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Geologic Map of the Caribou and Northern Presque Isle 15' Quadrangles, Maine

by

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INTRODUCTION

The Caribou and Presque Isle quadrangles lie in the heart of the largely cleared Aroostook County potato-growing region. The gently rolling topography of the eastern part of the quadrangles is largely due to the prominence of easily-eroded limestone and calcareous shale in the bedrock. The more elevated western and southern terrains are underlain by less carbonate-rich sedimentary rock units and very resistant rocks of volcanic origin. All of the sedimentary formations are unusually fossiliferous for the Appalachian Mountain region which largely accounts for the long history of geologic investigations in the region. This report summarizes the bedrock geology of the Caribou quadrangle, which has not been previously published, and presents revisions of the geology of the northern part of the Presque Isle quadrangle.

The Caribou and Presque Isle quadrangles lie along the boundary between the Aroostook-Matapedia anticlinorium to the east and Ashland synclinorium to the west as shown in Figure 1. In the Caribou quadrangle the boundary is located along the contact between the Carys Mills and New Sweden Formations. In the Presque Isle quadrangle, the Ashland synclinorium widens considerably and incorporates the Siluro-Devonian rocks of the Chapman syncline. The oldest rocks in the quadrangles are of Ordovician age and are found in the core of the Castle Hill anticline in the northwestern part of the Presque Isle quadrangle (Winterville Formation) and in the northwestern corner of the Caribou quadrangle (Madawaska Lake Formation). The youngest rocks of the quadrangles are of Middle Devonian age and form the Mapleton Formation near Presque Isle. The rocks of the quadrangles portray an extensive and complicated geologic history and provide much information important to our understanding of the northern Appalachians in New England and adjacent Canada.

The first systematic investigations of the rocks of the two quadrangles and the surrounding region were those by Williams and Gregory (1900). Their color map at a scale of 1:760,320 is the earliest published bedrock map and reflects Gilbert's primary interest in the igneous rocks of the region. Williams' interest was in the numerous fossil localities, many found originally by Olaf O. Nylander of Caribou who, some years later, privately published descriptions of several aspects of the bedrock geology of the region (Nylander 1936; 1937; 1938). In 1928, W. H. Twenhofel visited many of the localities studied by Williams and Gregory and reordered the succession of rock units as established by them based on reassessments of some of the fauna (Twenhofel, 1941).

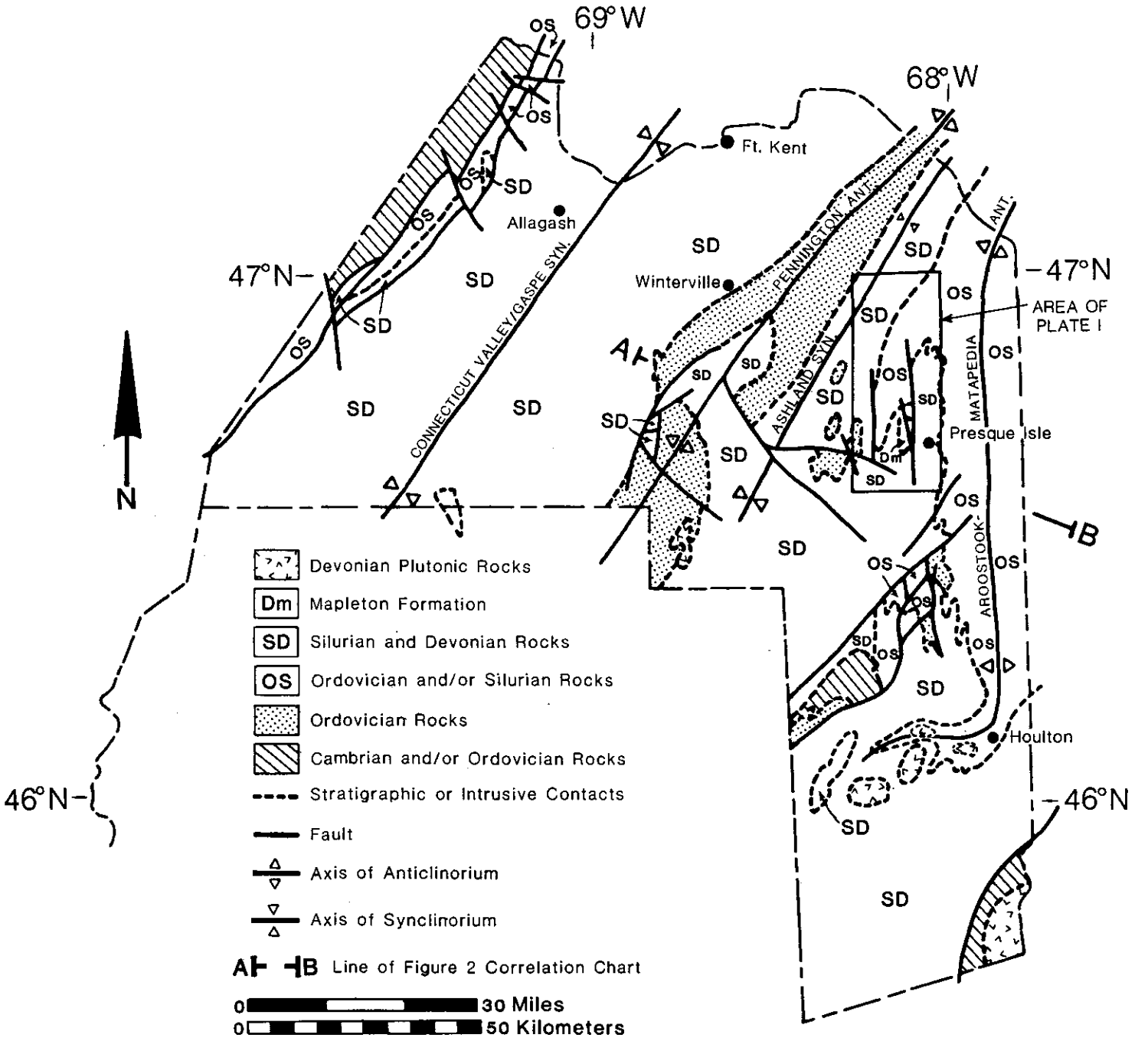

Figure 1. General geologic map of Aroostook County, Maine showing the location of the area of this report with respect to major tectonostratigraphic features.

The strategic importance of iron and manganese brought W. S. White and P. E. Cloud, Jr. to the Caribou and Presque Isle region in 1941 and 1942 (White, 1943) to examine the manganiferous ironstones presently assigned to the New Sweden Formation. R. L. Miller continued the investigation of these deposits for the Maine Geological Survey in 1943 and 1944 and presented a somewhat more extensive account of the local stratigraphy associated with the deposits (Miller, 1947). Pavlides (1962) also discusses aspects of the manganiferous deposits in this region in connection with his extensive study of similar deposits farther south in the county.

A comprehensive summary of the geology of the Presque Isle quadrangle is provided by Boucot and others (1964). This Maine Geological Survey report includes descriptions of some aspects of the adjacent Ashland and Caribou quadrangles based on reconnaissance work by R. S. Naylor (unpublished data, 1962) and D. Smith (unpublished data, 1962) respectively. Boucot and others (1964) provided the basis for the present understanding of the stratigraphic succession in the region that has been carried beyond the Presque Isle quadrangle and amplified by Pavlides and others (1964), Naylor and Boucot (1965), Pavlides (1968; 1978), Ayrton and others (1969), Roy (1970; 1980 a,b,c), Roy and Mencher (1976), and Naylor (1980). The present map of the northern part of the Presque Isle quadrangle shows revisions of the maps of Boucot and others (1964) and Pavlides (1968; 1978) based on work by the present writer (Roy, 1970; 1978; unpublished data) and that of White (1975) on the Mapleton Formation.

STRATIGRAPHY

General Statement

Figure 2 shows the stratigraphic units of the Caribou and Presque Isle quadrangles and the surrounding terrain. The low degree of metamorphism (Richter and Roy, 1976) and low intensity of deformation permit both fossil remains and sedimentary features to be well preserved. Pelitic rocks and limestone are usually foliated, but sandstone, conglomerate, and volcanic rocks only rarely show cleavage and have well preserved sedimentary textures and fabrics. Although all of the rocks show the effects diagenesis and subgreenschist facies metamorphism, sedimentary rock names will generally be used in this report; the principal exceptions are the pelitic rocks which are true slates or phyllites.

Both physical and paleontological evidence suggest complicated lateral facies changes from northwest to southeast across the region (Roy, 1970; Roy and Mencher, 1976). The facies relations within the Ordovician system are based on a modest paleontologic record and field evidence outside the quadrangles to the west. Siluro-Devonian lithofacies changes are documented by a large number of fossil localities as well as field evidence both within and outside the area discussed here. The stratigraphic relationships seen in the quadrangles are outlined by the dotted line in Figure 2. It is possible to demonstrate an almost continuous stratigraphic succession from the Caradocian (late Middle Ordovician), through the

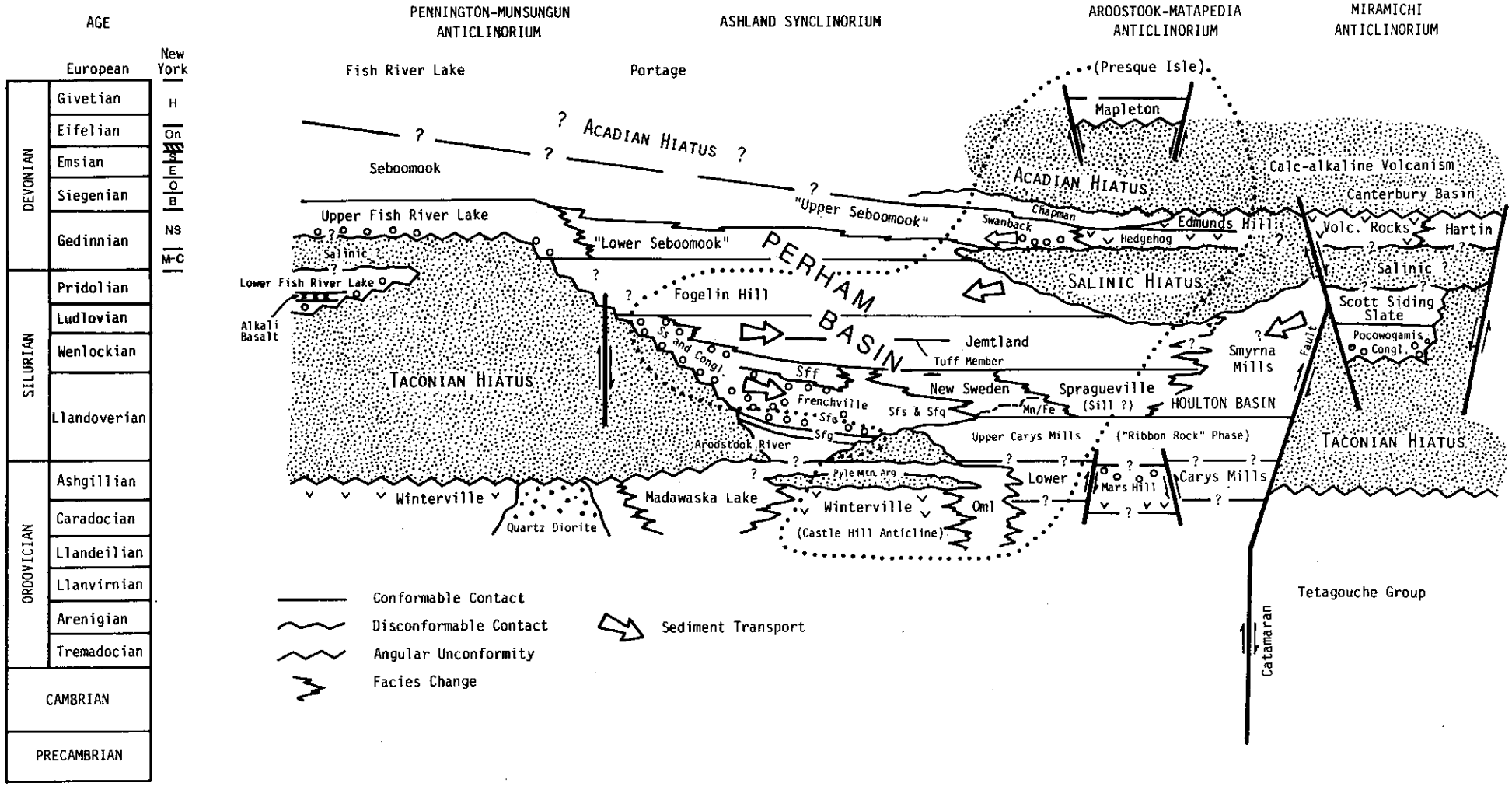

Figure 2. Correlation chart showing facies relations of the formational units of the Caribou and Presque Isle quadrangles and surrounding areas. The line of this section is A-B of Figure 1. The dotted line outlines the facies relationships documented within the region of this report.

Silurian, and possibly into the Early Devonian (Upper Fogelin Hill Formation of the Stockholm Mountain syncline). The region has, however, experienced the effects of the major periods of deformation that characterize the northern Appalachians. The unconformity between the Early Silurian Frenchville Formation and the Ordovician units in the western parts of the region reflects the importance of, as well as statigraphically date, the Taconian Orogeny in northern Maine. In the vicinity of Presque Isle, the Dockendorff Group (Hedgehog, Chapman, Swanback Formations and the Edmunds Hill Andesite) rests disconformably (or with slight angular unconformity) on the Late Silurian Jemtland Formation marking the effects of the Salinic Disturbance. The angular unconformity between the molasse of the Mapleton Formation and nearly vertical formations of Silurian and Early Devonian age provides the closest stratigraphic dating of the Acadian Orogeny in New England. The stratigraphy of the region therefore provides a case study in the effects of deformational events on depostional patterns (Roy, 1980a).

ORDOVICIAN SYSTEM

Winterville Formation

The Winterville Formation is confined to the axis of the Castle Hill anticline in the Presque Isle quadrangle but is also exposed in large terrains in the Ashland quadrangle to the immediate west and in the Pennington Mountain anticlinorium to the northwest (Figure 1). The type area of the formation is in Winterville Township, with reference exposures along Maine Rt. 11 from Winterville through T15R6, and for about two miles into T14R6. Excellent exposures of mafic volcanic rocks of the formation are present along Maine Route 163 where it crosses the Castle Hill anticline, and felsic volcanic rocks are well exposed on the slopes and summit of nearby Haystack Mountain. Dark chert and basaltic volcanic rocks are present along the north-south road on the east flank of Castle Hill; pillowed basalt is well exposed in cliffs along the 800-foot contour above the Aroostook River on the western slope of Castle Hill.

Lithology. The Winterville Formation is a complex of volcanic and sedimentary rocks. No internal stratigraphy has been established within the formation due to a lack of sufficient bedding and facing indicators. Detailed petrographic analyses of the igneous rocks of the formation are sparse but chemical analyses by Hynes (1981) and petrographic analysis by Horodyski (1968) and Richter (1973) suggest a predominance of pyroxene basalt and fragmental rocks of similar composition. Rhyolite, as at Haystack Mountain, is also present locally. In many places black sulfidic slate, chert (red, green, and gray), lithic graywacke, and granule or pebble conglomerate are important.

Basalt of the Winterville Formation is typically amygdaloidal, variably phenocrystic, rarely pillowed and highly fractured with secondary calcite and lesser pumpellyite and/or epidote filling the amygdaloids and veins (Richter and Roy, 1974; 1976). These rocks are commonly altered, showing chlorite and actinolite after pyroxene and variable saussuritization or albitization of plagioclase.

