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Robert G. Doyle, State Geologist

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Abstract

The map area, located in northern Maine approximately 25 miles north of Mt. Katahdin, straddles the southern end of the Munsungun anticlinorium, a northern, disconnected extension of the Boundary Mountain anticlinorium of New Hampshire. 36,000 feet of Cambrian(?) through Lower Devonian rocks have been differentiated into 10 formations: 1 of Cambrian(?) age; 4 of Middle Ordovician age; 4 of Late Silurian and Early Devonian age; and 1 of Early Devonian age. Nine of these are new and named herein. Most significantly the area contains what is probably the most fossiliferous slightly metamorphosed highly volcanic Middle Ordovician section in the northern Appalachians. The rocks record a remarkable tectonic history involving a minimum of about 36,000 feet each of subsidence and uplift during the Paleozoic.

The oldest unit, the Cambrian(?) Chase Brook Formation, was deformed and cleaved prior to deposition of the Middle Ordovician rocks. The age of this early deformation is not well-established, but tectonic unrest in the geosyncline prior to the classical Taconian orogeny is indicated.

Subsequent to this early deformation, approximately 18,000 feet of Middle Ordovician volcanic rocks, graywacke, conglomerate, slate, and chert were deposited, primarily in deep water. Correlation of these rocks with others in the northern Appalachians suggests the existence at that time of a volcanic belt coincident with what later became the Bronson Hill - Boundary Mountain - Munsungun anticlinorium. These rocks were folded but not cleaved or metamorphosed during the Taconian orogeny.

After the Taconian a marked change in depositional environment took place; shallow—rather than deep-water deposition resumed in the Late Silurian (Ludlow) with deposition of Ludlow through Helderberg (Lower Devonian) volcanic rocks, conglomerate, sandstone, and calcareous rocks of the East Branch Group and Spider Lake Formation. Facies changes in the East Branch Group indicate shoaling to the northwest toward the axis of the anticlinorium, which is considered to have been an emergent area at that time, probably due to an anticlinal configuration assumed during the Taconian. Siluro-Devonian sedimentary rocks reflect the shallow-water depositional environment; and, although they contain large amounts of volcanics and are, therefore, eugeosynclinal by definition, they are unlike the conventional eugeosynclinal assemblage. At least locally Siluro-Devonian deposition was interrupted by uplift and erosion during the pre-New Scotland (Early Devonian) Salinic disturbance.

Deposition of the Seboomook Formation in Oriskany (Early Devonian) time probably represented complete submergence of the area. This was followed by the Acadian orogeny which produced folding, cleavage, and chlorite-zone metamorphism.

At least two sets of faults are present: northeast-striking faults of post-Early Devonian age and later northwest-striking faults of post-Early Devonian age.

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Introduction

Purpose of Study

Until about 10 years ago detailed geologic mapping in the State of Maine had been concentrated in the coastal regions and in several limited inland areas. The rest of the State had been covered only in reconnaissance. Within about the last 10 years many mapping projects have been initiated by state, federal, private organizations or individuals, the results of which are, for the most part, not yet published. Many of these projects involve the highly metamorphosed terrain of the southern half of the State where the absence of fossils greatly hinders the establishment of a stratigraphy. In the northern part of the State the grade of metamorphism is much lower, fossils where initially present are still relatively well-preserved, and the advantages for stratigraphic and structural interpretation are obvious.

The initial mapping of the Spider Lake quadrangle was undertaken largely to delineate the stratigraphy and structure of the pre-Silurian rocks believed to be present in the area. The Geologic Map of Northern Maine (Boucot, *et al*, 1960) shows the Spider Lake quadrangle as spanning the largest belt of pre-Silurian rocks in the area.

Later mapping in the quadrangles adjacent to the Spider Lake quadrangle was undertaken to understand better the stratigraphic and structural relationships within the Siluro-Devonian section.

Location and Accessibility

The map area is located in northwestern Maine between latitudes 46°07′ and 46°34′ and longitudes 69°00′ and 69°28′ (Fig. 1). It contains the southern end of the Munsungun anticlinorium (Hall, 1966a) which is expressed topographically as an upland area surrounded by areas of lower elevation and less relief. The maximum elevation is about 1900 feet and the maximum relief about 1100 feet.

Until about 1955 the area was nowhere penetrated by roads. Since then the Great Northern Paper Company has built one gravel-surface road into the area for lumbering purposes. This and numerous log hauling roads in its vicinity are available for geologic work, although the bulk of the region is not accessible from roads of any kind. This necessitates travel by canoe, float-plane, and foot on unmapped trails.

Previous Work

Essentially no geologic work has been done in the Spider Lake and adjacent quadrangles except for several reconnaissance expeditions into the region. In addition, the geology has been shown in a very gross way on several large-scale maps of the State or parts of the State (Hitchcock, 1861, map facing p. 376; Keith, 1933; Boucot, *et al*, 1960).

The earliest reconnaissance was in 1837 by James T. Hodge (*in* Jackson, 1838) and another in 1862 by C. H. Hitchcock (1863). Both of these involved trips with Indian guides in birch-bark canoes up the Penobscot River and down the Allagash-St. John Rivers. The results consisted only of description of outcrops along the route and are of little more than historic interest. Several outcrops on the shores of Chamberlain, Eagle, and Churchill Lakes were described. In the second trip (Hitchcock, 1863) Spider Lake was visited. However, no outcrops were reported. The next work was done nearly 100 years later by L. A. Wing (1951) who reported volcanic rocks on the shores of Cliff Lake. Some of these rocks are Ordovician in age and others belong to the Siluro-Devonian Spider Lake formation of this report.

The only detailed work that has been done in immediately adjacent areas is the mapping of the Traveler Mountain quadrangle which adjoins the Spider Lake quadrangle on its southeast corner (Rankin, 1960, 1961; Dorf and Rankin, 1962; Neuman and Rankin, 1966).

Present Work

A total of approximately seven field seasons were spent mapping the southern end of the Munsungun anticlinorium. Field work was begun in July of 1959 and completed in August of 1967. Nearly all of the initial three field seasons were spent in the Spider Lake quadrangle, the geology of which was submitted in 1964 as a Ph.D. dissertation at Yale University. The remaining four field seasons were spent mapping in the Musquacook Lakes, Umsaskis Lake, Churchill Lake, Chesuncook Lake, and

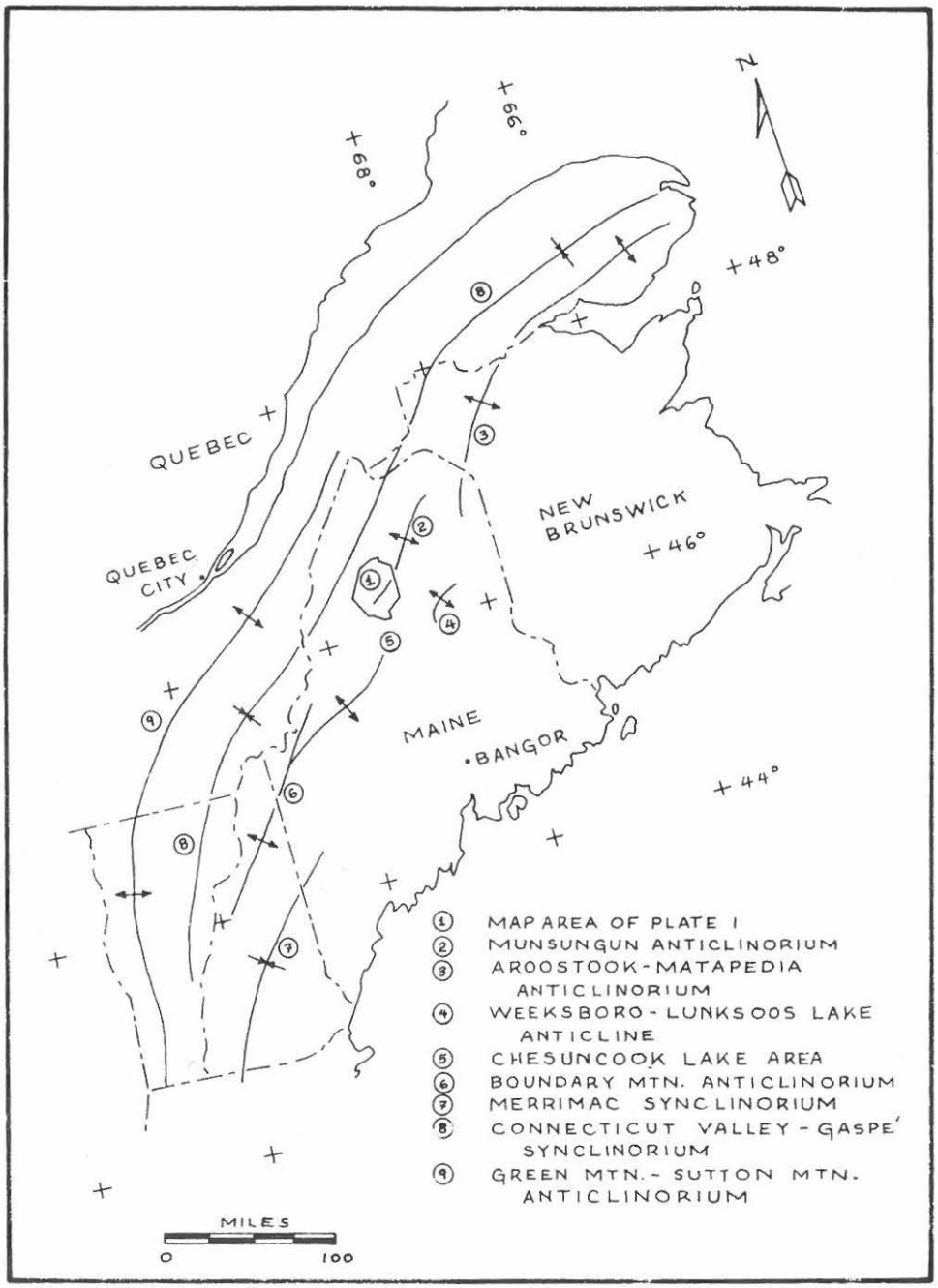

Fig. 1. Tectonic map of a part of New England and southeastern Canada, indicating the location of the map area of Plate 1.

Telos Lake quadrangles. In addition, several weeks of reconnaissance work were done in the Mooseleuk Lake and Millinocket Lake quadrangles. Although fossils from the Millinocket Lake quadrangle are described in this report and bear on the interpretation of the Ordovician section, the small amount of geology done in the latter two quadrangles is not shown on Plate 1.

The earlier mapping of the Spider Lake quadrangle was done on aerial photographs using the photographs and pace and compass for location of outcrops. Later mapping was done in a similar manner aided by enlargements of the 15 minute topographic maps to a scale of 1 inch equals 2000 feet.

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Regional Geologic Setting

Tectonic Belts

Within the Northern Appalachians several parallel tectonic belts are recognized (Fig. 1). The westernmost belt here considered is the Green Mountain anticlinorium in Vermont, along which are exposed metamorphosed Precambrian and Cambrian rocks. This anticlinorium continues to the south into Massachusetts, Connecticut, and New York as the Berkshire and Hudson Highlands. To the north in Quebec the Sutton Mountains and Notre Dame Mountains are its extension. Northeast of the Notre Dame Mountains the belt of Cambrian rocks narrows and disappears, although it reappears in the Shickshock Mountains of the Gaspé Peninsula. Lower and Middle Ordovician rocks flank the Green Mountain anticlinorium on the west from western Vermont to the tip of the Gaspé Peninsula and also on the east between it and the Connecticut Valley – Gaspé synclinorium.

The next major tectonic belt to the east is the Connecticut Valley – Gaspé synclinorium, along which rocks of Siluro-Devonian age are exposed from just east of the Berkshire Highlands in western Massachusetts into and through Vermont, the extreme northwestern corner of New Hampshire, and the extreme southeastern corner of southern Quebec. It then traverses the northwesterly parts of Maine, passes again into Quebec, and extends out to the tip of the Gaspé via the central part of the peninsula (Neale, *et al*, 1961, Fig. 1).

East of the Connecticut Valley – Gaspé synclinorium in Vermont and New Hampshire is another anticlinorium, referred to by Cady (1960) as the Boundary Mountain anticlinorium (includes the Coos and Gardner Mountain anticlines of Billings, 1956), at the core of which Ordovician rocks are again brought to the surface. Farther southwest it is known as the Bronson Hill anticlinorium and forms an irregular belt defined by many gneiss-cored domal structures extending from the Maine-New Hampshire border northeast of Littleton, New Hampshire, southwestward through western New Hampshire, central Massachusetts, and Connecticut immediately east of the Triassic Basin (Rodgers, *et al*, 1959). To the northeast in Maine the Boundary Mountain anticlinorium becomes highly segmented, although anticlinorial areas that are here considered part of the same belt extend northeastward at least as far as the Fish River Lake area and areas to the east.

After crossing into Maine from New Hampshire, the Boundary Mountain anticlinorium splits into two branches in the vicinity of Eustis, Maine. The branch that is considered the main extension of the anticlinorium continues a short distance to the northwest of the Moose River synclinorium of Boucot (1961), there ending abruptly; the other branch extends along the entire southeast side of the synclinorium (Albee, 1961). This unnamed branch continues to the northeast where it comes to an abrupt end southwest of Chesuncook Lake (Doyle, 1967). North and northeast of this, several similar, isolated anticlinoria occur: a small one in the vicinity of Caucomgomoc Lake (Boucot, *et al*, 1960), a larger one near Shin Pond (Pavlides, *et al*, 1964; Neuman and Rankin, 1966), and a

still larger one extending northeastward from Chamberlain Lake to the Fish River Lake area, the Munsungun anticlinorium. These anticlinal areas expose mainly Ordovician rocks – slate, graywacke, and volcanic rocks – and are separated by intervening synclinal tracts containing Siluro-Devonian rocks. East and northeast of these anticlinoria in northeastern Maine, and perhaps also farther southwest, large areas of very different Middle and Upper Ordovician rock, banded calcareous slate and argillaceous limestone ("ribbon rock"), are exposed along the Aroostook-Matapedia anticlinorium. These can be traced across the St. John River into New Brunswick and thence across the Gaspé Peninsula to Percé (Alcock, 1949; McGerrigle, 1953; Neale, *et al*, 1961, Fig. 1; Pavlides, *et al*, 1961; Pavlides, *et al*, 1964).

The area southeast of this belt in Maine is for the most part a little studied terrane of slate and phyllite with some coarser clastic rocks. It is probably grossly synclinal and the rocks predominantly Siluro-Devonian (Doyle, 1967). This may be a northern extension of the Merrimack synclinorium of Billings (1956) which in New Hampshire is mainly underlain by Devonian rocks.

Gross Facies Relationships

The western margin of the Northern Appalachians can be taken as a line extending southwestward along the shore of the St. Lawrence Estuary and River to Quebec City, at which point it leaves the river and arcs southwestward through the Eastern Townships of Quebec to the eastern shore of Lake Champlain. From here southward through Vermont and New York it parallels the eastern side of Lake Champlain and follows the Hudson River Valley (Neale, *et al*, 1961, Fig. 1; King, 1951). To the east of this line the stratified Cambrian through Devonian rocks can be separated into two zones, miogeosynclinal and eugeosynclinal, primarily on the basis of contrasting rock assemblages, the miogeosynclinal assemblage consisting primarily of quartz sandstone and carbonate rocks ("carbonate-quartzite" assemblage of Cady, 1960) and the eugeosynclinal assemblage consisting primarily of graywacke and shale with varying amounts of volcanics ("graywacke-shale" assemblage of Cady, 1960). These relationships are discussed in detail by King (1951), Cady (1960), and Boucot (1962) and will only be summarized here.

Cambrian and Ordovician miogeosynclinal rocks are restricted to a rather narrow western zone within the Northern Appalachians. In Vermont they lie between the Green Mountains on the east and Lake Champlain on the west, the transition zone between miogeosynclinal rocks and eugeosynclinal rocks being on the western flank of the Green Mountain anticlinorium (Cady, 1960). Northward in Quebec the miogeosynclinal zone narrows rapidly and disappears barely 100 miles north of the international boundary. The result is that in the vicinity of and north of Quebec City eugeosynclinal rocks are at the extreme western margin of the Appalachians.

Within the eugeosynclinal zone itself some gross east-west facies changes are evident, particularly in the Middle Ordovician rocks. Middle Ordovician volcanic rocks are thickest along the extent of the Boundary Mountain anticlinorium where they are associated with noncalcareous black slate and graywacke; they thin to the west. To the east in Maine, rocks of the same time interval consist of the thinly-bedded argillaceous limestone, calcareous slate, and graywacke of the Aroostook-Matapedia anticlinorium. Thus, the thickness distribution of Middle Ordovician volcanic rocks indicates a linear zone of maximum volcanism roughly parallel to the present Boundary Mountain anticlinorium and suggests a Middle Ordovician volcanic island arc system, an idea not original with the author (Rodgers, 1968).

Cady (1960, Pl. 2) and Boucot (1962) indicate that the eastern limit of Siluro-Devonian miogeosynclinal rocks lies within the west limb of the Connecticut Valley – Gaspé synclinorium, demanding an eastward migration of this zone from its position during the Ordovician. East of this boundary, gross facies changes are present as they are in the Ordovician rocks. Immediately east of the miogeosynclinal rocks are the Siluro-Devonian shale, calcareous shale, and argillaceous limestone of the Connecticut Valley – Gaspé synclinorium. To the east of this in Maine and northern New Brunswick volcanic rocks are found at various levels within the Siluro-Devonian strata along a belt roughly coincident with or just south of anticlinal extensions of the Boundary Mountain anticlinorium. This belt, which includes the south end of the Munsungun anticlinorium, probably consisted of numerous volcanic islands and/or islands of pre-Silurian rocks (Albee, 1961; Boucot,

1962). Siluro-Devonian rocks adjacent to the former islands are highly varied, consisting of impure sandstone, siltstone, calcarenite, reef limestone, volcanic flows, and pyroclastics. In the adjoining basinal areas less heterogeneous slate-sandstone sequences are present, interfingering at least in part with the island margin sequences (Boucot, *et al*, 1959).

In the synclinorial belt east of this in Maine (Merrimack synclinorium) the rocks are again predominantly slate, sandstone, graywacke, and argillaceous limestone of probable Siluro-Devonian age. In and near the Eastport area of extreme eastern Maine another belt of volcanic rocks is present (Bastin and Williams, 1914).

Unconformities

Two major Paleozoic orogenic episodes, the Taconic and the Acadian, are widely represented by unconformities in the Northern Appalachians (Cady, 1960; Neale, *et al*, 1961; Rodgers, 1967; Pavlides, *et al*, 1968).

The Taconic unconformity in New England is generally well-developed east of the central axis of the Green Mountain anticlinorium (Cady, 1960) although in parts of northern Maine, New Brunswick, and Quebec it is apparently absent (Pavlides, *et al*, 1968). The age of the Taconic varies from place to place, from early in the Middle Ordovician to late in the Upper Ordovician (Rodgers, 1967; Pavlides, *et al*, 1968).

In the Boundary Mountain anticlinorium the Lower and Upper Silurian Clough and Fitch Formations unconformably overlie Middle Ordovician rocks (Billings, 1937; Pavlides, *et al*, 1968). Similar relationships exist on the eastern limb of the Green Mountain anticlinorium near St. Luc, Quebec, where Silurian(?) conglomerate is angularly unconformable on the Middle Ordovician Beauceville Formation (Gorman), 1954; Cady, 1960).

In Maine Boucot (1954), Griscom (1966), and Pavlides, *et al* (1968), indicate that Lower Silurian rocks in the vicinity of Chesuncook Lake rest with probable angular unconformity upon pre-Silurian rocks of possible Ordovician age. Recent mapping in this area has proved this interpretation correct, although the age of the pre-Silurian rocks remains in question (D. Erinakes, 1967, M.S. thesis, University of Maine). Farther to the northeast in the Munsungun anticlinorium Upper Silurian rocks rest with angular unconformity upon highest Middle Ordovician rocks. The possibility exists that in this area the uppermost part of the Ordovician section is lower Upper Ordovician. Immediately southwest of the Spider Lake quadrangle Rankin (1961) reports Lower Silurian rocks above the unconformity. Neuman and Rankin (1966) indicate that Upper Ordovician rocks (Ashgillian) occur in the same area below the unconformity.

The effects of the Acadian orogeny were felt throughout the entire area under consideration (Cady, 1960; Boucot, 1962; Neale, *et al*, 1961; Rodgers, 1967). Boucot (1962) considered the Acadian to have produced unconformities of post-Early Devonian (post-Emsian) – pre-Late Devonian age. Boucot (1968), however, considers the oldest unconformity related to the Acadian to be of post-Eifelian age and that the Acadian orogeny was a mid-Middle Devonian event. On the other hand, an unconformity beneath the "Gaspé sandstone" (La Garde Formation) on the Gaspé Peninsula (Dineley and Williams, 1968) appears to be of late Early Devonian age, supporting a multiphase history for the Acadian (Rodgers, 1967).

In Maine the youngest known pre-Acadian stratified rocks are those of the Tomhegan Formation of Schoharie age (Boucot, 1961; 1968; personal communication, 1968) in the center of the Moose River synclinorium. No younger stratified rocks are found in this part of Maine, although younger Devonian intrusives are common (Faul, *et al*, 1963). To the northeast, west of the Weeksboro-Lunksoos Lake anticline, in the vicinity of Traveler Mountain the Matagamon Formation of Oriskany age (Rankin, 1961; Boucot and Johnson, 1967) was deformed during the Acadian. According to Rankin (1960; 1968) the conformably overlying Traveler Felsite is part of a geographically discontinuous unit of felsite exposed in several areas of Maine including the Moose River synclinorium where it is known as the basal Kineo volcanic member of the Tomhegan Formation (Boucot, 1961). Boucot (1968, Table 2; personal communication, 1968) considers this member to be of Esopus or Schoharie age. Unconformably above the Traveler Felsite is the Trout Valley Formation, dated as late Early Devonian in age (Dorf and Rankin, 1962; Henry Andrews, 1969, personal communication) on the basis of contained plant remains. The Trout Valley Formation, which consists of non-marine shale, siltstone,

sandstone, and conglomerate, is unique in this part of Maine because it is so slightly deformed and poorly indurated relative to the older rocks of Oriskany age surrounding Traveler Mountain. Although Neuman and Rankin (1966) considered the Trout Valley to be probably post-Acadian, controversy still exists as to the relationship of the Trout Valley to the Acadian (Rankin, 1968). If all Acadian movement occurred in the mid-Middle Devonian as suggested by Boucot (1968), then the undeformed condition of the Trout Valley must be ascribed to tectonic shielding by the underlying Traveler Felsite (Rankin, 1968). However, the possibility of a late Early Devonian preliminary phase of the Acadian remains in this area. A similar deposit, the Mapleton Sandstone, in the vicinity of Presque Isle, Maine, is considered to be post-Acadian (Boucot, *et al*, 1964) and of late Middle Devonian age (Schopf, 1964).

In addition to the major unconformities discussed above, several other stratigraphic breaks appear in the Cambrian through Devonian section of the Northern Appalachians (Cady, 1960; Boucot, 1962). First, one or more breaks (Hall, in press) have been reported below Middle Ordovician rocks in Maine, Vermont, Quebec, and New York. In Maine the event leading to a post-Cambrian – pre-Middle Ordovician unconformity has been called the Penobscot disturbance (Neuman and Rankin, 1966; Rodgers, 1967).

Within the Siluro-Devonian section at least two other stratigraphic breaks occur. The youngest of these is a disconformity ("paraconformity" according to the usage of Dunbar and Rodgers, 1957) between rocks of Oriskany and Schoharie age (Boucot, 1959; 1962; personal communication, 1968). According to Boucot, this break is found everywhere in the Northern Appalachians except in eastern New York, southwestern Nova Scotia, and the Gaspé Peninsula. On the Gaspé Peninsula the generally missing interval is represented by the lower part of the Gaspé sandstone series (York River). In Maine the hiatus is between the Tarratine and Tomhegan Formations of the Moose River synclinorium.

A somewhat older stratigraphic break is also recognized within the Siluro-Devonian of the Northern Appalachians. According to Boucot (1962) this break is found as a disconformity between rocks of early Late Silurian (Lower Ludlow) age and New Scotland age east of the Hudson River. He terms the associated tectonic event the Salinic disturbance.

Regional Metamorphism

Regional metamorphism in Maine ranges from sillimanite zone in southern Maine (Doyle, 1967) through chlorite zone in northern Maine (Pavlides, 1962; Boone, 1959; Boucot, 1961). The transition from higher grade to chlorite zone occurs quite abruptly in the southern part of the state. Faul, *et al*, (1963; Fig. 2) indicate that this transition zone is probably the northern limit of post-Acadian (Permian) regional metamorphism.

As noted above, other workers have considered the Paleozoic rocks of northern Maine to be within the chlorite zone of regional metamorphism. The author's work in the Spider Lake quadrangle is in accord with this; chlorite and sometimes epidote are present in all the mafic volcanic rocks and the assemblages chlorite-muscovite or chlorite-muscovite-epidote in some of the sedimentary rocks.

There appears to be no difference in metamorphic grade stratigraphically within the rocks of the Spider Lake quadrangle, and, thus, no reason to believe, on this basis, that the pre-Silurian rocks were subjected to regional metamorphism during the Taconic orogeny. To the contrary, the presence of an Acadian cleavage in rocks of all ages in the quadrangle, the *absence* of a pre-Acadian cleavage in the Ordovician rocks, and the *presence* of a pre-Acadian cleavage in the still older Cambrian(?) rocks indicates that the Taconic deformation in this area was not even intense enough to produce cleavage.

This observation is in direct contrast to the interpretation made by Albee (1961) who reports that in west-central Maine and northern New Hampshire quartzo-feldspathic granulites contain garnet and relict sillimanite, partly altered to white mica. In the surrounding area are Middle Devonian and Upper Silurian rocks of chlorite grade. Albee believes that the granulites are Cambrian and/or Ordovician and were subjected to high-grade metamorphism during the Taconic orogeny and later retrograded (presumably during the Acadian). If so, the eastern limit of Taconic metamorphism must fall between this area and the Spider Lake quadrangle.

Stratigraphy

General

The bedrock of the map area (Plate 1) ranges in age from Cambrian(?) to Early Devonian and has a composite thickness of 36,000 feet which has been differentiated into a total of ten mappable rock units or formations by the author. Of these, only one, the Seboomook Formation, has been referred to a named formation established elsewhere in Maine (Perkins, 1932). The remaining nine formations and several of the subsidiary members are named herein. In addition, three of the new formations are combined to form the East Branch Group. From youngest to oldest these stratigraphic units are:

Lower Devonian	Seboomook Formation Basal sandstone member
Upper Silurian and Lower Devonian	Spider Lake Formation East Branch Group Third Lake Formation Chandler Pond Formation Carpenter Pond Formation
Middle Ordovician	Blind Brook Formation Munsungun Lake Formation Reed Pond Member Bluffer Pond Formation Ragged Mountain Member Chase Lake Formation Slate-graywacke member Conglomerate-graywacke member
Cambrian(?)	Chase Brook Formation

Of these ten formations, the ages of the younger nine are reasonably well established with varying degrees of resolution. The assigned ages are based on fossils discovered in or adjacent to the map area. The oldest unit, the Chase Brook Formation, has produced no fossils, and its age is inferred from more subjective criteria.

The equivalency of series and stages, as used in Plate 2 and the discussions below, is taken from Pavlides, *et al* (1964), and Pavlides and Berry (1966). The equivalency of Ordovician graptolite zones, stages, and series is taken from Berry (1960) and Pavlides, *et al* (1964). The treatment of the uppermost Silurian in which the Pridoli (Boucot and Pankiwskyj, 1962) is equated with the upper part of the Salina through the Rondout is after Boucot (personal communication, 1968). The treatment of the Helderbergian is after Boucot and Johnson (1967).

Cambrian (?) Rocks

Only one of the rock units mentioned in the above section, the Chase Brook Formation, is assigned to the Cambrian(?). Reasons for this assignment are given below.

Chase Brook Formation

General: The Chase Brook Formation is named in this report for Chase Brook (Town 9 Range 10) in the Spider Lake quadrangle. The type section of the Chase Brook Formation is here designated as that section exposed in Chase Brook from a point approximately 300 yards to a point approximately one mile from its mouth in Chase Lake.

In addition to those areas of outcrop shown on Plate 1, the Chase Brook Formation has been seen during reconnaissance in two other areas. The first is in the Mooseleuk Lake quadrangle approximately one-third of a mile southwest of Mooseleuk Lake (T10 R9). The second is in the Millinocket Lake quadrangle (T8 R9) in scattered exposures along the shores of Little Munsungun Lake and along Munsungun Stream as far downstream as Munsungun Falls.

Wherever present, the formation occupies areas of low topographic relief and is best exposed along streams and lake shores. In fact, numerous traverses in the area adjoining the type section have failed to disclose outcrops more than several yards away from Chase Brook.

The thickness of the Chase Brook Formation is not well known, neither original top nor original bottom of the formation having been recognized. In map pattern in the type section the formation is approximately one mile thick. However, the unit is highly folded, and several

minor faults are present, so that the apparent thickness is certainly unreliable. A thickness of 2,500 feet is assigned to the unit.

The upper contact with the overlying Chase Lake Formation is considered to be an angular unconformity (Hall, in press). This is indicated by a basal conglomerate in the overlying Chase Lake Formation. The conglomerate contains slate clasts similar to the slate of the Chase Brook. In addition, the unconformity is indicated by the structural evidence discussed below.

