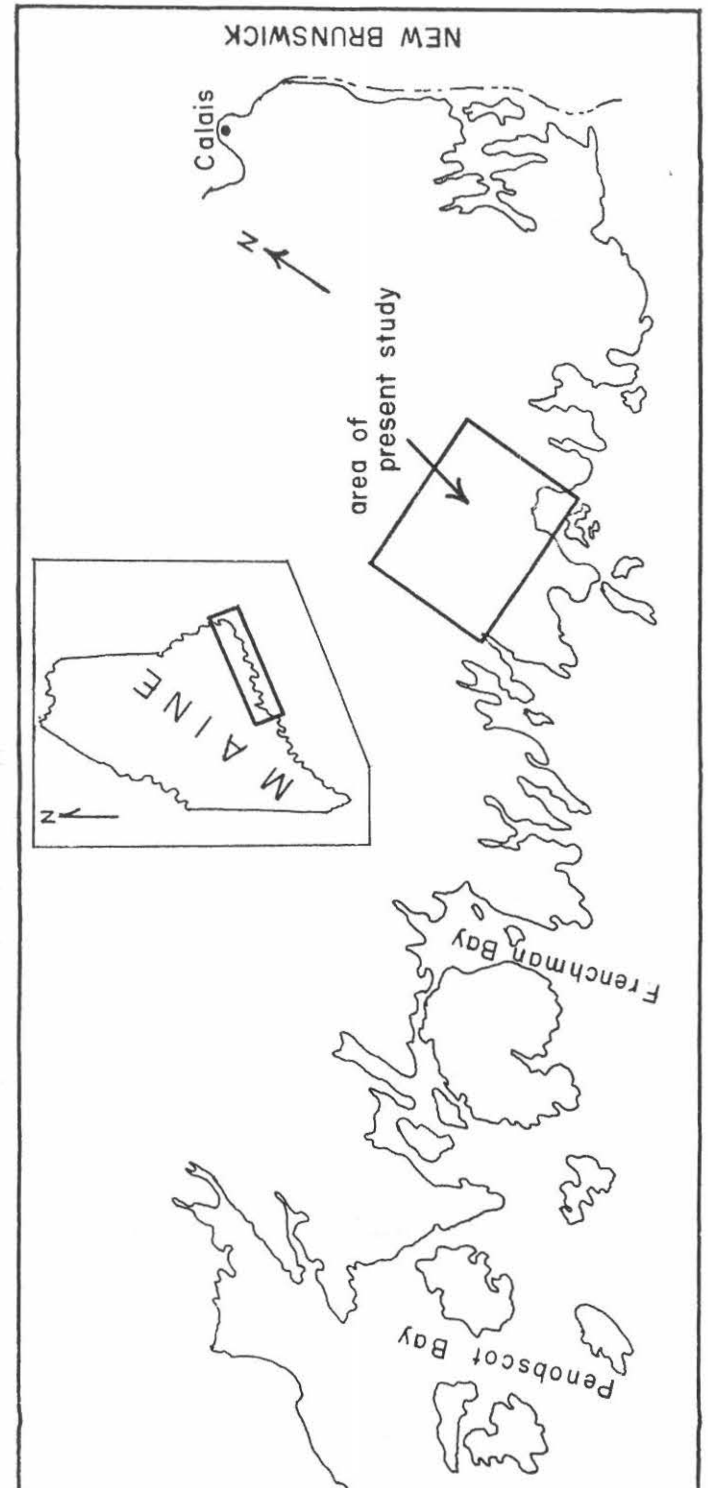

Figure 1. Index map showing location of study area.