Dark-gray to black slate is probably second in abundance to volcanic rocks in the formation. The slate is usually sulfidic and locally contains well-preserved graptolites. Variably-colored bedded chert is seen interbedded with the slate or associated with fragmental volcanic rocks. Most of the chert seems to be true sedimentary chert with abundant chlorite, muscovite, and silt-size quartz grains mixed with the microcrystalline quartz; this chert in places contains recrystallized radiolarian tests. Other, more feldspathic chert is probably at least in part composed of devitrified volcanic ash.

Conglomerate and sandstone of the Winterville Formation contain abundant detritus of volcanic origin that is likely of local derivation from penecontemporaneous volcanic sources. A spectrum of coarse clastic rock types is present from sandstone and conglomerate containing well water-worked and diverse detritus to rocks that contain more homogeneous and angular fragments that may be resedimented pyroclastic material.

Thickness. The thickness of the Winterville Formation is unknown since the bottom of the formation is nowhere seen. It is thought to be well in excess of 1500 meters (4900 feet) thick (Horodyski, 1968; Roy and Mencher, 1976).

Age. Based on fossil localities within and outside of the Presque Isle quadrangle, the Winterville Formation has been shown to span the Caradocian and Ashgillian stages (graptolite zones 11-15 of W. B. N. Berry) of the Late Ordovician (Roy, 1970; Roy and Mencher, 1976). The only Winterville Formation fossil locality within the area discussed here is F-C6 reported by Boucot and others (1964) to be assigned to the Orthograptus truncatus var intermedius zone (zone 13) of the Caradocian.

Madawaska Lake Formation

The Madawaska Lake Formation is restricted to the northwestern corner of the Caribou quadrangle in the region of this report. It is, however, widespread in the Stockholm quadrangle to the north and in the Portage quadrangle to the west, where it forms an extensive part of the core terrain of the Pennington Mountain anticlinorium. The type area of the formation is the vicinity of Madawaska Lake which is located in Westmanland Township and T16R4 in the Stockholm quadrangle (Roy and Mencher, 1976). The Madawaska Lake Formation is well exposed along numerous lumber roads northwest of the railroad siding at Blackstone.

Lithology. The Madawaska Lake Formation is a monotonous formation of slate and graywacke with important occurrences of sulfidic micrite and conglomerate outside the quadrangles discussed here. Slate is the most abundant lithology and is characteristically olive-green in color, fine-grained, and has thin parallel and ripple-laminated siltstone beds (less than 10 cm (3 inches) thick). A well-developed fracture cleavage combines with a bedding parting to produce a common and distinctive "pencil fracturing". Maroon and red slate locally associated with green slate is seen in some places within the formation but these slates do not form mappable units; the maroon and green color appear to be secondary as they are not strata-bound. Dark gray, lithic and feldspathic graywacke beds

from 0.1 to 1 meter (0.3-3 feet) are common. The graywacke weathers to a brown color and beds do not show well-developed sedimentary structures as a rule. Some thin graywacke beds show turbidite sedimentary structures.

Thickness. The lower contact of the formation has not been seen anywhere in the region and the full outcrop belt has not been sufficiently mapped internally to permit a determination of the thickness of the unit. Hamilton-Smith (1970) gives a minimum thickness of about 600 meters (1900 feet) for the formation (his "unnamed unit") along the international border near Sieges, New Brunswick.

Age. No fossil localities in the Madawaska Lake Formation are present in either the Caribou quadrangle or the Presque Isle quadrangle, but two localities are known in the formation's outcrop belt to the northeast. The nearest locality is in Stockholm Township in the Stockholm quadrangle along a lumber road 0.3 miles west of Collins Siding and 0.1 miles south of the northern town line. W.B.N. Berry and O.M. Bulman identified the following graptolites: Amplexograptus sp.; Glyptograptus sp.; Diplograptus sp., and suggested that they indicate an age span of Berry's zones 11-15, probably in the span of zones 11-13 (locality 15 of Roy, 1970, and Roy and Mencher, 1976). The second locality, near Upper Sieges in New Brunswick, is described by Hamilton-Smith (locality Th 205; 1969, 1970; also cited as locality 16 by Roy, 1970, and Roy and Mencher, 1976). The Upper Sieges locality contains deformed graptolites identified by W.B.N. Berry as Diplograptus sp. (possibly D. mohawkensis (Ruedemann)) that suggests a Late Ordovician age (possibly zone 13). Brachiopods from the same locality, identified by R.B. Neuman, suggest a Late Ordovician age. In summary, the present paleontologic information suggests that the Madawaska Lake Formation is of Late Ordovician age (Caradocian-Ashgillian) which is consistent with the following stratigraphic evidence: 1) the Madawaska Lake Formation is overlain unconformably by the Early Silurian Frenchville Formation, and 2) the Madawaska Lake Formation appears to interfinger with volcanic rocks of the Winterville Formation near Portage to the west of the Caribou quadrangle (Roy and Mencher, 1976).

Pyle Mountain Formation

The "Pyle Mountain Argillite", as established by Boucot and others (1964), is here renamed the Pyle Mountain Formation. This formation overlies the Winterville Formation and, although poorly exposed, seems to form a continuous belt along the eastern flank of the Castle Hill anticline. The formation can be followed around the nose of the anticline and traced southward along the west limb of the fold to about one mile south of Maine Route 127 where it is inferred to thin to extinction beneath the Frenchville Formation. The type locality of the Pyle Mountain Formation consists of pavements and road-ditch exposures (fossil locality F-D4) at and near the intersection of Turner Road with the un-named road from Mapleton to Pyle Mountain.

Lithology. At the type locality the Pyle Mountain Formation consists of brown-weathering, blocky, fracture cleaved siltstone containing abundant trilobite fragments. A similar lithology is present at fossil locality F-D11 and in poor road-ditch exposures along Maine Route 163, just east of

fossil locality F-C6. On the west slope of Castle Hill, at and south of locality F-D7, are extensive outcrops of greenish gray, brown weathering, well cleaved silty slate that forms the second type of rock present in the formation. Similar slate is also present in poor exposures just north of Maine Rt. 163 where the outcrop belt of the Pyle Mountain Formation crosses the highway. The distribution of outcrops of the blocky siltstone and well-cleaved silty slate in the vicinity of locality F-D11 suggests that the highly fossiliferous blocky siltstone may be stratigraphically lower than the slate.

Lower Contact. The lower contact of the formation is not exposed but is closely approachable near locality F-D11. Roy (1970) and Roy and Mencher (1976) have suggested on the basis of regional considerations that the contact is probably a disconformity but there is no physical evidence as to nature of the contact.

Thickness. The formation is approximately 182 meters (600 feet) thick at the type locality and does not seem to vary much along strike on either limb of the Castle Hill anticline, but is probably tectonically thickened in the nose of the fold. Since the formation has not been observed south of MacDonald Mountain on the west flank of the anticline, it has been inferred that it thins to zero southward along the structure (Boucot and others, 1964; Roy, 1970; Plate 1); since exposures are sparse it is possible that the formation is present but simply not exposed.

Age. The age of the Pyle Mountain Formation is considered to be Ashgillian of the Late Ordovician based on four fossil localities (Boucot and others, 1964). The localities F-D4, F-D7, F-D11, and F-E3 were all originally sampled by P.E. Cloud; localities F-D4, F-D7, and F-E3 were recollected by Boucot and others. The age is based on trilobites from the three localities collected by Boucot and others (1964) and identified by H.B. Whittington. R.B. Neuman found brachiopods from Cloud's collections to be consistent with an Ashgillian age but not in themselves diagnostic. Boucot and others (1964) describe collections of fossils (locality F-D8) made by Cloud from road-ditch outcrops at the northern end of Castle Hill (locally known as Richardson Hill) as part of the age discussion of the Pyle Mountain. These collections were assigned by them to an undifferentiated Ordovician-Silurian unit, a confusion that is perhaps compounded by the present assignment of the rocks at the F-D8 locality to the Frenchville Formation (Roy 1970; Plate 1). R.B. Neuman's conclusion is that the brachiopod genera obtain from the F-D8 collection and reported by Boucot and others (1964, page 23) are not restrictive as to age and could be of either Ordovician or Silurian age (R.B. Neuman personal communication, 1970).

ORDOVICIAN and/or SILURIAN SYSTEMS

Carys Mills Formation of the Meduxnekeag Group

The Carys Mills Formation is widespread in the eastern part of Aroostook County and is continuous with the Matapedia Group of New Brunswick to the east and northeast (Pavlides, 1968). Pavlides (1965,

1968) should be consulted concerning the other formations within the Meduxnekeag Group; in the Caribou and Presque Isle quadrangles the Carys Mills Formation is the only unit of the group that is present. In this report the Carys Mills Formation has been divided into lower and upper members but these members have not been carried beyond the two quadrangles considered here.

Lower Member. The Lower Member of the Carys Mills Formation is found in the cores of anticlines in the Carys Mills terrain of the Caribou quadrangle. The rocks of the Lower Member can be best seen in exposures at fossil locality F-1115 on Maine Rt. 161 east of Colby and in a large outcrop along the county road south of, and paralleling, the Aroostook River near F-402. The member is made up of five rock types:

1. Gray and green-gray, calcareous slate. In many outcrops this lithology is better characterized as calcareous phyllite.
2. Light gray, parallel and cross-laminated, micaceous, and calcareous siltstone. Thicker beds of this lithology show grading from fine-grained sandstone at the base to siltstone at the top. Beds are typically a few centimeters thick but beds up to 30 cm have been observed. Weathering of this rock type produces a rust-colored, leached rind.
3. Light gray, massive, calcareous quartz arenite. The arenite weathers to a bright orange color. Beds of the quartz arenite range from a few centimeters to a few meters in thickness and are typically laced with calcite veins. Sedimentary structures are conspicuously absent in medium and thick beds of this rock type but thin beds may show internal lamination.
4. Dark gray, variably silty and argillaceous micrite. The micrite occurs in beds up to 15 cms thick which are present singly or in thin micrite-slate sequences.
5. Gray lithic and feldspathic graywacke. Beds of this lithology are not common in the lower member but are well displayed at locality F-1115 where they show turbidite features.

As seen in small outcrops, the Lower Member is usually made up of thinly interlayered slate and siltstone (rock types 1 and 2) but pavement outcrops of the massive quartz arenite are common. Micrite is rare.

The lower contact of the member is not seen, therefore there is no basis for assessing the total thickness of the Lower Member. In the vicinity of locality F-1115, at least 550 meters (1800 feet) of section appears to be present, but the formation is likely to be much thicker.

Upper Member. Reconnaissance mapping outside the Caribou and Presque Isle quadrangles to the east and northeast suggests that the Upper Member is the regionally most extensive phase of the formation. The member is well exposed at locality F-402 and beneath the bridge across the Aroostook River at Bugbee, both along the banks of Aroostook River near Washburn. Road cuts along US Route 1, a mile south of the Little Madawaska River bridge and near the rest area on the Caribou bypass, provide fresh exposures of the predominant micritic limestone.

The Upper Member is a sequence formed of thinly interlayered micritic limestone and calcareous phyllitic slate. Beds of limestone and slate range from 2 to 30 centimeters thick, but the member is usually seen to be a very even-bedded succession with beds about 5 centimeters or so thick. No mappable slate horizons, such as those seen by Pavlides (1978) in the Mars Hill quadrangle, are present in the quadrangles described here, but the occasional presence of limestone-poor outcrops may represent slate intervals of insufficient thickness to be mapped.

Micrite generally exceeds, or is equal to, slate in abundance. The micrite is dark-gray, argillaceous, and variably silty. In many of the limestone beds, weathering highlights lamination formed by segregation of the silt (largely quartz with lesser but conspicuous muscovite) into both parallel and cross lamination indicating the importance of currents during deposition of the limestone beds. Upward grading of the terrigenous component is sometimes conspicuous but usually is not well developed. Non-silty, but argillaceous, micrite is also common. Weathered exposures commonly show alternating gray and rust-brown limestone layers that form the prominent "ribbon rock" appearance of the member.

Thin calcareous siltstone beds and somewhat thicker lithic graywacke form minor rock types in the Upper Member. These are similar to rock types 2 and 5 respectively of the Lower Member described above.

The lower contact of the Upper Member can be crossed in a series of outcrops on the steep river embankment between localities F-403 and F-402 where it is inferred to be conformable since in crossing the contact there appears to be only changes in relative abundances of the rock types of the Carys Mills Formation.

There is very little basis for estimating the thickness of the member in the Caribou and Presque Isle quadrangles since the member is tightly folded and facing indicators are few. Hamilton-Smith (1970) found a composite section of rocks assignable to the Upper Member in the Seigas area of New Brunswick to have a minimum thickness of about 400 meters (1300 feet) with evidence of erosion of some of the Carys Mills prior to the deposition of the overlying Seigas Formation. Assuming no substantial structural complications, about 550 meters (1800 feet) of Upper Member section seems to be present between the Lower Member and the overlying New Sweden Formation west of the village of Carson. Northwest of locality F-1115 a maximum of about 1500 meters (5000 feet) of the Upper Member is present. Therefore, in the Caribou quadrangle the Upper Member is probably at least a few hundred meters and possibly in excess of a 1000 meters thick. Pavlides (1965) estimated the Carys Mills to be about 500 meters thick in the western part of its exposure belt but to thicken eastward to as much as 3700 meters (12000 feet). The estimates by Hamilton-Smith and those presented here seem to be in good agreement with those for the western part of the Carys Mills terrain suggested by Pavlides and it is quite probable that the formation thickens eastward.

Age. There are three fossil localities in the Caribou quadrangle, and several outside of the two quadrangles considered here, that have been used to assign an age-range to the Carys Mills Formation. Historically, locality F-1115 has been the most important and recently the most

controversial locality in the formation. Early graptolite collections from that locality by W.H. Forbes and R.B. Neuman were interpreted to contain a Caradocian (Berry's zone 13) assemblage of Amplexograptus sp., A. cf. A. perexcavatus (Lapworth), Climacograptus cf. typicalis mut. posterus (Ruedemann), Diplograptus spp., D. cf. D. multidens, Orthograptus aff. O. truncatus (Lapworth), O. truncatus var. intermedius (Ellis and Wood), an Orthograptid of the O. truncatus type, and an Orthograptid of the O. calcaratus type (Berry and others, 1961). The Caradocian age assignment was taken to be the age of the Carys Mills for several years (Boucot and others, 1964; Pavlides and others, 1964; Pavlides, 1965) with recognition that it is risky to generalize from one fossil locality the age-span of a thick formation. Additionally, an early graptolite collection from locality F-403 by W.H. Forbes and R.B. Neuman was identified by W.B.N. Berry to contain Orthograptus truncatus var. socialis (Lapworth) which he assigns to the Ashgillian (personal communication, July, 1966; see locality 6 of Pavlides, 1968). Attempts to recollect locality F-403 have not been successful. Both of these localities are assigned here to the lower micrite-poor member of the Carys Mills.

In 1964, the present writer recovered a graptolite from locality F-402 which was identified by W.B.N. Berry as Monograptus cf. M. cyphus (Lapworth) and was assigned by him to the Early Llandoverian (zone 18 of Elles and Wood; see Pavlides and Berry, 1966). Soon thereafter, other Early Silurian graptolite and ostracod collections were obtained from the micrite phase of the formation from widespread localities (Pavlides and Berry, 1961; Pavlides, 1968; Hamilton-Smith, 1970) which confirmed extension of the age-span into the mid-Llandoverian. More recently, Pavlides (1978) has described several ostracod localities from the Carys Mills Formation in the Mars Hill and Fort Fairfield quadrangles that give ages within the Llandoverian, typically in the span of brachiopod zones A4 to C2.