Rock descriptions: The Chase Brook Formation consists primarily of alternating beds of very dark gray (N3) or black slate and greenish gray (5GY 6/1) slate. Typically, beds are one-fourth to one inch thick. Where black, the slate may be slightly carbonaceous, and locally the unit may be all dark gray or all greenish gray slate for several feet of section. Masses of pyrite up to two inches in diameter are often found in the noses of small drag folds, sometimes occuring as round, crystalline rosettes. A few beds half an inch to three inches thick of dark gray (N3) limestone, and medium (N5) to dark (N3) gray siltstone occur within the slate. In addition, two other rock types are found as blocks within the slate. The first of these rock types is a medium (N5) gray, generally cross-bedded, calcareous siltstone, found in blocks as much as about two feet in longest dimension. The second is a medium-to very coarse-grained medium gray graywacke, found in blocks up to about four feet in longest dimension.

In thin section this latter rock type consists of the following*:

	BH-31c-60	BH-123e-61
matrix	57.3%	63.1%
quartz	40.1	23.6
plagioclase	.6	8.1
K-feldspar	–	4.1
muscovite	.3	.9
pyrite	1.8	.2
	100.1%	100.0%

Both samples are poorly sorted and following the classification of Williams, Turner, and Gilbert (1954) are graywackes; BH-31c-60 a quartz graywacke (Fig. 2) and BH-123e-61 an arkosic graywacke. Grain size ranges from submicroscopic to a maximum of about 2 mm. The matrix consists of quartz, plagioclase, chlorite, calcite, white mica, and opaque brown iron oxide(?). Plagioclase clasts are almost all clouded with small flakes of sericite and calcite, some of the larger plagioclase clasts are partially altered to albite and calcite, and the generally irregular boundaries of quartz and feldspar clasts are penetrated by grains of chlorite, sericite, and calcite. It is probable that much or all of the matrix material is similarly recrystallized. As noted above, the matrix contains fine-grained white mica or sericite. Such grains are generally bent and unclear in ordinary light and impart a vague preferred orientation to the rock. In addition, a few larger, unbent clear grains of muscovite are present and have been counted separately in the above modal anaylses. Trace amounts of rounded, metamict zircon are present. In BH-123e-61 the potassium feldspar is predominantly microcline.

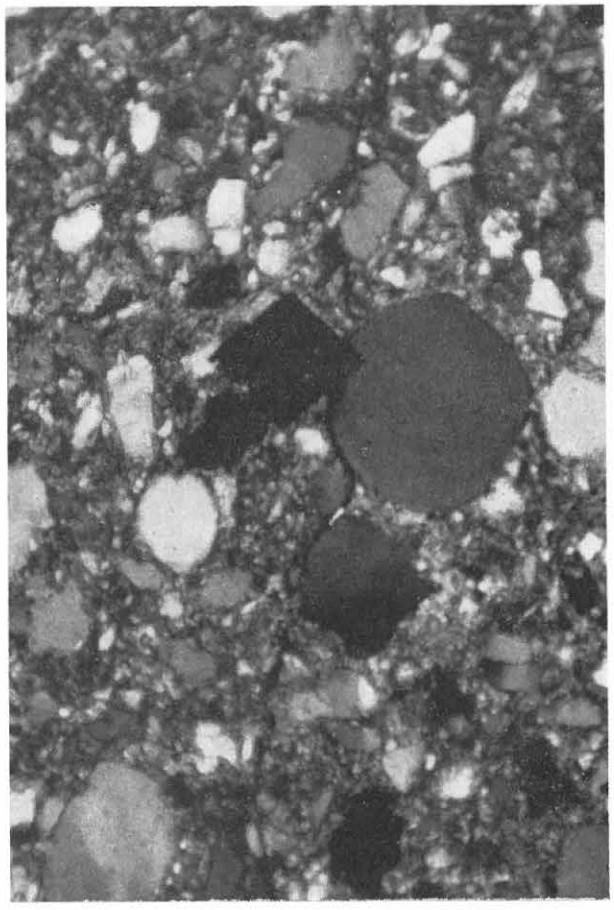


Fig. 2. Photomicrograph of quartz graywacke from the Chase Brook Formation (BH-31c-60; x32; crossed nicols).

Perhaps the most characteristic feature of the Chase Brook Formation is its "style" of deforma-

* 1,400 counts were made for each modal analysis in the report.

tion which is unlike that of any other rock unit in the map area except the unnamed green phyllite unit also considered to be of Cambrian(?) age. Drag folds of various sizes are commonly seen, the more silty and calcareous beds are often broken by boudinage, and in many places the rocks are cut by numerous quartz stringers. In addition, two cleavages may be seen; the first or earliest folded and cut by a second, younger, undeformed cleavage typical of the region. The earlier, deformed cleavage is megascopically defined by small flakes of sericite.

Unnamed Cambrian(?) Phyllite And Slate

General: Rocks of this unit are exposed only in the vicinity of the Arm of Chamberlain Lake in the Telos Lake quadrange. Typical exposures of the unit can best be seen on and in the vicinity of the north shore of the largest cove on the north side of the Arm of Chamberlain.

Top and bottom contacts of this unit have not been distinguished. It appears to grade northward into darker gray slate and phyllite of the Chase Brook Formation to the north. To the south it is unconformably overlain by the basal sandy member of the Seboomook Formation, conglomerate of the Chandler Pond Formation, and unnamed Silurian volcanics. Locally, beneath the Silurian rocks, the upper ten feet or so appear to have been intensely weathered so that bedding and lamination become increasingly obscure and fragmented toward the base of the Silurian rocks.

No estimate of the thickness of these rocks is possible owing to inadequate exposures and intense deformation. Although no field evidence for superposition of this unit with regard to the Chase Brook Formation is available, it is felt that the Chase Brook Formation is the older of the two. This relationship is discussed in the section dealing with age and correlation of the Cambrian(?) rocks.

Rock descriptions: The rock types present in this unit are light green phyllite, light gray phyllite, and alternating one to four inch thick beds of light purplish red and light gray to green phyllite. Gray or green phyllite without red interbeds predominates.

Like the Chase Brook Formation, the "style" of deformation is unlike that of any of the younger rocks in the area. In outcrop, a highly penetrative micaceous foliation is the most characteristic feature of the rock and generally is the only structure visible except for red and gray or green banding locally. The highly penetrative foliation, when present with the red and green banding, can be seen to cut the banding and be axial plane to early isoclinal folds. In only one or two instances a pre-foliation lamination can be seen in the gray or green bands. This lamination is parallel to the color-banding and looks much like the foliation. Its absence in most of the outcrop is apparently due to the nature of the highly penetrative foliation. Its parallelism to color banding where present argues for sedimentation as the primary control of the color banding.

In addition to the foliation discussed above, outcrops generally display a younger, much less penetrative cleavage. This cleavage can be seen in nearby Siluro-Devonian rocks and is attributable to Acadian deformation. It is axial plane to folds which deform the earlier foliation.

Age And Correlation Of The Cambrian(?) Rocks

No fossils have been found in the Chase Brook Formation, or the unnamed phyllite of the Telos Lake quadrangle, and the only indication in the map area of its age is the presence of lower Caradocian fossils in the overlying Chase Lake formation. It is thus pre-lower Caradocian.

Consideration of other, better dated pre-Caradocian rock units in the northern Appalachians that are lithologically like the Cambrian(?) rocks of the Munsungun anticlinorium appear to shed more light on the age of these rocks. These considerations have been treated in detail by Hall (in press) and will only be summarized here and in Plate 2. Hall (in press) designated the two Cambrian(?) units as rock group A. The Chase Brook Formation was referred to as unit 2 of group A and the unnamed phyllite unit as unit 1 of group A.

The Chase Brook Formation is tentatively assigned to the Middle and Upper Cambrian(?). The basis for this assignment is: 1) the lithic resemblance of the Chase Brook Formation to the Ottauquechee Formation of north-central Vermont which in turn is correlated with the Middle and Upper Cambrian Rugg Brook to Hungerford section in the St. Albans synclinorium of Vermont (Osberg, 1956; Cady, 1960; Shaw, 1966); 2) similar lithic resemblance to the lower unit of the Aziscohos

Formation in the Errol quadrangle of Maine and New Hampshire which Green (1964) suggests is a correlative of the Ottauquechee; and 3) a similar lithic resemblance to some of the rocks in the Grand Pitch Formation of the Weeksboro-Lunksoos Lake anticline, Maine, which contains the Early Cambrian(?) trace fossil *Oldhamia* (Neuman, 1962; Neuman and Rankin, 1966). The rocks in the Grand Pitch Formation that contain *Oldhamia* are *not* the Grand Pitch rocks lithologically similar to the Chase Brook Formation.

The author has mapped the Chase Brook Formation in reconnaissance in the Millinocket Lake quadrangle as far southeast as Munsungun Falls on Munsungun Stream. Dr. Robert B. Neuman (personal communication) of the U. S. Geological Survey has observed the Grand Pitch Formation during reconnaissance in the same quadrangle to the southeast and within six miles of Munsungun Stream. Thus, their geographic proximity makes more appealing the possibility that the two units are in part correlative.

The assignment of age to the unnamed phyllite unit is even more tenuous in that its stratigraphic relationship to the Chase Brook Formation within the map area is not known. Lithologically it resembles the post-Ottauquechee, Late Cambrian or Early Ordovician (Cady, 1960) Stowe Formation of Vermont, and its intimate relationship with Ottauquechee-like rocks strengthens this correlation. It does not contain the heavy-bedded quartzite of the nearby Early Cambrian(?) Grand Pitch Formation. The unnamed phyllite unit is tentatively assigned a Late Cambrian or Early Ordovician age.

As indicated above, the Chase Brook Formation is correlated with the Ottauquechee Formation, the lower unit of the Aziscohos Formation and some upper part of the Grand Pitch Formation. In addition (Hall, in press), it is probable that the Chase Brook Formation is correlative with similar dark gray slates and phyllites below probable Middle Ordovician basaltic rocks in the Chesuncook Lake area (Griscom, 1966). A further correlation is probable with the sandstone, siltstone, and slate of the Rosaire Formation (Béland, 1957) which Cady (1960) considers correlative with the Ottauquechee.

Cady (1960) indicates that the Ottauquechee type rocks interfinger to the west in the St. Albans synclinorium with more quartzose rocks of the western carbonate-quartzite assemblage (Rugg Brook Formation, etc.). The implication is that the Middle Cambrian rocks of this region decrease in quartzite content from west to east. The lack of quartzite in the Chase Brook Formation relative to that in the Ottauquechee and Rosaire Formations may be due to an extension of this facies relationship.

As indicated above, the unnamed phyllite unit is considered correlative with the Stowe Formation and the upper unit of the Aziscohos Formation. In addition (Hall, in press), this unit is quite probably correlative with identical phyllites seen by the author in the Chesuncook Lake area and may be correlative with the Armagh Formation of Quebec which consists of sandstone, siltstone, and green, red and gray slate, although sandstone and siltstone are conspicuously absent in the Munsungun anticlinorium.

Cambrian or Ordovician Rocks

Cambrian(?) Through Ordovician(?) Volcanic Rocks

General: A belt of heterogeneous volcanic and pyroclastic rocks extending from Chamberlain Lake northeast to the northeast end of East Branch Ridge are not referrable with certainty to any of the named stratigraphic units. In general, the rock types present are most like those of the Middle Ordovician Bluffer Pond Formation and most unlike the volcanics of the Siluro-Devonian units. A pre-Silurian age is strongly suggested by the presence of medium-grained doleritic rocks similar to the probably intrusive rocks mapped within units known to be of Middle Ordovician age.

The unit is overlain to the north with probable angular unconformity by rocks of the East Branch Group. To the south they are considered to be bounded in part by the Moose Pond fault, although their relationship to the Cambrian(?) rocks mapped in this area is not well known. The presence of the Moose Pond fault is indicated at the north end of the outcrop belt by quarried exposures demonstrating intensive shearing at and adjacent to the contact with the Chase Brook Formation.

Rock descriptions:

The bulk of this unit consists of medium to medium dark gray basaltic(?) rock with inter-

sertal to pilotaxitic texture. Thin-sections examined display extensive alteration of the primary minerals, particularly feldspars which are almost completely altered to sericite and carbonate. Locally the rock displays pillow-structure similar to that in the Bluffer Pond Formation. The feldspars of the coarser-grained dolerites are also highly saussuritized. Pyroxene in these rocks is probably pigeonite (colorless or neutral, birefringence of the lower second order, optically positive, 2V less than 40°).

Also present in apparently lesser amounts are medium to dark gray tuffaceous mudstone and sandstone and medium gray, white-weathering rhyolite(?). The later is present on the north shore of the Arm of Chamberlain Lake. It contains a well-developed sericitic cleavage making mineral identification difficult.

Middle Ordovician Rocks

Middle Ordovician rocks have been divided into four formations and four subsidiary members. These have a composite thickness of approximately 18,000 feet, of which at least half is volcanic.

Chase Lake Formation

General: The Chase Lake Formation is herein named for Chase Lake in the Spider Lake quadrangle. Immediately southwest of the Munsungun Lake fault the formation has been differentiated into two members: (1) a lower conglomerate-graywacke member, and (2) an upper slate-graywacke member. To the northeast of this fault and in the Churchill Lake quadrangle paucity of outcrops did not permit this distinction. No well-exposed, extensive section of the Chase Lake Formation has been found in which both members can be seen. The author, therefore, designates separate outcrops as type localities for each member, which together constitute the type section for the formation.

The only outcrop on the northeast shore of Chase Lake, approximately 300 yards south of the mouth of Chase Brook, is designated as the type locality for the lower conglomerate-graywacke member, and, similarly, the only outcrop on the south shore of Chase Lake is designated as the type locality for the upper slate-graywacke member. The latter occupies the end of the prominent point of land jutting into the lake approximately 200 yards west of the outlet of Chase Lake (Plate 1).

The lower contact of the Chase Lake Formation is considered to be unconformable. The upper contact with the Bluffer Pond Formation is conformable. Considering the complexity of structure and the paucity of outcrop, the thickness of the formation is not well known, but 2,000 feet is probably a minimum.

Rock descriptions:

(1) *Conglomerate-graywacke member:* The conglomerate-graywacke member of the Chase Lake Formation consists of interbedded conglomerate and graywacke. From what outcrops are present southwest of Chase Lake, it appears that the member becomes less conglomeratic upward, and at the top consists entirely of coarse-grained graywacke. Bedding is generally, but not everywhere, very poorly developed. Outcrops may display several feet of section of either graywacke or conglomerate with no bedding visible.

Conglomerate and graywacke are, almost without exception, the only rock types of the unit. The one exception is a dark gray (N3) siltstone seen in two outcrops.

The conglomerate may have either a slaty or sandy matrix. Fresh surfaces are dark gray, but weathered surfaces are often light gray (N7). Clasts larger than two inches are rare, but some have been seen as large as two feet in longest dimension. Clasts consist chiefly of dark gray slate, aphanitic mafic volcanic rocks, aphanitic siliceous volcanic rocks, chert, and rarely, phaneritic mafic volcanic rocks (dolerite?). Much of the dark slate clast component, particularly at the type section or locality as designated above, is very similar to the dark gray slate of the Chase Brook Formation. Fossils are present in the sandy matrix in some outcrops. Where the matrix is slaty, fossils are better preserved.

The graywacke of the conglomerate-graywacke member is medium (N5) to medium-dark gray (N4). It is poorly sorted, and rarely are any primary sedimentary structures seen. Locally poorly-developed graded bedding is present.

The composition of the graywacke is shown in Table 1. Two samples (436-61 and 56c-60) (Fig. 3) are feldspathic graywackes, and one (50e-60) is an arkosic graywacke. Matrix material is principally finely divided quartz, chlor-

ite, calcite, plagiaclase(?), white mica, and traces of epidote (pistacite) which is not seen in all sections. These graywackes contain very little white mica in the matrix and, in that respect, differ from the graywackes of the Chase Brook Formation.

The percentages of different types of clast in these graywackes are shown in Table I-B. Quartz (generally strained) is the most abundant. Unlike the graywackes of the Chase Brook Formation, these graywackes contain variable but appreciable amounts of volcanic and sedimentary rock clasts. The sedimentary clasts are predominantly dark, nearly opaque slate and mudstone(?). The volcanic clasts are dark and mafic in composition with a felty texture. Chert and fine-grained quartzite are common.

As in the conglomerates of this unit, macerated shell debris is present in some outcrops of the graywacke.

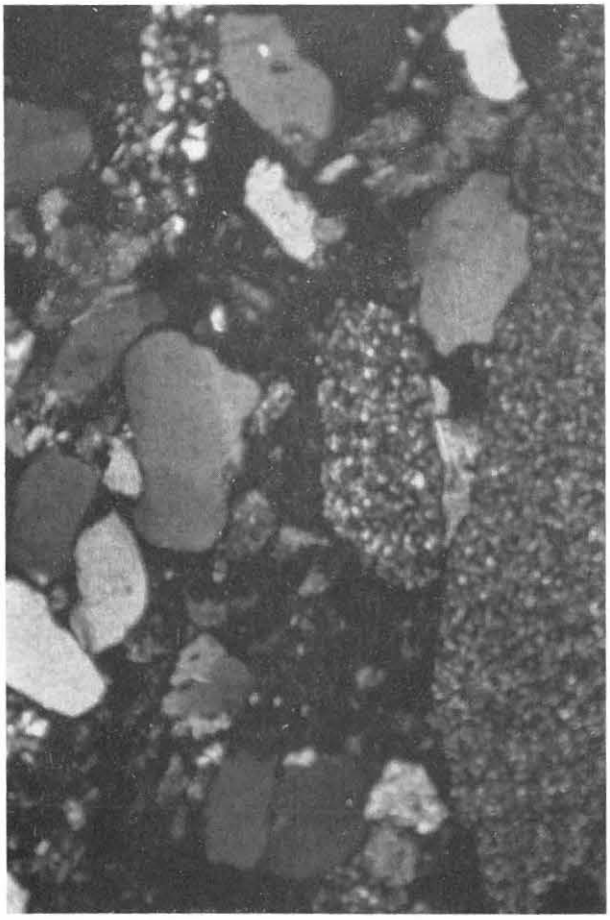


Fig. 3. Photomicrograph of feldspathic graywacke from the conglomerate — graywacke member of the Chase Lake Formation (BH-56c-60; x32; crossed nicols).

(2) *Slate-graywacke member:* The slate-graywacke member consists of interbedded medium-dark gray slates and medium to medium-dark gray graywackes. Beds vary from approximately half an inch to approximately ten inches in thickness. The graywackes are commonly graded. Very few clasts attain a length of 1.0 mm.

The composition of the graywackes is indicated in Table 1 by sample 131-60, an arkosic graywacke. It differs from the graywackes of the lower member in having a greater carbonate content and a smaller content of rock fragments. In other respects it is similar.

Comminuted shell debris has been found in one outcrop, the type locality.

Age and correlation: Five fossiliferous outcrops have been collected in the Chase Lake Formation. One locality (BH-49-60) is in the upper slate-graywacke member, two localities (BH-50-60 and BH-440-61) are in the lower conglomerate-graywacke member, and two localities (BH-56-60 and BH-8-64) in Chase Lake Formation undifferentiated. Fossils were collected from all five localities and a complete list of forms identified can be found in Appendix I. Of these five collections, only three (BH-50-60, BH-56-60 and BH-8-64) contain forms diagnostic of age.

The oldest collection (BH-50-60) was made from the slate matrix of the conglomerate exposed on the northeast shore of Chase Lake at the type locality of the conglomerate-graywacke member. The fossils are gastropods, brachiopod fragments, graptolites, and a possible pelecypod. Of these forms, the graptolites and brachiopods are most diagnostic of age. Dr. W. B. N. Berry reports (personal communication) that the graptolites could range as high as his zone of *Climacograptus bicornis* or possibly into his zone of *Orthograptus truncatus* var. *intermedius*. He also states that the collection may be older than BH-64-60 and BH-177-61 on the basis of the probable *Hallograptus*. The two latter collections belong to the zone of *C. bicornis*. Dr. R. B. Neuman indicates (personal communication, see Appendix I) that one of the brachiopods from the collection "is punctate and has branching ribs, suggesting that it is a dalmanellid". In a later verbal communication Dr. Neuman states that this brachiopod can be no older than the Porterfield stage of Cooper (1956). Dr. E. L. Yochelson (personal communication)

considers the gastropods suggestive of a Middle Ordovician age.

Thus, the fossils of collection BH-50-60 indicate that the rock is no older than Porterfield but probably older than some part of the zone of *C. bicornis*. Therefore, the oldest part of the Chase Lake Formation may be Porterfield in age. Berry (1960) equates the zone of *Nemagraptus gracilis* (zone 11) with the Porterfield.

Collection BH-56-60 was made from feldspathic graywackes on Chase Brook approximately one and one-half miles from its mouth. This collection contains 5 identifiable genera of brachiopods in addition to much unidentifiable brachiopod, trilobite, and bryozoan debris (R. B. Neuman, personal communication). Dr. Neuman, who examined this fauna, considers it no older than late Wilderness (Cooper, 1956) but states that "it could be somewhat younger" (see Apendix I). The Wilderness stage of Cooper (1956) is correlated by Berry (1960) with graptolite zone 12 *(C. bicornis)*. Stratigraphically in its type area the Chase Lake Formation lies beneath rocks (Munsungun Lake Formation) containing graptolites of zone 12 age. Therefore, collection BH-56-60 and the upper part of the Chase Lake Formation must lie within zone 12 or some part of the Wilderness stage of Cooper. It would then appear that the Chase Lake Formation ranges in age from zone 11 (Porterfield) into zone 12 (Wilderness).

Collection BH-8-64 was made in the vicinity of Otter Brook in the Churchill Lake quadrangle from graywacke and conglomerate as-

TABLE I

MODAL ANALYSES OF CHASE LAKE FORMATION GRAYWACKES

A. Composition of Chase Lake Formation graywackes

	Slate-graywacke member	Conglomerate-graywacke member		
Sample	131-60	436-61	50e-60	56c-60
matrix	30.2%	49.1%	52.0%	32.4%
quartz, etc.	13.0	30.0	17.7	35.2
rock fragments	1.5	5.2	7.1	12.9
feldspar	6.5	8.9	11.9	12.8
carbonate	48.1	6.4	10.5	6.5
pyrite	0.6	0.6	0.4	0.3
epidote	Tr	Tr	0.4	–
	99.9%	100.2%	100.0%	100.1%

B. Clast composition of Chase Lake Formation graywackes

quartz, etc.				
quartz	80%	53%	73%	65%
chert	11%	40%	14%	9%
quartzite	9%	7%	13%	26%
feldspar				
plagioclase	91%	74%	96%	96%
K-feldspar	9%	26%	4%	4%
rock fragments				
sedimentary	68%	52%	58%	49%
volcanic	32%	48%	42%	51%

signed to the Chase Lake Formation. Dr. R. B. Neuman reports that this collection may be as young as younger Caradoc or even Ashgill. However, he indicates that, "the few specimens in this collection are hardly enough to give confidence to any interpretation". The Chase Lake rocks in this area are thus tentatively assigned the same age (Porterfield-Wilderness) as the Chase Lake Formation in its type area. The possibility exists that these rocks represent a unit similar to but younger than the Chase Lake Formation.

To the author's knowledge no Porterfield (zone of *Nemagraptus gracilis*) age fossils are known from nearby rocks in the northern Appalachians. However, in several areas rocks lithologically like those of the Chase Lake Formation are found beneath rocks containing fossils that are slightly younger (zones of *Climacograptus bicornis* and/or *Orthograptus truncatus*).

Southwest along strike in the Errol and Cupsuptic quadrangles the Dixville Formation of Green (1964) may be in part correlative with the Chase Lake Formation. In the Cupsuptic quadrangle Harwood and Berry (1967) divide the Dixville Formation into a lower greenstone and slate unit and an upper black slate unit.

The lower part of the upper black slate unit consists of calcareous lithic graywacke which, where seen by the author, is identical with the graywacke of the Chase Lake Formation. Harwood and Berry report that fossils in the lower part of the black slate unit are diagnostic of Berry's zone 12. Macerated shell debris from graywacke lower(?) in the section is consistent with a Middle Ordovician age. Similar graywacke in the Munsungun anticlinorium appears to span parts of both zones 11 and 12. It is suggested here on the basis of such a lithic correlation that possibly the lowest parts of the black slate unit and the greenstone and slate unit may be as old as zone 11 age. Furthermore, if, as suggested by Harwood and Berry, the Ammonoosuc Volcanics of Billings (1956) are correlative with the lower greenstone and slate member of the Dixville, then following the correlation suggested above, the Ammonoosuc could be as old as zone 11.

Across strike in the Green Mountain – Sutton Mountain anticlinorium of Quebec the Beauceville Group of MacKay (1921) contains graptolites which Berry (1962; 1968) assigns to his zones of *C. bicornis* and *O. truncatus* var. *intermedius*. The graptolites from the Beauceville studied by Berry were collected from rocks in "the basal part of the unit" (Berry, 1962, p. 146). For present purposes it is worth noting that several workers report conglomerates basal to the Beauceville (Dresser, 1913; Clark, *in* Cooke, 1937). Béland (1957) reports conglomerate as being intraformational in the lower part. These occurrences are treated in more detail in Hall (in press). Berry (1962) reports no conglomerates associated with graptolitic slates of Castle Brook. In view of this, it seems quite possible that there is some unknown amount of section beneath the slates from which the oldest graptolites have been collected. If so, this section could be pre-*C. bicornis* zone and correlative with the basal zone 11 age part of the Chase Lake Formation.

Cady (1960) correlates the Moretown, Cram Hill and Umbrella Hill Formations of Vermont with the Beauceville Group and also considers them correlatives of the Albee and Ammonoosuc Formations in New Hampshire. However, Osberg (personal communication) indicates that at least part of the Moretown may be as old as Early Ordovician. It seems reasonable that part of the Moretown is older than the Cram Hill and Beauceville if the Albee-Moretown correlation of Cady (1960) is accepted. In the Errol and Cupsuptic quadrangles of Maine and New Hampshire the Albee lies beneath the Dixville Formation which may be as old as Berry's zone 11 and is certainly as old as zone 12. The oldest fossils found in the Beauceville are of zone 12 age. On this basis the Cram Hill is here considered correlative with the Beauceville in Quebec and the Ammonoosuc-Partridge (=Dixville) in New Hampshire. The Chase Lake Formation would then be correlative with some part of the Cram Hill. If the Moretown and Umbrella Hill are correlative with the Albee Formation in Maine and New Hampshire they are at least in part older than the oldest part of the Middle Ordovician section in the Munsungun anticlinorium.

In the Weeksboro-Lunksoos Lake anticline of northern Maine an Ordovician section is present whose lowest unit, the Shin Brook Formation, is of earliest Middle Ordovician age (Whiterock Stage of Cooper, 1956) or possibly late Early Ordovician age (Neuman, 1964; Neuman and Rankin, 1966; Neuman, 1967). The Shin Brook consists of tuff, tuffaceous conglomerate, breccia, flows, and fossiliferous tuffaceous sandstone. An unfossiliferous greenstone unit with

some volcanic breccia lies above the Shin Brook Formation. Pillows are seen locally in the greenstone of this unit. Next above the greenstone is the Wassataquoik Chert unit, and above that, unit of conglomerate and sandstone. The topmost conglomerate and sandstone unit contains abundant shelly faunas of Ashgill age. The Wassataquoik Chert contains graptolites of Berry's zone of *C. bicornis*. In addition, clasts in a conglomerate probably overlying the Wassataquoik contain graptolites of Berry's zone of *O. truncatus* var. *intermedius*. On this basis, the Wassataquoik Chert is assigned (Neuman, 1967) to Berry's zones 12 and 13.

The age of the greenstone unit is more questionable. It underlies the Wassataquoik Chert and on that basis is of zone 12 or older age. Neuman (1967) indicates that part of the greenstone unit may be contemporaneous with the Shin Brook Formation. An upper age for the Shin Brook is not established. On the basis of its position below fossiliferous rocks of known zone 12 age and its lithologic similarity to the zone 11-12 age Bluffer Pond Formation of the Munsungun anticlinorium, the greenstone is considered here to be of zone 11-12 age and possibly older. This would be correlative with the Chase Lake Formation which is considered in part a facies equivalent of the Bluffer Pond.

Northeast of the Weeksboro-Lunksoos Lake anticline an Ordovician section is present in the Aroostook-Matapedia anticlinorium of Pavlides (*et al*, 1964). Here, the Ordovician and Silurian Meduxnekeag Group (Pavlides, 1962, 1965a, 1965b) consists from oldest to youngest of three formations: the Chandler Ridge Formation, the Carys Mills Formation, and the Burnt Brook Formation. The Chandler Ridge Formation ". . . is a lenticular deposit of local extent consisting of slate, graywacke, and conglomeratic graywacke and minor amounts of siltstone and quartzite. . ." (Pavlides, 1965b, p. 54). No fossils have been found in the unit. The Carys Mills Formation ("ribbon rock" of Pavlides, *et al*, 1961) consists of limestone and calcareous siltstone interbedded with ankeritic limestone and with gray and green slate. Graptolites from the Carys Mills near Colby, Maine indicate an age of Berry's zone 13 (*O. truncatus* var. *intermedius*) (Pavlides, *et al*, 1961; Pavlides, 1965a, 1965b; Pavlides and Berry, 1966). Graptolites from the Carys Mills in the Smyrna Mills area are of Early Silurian age (Berry's zone 19; A_1-B_1 of the Llandovery) (Pavlides, 1965b; Pavlides and Berry, 1966). Thus, the Carys Mills is considered to be Middle Ordovician through Early Silurian in age. The Burnt Brook Formation consists primarily of green noncalcareous slate and gray calcareous slate and is considered to be of Silurian age.

Lithologically a strong resemblance exists between the zone 11-12 Chase Lake Formation of the Munsungun anticlinorium and the pre-Carys Mills (zone 13) Chandler Ridge Formation. On this basis it is suggested that the Chandler Ridge may be correlative with the Chase Lake.

