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Stratigraphy and structure in the upper St. John River area of northwestern Maine

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STRATIGRAPHY AND STRUCTURE IN THE UPPER ST. JOHN RIVER AREA OF NORTHWESTERN MAINE

by

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ABSTRACT

Recent bedrock mapping (1979; 1981) has refined our understanding of the stratigraphy and structure along the northwestern margin of the Connecticut Valley-Gaspe Synclinorium in Maine as previously established by Boudette and others (1976). The region presents the most tectonically northwesterly belt of pre-Silurian to be seen in Maine; the belt is tectono-stratigraphically equivalent to the southeastern townships of Quebec and eastern Vermont. The region is broken by two major strike faults, the Dead Brook and Rocky Mountain faults, that subdivide the area into three parallel and quite different belts. The oldest rock unit, the Cambro-Ordovician Estcourt Road Formation, forms the northwestern-most belt. The Estcourt Road Formation (formerly "Estcourt Road Sequence") is predominantly gray phyllite with thin beds of calcareous quartzo-feldspathic siltstone/ sandstone; lesser but important massive quartzite, limestone conglomerate black sulphidic phyllite, and red/green slate are also present. The Depot Mountain Formation, of Late Ordovician and Early Silurian age, together with the Late Silurian Fivemile Brook Formation and Rocky Mountain Quartz Latite comprise the middle belt. The Depot Mountain Formation consists of gray slate (phyllite and interbedded distinctive lithic graywacke and conglomerate; a volcanoclastic member can be traced locally. The Depot Mountain Formation appears to be derived largely from the Estcourt Road Formation and it is lithologically identical with the Cabano Formation along strike to the northeast in the Temiscouata region of Quebec. The Depot Mountain is overlain conformably or disconformably by the Fivemile Brook Formation consisting of calcareous phyllite and limestone with mappable basalt units. The Fivemile Brook Formation at least in part interfingers northward with the Rocky Mountain Quartz Latite, a felsic volcanic sequence. Late Silurian volcanism in the region thus appears to have been bimodal. The youngest formation, the Devonian Seboomook Formation, is in fault contact with the pre-Devonian along the northwestern margin of the synclinorium. Gray slate and graywacke predominate in the Seboomook with the graywacke-to-slate ratio higher in the lower part of the formation. All of the Siluro-Devonian formations show a single N 35^{o} E-trending and steeply-dipping slaty cleavage (regional S_2) associated with tight upright folds. These younger rocks were deformed during the Acadian Orogeny. The Cambro-Ordovician Estcourt Road Formation shows at least two cleavages; the most prominent foliation is taken to be the regional S_1 foliation (with associated bedding transposition) which is overprinted by a crenulation or slip cleavage (regional S_2) that is interpreted to be of Acadian origin. The S_1 foliation is assigned to the Taconian Orogeny.

INTRODUCTION

During the 1981 field season bedrock mapping concentrated in the Beau Lake and Rocky Brook 15-minute quadrangles in far northwestern Maine was undertaken to extend northward the work begun during the summer of 1979 (Roy 1980a). Besides the mapping of the two new quadrangles, re-examination of the volcanic rocks and other aspects of the geology of the Rocky Mountain and Seven Islands quadrangles was also accomplished and revision of the bedrock map of the 1980 report seems warranted and is included within Plate I of this report. The overall objective of the MGS mapping project in this remote portion of the state is to provide a more detailed inventory of bedrock types and their distribution than provided by the reconnaissance work of Boudette, and others, 1976. An understanding of the formations and structure of the bedrock can be used for resource evaluation and for the determination of the geologic history of the region.

The Beau Lake and Rocky Brook quadrangles are the most northerly quadrangles in northwestern Maine. They lie in a region that contains the only pre-Devonian rocks along the northwestern flank of the Connecticut River-Gaspe' Synclinorium (DSB of figure 1) to be seen in Maine. The pre-Devonian rocks are closely comparable to formations seen along strike in the Province of Quebec, Canada; direct lithologic correlations with units elsewhere in Maine is less certain. The pre-Devonian rocks fall within the Internal Tectonic Domain of the Quebeck Appalachians as defined by St. Julien and Hubert (1975) and therefore are along strike from the Thetford Ultramafic rocks which