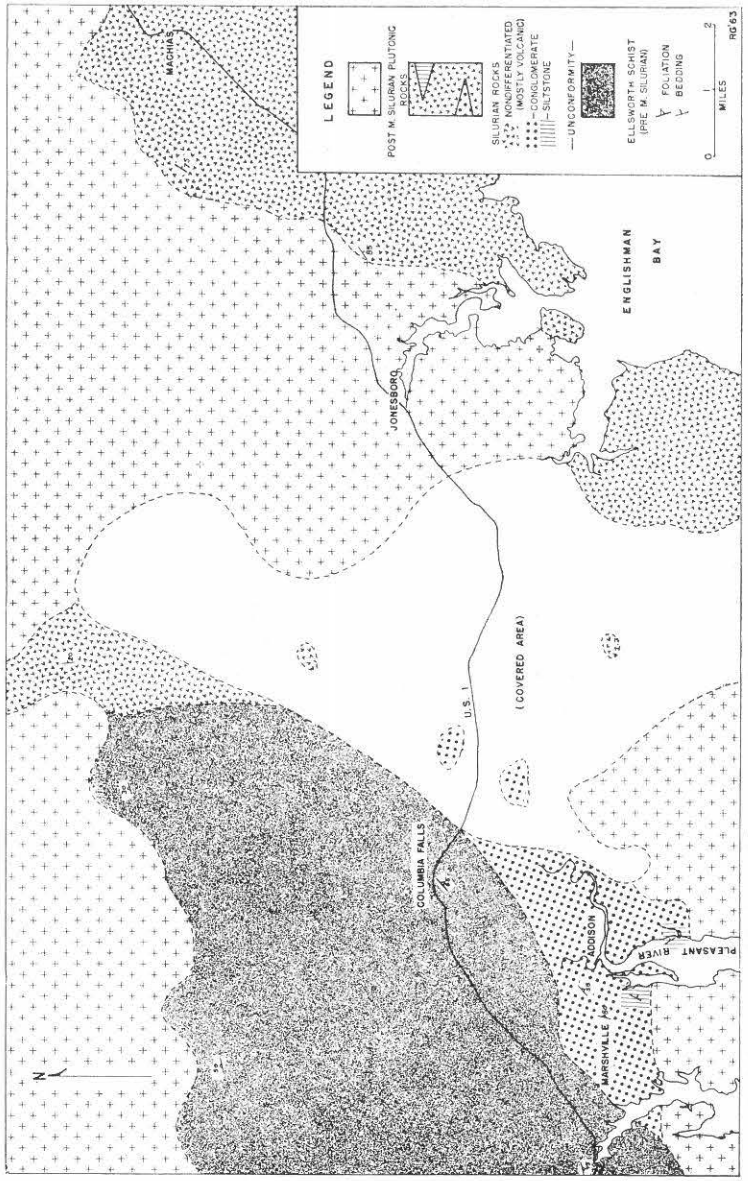

Figure 2. Geologic map in the vicinity of Addison, Washington County, Maine.

In contrast to the schists, the Silurian volcanic rocks are relatively fresh and unmetamorphosed. These range from basalts to rhyolites and commonly are pyroclastic in origin (Doggett, 1930; Gates, 1961). Exposures of interlayered volcanic and minor sedimentary units are

abundant in the Machias area. The conglomerates crop out between the metamorphic rocks to the north and west, and the volcanic units to the east.

DESCRIPTION OF THE CONGLOMERATE

Conglomeratic rocks are well exposed on a ridge between Addison and Marshville, on the east side of Pleasant River in a quarry about one mile south of Addison, and north and south of U. S. Highway 1, two miles east of Columbia Falls.

DESCRIPTION

Abundant outcrops are found in cleared blueberry fields on a ridge west of Addison. The dark gray-green, crudely foliated, non-bedded rock appears to be fragmental. However, the detailed texture of the rock is not always apparent because of the difficulty in recognizing the boundaries between fragments and matrix. Fragments are angular to round, light to dark gray, and range from sand size up to eight or ten inches in diameter. Light-colored cobbles and pebbles stand out in marked contrast to the matrix and appear to float in it, rarely touching adjacent fragments. The difficulty of distinguishing dark gray fragments from the matrix prohibited a detailed pebble count at the outcrops.

Varved siltstones are associated with the conglomerate, but the contact is not exposed. The silt is medium to dark gray and has an exposed thickness of ten feet. Microscopically the siltstone consists of quartz, feldspar and minor biotite. Excellent graded bedding was observed in one thin section which indicates the rocks are not overturned at this location.

Conglomerate is exposed in a small quarry on the east side of Pleasant River approximately one mile south of Addison. Numerous light gray, rounded cobbles and boulders of granophyre ranging from a fraction of an inch to two feet in diameter are scattered throughout the dark gray matrix. Closer examination reveals the presence of dark gray aphanitic fragments and a few pebbles of diorite. Fragments are usually floating in the matrix with adjacent cobbles rarely touching each other. A few fragments are tabular and show a slight preferred orientation, possibly parallel to bedding. Measurement of these lineations suggests a 20° to 30° dip to the northeast. In marked contrast to the exposures west of Pleasant Bay the rock in the quarry is not foliated.