Bluffer Pond Formation

General: The Bluffer Pond Formation is a new formation named herein for Bluffer Pond (T8 R11) in the Spider Lake quadrangle. The formation is primarily a volcanic unit consisting of basalt and dolerite with lesser amounts of porphyritic rhyolite (including the Ragged Mountain member); rhyolite tuff(?); mafic tuff; black, carbonaceous, locally graptolitic chert and slate; and dark gray, tuffaceous, siliceous mudstone.

No type section displaying all these rock types and their relationships to one another can be designated. The most illustrative and most easily accessible area of basalt and minor amounts of graptolitic chert and mudstone is seen along the main Great Northern Paper Company road from approximately three-fourths of a mile to about three miles north of Pillsbury Pond. Typical dolerites may be seen on most of the many logging roads traversing Haymock Mountain (north side of Haymock Lake). Scattered outcrops of mafic tuffs appear throughout the formation. In addition to the porphyritic rhyolite of the Ragged Mountain member, scattered outcrops of rhyolite and rhyolitic tuff(?) are found. These last are primarily restricted to the northeastern part of the outcrop of the formation; i.e., northwest and southeast of Bluffer Pond, south of Sewall Deadwater, and to the east of Atkins Brook in the Spider Lake quadrangle. Their spatial distribution with regard to map pattern suggests that they lie within or near the middle of the formation.

The thickness of the Bluffer Pond Formation can be only roughly approximated, and, in fact, is probably quite variable. A maximum thickness of 4,000 feet is tentatively assigned to the Bluffer Pond.

The contact of the Bluffer Pond Formation is considered to be conformable with the Chase Lake Formation. However, west of Chase Lake basalt of the Bluffer Pond can be shown locally to lie both above and below rock types of the Chase Lake Formation. This is in accord with the facies equivalency of the two formations suggested by the fossil data discussed below. The upper contact of the Bluffer Pond is gradational with the Munsungun Lake Formation and is considered more fully under the discussion of the Munsungun Lake Formation. West of the Munsungun Lake fault and on the north limb of the anticlinorium the Bluffer Pond Formation lies with angular unconformity beneath the Spider Lake Formation of Siluro-Devonian age.

across. This feature makes them desirable as road metal for which they are often used.

Another characteristic feature of the basalts are pillows which are usual but not ubiquitous (Fig. 4). The pillows are generally ovoid in shape, commonly showing protrusions at the bottoms where they have assumed the shape of the interstices between underlying pillows. Such pillows are typically one to two feet in longest dimension. Interstices are filled with calcite or a light gray, white-weathering, cherty material. Locally the classical shape is not seen, and the pillows are long (up to about six feet) and sinuous. In addition to being pillowed, basalt commonly contains abundant small amygdules (one-eighth to one-sixteenth inch in diameter).

Fig. 4. Pillow basalt from the Bluffer Pond Formation, Bluffer Brook, Spider Lake quadrangle.

Rock descriptions:

(1) *Main part of the formation:* Basalt and dolerite comprise the bulk of the Bluffer Pond Formation. They total seventy-five per cent of all outcrops seen and may actually comprise more than seventy-five per cent of the formation. The basalt and dolerite range from medium light gray to medium dark gray. Weathered surfaces are either light gray or dark rusty brown. Neither is cut by the regional cleavage although locally they are strongly jointed. Where uncovered by bulldozers during logging operations, the basalts are often highly fractured and break into angular fragments an inch or so

It should be emphasized that while there is no doubt about the extrusive nature of much of the basalt, the nature of most of the dolerite is open to question. The finer-grained, non-pillowed dolerite and the coarser-grained pillow basalt are mineralogically and texturally very similar, suggesting similar origins. However, if the entire section were deposited under marine conditions, it is difficult to understand why all the extrusives should not be pillowed. Locally, as on some of the islands in the east end of Churchill Lake, Ordovician rocks are cut by basalt and dolerite dikes up to approximately twelve feet thick attesting to an intrusive origin

for at least some of the non-pillowed basalt and dolerite. The dolerites exhibit a rather wide range in grain-size, from fine-to coarse-grained. The coarse-grained dolerite contains grains up to about one centimeter in length and is probably intrusive. The typically lens-like spatial configeration of the coarse-grained dolerites is consistent with an intrusive origin. Where possible these coarsest-grained rocks have been differentiated on the map and designated gabbro. However, the finer-grained dolerites are included as part of the main body of the formation. Coarse-grained dolerite is found in most of the other pre-Silurian formations and is considered intrusive.

Texturally the dolerite ranges from intersertal to subophitic or ophitic and consists of plagioclase, pyroxene, chlorite, ilmenite, leucoxene, sphene, and trace amounts of carbonate and sericite. Plagioclase is almost without exception partially or completely altered to chlorite, sericite, and carbonate which appear as small scaly masses on plagioclase laths. Less commonly small granules of sphene occur within the plagioclase. Many sections, however, contain plagioclase still well enough preserved that its composition can be determined from extinction angles against albite twins and its refractive indices. Such determinations indicate that the plagioclase is labradorite varying from Ab_{15} to Ab_{35}.

Only one type of pyroxene is present. It is colorless or neutral, has a birefringence of the lower second order, is optically positive, and has a 2V less than 40°. These data indicate pigeonite.

Chlorite is very fine-grained and varies from colorless to yellowish green or apple-green. It is weakly pleochroic and birefringent, some exhibiting an anomalous blue color. Structurally the chlorite occurs as fibrolamellar aggregates or as poorly cleaved anhedral masses. In the cleaved masses, the cleavage traces are parallel to the slower ray. The fibrolamellar aggregates are length slow and probably antigoritic.

Sphene, ilmenite, and leucoxene are present in all sections. The ilmenite generally has a herringbone structure and may penetrate either pyroxene or plagioclase. In some sections it is partially altered to leucoxene and in some it is completely altered. Sphene is most common as a groundmass constituent, occurring in brown, highly birefringent, granular masses.

Modal analyses of two dolerite specimens from the Bluffer Pond Formation are as follows:

	BH-120-60	BH-182-61
plagioclase	51.4%	52.9%
pyroxene	27.4	25.3
chlorite	14.4	18.4
ilmenite	4.9	–
leucoxene	–	2.5
sphene	1.9	1.0
	100.0%	100.0%

The basalt of the Bluffer Pond Formation is almost all pilotaxitic and rarely intersertal in texture. Where it is pilotaxitic, the sections consist of plagioclase microlites set in a fine-grained groundmass of sphene and leucoxene, opaques, chlorite, carbonate, and possibly some specks of epidote. In a few sections the groundmass is entirely leucoxene.

The rare coarser-grained basalt with an intersertal texture allows more accurate mineral identification. It contains labradorite (within the compositional range of the dolerite plagioclase) set in a groundmass somewhat similar mineralogically to that of the pilotaxitic basalt. It differs in that it contains abundant purplish-brown, slightly pleochroic, optically positive pyroxene which is probably augite. A modal analysis of a section from a basalt pillow with intersertal texture is as follows:

	BH-24b-60
plagioclase	45.5%
pyroxene	30.6
chlorite	9.3
ilmenite	1.9
sphene	12.8
	100.1%

Amygdules are of two main types. The first and most common contains an outer rim of ilmenite or leucoxene and sphene. Concentrically within this outer rim is first a zone of leucoxene or ilmenite, then a zone of chlorite, and finally a central area filled with calcite. Pyrite cubes may occur within the calcite core. The second, less common, type of amygdule consists of an outer rim of leucoxene and sphene followed by an inner zone of coarse, anhedral quartz and a central core of chlorite.

According to the classification of Wentworth and Williams (1932), the mafic tuffs of the Bluffer Pond Formation are lithic tuffs. In hand

specimen the rocks are medium gray, with weathered surfaces becoming quite rusty. Fragments or clasts are rarely larger than several millimeters and are generally less than one millimeter. In spite of this, hand specimens are quite obviously fragmental. The groundmass material as seen in thin section is chiefly microcrystalline quartz with varying amounts of chlorite and carbonate. Fragments consist of cryptocrystalline, siliceous volcanics or chert; dark brown volcanics with a cryptocrystalline matrix and plagioclase microlites; and yellow to brown angular fragments of altered volcanic glass(?) with remnant perlite structure. The latter type sometimes contains a few plagioclase microlites. In addition to the above rock types a few clasts of pyroxene, quartz, and highly altered plagioclase may be present.

As mentioned above, scattered outcrops of rhyolitic rocks similar to those of the Ragged Mountain member occur in the Bluffer Pond Formation. For the most part, these are similar to the Ragged Mountain member mineralogically and texturally, and probably represent minor flows or intrusions. Some, however, consist primarily of cryptocrystalline rhyolite(?) fragments with perlitic cracks, or consist primarily of angular to subrounded clasts of quartz, plagioclase, potassium feldspar, and rhyolitic fragments with minor amounts of cryptocrystalline, rhyolitic groundmass. These are probably pyroclastic and probably rhyolitic in composition. Associated with them is dark gray, laminated mudstone. The mudstone has a siliceous, cryptocrystalline groundmass or matrix containing abundant chlorite. In addition small plagioclase laths are present in the groundmass indicating that it too is probably tuffaceous.

Several outcrops of dark gray to black slate and dark gray to black cherty slate or chert occur within the Bluffer Pond Formation. The rocks are locally graphitic, and pyrite is commonly present. Graptolites have been found in such rocks at several localities.

(2) *Ragged Mountain Member:* The Ragged Mountain Member of the Bluffer Pond Formation is named herein for Ragged Mountain (T9 R10) in the Spider Lake quadrangle. The unit is lenticular and less than 1,000 feet thick and is primarily exposed on Ragged Mountain which is designated as the type section. As mapped, the Ragged Mountain Member is confined to the area east of the Munsungun Lake fault and to the north limb of the anticlinorium. Some of the rhyolitic rocks discussed in the previous section may belong to the member, but this relationship has not been established.

Hand specimens are light gray to medium light gray, weathering to a whitish chalky rind as much as one-eighth of an inch thick. The rock is aphanitic and porphyritic with phenocrysts generally less than one-sixteenth of an inch long. In thin section phenocrysts make up less than twenty per cent of the rock and consist of rounded to angular grains of quartz, plagioclase, potassium feldspar, and minor amounts of myrmekite. The groundmass is microcrystalline to cryptocrystalline. Where microcrystalline it consists of quartz, plagioclase and potassium feldspar with a granitic texture. The microcrystalline groundmass is probably due to recrystallization of a cryptocrystalline or glassy groundmass, as suggested by: (1) inclusions, probably once glass, of similar material in quartz phenocrysts, and (2) veinlike aggregates of similar material cutting plagioclase phenocrysts. Minor amounts of chlorite are present in the groundmass. Groundmass plagioclase has refractive indices less than 1.540, and extinction angles measured against albite twins indicate albite. The potassium feldspar has a small 2V (40°-50°) and is presumably ortholcase-sanidine. The rock is probably soda rhyolite.

Marginally the rock is fragmental. Fragments of rhyolite (one or two inches in diameter) are cemented by quartz and albite which is similar to that of the rhyolite proper but considerably coarser-grained. The coarseness of the cementing material suggests that the breccia is of intrusive origin rather than of flow origin. On the other hand, recrystallized glass of extrusive origin might assume the same characteristics.

Age and correlation: Three fossiliferous outcrops (BH-162-61, BH-177-61, and BH-223-62) have been found in the Bluffer Pond Formation and are described in detail in Appendix I. BH-177-61 is from dark gray slate on the north limb on the anticlinorium. The relationships in this area are not clear, and, although the slate has been assigned to the Bluffer Pond Formation, the possibility exists that it is part of the Chase Lake Formation. The graptolites from BH-177-61 are diagnostic of Berry's zone of *Climacograptus bicornis.* Locality BH-162-61 is near the base of the unit. According to Berry it could be the same age as BH-177-61, but the material is too poor to be sure. BH-223-62

probably belongs to the zone of *Nemagraptus gracilis* (zone 11 of Berry). It is possible that this collection is still of zone 12 age but older within that zone than collection BH-177-61. Thus, like the Chase Lake Formation, some part of the Bluffer Pond is older than the zone 12 graptolites of BH-177-61. If BH-223-61 is of zone 11 age then parts of the Bluffer Pond are the same age as the oldest parts of the Chase Lake. It is considered here that the Bluffer Pond ranges in age from zone 11 through some lower part of zone 12. It is then a facies equivalent of the Chase Lake Formation although some upper part appears to be younger (zone 12 graptolites of BH-177-61). Parts of the Bluffer Pond may be older than the Chase Lake Formation although this relationship is not established. Just to the west of Pillsbury Pond outcrops of Bluffer Pond Formation are found within several hundred feet of outcrops of Chase Brook Formation. Apparently no Chase Lake separates these two formations here and Bluffer Pond lies directly on Chase Brook. This is in accord with the above facies interpretation, although the proximity of these two units could also be due to faulting.

Several units, correlative or possibly correlative with the Bluffer Pond Formation, exist in Maine, Quebec, and Vermont. As the Bluffer Pond Formation appears to be a facies equivalent of the Chase Lake Formation, the correlations made above for the Chase Lake would presumably hold true for the Bluffer Pond. Thus, the Bluffer Pond is probably correlative with the greenstone and slate unit and possibly the lower part of the black slate unit of the Dixville Formation in the Cupsuptic area of Maine; possibly correlative with some lower part of the Beauceville Group in Quebec and some lower part of the Cram Hill in Vermont; probably correlative with the greenstone unit of the Weeksboro-Lunksoos Lake anticline, Maine; and probably correlative with the Chandler Ridge Formation of the Aroostook-Matapedia anticlinorium, Maine. In the case of the correlation with some lower part of the Beauceville in Quebec, it is in the lower portions of the section where mafic volcanics (Bolton mafic lavas) are found (Ambrose, 1957; Cady, 1960).

Munsungun Lake Formation

General: The Munsungun Lake Formation is named herein for Munsungun Lake (T8 R10) in the Spider Lake quadrangle. On the south limb of the anticlinorium it conformably overlies the Bluffer Pond Formation and is unconformably overlain by Upper Silurian and Lower Devonian rocks. On the north limb of the anticlinorium to the north of the Munsungun Lake fault it conformably overlies the Bluffer Pond Formation and is conformably overlain by the Blind Brook Formation, also of Middle Ordovician age. To the west of the fault on the same limb of the anticlinorium, the formation presumably lies unconformably beneath the Spider Lake Formation.

The separation of the Bluffer Pond Formation and the Munsungun Lake Formation is somewhat arbitrary, but is generally readily mapped in the field. The distinction is a combination of several characteristics rather than any one feature. Pillow basalts, so characteristic of the Bluffer Pond Formation, are almost totally lacking in the Munsungun Lake Formation. Felsic, pyroclastic rocks are relatively rare in the Bluffer Pond Formation, but together with dolerites are the most common and characteristic rocks of the Munsungun Lake Formation. On the southern limb of the anticlinorium the distinction is made even clearer by the presence of red cherts and slates and mafic volcanic breccias in the Munsungun Lake Formation. The latter (red cherts and slates and mafic volcanic breccias) are not present in the Munsungun Lake Formation of the north limb, and the unit is less readily distinguished.

The best exposed section of felsic tuff and red and black chert and slate can be seen in a northwest-southeast traverse of Munsungun Ridge on the west side of Munsungun Lake. A more accessible section of felsic tuff and dolerite can be seen on the road to Island Pond south of Mule Brook Mountain (T10 R10).

The structurally most uncomplicated section of the Munsungun Lake Formation is north of Island Pond. In this area its thickness is approximately 5,000 feet.

Rock descriptions:

(1) *Main part of the formation:* The dolerites of the Munsungun Lake Formation are the same as those of the Bluffer Pond Formation in color, mineralogy, texture, and occurrence, the distinction between the formations being arbitrary and based on other rocks, as pointed out above. Typically the dolerites are subophitic though occasionally intersertal textures are

found. Plagioclase is labradorite, falling within the compositional range of the plagioclase of the Bluffer Pond dolerites. The plagioclase is altered in varying degrees to sericite, carbonate, chlorite, sphene, and epidote. Pyroxene is pigeonite in almost all sections examined. In a very few finer-grained specimens with an intersertal texture the fine-grained pyroxene has the optical characteristics of augite. Ilmenite and granular masses of leucoxene and sphene are ubiquitous. Chlorite apparently similar to that in the Bluffer Pond dolerites is present. Small veins of quartz, epidote, and chlorite are present in some sections. As in the Bluffer Pond Formation, the dolerites are probably intrusive.

Outcrops of mafic tuffs similar to those of the Reed Pond Member (described below), but not considered part of it, are seen locally between Reed and Chandler Ponds. Some of them differ from the Reed Pond Member in that they contain brown basaltic hornblende in addition to less amounts of pyroxene. Typically the pyroxene is pigeonite but in one section the only pyroxene is light brown and optically negative with exsolved masses of colorless, optically positive pyroxene.

Felsic Flows(?) and pyroclastic rocks consisting of volcanic breccia and tuff make up a large part of the maine body of the Munsungun Lake Formation and differ markedly from the mafic volcanic breccias of the Reed Pond Member and similar rocks in the main body of the formation.

The coarsest of these rocks, the volcanic breccias, are quite varied in color. Fragments as large as two inches long are present, but typically fragments are less than half an inch long. Most commonly the fragments or blocks and the finer-grained matrix material are some shade of greenish-gray, with the matrix the lighter of the two. Occasionally pale grayish-red (R5 5/2) fragments of red slate or chert are the predominant clast material. The greenish-gray fragments are mostly of cryptocrystalline tuffs or cherts(?) and like the fragments of red slate are presumably accidental (Wentworth and Williams, 1932). The slate, tuff, and chert(?) fragments are almost all identical to rocks interbedded in the formation itself. A very few fragments of fine-grained felsic volcanic rock with intersertal texture are found as well as a few altered palagonitic(?) shards.

The finer-grained matrix consists mostly of angular quartz and feldspar fragments as well as small rock fragments similar in rock type to the coarser fragments. The feldspar is almost entirely twinned plagioclase, partially or wholly altered to sericite and calcite. Its composition determined with the universal stage (Slemmons, 1962) is generally sodic andesine (An_{33}) although considerable variation (An_{28}-An_{45}) is present. The rocks are therefore dacitic or andesitic. The cementing material is dark, opaque, and cryptocrystalline with occasional patches of chlorite.

The fragments themselves are angular and attenuated or strung out in such a way as to suggest that they were not completely indurated when the breccias formed. In some specimens these fragments make up more than ninety per cent of the rock and interlock together with little or no intervening finer-grained matrix material. In some such cases intervening angular quartz or feldspar fragments completely protrude into the rock fragments above and below as if the rock fragments had been plastic during compaction. Such observations suggest that the rock fragments were incompletely indurated and derived from the sediments and ash through which extrusion occurred.

Finer-grained pyroclastic rock or tuff (grain-size less than 4 mm.) is much more common in the Munsungun Lake Formation than volcanic breccia. It is highly variable in grain-size and clast or fragment composition and frequency. Extremely fine-grained types containing no coarse fragments are here referred to as felsic tuff. Most is grayish-green (5GY 6/1) to medium bluishgray (5B 6/1) in color with light gray weathered rinds one-eighth to one-fourth of an inch thick. Some is more decidedly green (5G 6/1) with light brownish-gray (5YR 4/1) to grayish-red (5R 4/2) beds or laminae. Generally such rocks are massive with a conchoidal fracture, although laminae may often be seen on weathered or wet fresh surfaces. Such rocks are not cut by the regional cleavage, although a few outcrops of well-cleaved greenish slaty tuff or tuffaceous slate are found. Microscopically the massive tuffs are micro- to cryptocrystalline granular aggregates of quartz and feldspar giving a pepper-and salt appearance under crossed nicols. Such a texture suggests recrystallization, perhaps from volcanic dust. Rarely such rocks are recrystallized to the extent that twinning may be seen under highest magnification in some of the granules. In such cases it is very similar in appearance to the matrix plagioclase

of the Ragged Mountain rhyolite of the Bluffer Pond Formation, though finer-grained. Some chlorite is interstitial to the quartz and feldspar. X-ray diffractometer traces of several powdered tuff samples are nearly identical in d-spacings and peak intensities to traces made of the Ragged Mountain soda rhyolite suggesting similar composition for the tuffs. In some instances such rocks are interbedded or interlaminated with coarser-grained crystal or mixed tuffs or rarely slaty tuffs, which seems to preclude a flow origin. Also the very regular lamination over long distances (ten feet) in outcrop is not consistent with flow banding.

In addition to the felsic tuffs described above, crystal tuffs and mixed tuffs are abundant. The author uses the term "mixed tuff" to refer to tuffs containing abundant lithic fragments in addition to feldspar and quartz fragments. The crystal and mixed tuffs are usually heavy-bedded, devoid of primary sedimentary features, and contain subangular to angular fragments. Graded bedding is very rare. One outcrop has been seen in which fine-grained mixed tuffs are cross-bedded indicating some amount of reworking by water. However, angularity of fragments and extreme rarity of such primary sedimentary features argues against extensive reworking of most of these rocks. In color they range from light gray to medium gray. A very characteristic feature in the field is the presence in hand specimens of a few dark gray chert fragments much like the chert and mudstone in the underlying Bluffer Pond Formation. A complete grain-size spectrum exists from the felsic tuffs through the crystal and mixed tuffs to the volcanic breccias described above. There is also a more or less complete spectrum from crystal tuffs in which lithic fragments are always present, to the mixed tuffs in which lithic fragments may comprise fifty per cent of the total fragments. Quartz and plagioclase fragments or clasts in the crystal tuffs seldom exceed 1 mm. in length. In some, plagioclase makes up more than eightly per cent of the rock with minor amounts of angular or shard-like quartz fragments (Fig. 5). In others quartz fragments predominate. The matrix in such rocks is either very dark, opaque, and cryptocrystalline or, more commonly, similar to the fine-grained felsic tuffs described above. Small amounts of chlorite and sphene are present in the matrix.

The mixed tuffs (Fig. 6) are similar to the crystal tuffs in all respects except for the abundance of lithic fragments. Lithic fragments are either of cryptocrystalline felsic tuff or chert similar to that in the volcanic breccias or are of volcanic fragments with an intersertal texture.

In addition to the above volcanic rocks, lesser amounts of chert and slate are present in the main body of the formation. Grayish-red (5R 4/2) to pale red (5R 5/3) chert or cherty slate are fairly common in massive beds up to many feet thick. The rock typically breaks into rectangular fragments several inches across coated with pyrolusite. Medium gray slates and medium dark gray to dark gray cherts are also found. Some of the dark gray cherts are laminated, with some laminae weathering to a white chalky rind. This suggests that they are in part tuffaceous.

(2) *Reed Pond Member:* The Reed Pond Member of the Munsungun Lake Formation is named herein for Reed Pond (T8 R10) in the Spider Lake quadrangle. It is less than 1,000

Fig. 5. Photomicrograph of crystal tuff from the Munsungun Lake Formation. Clasts are of plagioclase (maximum length of 1 mm.) set in a dark cryptocrystalline matrix. Plagioclase is altered to calcite and sericite (BH-16a-60; x32; crossed nicols).

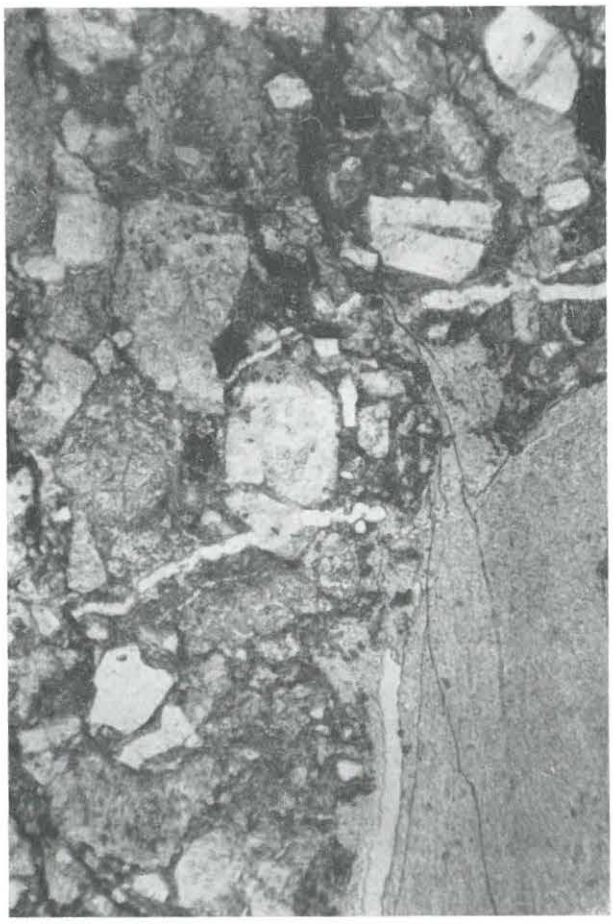


Fig.6. Photomicrograph of mixed tuff from the Munsungun Lake Formation. Smaller clasts are altered feldspar (SL6-G5-NC; x32; plain light).

feet thick and probably quite variable in thickness. The member is best exposed on the southeast shore of Little (or Upper) Reed Pond. Some of the mafic tuffs and breccias described above that are not assigned to this member, but are from the same area, are very similar. It is possible that more detailed work between Reed and Chandler Ponds would establish that this member is more widely distributed than shown on the present map.

The Reed Pond Member is composed exclusively of greenish-gray (5GY 6/1) to bluish-gray (5B 6/1) mafic volcanic breccia, consisting of a tuffaceous matrix with large mafic volcanic fragments up to about four inches in longest dimension. The tuffaceous matrix is composed of coarsely crystalline, twinned calcite plus chloritic altered glass shards, chlorite, sphene, altered plagioclase, pigeonite fragments up to about 5 mm. in length, and fragments of dark pilotaxitic mafic volcanic rocks with plagioclase microlites and pyroxene phenocrysts.

The large angular clasts appear to be of only one rock type, which consists of small (0.05 mm.) plagioclase laths and pigeonite set in a dark, cryptocrystalline groundmass. In addition the rock is glomeroporphyritic. Phenocryst clusters are mostly of pigeonite with aggregates of microcrystalline quartz and calcite that appear to be pseudomorphs after plagioclase. In plain light the aggregates are rectangular in outline and very sharply defined. Occasionally they protrude into the pyroxene phenocrysts or are completely embayed by them, indicating a remnant subophitic texture for the phenocryst clusters. Some of the pyroxene is strongly zoned. Former vesicles or cavities are rimmed with anhedral quartz and have central spaces filled with chlorite and/or calcite.

Age and correlation: Only two fossil localities, BH-64-66 and BH-184-64, have been found within the Munsungun Lake Formation. BH-64-60 is on Norway Brook in the Millinocket Lake quadrangle and is diagnostic of Berry's zone of *Climacograptus bicornis*. This locality is believed to be very near the base of the Munsungun Lake Formation. Locality BH-184-64 near Haymock Lake in the Spider Lake quadrangle also lies near the base of the Munsungun Lake Formation and is diagnostic of Berry's zone of *C. bicornis*. As the Blind Brook Formation contains graptolites of the zone of *Orthograptus truncatus* var. *intermedius* and is apparently conformable above the Munsungun Lake Formation, the Munsungun Lake Formation may lie entirely within the zone of *C. bicornis* or may span the boundary between the zones of *C. bicornis* and *O. truncatus* var. *intermedius*.

As discussed above graptolites of Berry's zone of *C. bicornis* (zone 12) have been found in the black slate unit of the Dixville Formation of the Cupsuptic area of western Maine. Thus, the upper part of the Dixville Formation is considered correlative with the Munsungun Lake Formation. As indicated above it seems likely that the greenstone and slate unit and possibly the lower part of the black slate unit of the Dixville are correlatives of the Bluffer Pond and Chase Lake Formations.

Harwood and Berry (1967) state that the Ammonoosuc Volcanics and Partridge Formation (Billings, 1956) are probably correlatives of the greenstone and slate unit and the black slate unit respectively. While this may be correct a second possibility exists. Billings (1956,

p. 18) divides the Ammonoosuc into three main groups: (1) "Dark-green chlorite and chlorite-epidote schists some of which are conglomeratic," (2) "buff to white soda rhyolite that is massive to schistose; some of these rocks have conspicuous quartz and albite crystals up to one-eighth inch in diameter; some of the soda rhyolite is volcanic conglomerate," and (3) "dark slate and impure quartzite." According to Billings the rocks of the first group have the chemical composition of andesite and basalt. He further states that some of these are pyroclastic in origin. It seem probable that only part of the Ammonoosuc is correlative with the greenstone and slate unit of Dixville and by extension the basalts of the zone 11-12 Bluffer Pond Formation of this report. A further lithologic similarity and possible correlation exists between the rhyolitic rocks of the Ammonoosuc and the zone 12 rocks of the Munsungun Lake Formation and between the Partridge Formation and the zone 13 rocks of the Blind Brook Formation. This would then imply that much of the black slate unit of the Dixville is also equivalent to the Ammonoosuc, although the rhyolitic volcanic facies of the Ammonoosuc and Munsungun Lake are not present in that area. This does not preclude the possibility that some upper part of the black slate unit is partridge equivalent and of either zone 12 or 13 age.

Ordovician rocks have been mapped by Boucot (1961) on the flanks of the Moose River synclinorium. The Kennebec Formation of Boucot consists of rhyolite tuff and felsite. Adjacent to the Kennebec Formation is an unnamed unit of slate, phyllite, graywacke, dark sandstone, volcanic rocks, and carbonate rock. The age of this unit is not well-known, but Boucot (1961) considers it to be of Cambrian or Ordovician age. Brachiopods from the Kennebec Formation are considered by Neuman (1964, p. 2) to suggest ". . . an age no greater than the Marmor. . .", although he (1963) considers them to be Llandeilo or lower Caradoc. Harwood and Berry (1967) suggest correlation of the Ordovician rocks of the Moose River synclinorium with the Dixville Formation in the Cupsuptic quadrangle. As shown in Plate 2 they may in large part be correlative with the Ordovician rocks of the Munsungun anticlinorium.