GEOLOGIC MAP OF NORTHERN MAINE

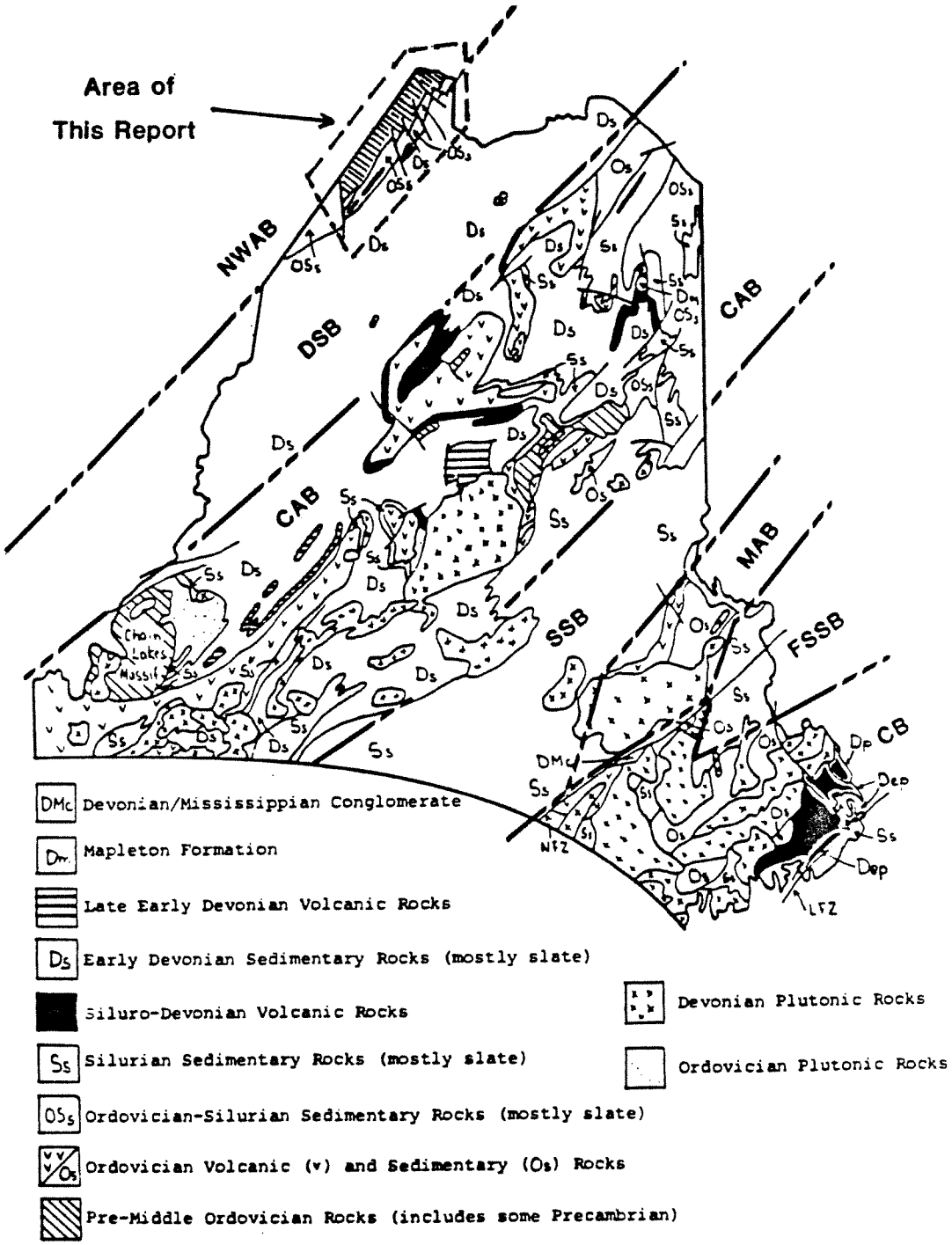

Figure 1.

MAJOR LITHOFACIES BELTS

NWAB - Northwestern Anticlinorial Belt
DSB - Devonian Slate Belt
CAB - Central Anticlinorial Belt
SSB - Silurian Slate Belt
MAB - Miramichi Anticlinorial Belt
FSSB - Fredericton Slate Belt
CB - Coastal Belt

occupy a medial position within the domain as close as 40 miles to the southwest. The position of the ultramafic trend seems to be approximately along the Dead Brook fault in northwestern Maine (Plate I) but as yet no trace of the ultramafic rocks has been found along the fault.

STRATIGRAPHY

The descriptions of formations given below involve generally minor revisions of those given earlier by Roy (1980a). All units except for the Fivemile Brook Formation and Rocky Mountain Quartz Latite are well exposed in the Beau Lake and Rocky Brook Quadrangles.