Small dikes of granophyre cut the conglomerate, evidence that the conglomerate is older than granophyre of the Bays-of-Maine igneous complex which crops out a few hundred feet away.

Two small exposures of well-bedded dark and light gray siltstone crop out at the shore on the east side of Pleasant River (Fig. 2). These varved sediments show minute laminations within the one-inch thick layers. The rock is locally strongly fractured and cut by quartz veins; bedding dips approximately 50° northeast.

Two miles east of Columbia Falls, the conglomerate is exposed about half a mile north and half a mile south of U. S. 1. Exposures south of the highway consist of a massive dark gray aphanitic matrix with scattered rounded cobbles of light-colored rocks up to one foot in diameter. In addition, close examination reveals many dark gray fragments. There is no evidence of bedding or foliation like that observed west of the Pleasant River. One glacially polished surface shows numerous pebbles and cobbles, all moderately well rounded and in physical contact with their neighbors.

Numerous small exposures are found in the woods north of U. S. 1. The rocks are dark gray-green, massive, and as strongly fractured as the conglomerates south of the road. Light-colored fragments are most numerous, but dark ones are also present.

The appearance of the conglomerates from the different exposures may be summarized as follows.

1. All have a dark gray-green aphanitic matrix.
2. All are polymictic and non-bedded.
3. Most have numerous roundstones which appear to float in the matrix; locally, however, the pebbles are abundant enough to form a pebble-supported rock framework.
4. The conglomerate is associated with bedded siltstone in two localities.
5. Shearing, which makes the rocks superficially similar in appearance to the Ellsworth schist, has occurred only in the locality west of the Pleasant River.
6. Thicknesses have nowhere been determined. However, continuous exposures west of Addison suggest thicknesses of several hundred feet.

ANALYSIS OF FRAGMENTS

Field identification of fragments in the conglomerate is extremely difficult with the exception of light-colored granitic and felsitic types. In an attempt to obtain a better estimate of the variety and abundance of different lithologic types found as roundsones, several large specimens were sawed into slabs. The nature of the rocks was more clearly observed from these surfaces after being sprayed with Krylon. Pebbles and matrix materials were also studied in thin section.

Pebbles were classified according to lithologic type and degree of roundness, both on the basis of thin section study and from examination of the slabs under a binocular microscope. A total of 186 pebbles were recorded from 50 thin sections and 273 were recorded from the cut slabs. Figure 3 shows the abundance of pebbles over 2 mm diameter examined in thin section and from the cut slabs.

The graphs for the exposures west of Pleasant River show that several lithologies are represented. Of significance are the abundance of quartzite and granite, the small amount of fresh volcanic material, and the large percentage of silt fragments. The conglomerate exposed in the quarry has a simple suite of pebbles consisting primarily of light and dark gray volcanic rocks and granophyre. North of Highway U. S. 1 the fine grained volcanic debris is primarily basaltic in composition whereas south of the highway the volcanic constituents are primarily felsitic. In both localities roundstones of quartzite and granite are found.

The results of roundness estimates of the fragments determined from the cut slabs are shown in Figure 4. In each case rounded fragments predominate.

ANALYSIS OF MATRIX

The matrix of the conglomerate consists mostly of poorly sorted detritus embedded in either recrystallized hornblende or fine silt.

West of Pleasant River the matrix consists of lithic fragments and mineral grains enclosed in poorly sorted silt. The larger elements of the matrix (less than 2 mm diameter) consist of a variety of types as indicated in Figure 5. In most instances there is a marked similarity between the lithologic types, but not necessarily abundances, of the fine particles and the coarser pebbles discussed earlier (compare Figures 3 and 5A). Shearing is pronounced in the matrix and produces an augen-type structure in some instances. Recrystallized hornblende can be seen locally.

The matrix from the remaining localities is characterized by abundant amphibole, sometimes with granular pyroxene, enclosing either quartz grains or lithic fragments. In most cases the fragments of the matrix are similar to the coarser pebbles. In some instances, however, the matrix is composed almost entirely of quartz enclosed in recrystallized amphibole.