Rickards and Riva (1981) have recently challenged both the graptolite assemblage and age previously assigned to the strata at locality F-1115. They conclude that the graptolites are deformed and that a single form, Glyptograptus(?) persculptus (Salter), appears to have characteristics similar to Glyptograptus tamariscus (Nicholson) where oriented parallel to the bedding-cleavage intersection, and to look more like Ampexograptusor Diplograptus when they are at high angles to the bedding-cleavage intersection. They assign the strata at F-1115 to the G. persculptus zone, which at the time was the lowest graptolite zone assigned to the Silurian. Recently, this graptolite zone has been reassigned to the Ashgillian of the Ordovician by the International Commission on the Ordovician-Silurian Boundary. The upper strata of the Lower Member and all of the Upper Member of the Carys Mills are therefore probably within the early Llandoverian of the Silurian but the lower part of the Lower Member is likely of Ordovician age.

The age span of the Carys Mills Formation is here concluded to most likely span at least the Ashgillian of the Ordovician to mid-Llandoverian of the Silurian. The Matapedia Group along strike in New Brunswick, with which the Carys Mills Formation is correlated, has produced fossils of Ashgillian and earliest Silurian age (Rickards and Riva, 1981). Since the base of the Carys Mills Formation has not been dated and the youngest age

suggested for locality F-1115 is very near the Ordovician-Silurian boundary, it seems likely that the Carys Mills Formation could very well extend into the Ashgillian. The age assigned by Berry to locality F-403 is consistent with an Ashgillian age for a part of the Lower Member as defined here, but the close stratigraphic proximity of the strata of that locality to the base of the Upper Member where G. cyphus is present (locality F-402) would imply a somewhat compressed section. The question of the extension of the formation into the Caradocian (Roy and Mencher, 1976; Pavlides, 1978) is pending additional fossil localities or resolution of the technical question as to the identification of the fauna at F-1115 by the experts.

SILURIAN SYSTEM

As depicted in Figure 2, the Silurian system of the region considered here is represented by five formations in addition to the Silurian part of the Carys Mills Formation just described. The laterally equivalent Frenchville, New Sweden, and Spragueville Formations are of late Llandoverian-early Wenlockian age and comprise a lithofacies system that becomes less sandstone-rich and more distal eastward (southeastward) across the Caribou and Presque Isle quadrangles. These three formations are each overlain conformably by the Jemtland Formation of late Wenlockian-early Ludlovian age that itself also becomes finer-grained and more distal eastward. The Fogelin Hill Formation overlies the Jemtland Formation in the Stockholm Mountain syncline in the northwestern part of the Caribou quadrangle and may range in age into the Early Devonian. The Jemtland and New Sweden Formations comprise the Perham Group (Roy and Mencher, 1976).

Frenchville Formation

The Frenchville Formation is a thick sequence of sandstone, conglomerate, and generally lesser slate that is found on the flanks of the Stockholm Mountain syncline and adjacent structures in the western and northwestern part of the Caribou quadrangle and along the west flank and plunge of the Castle Hill anticline. The type area for the Frenchville Formation is in the small community of Frenchville within the Ashland Township (Boucot and others, 1964). Roy (1970) and Roy and Mencher (1976) have subdivided the formation into five members based on relative abundances of rock types; these are the Graywacke, Conglomerate, Feldspathic Sandstone, Sandstone-Slate, and Quartzose Sandstone Members. In the type area the Graywacke, Conglomerate, and Feldspathic Sandstone Members, in that order with the Graywacke Member at the base, form the Frenchville Formation section; however, only the Conglomerate and Feldspathic Sandstone Members of the type section extend into the Caribou and Presque Isle quadrangles. The more slate-rich Sandstone-Slate and Quartzose Sandstone Members form eastern and more off-shore facies of the formation.

Conglomerate Member. The Conglomerate Member forms an outcrop belt along the northwest flank of the Stockholm Mountain syncline, where it is the only member of the formation present. In addition it is seen poorly exposed on the west flank of the Castle Hill anticline. The member

consists mostly of pebble/cobble conglomerate and medium-to-coarse grained lithic graywacke. The conglomerate and sandstone occur in medium-to-massive beds that typically show little or no sedimentary features. Common bedding-alignment of pebbles and cobbles and rare graded bedding (see Figure 6 of Roy and Mencher, 1976) are the only sedimentary fabrics seen in conglomerate beds. Sandstone beds also display clast orientation parallel to bedding but also show parallel and lesser cross-lamination as well as poorly developed graded bedding. Based on field modes, a typical conglomerate is composed of approximately 40 percent graywacke sandstone matrix, 30 percent felsic volcanic clasts, 10 percent mafic volcanic clasts, 10 percent chert clasts, and trace abundances of plutonic, limestone, and quartz clasts. Table 1 gives modal analyses from thin sections of conglomerates and sandstones of the member showing the range of compositions seen. Both rock types are derived from a source terrain made up of mixed mafic (largely basalt) and felsic volcanic rocks together with chert, slate, and hypabyssal mafic and quartz-dioritic (?) rocks that are all characteristic of the Winterville Formation (Roy and Mencher, 1976). Conglomerates in the member where it is underlain by the Madawaska Lake Formation contain relatively abundant green-gray slate clasts in addition to contributions from the Winterville Formation. The sandstones have a few to more than 30 percent argillaceous matrix and therefore may be either lithic arenites or lithic graywackes. Pebbly mudstone and red slate seen in the member elsewhere have not been observed in the quadrangles considered here.

Except in the type area, the Conglomerate Member forms the base of the Frenchville Formation and rests with angular unconformity on both the Winterville and Madawaska Lake Formations. Two localities where the unconformity may be clearly seen, outside the quadrangles discussed here, have been previously described (Roy, 1970; Roy, 1980). In the northwestern corner of the Caribou quadrangle at locality C-2083 the contact between the Conglomerate Member and the Madawaska Lake Formation is exposed in a small road-metal borrow pit. Abundant olive-green slate chips that are identical to the slate of the Madawaska Lake Formation are present in the Frenchville conglomerates. The contact itself has had at least some movement along it but displacements are considered small.

Along the northwestern flank of the Stockholm Mountain syncline, the Conglomerate Member is approximately 460 meters (1500 feet) thick, but may thicken to the southeast within the fold. The Conglomerate Member is replaced on the southeast flank of the fold by the Sandstone-Slate Member which may be as much as 1200 meters (4000 feet) thick. At least 240 meters (800 feet) of the member overlies the Winterville Formation on the west limb of the Castle Hill anticline but it is possible that a considerably thicker section is present there. In general the thickness of the Conglomerate Member within the Caribou and Presque Isle quadrangles is greater than the approximately 214 meters (700 feet) seen in the type area (Roy and Mencher, 1976).

Feldspathic Sandstone Member. The Feldspathic Sandstone Member is projected into the western part of the Presque Isle quadrangle from the Ashland quadrangle. Since no exposures of the member have been seen in the Presque Isle quadrangle it will not be described in detail here. The member consists of fine and medium grained sandstone in beds that are

Table 1. Representative model thin section analyses of conglomerate and sandstone, Conglomerate Member of the Frenchville Formation.

Modal Component	**Analysis Number**					
	Conglomerate		**Sandstone**			
	C-279B	A-875	P-1400	P-1443	P-24	P-29
Quartz	5.8	18.8	25.3	8.5	54.8	22.4
Plagioclase	9.4	1.8	16.9	27.0	30.7	15.6
Potassium Feldspar	-	-	-	-	-	-
Detrital Mica	.2	-	1.0	.2	-	.6
Pyroxene	tr	-	tr	-	-	-
Sphene (?)	.2	-	-	-	-	-
Argillaceous Matrix	10.6	10.8	30.4	5.5	9.3	20.8
Secondary Carbonate	-	-	1.0	2.2	2.8	2.6
Opaque	.4	.4	.8	2.2	1.6	2.2
Micrographic Qtz-Feld	1.0	.1	.6	-	.6	2.8
Mafic Volcanic Rocks	53.2	31.7	15.1	39.0	-	17.8
Felsic Volcanic Rocks	17.0	26.2	4.6	2.0	-	3.8
Chert	.2	9.0	.6	1.6	-	2.4
Phyllite	-	-	2.3	-	-	-
Slate/Shale	1.8	-	.8	1.2	-	7.2
Sandstone	-	-	-	-	-	.8
Limestone	-	-	.2	-	-	-
Fossil Fragments	-	-	-	-	-	-
Misc.	-	-	-	.2	-	-
Unidentified	.2	1.2	.4	.4	.2	1.0
	100.0	100.0	100.0	100.0	100.0	100.0

Note: Modes are based on 500+/- counts. Locality A-857 is described at Stop 4 by Roy (1980b)

generally thick and only rarely interlayered with shale. The sandstone averages 26% quartz, 38% plagioclase, 5% volcanic rocks, and 15% argillaceous matrix. Quartz and feldspar are commonly in composite detrital grains (average 26% of the detrital grains) showing igneous textures that indicate a plutonic source (probably a quartz-diorite). The Feldspathic Sandstone Member is 686 meters (2250 feet) thick in the type section of the Frenchville Formation (Roy 1970), but is of unknown thickness in the Presque Isle quadrangle.

Sandstone-Slate Member. The Sandstone-Slate Member is found along the southeastern flank of the Stockholm Mountain syncline in the Caribou quadrangle and in the plunge area of the Castle Hill anticline. The member is made up of about equal proportions of lithic sandstone and slate and forms a more easterly facies of the Frenchville Formation. The largest exposure of the member is at locality F-905 on the south bank of the Aroostook River west of Washburn. The medium- to thin-bedded sequence at F-905 is thought to be representative of the eastern-most phase of the member near its interfingering with the New Sweden Formation. Elsewhere the member is represented by outcrops of sandstone interspersed with exposures of gray, generally non-calcareous, slate.

Sandstone beds of the member commonly show better development of sedimentary structures such as grading and parallel or cross lamination than seen in the Conglomerate Member and are thinner, usually less than about 40 centimeters. Modal analyses of sandstones from the member as shown by typical examples given in Table 2 show that they are similar in composition to those of the Conglomerate Member; the more feldspathic sandstones are typical of those of the Feldspathic Sandstone Member. It is therefore not possible to distinguish the Sandstone-Slate Member on sandstone composition alone; the association of the sandstones with slate and the virtual absence of conglomerate are the important mapping characteristics.

The Sandstone-Slate Member is considered to be an eastern facies of both the Conglomerate and Feldspathic Sandstone Members (Roy and Mencher, 1976). In the plunge of the Castle Hill Anticline the Sandstone-Slate Member rests with apparent disconformity on the Pyle Mountain Formation and west of Washburn, in the Portage quadrangle, it is inferred to similarly overlie the Madawaska Lake Formation. The basal contact of the member has not been observed, but no evidence of marked angularity across the contact is present. At Castle Hill the lowest rocks assigned to the member are poorly exposed beds of lithic graywacke overlain by interbedded sandstone, slate, and calcareous pebbly and fossiliferous sandstone (fossil locality F-E2). These rocks were previously mapped as part of an undifferentiated Ordovician-Silurian unit by Boucot and others (1964), but are here assigned to the member because of their general lithologic similarity to rocks assigned to the Frenchville Formation by them just to the north which are here placed within the Sandstone-Slate Member.

Approximately 1070 meters (3840 feet) of section of the Sandstone-Slate Member is present in the Castle Hill area, but structural thickening is likely. Along the southeastern flank of the Stockholm Mountain syncline, the member is estimated to be 1067-1220 meters (3500-4000 feet) thick based on structural sections; however, the bottom of the formation is not exposed.

Table 2. Thin section modal analyses of sandstones from the Sandstone-Slate and Quartzose Sandstone members of the Frenchville Formation

Modal Component	**Analysis Number**						
	Sandstone-Slate Member				**Quartzose Sandstone Member**		
	P1416	C905U1	C929	C1668	C310-2	C122	C1223
Quartz	4.4	12.8	35.6	9.4	49.6	91.0	54.0
Plagioclasee	25.8	25.1	21.4	33.2	14.6	4.2	12.2
Potassium Feldspar	-	-	18.0	-	.2	-	-
Detrital Mica	-	-	.6	.4	tr	-	-
Pyroxene	-	.4	tr	.2	-	-	tr
Sphene (?)	-	-	-	-	-	-	-
Argillaceous Matrix	30.8	11.0	14.6	20.4	15.6	4.0	25.2
Secondary Carbonate	13.0	10.2	-	1.0	7.2	-	-
Opaque	3.8	.2	1.2	tr	.2	.6	.2
Micrographic Qtz-Feld	-	2.6	5.0	6.2	.8	-	1.0
Mafic Volcanic Rocks	8.6	25.5	.8	22.2	2.2	-	5.4
Felsic Volcanic Rocks	8.8	8.6	.8	3.8	6.4	.2	.2
Chert	2.8	2.0	2.0	2.0	1.8	tr	.2
Phyllite	-	-	-	-	-	-	-
Slate/Shale	.2	-	-	.2	1.2	-	-
Sandstone	-	-	-	-	-	-	-
Limestone	-	-	-	-	-	-	-
Fossil Fragments	-	-	-	-	-	-	-
Misc.	-	-	-	-	-	-	-
Unidentified	1.8	1.6	-	1.0	.2	-	1.6
	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: Based on 500+/- counts per thin section

Quartzose Sandstone Member. The Quartzose Sandstone Member is found along the southeastern flank of the Stockhom Mountain syncline where it occupies the same stratigraphic/structural position as the Sandstone-Slate Member. The Quartzose Sandstone Member is neither well exposed nor extensive in the Caribou quadrangle but forms a broad belt along the northwestern flank of the Stockholm Mountain syncline in the Stockholm quadrangle to the north. Quartzose sandstone, the hallmark of the member, is best seen in the Caribou quadrangle in field exposures on the southeastern slopes of Fogelin Hill and in fields along West Road south of Fogelin Hill.

The Quartzose Sandstone Member is composed of interbedded sandstone and slate. Quartz arenite and graywacke are common and distinguish this member from the Sandstone-Slate Member with which it shares many similarities. The sandstone is typically medium-grained and occurs in beds a few tens of centimeters thick but beds several meters thick have been seen in western parts of the member. Table 2 shows modes of typical sandstones of the member. Quartz abundance is conspicuously elevated as compared with sandstones of the other members of the Frenchville Formation; plagioclase and volcanic rock fragments are variable in abundance but are usually prominent among the non-quartz constituents.

Lower Contact. In the Caribou and Presque Isle quadrangles the Frenchville Formation overlies the Winterville and Madawaska Lake Formations unconformably. The basal contact has been observed in three places where it is seen to be an angular unconformity. Two of the localities where the base of the Frenchville Formation have been seen are in the Ashland and Portage quadrangles and are described by Roy (1970, 1980 b).

A third locality, a small pit along a lumber road at C-2083, is present in the northwest corner of the Caribou quadrangle and shows the contact between the Frenchville and Madawaska Lake Formations. The contact is interpreted to be an angular unconformity along which there has been some fault displacement. The sandstone and conglomerate beds of the Frenchville Formation are typical of those of the Conglomerate Member and contain abundant clasts of green slate that are typical of the underlying Madawaska Lake Formation. The broken character of the rocks of the pit make it difficult to determine the exact nature of the contact but it trends N 40 E and dips steeply to the northwest in contrast to northwesterly trending bedding strikes in the Madawaska Lake Formation near the contact.

The basal contacts of members of the Frenchville Formation with the Winterville (Conglomerate Member) and Pyle Mountain (Sandstone-Slate Member) Formations in the Presque Isle quadrangle have not been observed but are inferred to be unconformities (Roy and Mencher, 1976).

Age. A total of seventeen fossil localities have been found in the Frenchville Formation and have been described by Boucot and others (1964) and Roy (1970). Fossils from these localities taken together indicate an age span for the formation of Late Llandoverian to Early Ludlovian but stratigraphic relationships with older and younger formations suggest a possible range of Early Llandoverian to Earliest Ludlovian.