The region may be divided into three stratigraphic belts. Northwest of the Dead Brook Fault is the Estcourt Road Formation; between the Dead Brook and Rocky Mountain Faults are the Depot Mountain and Fivemile Brook formations and Rocky Mountain Quartz Latite which are all largely Silurian; southeast of the Rocky Mountain Fault is the Seboomook Formation which forms a 40-mile wide tract along the axis of the Connecticut Valley-Gaspe' Synclinorium. The ages of the formational units are not well known but it is certain that the belts contain progressively younger rocks toward the southeast as indicated in the stratigraphic column of Figure 2.

Estcourt Formation

The Estcourt Road Formation of the northwestern belt is a correlative of the Quebec Group along strike to the northeast and of the Rosaire Group of the Notre Dame Anticlinorium along strike to the west and southwest. As such it is part of the ensialic Internal Domain

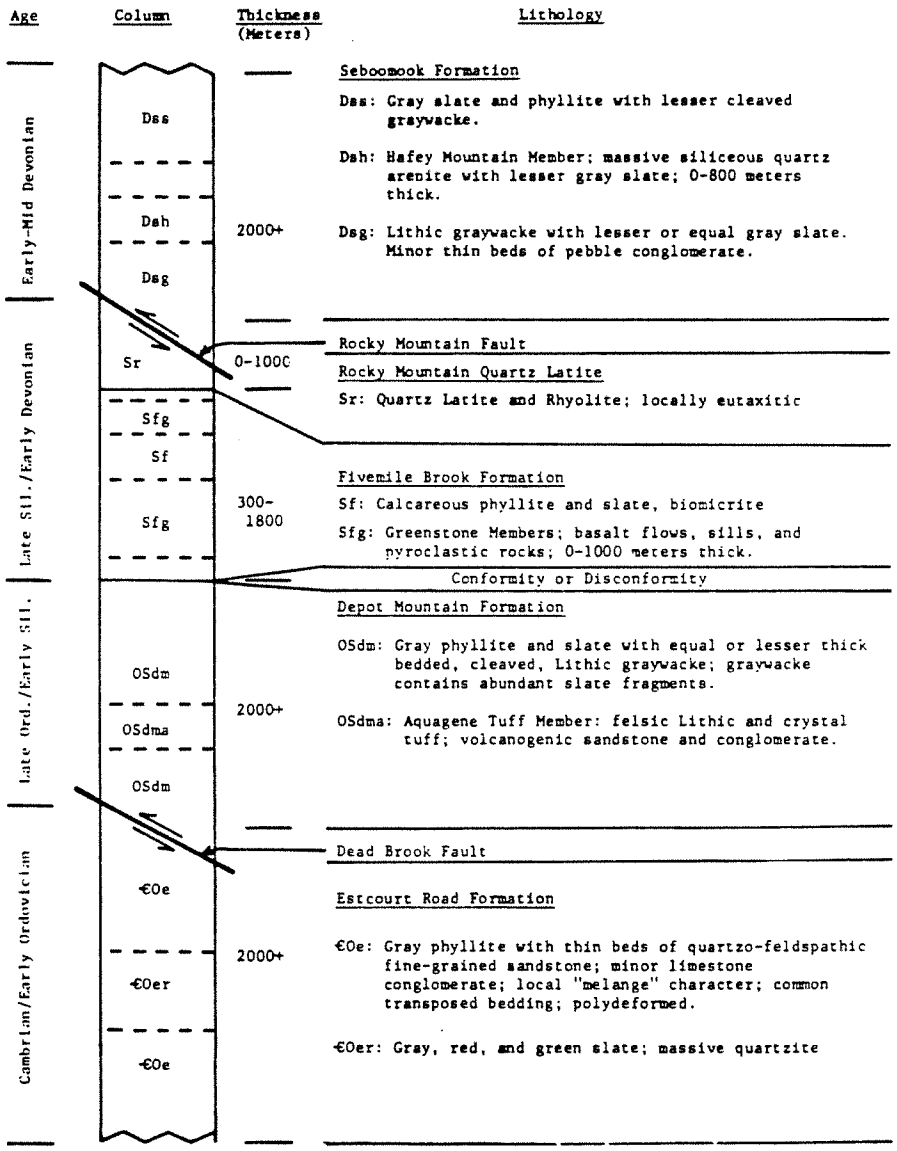

Figure 2. Stratigraphic column for Upper St. John River Valley, Northwestern Maine.

of St. Julien and Hubert (1975). The formation is dominantly medium gray to black phyllite which is commonly interlayered with thin beds of calcareous quartzo-feldspathic fine grained sandstone or siltstone (localities 2776, 2782, 2798). The sandstone and siltstone beds rarely exceed a few centimeters in thickness and commonly show parallel- and cross-lamination. In most exposures the bedding is transposed along the most prominent foliation (regional S_1) and only lens-shaped bed-fragments of the sandstone layers are seen. Locally within the Estcourt Road terrane are areas, interpreted as lentils, of red, green, and gray phyllite or slate interlayered with thin-to-massive beds of quartzite that are separated in Plate I as €Oer (localities 2739, 2780). These "lentils" may in fact be stratigraphic units that are older or younger than the main sequence.