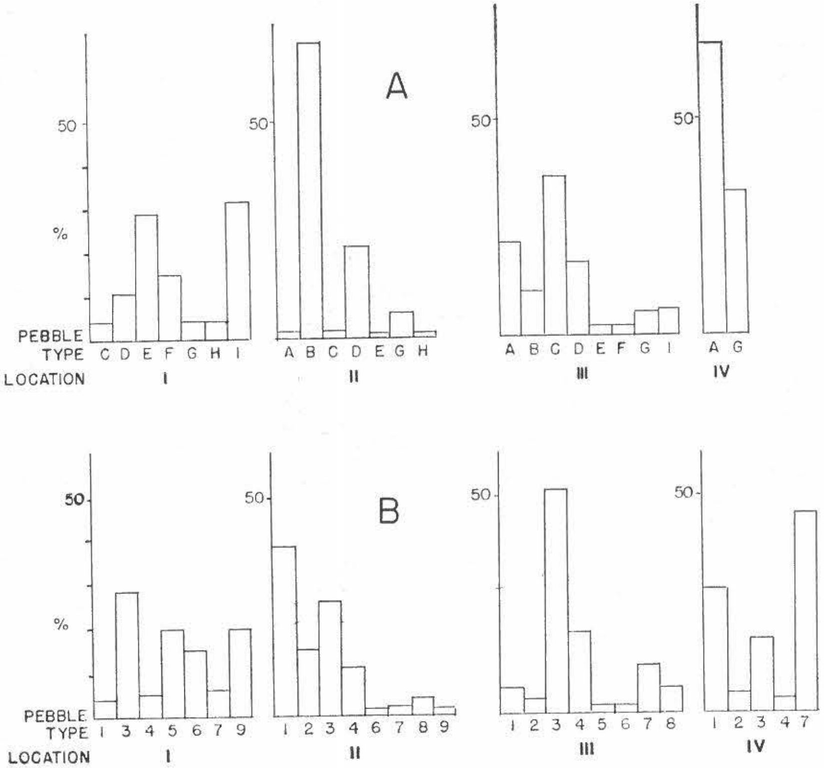

Figure 3. Histograms of pebble distribution.

Determined from thin section analysis. I West of Addison, 25 pebbles counted; II North of U. S. 1, 98 pebbles counted; III South of U. S. 1, 60 pebbles counted; IV Addison quarry, 3 pebbles counted; A equigranular plagioclase and hornblende; B diabase; C equigranular quartz and feldspar; D felsite showing volcanic texture; E quartzite; F granite; G granophyre; H diorite; I silt.

Determined from analysis of cut slabs. I West of Addison, 56 pebbles counted; II North of U. S. 1, 104 pebbles counted; III South of U. S. 1, 72 pebbles counted; IV Addison quarry, 41 pebbles counted; 1 aphanitic, black; 2 diabase; 3 felsite, general; 4 felsite, volcanic texture; 5 quartzite; 6 granite; 7 granophyre; 8 diorite; 9 silt.

The fragments of the matrix less than 2 mm in diameter are much more angular than the larger pebbles (compare Figures 4 and 5B).

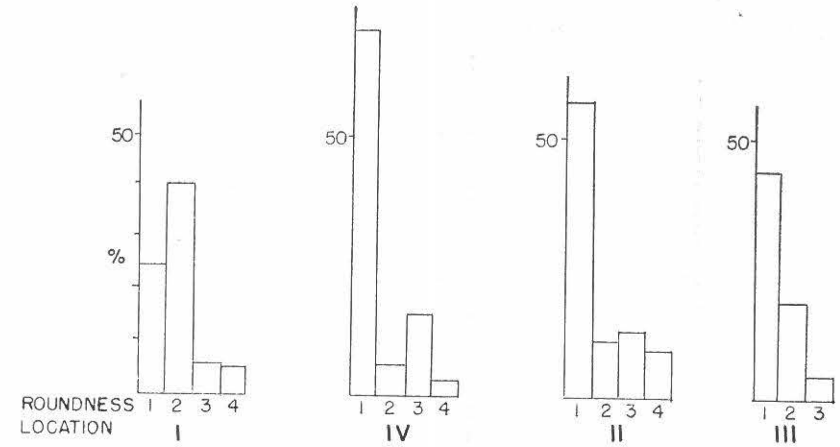

Figure 4. Histograms of estimated roundness of fragments over 2 mm diameter. I West of Addison, 25 pebbles recorded; II North of U. S. 1, 104 pebbles recorded; III South of U. S. 1, 71 pebbles recorded; IV Addison quarry, 41 pebbles recorded; 1 round; 2 sub-round; 3 sub-angular; 4 angular.