In Quebec and Vermont the Beauceville Group and Cram Hill Formation respectively are in part correlatives of the Munsungun Lake Formation. Graptolites of zone 12 and 13 ages are present in the Beauceville (Berry, 1960), and, as indicated above, the Cram Hill is considered a southern extension of the Beauceville.

To the northeast in Maine in the Weeksboro-Lunksoos Lake anticline and the Aroostook-Matapedia anticlinorium the Wassataquoik Chert and part of the Carys Mills Formation are correlatives of the Munsungun Lake Formation. The ages of these units have been discussed above.

Blind Brook Formation

General: The Blind Brook Formation is a new formation named for Blind Brook (T10 R9) in the Mooseleuk Lake quadrangle. No extensive, well-exposed section of this unit has been found in the area studied, and the author has, therefore, named the formation for Blind Brook where the most accessible section is to be seen. The locality is on the south side of the main Great Northern Paper Company road approximately 250 yards east of its crossing with Blind Brook. This section is typical of the dark gray, pyritiferous slates which constitute the bulk of the formation. In addition to dark gray, pyritiferous slate, the formation contains minor amounts of interbedded tuff and tuffaceous slate. However, unlike the underlying Munsungun Lake Formation, the Blind Brook Formation is primarily sedimentary.

The thickness of the formation is unknown, as the original top is not exposed and is probably not present in the study area. Considering the width of the belt of outcrop and the bedding attitudes measured, the part of the formation exposed in the quadrangle may be as great as 6,000 or 7,000 feet. This does not take into account repetition of section due to unknown structural complexity.

The formation has been found in the Spider Lake quadrangle only on the north limb of the anticlinorium east of the Munsungun Lake fault. Here it lies below Siluro-Devonian rocks to the northwest with angular unconformity. The Munsungun Lake Formation to the southeast lies conformably beneath it.

Rock Descriptions: The greatest part of the Blind Brook Formation is composed of medium gray to dark gray, laminated or very thin-bedded, pyritiferous slate. Pyrite occurs as discrete laminae one-eighth to one-fourth inch thick. Graptolites are found in the dark gray slate. In one outcrop a bed of micaceous mixed

tuff six inches thick was found. It is very similar to the mixed tuff of the Munsungun Lake Formation except that the fragments are partly crushed and attenuated as if the rock has been sheared. In addition to chlorite the matrix contains distorted sheafs or bundles of white mica up to a millimeter in length interspersed with minute speaks of sphene. Similar beds are seen in the section discussed above at Blind Brook.

An outcrop of medium gray slate and sandy slate is found on the southeast shore of Upper Island Pond. These rocks are calcareous and probably tuffaceous. These rocks are considered to be part of the Blind Brook Formation stratigraphically higher than the pyritiferous, gray slate.

Age and correlation: Three fossiliferous outcrops have been found in the Blind Brook Formation, two (BH-61-59 and BH-180-59) within the Spider Lake quadrangle and one (BH-194-59) within the Mooseleuk Lake quadrangle in the section at Blind Brook. BH-61-59 and BH-194-59 are graptolite localities from the pyritiferous, gray slate. BH-180-59 is the outcrop of tuffaceous(?) slate (tuffaceous beds cited by Neuman, 1968, p. 41) from Upper Island Pond. It contains a shelly fauna and is considered younger than the other two localities on the basis of field relationship.

Dr. William B. N. Berry has examined both graptolite collections and assigns them to his zone of *Orthograptus truncatus* var. *intermedius*. The shelly fauna (brachiopods) of BH-180-59 has been examined by Dr. Robert B. Neuman who reports that the forms present are confined to the Caradoc and Ashgill. Thus, the Blind Brook Formation is assigned to the zone of *O. truncatus* var. *intermedius* or upper Middle Ordovician, but the possibility exists that the upper part of the formation as defined may extend into the Upper Ordovician (Ashgill).

Correlation of the Blind Brook Formation with rocks in the Cupsuptic area of western Maine and the New Hampshire Ordovician section has been discussed above in the section dealing with the Munsungun Lake Formation. It seems probable that the Blind Brook is at least partly correlative with the Partridge Formation of New Hampshire. It may also be correlative with some upper part of the black slate unit of the Dixville Formation.

Graptolites of zone 13 age are present in the Beauceville Group of Quebec (Berry, 1962). The Blind Brook is then correlative with that part of the Beauceville and its southern equivalent in the Cram Hill of Vermont.

In the Weeksboro-Lunksoos Lake anticline of northern Maine the Blind Brook may be correlative with an upper part of the Wassataquoik Chert. Fragments of rock identical to the Wassataquoik and containing zone 13 graptolites have been found in overlying Ashgill conglomerates (Neuman, 1967). If the upper parts of the Blind Brook are Ashgill, they would be correlative with the Ashgill conglomerate and sandstone of the Weeksboro-Lunksoos Lake anticline.

The Carys Mills Formation of the Aroostook-Matapedia anticlinorium has yielded graptolites of zone 13 age (Pavlides, *et al*, 1961). The Blind Brook is therefore correlative with this part of the Carys Mills. Two other Ordovician units are present in the western part of the Presque Isle area. The oldest is an unnamed unit (Ovs of Boucot, *et al*, 1964) of silicic and intermediate volcanic rocks, black chert, argillite, and shale. Graptolites from black shale at the top of the unit are diagnostic of Berry's zone of *Orthograptus truncatus* var. *intermedius*. Thus, at least the upper part of the unit is correlative with the Blind Brook Formation. The lower volcanic-and chert-rich part of the section may be correlative with similar rocks in the Munsungun Lake and Bluffer Pond Formations. The unnamed unit is overlain by the Pyle Mountain Argillite which contains a possible Ashgill fauna and is presumably younger than any of the Ordovician rocks of this report.

Ordovician Sedimentary And Volcanic Rocks Undifferentiated

General: An area, of the geologic map extending from Eagle Lake northeastward to Big Pleasant Lake in the northwestern part of the map is underlain by undifferentiated sedimentary and volcanic rocks. To the south in the vicinity of Otter Brook these rocks appear to overlie rocks assignable to the Chase Lake Formation. On the southeast these rocks are overlain with probable angular unconformity by the Siluro-Devonian rocks of the Spider Lake Formation. On the northwest they are overlain by Silurian volcanics, by the Siluro-Devonian Spider Lake Formation, by undifferentiatel Ordovician-Devonian volcanics, and probably by the Lower Devonian Seboomook Formation. As on the southeast, the Siluro-Devonian rocks on the

northwest probably overlie the undifferentiated Ordovician rocks with angular unconformity.

Rock Descriptions: Rocks similar to the graywacke of the Chase Lake Formation, the basalt and dolerite of the Bluffer Pond Formation, and the tuffaceous rocks of the Munsungun Lake Formation are all present within this unit. For this reason the unit is considered equivalent to those three formations. Rocks similar to those of the Blind Brook Formation have not been seen.

Rhyolite(?) porphyry is present on Churchill Lake. Plagioclase phenocrysts are highly altered and their composition undeterminable optically.

Ordovician, Silurian, or Devonian Rocks

Ordovician Through Devonian Volcanic Rocks

General: Three areas underlain largely by volcanic rocks are shown on Plate 1 only as Ordovician through Devonian rocks undifferentiated. The three areas are: 1) from Chamberlain Lake west to Mud Pond, 2) from the vicinity of Fourth Lake northeast to the vicinity of Grant Mountain, and 3) from the vicinity of Churchill Ridge northeast to Clear Lake Mountain. These areas include volcanic rocks not assignable on a lithologic basis with confidence to any of the Ordovician or Siluro-Devonian rock units.

Rock descriptions: In the area from Chamberlain Lake west to Mud Pond volcanics similar to those in the adjacent belt of undifferentiated Siluro-Devonian volcanics and volcanics similar to the more mafic rocks of the Ordovician section are both present.

The second area extending northeast from Fourth Lake consists primarily of rocks similar to and probably part of the Carpenter Pond Formation plus scattered outcrops of volcanics similar to the Munsungun Lake Formation. Also present scattered within this belt are outcrops of light to medium gray, white-weathering soda rhyolite porphyry. Plagioclase phenocrysts determined with the universal stage are albite. The groundmass is generally microgranitic in texture.

The third area, from Churchill Lake northeast to Clear Lake Mountain consists primarily of gray to greenish-gray andesitic and basaltic volcanics. Red porphyritic dacite similar to that in the Spider Lake Formation is present on Harrow Mountain. Plagioclase phenocryst composition determined on the universal stage is sodic andesine.

Siluro-Devonian Rocks

General

In this section those rocks of Ludlow through Pridoli (Late Silurian) and/or Helderberg (Early Devonian) age are discussed. Rocks of both Silurian and Devonian age are discussed together, as Late Silurian and earliest Devonian sedimentation and volcanism are best treated as a single event in the development of the Munsungun anticlinorium. This is true in spite of the fact that Late Silurian and earliest Devonian rocks are at least locally separated by an unconformity attributable to the Salinic disturbance of Boucot (1961). In other parts of the map area sedimentation and volcanism are believed to have been continuous throughout this period of time.

The Siluro-Devonian rocks on the southeast flank of the anticlinorium are readily mapped as three formations: the Carpenter Pond Formation, the Chandler Pond Formation, and the Third Lake Formation. These three formations are herein assigned to the East Branch Group, a new name taken from East Branch Stream (Penobscot) in the southern part of the map area.

The Siluro-Devonian rocks on the northwest flank of the anticlinorium appear to be the same age and are lithologically similar to those of the East Branch Group. However, the internal stratigraphy is less well developed, and the area itself was less well studied. For these reasons the rocks have been mapped as belonging to a single formation, the Spider Lake Formation. More detailed work may in fact reveal in these rocks a stratigraphy similar to that in the East Branch Group. If so, the name Spider Lake Formation should probably be dropped and the nomenclature of the East Branch Group applied.

In addition to the Spider Lake Formation and East Branch Group small outliers of Silurian and/or Devonian rocks are found. Because of complex facies relationships these are not always assignable to the named stratigraphic units, and are referred to as various unnamed Silurian, Siluro-Devonian, or Devonian rock units. Correlation of all the Siluro-Devonian rocks of this section are discussed separately at the end of the section.

East Branch Group

In the following section on the East Branch Group the general characteristics and rock descriptions of each of the three formations are first presented, followed by a discussion of the age of the group as a whole.

Carpenter Pond Formation

General: The Carpenter Pond Formation is named herein for Carpenter Pond (T7 R11) in the Spider Lake quadrangle. Rocks typical of the formation are best exposed and most readily accessible northwest of Carpenter Pond on the Great Northern Paper Company road from Haymock to Carpenter Mountains and in the low hills immediately south of the crossing of that road with East Branch Stream.

The formation is believed to overlie the Munsungun Lake Formation with angular unconformity. It lies between the upper and lower tongues of the Chandler Pond Formation and is in part a facies of the Chandler Pond. A lower tongue of the Carpenter Pond underlies much of the Third Lake Formation, but the main body is considered to be a facies of the Third Lake (see Fig. 7). At the southwest end of its main outcrop belt it lies unconformably beneath the Seboomook Formation. These relationships are discussed more fully below in the section dealing with the age of the East Branch Group.

The thickness of the Carpenter Pond Formation is very poorly known, as few outcrops produce bedding data. The author tentatively assigns it a minimum thickness of 800 feet, recognizing that it may be considerably more and is certainly quite variable.

Rock descriptions: The Carpenter Pond Formation consists of aphanitic to medium-grained phaneritic volcanic rocks. In color they are primarily greenish-gray (5G 5/2), some value of gray, or grayish-red-purple (5RP 4/2). A very characteristic feature of most of these rocks is the presence of grayish-red (5R 4/2) hematitic material. Some of the finer-grained volcanics are locally pillowed and brecciated (probably flow breccias). Such rocks, and others without these structures, have fractures coated with the red hematitic material or, where brecciated contain fragments of volcanic rock cemented by it. Hematitic material is present in some of the volcanics as tiny (1 mm.) specks in the matrix, disseminated throughout the matrix, and, rarely, along cleavage planes in plagioclase. The decidedly greenish color plus the red hematitic material is a valuable criterion for distinguishing these rocks from the dolerites of the Munsungun Lake Formation.

The Carpenter Pond volcanics are primarily andesite with an intersertal to intergranular texture. Commonly they contain amygdules with chlorite centers and epidote (pistacite) rims.

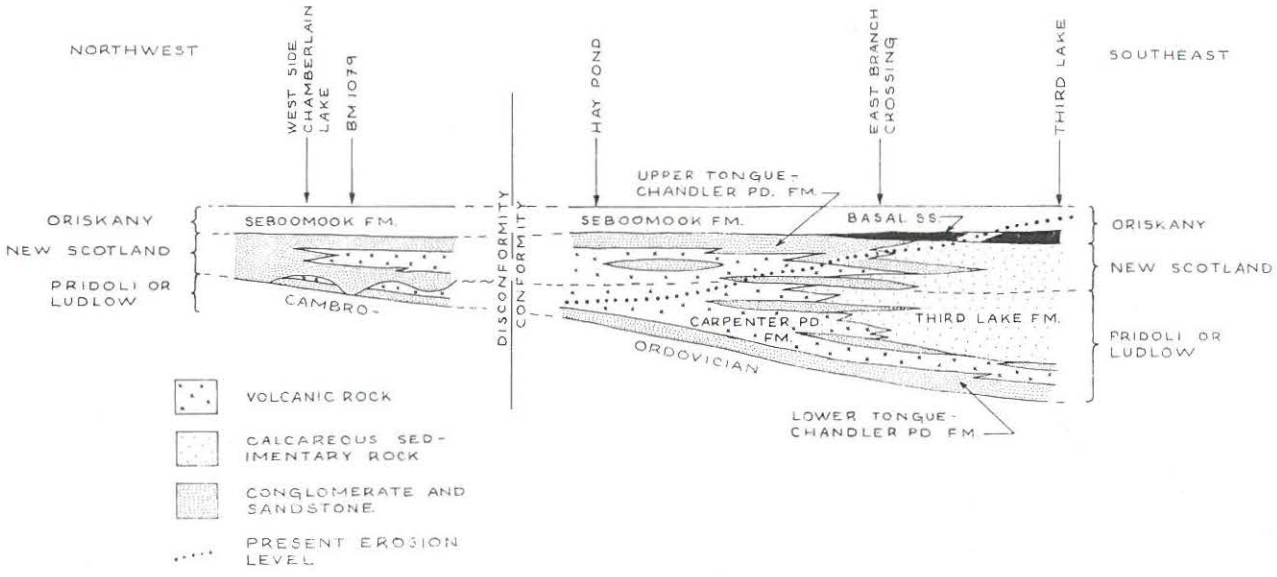


Fig 7. Diagrammatic representation of the depositional relationships of the Siluro-Devonian rocks in the southern part of the map area. Relationships within the East Branch Group from Third Lake Matagamon and northwest to East Branch Crossing and Hay Pond are shown on the right side of the diagram. Relationships at BM 1079 southeast of Woodman Pond and on the southwest shore of Chamberlain Lake are shown on the left side of the diagram.

Plagioclase composition is sodic andesine, Ab_{65}. Plagioclase laths are partially altered to sericite, chlorite, sphene, and epidote. The groundmass is chlorite, sphene plus leucoxene, epidote (pistacite), pyroxene, hematite, and trace amounts of quartz. Calcite appears as veinlets in thin section. Hematite occurs as red intergranular stains or as opaque, metallic, specular(?) intergranular masses surrounded by translucent red hematite. Only one pyroxene is present. It has the characteristics of pigeonite (colorless, 2V less than 40°). A modal analysis of a typical amygdaloidal andesite is as follows:

	BH-395-61
plagioclase	68.1%
pyroxene	5.4
calcite	0.6
chlorite	7.1
hematite	7.1
sphene plus leucoxene	3.9
epidote	7.8
quartz	Tr
	100.0%

Locally the volcanics contain greater than 10 percent quartz as phenocrysts and are dacitic in composition.

Chandler Pond Formation

General: The Chandler Pond Formation is named herein for Chandler Pond (T8 R10) in the Spider Lake quadrangle. Hall (1964, Ph.D. thesis, Yale University) designated the outcrops in and about the yard of the hunting camp on the southeastern shore of Chandler Pond as the type locality even though this particular area of outcrop is an erosional outlier. A more accessible section of the Chandler Pond lies on the first ridge north of the intersection of East Branch Stream and the Great Northern Paper Company road from Pillsbury Pond to Snake Pond (hereafter referred to as East Branch Crossing). This section is in the upper tongue of the Chandler Pond Formation and is designated the type section. The Chandler Pond consists primarily of two parts: an upper tongue and a lower tongue (see Fig. 7). The lower tongue underlies a lower tongue of the Carpenter Pond which in turn underlies the Third Lake Formation. It is thickest in the southeast and thins to possible local disappearance northwestward. The upper tongue generally overlies with apparent conformity the Carpenter Pond and Third Lake Formations. It is at least locally a facies of the Carpenter Pond and Third Lake. In the vicinity of East Branch Crossing beds of Chandler Pond-like conglomerate are found at various levels within the Third Lake Formation. These relationships will be treated more thoroughly in the section dealing with the age of the East Branch Group.

The thickness of the Chandler Pond Formation in the area southwest of Carpenter Pond is 400 feet. This appears to be a minimum, and locally the unit may be considerably thicker.

Fig. 8. Poorly sorted massive Chandler Pond conglomerate, East Branch Stream, approximately one-fourth mile northwest of Third Lake.

Rock descriptions: The Chandler Pond Formation consists predominantly of conglomerate with minor amounts of lithic sandstone and mudstone. Typically it is poorly sorted, contains angular to well-rounded clasts, and is massive with no visible bedding (Fig. 8). Locally, however, it is better sorted and bedded. The overall color is somewhat variable depending in

large part upon local variations in clast composition. The matrix is either grayish-red (5R 4/2), light gray, or near light yellow-green (5GY 8/4). The clasts are highly variable in size and composition. A wide spectrum in grain-size is present up to a maximum of about four feet. The most characteristic clast type is of grayish-red chert and cherty slate of the Munsungun Lake Formation. In addition, clasts of the various Ordovician siliceous tuffaceous rocks are nearly always present, although mafic volcanic and dolerite clasts are rare. Locally clasts of Chase Brook quartz graywacke predominate. Quartz clasts are generally present in thin-section.

The fine-grained matrix or cement of nearly all sections contains calcite, sericite, chlorite, sphene, hematite, and quartz. Some sections contain very small amounts of epidote which has the characteristics of pistacite. One section examined contained only calcite in the matrix.

Third Lake Formation

General: The Third Lake Formation is named herein for Third Lake (Matagamon – T7 R10) in the Spider Lake and Traveler Mountain quadrangles. The formation consists mainly of calcareous siltstone and impure limestone with minor amounts of other sedimentary rock types. The section that lies above a lower tongue of the Carpenter Pond Formation and below the upper tongue of the Chandler Pond Formation at East Branch Crossing is designated the type section of the Third Lake Formation. In the vicinity of East Branch Crossing the formation is approximately 800 feet thick.

The Third Lake Formation lies conformably above either a lower tongue of the Carpenter Pond Formation or the lower tongue of the Chandler Pond Formation. It is overlain with probable conformity by the upper tongue of the Chandler Pond and is at least in part a facies of the Chandler Pond and Carpenter Pond.

Rock descriptions: The main part of the Third Lake Formation consists of thin-bedded to massive, medium to dark gray impure limestone and medium gray calcareous siltstone. The impure limestone contains scattered, recognizable clasts of organic and inorganic carbonate debris set in a silt-sized or smaller clastic carbonate matrix. In addition, small (.05 mm.) angular quartz clasts appear in the matrix.

The calcareous siltstone consists of subrounded to angular quartz (and minor amounts of feldspar) clasts about .01 mm. in size set in a finer-grained matrix of calcite, sphene, sericite, chlorite, and quartz(?). Clear, euhedral muscovite laths up to .5 mm. are scattered through the matrix. In addition, the rock may contain abundant fossil debris (brachiopods, corals, stromatoporoids, crinoid columnals, trilobites) and lenses or beds of coarser-grained calcarenite composed of sand-sized organic debris. In some cases the calcarenite lenses may be allochthonous clasts and the rock a limestone conglomerate. In some exposures the larger fossils and the lenses of calcarenite weather more rapidly than the enclosing rock leaving pitted surfaces.

Besides the above two rock types which comprise the bulk of the main body of the formation, there are local beds or lenses of conglomerate similar to that of the Chandler Pond Formation, light gray calcarenite, medium gray lithic sandstone, greenish-gray (5GH 5/1) tuffaceous calcareous sandstone, and brownish-gray (5YR 4/1) fine-grained sandstone.

Tuffaceous, medium-grained sandstones consist of subrounded to angular clasts of quartz and plagioclase in a matrix of calcite, chlorite, epidote, sphene, sericite, ilmenite (marginally altered to leucoxene), quartz(?), and small (up to .5 mm.) laths of muscovite. Such rocks are often laminated and may be fossiliferous. The calcarenites and lithic sandstones have matrices similar to those of the tuffaceous sandstones. Lithic clasts are predominantly of tuff and other fine-grained volcanic rock while calcareous clasts are predominantly coarsely twinned calcite fragments with some organic debris.

Age Of The East Branch Group

A total of twenty-three fossil localities have been collected from rocks of the East Branch Group – eight from the Chandler Pond Formation and fifteen from the Third Lake Formation. Only those most pertinent to the age of the East Branch Group will be mentioned here. All are described in Appendix 1.

The critical fossil collections south of the Moose Pond fault are BH-317-61, BH-432-61, BH-37-62, and BH-300-65. The first two collections are of Pridoli age, the second two of Ludlow or Pridoli age. All four are from the Third Lake Formation, BH-432-61 being immediately above the base of the formation. Thus, in this part of the map area the Third Lake Formation

is probably all of Pridoli age. The Carpenter Pond and Chandler Pond Formations in this area are therefore Pridoli or older.

North of the Moose Pond fault the relationships are more complex and the interpretation presented here must be considered preliminary. As mapped, the Third Lake Formation extends from the vicinity of Beetle Mountain southwestward to Chamberlain Lake. Of the ten fossil collections from the main part of this outcrop belt of Third Lake Formation five of the northeasternmost collections (BH-279-61, BH-139-66, BH-140-66, BH-37-67, BH-67-67) are of Ludlow or Pridoli age. One collection, BH-62-67, is of probable Pridoli age. Of the four southeasternmost collections BH-157-66 is of Pridoli or younger age and BH-197-65 and BH-136-66 are of either Ludlow or Helderberg age. Thus, this entire belt of Third Lake Formation could be of Pridoli age or it could range in age from Ludlow or Pridoli in the northeast to Pridoli or Helderberg in the southwest. The Chandler Pond and Carpenter Pond Formations immediately north of East Branch Ridge lie beneath the Third Lake Formation and must be of Pridoli or older age.

Eight fossiliferous outcrops (BH-332-61, BH-355-61, BH-263-65, BH-130-55, BH-154-66, BH-162-66, BH-165-66, BH-52a-67) have been collected from rocks of the East Branch Group north of the above discussed main belt of Third Lake Formation. Only four of these collections yielded ages more highly resolved than Siluro-Devonian. Both BH-263-65 and BH-165-66 are probable Helderberg; BH-52a-67 is middle or upper Helderberg; and BH-355-61 is probably Pridoli but younger than most of the Pridoli corals seen by Oliver from the Third Lake Formation. BH-263-65 is from conglomerate of the Chandler Pond Formation; BH-52a-67 is from a red shelly limestone apparently beneath Chandler Pond; BH-165-66 is from limestone whose relationships to the Chandler Pond are not known; and BH-355-61 is from a lens(?) of Chandler Pond-like conglomerate and sandstone near the base of the Carpenter Pond volcanics.

Before presenting an interpretation of the sedimentary-tectonic relationships within the East Branch Group it is necessary to examine the ages and relationships of three nearby areas of Siluro-Devonian rock not included in the East Branch Group. Approximately one mile southeast of Woodman Pond conglomerate and sandstone unconformably overlie red and gray slate of the Middle Ordovician Munsungun Lake Formation (Hall, 1966b, stop 8). Fossils (BH-226-62) from near the base of this section are of New Scotland (Helderberg) age. Two other collections (BH-115-66, BH-116-66) higher in this section are probably also of Helderberg age. Southwest along strike on the north shore of Indian Pond conglomeratic reefal limestone rests with angular unconformity on the Chase Brook Formation (Hall, 1966b). Corals (BH-82-64) from this limestone are of Pridoli age but, like those at Hay Pond (BH-355-61), are probably younger than the Pridoli corals from the Third Lake Formation. On the southwest shore of the southern part of Chamberlain Lake conglomerate and coralline reefal breccia rests with angular unconformity on the Chase Brook Formation. Fossils (BH-161-62) at the base of this section are of Ludlow or Pridoli age. Approximately one mile farther southeast along this shore is an isolated outcrop of lithic conglomerate containing lenses or beds of stromatoporoid-coral breccia and large (two feet diameter) rounded clasts of conglomerate. The conglomerate clasts consist of lithic fragments in a calcarenite matrix. Corals (BH-169c-62) from the calcareous conglomerate clasts, like those from BH-82-64 and BH-355-61, are of Pridoli age and probably younger than the Third Lake Pridoli corals. On the basis of corals from the breccia lense (BH-169b-62), the lithic conglomerate itself is of latest Silurian or Helderberg age. A Helderberg age is reinforced by the Pridoli age of the older conglomerate clasts it contains and by the position of the conglomerate beneath the Seboomook Formation.

The "younger" Pridoli ages (BH-82-64, BH-355-61) of rocks resting directly on pre-Silurian "basement", the absence of a well-developed East Branch stratigraphy in these rocks, and/or the shallow water reefal nature of these rocks at Indian and Hay Ponds suggests Late Silurian transgression from southeast to northwest in this area of the map. The presence of Helderberg age conglomerate assigned to the Spider Lake Formation directly on Ordovician rock southeast of Woodman Pond and to the north on the south side of Pillsbury Pond (BH-43-61) may mean that Silurian rocks were never deposited here. On the other hand, post-Pridoli – pre-Helderberg erosion is indicated by the conglomerate (BH-169-62) on the southwest shore of Chamberlain Lake, and it may be that erosion

during this interval of time removed previously deposited rocks in the vicinity of Woodman and Pillsbury ponds. No identifiable Silurian rock is, however, seen as clasts in the conglomerate at these localities.

It is believed that the Ludlow(?) through Helderberg rocks in this part of the map area comprise a highly complex transgressive-regressive facies sequence. That the Chandler Pond is at least in part a facies equivalent of the Carpenter Pond and some of the probable Siluro-Devonian volcanics in the Ordovician-Devonian volcanic unit is attested to by fragments of the volcanics in the conglomerate and by inclusion of polymict, rounded conglomeratic Chandler Pond material in the volcanics. Lava flows, apparently originating to the north, periodically invaded the areas of nearshore marine deposition and gravel was incorporated into them. During periods of volcanic quiescence, erosion of the volcanics occurred and fragments were incorporated into the conglomerate. Locally the Chandler Pond consists of a chaotic mixture of large (up to at least four feet across) angular fragments of volcanic rock with a conglomeratic matrix. In one case an associated crinoidal and coral-rich, limy, conglomeratic lens is present. Such relationships suggest wave-cut cliffs of volcanic rock, which is consistent with the above interpretation. These relationships are shown diagrammatically in Figure 2.

In the vicinity of fossil locality BH-139-66 at East Branch crossing the East Branch Group is folded in a narrow, tight syncline with Chandler Pond conglomerate overlying Ludlow or Pridoli and Helderberg calcareous rocks with no apparent unconformity. It is suggested (see Fig. 7) that to the north, northwest, and west the section was subjected to post-Pridoli uplift and erosion of the Salinic Disturbance but that at least in the vicinity of East Branch crossing the Salinic was evidenced only by an incursion of Helderberg conglomerate from this uplifted area to the northwest.

Spider Lake Formation

General: The Spider Lake Formation is named herein for Spider Lake (T9 R11 and T9 R12) in the Spider Lake quadrangle. The formation consists predominantly of andesitic volcanic flows and pyroclastic rocks with lesser amounts of dacite(?) and sedimentary rock. No formal members are designated within the Spider Lake Formation. However, on Plate 1 basal conglomerate and sedimentary rocks within the main volcanic mass are shown. No attempt has been made on the map to differentiate the various sedimentary rock types composing the latter group. Also, these sedimentary rocks are in part shown on the map as discontinuous lenses. Although some of them so indicated are definitely lens-like, Supkow (1965, M.S. thesis, University of Maine) has demonstrated a reasonably continuous stratigraphy in the vicinity of the Soper Ponds. The basal conglomerate is lense-like or discontinuous in distribution.

The maximum thickness of the Spider Lake Formation is estimated to be about 10,500 feet. In the vicinity of Cliff Lake and Soper Ponds, Supkow estimated the main body of sedimentary rock to have a maximum thickness of 1000 feet. This separates a lower group of andesitic volcanics (3500-5300 feet) from an upper group (1100-4000 feet). The basal conglomerate varies from zero to perhaps 50 feet in thickness.

The Spider Lake Formation rests with probable angular unconformity on the Bluffer Pond, Blind Brook, and Munsungun Lake Formations.