Limestone conglomerate has been seen in the Estcourt Road Formation at one place (locality 3048). This conglomerate is similar to those commonly seen in Cambro-Ordovician sequences in both the External and Internal-Ensialic domains of the Quebec Appalachians. These conglomerates are usually interpreted to be "bank-foot" conglomerates deposited at or near the base of an Early Paleozoic continental slope. At one locality (3101) an interesting "melange" is present in which rounded chert and graywacke blocks are set in a black phyllite; this material cannot be traced as yet and is located near the Dead Brook Fault with which it might be associated.

The Estcourt Road Formation is inferred to be Cambrian and/or Early Ordovician in age. It is polydeformed with the first deformation probably associated with the Taconian and a second deformation during the Acadian.

Depot Mountain Formation

The Depot Mountain Formation is lithologically identical to the Cabano Formation along strike to the northeast in the Lake Temiscouata region of Quebec. It consists of medium- to dark-gray slate with equal or greater lithic graywacke (locality 2828). The graywacke is present in beds from a few centimeters to a few meters thick; the thinner beds typically show lamination, cross-lamination, and grading consistent with turbidity current deposition; the thicker beds are less internally structured and usually medium-to-coarse grained. Lithic fragments in the graywacke are predominantly sedimentary or low-grade metasedimentary in origin (slate > siltstone/fine sandstone > carbonate). Granule and pebble conglomerate occurs in more or less isolated outcrops and no systematic stratigraphic pattern has emerged.

Felsic tuff (localities 2838, 2626) is seen in the Depot Mountain Formation and forms locally mappable horizons (OSdma). Lithic and crystal tuff as well as volcanogenic sandstone and conglomerate comprise most of these felsic units but thin beds of gray, and locally siliceous, slate/argillite are present as are beds of lithic graywacke. The tuff beds are taken to be water-laid and to be derived from an unknown Late Ordovician/Early Silurian source. No such tuffaceous sequences have been reported from the Cabano Formation and their presence in the Depot Mountain Formation may simply represent proximity to the sources.

On the basis of one fossil locality (approximately locality 2833) at Depot Mountain in the south extremity of Plate I, Boudette and others (1976) assigned a Late Medial Ordovician age to the "Depot

Mountain Sequence" which corresponds closely to the formation as presently mapped. They recognized, however, that the unit is lithologically similar to the Cabano Formation of Lesperance (1960) and Lajoie and others (1968). The Cabano has Early/Medial Llandoverian fossils in its upper part and it is here inferred that the Depot Mountain Formation also extends into the Silurian. It was not possible during the present work to recover the Depot Mountain fossil locality and to determine whether the graptolites are present in an interbedded shale layer or in a large shale clast in a conglomerate. For the moment, the Depot Mountain must be considered to span the Ordovician-Silurian systemic boundary.

The Depot Mountain Formation represents a southwest extension into Maine of the post-Taconian Mistigougueche Basin (Roy 1980b; Lajoie and Lesperance, 1968). The basin may have developed in the Late Ordovician and represent a northeastward extension of the late-to-post Taconian St. Victor Flysch basin (Magog Group) which St. Julien and Hubert (1975) interpret as a back-arc basin to the Ascot-Weedon volcanic arc. The pyroclasic rocks of the Depot Mountain Formation may represent ash falls from the arc. The Ascot-Weedon volcanic belt is not present in Maine probably due to cover by Devonian rocks along the western boundary of the Connecticut Valley Gaspe' Synclinorium.

Fivemile Brook Formation

The Depot Mountain Formation is overlain by the Late Silurian Fivemile Brook Formation. The contact is not observed but there is a marked change in stratigraphy and facing directions in the Depot

Mountain all point toward a stratigraphic rather than a structural relationship. It is considered likely that the contact is a disconformity without substantial uplift since conglomerates are absent in the Fivemile Brook Formation.