Only four of the fossil localities come from the quandrangles considered here but they are broadly representative of both the fauna and age span of the formation. The fauna and age assignments for these four localities are given in Table 3. It is important to note that most of the fossil localities in the Frenchville Formation are stratigraphically in the upper half of the formation; therefore the lower part of the unit is generally undated. The notable exception is locality F-E2, located near the base of the formation within the Sandstone-Slate Member in the plunge of the Castle Hill anticline. Locality F-E2 suggests that the base of the formation is likely to be Late Llandoverian in the Castle Hill area. However, north of Ashland in the Ashland quadrangle the basal Graywacke Member of the Frenchville Formation rests conformably on the Aroostook River Formation of Ashgillian-Early Llandoverian age (Roy and Mencher, 1976) and thus the lower part of the Frenchville Formation may there be of Early Llandoverian age. Along the northwestern flank of the Stockholm Mountain syncline in the Caribou quadrangle, the base of the Frenchville Formation has not been dated and may also be as old as Early Llandoverian.

New Sweden Formation

The New Sweden Formation is the lower of the two formations of the Perham Group. Rocks presently assigned to this formation in the Presque Isle quadrangle were included in the "Lower Member" of the Perham Formation by Boucot and others (1964) and later by Pavlides (1968, 1978). Roy and Mencher (1976), in elevating the member to formation rank, cited the poorly exposed section in Woodland Township (which includes fossil locality F-303) as the type section of the group following its citation as the type section of the Perham Formation by Boucot and others (1964). Rocks typical of the formation are also widespread in Perham Township and are well exposed in the village of Perham itself. The New Sweden Formation is named for the village of New Sweden in which the formation is also well exposed, especially on Capital and Gelot Hills. Although largely a unit of phyllite with lesser micrite, the New Sweden Formation contains some lithic sandstone and noteworthy occurrences of laminated manganiferous ironstone.

Phyllite and Micrite. The most common rock type in the New Sweden Formation is gray calcareous phyllite (locally slate) that generally contains abundant calcareous siltstone laminae. Argillaceous micrite in lenses and thin beds, usually less than 5 centimeters thick, is a common interlayered lithology. The calcareous phyllite with interlayered micrite produces sequences in outcrop that are similar to those seen in the underlying Upper Member of the Carys Mills Formation. Along the contact between the Carys Mills and New Sweden Formations, the two units are distinguished by proportion of micrite; the Carys Mills Formation is defined along the contact as containing 50 percent or more micrite. The loss of micrite upward within the New Sweden Formation takes place over a short distance from the contact so that micrite is typically less than 10 percent of the formation. It is common for the micrite beds to be segmented by the cleavage with pelite "injection" along the cleavage producing lenticular pseudolenses of micrite which can be confused for bedding.

Table 3. Fossil localities in the Frenchville Formation from the Caribou and Presque Isle quadrangles, Maine.

Fauna	Locality			
	F-1343	F-E12	F-E2	F-905
Brachiopods				
Amphistrophia cf. A. straiata			X	
Artriotreta sp.				X
Coolinia sp.			X	
Dinobalus sp.			X	
Dolerorthis flabellites			X	
dalmanellid			X	
Eoceolia cf. hemisphaerica		X		
Leangella sp.	X		X	
Leptaena "rhombodalis"		X	X	
Pentamerus sp.		X		
Plectodonta sp.	X	X	X	
Protomegastrophia sp.			X?	
Ptychopleurella sp.			X	
Stricklandia lens cf. ultima		X		
stricklandid	X		X	
stropheodont			X	
Corals				
Porpites porpita	X			
Conodonts				
Spathognathodus celloni Walliser				X
Spathognathodus pennatus angulatus Wallister				X

Notes:

F-1343: Conglomerate Member. "Probably C_6-to-lowest Wenlock or possibly C_5 based on Porpites" (A. J. Boucot, personal communication, 1966).

F-E12: Quartzose Sandstone Member. C_4-C_5 of the Llandoverian (Boucot and others, 1964).

F-E2: Sandstone-Slate Member. Late Llandoverian (A. J. Boucot, personal communication, 1964).

F-905: Sandstone-Slate Member. On the conodonts, G. Klapper (personal communication, 1969) assigns the age to celloni zone of Walliser or approximately C_2-C_4 of the Llandoverian.

Sandstone and Conglomerate. Lithic arenite and graywacke are present in the New Sweden Formation as isolated beds, especially along the western margin of its outcrop belt. Such medium-to-coarse grained sandstone is present at F-1485 and in extensive exposures along the north bank of the Aroostook River downstream from F-905 about 0.7 miles. These sandstones are compositionally similar to sandstones of the Frenchville Formation and occur in beds showing typical turbidite features. Fine-grained sandstone is also present in the New Sweden Formation as thin beds (generally less than 8 cm thick) that are parallel-laminated or cross-laminated and calcareous.

Conglomerate is present near the base of the New Sweden Formation east of Castle Hill and near the contact with the overlying Jemtland Formation that lies in the core of a small syncline. This conglomerate is composed of angular to rounded pebbles of chert, felsic volcanic rocks, and lesser mafic volcanic rocks and is interbedded with feldspathic sandstone.

Manganiferous Ironstone and Red Slate. White (1943), Miller (1947), and Pavlides (1962) have described in detail the manganiferous ironstones that are widespread in eastern Aroostook County. The ironstones in the Caribou and Presque Isle quadrangles constitute the "northern district" and are confined to the New Sweden Formation. The ironstones are present at all stratigraphic levels. They are present at the base of the formation along Turner Road east of the Castle Hill anticline near F-444 and at the top of the formation stratigraphically below F-A2, the "Dudley Deposit". Where well exposed, the ironstones can be shown to be of a generally lenticular character and they commonly consist of a zone of "high grade" laminated ironstone surrounded by red noncalcareous slate. The lenticular deposits vary in thickness from a few decimeters to several tens of meters and in length to in excess of 1000 meters. The largest deposit in the region discussed here is at Capital Hill; it has been described by Miller (1947) following extensive trenching. The map traces of ironstone horizons encountered during mapping are shown on Plate 1 but in most cases limited outcrop prevents tracing them to their stratigraphic terminations. The highest grade ore in manganese was reported by Miller to be at the Dudley Deposit.

Lower Contact. In the quadrangles covered in this report, the New Sweden Formation is observed to overlie the Pyle Mountain Formation along the east flank of the Castle Hill anticline and to overlie the Carys Mills Formation along a contact from Washburn to Conner in the Caribou quadrangle. The formation also apparently rests on the Madawaska Lake Formation in the northeastern part of the Stockholm quadrangle as described by Roy (1970).

The contacts with the Pyle Mountain and Carys Mills Formations have not been seen in outcrop but are locally approached to within a few tens of meters. The lower contact with the Pyle Mountain Formation is inferred to be an unconformity, possibly a disconformity, based on the hiatus between the two formations suggested by fossil localities near the contact (Late Ashgillian-to-Late Llandoverian) and the absence of physical evidence that the contact is a fault. The contact with the Carys Mills Formation appears to be gradational, although it is possible that it is at least in part faulted. The Dudley fault seems to be clearly established along the

contact between the two formations in the Presque Isle quadrangle (see discussion below) and may extend farther northeast in the Caribou quadrangle. The lithologic similarities between the formations discussed above and the near absence of a hiatus as suggested by the presence of graptolites of zone 18 in the Carys Mills (F-402) and zone 19 in the New Sweden (Stockholm quadrangle; Roy, 1970) further suggest a gradational contact.

Age. There are three fossil localities in the New Sweden Formation that suggest an age span for the formation of Middle Llandoverian to possibly as young as Early Ludlovian. Stratigraphic relations with the overlying and well dated Jemtland Formation suggest that the top of the New Sweden Formation is probably no younger than Late Wenlockian. Table 4 shows the fauna collected from two localities in the Caribou (F-1485) and Presque Isle quadrangles and one locality from the northeastern part of the Stockholm quadrangle (F-EM305, Roy 1970). Localities F-444 and F-EM305 are stratigraphically near the bottom of the formation and suggest that there is likely to be some diachronism in the base of the unit. Locality F-444 is located just above the contact with the Pyle Mountain Formation east of the Castle Hill anticline where the base of the formation is of Late Llandoverian age. This is consistent with the age of the generally coeval Frenchville Formation on the flanks of the anticline as suggested by the fauna at F-E2 discussed above. Locality F-EM305 is also stratigraphically equivalent to the lower Frenchville Formation along the northwestern flank of the Stockholm Mountain syncline west of Martins Siding in T17R3 (Roy, 1978) but is of Middle Llandoverian age. Locality F-1485 is stratigraphically near the top of the New Sweden Formation and is of probable Wenlockian age.

Spragueville Formation

Pavlides (1966) named the Spragueville Formation and cited the vicinity of the village of Spragueville, south of Presque Isle, as the type area. The Spragueville Formation as presently mapped is synonymous in the Presque Isle quadrangle with the upper ("nubbly") member of the "Aroostook Limestone" as used by White (1943) and the "Unnamed Silurian Limestone" of Boucot and others (1964). Pavlides (1968, 1978) and Roy (1970, 1978) modified the distribution of the formation in the Presque Isle quadrangle from that shown by Boucot and others (1964) and have extended the unit into the southeastern part of the Caribou quadrangle. The best exposures of the formation are located along Maine Rt. 163 in the town of Mapleton, at and near F-E10.

Lithology. The Spragueville Formation is largely made up of a very calcareous laminated silty mudstone that typically is broken along bedding partings spaced 1 to 15 centimeters apart. In outcrop therefore the formation presents a "flaggy" appearance, especially in the region discussed here. In the Fort Fairfield and Mars Hill quadrangles to the east, the formation is generally well cleaved and the flaggy character is absent or only locally seen. The lamination is caused by an alternation of layers of light gray highly calcareous siltstone or silty limestone with layers of dark gray calcareous silty mudstone. The highly calcareous siltstone/limestone contains abundant bioclastic particles with quartz,

Table 4. Fossil localities in the New Sweden and Spragueville Formations

Fauna	Localities					
	New Sweden			Spragueville		
	F-44	F-1485	F-305	F-E10	F-210	F-F4
Graptolites						
Climacograptus scalaris var. miserabilis					x	
Climacograptus of the C. scalaris type			x			
Monograptus communis (Lapworth)					x	
Monograptus triangularis			x			
Rastrites approximatus approximatus (Perner)					x	
Brachiopods						
Amphistrophia		x				
Atrypa "reticularis"		x		x		
Coolinia sp.		x				
Cyrtia sp.		x				
Dalejina sp.		x		x		
Decaelosia sp.		x				
Eocoelia cf. intermedia or curtisi	x					
Eospirifer sp.		x				
Glassia sp.				x		
gypidulinid		x				
Howellella sp.		x		x		
Leangella sp.		x				
Leptaena "rhomboidalis"		x		x		
Linoporella sp.		x?				
Meristina sp.		x				
Mesopholidostrophia sp.		x		x		
Nucleospira sp.				x		
orthotetaceid				x		
Pentamerus sp.	x					
Plectodonta sp.	x	x		x		
Protomegastrophia sp.	x?	x				
Ptychopleurella sp.	x					
Resserella sp.		x		x		
rhynchonellid		x		x		
Salopina sp.		x				
stricklandid	x					
Strophonella sp.		x				
Ostracods						
Apatobolbina sp.				x		
Bolbineossia sp.				x		
Zygobolba inflata (Ulrich and Bassler)				x		
Gastropods						
undetermined		x				
Trilobites						
Portlockia sp.				x		
Conodonts						
Walliserodus curvatus (Branson and Branson)						x

Notes:

F-444: C_3-C_5 of the Late Llandoverian, A. J. Boucot (personal communication, 1966).
F-1485: Probably Wenlockian, A. J. Boucot (personal communication, 1965).
F-305: Stockholm quadrangle, approximately zone 19 of the Llandoverian (W. B. N. Berry, personal communication, 1965).
F-E10: C_3-C_5 of the Late Llandoverian, Boucot and others (1964).
F-210: Fort Fairfield quadrangle, zone 19 or 20 of the Llandoverian (loc. 2 of Pavlides, 1968).
F-F4: Llandoverian-Early Wenlockian (Pavlides, 1978).

feldspar, and muscovite as the principal siliciclastic detritus. The calcareous mudstone layers are composed of a carbonate and argillaceous "matrix" enclosing silt-sized quartz, muscovite, and lesser feldspar grains. In some cases these two types of layers can be seen in thin section to form graded couplets with the light gray siltstone grading upward into the calcareous mudstone.

Argillaceous micrite is an common lesser rock type in the Spragueville Formation. It occurs in beds from 1 to 15 centimeters thick and is usually weathered to a gray color with no "rind". These micrite beds are indistinguishable from micrite beds in the underlying Carys Mills Formation and the coeval New Sweden Formation. Light gray, orange weathering, variably bioturbated, silty limestone is also seen in beds to several tens of centimeters thick.

Bioturbation is a very common feature of the rocks of the Spragueville Formation. Indeed it is the only formation in the area that shows pervasive reworking by burrowing organisms. The bioturbation is manifested by both cross-stratal and intra-stratal burrow fillings. The largest diameter burrow fillings are about 2 centimeters in diameter and are traceable in some specimens for up to about 15 centimeters. The larger burrows generally show meniscate backfilling segments and can sometimes be seen to radiate outward from a common center. Most outcrop surfaces, however, show cross-sections of the burrows which appear as "knots" in wood which possibly led White (1943) to call the unit the "nubbly" limestone. Small intrastratal burrows are usually easily seen on bedding surfaces and show branching and/or radiating patterns. William H. Forbes (personal communication) reports the presence in some exposures of well developed trilobite rest marks (Cruziana). As yet, however, there has been no formal categorization of the trace fossils of the Spragueville Formation.

Lower Contact. The Spragueville Formation overlies the Carys Mills Formation in the Presque Isle and Caribou quadrangles. In these quadrangles the lower contact of the formation is not seen and is generally not even closely located. In the vicinity of Giggey Hill, just northwest of Fort Fairfield, Maine and on Stewart Hill, south of Limestone, Maine, successions of exposures suggest that a complete transition between the Carys Mills and Spragueville Formations is present (Roy, unpublished data; Pavlides, 1968, 1978). A gradational contact is further suggested by the presence of graptolites as young as zone 19 in the Carys Mills Formation and graptolites in the span of zones 19-20 in the Spragueville Formation from localities outside the area of this report (Pavlides, 1968).

Thickness. Boucot and others (1964) estimated the Spragueville Formation (their "Unnamed Silurian Limestone") to be no greater than 1220 meters (4000 feet) thick in the Presque Isle quadrangle. Pavlides (1968) modified the distribution of the formation in the vicinity of Presque Isle itself and suggested a thickness of 915 meters (3000 feet) with apparent thinning southward to near extinction along the eastern slopes of Green Mountain. At Mapelton, the thickness appears to be approximately 1130 meters (3700 feet) but the base of the formation is not closely located and near Fort Fairfield approximately 760-915 meters (2500-3000 feet) are preserved in a syncline (Roy, unpublished data).

Age. In the region of this report there are two important fossil localities within the Spragueville Formation. The fauna recovered from these localities and a locality near Nadeau Pond in the Fort Fairfield quadrangle are shown in Table 4. These localities suggest an age span for the formation of graptolite zone 19 or 20 to possibly Early Wenlockian; conodots reported by Pavlides (1978) for locality F-F4 are consistent with this age span. Therefore the Spragueville Formation is a temporal equivalent of the Frenchville and New Sweden Formations.