Rock descriptions:

(1) *Volcanic rocks:* The main body of the formations consists predominantly of andesitic volcanic flows and pyroclastics with lesser amounts of dacitic(?) flows. The andesitic flows are quite varied in color with grayish-red (5R 4/2), medium gray, and greenish-gray (5GY 6/1) most common. Some are hematitic and identical to those of the Carpenter Pond Formation. Commonly the flows contain amygdules of quartz and epidote; chlorite, epidote, and calcite; or chlorite. Pillows are rare but locally present and contain epidote-rich selvages. In the non-pillowed rocks irregular epidote-rich selvages are very characteristic. Some flows contain angular fragments (up to one foot in length) of amygdaloidal rock similar to that of the containing matrix. Apparently these fragments represent solidified lava crust brecciated during flow. In some, the fragments are rounded and bomb-like in appearance and may be of pyroclastic origin. Also common are hornfelsed inclusions of gray or red siltstone, which may contain fossils (see collection 25, Appendix I). Pyroclastic equivalents are present and in some cases are more felsic in composition (Supkow,

1965). Typically the pyroclastics consist of tuff or volcanic breccia in which the finer-grained matrix consists of altered, chloritic glass shards and dark cryptocrystalline mafic volcanic fragments with plagioclase microlites set in a groundmass of calcite, sphene, and dark, opaque, cryptocrystalline material. The pyroclastics are massive to thin-bedded. Some are cross-bedded and obviously reworked, although thin-sections of the matrix indicate reworking has not been extensive. On the east-central shore of Spider Lake a massive volcanic(?) breccia of angular polymict volcanic fragments up to two feet across and of stromatoporoid debris with a tuffaceous matrix crops out.

The andesitic flows are generally porphyritic containing plagioclase, pyroxene, or biotite phenocrysts. When biotite is present, it displays all stages of resorption by hematite. Texturally the rocks are intersertal, felty, or intergranular to subophitic. Plagioclase is sodic andesine. It is almost always partially altered to chlorite, sphene, epidote, and quartz. Only one pyroxene is present and it has the characteristics of pigeonite (optically positive, 2V less than 40°). The finer-grained groundmass consists of plagioclase, chlorite, sphene, pyroxene, epidote, and ilmenite. A modal analysis of a typical andesite follows:

	BH-139-59
plagioclase	53.9%
pyroxene	12.5
chlorite	25.6
sphene	6.0
ilmenite	1.8
epidote	0.1
	99.9%

Dacitic(?) volcanics are relatively rare in the formation and are best exposed near the base of the section south of Peaked Mountain. In color they are grayish-red (5R 3/2), pale red (10R 6/2), or greenish-gray (5GY 6/1). They are flow-banded with individual bands 1 mm. or less thick. In thin-section they have a trachytic texture and are porphyritic. The phenocrysts are mostly twinned plagioclase with minor amounts of untwinned feldspar. Bands or veins of secondary(?), anhedral, granular quartz approximately 1 mm. thick, parallel the flow banding in some of the rocks.

(2) *Sedimentary rocks:* The sedimentary rocks of the Spider Lake Formation are for the most part similar to those of the Third Lake Formation, the predominant rock types being medium gray calcareous siltstone and medium dark gray to dark gray impure limestone. Calcarenite, lithic sandstone, and fine-grained brownish-gray sandstone (5GY 5/1) similar to those of the Third Lake Formation are also present.

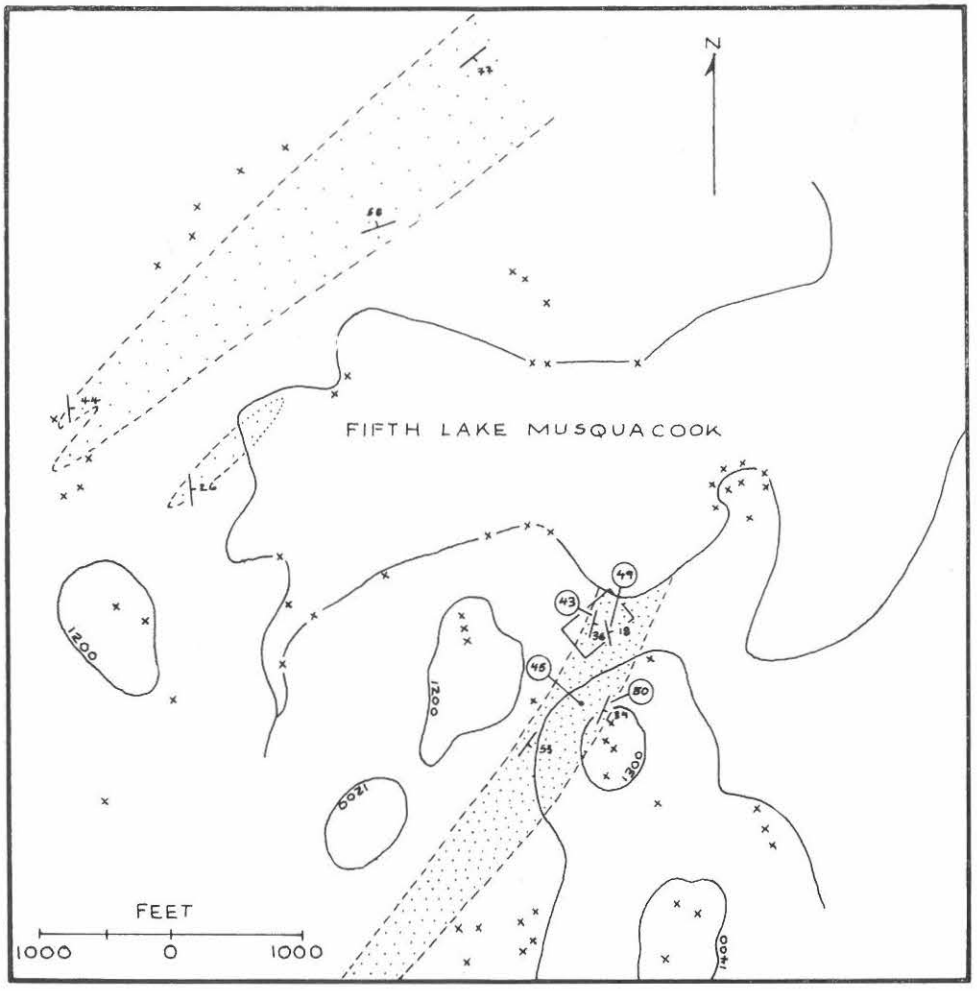
(3) *Basal conglomerate:* As noted above the basal conglomerate is thin and discontinuous. Like the conglomerates of the East Branch Group its clast composition strongly reflects the lithology of the local pre-Silurian "basement". The northernmost outcrop seen – south of Peaked Mountain – overlies the upper, less mafic part of the Ordovician section and contains clasts predominantly identifiable as having been derived from siliceous Ordovician rocks.

West and southwest of Soper Pond basal conglomerate overlies basalt and dolerite of the Ordovician Bluffer Pond Formation. Here the underlying bedrock is reflected by the presence in the conglomerate of rounded dolerite clasts up to fifteen inches in diameter. Sorting in these conglomerates is generally poor and bedding indistinct or absent on the scale of the outcrops (Supkow, 1965).

Age of the Spider Lake Formation: Twenty-three fossiliferous outcrops have been collected from what is herein designated Spider Lake Formation. Excluding the fossil localities immediately south of Fifth Lake Musquacook in the northern part of the map area, four collections (DS-1, BH-46-64, BH-70-66, BH-77-67) are definitely or probably Silurian or Ludlow-Pridoli in age and six (BH-16-59, BH-42-59, BH-71-59, BH-43-61, BH-252-62, BH-253-62) are definitely or probably Helderberg or middle or upper Helderberg in age. Thus, in this part of the map area the Spider Lake Formation is Ludlow or Pridoli through Middle or Upper Helderberg and possibly older. Mapping has not been detailed enough to establish the relationships between the Silurian and the Devonian rocks. In the vicinity of Soper Pond and Cliff Lake both Silurian and Devonian rocks may be present in the same sedimentary unit as mapped. In the vicinity of Spider Lake and Portage Pond sedimentary rock distribution within the volcanics may be more lens-like in configuration and the boundary between Silurian and Devonian rocks may lie within the volcanics. No evidence for

post-pridoli – pre-Helderberg unconformity has been discovered except for the apparent lack of fossils within that time interval.

A critical area lies immediately south of Fifth Lake Musquacook, the detailed geology of which is shown in Figure 9 and Figure 1 of Appendix I. The available information indicates a unit of calcareous sedimentary rock surrounded by andesitic volcanic rock. Seven fossil collections have been made from the calcareous unit. Six of these (BH-41a-65, BH-41b-65, BH-43-65, BH-56-66, BH-114-67, BH-115-67) are of Ludlow or Pridoli age. The seventh (BH-57-66) is structurally the youngest and is, in fact, of middle or upper Helderberg age. Furthermore, BH-57-66 is identical in its lithology to the adjacent Silurian rocks. It seems quite probable that a continuous section exists between the Silurian and Devonian rocks. No evidence, other than the possible absence of Pridoli-Middle Helderberg fossils, for an unconformity is present in these rocks. Thus, at least parts of the Spider Lake Formation may, like part of the East Branch Group have undergone continuous sedimentation and/or volcanism from Ludlow(?) through Upper(?) Helderberg times.



SEBOOMOOK FM.

CALCAREOUS SILTSTONE

OUTCROP OF VOLCANIC ROCK

FOSSIL LOCALITY-NUMBER REFERS TO APPENDIX I

Fig. 9. Geology and fossil localities in the Spider Lake Formation in the vicinity of Fifth Lake Musquacook. See Figure 1 of Appendix I for further details of area within small rectangle.

Unnamed Siluro-Devonian Volcanic Rocks

General: This group includes volcanic rocks in most respects similar to those of the Spider Lake Formation and East Branch Group. Because they are spatially separated from these two named units they are referred to neither. There is great likelihood, however, that they are erosional remnants of parts of these two named units.

The rocks are found in a belt extending from the northern part of Eagle Lake southward to Chamberlain Lake, north of Indian Pond, interbedded with sedimentary rock on the southwest shore of Chamberlain Lake (not shown separately on Plate 1) and on the northeast shore of Chamberlain Lake.

Rock descriptions: Rocks assigned to this unit are best exposed in Eagle Lake along the shore southeast of Russell Cove and on numerous islands from there southwest to Hog Island. The rock consists primarily of grayish green (5G 4/2) to medium dark gray (N4) andesitic breccia, flows, and tuff. Compositionally and texturally the rocks are like the volcanics of the Carpenter Pond and Spider Lake Formations although the coarse volcanic breccias near Russell Cove are not seen elsewhere. Plagioclase composition is sodic andesine, Ab_{62-67}.

Volcanic breccia is the most common rock type. It consists of aphanitic andesite fragments, locally amygdaloidal, up to a foot or more in longest dimension in a highly chloritic matrix containing altered glass. Crude graded bedding up to several feet thick is present in some outcrops.

Locally the rock is finer-grained, layered, and apparently tuffaceous. Pillows are also present locally and in one place (BH-39-64) contain inclusions of fossiliferous aphanitic limestone.

Age: The age of these rocks is established as Siluro-Devonian on the basis of: 1) their lithologic similarity to volcanic rocks of known Siluro-Devonian age, 2) the intimate relationship of these rocks with sedimentary rocks of known Siluro-Devonian age as on the southwest shore of Chamberlain Lake and the north shore of Indian Pond, and 3) the presence of probable Late Silurian fossils (BH-39-64) in hornfelsed limy inclusions interstitial to volcanic pillows on an island in Eagle Lake.

Unnamed Siluro-Devonian Sedimentary Rocks

General: This group includes various kinds of shallow-water sedimentary rocks spatially separated from the Spider Lake Formation and East Branch Group. Because of this they are assigned to neither of the above two named units. Moreover, they do not in themselves represent a stratigraphy matched with certainty to parts of these two rock units. Nevertheless, as with the unnamed Siluro-Devonian volcanics they must necessarily be extensions of parts of these units.

Rock descriptions: Rocks assigned to this unit are found in two areas: 1) on the north shore of Indian Pond, and 2) on the southwest shore of Chamberlain Lake. At Indian Pond the rocks consist of massive coralline limestone, probably reefal in nature. The basal part rests with visible angular unconformity on the Chase Brook Formation and is conglomeratic. At Chamberlain Lake dark gray conglomerate composed of fragments of Chase Brook Formation rests unconformably on the Chase Brook. Above the conglomerate are light gray coralline limestone, light gray-green calcareous siltstone, red siltstone, and gray calcarenite. Green andesitic volcanics are interbedded locally.

Age: Corals (BH-82-64) from Indian Pond are of Pridoli age but younger than the mass of Pridoli corals from the East Branch Formation. This relationship has been discussed above. At Chamberlain Lake corals (BH-161-62) from just above the basal conglomerate are of Ludlow-Pridoli age.

Correlation Of The Siluro-Devonian Rocks

In eastern and central Vermont the Siluro-Devonian section from bottom to top consists of the Shaw Mountain, the Northfield, and the Waits River and Gile Mountain Formations. The Shaw Mountain consists of quartzose limestone, conglomerate, and calcareous quartzite containing some greenstone. The Northfield consists of dark gray to black quartz-sericite slate or phyllite with interbeds of siltstone and silty crystalline limestone like that of the Waits River. The Waits River contains quartzose and micaceous crystalline limestone interbedded and intergradational with quartz-muscovite phyllite or schist. The Gile Mountain contains gray quartz-muscovite phyllite or schist, interbedded and intergradational with gray micaceous quartzite, calcareous mica schist, and some quartzose and micaceous crystalline limestone like that of the Waits River (Doll, 1961).

The Siluro-Devonian age of these rocks seems well-established (Cady, 1960), although more specific age assignments to individual stratigraphic units is less certain. Correlation of the Shaw Mountain with the Clough Formation (Billings, 1956) of New Hampshire has been suggested by Boucot (*et al*, 1953), although this relationship may be more complicated as shown by Boucot (1968, Table 1). Boucot and Thompson (1958) describe late Early Silurian fossils from the Clough. Cady (1960) indicates a marked lithologic resemblance between the Shaw Mountain and the Peasley Pond conglomerate in the Lake Memphremagog area of Quebec and also points out an equally strong resemblance between the Northfield and similar rocks (argillites of Cooke, 1950) in the Glenbrooke Formation above the Peasley Pond. According to Cooke (1950) these argillites are Middle or late Middle Silurian. Naylor and Boucot (1965) and Boucot (1968, Table 1) consider that the Sargent Bay and lower part of the Waits River Formations are Ludlow. The upper part of the Waits River is considered to be a facies equivalent of the Lower Devonian Gile Mountain (Doll, 1943, 1961; Naylor and Boucot, 1965; Boucot, 1968). These considerations indicate that the Spider Lake Formation, East Branch Group and other Ludlow-Helderberg rocks of the Munsungun anticlinorium are correlative with parts of the Waits River, Gile Mountain and Northfield in Vermont and with the Sargent Bay and Glenbrooke in Quebec.

As indicated above, on the east flank of the Boundary Mountain anticlinorium in New Hampshire the Clough Formation contains fossils of late Early Silurian age. The overlying Fitch Formation was assigned to the Middle Silurian by Billings (1956). Naylor and Boucot (1965) assign fossils from the Fitch to the Early Ludlow. They suggest that parts of the Fitch may be as old as Wenlock or Late Llandovery. They also suggest that the overlying Littleton Formation may be disconformable on the Fitch. Billings (1956) considers the Littleton to be of Oriskany and/or Schoharie age. Boucot (1968) indicates that fossils from the Littleton are of Schoharie age. Cady (1960) suggests correlation of the Littleton, at least in its lower part, with the Seboomook Formation (Boucot, 1961) of Maine. Griscom (1960) indicates that in the Stratton quadrangle of west-central Maine a thick sequence of gray slate and abundant sandstone beds is probably correlative with the Littleton to the west and the gray slate, i.e., the Seboomook, of the Moose River synclinorium (Boucot, 1961) to the east. Here fossils indicate that the bulk of the Seboomook is of Oriskany age, but that the lower part is of New Scotland age, and some uppermost part may be Schoharie (Boucot, 1961; *et al*, 1951; personal communication, 1968). It is thus possible that the lower part of the Littleton may be as old as Helderberg as shown by Boucot (1968, Table 2). The Spider Lake Formation, East Branch Group, and associated Ludlow-Helderberg rocks of the Munsungun anticlinorium are probably correlative with the upper part of the Fitch and possibly the lower part of the Littleton.

In the Cupsuptic area of Maine on the Boundary Mountain anticlinorium, limestone containing *Eccentricosta* is of Ludlow-Pridoli age (Boudette, U.S. Geol. Survey, 1965, p. A74; Naylor and Boucot, 1965) and correlative with parts of the Spider Lake Formation and East Branch Group.

In and near the Moose River synclinorium of Boucot (1961) two formations, the Hardwood Mountain and the Lobster Lake, are of Ludlow-Pridoli and Ludlow ages respectively. (Naylor and Boucot, 1965; Boucot, 1968, Table 1) and probably correlative with the lower parts of the Spider Lake Formation and East Branch Group. The Lobster Lake Formation (Lobster Lake series of Toppan, 1932) is found on the southeast limb of the synclinorium. It is composed of calcareous siltstone, calcareous sandstone, calcareous slate, limestone conglomerate, and limestone. At the base of the formation is the Big Claw-red-bed member containing red quartzite, red sandstone, red slate, and red conglomerate with a small amount of gray sandstone. The conglomerate is like that of the Chandler Pond Formation in that it contains a large amount (50 per cent; Boucot, 1961) of "red phyllite" and "gray and greenish felsite" derived from the underlying pre-Silurian rocks.

The Hardwood Mountain Formation on the northwest limb of the Moose River synclinorium is a "heterogeneous assemblage of fine- to medium-grained quartz- and feldspar-rich calcareous clastic rocks, with some impure limestone". It is much like the Third Lake Formation in that calcareous siltstone and mudstone form much of the unit (60%). Limestone conglomerate with pitted weathered surfaces is also present.

In the Moose River synclinorium several units of Helderberg age are reported by Boucot (1961, 1968, Table 2; *et al*, 1959). The Beck Pond Formation is a "heterogeneous assemblage of calcareous rocks" (Boucot, 1961, p. 173) including limestone, arkosic limestone, and limestone conglomerate. Stromatoporoid biostromes are present and considered by Boucot (1961, p. 165) to indicate "deposition in shallow water on a topographic high". It contains in its basal portions fossils of Late Silurian age, but Boucot suggests these may have been reworked from the Hardwood Mountain Formation. The formation contains brachiopods of New Scotland age and rests nonconformably upon pre-Silurian granitic rocks.

In the same area the lowest part of the Seboomook Formation contains brachiopods of New Scotland age (Boucot, *et al*, 1959). In addition, a fossiliferous, blue-gray limestone (Bear Pond member of the Seboomook) of New Scotland age occurs within the Seboomook near its base. Thus, the lowest part of the Seboomook (and the Bear Pond limestone member) in this area is correlative with the upper part of the Spider Lake Formation and the East Branch Group.

Although some part of the Seboomook may be correlative with the Beck Pond limestone, other parts are disconformable upon it. Boucot (*et al*, 1959) feels that the Beck Pond was deposited on a Lower Devonian topographic high while Seboomook slate was being deposited in nearby depressions. Depositional encroachment of the Seboomook finally covered the Beck Pond limestone and adjacent basement complex with disconformable and angularly unconformable relations respectively.

The Parker Bog Formation (Boucot, 1961) occurs on the southeast limb of the Moose River synclinorium. It is about 200 feet thick and consists of interbedded light gray limestone and white-weathering, flinty, waterlaid tuff containing marine fossils. Boucot (1968, Table 2) assigns the unit to the Middle and Upper Helderberg, and it is, therefore, correlative with parts of the Spider Lake Formation and East Branch Group.

The Hobbstown Formation (Boucot, 1961) occurs on the northwest limb of the Moose River synclinorium. It is approximately 1,500 feet thick and consists primarily of interbedded coarse-grained arkose and conglomerate with poorly rounded pebbles and cobbles. Boucot reports it is of Late Silurian to Early Devonian age on the basis of stratigraphic position between the Hardwood Mountain and Seboomook, but further work (Boucot, personal communication) has produced fossils suggestive of a New Scotland age. Thus, it is probably, at least in part, correlative with the Spider Lake Formation and East Branch Group.

Southeast of the main axis of the Moose River synclinorium on and about Moosehead Lake are the Whiskey Quartzite and the Capens Formation (Boucot, 1961). The former lies conformably or disconformably upon the latter and below the Seboomook Formation. The Whiskey Quartzite consists of coarse-grained and conglomeratic quartzite containing approximately eighty per cent quartz. It is about 200 feet thick. The Capens Formation is red slate, green slate, and conglomerate and is 200 to 400 feet thick. No diagnostic fossils have been found in either, and Boucot refers both to the Silurian or Early Devonian. They may be partly or wholly correlative with the Spider Lake Formation and East Branch Group.

Northeast of the Moose River synclinorium in the Chesuncook Lake area Ordovician(?) rocks are overlain with angular unconformity by Silurian rocks (Willard, 1945; Boucot, 1954, 1968; Griscom, 1966). The Silurian section consists of a basal hematite-stained quartz conglomerate and sandstone. This is overlain by quartz sandstone, sandy limestone, limestone, and limestone conglomerate. Andesitic lava flows lie at the top of the unit near Ripogenus Dam (Griscom, 1966). Fossils dated by Boucot from the calcareous part of the unit in the vicinity of Chesuncook Lake range in age from Late Llandovery to Ludlow (Erinakes, 1967). Calcareous sandstone interbedded with the volcanic flows are like those in the underlying sedimentary section and suggest that the flows are also of Silurian age (Griscom, 1966). The upper part of this section is correlative with the lower parts of the Spider Lake Formation and East Branch Group.

In the Weeksboro-Lunksoos Lake anticline of northern Maine Siluro-Devonian rocks are found on both the northwest and southeast limbs (Neuman and Rankin, 1966; Neuman, 1967). The rocks of the northwest limb are better understood, and only those will be treated here. From bottom to top the Silurian through Helderberg section consists of the following five unnamed units (Neuman, 1967): 1) conglomer-

ate, sandstone, siltstone and slate of Upper Llandovery (C_4-C_5) age; 2) calcareous siltstone and fine-grained sandstone of Late Llandovery or Wenlock age; 3) reefal limestone of Wenlock or Early Ludlow age; 4) calcareous siltstone of Early Ludlow age; 5) and intermediate to mafic tuff, breccia, and flows(?) of Late Silurian or Early Devonian age. The volcanic rocks and the uppermost unit of calcareous siltstone are at least in part correlative with the Spider Lake Formation and the East Branch Group.

On the west flank of the Aroostook-Matapedia anticlinorium in the Presque Isle area the Carys Mills Formation of the Meduxnekeag Group grades upward conformably into the Spragueville Formation (Pavlides, 1965b). The upper formation, the Burnt Brook, of the Meduxnekeag is not present in this area. The youngest fossils from the Carys Mills are early to middle Llandovery (zone 19; Pavlides and Berry, 1966). The Spragueville ("unnamed Silurian limestone" of Boucot, *et al*, 1964) is of Late Llandovery (C_3-C_5) age (Boucot, *et al*, 1964; Pavlides, 1965). This unit is the nubbly limestone of White (1943) and consists of silty gray limestone in thin beds separated by very thin argillaceous layers.

In the western part of the Presque Isle area the Carys Mills is overlain with possible unconformity by the Frenchville Formation of Late Llandovery (C_4-C_5) age (Boucot, *et al*, 1964). The Frenchville consists primarily of fine-grained, feldspathic sandstone interbedded with conglomerate and small amounts of shale.

Conformably above the Frenchville and Spragueville Formations is the Perham Formation (Boucot, *et al*, 1964). It contains an upper member of siltstone, shale, and limestone breccia and a lower member of argillite with manganese- and iron-rich lenses. Fossils from the upper member are of early Ludlow age (Boucot, *et al*, 1964; Naylor and Boucot, 1965). The lower member is of probable Wenlock age (Naylor and Boucot, 1965).

Rocks of the Dockendorff Group overlie the Perham Formation with probable unconformity. Boucot and Johnson (1967) assign these rocks to the upper Helderberg. The Dockendorff Group is a complex assemblage of andesite, trachyte, rhyolite, graywacke, shale, and slate. This unit plus the upper member of the Perham Formation are probable correlatives of the Spider Lake Formation and the East Branch Group.

Devonian Rocks

Rocks treated in this section are those of the Seboomook Formation and a unit of unnamed Lower Devonian conglomerate and sandstone.

Unnamed Devonian Conglomerate

Conglomerate and other sedimentary rocks of Early Devonian age are found in two isolated outcrop areas beneath the Seboomook Formation. Their relationships to the Seboomook or rocks of the nearby East Branch Group are not precisely known, and they are, therefore, treated separately.

The first area is located approximately one mile southeast of Woodman Pond in the vicinity of Bench Mark 1079 (Hall, 1966b, stop 8). This section rests with visible angular unconformity on red slate of the Middle Ordovician Munsungun Lake Formation. It consists from bottom to top of a thin rubble zone of fragmented Ordovician red slate, green or gray conglomerate, calcirudite consisting mainly of crinoidal debris, red and gray fossiliferous medium-grained sandstone and siltstone. Three fossil collections (BH-226-62, BH-115-66, BH-116-66) indicate a New Scotland age for the basal parts of the section and a Helderberg age for the upper parts. These rocks are discussed further above in the section dealing with the age of the East Branch Group.

The second outcrop is also discussed above in the section dealing with the age of the East Branch Group. It is located on the southwest shore of the southern part of Chamberlain Lake and consists of lithic conglomerate containing lenses of stromatoporoid-coral breccia and large rounded conglomerate clasts. Fossils (BH-169b-62) from the stromatoporoid-coral breccia date the outcrop as possible Helderberg age. The conglomerate clasts are of Pridoli age. This outcrop may be part of the basal sandstone member of the Seboomook Formation.

Seboomook Formation

General: The name Seboomook slate was first used by Perkins (1925, p. 376) and, although Perkins did not formally designate a type sec-

tion, it is clear he considered the interbedded sandstones and "dark bluish" slates about Seboomook Dam as typical. The name "Seboomook" has since found acceptance with geologists working in west-central and northwestern Maine, but the unit is now known as the "Seboomook Formation". Boucot (1961, p. 169) designates a formal type section "on the road and shore at the east end of Seboomook Lake (North East Carry and Seboomook Lake quadrangles) and on the Penobscot River (North East Carry quadrangle) for about a mile downstream from Seboomook Dam".

Rocks mapped as Seboomook Formation in the area of this report are considered so for the following reasons. First, they are lithologically similar to the type Seboomook. Second, they are continuous with the type Seboomook as mapped in reconnaissance by Boucot (*et al*, 1960) and as shown by Doyle (1967). Third, they are in the correct gross stratigraphic position.

In the map area the Seboomook Formation is the youngest unit present. The top of the formation has been removed by erosion to some unknown depth, and the thickness, therefore, is unknown.

Rock descriptions:

(1) *Main part of the formation:* According to Boucot (1961, pp. 169-70) the Seboomook Formation consists typically of "cyclically layered dark sandstone and slate" with blue-gray fresh surfaces, gray weathered surfaces, and layers fractions of an inch to several feet thick. In several places the unit is conglomeratic at the base. According to Boucot the thickness is as much as 20,000 feet. In the Spencer quadrangle the upper part of the Seboomook contains conformable(?) bodies of greenstone (Camera Hill greenstone member of Boucot, 1961).

Throughout much of its outcrop area the Seboomook Formation consists of interlaminated to very thin interbedded (cyclical) dark gray, calcareous very fine-grained sandstone and dark gray slate. Weathered surfaces are light gray. Sandstone comprises less than fifty per cent of the rock. One isolated outcrop of red slate near Peaked Mountain Pond may be from the basal portion. Red slate is basal to the Seboomook Formation in the Fish River Lake area (Boone, personal communication).

Local variations in what is mapped as Seboomook are present. The Seboomook in the syncline extending northeast from Chamberlain Lake toward Little Indian Pond is in general more coarse-grained and consists of laminated two to twelve inch beds of gray siltstone and fine-grained sandstone. Some more typical Seboomook is also present.

On the southern end of Telos Lake beds of fine- to medium-grained brown or gray, fossiliferous sandstone up to several feet thick are present. The sandstone locally contains cross-bedding and ripple marks.

(2) *Basal sandstone member:* A basal sandstone member of the Seboomook is mapped principally in the vicinity of the Arm of Chamberlain. It is best exposed on the north shore of the Arm of Chamberlain Lake on the point of land between the Arm and the west side of the cove at the mouth of the large unnamed brook (stop 4 of Hall, 1966b). Here it overlies Cambrian(?) red and green phyllite and is conglomeratic at the base containing cleaved fragments of the Cambrian(?) rock. Similar conglomerate is seen farther up in the section in beds up to about six feet thick. Typically the unit consists of one to six inch laminated beds of gray, calcareous micaceous fine-grained sandstone with thinner siltstone interbeds. Cross-bedding is common.

Age and correlation: Four fossil collections (BH-178-62, BH-191-62, BH-153-66, BH-5-63) were made from the Seboomook. Of these, the first three contained diagnostic fossils and indicate an Oriskany age. Thus, the main mass of the Seboomook in this area, including the sandstone beds of Telos Lake, appears to be of Oriskany age. No fossils have been found in rocks unequivocally belonging to the basal sandstone member, although the isolated outcrop (BH-169-62) of Helderberg(?) conglomerate in the Devonian conglomerate unit on the southwest shore of Chamberlain Lake may be part of the basal sandstone member. If so, the Seboomook as here defined is Helderberg in its lower part and a probable facies equivalent of the upper parts of the Spider Lake Formation and East Branch Group.

As indicated earlier, the Seboomook in the Moose River synclinorium ranges in age from New Scotland (middle Helderberg) through Oriskany. As indicated above correlation of at least the lower part of the Littleton Formation of New Hampshire with the Seboomook is sug-

gested by Cady (1960) and Griscom (1960). A further correlation of the Gile Mountain Formation of Vermont with the Littleton of New Hampshire is suggested by Cady (1960). It is thus probable that the Seboomook of the Munsungun anticlinorium is at least in part correlative with the Littleton and the Gile Mountain.