PETROLOGIC CONSIDERATIONS

The writer believes that the origin of the conglomerate is best explained by subaqueous mass movement of unconsolidated sediments along the margins of the sedimentary basin. Turbidity currents were perhaps involved, as suggested by the graded beddings of the associated siltstones, but the main mass of conglomerate is thought to have moved down the slope as a plastic body, capable of transporting boulders up to a few feet in diameter and yet allowing mixing of coarse and fine debris. Gates (1961) proposed a similar origin for Silurian volcanic breccias in the Cutler area. Similar conclusions were also reached by Dott (1961) considering the origin of the questionable Squantum "tillite".

The evidence supporting this conclusion is based on the texture and composition of the conglomerate and on the rocks found associated with the conglomerates.

There are several textural features suggesting mass movement. It is evident from field observations and examination of cut slabs that in general the roundstones do not touch their neighbors; that is, the rock has a disrupted framework. The origin of such rocks is normally attributed to deposition by mass flow or mudstreams (Pettijohn) 1957, p. 265; Crowell, 1957). Sorting is very poor; particles range from microscopic to a foot or more in diameter. The roundness of the pebbles suggests a considerable amount of abrasion during stream transporta-

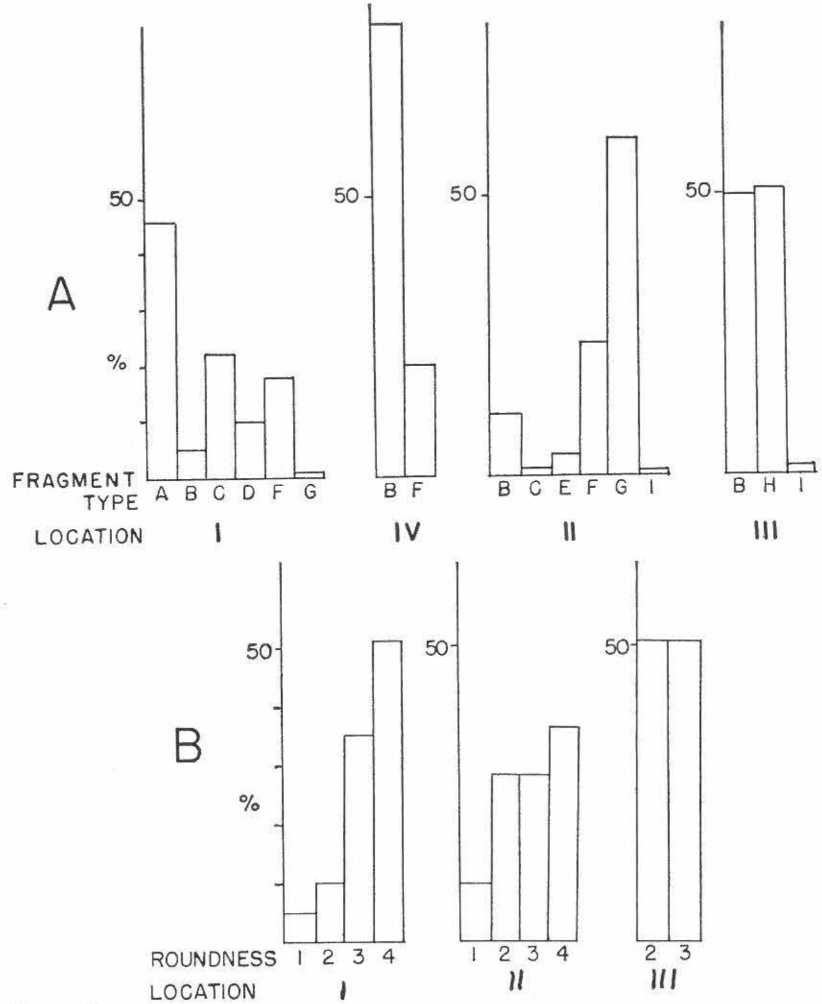

Figure 5

Histograms of distribution of matrix fragments less than 2 mm diameter. I West of Addison; II North of U. S. 1; III South of U. S. 1; IV Addison Quarry; A silt; B quartz; C quartzite; D granite; E granophyre; F felsite, general; G felsite with volcanic texture; H granular plagioclase and hornblende; I feldspar.