Jemtland Formation

The Jemtland Formation is part of the Perham Group (Roy and Mencher, 1976). As presently mapped, it is nearly synonymous with the Upper Member of the Perham Formation of Boucot and others (1964). The formation is named after the small settlement of Jemtland in the Stockholm quadrangle along Maine Route 161 just 0.5 miles north of the Caribou quadrangle. The type areas for the formation are the outcrop belts of the formation along both flanks of the Stockholm Mountain syncline between Jemtland and the village of Stockholm. The best exposures of typical rock types of the western graywacke facies (see Roy, 1980) are at fossil localities F-498 and in a large road cut along Maine Route 161 in Jemtland. The more eastern slate facies is best seen along the railroad tracks about 1.75 miles northwest of Perham, but the outcrop expression of this facies is poorer than that for the graywacke facies.

Lithology. The Jemtland Formation is a sequence of thinly interlayered shale (slate) and siltstone (on thickness scale of centimeters) in which thicker beds of graywacke are variably interbedded. In addition, micritic limestone, conglomerate, and limestone breccia are important but minor rock types. Tuff forms the Aquagene Tuff Member along the western limb of the Stockholm Mountain syncline and to a lesser extent along the eastern limb of the fold.

There are actually three different types of shale recognized in the formation (Roy, 1970; Roy and Mencher, 1976; Carey and Roy, 1985). Following Carey and Roy (1985) these shales may be described as (1) nonlaminated, dark gray to black, silt-poor shale (or slate; <20% silt), (2) nonlaminated, calcareous, silty shale (20-60% silt), and (3) intermittently laminated, calcareous silty shale (45-60% silt). These shales are in beds from 1 to several centimeters thick and are interlayered with each other and with siltstone. The silt-poor shale almost everywhere shows an axial plane, or near-axial plane, cleavage whereas the silty shales, especially in the graywacke rich facies of the formation, more typically display a cleavage/fissility parallel to bedding. Graptolites, though found in all of the types of shale, are most common and best preserved in the laminated shale.

Interlayered with the three types of shale are laminae and thin beds of light gray, laminated and/or cross-laminated, calcareous siltstone. The siltstone beds weather to a bright orange color and a exhibit well developed leached weathering rind. The siltstone is composed largely of quartz and lesser muscovite detrital grains with a matrix of carbonate and variable chlorite sericite.

Conspicuous in the western and southwestern parts of the Jemtland Formation are beds of lithic and feldspathic graywacke. The graywacke is present in beds from a few centimeters to as much as a meter thick. The beds are most commonly graded and show internal sedimentary structures typical of turbidite sandstones. Petrographically, graywacke of medium and coarse grain size contains abundant clasts of volcanic rocks, chert, carbonate, and dark slate typically as in the sandstones of the underlying Early Silurian formations as shown in Table 5. Fine-grained sandstones are typically more quartz-rich and have higher abundances of secondary carbonate. There is also pervasive alteration of feldspathic rock fragments and feldspar detrital grains to carbonate which makes analysis of the original textures of the sandstones difficult.

At locality F-A2, on the Dudley Farm west of Mapleton, there is a limestone breccia near the base of the Jemtland Formation and stratigraphically just above the Dudley ironstone deposit at the top of the New Sweden Formation. This breccia was correlated by Williams and Gregory (1900) and Twenhofel (1941) with what are now known to be Devonian limestones near Ashland. Boucot and others (1964) correlated the breccia on the Dudley farm with limestone breccia near Chapman; the Chapman breccia is probably of similar origin but somewhat higher in the section. The breccia consists of angular to rounded, gray, biomicrite pebbles and cobbles (up to 20 centimeters in greatest dimension) that are closely packed and cemented by an argillaceous micrite matrix. The clasts have abundant fossil hash within them. In parts of the breccia the fragments form an angular mosaic that suggests brecciation in place, but generally the breccia appears to have been transported, presumably from penecontemporaneous shallow water shelves nearby. Pebble conglomerate and micritic limestone are seen in the Jemtland Formation outside of the region described here but neither is common.

Tuff Member. Lithic and vitric aquagene tuff forms a mappable unit on the western limb of the Stockholm Mountain syncline and is present at F-498. Although discontinuously exposed, the member is probably continuous and forms a marker horizon in about the middle of the Jemtland Formation. On the western flank the member is approximately 18 meters (60 feet) thick; on the eastern flank of the fold a few outcrops of a much thinner tuff horizon are present in about the same stratigraphic level and may be the same volcaniclastic interval. Roy (1980) has described the lithology of the member based on a measured section in the Stockholm quadrangle as follows:

> Four broad tuffaceous rock types comprise this section. Type I tuff, the most abundant, is light gray-green, chalk-white weathering, and variably lithic in section, devitrified shards and pumice fragments are clearly visible. Plagioclase, quartz, and chlorite are dominant mineral phases. Lithic tuff, designated as Type II, is composed of sand-to-pebble size fragments of intermediate and mafic volcanic rocks, plagioclase, quartz, myrmekitic quartz-feldspar, and detrital carbonate (including fossil fragments) set in a matrix of devitrified shards and pumice fragments. Type II tuff usually [changes]

Table 5. Modal analyses of sandstones and a conglomerate from the Jemtland Formation

Modal Component	**Analysis Number**					
	Sandstones					**Congl.**
	C-386	P-393-1	S-635	C-307	S-636	P-393-2
Quartz	44.7	8.0	6.0	9.6	5.4	7.6
Plagioclase	1.4	14.8	12.0	20.2	10.8	-
Potassium Feldspar	-	-	-	-	-	-
Detrital Mica	6.1	-	0.2	-	tr	0.2
Pyroxene	-	-	-	0.2	tr	-
Sphene (?)	-	-	-	-	-	-
Argillaceous Matrix	19.1	23.6	17.0	15.0	23.5	5.4
Secondary Carbonate	28.1	4.4	18.6	1.2	1.4	0.4
Opaque	0.6	2.0	0.8	0.4	-	1.2
Micrographic Qtz-Feld	-	-	-	13.4	31.6	7.2
Mafic Volcanic Rocks	-	40.4	44.0	1.4	0.6	13.3
Felsic Volcanic Rocks	-	2.0	0.4	1.6	0.8	45.0
Chert	-	3.8	0.2	-	-	-
Phyllite	-	-	-	-	-	-
Slate/Shale	-	-	-	-	0.2	0.8
Sandstone	-	-	-	-	-	-
Limestone	-	1.0	0.4	6.6	1.4	1.2
Fossil Fragments	-	-	-	-	-	0.2
Misc.	-	-	-	-	-	9.3
Unidentified	-	-	0.4	1.2	1.6	1.4
Total	100.0	100.0	100.0	100.0	100.0	100.0

Notes:

1) All modes based on 500 counts.
2) C-386 is a fine-grained sandstone: other sandstones are medium-grained.

upward into Type I in apparently graded sedimentation units. Type III tuff is a chlorite-rich rock that differs from Type I primarily in the presence of large chlorite "patches" that are flattened parallel to a bedding parting. Upward gradation from Type I to Type III tuff is observed in three beds. Type IV tuff is fine-grain, light gray-green in color, cherty in appearance, and occurs in beds less than 6 inches thick that commonly show faint lamination. Type IV shows devitrified shards and pumice fragments in a dominant matrix of microcrystalline quartz-chlorite-plagioclase.

Lower Contact. The Jemtland Formation overlies, from west to east, the Frenchville, New Sweden, and Spragueville Formations. Transitional contacts with the Frenchville and New Sweden Formations can be observed; the contact with the Spragueville Formation is not exposed but may also be gradational. In the Caribou quadrangle the contact with the Frenchville Formation can be observed in the Little Madawaska River near F-1343 on the western flank of the Stockholm Mountain syncline. The transition involves the upward introduction of the shales and graywacke beds of the Jemtland-type with the gradual loss and fining of sandstones of the Frenchville-type.

The contact with the New Sweden Formation can be seen at (1) the Blackstone Farm section at locality F-303 in Woodland Township, (2) in road ditch and cut exposures along Maine Route 228 on the west limb of the small syncline cored by Jemtland Formation east of Castle Hill, and (3) in ditch and road cut exposures along the unnamed road just north of locality F-A2. In all of these cases the slate and phyllite characteristic of the New Sweden Formation are replaced by thin bedded shales and siltstones of the Jemtland Formation.

Thickness. The Jemtland Formation is remarkably uniform in thickness over a wide area. In the Stockholm Mountain syncline, where the top and bottom of the formation are generally well located, the formation averages about 760 meters (2800 feet) thick. In the Presque Isle quadrangle, near Mapleton, about 600 meters (2000 feet) of section appears to be present.

Age. A total of 55 fossil localities, most yielding graptolites, have been found in eastern Aroostook County and adjacent New Brunswick. These localities span the formation stratigraphically from bottom to top and suggest an age range of Wenlockian-to-Early Ludlovian. The fossil localities from the Caribou and Presque Isle quadrangles are given in Table 6 and Table 7 respectively. The stratigraphic distribution of the localities suggest the upper 85-90 percent of the Jemtland Formation is of Early Ludlovian age with the top of the formation probably within graptolite zone 34.

SILURIAN and/or DEVONIAN SYSTEMS

Fogelin Hill Formation

The Fogelin Hill Formation is a sequence of red and green shale (slate) interlayered with siltstone and fine-grained sandstone that

Table 6. Fossil localities in the Jemtland Formation in the Caribou Quadrangle.

Fauna	Locality								
	F-303	F-307	F-312	F-664	F-411	F-412	F-413	F-498	F-190
Graptolites									
Cyrtograptus sp.		X?							
Monograptus bohemicus (Barrande)				X					
M. colonus (Barrande)								X	
M. colonus var. compactus (Wood)							cf.		
M. crinitus (Wood)	X_B		cf.						
M. sp. (of the M. dubius type)	X_B	X			X	X	X	X	
M. flemingii (Salter)		X							
M. micropoma (Jaekel)									cf.
M. micropoma micropoma (Jaekel)						aff.			
M. nelssoni (Barrande)	X_B								
M. sp. (of the M. priodon group)	X_A								
M. scanicus (Tullberg)					X				
M. sp. (of the M. scanicus type)			X						
M. uncinatus (Tullberg)								X	M.
M. new sp. (of the M. uncinatus type)						X			
M. varians (Wood)							X		
M. sp. (of M. vomerinus type?)	X_A								
M. sp. (of the M. vulgaris type)				X			X		
M. sp. A of Berry (1964)				X					
M. sp. (plain thecae)	X_A								X
Plectograptus macilentus (Tornquist)								X	

Notes:

F-303: This locality is the type section of the "Perham Formation" of Boucot and others (1964). Fauna are from two collections (A and B) separated stratigraphically by about 90 meters (300 feet). Collection "A" made by the present writer is from a lower stratigraphic level than "B" and is of Late Llandoverian-Wenlock age (W. B. N. Berry, personal communication, 1964). Collection "B" is locality of "PV" of Boucot and others and is of Early Ludlovian of the Silurian (graptolite zones 33-34).

F-307: Late Wenlockian (W. B. N. Berry, personal communication, 1964).

F-312: Early Ludlovian, zones 33-34 (W. B. N. Berry, personal communication, 1964; collection by W. H. Forbes).

F-664: Early Ludlovian, zones 33-34 (W. B. N. Berry, personal communication, 1964; collection by Douglas Smith).

F-411, F-412, F-413, F498: Early Ludlovian, zones 33-34 (W. B. N. Berry, personal communication, 1964; collection by Ely Mencher).

F-190: Probably Early Ludlovian, zones 33-34 (W. B. N. Berry, personal communication, 1965; collection by Gary Laux and Richard Warner).

Table 7. Fossil localities in the Jemtland Formation of the Presque Isle Quadrangle.

Fauna	Locality										
	F-498	F-594	F-596	F-E13	F-D3	F-B2	F-E5	F-E9	F-A8	F-E7	F-A2
Graptolites											
Monograptus bohemicus (Barrande)		X	X								
M. chimaera (Barrande)						X					
M. colonus (Barrande)							X	X			
M. colonus var. compactus (Wood)		X	X		X	X			cf.		
M. crinitus (Wood)	cf.	X	cf.								
M. dubius (Suess)	X	X	cf.		X	X	X	cf.	X		
M. forbesi (Berry)		X	X			X		X			
M. nilssoni (Barrande)		X			X	X					
M. scanicus (Tullberg)			cf.			cf.		X			
M. sp. (M. scanicus type)	X										
M. tumescens (Wood)		X	X								
M. turmescens var. contus (Berry)		X				X					
M. uncinatus var. micropoma						X					
M. sp. (thecae like those of M. uncinatus)											
M. varians (Wood)			X	X		cf.					
M. vicinus (Perner)		X	cf.		cf.	cf.			cf.		
M. sp. A of Berry (1964)			X			X					
monograptid of type III									X		
M. sp.							X	X			
Brachiopods											
atrypacean (smooth)				X							
"Camarotoechia" sp.										X	
Coelospira saffordi										cf.	
Conchidium sp.											X
Encrinurus sp.										X	
Glassia sp.										X	
Leangella sp.				X							
Plectodonta sp.										X	
Trilobites											
Diacalymere sp.				X							
Phacops sp. (of the P. orestes group)				X							
Ostracods											
Condracupris sp.				X							
Grammolomatella sp.				X							
Rishona sp.				X							
Spinobairdia sp.				X							
Tubulibairdia sp.				X							
Gastropod											
Platyceras sp.										X	

Notes:

F-489: Early Ludlovian, graptolite zones 33-34 (W. B. N. Berry, personal communications, 1970; collected by Berry and W. H. Forbes).

F-594, F-596: Early Ludlovian, graptolite zone 33 (localities "LB" and "SR1/SR2" of Berry, 1964).

F-E13: Lake Wenlockian (Boucot and others, 1964; Pavlides, 1968).

F-D3, F-B2, F-E5, F-E9, F-A8: Early Ludlovian, graptolite zone 33 (Boucot and others, 1964: localities D3, B2, and A8 are localities "DB", "DF", "CS", respectively of Berry, 1964).

F-E7: Late Wenlockian-Ludlovian (Boucot and others, 1964; A. J. Boucot, personal communication, 1970).

F-A2: Ludlovian (Boucot and others, 1964).

overlies the Jemtland Formation in the Stockholm Mountain syncline. The formation is named for Fogelin Hill in the northwestern corner of the Caribou quadrangle. The most easily accessible exposures of the formation are in road metal pits and road cuts along lumber roads in the central part of T13R5 in the southern part of the Portage quadrangle (Roy, 1978), in modest road cuts and adjacent fields along the road between Jemtland and Stockholm, and along the road and in fields on the western slope of Fogelin Hill itself.

Slate. It is estimated that slate forms between 40 and 60 percent of the Fogelin Hill Formation. Most of the slate is light olive-green or red brown in color, silty, and micaceous. The slates are generally non-calcareous but some are slightly calcareous and cleavage is commonly parallel or subparallel to bedding. The generally red and green slates of the Fogelin Hill Formation are the most distinctive feature of the unit and contrast markedly from the gray and black shales of the underlying Jemtland Formation. The red and green color is not usually stratabound and patches of one color may be found within areas of the other. The coloration also does not seem to be controlled by cleavage.

Sandstone. Light green-gray, very calcareous and micaceous, fine-grained sandstone is interbedded with the varigated slates. Beds of the sandstone are typically laminated, which causes a characteristic bedding parting in most outcrops of the formation. Less commonly the sandstone beds are cross-laminated or partially cross-bedded but the typical turbidite succesions seen in the Jemtland Formation graywacke beds are not commonly seen.