In the Moose River synclinorium the upper, Oriskany part of the Seboomook and its Oriskany (Boucot and Johnson, 1967) facies equivalent (Boucot, 1961), the Tarratine Formation, are correlative with the Seboomook around the Munsungun anticlinorium. The lower part of the Seboomook containing the late Helderberg Bear Pond limestone member may also be correlative.

In the Chesuncook Lake area rocks mapped as Seboomook by Griscom (1966) contain fossils of Oriskany age. At Soubunge Mountain these rocks are overlain by sandstone also of Oriskany age (Griscom, 1966; Boucot and Johnson, 1967; Boucot, 1968). The sandstone is in turn overlain by quartz latite lava and ash flows. The Seboomook and the sandstone at Soubunge Mountain are correlative with the Seboomook of this report.

West of the Weeksboro-Lunksoos Lake anticline in the vicinity of Matagamon Lake and Traveler Mountain, rocks containing fossils of Early Devonian age are designated Seboomook by Rankin (1965), Rankin and Neuman (1966), and Neuman (1967). Rankin (1965), considers the Matagamon Sandstone to be of Oriskany age (Boucot and Johnson, 1967) and a facies of the Seboomook. Both of these units are correlative with at least the upper part of the Seboomook in the Munsungun anticlinorium. Quartz latite on Traveler Mountain conformably overlies the Matagamon Sandstone and is probably correlative with the Early Devonian felsite at Soubunge Mountain in the Chesuncook area and the Kineo Rhyolite in the Moose River synclinorium (Rankin, 1960, 1968; Griscom, 1966). The quartz latite of Traveler Mountain is unconformably overlain by the Trout Valley Formation of Dorf and Rankin (1962) which has been discussed in an earlier section of this paper.

Pleistocene Geology

Evidence of Pleistocene glaciation is present in the map area in the form of ice erosional features and glacial deposits. The former consist of bedrock striations and grooves and ice-

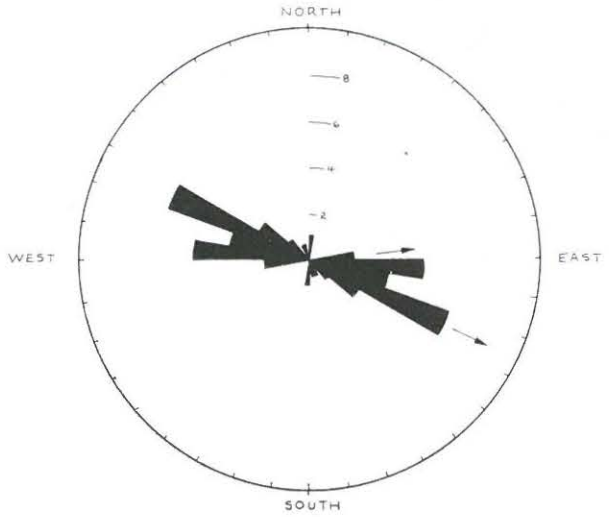


Fig. 10. Glacial ice movement in the Munsungun anticlinorium as determined from bedrock grooves and striae, and ice moulded bedrock knobs; 25 measurements, of which 8 indicate west to east direction of ice movement.

sculptured bedrock knobs with lee and stoss features. Figure 10 indicates that the direction of ice movement was predominantly S 75° E. Lee and stoss features associated with bedrock knobs and grooved outcrops indicate ice movement was from northwest to southeast. One exception was found on a small island in Carpenter Pond, where bedrock grooves indicate movement from the southwest to the northeast. This probably reflects local movement in this direction at the base of the ice in a pre-Wisconsin valley of similar orientation. On the south shore of the Arm of Chamberlain Lake striations trending N 85° E are cut by a later set trending N 65° W (Hall, 1966b, stop 1).

The most widespread glacial deposits in the map area are till, which blanket the area at nearly all elevations. In addition, outwash sands and gravels are present along the length of the Portage Pond – Sewall Deadwater – Chase Lake – Munsungun Lake valley system. Apparently this valley system was a distributary for glacial melt-water and outwash during deglaciation. Outwash northwest of Sewall Deadwater indicates that drainage probably was not through the valley now containing Echo Lake but through the next valley north of Echo Lake. In the lower part of the valley system, at Munsungun Lake, outwash sands and gravels now stand about ten feet above the present lake surface. Furthermore, on the east side of the lake at the mouth of Norway Brook is a small

delta containing foreset bedding. The top of the delta is approximately at the same elevation as the tops of outwash remnants along the margin of the lake in other areas. An interesting feature is the depth of Munsungun Lake, 122 feet, in parts of the lake adjacent to the outwash remnants. It does not seem possible that these deep portions of the lake could have been previously filled with outwash, as this would necessitate removal of the outwash from depths below the elevation of the outlet of the lake itself, which is bedrock floored, and, thus, constitutes a temporary base level for Munsungun Lake. A possible explanation is that the deeper portions of Munsungun Lake contained stagnant blocks of glacial ice around which outwash was deposited. Later melting of the ice left the marginal outwash remnants adjacent to the deeper, once ice-filled parts of the lake.

Structure

General

The map area as a whole is anticlinorial. Pre-Silurian rocks are exposed in a central anticline which trends about N 45° E and plunges to the southwest. It extends from the vicinity of Eagle Lake and Indian Pond northeastward through Munsungun Lake and out of the map area. Smaller anticlines exposing pre-Silurian rocks are present to the northwest and southeast of the central anticlinal axis. The complex anticlinal area in the vicinity of East Branch Ridge probably continues to the southwest in the vicinity of Mud Pond.

Northeast along strike of the map area pre-Silurian rocks are exposed in an anticline extending from Clayton Lake to Carr Pond (Doyle, 1967) and in the Pennington and Portage anticlines of the Fish River Lakes area (Pavlides, *et al*, 1964). This anticlinorial belt comprises the Munsungun anticlinorium (Hall, 1966a).

Presumably, the Munsungun anticlinorium attained its present configuration during the Acadian orogeny, as Silurian and Devonian rocks are folded by it and its axis parallels the strike of the Acadian axial-plane cleavage. Siluro-Devonian rocks, however, indicate that at least part of the anticlinorium was a topographic high during Siluro-Devonian deposition. This suggests in turn that the anticlinorium may have been prefigured to some unknown degree by Salinic and Taconic deformation.

Folding

Folds and cleavage attributed to Acadian deformation are present in rocks of all ages in the Munsungun anticlinorium. These folds trend approximately N 40° E and plunge either NE or SW at about 20°. Typically the folds are open, although locally they are isoclinal or nearly so.

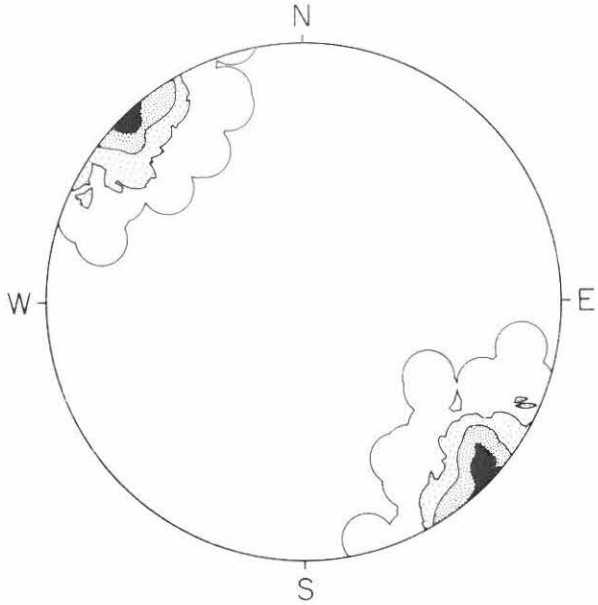


Fig. 11. Poles to 94 cleavage planes. Maximum: 22% per 1% area; contours: 1.1%, 5.3%, 11.7%, 18.1% per 1% area.

Except in the Cambrian(?) rocks only one cleavage has been observed in the map area. It is axial plane to the above folds and is considered, therefore, to have been formed during the Acadian orogeny. This cleavage is best developed in the more argillaceous sedimentary rocks and some of the tuffaceous volcanic rocks. Coarser-grained and more massive sedimentary rocks and the volcanic rocks in general do not contain a well-developed cleavage. Poles to cleavage plane from all stratigraphic units, primarily in the Spider Lake quadrangle, are plotted in Figure 11. The diagram indicates

that cleavage has a predominant N 45° E strike and a vertical dip. The strike ranges about 30° on either side of N 45° E, and dips may be less than vertical but very rarely less than 60°.

Northwest trending folds locally affect the Siluro-Devonian rocks. One such fold can be seen in the map pattern of Plate 1 in the vicinity of Upper Moose Pond. Steeply plunging minor folds trending northwest are seen rarely in outcrop. In one case a northwest trending fold was seen to deform the northeast striking Acadian cleavage. Thus, these folds postdate the main Acadian folding. They may only represent a slightly younger phase of the Acadian or may be considerably younger.

The evidence for Taconic deformation in this area has been previously enumerated (Hall, in press). It consists of: (1) the presence in the Silurian Chandler Pond Formation of clasts of rock representative of nearly all the Cambrian(?) and Middle Ordovician formations, (2) dolerite and gabbro intrusive into the Cambro(?)-Ordovician section but not the Siluro-Devonian section, (3) the presence immediately beneath the Siluro-Devonian rocks of different Cambrian(?) and Ordovician formations in different parts of the map area, and (4) angular discordance of approximately 50° between rocks of the Munsungun Lake Formation and Lower Devonian conglomerate south of Haymock Lake (Hall, 1966b, stop 8). Although the time span represented by the unconformity south of Haymock Lake is such that it could be attributed to the post-Ludlow-pre-New Scotland Salinic disturbance, this does not seem likely. No evidence has been found to suggest that Salinic folding of this magnitude took place. Minor folds or cleavage that are not attributable to the Acadian have not been seen in the Ordovician rocks. This indicates that Taconic folding was broad and open and not intense enough to produce cleavage.

The evidence for post-Cambrian(?)-pre-Middle Ordovician deformation (Penobscot disturbance of Neuman and Rankin, 1966) is both stratigraphic and structural. Conglomerate at or near the base of the Chase Lake Formation on Chase Lake contains slate clasts similar to slate in the underlying Chase Brook Formation. The structural evidence consists of contrasting structural styles of the Cambrian(?) and Middle Ordovician rocks. The Chase Brook Formation and other Cambrian(?) rocks in the vicinity of the Arm of Chamberlain Lake display complex, isoclinally folded strata locally laced with quartz stringers, a style not seen in younger rocks of comparable lithology. In addition, a highly penetrative micaceous foliation is present in the Cambrian(?) rocks and folded by Acadian minor folds containing the regional axial plane cleavage (Hall, 1966b, stop 2). The early foliation is axial plane to more northerly trending pre-Acadian minor folds. It is much more penetrative than the Acadian cleavage but is not seen in Ordovician rocks where the Acadian cleavage is present. The Penobscot deformation appears to have been considerably more intense than the Taconic and probably the Acadian. This deformation probably occurred late in the Cambrian or early in the Ordovician (Hall, in press).

Faulting

A number of faults, inferred from offset or termination of stratigraphic units, are shown on Plate 1. Such faults are probably much more common than indicated. The majority of the faults, such as the Munsungun Lake fault and the Haymock Lake fault, strike about N 50° W. Several faults, including the Moose Pond fault and the Sly Brook fault, strike about N 70° E.

Of the northwest trending faults, one of the most significant, the Munsungun Lake fault, is inferred to extend through Munsungun and Chase Lakes, Sewall Deadwater, and probably to the northwest across the Ordovician-Devonian unconformity. Evidence for or against offset of the unconformity is lacking, as outcrops are not present in critical areas along the extension of the fault. The Munsungun Lake fault could as well be shown on the geologic map as cutting the tongue of Seboomook that extends southwestward into the northern part of the map area, for the rather wide belt of Seboomook outcrops seems to terminate abruptly.

The presence of the Chase Brook Formation only on the northeast side of the fault and the apparent lack of major horizontal displacement of the units cut indicate that movement on the fault was primarily dip-slip with the northeast side up. The attitude of the fault plane itself is not known. As the Chase Brook Formation, whose probable minimum thickness is 2,500 feet, is exposed only on one side of the fault, the minimum displacement is about 2,500 feet.

Although control is generally poor, offset on some of the other northwest trending faults

suggests southwest-side-up dip-slip movement or wrench-fault movement as in the case of the Haymock Lake fault.

The northeast trending Moose Pond fault and Sly Brook fault are not seen in outcrop and their attitudes and nature are speculative. The slight differences in sequence across these faults along their lengths suggests they are not trans-current. The stratigraphy across the Moose Pond fault suggests the south side has moved up relative to the north side. The same relationship holds for the southwest end of the Sly Brook fault. Stratigraphy across the northeast end of the Sly Brook fault suggests that the south side moved down relative to the north side, although control here is particularly poor.

Two faults striking roughly parallel to the Moose Pond fault are believed to bound the small inlier of Chase Brook and Chase Lake Formations to the east of Big Reed Pond. The more northerly of these has south side up; the other, north side up. The northernmost (and possibly the Moose Pond fault) may be a thrust fault, the sliver of Chase Brook and Chase Lake Formations having been forced up between the Ordovician rocks on both sides. This interpretation is strengthened by a pronounced scarp on the northeast side of Munsungun Lake in the Millinocket Lake quadrangle. The scarp strikes more nearly east-west than do the faults under discussion but separates rocks of the Munsungun Lake Formation from rocks of the Chase Brook Formation to the south. Reconnaissance to about three miles south of this scarp has turned up nothing but Chase Brook Formation.

Thus, at least two distinct sets of faults are present. The first set strikes northeast and is probably post-Early Devonian in age. The cutting of the first by the second is indicated by the areas of Chase Brook Formation west of the Munsungun Lake fault which is much smaller than the area east of it (in the Millinocket Lake quadrangle).

Geologic History

The Munsungun anticlinorium contains one of the most complete and well-dated Paleozoic sections in the highly volcanic part of the northern Appalachians. It, thus, affords an excellent opportunity to reconstruct the geologic history and paleogeography as it developed in this part of the Appalachian geosyncline during the Paleozoic. In addition, the rocks record a remarkable tectonic history of vertical movement during the Paleozoic.

The oldest unit, the Cambrian(?) Chase Brook Formation, consists of non-fossiliferous slate with minor amounts of thin-bedded siltstone and limestone, which suggests deposition in rather deep, relatively quiet water, presumably marine. The additional presence of abundant large blocks of both graywacke and cross-bedded calcareous siltstone suggests that the area of Chase Brook deposition was adjacent to a shallower area(s) from which the blocks were transported by gravity. The presence of microcline and abundance of quartz in these graywackes distinguishes them from all other rocks in the quadrangle and indicates a granitic or crystalline metamorphic (perhaps Precambrian) provenance, not available later.

The 2,500 feet of Cambrian(?) rocks records an initial(?) minimal subsidence of 2,500 feet plus the unknown depth of water present at that time. The unconformity between the Chase Brook and Chase Lake Formations, and the conglomerate in the basal part of the Chase Lake, record post-Chase Brook – pre-Chase Lake emergence and erosion as a result of the Penobscot disturbance in Late Cambrian or Early Ordovician time. A minimum of 2,500 feet of uplift is indicated.

Following the deformation, emergence, and erosion of the Cambrian(?) rocks, the area was submerged in the Middle Ordovician (Porterfield), and deposition of the Chase Lake, Bluffer Pond, Munsungun Lake, and Blind Brook Formations ensued at least into the uppermost part of the Middle Ordovician (Trenton in the sense of Cooper, 1956). Deposition was for the most part in deep water as suggested by the presence of a graptolitic rather than a shelly fauna and the presence of interbedded gray slate and graded graywacke beds. The presence in some of the graded graywacke of comminuted shell debris (brachiopods, gastropods, bryozoans, pelecypods(?), crinoid stems) indicates an adjacent area(s) of shallower water, perhaps volcanic islands as further suggested

by the volcanic debris in the graywackes and pyroclastics in the upper three formations.

The volcanic flows and pyroclastics of the Bluffer Pond and Munsungun Lake Formations indicate that a part of Middle Ordovician time in this area was highly volcanic. Furthermore, it seems probable that the volcanics are part of a major volcanic axis in the eugeosynclinal zone of the Northern Appalachians including the Ammonoosuc volcanics of New Hampshire and perhaps extending as far south as Connecticut along the Bronson Hill anticlinorium, for the Middletown Formation of eastern Connecticut is lithologically similar to and may be correlative with the Ammonoosuc (Rodgers, *et al*, 1959). Whether the volcanic rocks in a similar stratigraphic position (volcanics in the Cram Hill and the Bolton lavas) on the west limb of the Connecticut Valley – Gaspé synclinorium connect at depth beneath the synclinorium with those in New Hampshire and Maine is not definitely known. Currier and Jahns (1941) indicate that the thickness of the Cram Hill averages about 1,700 feet, of which only a part is volcanic. Billings (1956) indicates that the Ammonoosuc in New Hampshire is from 2,000 to 5,000 feet thick and Harwood and Berry (1967) indicate that volcanics in the Dixville Formation in west-central Maine are on the order of 7,500 feet thick. The Bluffer Pond and Munsungun Lake together are about 9,000 feet thick. The Vermont-Quebec volcanics appear in general to be thinner than the volcanics of the Bronson Hill-Boundary Mountain-Munsungun anticlinorial belt. Correlation of the Middle Ordovician rocks of the Munsungun anticlinorium with the non-volcanic Meduxnekeag Formation farther to the east in Maine indicates a rapid and apparently complete facies change in that direction. Also, in the Presque Isle area, unnamed Middle Ordovician volcanics, chert, and argillite are mapped (see Boucot, *et al*, 1964, Plate 1) two miles west of the Meduxnekeag Formation. The volcanic unit has a maximum thickness of 4,000 feet, of which only a part is volcanic. Thus, volcanics in the Northern Appalachians are thickest along a belt coincident with the Bronson Hill-Boundary Mountain-Munsungun anticlinorial belt, from Connecticut to the Pennington anticline of the Fish River Lake area in northern Maine.

The probable deep-water nature of the slate and graywacke of the Chase Lake Formation has been mentioned above, and a similar environment is suggested for the Bluffer Pond and Munsungun Lake Formations by the presence of chert, mudstone, and slate and a graptolite fauna. The Blind Brook Formation on the other hand contains large amounts of pyrite which is consistent with deposition in restricted, perhaps shallow-water, basins. In addition, abundant non-comminuted brachiopods in the upper part of the formation are in keeping with a more shallow-water environment. Thus, whereas a major portion of the Middle Ordovician rocks may have been deposited in a deep-water environment, the latest Middle Ordovician depositional environment was one of shallower water.

Regardless of the depth of water at the time of deposition, the thickness of Middle Ordovician rocks in the area requires subsidence of more than 18,000 feet after the post-Chase Brook emergence. Subsequent to the deposition of the Middle Ordovician rocks, the area was subjected to the Taconic orogeny and probably assumed an anticlinal configuration. No slaty cleavage or other metamorphic effects are known to have been developed at this time. This event requires uplift of more than 18,000 feet as clasts of Chase Brook Formation rocks are present in basal Silurian conglomerate.

Erosion followed Taconic deformation, and deposition was not resumed until Ludlow time when the shallow-water, clastic, carbonate, and volcanic rocks of the East Branch Group (2,000 feet thick) and Spider Lake Formation (10,500 feet) were deposited. During the deposition of the East Branch Group and the Spider Lake Formation, the deformed Ordovician rocks along at least the southern part of the axis of the Munsungun anticlinorium acted as an emergent area, upon which the various lithologic facies of the group onlapped. To the southeast in the Weeksboro-Lunksoos Lake anticline Lower and Upper (?) Silurian rocks are present, but the southern part of the Munsungun anticlinorium was not submerged at this time.

The onset of Siluro-Devonian deposition marked a striking change from the Ordovician and older graywacke, slate, chert, and mudstone containing graptolite faunas to shallow-water clastics and carbonates containing abundant shelly faunas. Thus, whereas the Siluro-Devonian rocks are highly volcanic and, therefore, eugeosynclinal by definition, the associated sedimentary rocks are atypical of the assemblage conventionally considered eugeosynclinal and reflect a major change in depositional environ-

ment which accompanied the Taconic orogeny.

Upper Silurian onlap took place from Ludlow(?) into Pridoli time and was then interrupted locally by Salinic uplift. The amount of uplift is difficult to estimate but was probably not great. A figure of 500 feet is used here. Following the Salinic which probably took place during latest Silurian and/or lower Helderberg (Coeymans-Manlius) time, middle and upper Helderberg onlap of the upper parts of the East Branch Group and Spider Lake Formation covered the southern end of the anticlinorium.

Along strike to the southwest of the Spider Lake quadrangle near the New Hampshire-Maine boundary, Boucot (1961), and Albee (1961) report that Upper Silurian conglomerate, reefal material, etc., occur above pre-Silurian rocks on the east side of the Boundary Mountain anticlinorium. The presence of fossil "seacliffs and seastacks" indicates that the pre-Silurian rocks were emergent during "much of the Late Silurian and Early Devonian". On the west side of the anticlinorium Lower Devonian slate rests directly on the pre-Silurian rocks. The absence of Silurian rocks here is attributed by Albee to the onlap of Lower Devonian slate over Silurian rocks now at depth beneath the slate. This interpretation is identical to that proposed for the Munsungun anticlinorium, except that in the latter area Salinic erosion locally preceded Early Devonian onlap. Deposition of the East Branch Group and Spider Lake Formation require at least 10,500 feet of subsidence.

The last stage in the Siluro-Devonian depositional history was attained when perhaps as much as 5,000 feet of the offshore slate and siltstone facies, Seboomook Formation, finally onlapped over its possible earlier facies equivalents, the East Branch Group and Spider Lake Formation. Subsequent to this the rocks were deformed and uplifted in the Acadian Orogeny. Evidence presented above indicates that the Acadian produced the metamorphic effects and principal cleavage now displayed by the rocks of the map area. Acadian uplift of the East Branch Group, Spider Lake Formation, and Seboomook Formation require a minimum vertical movement of 15,500 feet. This figure, plus uplift figures of 2,500 feet for the Penobscot disturbance, 18,000 feet for the Taconic orogeny, and 500 feet locally for the Salinic disturbance total 36,500 feet. This figure in turn added to the maximum estimated thickness of the entire section, 36,000 feet, indicates a minimum vertical movement during the Early Paleozoic of 72,500 feet.

At least two distinct periods of faulting are recorded in the rocks of the Munsungun anticlinorium. The earliest is represented by northeast-trending faults. The second is represented by northwest-trending faults of unknown dip. These strike at nearly 90° to the earlier faults and cut them. Both sets are considered to be post-Early Devonian in age.

Appendix I

Location and Description of Fossil Collections from the South End of the Munsungun Anticlinorium

In the following fossil collection descriptions the last name of the worker responsible for each faunal list and age designation is indicated in parentheses beside the museum number or locality number under which that part of the collection has been described by the paleontologist concerned.

Museum number and locality number abbreviations are as follows:

UCMP = University of California Museum of Paleontology
USGS = United States Geological Survey Locality Number
USNM = United States National Museum Locality Number

When no number is listed the worker indicated has used the fossils of the museum number when available next above.

The names of these workers are as follows:

William B. N. Berry
Arthur J. Boucot
Robert B. Neuman
William A. Oliver, Jr.
Lawrence V. Rickard
Ellis Yochelson

In addition, occasional parathetical notes in the faunal lists indicate that a specimen was sent to one of the following persons or that a specimen is similar to one from the field area of one of the following persons:

G. Arthur Cooper
Pierre Lesperance
A. Lee McAlester
Eli Mencher
Harry Whittington

Age designations where quoted directly from reports are so indicated. Where not in quotes, age designations have been abstracted by the author from reports by the paleontologist indicated above.

Fossil collections are numbered consecutively in the Appendix and keyed to Plate I.

1. Collection BH-9-59
   ROCK UNIT: Spider Lake Formation.
   LOCATION: Outcrop in main Great Northern Paper Company road several hundred yards north of its crossing with Ledbetter Stream.
   FAUNAL LIST AND AGE:
   USNM 11367 (Boucot)
   rostrospiroid brachiopod
   (?) Siluro-Devonian

2. Collection BH-16-59
   ROCK UNIT: Spider Lake Formation.
   LOCATION: First outcrop of sedimentary rock on south side of main Great Northern Paper Company road approximately two miles south of its crossing with Portage Ponds Stream.
   FAUNAL LIST AND AGE:
   USNM 11366 (Boucot)
   Kozlowskiellina sp.
   Leptaena "rhomboidalis"
   Levenea? sp.
   Middle or upper Helderberg

3. Collection BH-25-59
   ROCK UNIT: Spider Lake Formation.
   LOCATION: Sedimentary inclusion within andesitic flow on north side of main Great Northern Paper Company road approximately 100 yards west of Collection BH-27-59.
   FAUNAL LIST AND AGE:
   USNM 11359 (Boucot)
   orthotetacid
   Siluro-Devonian

4. Collection BH-27-59
   ROCK UNIT: Spider Lake Formation.
   LOCATION: Road metal quarry in red reefal material on north side of main Great Northern Paper Company road approximately 300 yards north of its crossing of northeast corner of T8 R12.
   FAUNAL LIST AND AGE:
   USNM 11368 (Boucot)
   "Camarotoechia" sp.
   (?) Silurian
   USGS 6513-SD (Oliver)
   Lyrielasma annulatum? USGS Bull. 1111 A., p. 10.
   Clathracoilona sp. (several fragments) This genus is considered Devonian by Calloway
   Favosites? sp.
   Thamnopora sp. (common)
   Initially (12/10/59) reported as Helderberg, correlative with the Beck Pond Limestone.
   Later correspondence (2/27/67) indicates that there is question as to whether Ludlow and Helderberg can be distinguished on the basis of *Lyrielasma*.
   The collection is here considered to be Ludlow or Helderberg.

5. Collection BH-42-59
   ROCK UNIT: Spider Lake Formation.
   LOCATION: Outcrop of impure limestone at spring approximately 200 feet south of cabins on south shore of Spider Lake.
   FAUNAL LIST AND AGE:
   USGS 6514-SD (Oliver)
   Lyrielasma annulatum? (Poorly preserved but probably the same species as in collection BH-27-59).
   Aknisophyllum consuitum?
   Helderberg age, correlative with the Beck Pond limestone.
   USNM 11365 (Boucot)
   Strophonella? sp.
   "Schuchertella" sp.
   Platyorthis sp.
   Ambocoelia? sp.
   Dalejina? sp.
   Leptaena "rhomboidalis"
   Helderberg

6. Collection BH-61-59
   ROCK UNIT: Blind Brook Formation.
   LOCATION: Logging road approximately 1 mile southwest of west end of Island Pond.

FAUNAL LIST AND AGE:
UCMP B7433 (Berry)
Amplexograptus macer (Ruedemann)
Climacograptus spiniferus Ruedemann
Climacograptus typicalis J. Hall
Dicellograptus sp.
Dicranograptus cf. *D. hians* T. S. Hall
Dicranograptus nicholsoni Hopkinson
Orthograptus truncatus aff. var. *intermedius* (Elles and Wood)
Orthograptus aff. *O. Pageanus* (Lapworth)
Orthograptus sp.
The collection is diagnostic of Berry's graptolite zone 13 *(Orthograptus truncatus* var. *intermedius).* It is fairly typical of the graptolite assemblages from the Canojoharie shales, which are Trenton (in the sense of Cooper, 1956) in age.

7. Collection BH-71-59
ROCK UNIT: Spider Lake Formation.
LOCATION: Large outcrop on southeast side of logging road between Spider and Big Pleasant Lakes. Approximately ¾ mile from Spider Lake.
FAUNAL LIST AND AGE:
USNM 11369 (Boucot)
Strophonella sp.
Levenea? sp.
Dalejina sp.
pterinoid clam
Platyorthis sp.
Leptaena "rhomboidalis"
Pholidops sp.
"Uncinulus" sp.
"Schuchertella" sp.
Dicaelosia sp.
Kozlowskiellina sp.
Skenidium sp.
Middle or upper Helderberg

8. Collection BH-109-59
ROCK UNIT: Spider Lake Formation.
LOCATION: Intersection of main Great Northern Paper Company road with branch road to Cliff Lake.
FAUNAL LIST AND AGE:
USNM 11363 (Boucot)
Oriostoma? sp.
Howellella sp.
pelecypods
Calymene sp.
Silurian

9. Collection BH-180-59
ROCK UNIT: Blind Brook Formation.
LOCATION: Outcrop between logging road and southeast corner of Upper Island Pond.
FAUNAL LIST AND AGE:
USGS 4089-CO (Neuman)
"Although fossils were abundant in this rock, they have been deformed nearly to obliteration. I found only one specimen whose features are sufficiently characteristic to permit a determination; it is ventral valve like that of *Diambonia* or *Bilobia.* Only delicate features of the dorsal valve permit distinction between these, but both of these genera are confined to the Middle and Upper Ordovician (Caradoc and Ashgill)".

10. Collection BH-194-59
ROCK UNIT: Blind Brook Formation.
LOCATION: Approximately 150 yards north of intersection of main Great Northern Paper Company road and Blind Brook.
FAUNAL LIST AND AGE:
UCMP B7432 (Berry)
Amplexograptus macer (Ruedemann)
Climacograptus spiniferous Ruedemann
Climacograptus typicalis J. Hall
Climacograptus typicalis n. var. aff. var. *crassimarginalis* Ruedemann and Decker
Cryptograptus tricornis (Carruthers)
Dicranograptus cf. *D. hians* T. S. Hall
Dicranograptus nicholsoni Hopkinson
Diplograptus n. sp. aff. *D. edenensis* Ruedemann
Glyptograptus? sp.
Orthograptus aff. *O. pageanus* (Lapworth)
The collection is diagnostic of Berry's zone 13. It is fairly typical of the graptolite assemblages from the shales, which are Trenton (in the sense of Cooper, 1956) in age.