Histograms of estimated roundness of matrix fragments less than 2 mm diameter. I West of Addison; II North of U. S. 1; III South of U. S. 1; IV Addison quarry; 1 round; 2 sub-round; 3 sub-angular; 4 angular.

tion and/or wave action. Several pebbles show weathering rims perhaps indicating an extensive period of weathering and transportation. The lack of bedding within the conglomerates suggests that the mass was largely in a plastic state at the time of deposition, thus prohibiting selective settling and orientation of particles.

There is considerable compositional evidence that the conglomerates represent the mixing of debris from different sources. The presence of granitic and quartzitic elements suggests erosion of a crystalline highland (Pettijohn, 1957, p. 257). The source of this material is unknown. No granites of the type found as roundstones are known that are older than the Silurian volcanic units. The quartzite roundstones may have been derived from the Ellsworth schist or from the earlier Charlotte group; the latter being quartzitic and known to crop out farther inland. The general presence and local predominance of volcanic constituents indicates that volcanism had started prior to the deposition of the conglomerate. The rounded pebbles indicate that they were also subject to stream and/or wave erosion prior to deposition. Tabular fragments of reworked silt suggest that the movement was sufficiently active to disrupt the bottom sediments and incorporate them into the main body. Minor contortions of bedding and irregular shaped fragments, occasionally molded around other grains, suggest that these were still plastic at the time of reworking. In most cases the matrix fragments are simply smaller pieces of the same rock types as those comprising roundstones. However, in a few specimens the fine fragments are mostly quartz grains whereas the roundstones are of various volcanic types. This is suggestive of mixing of arenaceous sediments with volcanic debris. There are two types of matrix. West of Pleasant River the matrix is largely poorly sorted silt with some recrystallized amphibole. The predominance of amphibole in the second type suggests that the original matrix was basic in composition, perhaps chloritic mud mixed with, or derived from, basaltic material. The two contrasting types suggest contrasting source conditions.

The thinly bedded, laminated, varved siltstones found associated with conglomerate on both sides of Pleasant River suggest the subaqueous formation of the conglomerate. The writer believes they may be interpreted in several ways. They may represent turbidity current deposits, the currents being generated from the mass sliding of the conglomerate. Graded bedding is consistent with this. Some may represent a clearing of debris from water directly above the freshly deposited mud slide. However, only one graded sequence would be expected overlying each slide deposit. It is therefore difficult to explain the rhythmic layering of thin beds, since this requires a pulsation in the influx of material. The beds may also represent the resumption of normal sedimentation which had been interrupted by the mass slide. They are largely quartzofeldspathic in composition suggesting a tuffaceous origin. If volcanic ash was accumulating on surrounding land areas, periodic storms might provide a pulsating supply of ash-laden stream water to the basin and account for their varved nature. The writer favors the latter interpretation.

STRATIGRAPHIC CONSIDERATIONS

When discovered in the summer of 1959 the conglomerates on the west side of Pleasant Bay were thought to belong to the pre-Silurian metamorphic rocks. This was based largely on the dark green-gray color of the matrix and the pronounced foliation which trends in approximately the same direction as that of the nearby Ellsworth schist. However, on the basis of detailed field and laboratory investigation, the writer now believes there is sufficient evidence to indicate the conglomerates belong in the Silurian section even though the conglomerates are not seen in contact with the Silurian volcanics.

This conclusion is based on the following evidence. Detailed examination in the field suggests that the foliation is more of a fracture cleavage than a true schistosity as is developed in the schist. In thin section the matrix is considerably sheared but lacks the recrystallized texture of the schist. The matrix has been recrystallized to various degrees but the lack of preferred orientation of mineral grains suggests this to be of thermal, not dynamothermal origin. (2) West of Pleasant River numerous volcanic pebbles are present. In thin section these show no evidence of having undergone recrystallization under regional metamorphic conditions. The logical source of these fragments is the early phases of Silurian volcanic activity. In no case known to the writer do similar fresh volcanic fragments occur within the pre-Silurian schist. (3) The pronounced foliation as seen on the west side of Pleasant River is not found at other conglomerate exposures, suggesting that it is only of local significance. Similar local shearing is found in the younger granites (Gilman, 1961, p. 86) where the shearing trends northeast and produces a mildly foliated granite showing a cataclastic structure in thin section. In the Cutler area east of Machias, Gates (1961, p. 55) reports local northeast trending shearing of the Silurian rocks. (4) The thinly bedded, laminated siltstones on both

sides of Pleasant River are not foliated. Original sedimentary structure —graded bedding and varved bedding—are preserved although there is evidence of thermal recrystallization, especially on the east side of the river. (5) The geographic distribution of the conglomerate suggests that it occupies a stratigraphic zone between the schists on the north and west and the volcanic units to the southeast. The latter presumably overlie the schist unconformably.