Lower Contact. The Fogelin Hill Formation rest conformably on the Jemtland Formation in the Stockholm Mountain syncline. A section crossing the contact is locally exposed in road ditches and cuts in the village of Stockholm; the section shows the introduction of the red and green slate at the expense of the darker slates/shales of the Jemtland Formation over a several meter thick stratigraphic interval.

Thickness. The upper contact of the Fogelin Hill Formation is not observed in the Stockholm Mountain syncline. As a result, the total original thickness of the formation is unknown. In the syncline approximately 760 meters (2500 feet) of Fogelin Hill Formation is preserved.

Age. There are three fossil localities in the Fogelin Hill Formation but none are in the Caribou and Presque Isle quadrangles. These localities suggest an age span of Early Ludlovian to Siegenian of the Devonian based on graptolites (Roy, 1970; Roy and Mencher, 1976).

DEVONIAN SYSTEM

Dockendorff Group

The Dockendorff Group of the Chapman syncline in the Presque Isle quadrangle was established by Boucot and others (1964) and is a thick succession of volcanic rocks interlayered and interfingering with

sedimentary rocks. The mapped distribution of the group shown in Plate 1 is little changed from that shown by Boucot and others (1964) and later by Pavlides (1978). Sargent (1985) has recently completed an important geochemical study of the volcanic rocks of the group which has improved the understanding of the magmatic history they represent and altered the names given to some of the rocks by Boucot and others (1964) and previously by Williams and Gregory (1900).

Hedgehog Formation

The Hedgehog Formation is exposed as two high ridges on the east and west flanks of the Chapman Syncline in the Presque Isle quadrangle. The formation gets its name from the ridge presently called Squa Pan Mountain but previously called Hedgehog Mountain (Williams and Gregory, 1900). In addition, the formation is also seen exposed in low ridges between Squa Pan Mountain and Squa Pan Lake, on Gardner Mountain, and less well on Griffin Ridge. The Hedgehog Formation is estimated to be in excess of 1200 meters (4000 feet) thick and made up largely of rhyolitic crystal and lithic tuffs that commonly show eutaxitic textures. Quartz phenocrysts are common, making up between 8 and 25 percent of the tuffs with rarer crystals of rounded potash feldspar (Sargent, 1985). Mappable units of basalt (west flank of the syncline) and andesite (east flank) are also present but of lesser volume. These intermediate and mafic units were all originally mapped as Andesite (Dha) by Boucot and others (1964) but found to be geochemically and petrographically separable by Sargent (1985). Sargent found the silicic volcanic units within the formation as mapped by Boucot and others (1964) to be appropriate but suggested that they be redesignated as follows: Trachyte and Rhyolite (Dhtr) redesignated **Fused Tuff**; Tuff (Dht) redesignated **Green Tuff**; and Dark Colored Trachyte (Dhdt) redesignated **Blue Tuff**. The Hedgehog Formation also contains lentils of sedimentary rocks that include gray and red siltstone as well as sandstone (Boucot and others, 1964).

Edmunds Hill Andesite

Boucot and others (1964) established the Edmunds Hill Andesite and divided it into Upper and Lower Members. The Edmunds Hill is approximately 900 meters (3000 feet) thick and overlies the Hedgehog Formation, occupying the axial region of the Chapman syncline between Edmunds Hill and Hobart Hill. The Lower Member is composed of dark brown, augite-bearing andesite and andesite braccia whereas the Upper Member is made up of dark gray and black, augite-poor, biotite-bearing andesite (Boucot and others, 1964; Sargent, 1985).

Chapman Sandstone

The Chapman Sandstone is found along the axis of the Chapman syncline, largely in Chapman Township after which it is named. The Chapman Sandstone has long been known for its locally abundant fossils (Williams, 1899). Fine-to-medium grained, gray, brown weathering, lithic arenite and graywacke comprise most of the formation. Locally the sandstones are interbedded with thin beds of green micaceous mudstone or slate. The

sandstone beds are typically thick-bedded and show crossbedding and parallel lamination. The formation is estimated by Boucot and others (1964) to be at least 2400 meters (8000 feet) thick, but it is so poorly exposed that it is possible that unrecognized faults and folds contribute to make the section appear to be much thicker than suggested by the simple syncline as presently interpreted.

Swanback Formation

The Swanback Formation forms a broad terrain in the southern part of the Presque Isle quadrangle along the axis and flanks of the Chapman syncline. Green silty argillite and laminated slate comprise most of this poorly exposed formation. Sandstone in the formation contains volcanic detritus, especially along its contact with the underlying Hedgehog Formation along the western limb of the syncline (Boucot and others, 1964). The formation may be as much as 3000 meters (10,000 feet) thick according to Boucot and others (1964) as suggested by the structure of the Chapman syncline.

Age of the Dockendorff Group. The age of the Dockendorff Group has been established as New Scotland of the New York Reference Section or Late Gedinnian of the European Section by Boucot and others (1964). This age is based on fauna from five fossil localities, one from the basal Hedgehog Formation just west of Edmund's Hill, three from the Chapman Sandstone, and one from the Swanback Formation; see Boucot and others (1964) for faunal lists and discussions. The Hedgehog Formation unconformably overlies the Jemtland Formation everywhere the basal contact of the formation has been mapped, and the hiatus seems to span the Late Ludlovian, Pridolian, and Early Gedinnian (Manlius/Coeymans), or a span of approximately 12 million years. The Chapman Sandstone and the Swanback Formation are probably temporal equivalents of each other and the Edmunds Hill Andesite (Boucot and others, 1964). The hiatus and the pre-Hedgehog deformation of the Jemtland and older units in the Presque Isle area are taken to represent a local expression of the Salinic Disturbance as described by Boucot (1962).

UNDIVIDED LOWER DEVONIAN ROCKS

West of Squa Pan Mountain are poorly exposed rocks of Early Devonian age that have not as yet been subdivided. The rocks so far seen in the Presque Isle quadrangle consist of slate and sandstone similar to those seen in the Swanback Formation and the Chapman Sandstone. In the Ashland quadrangle to the west, similar rocks are seen unconformably overlying the Winterville Formation, and are associated with fossiliferous limestone and mudstone conglomerate. The mudstone conglomerates contain pebbles and clasts of the Jemtland Formation and a variety of volcanic rocks; the Jemtland Formation clasts contain Ludlovian graptolites at two localities (Roy, 1970; 1980 a). The relationship of the undivided Devonian rocks to those of the Dockendorff Group are not established but it seems likely that the Jemtland-type clasts in the mudstone conglomerates were derived from the pre-Hedgehog Formation rocks of the Chapman syncline.

MIDDLE DEVONIAN ROCKS

Mapleton Formation

The Mapleton Sandstone of Williams and Gregory (1900) and Boucot and others (1964) is here redesignated the Mapleton Formation. The formation is seen in an oval outcrop area just west of the city of Presque Isle where it lies in the Mapleton syncline, which is nearly co-axial with the underlying and older Chapman syncline. H.E. Gregory was the first to describe the formation and he cited a section along the east-west road passing near locality F-C9 (Williams and Gregory, 1900) that was subsequently selected as the type section by Boucot and others (1964). White (1975) divided the formation into two members, provides the most detailed petrographic descriptions of the rocks of the formation, and produced the revised map of the Mapleton syncline that is given here in Plate 1. The members defined by White are formally proposed here.

Lithology of the Lower Member. The Lower Member consists of pebble and cobble conglomerate with lesser coarse and medium grained lithic sandstone. Both the sandstone and conglomerate are buff to red in color and contain abundant fragments of vein quartz, micritic limestone, chert, and volcanic rocks, which are derived from pre-Mapleton formations seen in the near vicinity of the Mapleton syncline. The sandstones of the member are quartzolithic arenites with mean quartz content of about 33%, little feldspar(average about 5%), and large variations in quartz-to-rock fragment ratio around an average of about 1:1. Although large exposures are not available, the sedimentary structures seen in both the conglomerate and sandstone beds suggest that the member is of fluvial origin and was deposited in a post-Acadian intermontane basin (White, 1975; White and Roy, 1975).

Lithology of the Upper Member. The Upper Member is made up of fine-to-coarse grained sandstone and much lesser pebble conglomerate. There is a general decrease in grain size of sandstone beds upward in the member. The sandstones are quartzolithic arenites that are more uniform in composition than those of the Lower Member with an average of about 43% quartz, 9% feldspar, and 20% rock fragments (White, 1975). Sandstone beds range from 1 to 60 centimeters thick.

Lower Contacts. The basal contact of the Lower Member has not been observed but is most closely located on Griffin Ridge where conglomerate is exposed within about 46 meters (150 feet) of outcrops of the Hedgehog Formation. Boucot and others (1964) recognized the basal contact of the formation to be an angular unconformity because the formation rests on both Ordovician and Silurian units along the flanks of the Mapleton syncline and because the dips of Mapleton beds never exceed 50 degrees whereas the pre-Mapleton Formation units show dips generally in excess of 70 degrees. The contact between the Lower and Upper Members of the Mapleton Formation is also not observed and is thought to be gradational and to some extent a facies transition (White, 1975).

Thickness. A maximum of about 1020 meters (3600 feet) of the Mapleton Formation is preserved in the Mapleton syncline according to White (1975); an estimate about 1.5 times the thickness of 670 meters (2200 feet)

suggested by Boucot and others (1964). White's estimate corrects for the presence of two faults not recognized by earlier workers. The Upper and Lower Members vary in thicknesses from southeast to northwest. The Lower Member thins from approximately 690 meters (2300 feet) in the southwest to about 300 meters (1000 feet) in the northwest; concurrently, the Upper Member thickens northwestward from about 360 meters to 510 meters.

Age. Schopf (1964) has described the fauna from locality F-C9 in the Upper Member and assigns an age of Early Givetian (early late-Middle Devonian). Brachiopods found in sandstone cobbles from the formation suggest a Late Gedinnian age to A.J. Boucot (in Boucot and others, 1964). The sandstone cobbles are therefore likely to have been derived from the underlying units of the Dockendorff Group.

INTRUSIVE ROCKS

The intrusive rocks of the Caribou and Presque Isle quadrangles have not been studied by the present writer but were first described by Williams and Gregory (1900) and later summarized by Boucot and others (1964). The most recent examination of some of the intrusive rocks is that by Sargent (1985) in connection with her study of the volcanic rocks of the Dockendorff Group. Here only a general account will be given using the results of Sargent's study.

PLUTONIC ROCKS

Munson Stock

Boucot and others (1964) named the small stock on Haines Hill, northwest of Presque Isle, "Munson's Granite" in favor of "Mapleton Granite" originally suggested by Williams and Gregory (1900). Herein the intrusive is referred to as the "Munson Stock" due to its small size (1-2 km^2) and the more recent determination that it is of monzonitic composition. The stock intrudes the New Sweden and Spragueville formations in the plunge-area of the Chapman Syncline. A narrow contact aureole of hornfels is developed in the two formations.

The Munson stock is composed largely of a hornblende - and biotite-bearing quartz-monzonite porphyry. In substantial agreement with Williams and Gregory (1900), Sargent (1975) describes the principal rock of the stock as:

> .....composed of coarse (up to 3 mm) white-to-pink feldspar euhedra set in a finer-grained mass of greenish black mafic minerals. Some of the [dark mineral grains] can be identified with unaided eye as laths of hornblende. Near the contact with the sedimentary rocks, the feldspars are salmon pink and the [rock] texture much finer. Two thirds of the rock is feldspar with a 1:3 ratio of perthitic feldspar to plagioclase. The plagioclase (An42-55) forms large, highly sericitized euhedra, some showing broad bands of zoning. Perthitic

orthoclase feldspar forms jackets around the plagioclase and occurs graphically intergrown with quartz in the interstices. Rare microphenocrysts of microcline are present. The chief mafic minerals are pale green to brown hornblende and biotite; the latter forms discrete plates as well as less regular grains.....at the expense of hornblende. The abundant chlorite.....is principally derived from the biotite. Rare clinopyroxene (augitic) shows extensive replacement textures to hornblende and biotite..... Accessory phases include apatite, zircon (up to 0.4 mm), sphene, and allanite; all forming euhedral grains. Equant grains of iron oxide are often coated with granular, highly birefringent material.

In the bed of the Aroostook River just north of Haines Hill are exposures of the Munson stock that are visible only at low water. These exposures show the border phases of the stock which are dominated by even-grained hornblende-biotite monzonite similar to that described by Sargent but containing abundant country rock xenoliths and forming dikes into the hornfels (Spragueville Formation). Coarsely crystalline granophyric granite or monzonite is also present.

Dikes

Dikes are not widespread in the Caribou and Presque Isle quadrangles. In the Presque Isle quadrangle, just east of Mapleton, is a swarm of altered diabasic dikes including some composed of teschenite, an analcime-bearing diabase, that have been described by Williams and Gregory (1900) and Boucot and others (1964). In addition, Boucot and others (1964) describe a large diabasic dike which outcrops on a ridge located along the eastern shore of Squa Pan Lake just across the lake from Walker Siding and a much smaller such dike on the western slopes of Haines Hill. Sargent (1985) performed major and trace element analyses on one of the nonteschenitic diabase dikes near Mapleton and on one sample from the dike (sill?) near Squa Pan Lake. She found the diabase near Mapleton to be alkalic and considered the dike near Squa Pan Lake to be a part of the Dockendorff Group and to be magmatically related to the basalts within the group on nearby Garland Hill.

Gottfried and others (1984) analysed samples from the teschenite and associated dikes near Mapleton for major and trace elements together with $^{40}Ar/^{39}Ar$ age measurements as part of a regional study of dikes in the Presque Isle, Mars Hill, and Bridgewater quadrangles. They conclude that the teschenitic dikes contain prograde analcime and not primary analcime as suggested by Williams and Gregory (1900) and that the associated dikes include porphyritic biotite-albite basalt of alkalic affinities.

In the central part of the Caribou quadrangle, between Carson and Woodland Center, a N30E trending vertical dike has been traced for about 5 km (3 miles). The trend of the dike cuts across, at a small angle, the trend of the folds in the Carys Mills Formation which it intrudes. The dike appears to be 10-20 meters (30-60 feet) wide and is composed of green-gray, brown weathering, amygdaloidal basalt. The rock is made up of felted

plagioclase microlites with abundant intersertal chlorite which may be after pyroxene or olivine. Carbonate and sericitic alteration of the plagioclase is pervasive. The amygdules are round-to-irregular in shape, less than 4mm and typically about 1mm in greatest dimension, and are filled with calcite but rimmed by chlorite. Phenocrysts are absent in the samples studied and no remnants of pyroxene, olivine, amphibole, or biotite are visible.

Age of the Intrusive Rocks

All of the intrusive rocks cut the regional cleavage associated with the Acadian orogeny and hence post-date the principal compressive deformation of that orogeny. Gottfried and others (1984) found that the relatively unaltered basaltic dikes they studied yielded apparent weight-average plateau $^{40}Ar/^{39}Ar$ ages of 375 $\pm$ 8 Ma and 414 $\pm$ 8 Ma (total gas ages of 376 and 390 Ma respectively) for samples producing good age plateaus. One teschenite sample produce an age plateau of 293 $\pm$ 6 Ma (total gas age of 300 Ma). They conclude that the older plateau ages probably represent intrusion ages in the span of latest Silurian to Middle Devonian consistent with the superposition relationships seen in the field. Some of the samples give no plateau and show a total gas age of about 300 Ma suggesting a metamorphic disturbance of the dikes in the Late Carboniferous (Pennsylvanian).

The Munson stock has not been radioisotopically dated but clearly post-dates the development of the Chapman syncline. Its temporal relationships to the deposition of the Mapleton Formation and the gentle folding that produced the Mapleton syncline are not established. Sargent (1985) found that the geochemistry of the Munson and the Early Devonian Edmunds Hill Andesite are consistent with a magmatic model in which the two magmas are differentiates from a common parent magma. If this is true then the Munson magma was differentiated prior to the Acadian Folding and was emplaced at a shallow structural level after the folding. A somewhat similar history can be inferred for the magma differentiates forming the Traveler Rhyolite (the eruptive; predeformational) and Katahdin granite (the intrusive; postdeformational) along regional strike to the southwest (Hon, 1980).