11. Collection BH-49-60
ROCK UNIT: Chase Lake Formation; slate-graywacke member.
LOCATION: Type outcrop of the slate-graywacke member of the Chase Lake Formation. Outcrop on point of land at south end of Chase Lake.
FAUNAL LIST AND AGE:
Sample discarded (Neuman)
The rock contains an abundance of comminuted shell debris, but nothing identifiable.

12. Collection BH-50-60
ROCK UNIT: Chase Lake Formation; conglomerate-graywacke member.
LOCATION: Type outcrop of the conglomerate-graywacke member of the Chase Lake Formation. Only outcrop on east shore of Chase Lake. Point of land between Chase and Currier Brook outlets.
FAUNAL LIST AND AGE:
No number (Boucot)
pleurotomarian
sowerbyellid? sp. indet.
operculum?
pelecypod?
Probably Middle Ordovician on the basis of a possible sowerbyellid and some pleurotomarian gastropods.
USGS 6280-CO (Neuman)
"In addition to the . . . sowerybellid identified by Boucot, the collection yielded several other scraps of brachiopods; one of these is punctate and has branching ribs, suggesting that it is a dalmanellid". The brachiopods can be no older than Porterfield.
USGS 6280-CO (Yochelson)
bellerophontacean gastropod, indet.
raphistomatid? pleurotomariacean gastropod
pleurotomariacean gastropods, indet, (2 or more genera)
"The gastropods are poorly preserved and are inadequate for age determination. A specimen which was identified as an operculum (probably of an oriostomatid gastropod) is indicative of Silurian or Devonian. However, I am not convinced that this is after all an operculum. Scraps of pleurotomariacean gastropods suggest to me a mid-Ordovician age, but in view of the inadequacy of the material I would not hold to this opinion if it is in the slightest conflict with the stratigraphic data or age opinion derived from the study of other fossils".

No number (Berry)
Glossograptus hincksii (Hopkinson)?
Hallograptus? n. sp.
" . . . the material is very poorly preserved . . . and . . . indicative of a Middle Ordovician age. It indicates an age in the span of the *Paraglossograptus etheridgei* into the *Climacograptus bicornis* – or possibly even the *Orthograptus truncatus intermedius* zones. The correlative shelly fossil stages are the latter part of the Whiterock into the Trenton." An earlier report by Berry indicated that the collection is probably older than BH-64-60 and BH-177-60 (both *C. bicornis* zone) on the basis of the probable *Hallograptus*.

13. Collection BH-56-60

ROCK UNIT: Chase Lake Formation; undivided.
LOCATION: East bank of Chase Brook approximately 2 miles from its mouth in Chase Lake.
FAUNAL LIST AND AGE:
USGS 6279-CO (Neuman)
Glyptorthis sp.
Skenidioides sp.
Rhynchotrema s. 1. sp.
Sowerbyella sp.
Dalmanella sp.

There are, in addition, numerous unidentifiable fragments of brachiopods, trilobites, and portions of bryozoan zoaria.

"The most diagnostic fossils for dating purposes are the *Rhynchotrema* s. 1. (the features that would permit distinction of *Rhynchotrema* from *Lepidocyclus* are not preserved) and the *Dalmanella*. In North America these genera appear in Late Wilderness time (= lower Trenton). The The assemblage is probably no older than this, but it could be somewhat younger".

14. Collection BH-64-60

ROCK UNIT: Munsungun Lake Formation.
LOCATION: On Norway Brook approximately 1 mile from its mouth in Munsungun Lake.
FAUNAL LIST AND AGE:
No number (Berry)
Amplexograptus? sp.
Climacograptus bicornis (Hall)
Climacograptus eximius Ruedemann
Climacograptus phyllophorus Gurley
Corynoides incurvus Hadding
Cryptograptus? sp.
Dicellograptus intortus Lapworth
Dicellograptus sextans (Hall)
Dicellograptus sextans var. *exilis* Elles and Wood
Dicranograptus ramosus
Didymograptus sp.
Didymograptus n. sp.
Glossograptus sp.
Glyptograptus euglyphus (Lapworth)
Hallograptus bimucronatus (Nicholson)
Hallograptus mucronatus (Hall)
Nemagraptus exilis var. *linearis* Ruedemann
Nemagraptus sp.
Orthograptus calcaratus var. ?
Orthograptus whitfieldi (Hall)
Retiograptus genitzianus Hall

Zone of *Climacograptus bicornis*—Wilderness age.

15. Collection BH-43-61

ROCK UNIT: Spider Lake Formation.
LOCATION: Outcrop in logging road on south shore of Pillsbury Pond.
FAUNAL LIST AND AGE:
USNM 11361 (Boucot)
Leptostrophia ? sp.
orthotetacid
Leptaena "rhomboidalis"
dalmanellid
rhynchonellid
schizophorid
Stropheodonta ? sp.
Unidentified
Howellella ? cf. *cyclopterus*

Middle or upper Helderberg if the *Howellella* cf. *cyclopterus* is correctly identified.

16. Collection BH-162-61

ROCK UNIT: Bluffer Pond Formation.
LOCATION: Several hundred yards east of intersection of north branch of Bluffer Brook and town line between T8 R10 and T8 R11.
FAUNAL LIST AND AGE:
No number (Berry)
" . . . . collection BH-162-61 doesn't have anything diagnostic in it. It may be the same as BH-177-61, but I'm not sure". BH-177-61 is of zone 12 age.

17. Collection BH-177-61

ROCK UNIT: Bluffer Pond Formation.
LOCATION: Intersection of Ragged Pond-Island Pond trail with first brook north of intersection of trail and Ragged Pond Brook.
FAUNAL LIST AND AGE:
No number (Berry)
Climacograptus bicornis
Climacograptus bicornis var. *peltifer*
Climacograptus eximius
Climacograptus modestus
Climacograptus phyllophorus
Cryptograptus tricornis
Dicellograptus intortus
Dicellograptus sextans
Glyptograptus sp.
Glyptograptus euglyphus var. *pygmaeus*
Hallograptus sp.
Hallograptus bimucronatus
Orthograptus calcaratus var. *acutus*
Orthograptus calcaratus var.? *acutus*

Zone of *Climacograptus bicornis*.

18. Collection BH-279-61

ROCK UNIT: East Branch Group; Third Lake Formation.
LOCATION: Outcrop at Maine Forestry Service wharf on north shore of Upper Moose Pond.
FAUNAL LIST AND AGE:
USNM 11360 (Boucot)
Lissatrypa? sp.
Merista sp.
Atrypa "reticularis"
Leptaena "rhomboidalis"
Strophonella? sp.
Gypidula sp.
Isorthis sp.
Nucleospira sp.
Mesodouvillina sp.
Dalejina sp.
orthotetacid
Cypricardinia sp.

Silurian, probably Ludlow or Pridoli. The occurrence of *Lissatrypa* is most critical.

19. Collection BH-317-61

ROCK UNIT: East Branch Group; Third Lake Formation.

LOCATION: Outcrops at cabin on north shore of Third Lake Matagamon.

FAUNAL LIST AND AGE:

USNM 11364 (Boucot)

Nucleospira sp.
Mesoleptostrophia
Atrypa reticularis
Eccentricosta sp.
Strophonella euglypha
Amphistrophia cf. *funiculata*
Dolerorthis cf. *hami*
trilobite
Ferganella sp.
Delthyris sp.
Gypidula sp.
Plectodonta? sp.
Resserella sp.
Dalejina sp.

Pridoli on the basis of *Eccentricosta*.

USGS 6525-SD (Oliver)

Tabulate corals
Cladopora? sp.
Favosites sp.
Halysites sp.
Heliolites sp.
Syringopora sp.

Rugose corals
Cystiphyllum sp.
Disphyllum sp.
Entelophyllum sp.
Rhizophyllum sp.
Tryplasma? sp.

Definitely Silurian, probably Ludlovian but possibly Wenlockian. Several genera indicate that the collection is not pre-Wenlock or post-Ludlow. *Rhizophyllum* is apparently limited to the Ludlow in Western Europe, but occurs in the Brownsport formation of Tennessee which may be as old as Wenlock.

USGS 7597-SD (Oliver)

Cladopora sp.
Favosites intermittens Stumm
Halysites sp.
Heliolites sp.
Cystiphyllum sp.
Rhizophyllum sp.

"This list is incomplete; many additional forms are present and most of these could be identified to species. This is more than enough, however, to recognize the Late Silurian (Ludlow) fauna typical of the Cobleskill Ls., N. Y., the Hardwood Mountain and Lobster Lake Fms., Maine, and the Mt. Wissick Fm., Quebec . . . . "

20. Collection BH-332-61

ROCK UNIT: East Branch Group; Chandler Pond Formation.

LOCATION: Ridge of Chandler Pond conglomerate between Carpenter Pond and East Branch Stream.

FAUNAL LIST AND AGE:

USGS 6523-SD (Oliver)

"Innumerable fragments of a small branching tabulate coral referable to *Cladopora* are present in the conglomerate. The genus ranged through the Silurian and Devonian and is common in rocks of both ages. Theoretically the corals could have been derived from a Silurian rock and buried in a Devonian one, but the specimens, although broken, show little sign of wear, and I would guess that they were living during the time of conglomerate deposition or shortly before.

The only fossils seen other than the *Cladopora* fragments were crinoid stems."

21. Collection BH-355-61

ROCK UNIT: East Branch Group; Carpenter Pond Formation.

LOCATION: Approximately 200 feet from central part of south shore of Hay Pond.

FAUNAL LIST AND AGE:

USGS 6603-SD (Oliver)

Cladopora sp.
Favosites intermittens (Stumm)
Undetermined horn coral

Almost certainly Silurian and probably Ludlow. This collection may be somewhat younger than the mass of Ludlow corals studied by Oliver (but older than Helderberg). See discussion under Collection BH-82-64.

22. Collection BH-432-61

ROCK UNIT: East Branch Group; Third Lake Formation.

LOCATION: 100 feet northwest of north end of most northerly cove on Third Lake Matagamon.

FAUNAL LIST AND AGE:

USNM 11362 (Boucot)

Eccentricosta sp.
rhynchonellid
Conchidium ? sp.

Pridoli on the basis of *Eccentricosta*.

23. Collection BH-440-61

ROCK UNIT: Chase Lake Formation; conglomerate-graywacke member.

LOCATION: Approximately 1/2 mile southwest of northern tip of Chase Lake.

FAUNAL LIST AND AGE:

USGS 4099-CO (Neuman)

"Fossils are mostly small, fragmentary, and accordingly, largely indeterminate. *Glyptorthis* and *Hesperorthis* are present. Although these genera occur through the upper two-thirds of the Ordovician, my guess that this rock is older than BH-180-59 is based on the absence of genera that are common in younger well-dated rocks, and on the lithic similarity of this rock to that of Chase Lake (BH-50-60) and Chase Stream (BH-56-60) seen previously".

24. Collection BH-37-62

ROCK UNIT: East Branch Group; Third Lake Formation.

LOCATION: Approximately 1/3 mile southwest of the small unnamed pond north of the northeast end of Snake Pond.

FAUNAL LIST AND AGE:

USNM 11357 (Boucot)

Gypidula sp.
Atrypa "reticularis"
Strophonella sp. (coarse-ribbed)
Coelospira sp.
Dicaelosia sp.
Resserella sp.
orthotetacid
Isorthis cf. *I. arcuaria*
rhipidomellid
Amphistrophia sp.

tetracorals (to Oliver)
Cypricardinia (to McAlester)
trilobite (to Whittington)
new genus stropheodontid ?
Ludlow or Pridoli.

25. Collection BH-134-62

ROCK UNIT: East Branch Group; Chandler Pond Formation.

LOCATION: Northeast side of northwest trending cove (T7 R11) on northwest shore of the Arm of Chamberlain Lake.

FAUNAL LIST AND AGE:

USGS 6552-SD (Oliver)

indeterminate stromatoporoid
pycnactid horn corals

"My best guess is Upper Silurian because of the pycnactids, but I've had difficulty before in differentiating between some Wenlock and Helderberg forms so a safer range is Wenlock, Ludlow or Helderberg".

USNM 11473 (Boucot)

Coelospira sp.
Amphistrophia sp. (coarse ribbed)
Isorthis sp.
Dolorthis sp.

Late Wenlock (C_3) or Ludlow, or Pridoli.

26. Collection BH-161-62

ROCK UNIT: Reefal breccia in undifferentiated Siluro-Devonian sedimentary rocks.

LOCATION: Southwest shore of Chamberlain Lake at intersection with a S20°W bearing from Nugent's camps on northeast shore.

USGS 7879-SD (Oliver)

The faunal list for BH-161-62 and five other collections contained in this Appendix are presented below in Table 1 (In the table, the Stumm species were described from Maine in U. S. Geol. Survey Prof. Paper 430. The Swartz species from the lower Keyser in the Maryland Lower Devonian volume).

27. Collection BH-169a-62

ROCK UNIT: Lithic conglomerate from undifferentiated Siluro-Devonian sedimentary rock.

LOCATION: Prominent east jutting point on southwest shore of Chamberlain Lake at intersection of shore with S50°W bearing from northeast corner of T6 R6 WELS.

FAUNAL LIST AND AGE:

Collection discarded (Oliver)

". . . . granule conglomerate containing fragments of *Cladopora*. Coll. 169a-62 contains fragments of a massive stromatoporoid in addition. The fossils could be derived from Silurian or Devonian rocks since *Cladopora* and massive stromatoporoids are common elements in both the Ludlow and Helderberg coral faunas in Maine."

28. Collection BH-169b-62

ROCK UNIT: Stromatoporoid breccia within conglomerate of BH-169a-62.

LOCATION: Prominent east jutting point on southwest shore of Chamberlain Lake at intersection of shore with S50°W bearing from northeast corner of T6 R6 WELS.

FAUNAL LIST AND AGE:

USGS 7885-SD (Oliver)

Faunal list is given in Appendix Table 1. This collection contains *Lyrielasma* plus a type of *Favosites* that Oliver believes to be limited to the Ludlow. Geologically BH-169b-62 must be younger than BH-169c-62 below. Because of these relationships, Oliver states in a later report, "I slightly prefer Ludlow but if it is younger than 169c then it is most likely latest Ludlow or Helderberg."

Appendix Table 1. Faunal list and ages of fossil collections BH-161-62, BH-70-66, BH-140-66, BH-133-66, BH-169b-62, and BH-139-66.

	BH-161-62 USGS 7879-SD	BH-70-66 USGS 7882-SD	BH-140-66 USGS 7883-SD	BH-136-66 USGS 7884-SD	BH-169b-62 USGS 7885-SD	BH-139-66 USGS 7886-SD
Massive stromatoporoid	X				X	X
Cystihalysites sp.						X
Cladopora sp.	X		?			X
Favosites sp. cf. *F. intermittens* Stumm	X	X	?		X	X
F. sp. cf. *F. favosus integritabulatus* Swartz		X				
Heliolites interstinctus occidentalis Stumm			X			
Cantrillia? sp.	X					
Cystiphyllum sp. cf. *C.* sp. A Stumm	X		X			
Lyrielasma sp.	X		?	X	X	?
Spongophylloides sp.			X			
Syringaxon? sp.			X			
Tryplasma nordica Stumm	X	?	?			X

All of the above collections probably belong to the Cobleskill coral fauna. BH-136-66 contains only *Lyrielasma* and its age must be questioned. Oliver (2/27/67) indicates that there is some question as to whether he can separate the Ludlow and Helderberg on the basis of *Lyrielasma* alone. BH-169b-62 contains *Lyrielasma* plus a type of *Favosites* that Oliver believes is limited to the Ludlow. The other collections are almost certainly Ludlow. An earlier collection accidentally mixed with collections from BH-46-64 and BH-82-64 is not reported on.

29. Collection BH-169c-62

ROCK UNIT: Blocks of limy conglomerate within conglomerate of BH-169a-62.

LOCATION: Prominent east jutting point on southwest shore of Chamberlain Lake at intersection of shore with S50°W bearing from northeast corner of T6 R6 WELS.

FAUNAL LIST AND AGE:

USGS 7881-SD (Oliver)

This collection contains only one specimen of a rugose coral whose age is considered to be Ludlow but younger than the mass of Ludlow studied by Oliver. For further details, see the discussion under collection BH-82-64, page 56.

No number (Boucot)

"As far as I could gather from the scanty material, you are most likely dealing with a Ludlow occurrence owing to the presence of a Gypidulinid. There also appear to be a possible *Meristina* and a possible Rhynchonellid."

30. Collection BH-178-62

ROCK UNIT: Seboomook Formation.

LOCATION: Outcrop in third cove west of large point 1¾ miles southwest of Telos Dam.

FAUNAL LIST AND AGE:

USNM 11354 (Boucot)

Schuchertella sp.
Meristella sp.
Leptocoelia flabellites
Beachia sp.
Acrospirifer cf. *A. murchisoni*
Dawsonelloides canadensis
Leptostrophia sp.
trilobites (to Whittington)
Edriocrinus sp.
Camarotoechia sp.
Dalejina sp.
Hipparionyx sp.
gastropods
Leptaena "rhomboidalis"
rhynchonellid

Tarratine equivalent, Oriskany age. Characterized by *Beachia* and *Leptocoelia flabellites.*

31. Collection BH-191-62

ROCK UNIT: Seboomook Formation.

LOCATION: Southwest end of island in Round Pond between Telos and Chamberlain Lakes. Island is 1500 feet in S45°E direction from Maine Forestry Service cabin on north shore of Round Pond.

FAUNAL LIST AND AGE:

USNM 12464 (Boucot)

crinoid (to Cooper)
Salopina jacksoni
Leptocoelia flabellites
Platyceras sp.
Dawsonelloides canadensis
Leptostrophia sp.

Tarratine equivalent, Oriskany age; evidenced by the presence of a *Leptocoelia flabellites* and *Dawsonelloides canadensis,* known elsewhere in Maine only in beds of Tarratine age.

32. Collection BH-223-62

ROCK UNIT: Bluffer Pond Formation.

LOCATION: East side of main Great Northern Paper Company road approximately 2 miles north of its crossing of Pillsbury Stream.

FAUNAL LIST AND AGE:

No number (Berry)

Climacograptus cf. *C. modestus* Ruedemann
Climacograptus eximius Ruedemann
Climacograptus phyllophorus Gurley?
Climacograptus scharenbergi Lapworth?
Climacograptus sp.
Corynoides calicularis Nicholson?
Dicellograptus sp.
Dicranograptus contortus Ruedemann
Glyptograptus sp.

Berry indicates that the collection belongs in the interval of his zones 11 and 12 but that it is slightly older than collections BH-64-60 and BH-177-61. He further states that it is, " . . . . probably *Nemagraptus gracilis* Zone – as no large climacograptids, orthograptids, dicranograptids, or dicellograptids have as yet come from this locality, I favor assignment of the beds there to the *N. gracilis* Zone rather than the next younger Zone, that of *Climacograptus bicornis,* although I can't be sure of this assignment."

33. Collection BH-226-62

ROCK UNIT: Devonian conglomerate and sandstone.

LOCATION: Outcrops in main Great Northern Paper Company road approximately 2½ miles south of outlet of Haymock Lake.

FAUNAL LIST AND AGE:

USGS 7600-SD (Oliver)

Favosites spp.
Thamnoporoid
Briantelasma mainense Oliver

"This collection is Helderberg in age as indicated by several specimens of *B. mainense* previously described from the Beck Pond Limestone. Fragments of 2 or 3 other rugose corals are present. On the assumption that they are of the same fauna I could put names on them but this would be misleading. The Helderberg age must rest on the *Briantelasma* only."

USNM 11358 (Boucot)

Leptostrophia sp.
Protomegastrophia sp.
orthotetacid
rhynchonellid
favositid (to Oliver)
dalmanellid

Possibly Helderberg. *Leptostrophia* and *Protomegastrophia* are more like Helderberg than Silurian forms.

A latter collection from this locality follows.

USNM 12144 (Boucot)

rhynchonellid
Mesodouvillina sp. = *Protomegastrophia* of USNM 11358 above.

"Collection BH-226-62, which was looked at previously, this time yielded some more definite information. It certainly is of Devonian age and most likely New Scotland. A shell I previously identified as *Protomegastrophia* should now be reinterpreted as *Mesodouvillina. Mesodouvillina* is a genus which has not been seen elsewhere below the Devonian in the world."

34. Collection BH-252-62

ROCK UNIT: Spider Lake Formation.

LOCATION: Outcrop in branch road to Portage Pond from main Great Northern Paper Company road. Approximately 250 yards east of Warden Service cabin on shore of Portage Pond.

FAUNAL LIST AND AGE:
USNM 11355 (Boucot)
Megakozlowskiellina sp.
Meristella sp.
Strophonella cf. *punctulifera*
Dalejina? sp.
Levenea? sp.
Leptaena "rhomboidalis"
Nucleospira sp.
orthotetacid
Craniops sp.

Middle or upper Helderberg.

35. Collection BH-253-62
ROCK UNIT: Spider Lake Formation.
LOCATION: Northwest side of outlet of Soper Pond.
FAUNAL LIST AND AGE:
USNM 11356 (Boucot)
Orthostrophia cf. *strophomenoides*
dalmanellid
tetracoral (to Oliver)

Probable middle to upper Helderberg.

36. Collection BH-2-63
ROCK UNIT: Spider Lake Formation.
LOCATION: 100 feet west of a point in main Great Northern Paper Company road 1300 feet northeast of its crossing of outlet of Haymock Lake.
FAUNAL LIST AND AGE:
USNM 17018 (Boucot)
Dalejina sp.

Silurian or Devonian age, C_2 or younger.

37. Collection BH-5-63
ROCK UNIT: Seboomook Formation.
LOCATION: 300 feet northeast along main Great Northern Paper Company road from intersection with road to Indian Pond. Southeast side of road.
FAUNAL LIST AND AGE:
USNM 12140 (Boucot)
Acrospirifer? sp.
Dawsonelloides canadensis
Salopina? sp.
leptostrophid
Leptocoelia flabellites

Becraft-Oriskany age, Tarratine equivalent.

38. Collection BH-8-64
ROCK UNIT: Chase Lake Formation.
LOCATION: Outcrops on logging road between Cliff Lake and thoroughfare between Churchill and Eagle Lakes. 3,800′ S80°E from mouth of Otter Brook.
FAUNAL LIST AND AGE:
USGS 4546-CO (Neuman)
Dalmanella sp.
new genus aff. *Leptellina*
Sowerbyella sp.

"There are also several fragments of indeterminate orthid and rhynchonellid brachiopods, bryozoans, and a heliolitid coral.

The assemblage suggests an early Caradocian or Trenton age."

A later report indicates, " . . . the addition of two brachiopod genera to the list — *Nicolella* and *Catazyga*. These suggest a somewhat younger age than I had indicated earlier, probably younger Caradoc or perhaps Ashgill. But the few specimens in this collection are hardly enough to give confidence to any interpretation".

39. Collection BH-39-64
ROCK UNIT: Limestone inclusions in volcanic flow of Silurian volcanic unit.
LOCATION: Eagle Lake. Small island approximately halfway between Hog and Farm islands.
FAUNAL LIST AND AGE:
USNM 11129 (Boucot)
Merista sp.
n. gen. spiriferoid, relationships uncertain
rhychonellid
dalmanellid

Most likely Ludlow or Pridoli. Boucot has seen *Merista* from Maine only in beds of Ludlow or Pridoli age.

40. Collection BH-46-64
ROCK UNIT: Spider Lake Formation.
LOCATION: Smith Brook approximately 4000 feet below deadwater divides into two branches. From dividing point locality is approximately 1400 feet on northwest flowing branch on northeast bank.
FAUNAL LIST AND AGE:
USGS 8104-SD (Oliver)
massive stromatoporoid
Cladopora sp.
Favosites intermittens
F. sp.
Heliolites sp. cf. *H. interstinctus*
Thamnopora sp.

This collection is considered by Oliver to be Silurian and probably Ludlow. However, the collection was accidentally mixed with material from several other collections (BH-82-64 and BH-161-62) and subsequently separated on the basis of lithology. A later collection is reported on below, and corresponds well with this one.

No number (Oliver)
Massive stromatoporoids (4 or more spp.)
Labechiid stromatoporoid
Cladopora sp.
Favosites intermittens Stumm
Favosites spp. (3 or more spp.)
Heliolites sp. (apparently not the one described by Stumm)
Thamnopora sp.

"This is certainly pre-Devonian and probably either Ludlow or Pridoli. Only two rugose coral fragments were found; one may be *'Columnaria' coraliferum*, the other a cystimorph, but I was unable to get a longtitudinal section of either and they cannot be safely listed as part of the fauna. The whole aspect of the collection is that of the Hardwood Mountain or Mount Wissick except that the characteristic rugose corals and *Cystihalysites* are lacking.

I consider this Silurian, rather than Devonian, because 1. *Heliolites* has not previously been found in the eastern Devonian, 2. because labechiid stromatoporoids are very rare above the Silurian and 3. because several of the tabulates seem to be conspecific with other forms known to be in the late Silurian fauna of this area. The downward range of the species is not really known but it seems unlikely to me that so many species would range up very far. So, on these somewhat tenuous grounds I would consider the corals to be post-Wenlock and pre-Devonian."

41. Collection BH-82-64
ROCK UNIT: Siluro-Devonian sedimentary rocks undifferentiated.

LOCATION: Point of land on north shore of Indian Pond. N17°E from largest island in east end of Indian Pond.

FAUNAL LIST AND AGE:

No number (Oliver)

An earlier collection accidentally mixed with collections from BH-161-62 and BH-82-64 is not reported on.

USGS 7880-SD (Oliver)

Massive stromatoporoid		
Cladopora sp.	L-H	*
Favosites sp. cf. *F. intermittens*	L	*
cf. *Brantelasma mainense*	H	
Spongophylloides sp.	L	
"*Streptelasma*" sp. cf. "*S.*" sp. A Stumm	L	
"*Tryplasma*" *marylandicum* (= *rhopalium*)	H	
Rugose coral sp. A.		*
Rugose corals undetermined		

"The coral identified as Rugose coral sp. A is conspecific with the only coral in . . . collection . . . BH-169c-62 . . . This species and the other starred (*) ones appeared in your collection BH-355-61 . . . I consider it very likely that these three collections are of the same age. The age however, is uncertain. "*T.*" *marylandicum* is from the lowest part of the Devonian part of the Keyser Limestone in Maryland and I described it (as *T. rhopalium*) from the Beck Pond Ls. in Maine (USGS Bull. 1111-A); I have previously considered it to be a good Helderberg coral. I don't think there can be any doubt of its presence here as I have several specimens. *Briantelasma mainense* is another Beck Pond species but there is only one specimen here and its identification must be questioned. Without the "*Tryplasma*" and *Briantelasma?* I would have considered this to be Ludlow (as I did in my report on BH-355-61). The most suggestive forms are marked L in the above list. None of the "L" species can be precisely identified with other Ludlow species; there are differences that may be due to preservation or to individual variations, or possibly to a difference in age. Possibly this and the related collections are younger than the mass of the Ludlow corals I've studied but older than the Helderbergian corals, or it may be that it is a mixture of Ludlow and Helderberg forms.

This may be worth following up . . . Is it possible that you collected across the S-D boundary or that the older corals were reworked into the Lower Devonian?

42. Collection BH-184-64

ROCK UNIT: Munsungun Lake Formation.

LOCATION: 1000 feet due north of mouth of easternmost brook entering on north shore of Haymock Lake.

FAUNAL LIST AND AGE:

No number (Berry)

Climacograptus bicornis (J. Hall)
Climacograptus eximius Ruedemann ?
Climacograptus phyllophorus Gurley ?
Climacograptus sp.
Dicellograptus intortus Lapworth ?
Dicellograptus sextans var. *exilis* Elles and Wood

. . . "Many of the forms in this collection are poorly preserved, hence only questionable identification of them can be made. The one readily identifiable species in the lot is *C. bicornis*. Its presence with the other forms is clearly indicative of the *C. bicornis* Zone."

43. Collection BH-41a-65

ROCK UNIT: Spider Lake Formation.

LOCATION: South of prominent point on south side of Fifth Musquacook Lake. See Figure 1 of Appendix.

FAUNAL LIST AND AGE:

USNM 17023 (Boucot)

Isorthis cf. *I. arcuaria*
Dicaelosia sp. (long lobed)

Ludlow or Pridoli on the basis of the *Isorthis* and the long-lobed *Dicaelosia*.

44. Collection BH-41b-65

ROCK UNIT: Spider Lake Formation.

LOCATION: South of prominent point on south side of Fifth Musquacook Lake. See Figure 1 of Appendix.

FAUNAL LIST AND AGE:

USNM 17021 (Boucot)

Isorthis sp.
trilobite (to Lesperance)

Silurian age as shown by the *Isorthis* of Ludlow-Pridoli aspect.

45. Collection BH-43-65

ROCK UNIT: Spider Lake Formation.

LOCATION: Halfway up northwest side of hill south of prominent point on south side of Fifth Musquacook Lake.

FAUNAL LIST AND AGE:

USNM 12143 (Boucot)

Gypidula sp. (smooth)
Merista sp.
Leptaena "*rhomboidalis*"
n. gen. stropheodontid like that at Scraggly Lake (Neuman's) and in Mencher's area.
Howellella sp. (coarsely plicate)
Isorthis aff. *arcuaria* (Henryhouse type)
Atrypa "*reticularis*"

Ludlow or Pridoli age.

46. Collection BH-197-65

ROCK UNIT: East Branch Group; Third Lake Formation.

LOCATION: Southwest end of largest island in southwest end of Little Leadbetter Pond (Telos Lake quadrangle).