The Fivemile Brook Formation is composed of light greenish gray calcareous phyllite with abundant thin biomicrite beds and lenses, and Halysites and Favosites coral heads apparently in growth positions (locality F275). The sequence is interpreted to be a shallow subtidal facies. Interlayered with the sedimentary rocks are sills (minor) and thick basaltic flows. Some of the flows appear to have had subareally exposed upper surfaces; others show pillow structure (locality 2843)

The largest lentil of basalt is found between Fivemile and Twomile Brooks in the southern part of Plate I. During the 1981 field season Mr. William Schwartz studied the lentil and sampled it as part of a petrographic and geochemical study of the Silurian volcanic rocks in the region. Sample localities within the lentil are shown in figure 3; the geochemical analyses for major and trace elements (including REEs) are in progress. Preliminary petrographic analyses of samples from the Greenstone Member of the Fivemile Brook Formation both from the Fivemile Brook section itself and from the localities along strike to the northeast are given in Table 1. The volcanic rocks are all altered olivine basalt and not andesite as reported by Boudette and others (1976) and Roy(1980a) based on hand-specimen studies. The alteration involves epidote, calcite, quartz,

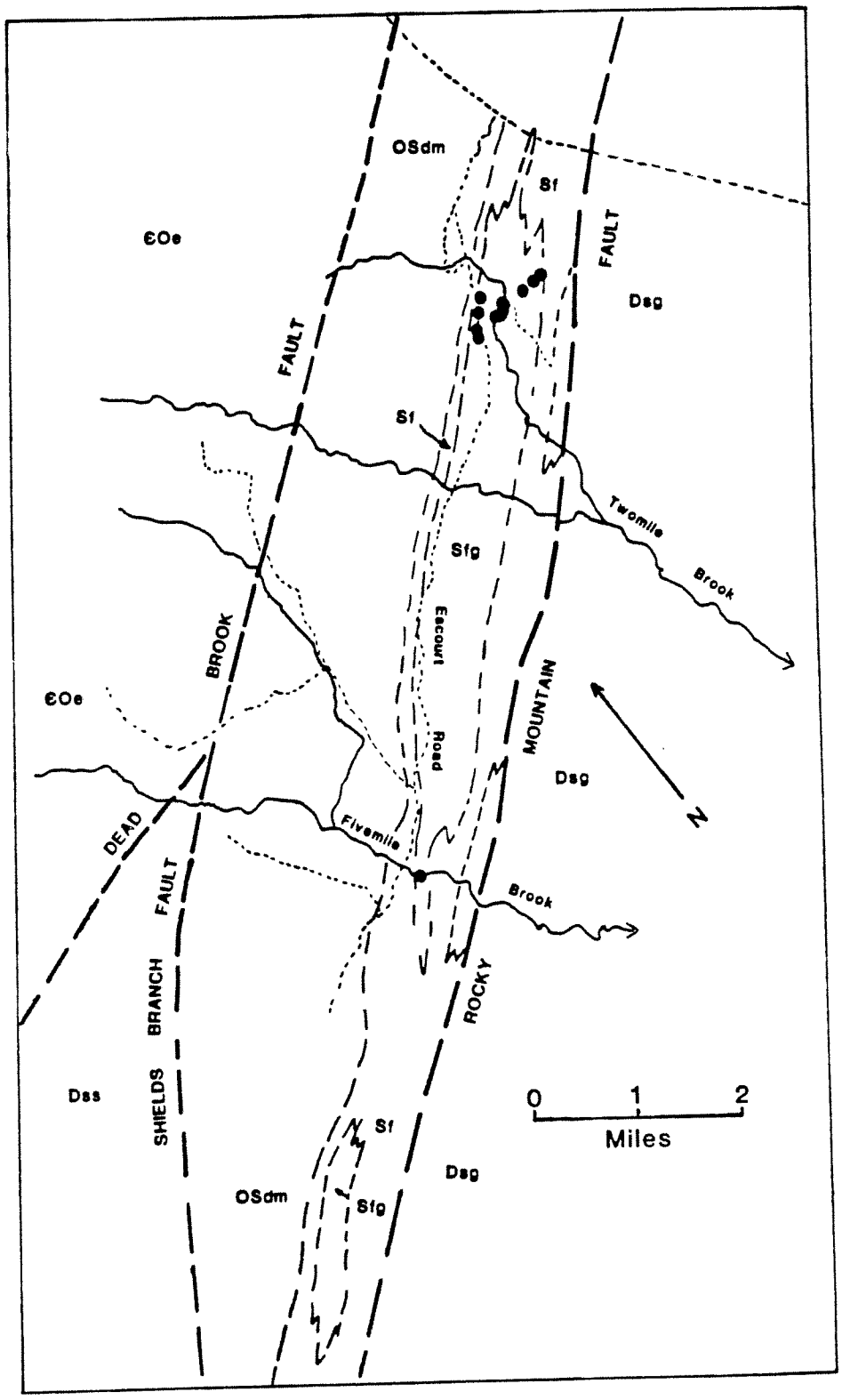

Figure 3. Geologic Map of the Fivemile Brook area showing distribution of 1981 geochemical samples (black dots) taken by W. Schwartz.