STRUCTURAL GEOLOGY

General Statement

The rocks of the Caribou and Presque Isle quadrangles record four episodes of tectonic folding with intervening periods in which soft-sediment deformation took place in some pelite-rich units shortly after deposition. The earliest tectonic deformation affected rocks of the late Middle Ordovician Winterville and Madawaska Lake Formations and is assigned to the Taconian Orogeny. The second deformation is demonstrable only in the Presque Isle area where it affects rocks of Late Silurian age and older and is assigned to the Salinic Disturbance. These first two periods of tectonism are recognized primarily by angular unconformities between the

deformed units and younger strata; neither deformation produced a foliation that can be separated from the foliation produced by the next and most intense period of folding. This next period of folding, the Acadian Orogeny, affects rocks of Early Devonian age and older and produced the regional foliation and is responsible for the folds that control the map distributions of the stratified units. Finally, the folding of the Mapleton Formation, after the Middle Devonian, was important in the Presque Isle area, but its effects are not clear beyond the limited area of outcrop of the formation.

Pre-Acadian Folds

The Taconian Orogeny was a weak deformational event during the late Carodocian-early Ashgillian time period (Roy, 1980a). No early folds or foliation recording this event have been recognized in the region discussed here or elsewhere in northeastern Maine. Folding of pre-Silurian strata during the orogeny is suggested by angular unconformities exposed in the Ashland and Portage quadrangles to the west described by Roy (1970; 1980 b,c) where maximum bedding dips below the unconformity were about 45° preceding deposition of Silurian strata.

Deformation associated with the Salinic Disturbance (Boucot, 1962; Boucot and others, 1964) is suggested by a probable angular unconformity at the base of the Dockendorff Group along the eastern flank of the Chapman syncline which Pavlides (1978) believes may have resulted from pre-Dockendorff folding of the Silurian units along northwest trending axes. Pavlides reports evidence for these early folds (his F1 folds) in the Carys Mills terrain in the adjacent Mars Hill quadrangle to the east. As yet these early folds have not been seen in that formation to the north and northwest of Presque Isle, which may indicate that Salinic effects are restricted to the region east and southeast of Presque Isle.

Acadian Folds

Acadian folds are present on several orders based on wavelength. In the region of cross-section A-B, especially, where the formations are composed predominantly of slate (with the sole exception of the Frenchville Formation) a relatively simple hierarchy of folds is produced. The largest scale folds, first order folds, are the anticlinoria and synclinoria which have wave lengths on the order of tens of kilometers and lengths along their axes of hundreds of kilometers. Cross-section A-B illustrates these long wavelength folds in the northern part of the Caribou quadrangle where the Pennington Mountain and Aroostook-Matapedia anticlinoria are separated by the Ashland synclinorium.

Second order folds have wavelengths of a few kilometers and can be traced along strike for a few kilometers and, in some exceptional cases, for tens of kilometers. These second order folds are delimited in many cases by the trace of the basal contact of the Jemtland Formation in the Ashland synclinorium and by the basal contacts of the Spragueville Formation and the Upper Member of the Carys Mills Formation in the Aroostook-Matapedia anticlinorium. Second order fold axes shown in Plate 1

are drawn based on the fold form outlined by the marker contacts as well as on bedding attitudes and facing directions where known. The most prominent second-order in the Caribou quadrangle is the uncommonly straight Stockholm Mountain syncline which can be traced for 24 kilometers (15 miles) to the northeast and 16 kilometers (10 miles) to the southwest of the quadrangle as a relatively simple nonplunging fold.

Acadian folds of third order and higher are typically seen in large outcrops in stratified rock units that are dominantly slate/phyllite, with or without micritic limestone. Where the formations are rich in sandstone and/or volcanic rocks, folds are generally open and more cylindrical in form, are of second order, and third and higher order folds are absent. In units composed largely of slate or phyllite, folds seen in outcrop are typically open-to-tight similar folds showing a single prominent axial planar, or nearly axial planar, cleavage. Such folds commonly show plunge angles from 0° to 40° and, more rarely, at steeper angles.

Cleavage

A prominent cleavage is present in pelitic rocks of the region. The cleavage is generally axial planar to folds defined by bedding surfaces and is considered to be S1. In non-calcareous slate, the cleavage is typically an anastomosing fracture cleavage but in calcareous slate a pressure solution cleavage producing a phyllitic slate is more usual. Thick-bedded sandstone beds and volcanic rocks are generally not cleaved or show a widely spaced and poorly developed fracture cleavage. Thin beds of sandstone and siltstone in slate dominated units typically show a cleavage refracted with respect to that in the pelitic beds.

Faults

Faults cutting across the structural trends of Acadian folds are readily mapped since they offset formation contacts and fold axes. These faults are considered to be late or post-Acadian in age. In the western part of the Caribou quadrangle, cross-faults trend approximately N45-50W and seem to have involved both normal and strike-slip displacements. Lack of outcrop control does not permit these faults to be traced through the Madawaska Lake and Carys Mills Formations. The region of plunge for the Castle Hill anticline is broken by several faults that radiate into the adjacent Ashland and Portage quadrangles. These faults appear to be mechanically related to the competence contrast between the brittle rocks of the Winterville and Frenchville Formations in the core of the anticline (and in the structures to the west) as compared to the more ductile-deforming formations to the north and east of the Castle Hill anticline. The generally east-west Alder Brook fault extends from the Ashland quadrangle, to the west, into the Presque Isle quadrangle just south of Haystack Mountain. Evidence for the Alder Brook fault is compelling in the Ashland quadrangle where it seems to have undergone displacements during both the Taconian and Acadian orogenies (Roy, 1970). In the Presque Isle quadrangle, the fault is considered to explain the partial termination of the Winterville Formation of the Castle Hill anticline and distributions of Silurian and Devonian rocks in the vicinity of Chapman.

Faults paralleling the axes of the Acadian folds are present in the Presque Isle quadrangle and extend into the southern part of the Caribou quadrangle. The Dudley and Hanson Brook faults are either normal or reverse faults with upthrown blocks to the east. The unnamed fault passing through the Mapleton syncline is probably largely strike-slip in its displacement. These strike faults are considered to be post-Acadian and at least the unnamed fault and the Hanson Brook fault are of post Middle Devonian age since they cut the Mapleton Formation.

METAMORPHISM

Richter and Roy (1974, 1976) and Combs and others (1970) have described the metamorphism of the rocks of a large part of northeastern Aroostook County, including the region of this report. Critical metamorphic minerals are found in mafic volcanic rocks, sandstones, and conglomerates of Ordovician and Silurian age. Richter and Roy (1976) found that the metamorphic mineral assemblages allow three metamorphic zones to be defined, the Prehnite-Analcime, the Prehnite-Pumpellyite, and the Pumpellyite-Epidote-Actinolite zones. These zones have trends that are subparallel to the trends of Acadian structures in the eastern part of the region they studied (including the area of this report) but cut across Acadian fold trends in the Fish River Lake and Big Machias Lake regions to the west. In the Caribou quadrangle, the sandstones of the Frenchville Formation in the northwest corner of the quadrangle are assigned to the Prehnite-Pumpellyite zone while the sandstones of the Frenchville Formation along the northwestern flank of the nearby Stockholm Mountain syncline are placed in the Pumpellyite-Epidote-Actinolita zone as are the sandstones and volcanic rocks in the Castle Hill anticline in the Presque Isle quadrangle. Thus, the volcanic rocks and volcaniclastic sandstones along the western margin of the quadrangles described here fall mostly into the Pumpellyite-Epidote-Actinolite zone. The eastern part of the area generally lacks rocks of suitable composition to form the diagnostic mineral assemblages. Where such rocks are present, in the Dockendorff Group for instance, the absence of the critical metamorphic minerals in the eastern part of the region is likely due to their suppression by high CO_2 chemical potentials in the fluid phase during metamorphism (Richter and Roy, 1976).

The pelitic rocks of the region display the assemblage: quartz, muscovite, chlorite, plagioclase (sodic), $\pm$ calcite, $\pm$ ferroan dolomite, $\pm$ pyrite. This assemblage is consistent with the subgreenschist metamorphism displayed by the volcanic rocks and the sandstones.

The age of the metamorphism is somewhat problematic. Richter and Roy (1976) argue for an Acadian age and suggest that Taconian metamorphism of the pre-Silurian rocks is possible but did not exceed the prehnite-pumpellyite grade seen in the Silurian rocks. The Mapleton Formation shows little evidence of metamorphism and would seem to suggest that the prehnite-pumpellyite metamorphism in the older rocks predates the deposition of that formation. Osberg (1974; personal communication) believes that the scattered presence of prehnite veins found throughout New England and prehnite-pumpellyite metamorphism in the area of this report

may be due to a widespread, possibly post-Triassic, thermal event that is unrelated to the Paleozoic history of deformations recorded in the rocks. Osberg's suggestion seems to be confirmed by the radioisotope ages obtained by Gottfried and others (1984) described above which suggest a thermal event during the Late Carboniferous, post-dating the youngest rocks of the region. However, since no evidence of retrograde metamorphism was seen by Richter and Roy (1976), it seems likely that Acadian metamorphism did not exceed the prehnite-pumpellyite grade.

ACKNOWLEDGEMENTS

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REFERENCES

Ayrton, W.G., Berry, W.B.N., Boucot, A.J., Lajoie, J., Lesperance, P.J., Pavlides, L., Skidmore, W.B., 1969, Lower Llandovery of the northern Appalachians and adjacent regions, Geologic Society of America, Bulletin, v. 80, p. 459-484.

Berry, W.B.N., 1964, Early Ludlow graptolites from the Presque Isle quadrangle, Maine: Journal of Paleontology, v. 38. p. 587-599.

Boucot, A.J., 1962, Appalachian Siluro-Devonian, in Coe, Kenneth, ed., Some Aspects of the Variscan fold belt, 9th Inter-University Geological Congress, Manchester University Press, p. 155-163.

____, Field, M.T., Fletcher, R., Forbes, W.H., Naylor, R.S., and Pavlides, L., 1964, Reconnaissance bedrock geology of the Presque Isle quadrangle, Maine: Maine Geological Survey, Bulletin 15, No. 2, 123 p.

Carey, D.L. and Roy, D.C., 1985, Deposition of laminated shale, a field and experimental study: Geo-Marine Letters, v. 5, p. 3-9.

Coombs, D.S., Horodyski, R.J., and Naylor, R.S., 1970, Occurrence of prehnite-pumpellyite facies metamorphism in northern Maine: American Journal of Science, v. 368, p. 142-156.

Gottfried, D., MacDonald, R., Sutter, J.F., and Pavlides, L., 1984, Geochemical features and $^{40}Ar/^{39}Ar$ age of tholeiitic and mafic-alkalic dikes in Aroostook County, northeastern Maine: U.S. Geological Survey, Bulletin 1612, 23 p.

Hamilton-Smith, T., 1969, Paleography of northwestern New Brunswick during the Llandovery, a study of the provenance of the Sieges Formation: Canadian Journal of Earth Sciences, v. 8, p. 196-203.

____, 1970, Stratigraphy and structure of Ordovician and Silurian rocks of the Sieges area, New Brunswick: New Brunswick Department of Natural Resources, Mineral Resources Branch Report of Investigations 12, 55 p.

Hon, R., 1980, Geology and petrology of igneous bodies within the Katahdin pluton, in Roy, D.C. and Naylor, R.S., A guidebook to the geology of northeastern Maine and neighboring New Brunswick, New England Intercollegiate Geological Conference, 72nd Annual Meeting, Presque Isle, Maine, p. 65-79.

Horodyski, R.J., 1968, Bedrock geology of portions of Fish River Lake, Winterville, Greenlaw and Mooseleuk Lake quandrangles, Aroostook County, Maine: unpublished MS thesis, Massachusetts Institute of Technology, Cambridge, MA., 192 p.

Hynes, A., 1976, Magmatic affinity of Ordovician volcanic rocks in northern Maine, and their tectonic significance: American Journal of Science, v. 276, p. 1208-1224.

Miller, R.L., Manganese deposits of Aroostook County, Maine: Maine Geologic Survey, Bulletin 4, 77 p.

Naylor, R.S., 1980, Bedrock geology of the Presque Isle area: in Roy, D.C. and Naylor, R.S., A guidebook to the geology of northeastern Maine and neighboring New Brunswick, New England Intercollegiate Geological Conference, 72nd Annual Meeting, Presque Isle, Maine, p. 169-178.

_____, Boucot, A.J., 1965, Origin and distribution of rocks of Ludlow age (late Silurian) in the northern Appalachians: American Journal of Science, v. 263, p. 153-169.

Nylander, O.O., 1936, The geology and poseidon balls of the Madawaska Lakes: privately published, 10 p.

_____, 1937, A reconnaissance of the head waters of Fish River, Aroostook County, Maine: privately published, 13 p.

_____, 1938, Geological formation of Square Lake on Fish River, Aroostook County, Maine: privately published, 17 p.

Osberg, P.H., 1974, Buchan-type metamorphism of the Waterville pelite, south-central Maine: in Osberg, P.H., ed., Guidebook for field trips in east-central and north-central Maine, New England Intercollegiate Geological Conference, 66th Annual Meeting, Orono, Maine, p. 210-222.

Pavlides, L., 1978, Bedrock geologic map of the Mars Hill quadrangle and vicinity, Aroostook County, Maine: U.S. Geological Survey Quadrangle Map 1-1064.

_____, 1968, Stratigraphic and facies relationships of the Carys Mills Formation, northeastern Maine and adjoining New Brunswick: U.S. Geological Survey, Bulletin 1264, 44 p.

_____, 1965 a, Meduxnekeag Group and Spragueville Formation of Aroostook County, northeast Maine: U.S. Geological Survey, Bulletin 1244-A, p. A52-A57.

_____, 1966, Meduxnekeag Group and Spragueville Formation of Aroostook County, northeast Maine, in Cohee, G.V., and West, W.S., Changes in stratigraphic nomenclature by the U.S. Geological Survey, 1965; U.S. Geological Survey, Bulletin 1244-A, p. A52-A57.

_____, 1965 b, Geology of the Bridgewater quadrangle, Aroostook County, Maine: U.S. Geological Survey, Bulletin 1206, 72 p.

_____, 1962, Geology and manganese deposits of the Maple and Hovey mountains area, Aroostook County, Maine: U.S. Geological Survey, Professional Paper 362, 116 p.

_____, Neuman, R.B., and Berry, W.B.N., 1961, Age of the "ribbon rock" of Aroostook County, Maine, U.S. Geological Survey, Professional Paper 424B, p. B65-B67.

_____, Berry, W.B.N., 1966, Graptolite-bearing Silurian rocks of the Houlton-Smyrna Mills area, Aroostook County, Maine: U.S. Geological Survey, Professional Paper 550B, p. B51-B61.

_____, Mencher, E., Naylor, R.S., and Boucot, A.J., 1964, Tectonic features of eastern Aroostook County, Maine: U.S. Geological Survey, Professional Paper 501C, p. C28-C38.

Richter, D.A., 1973, Prehnite-pumpellyite facies metamorphism in central Aroostook County, Maine: unpublished MS Thesis, Boston College, Chestnut Hill, MA, 70 p.

_____, and Roy, D.C., 1974, Subgreenschist metamorphic assemblages in northern Maine: Canadian Mineralogist, v. 12, p. 469-474.