FAUNAL LIST AND AGE:

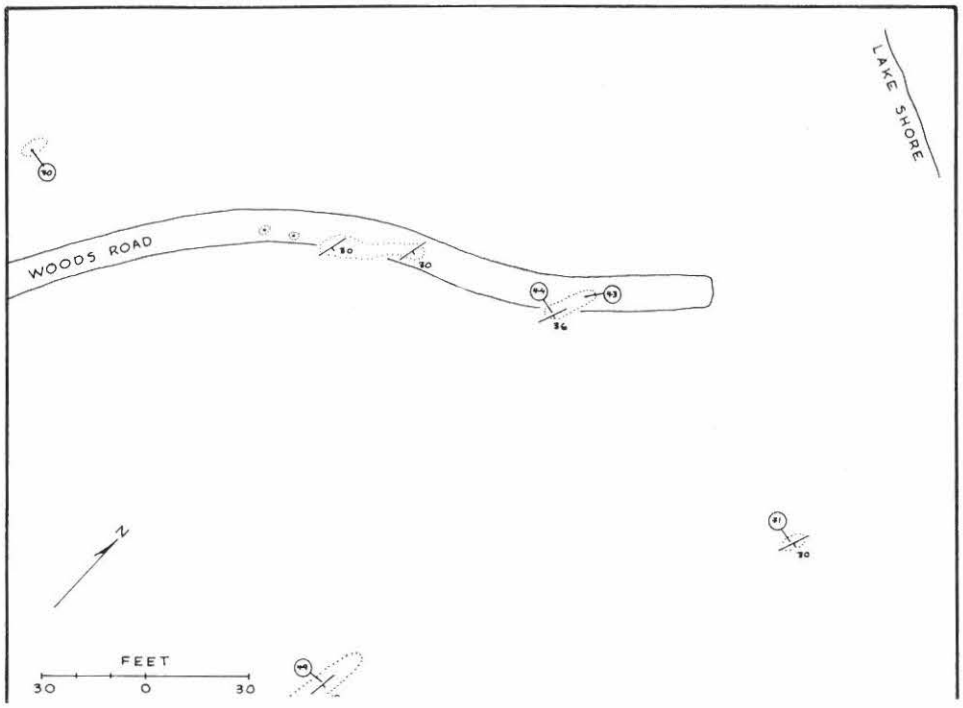
USGS 7598-SD (Oliver)

Massive stromatoporoid
Cladopora sp.
Favosites spp.
Thamnopora? sp.
Lyrielasma annulatum Oliver
Horn coral sp. undet.

Oliver initially reported that, "This is the Helderbergian fauna with abundant *Lyrielasma*, many embedded in stromatoporoids, and a variety of *Favosites*. Several elements of the Beck Pond fauna are missing, but this is typical, in that the rugose corals seem to clump with their own kind." In a later communication Oliver indicates there is question as to whether Ludlow and Helderberg rocks can be distinguished on the basis of *Lyrielasma*. The collection is considered Ludlow or Helderberg.

47. Collection BH-263-65

ROCK UNIT: East Branch Group; Chandler Pond Formation.



Appendix Fig. 1. Fossil collections and outcrop on south shore of Fifth Lake Musquacook. See Fig. 9 of text for location.

LOCATION: S10°W, approximately 3200 feet from outlet of Kyle Pond.
FAUNAL LIST AND AGE:
USGS 7599-SD (Oliver)
Massive stromatoporoid
Cladopora sp. (abundant)
? *Briantelasma mainense* (1 fragment)
"My best guess is that this is Helderberg because of the apparent *Briantelasma*. If the choice is between Helderberg or later age, it is almost certainly Helderberg."

48. Collection BH-300-65
ROCK UNIT: East Branch Group; Third Lake Formation.
LOCATION: N62°W, 1800 feet from crossing of Sly Brook and town line between T7 R10 WELS and T7 R11 WELS.
FAUNAL LIST AND AGE:
USNM 12142 (Boucot)
Isorthis aff. *I. arcuaria* (Henryhouse type)
Resserella sp.
Dicaelosia sp.
howellellid
Ludlow or Pridoli age.

49. Collection BH-56-66
ROCK UNIT: Spider Lake Formation.
LOCATION: South of prominent point on south side of Fifth Musquacook Lake. See Figure 1 of Appendix.
FAUNAL LIST AND AGE:
USNM 12463 (Boucot)
Isorthis cf. *I.* arcuaria
Dicaelosia sp.
Glassia? sp.
stropheodontid
Resserella sp.
Ludlow or Pridoli age.
USNM 17022 (Boucot)
Isorthis sp.
Resserella sp.
Ludlow or Pridoli age as shown by the *Isorthis*.

50. Collection BH-57-66
ROCK UNIT: Spider Lake Formation.
LOCATION: Near top of northwest side of hill south of prominent point on north side of Fifth Musquacook Lake.
FAUNAL LIST AND AGE:
USNM 12469 (Boucot)
Leptaena "rhomboidalis"
Orthostrophia cf. *O. strophomenoides*
Levenea cf. *L. subcarinata*
Meristella sp.
Atrypina sp.
Middle or late Helderberg.

51. Collection BH-70-66
ROCK UNIT: Spider Lake Formation.
LOCATION: North side of road from Upper Portage Pond to Echo Ridge. 400 feet southwest of side road shown on map heading south to Echo Ridge.
FAUNAL LIST AND AGE:
USGS 7882-SD (Oliver)
The faunal list is included in the table under collection BH-161-62. Oliver considers the collection to be almost certainly Ludlow.

52. Collection BH-115-66
ROCK UNIT: Unnamed Devonian conglomerate.
LOCATION: Approximately 1,000 feet S40°W of BM 1079.

FAUNAL LIST AND AGE:
USNM 12462 (Boucot)
orthotetacid
stropheodontid
unident. brac.

Possible Lower Devonian age. The orthotetacid is not like those seen in the Silurian of this region.

53. Collection BH-116-66
ROCK UNIT: Unnamed Devonian conglomerate.
LOCATION: Approximately 1,000 feet S40°W of BM 1079.
FAUNAL LIST AND AGE:
USNM 12461 (Boucot)
"*Schuchertella*" sp.
rhynchonellid
coral (to Oliver)

Helderberg age is most likely. Silurian cannot be completely ruled out.

54. Collection BH-121-66
ROCK UNIT: East Branch Group; Third Lake Formation.
LOCATION: S12°W, approximately 5200 feet from outlet of Kyle Pond.
FAUNAL LIST AND AGE:
Collection discarded (Oliver)
" . . . . granule conglomerate with no identifiable fossils other than crinoidal fragments."

55. Collection BH-130-66
ROCK UNIT: East Branch Group; Chandler Pond Formation.
LOCATION: S22°W, approximately 4600 feet from outlet of Kyle Pond.
FAUNAL LIST AND AGE:
Collection discarded (Oliver)
" . . . . granule conglomerate containing fragments of *Cladopora* . . . The fossils could be derived from Silurian or Devonian rocks since *Cladopora* and massive stromatoporoids are common elements in both the Ludlow and Helderberg coral fauna in Maine."

56. Collection BH-136-66
ROCK UNIT: East Branch Group; Third Lake Formation.
LOCATION: Approximately 400 feet northwest of Leadbetter Brook (Telos Lake quadrangle) about 8,000 feet from Chamberlain Lake.
FAUNAL LIST AND AGE:
USGS 7884-SD (Oliver)
The faunal list is included in the table under collection BH-161-62. Oliver considers that this collection is probably of Ludlow age, although its age must be questioned in that it contains only *Lyrielasma*.

USNM 12460 (Boucot)
rhynchonellid
orthotetacid
Nanothyris ?
Probable Helderberg age. If the *Nanothyris* is wrongly identified, the age is Siluro-Devonian.

57. Collection BH-139-66
ROCK UNIT: East Branch Group; Third Lake Formation.
LOCATION: 240 feet, N15°W of collection BH-140-66.
FAUNAL LIST AND AGE:
USGS 7886-SD (Oliver)
The faunal list is included in the table under collection BH-161-62. Oliver considers that this collection is almost certainly Ludlow.

58. Collection BH-140-66
ROCK UNIT: East Branch Group; Third Lake Formation.
LOCATION: North bank of East Branch Stream. At intersection of East Branch and S35°W bearing from triangulation point on Carpenter Mountain.
FAUNAL LIST AND AGE:
USGS 7883-SD (Oliver)
The faunal list is included in the table under collection BH-161-62. Oliver considers that this collection is almost certainly Ludlow.

59. Collection BH-153-66
ROCK UNIT: Seboomook Formation.
LOCATION: 3080 feet N87°E of outlet of Leadbetter Pond (Chesuncook quadrangle).
FAUNAL LIST AND AGE:
Collection discarded (Oliver)
" . . . fine-grained sandstone containing molds of branching colonies of bryozoans *or* corals — indeterminate in either case."

60. Collection BH-154-66
ROCK UNIT: East Branch Group; Chandler Pond Formation.
LOCATION: 2480 feet due east of outlet of Leadbetter Pond (Chesuncook quadrangle).
FAUNAL LIST AND AGE:
Collection discarded (Oliver)
" . . . granule conglomerate with no identifiable fossils other than crinoidal fragments."

61. Collection BH-157-66
ROCK UNIT: East Branch Group; Third Lake Formation.
LOCATION: Approximately 2000 feet N55°W of outlet of lowermost deadwater on Leadbetter Brook (Telos Lake quadrangle).
FAUNAL LIST AND AGE:
USNM 12465 (Boucot)
unidentifiable brachiopods
chips to Rickard for conodonts

Possible Ludlow or Pridoli.

No number (Rickard)
"Processed 2000 grams of this sample and recovered approximately 15 conodonts. Sample contains *Sapthognathodus remscheidensis, Ozarkodina denckmani, Hindeodella, Neoprioniodus, Lonchodina*. Presence of first two species indicates sample is Skala = Pridoli or Gedinne in age, can't tell which, but other possible ages are definitely ruled out. The fact that the specimens of S. *remscheidensis* are large, with relatively straight aboral margins inclines one towards a Gedinne age but *Icriodus woschmidti* was not found and confirmation thus is denied."
In a later report Rickard states, "A restudy of the *Spathognathodus* . . . . . earlier referred . . . . . to S. *remscheidensis* suggests that these . . . are possibly *eosteinhornensis*. - - - This change would not affect my age determination for Brad Hall's sample — still Pridoli or Gedinne. But it would shift my preference (if I must take a stab at it) from Gedinne to Pridoli."

62. Collection BH-162-66
ROCK UNIT: East Branch Group; Chandler Pond Formation.
LOCATION: Intersection of 1140 foot contour line with N27°W bearing from triangulation point on hill (Spider Lake quadrangle) north of Little Leadbetter Pond (Telos Lake quadrangle).
FAUNAL LIST AND AGE:
Collection discarded (Oliver)
" . . . granule conglomerate containing fragments of *Cladopora* . . . The fossils could be derived from Silurian or Devonian rocks since *Cladopora* and massive stromatoporoids are common elements in both the Ludlow and Helderberg coral fauna in Maine."

63. Collection BH-165-66
ROCK UNIT: East Branch Group; Third Lake Formation.
LOCATION: Intersection of 1160 foot contour line with S2°E bearing from triangulation point on hill (Spider Lake quadrangle) north of Little Leadbetter Pond (Telos Lake quadrangle).
FAUNAL LIST AND AGE:
USNM 12468 (Boucot)
Orthostrophia? sp.
Levenea? sp.
Probable Helderberg on the basis of the possible *Orthostrophia* and *Levenea*.

64. Collection BH-37-67
ROCK UNIT: East Branch Group; Third Lake Formation.
LOCATION: Point of land on north shore of East Branch Pond.
FAUNAL LIST AND AGE:
USNM 17017 (Boucot)
rhynchonellid
Howellella sp.
Coelospira sp.
"Collection BH-37-67 is of Ludlow or Pridoli age as shown by the presence of *Coelospira*, a genus not known elsewhere in northern Maine below the Ludlow or above the New Scotland. One could quibble with this collection and say that it might be of Devonian age but the presence of a *Howellella* would appear to preclude a Devonian age."

65. Collection BH-52a-67
ROCK UNIT: East Branch Group; Chandler Pond Formation.
LOCATION: 1200 feet N10°W of collection BH-140-66.
FAUNAL LIST AND AGE:
USNM 17015 (Boucot)
Atrypa "reticularis"
platyceratid
corals (to Oliver)
trilobites (to Lesperance)
rhynchonellids
rostrospiroids
Sieberella sp. (coarse)
rhynchospirid
unident. bracs
Eatonia sp.
dalmanellids
spirifirid
Leptaena "rhomboidalis"
Stropheodontid
Megakozlowskiella sp.
Middle or Upper Helderberg on the basis of a *Sieberella* similar to one from the Beck Pond limestone and also an *Eatonia* and a *Megakozlowskiella*.

66. Collection BH-62-67
ROCK UNIT: East Branch Group; Third Lake Formation.
LOCATION: On inlet brook to East Branch Pond 2480 feet in straight line from mouth of inlet.
FAUNAL LIST AND AGE:
USNM 17014 (Boucot)
coral (to Oliver)
rhynchonellid
Eccentricosta? sp.
parvicostellate stropheodontid
Probable Pridoli age based on the possible *Eccentricosta*.

67. Collection BH-67-67
ROCK UNIT: East Branch Group; Third Lake Formation.
LOCATION: Northwest side of small knoll 400 feet N30°W of collection BH-62-67.
FAUNAL LIST AND AGE:
USNM 17016 (Boucot)
n. gen. (Neuman's) stropheodontid
Atrypa "reticularis"
Isorthis sp.
Amphistrophia sp. (coarse-ribbed)
gypidulinid
Ludlow or Pridoli age as shown by the new genus of stropheodontid that is similar to ones from elsewhere in Maine.

68. Collection BH-76-67
ROCK UNIT: Spider Lake Formation.
LOCATION: Smith Brook approximately 4000 feet below deadwater divides into two branches. Locality is on south bank upstream from dividing point approximately 2600 feet.
FAUNAL LIST AND AGE:
USNM 17019 (Boucot)
Leptaena "rhomboidalis"
crinoid (to USNM)
Merista? sp.
cheirurinid (to Lesperance)
" . . . possible Silurian age as shown by the *Merista?* and the cheirurinid trilobite. Cheirurinids are not known above the Silurian so I would be very skeptical about this collection being other than of Silurian age."

69. Collection BH-77-67
ROCK UNIT: Spider Lake Formation.
LOCATION: Smith Brook divides into two branches approximately 4000 feet below deadwater. Locality is on south bank upstream from dividing point approximately 1400 feet.
FAUNAL LIST AND AGE:
USNM 17020 (Boucot)
Leptaena "rhomboidalis"
Calymene (to Lesperance)
dalmanellid
" . . . probable Silurian age as shown by the presence of *Calymene*, a genus unknown above the Silurian in Maine."

70. Collection BH-114-67
ROCK UNIT: Spider Lake Formation
LOCATION: South of prominent point on south side of Fifth Musquacook Lake. See Figure 1 of Appendix.
FAUNAL LIST AND AGE:
USNM 17025 (Boucot)
Skenidioides sp.
Leptaenisca sp.
Leptaena "rhomboidalis"
gypidulinid
Atrypa "reticularis"
Howellella sp.
Merista sp.
orthotetacid
clam (to McAlester)
Isorthis arcuaria
n. gen. stropheodontid
trilobite (to Lesperance)

Ludlow or Pridoli age on the basis of *Merista*, the *Isorthis*, and the new genus of stropheodontid.

71. Collection BH-115-67
ROCK UNIT: Spider Lake Formation.
LOCATION: South of prominent point on south side of Fifth Musquacook Lake. See Figure 1 of Apdix.
FAUNAL LIST AND AGE:
USNM 17024 (Boucot)
Dicaelosia sp.
Atrypina sp.
Isorthis sp.
Ludlow or Pridoli age as shown by the *Isorthis*.

72. Collection DS-1
ROCK UNIT: Spider Lake Formation.
LOCATION: 1060 feet N20°W of southeastern corner of T9 R12 WELS.
FAUNAL LIST AND AGE:
USNM 11130 (Boucot)
Howellella sp. (small)
Mesodouvillina? sp.

"Locality DS-1 is most likely of Silurian age as the association of *Howellella* and *Mesodouvillina* is more suggestive of Silurian age, but I can't prove it."

73. Collection DS-2
ROCK UNIT: Spider Lake Formation.
LOCATION: North end of prominent point of land on south shore of Soper Pond immediately adjacent to outlet of pond.
FAUNAL LIST AND AGE:
USNM 11131 (Boucot)
orthotetacid
Meristina? sp.
Pholidops sp.

Silurian-Lower Devonian age.

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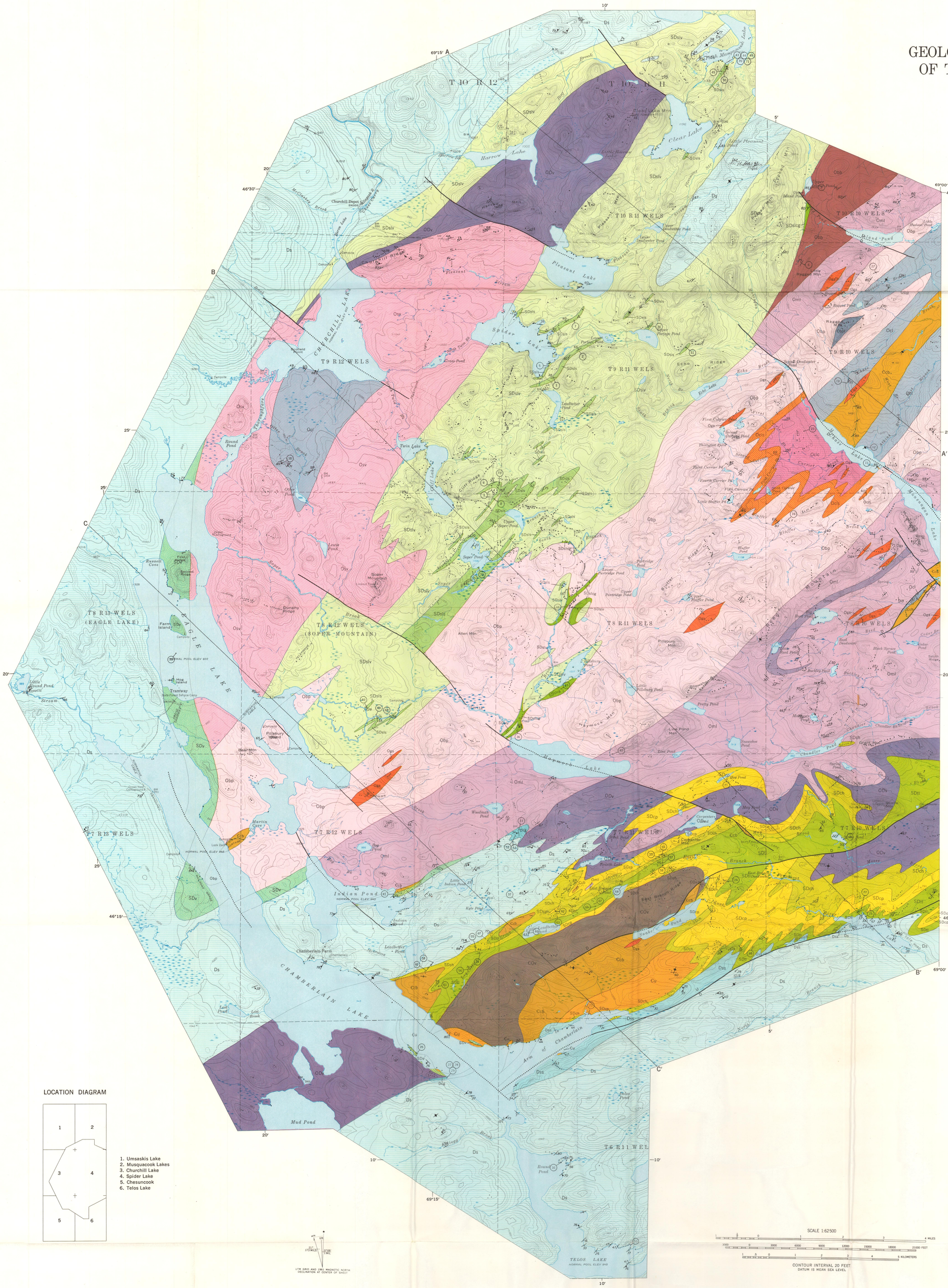
GEOLOGIC MAP OF THE SOUTHERN PART OF THE MUNSUNGUN ANTICLINORIUM

by
Bradford A. Hall
1970



EXPLANATION

Ds, Dss — Seboomook Formation
Graded beds of fine-grained sandstone and siltstone. Locally siltstone with widely spaced fine-grained sandstone laminae. Dss, *calcareous, micaceous sandstone and siltstone with local conglomerate beds.*

Dcg — *Conglomerate and sandstone.*

LOWER DEVONIAN

NORTHWEST — SOUTHEAST

SDslv, SDsls, SDslcg — Spider Lake Formation
Primarily andesitic volcanics, SDslv, *containing interbedded units of calcareous siltstone, stromatoporoid-coral limestone, sandstone, and siltstone,* SDsls. *Local basal conglomerate,* SDslcg.

— LOCAL UNCONFORMITY —

SDch, SDcp, SDtl — East Branch group
SDch, *conglomerate and sandstone of the Chandler Pond formation.* SDcp, *andesitic and dacitic volcanics of the Carpenter Pond formation.* SDtl, *calcareous siltstone, stromatoporoid-coral limestone, calcarenite, sandstone, and tuff of the Third Lake Formation.*

SDv — *Andesite breccia and flows*

SDs — *Stromatoporoid-coral limestone, reef detritus, minor sandstone.*

UPPER SILURIAN AND LOWER DEVONIAN

— UNCONFORMITY —

Oga — *Dolerite and gabbro*

ODv — *Undifferentiated Ordovician through Devonian volcanic rocks. Primarily andesitic or basaltic but locally rhyolitic or dacitic.*

Obb — Blind Brook Formation
Gray pyritiferous slate. Locally tuffaceous. Minor sandstone.

Oml, Omlr, Oml — Munsungun Lake Formation
Dolerite; white-weathering tuff and agglomerate; variolored slate and chert. Omlr, *volcanic breccia of the Reed Pond member.*

Osv — *Undifferentiated Ordovician sedimentary and volcanic rocks.*

Obbr, Obp — Bluffer Pond Formation
Pillowed basalt, dolerite, tuff, slate, mudstone. Obpr, *soda rhyolite of the Ragged Mountain member.*

Ocls, Ocl, Oclc — Chase Lake Formation
Slate, graywacke, and conglomerate. Locally mapped as a slate-graywacke member, Ocls, *and a conglomerate-graywacke member,* Oclc.

MIDDLE ORDOVICIAN

— UNCONFORMITY —

COv — *Undifferentiated Cambrian (?) and/or Ordovician volcanic rocks.*

Cu — *Red and green, green or gray phyllite and slate.*

Ccb — Chase Brook Formation
Gray and green phyllite and slate with some siltstone and sandstone, blocks of quartz graywacke and calcareous crossbedded siltstone, and minor thin dark gray limestone interbeds.

CAMBRIAN(?)

Outcrop.

Contact. Dotted under water.

Fault. Dotted where under water. U-upthrown side; D-downthrown side.

Strike and dip of beds. Dot indicates facing direction. (inclined, overturned, vertical)

Volcanic flow banding. (inclined, vertical)

Cleavage (inclined, vertical)

Fossil locality. Number refers to Appendix I.

Geology mapped in 1959-67 by B. A. Hall, assisted in 1964 by D. J. Supkow, in 1965 by D. Hattman.

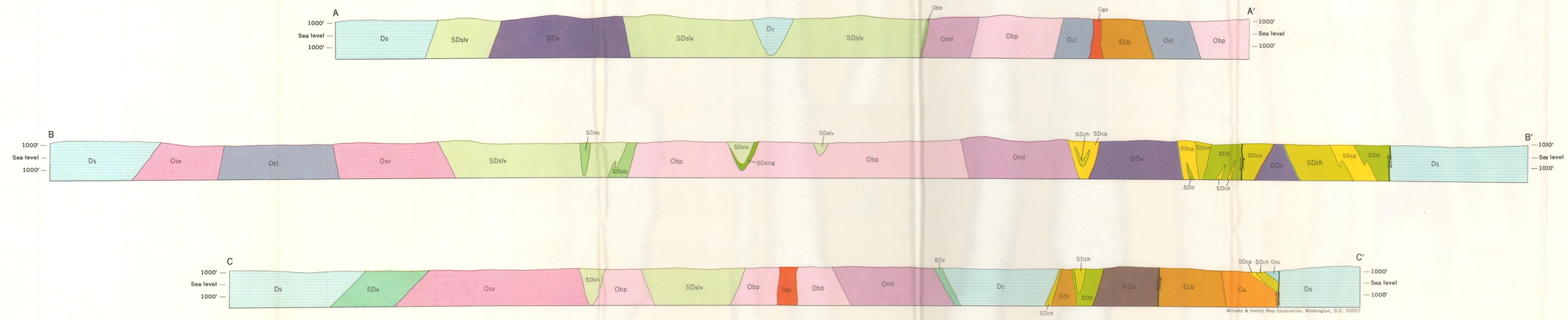
LOCATION DIAGRAM

1. Umsaskis Lake
2. Musquacook Lakes
3. Churchill Lake
4. Spider Lake
5. Chesuncook
6. Telos Lake

UTM GRID AND 1961 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:62500

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL



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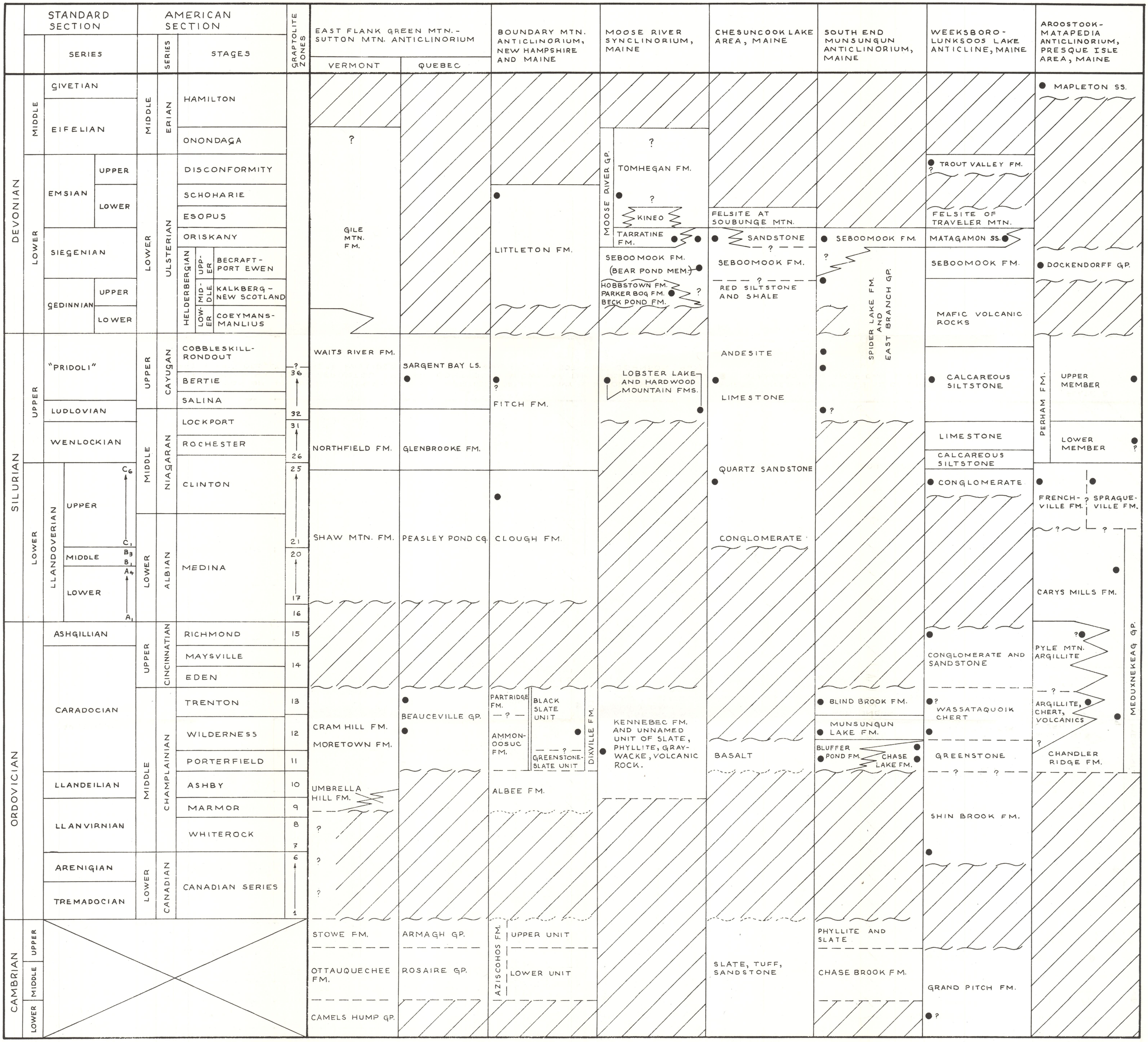

PLATE 2

CORRELATION OF THE ROCKS OF THE MUNSUNGUN ANTICLINORIUM. WAVY SYMBOL USED TO DESIGNATE UNCONFORMITIES IS DASHED WHERE NONE HAS BEEN REPORTED. FOSSIL CONTROL IS SHOWN BY THE FOLLOWING SYMBOL: ● STANDARD AND AMERICAN SECTIONS AFTER PAVLIDES, ET AL, (1964), PAVLIDES AND BERRY (1966), AND BOUCOT AND JOHNSON (1967).