Table 1: Estimated Mode of Mafic Samples From Fivemile Brook and Rocky Mountain Formations

	Sample Number																
Primary Components	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18
Phenocrysts																	
Olivine	2	2	1	2	2	1	3	1	1	2	3	5	.5	.5	.5	1	2
Clinopyroxene	3	2	1	2	3	2	4	1	-	3	4	10	.5	.5	.5	1	3
Plagioclase	8	9	5	4	5	4	8	2	-	5	8	20	1	1	4	2	1
Iron Oxides	7	7	4	5	6	4	5	4	4	6	5	5	2	3	5	15	5
Groundmass (Plagioclase with lesser CPX)	80	80	89	87	84	89	80	92	95	84	80	60	96	95	90	81	89
Secondary Components																	
Calcite	30	30	25	25	30	30	25	30	30	25	10	25	30	15	25	20	20
Chlorite	25	25	35	30	30	35	25	25	12	20	30	20	15	15	15	12	15
Epidote	5	5	4	4	5	3	5	4	5	2	6	4	8	6	10	5	8
Quartz	3	3	1	4	2	2	2	1	3	2	2	2	-	-	-	-	-

1. Samples 1 - 10 from sills and flows at Fivemile Brook
2. Samples 11 - 12 from Rocky Mountain
3. Sample 14 from basalt outcrop along strike at Riviere Bleu, Que.
4. Samples 15 - 18 from Twomile Brook area

chlorite, and hematite disseminated in the groundmass, in fractures, and in amygdules. Plagioclase is generally in the albite-to-andesine range and is likely altered from plagioclase of higher An content. Both flows and sills are present in the Fivemile Brook sequence section. but the flows predominate and appear to be of both subaqueous and subaerial origin suggesting flows erupting in a shallow and probably subsiding marine environment.

At Pockwock Stream farther north, felsic volcanic rocks typical of the Rocky Mountain Quartz Latite (see below) lie between the Depot Mountain Formation and sedimentary rocks of the Fivemile Brook formation and basalt appears to be absent (Plate I). Along strike just south of Rocky Mountain, basalt and limestone typical of the Fivemile Brook Formation are seen apparently near the base of the Rocky Mountain Quartz Latite (locality 2528). It is therefore inferred that the quartz latite is probably Silurian and the felsic and mafic volcanism are penecontemporaneous.

The Fivemile Brook is fairly well dated by a coral assemblage found near the base of the formation along Fivemile Brook ("type section;" see figure 3) as reported by Boudette and others (1976) and represents a reinvasion of the Late Silurian seas into northwestern Maine.

Rocky Mountain Quartz Latite

A thick sequence of felsic volcanic rocks forms Rocky Mountain, the highest elevation in the region. The sequence appears to consist of siliceous rocks ranging from latite to rhyolite with minor more-mafic rocks as well. The volcanic rocks of the unit (and the Fivemile

Brook Formation) are presently being studied in detail by William Schwartz and will be reported on later. Localities sampled for geochemical analyses are shown in Figure 4.

The Rocky Mountain Quartz Latite overlies the Depot Mountain Formation along the west flank of the ridge that is Rocky Mountain. In this regard it occupies a stratigraphic position similar to the Fivemile Brook Formation which is probably a temporal equivalent (see above). If the two units are of the same age, then bimodal volcanism took place in the region during the latest Silurian (and possibly into the earliest Devonian) in northwestern Maine but did not extend far into Canada along strike to the northeast.