It seems probable that there are several conglomeratic zones near the base of the Silurian rocks as indicated by the variation in composition at different localities. Structural data suggest that one should pass up section proceeding northeastward from Addison toward Machias. The writer is of the opinion that if exposures were adequate, interbeds of siltstone similar to those found along the Pleasant River would be found. In addition, occasional layers of tuffaceous and flow material might also be expected.

REGIONAL CONSIDERATIONS

It is tentatively concluded that the conglomerates in the Addison region are a local occurrence. It is interesting to note, however, that they are apparently at the same stratigraphic position as conglomerates in the Penobscot Bay and the Calais regions (see Fig. 1). In the Calais area a conglomerate containing pebbles of granite, quartz, and volcanic rocks is called the Oak Bay formation (Alcock, 1946; Amos, 1963, p. 175). It appears that this conglomerate may be the time equivalent of those in the Addison region and represent similar geologic conditions in the early part of Middle Silurian time.

In the Penobscot Bay region, conglomerates of the Ames Knob formation are also found at the base of Middle Silurian rocks (Smith, Bastin, Brown, 1907). In Frenchman's Bay metamorphic rocks are unconformably overlain by conglomerates that grade upward to sediments of the Bar Harbor series of possible Silurian age (Chapman, 1957). Although the details of the individual rock units vary with location, it seems significant that conglomeratic units at the base of the Silurian section are widespread along the coast. They may indicate a major unconformity similar to that found in New Hampshire between Ordovician and Lower or Middle Silurian units (Billings, 1956).

The detailed nature of the matrix of the conglomerate is also of regional interest in connection with Chapman's (1962) proposed sheetlike intrusions of gabbro from the Bays-of-Maine igneous complex into the volcanic rocks. The matrix is frequently poikiloblastic hornblende and occasionally granular pyroxene. This indicates thermal recrystallization of the original matrix which was probably of basaltic composition. West of Pleasant River, recrystallization may be accounted for in part by the proximity of a large granitic body. Similarly, in the quarry east of the river both gabbro and granophyre are found nearby. However, the exposures along U. S. 1 are not known to lie close to intrusive bodies, but they also show a recrystallized hornblende matrix. This is at least suggestive that gabbroic rocks may lie at depth, or that they at one time were above the conglomerate and have subsequently been removed by erosion. The rather uniform but widespread thermal effects suggest that the source of heat was a sheet-like extension of the Bays-of-Maine igneous complex intruded into the volcanic rocks, perhaps along subhorizontal bedding structures.

SUMMARY

The writer believes that present evidence indicates the conglomeratic units found in the vicinity of Addison were deposited largely by subaqueous mass sliding during Early or Middle Silurian time. It is believed that coarse gravels were initially deposited along the margins of the sedimentary basin, at the same time that fine sediments were being deposited in the deeper parts of the basin. Some factor, perhaps an earthquake shock, dislodged the coarse material which then moved down the basin slope by gravity and mixed with the finer sediments. The size of roundstones and the lack of bedding suggest that the movement was by plastic flow with only sufficient water content to allow mixing and churning (Dott, 1963). The sliding mass disrupted the varved bottom sediments and incorporated fragments of these, probably while still soft.

Fine siltstone showing one-inch rhythmic layering and in some cases graded-bedding may be interpreted several ways. In general, however, they represent either the clearing of mud-laden water after mass slides, or a rhythmic influx of sediment into the depositional basin.

There is no indication of depth of water or whether it was marine or non-marine. However, the thinly laminated siltstone suggests fairly deep, quiet water, and the presence of marine fossils in the younger Silurian rocks (Gates, 1961) indicates that a marine basin was available later in Silurian time.

The age of the conglomerate is nowhere directly indicated by fossils or other dating methods. It appears clear that it was formed after the initiation of active volcanism during Early or Middle Silurian time and that their correct stratigraphic position is close to the base of the Silurian section.

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