_____, and Roy, D.C., 1976, Prehnite-pumpellyite facies metamorphism in central Aroostook County, Maine: in Lyons, P.C., and Brownlow, A.H., eds., Studies in New England geology, Geolocial Society of America, Memoir 146, p. 239-261.

Rickards, R.B., and Riva, J., 1981, Glyptograptus ? persculptus (Salter), its tectonic deformation, and its stratigraphic significance for the Carys Mills Formation of N.E. Maine, USA: Geological Journal, v. 16, p. 219-235.

Roy, D.C., 1980 a, Tectonics and sedimentation in northeastern Maine and adjacent New Brunswick: in Roy, D.C. and Naylor, R.S., A guidebook to the geology of northeastern Maine and neighboring New Brunswick, New England Intercollegiate Geological Conference, 72nd Annual Meeting, Presque Isle, Maine, p. 1-21.

_____, 1980 b, Ordovician and Silurian Stratigraphy of the Ashland Synclinorium and adjacent terrane: in Roy, D.C. and Naylor, R.S., A guidebook to the geology of northeastern Maine and neighboring New Brunswick, New England Intercollegiate Geological Conference, 72nd Annual Meeting, Presque Isle, Maine, p.142-168.

_____, 1980 c, Sedimentology of Silurian flysch, Ashland Synclinorium, Maine: in Roy, D.C. and Naylor, R.S., A guidebook to the geology of northeastern Maine and neighboring New Brunswick, New England Intercollegiate Geological Conference, 72nd Annual Meeting, Presque Isle, Maine, p. 232-252.

_____, 1978, Geologic Map of a portion of northeastern Aroostook County, Maine: Maine Geological Survey, Open File Report 78-21.

_____, 1970, The Silurian of northeastern Aroostook County, Maine: unpublished PhD dissertation, Massachusetts Institute of Technology, Cambridge, MA, 470 p.

_____, and Mencher, E., 1976, Ordovician and Silurian stratigraphy of northeastern Aroostook County, Maine: in Page, L.R., ed., Contributions to the stratigraphy of New England, Geological Society of America, Memoir 148, p. 25-52.

Sargent, S.L., 1985, Petrology and geochemistry of the volcanic rocks of the Dockendorff Group and the Munson pluton, northeastern Maine: unpublished MS Thesis, Boston College, Chestnut Hill, MA, 150 p.

Schopf, J.M., 1964, Middle Devonian plant fossils from northern Maine: U.S. Geological Survey, Professional Paper 501D, p. D43-D49.

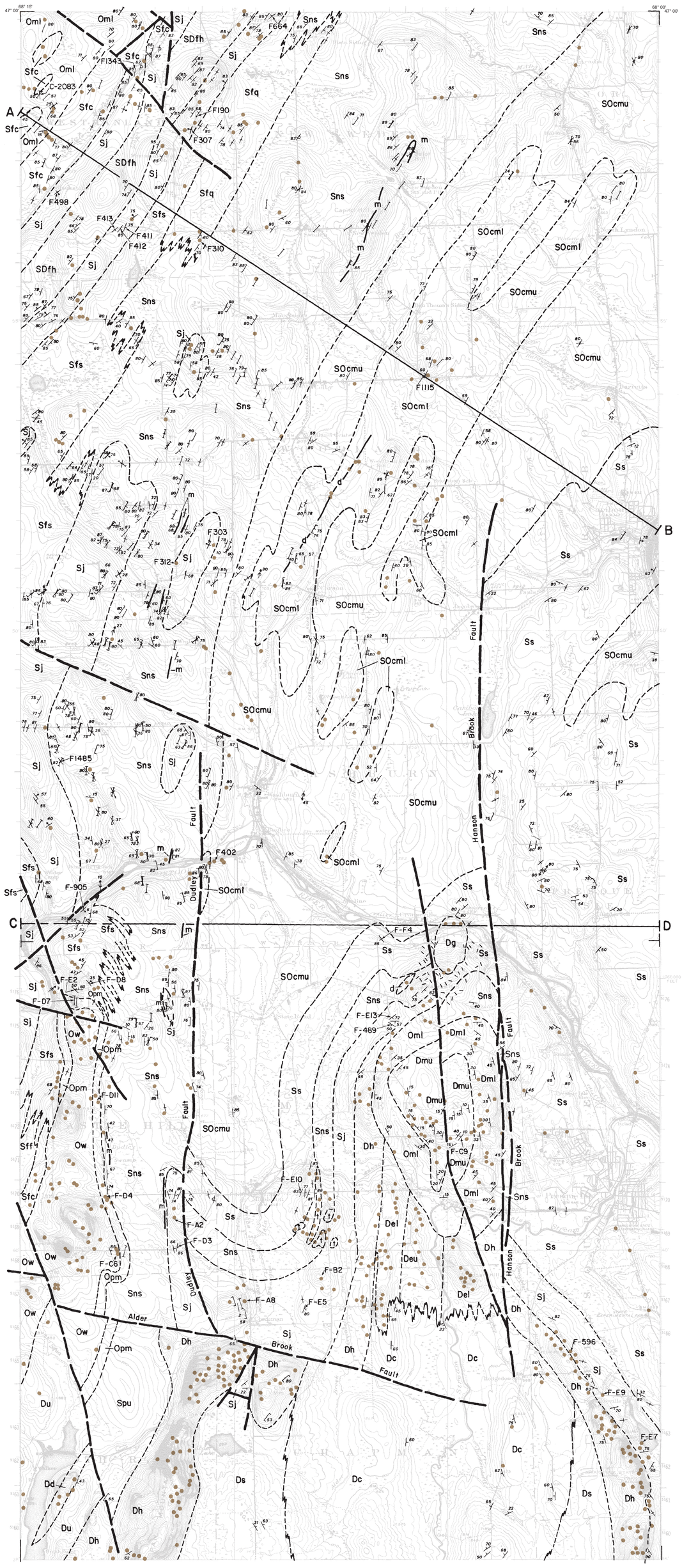
Twenhofel, W.H., 1941, The Silurian of Aroostook County, northern Maine: Journal of Paleontology, v. 15, p. 166-174.

White, K.J., 1975, The Mapleton Formation, an immediately post-Acadian basin fill: unpublished MS Thesis, Boston College, Chestnut Hill, MA, 70 p.

White, W.S., 1943, Occurrence of manganese in eastern Aroostook County, Maine: U.S. Geological Survey, Bulletin 940E, 40 p.

Williams, H.S., and Gregory, H.E., 1900, Contributions to the geology of Maine: U.S. Geological Survey, Bulletin 165, 212 p.

Williams, H.S., and Breger, C.L., 1916, The fauna of the Chapman Sandstone of Maine: U.S. Geological Survey, Professional Paper 89, 347 p.



See Maine Geological Survey Bulletin #15: Reconnaissance Bedrock geology of the Presque Isle Quadrangle, Maine, by A.J. Boucet, et al., 1964

GEOLOGIC MAP of the CARIBOU AND NORTHERN PRESQUE ISLE QUADRANGLES, MAINE

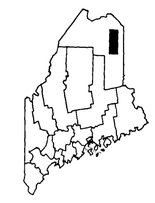
by

DAVID C. ROY

1985

Maine Geological Survey
DEPARTMENT OF CONSERVATION
Walter A. Anderson, State Geologist

OPEN-FILE NO. 87-2



QUADRANGLE LOCATION

SCALE 1:62,500

1 ½ 0 1 2 3 4 MILES

3000 0 3000 6000 9000 12000 15000 18000 21000 FEET

1 .5 0 1 2 3 4 5 KILOMETERS

N

EXPLANATION

INTRUSIVE ROCKS

Dg — Munson Stock: monozodiorite

d — Basaltic and diabasic dikes

t — Teschenite dikes

STRATIFIED ROCKS

Middle Devonian

Dmu, Dml — Mapleton Formation
Upper Member (**Dmu**): Red quartzolithic arenite, lesser conglomerate
Lower Member (**Dml**): Red conglomerate, lesser lithic arenite

Early Devonian

W/SW — E/NE: Du; Ds; Dc; Deu; Del; Dh

Dockendorff Group
Hedgehog Formation (**Dh**): Rhyolitic tuff, andesite, and basalt; lentils of siltstone and sandstone

Edmunds Hill Andesite
Upper Member (**Deu**): Biotite-bearing andesite
Lower Member (**Del**): Augite-bearing andesite and lesser andesite breccia

Chapman Sandstone (**Dc**): Lithic arenite and graywacke; lesser green mudstone

Swanback Formation (**Ds**): Green and gray mudstone and laminated shale

Undifferentiated Devonian Strata (**Du**): Gray slate, mudstone conglomerate, and lithic sandstone

Silurian

SDfh — Fogelin Hill Formation: Green and red slate, quartzose arenite and graywacke

Sj — Jemtland Formation: Thinly interlayered dark-gray slate (shale) and siltstone with quartzofeldspathic graywacke and lesser micrite; (**t**), aquagene felsic tuff

Sp — Perham Group Undifferentiated: New Sweden and/or Jemtland Formations

NW — SE: Sff; Sfs; Sfq; Sns; Ss; Sfc

Frenchville Formation
Conglomerate Member (**Sfc**): Thick-bedded polymictic conglomerate and lithic sandstone

Feldspathic Sandstone Member (**Sff**): Feldspathic sandstone

Sandstone-Slate Member (**Sfs**): Gray slate and lithic graywacke; minor micrite

Quartzose Sandstone Member (**Sfq**): Gray slate and quartzose graywacke, quartz arenite, lithic graywacke

New Sweden Formation (**Sns**): Gray calcareous phyllite with thin micrite beds; (**m**), manganiferous ironstone horizons

Spragueville Formation (**Ss**): Laminated bioturbated calcareous mudstone, argillaceous limestone and micrite

Ordovician

Sil. / Ord. — NW — SE: Hiatus; SOcmu; Oml; Opm; SOcml; Ow; ?

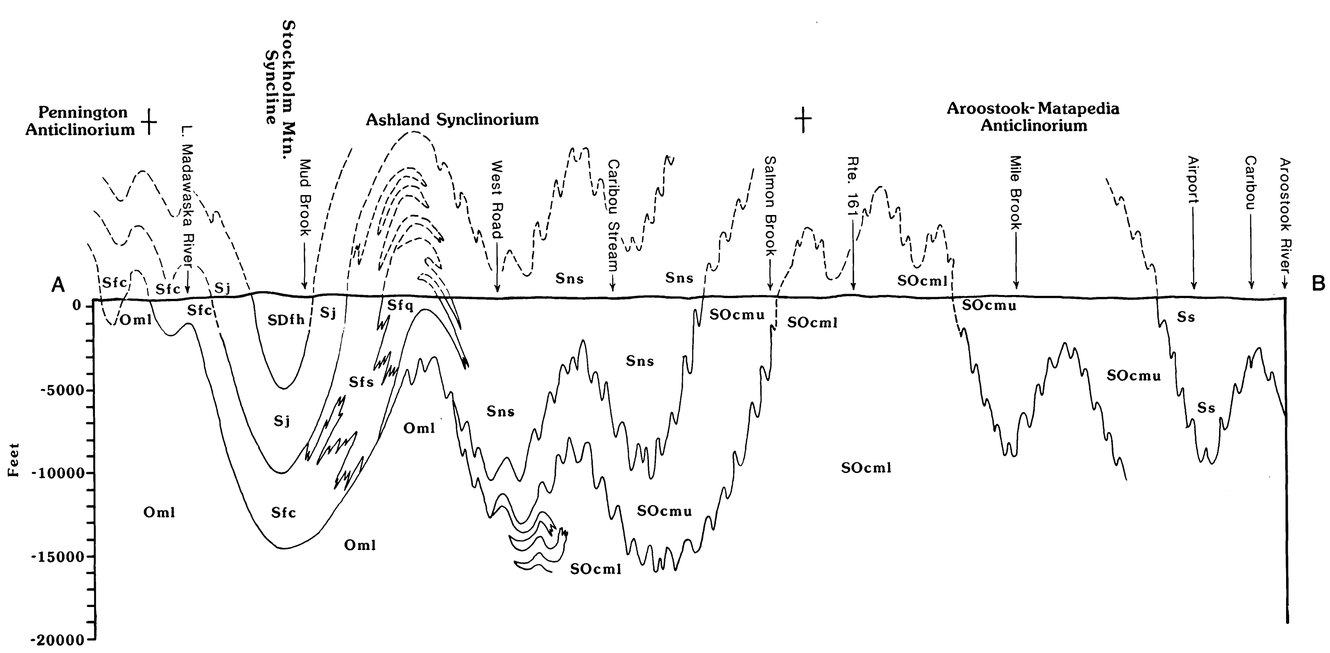
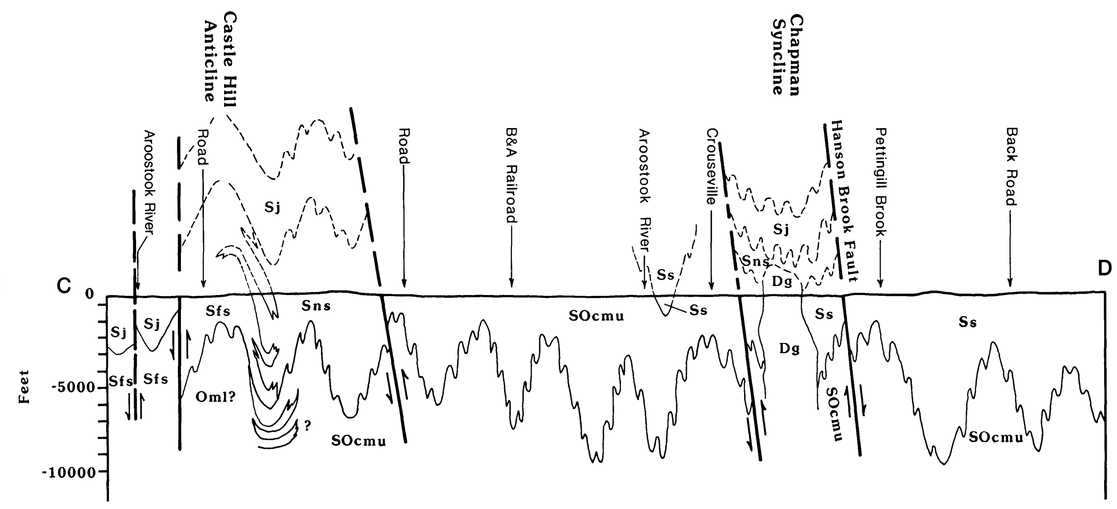
Carys Mills Formation
Upper Member (**SOcmu**): Thinly bedded argillaceous micrite and calcareous phyllite

Lower Member (**SOcml**): Thinly interbedded calcareous phyllite and quartzose siltstone and quartz arenite with minor micrite

Madawaska Lake Formation (**Oml**): Olivine green and green-gray slate and lithic graywacke

Pyle Mountain Formation (**Opm**): Fossiliferous siltstone and green-gray slate

Winterville Formation (**Ow**): Pyroxene basalt (both fragmental and non-fragmental), sulfidic slate, chert, lithic graywacke, conglomerate and rhyolite

SYMBOLS

- Rock unit contact (generally covered)
- Generalized facies contact
- Inferred fault
- Axis of major anticline
- Axis of major syncline
- Metamorphic aureole around Munson Stock
- Outcrop
- F412 — Fossil locality
- Horizontal bedding
- 70 — Inclined bedding (facing unknown)
- 70 — Inclined bedding (right-side-up)
- 60 — Overturned bedding
- 83 — Inclined slaty cleavage
- Vertical slaty cleavage
- 85 65 — Inclined bedding and cleavage (with differing strikes)
- Vertical bedding and cleavage (with same strike)
- 30 — Plunging minor antiform
- 30 — Plunging minor synform