Seboomook Formation

Southeast of the Rocky Mountain Fault is the Seboomook Formation. The name "Seboomook Formation" is widely applied to virtually any and all gray slates of Devonian age in northwestern Maine. Except for a few selected areas along the southeastern margin of the synclinorium, there has been insufficient study of the Devonian slate sequences to precisely define formational units and to establish confident age limits. The rocks assigned to the Seboomook here are typical of the belt but are understood only broadly. The useage here follows closely that of Boudette and others (1976). The formation is equivalent to the Temiscouata Formation in Quebec to the northeast. Medium-to dark-gray slate and lesser phyllite form the most abundant rock types in the formation. Lithic and quartz-rich cleaved graywacke is variably abundant. Graywacke beds are more common and thicker in

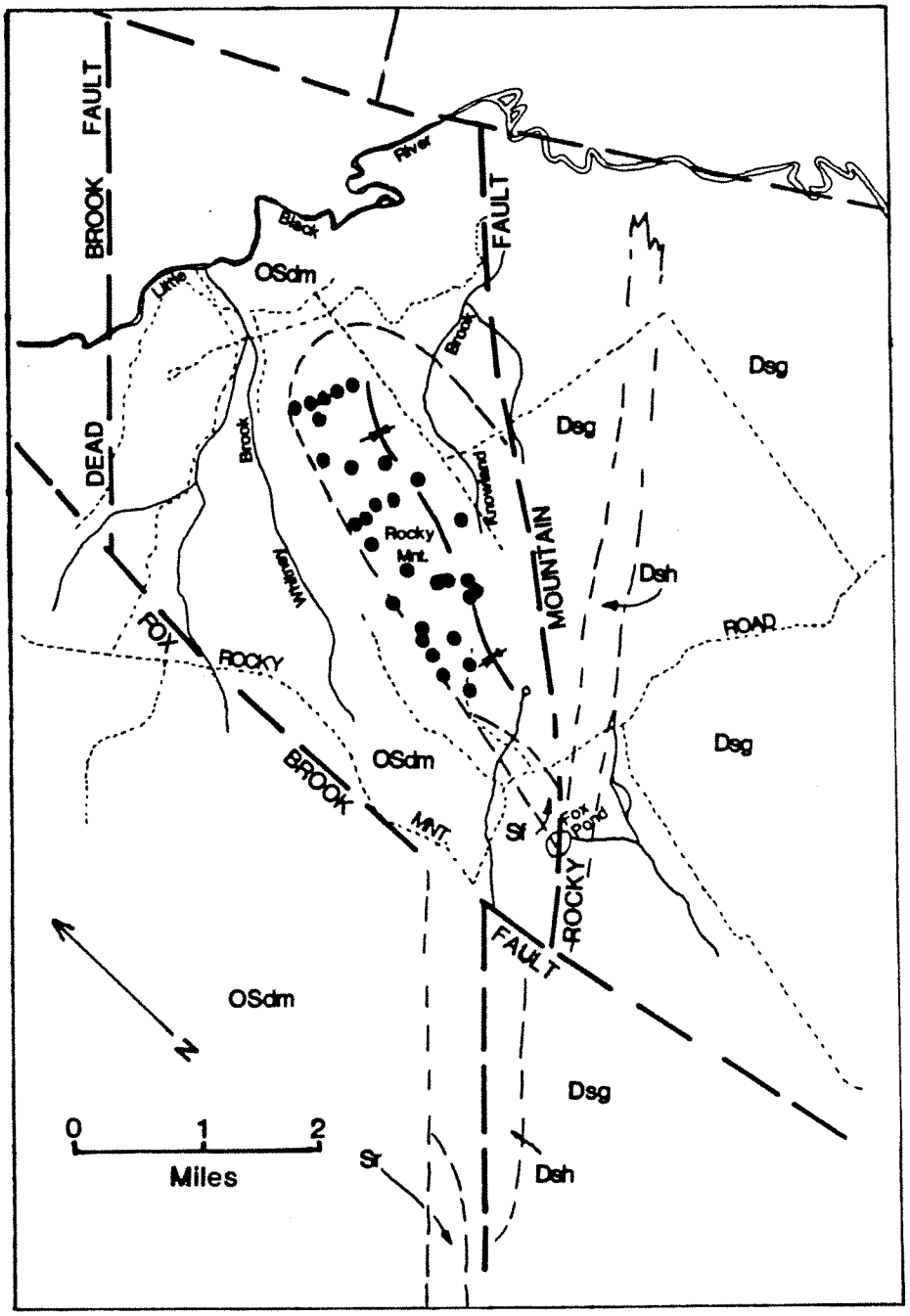

Figure 4. Geologic Map of the Rocky Mountain area showing distribution of 1981 geochemical samples (black dots) taken by W. Schwartz.

the formation near the fault; this phase of the unit is designated as Dsg in Plate I and is thought to be the lower part of the formation. The slate rich upper(?) phase, Dss, is seen away from the fault and seems to dominate the St. John and Allagash river valleys. Massive quartzite (quartz arenite) forms the Hafey Mountain Member which appears to be a lenticular unit within the formation. Sedimentary rocks coarser than medium sandstone are rare and conglomerate is present in only two or three outcrops well away from the fault. The base of the formation is not visible in the area and the formation appears to be in fault contact with older units, both in Maine and along strike in Quebec.

The age range of the formation is unknown beyond the general certainty that it is Devonian based on regional correlations and three widely scattered fossil localities of Becraft-Oriskany age cited by Boudette and others (1976). A case can be made that the sequence in northwestern Maine is largely younger than its youngest (Becraft-Oriskany) age along the southeastern flank of the synclinorium. It is likely the unit is in part of Middle Devonian age based on correlations northeastward where the Touladi Formation of Middle Devonian age is present near or at the base of the Temiscouata Formation. It thus seems probable that the axis of maximum Devonian slate/graywacke deposition moved northwestward during the Devonian so that during Middle Devonian it lay along the western margin of the present Connecticut Valley-Gaspe Synclinorium (Roy, 1980b).

STRUCTURE

Faults

Boudette and others (1976) recognized the importance of major strike faults in northwestern Maine. The present work supports the existence of such faults but the pattern shown in Plate I is modified from that given by Boudette and others (1976) and Roy (1980a) while retaining some of the fault names. Cross-faults with important strike-slip components to their motion are also recognized. The Rocky Mountain fault and the cross-faults are younger than the development of the slaty cleavage in the Siluro-Devonian rocks. The age of the Dead Brook Fault is less clear but probably is part Acadian as well since a Seboomook sliver is present along it in the southern part of the area.

Rocky Mountain Fault

The Rocky Mountian Fault forms the northwestern boundary of the Connecticut Valley-Gaspe Synclinorium. The fault is postulated on the following:

1. In the vicinity of Rocky Mountain the structural trends in the Depot Mountain Formation and the Rocky Mountain Quartz Latite are north-south whereas the structural trends in the Seboomook are 35^{o} east of north.

2. To the southwest of Rocky Mountain the fault separates the Fivemile Brook and Seboomook Formations. It helps to explain the thinning of the Fivemile Brook Formation northward and the abrupt juxtaposition of shallow-water Silurian and deep-water Devonian

without an apparent transitional phase.

3. The fault is closely approached along Chimenticook Stream where the Seboomook outcrops show complicated structure and unusually abundant quartz veins.

4. North of Rocky Mountain the Seboomook is against the Depot Mountain Formation and the Fivemile Brook formation is missing.

5. The fault is a natural extension of a contact in the same position between the Cabano and the Temiscouata formations in Quebec to the northeast that is almost certainly a fault.

The dip of the fault is unknown but it seems to be steep since no shallow dipping fabrics are present in the rocks against the fault.

Dead Brook Fault

The Dead Brook Fault is southeast of the location of a fault of the same name shown by Boudette and others (1976). The fault separates the Estcourt Road terrane from that of the Depot Mountain. Along most of its trace the fault is not closely located and its position must be considered tentative. The fault is based on:

1. Contrast in deformational history of the Depot Mountain and Estcourt Road formations in which the former has undergone one folding event and the latter has been folded at least twice.

2. It is difficult to make the contact between the formations an unconformity since the Depot Mountain formation next to the contact is of a deep-water, distal character and does not appear to have a coarse "basal" clastic facies.

The Dead Brook Fault appears to be steeply dipping and maps out as parallel to foliation (regional S_2) in the Depot Mountain Formation.

Shields Branch Fault

In the southern part of the map area there is a sliver of Devonian slate which is bounded on the west by the Dead Brook Fault and on the east by the Shields Branch Fault as recognized by Boudette and others (1976).

Cross-Faults

Several northwest trending cross-faults are recognized to explain offsets of the strike-faults and truncation of the Fivemile Brook Belt southwest of Rocky Mountain and near Seven Islands. Some of these cross-faults have strike-slip components which, of course, make them somewhat easier to recognize. They seem to follow northwest-trending topographic lineaments but the outcrop spacing does not severely constrain the map traces of most of these faults.

Folds

Bedding and slaty cleavage pi-diagrams for the Seboomook (figure 5) and Depot Mountain (figure 6) formations suggest that they are part of a single regional fold domain characterized by upright, nearly isoclinal folds. The folds strike N 35^{o} E and the slaty cleavage is axial-planar to the folds. In outcrop, a single cleavage, interpreted to be the regional S_2 foliation, is present and bedding transposition is essentially non-existent. Data from the Fivemile Brook Formation conform to the pattern suggested by data from the

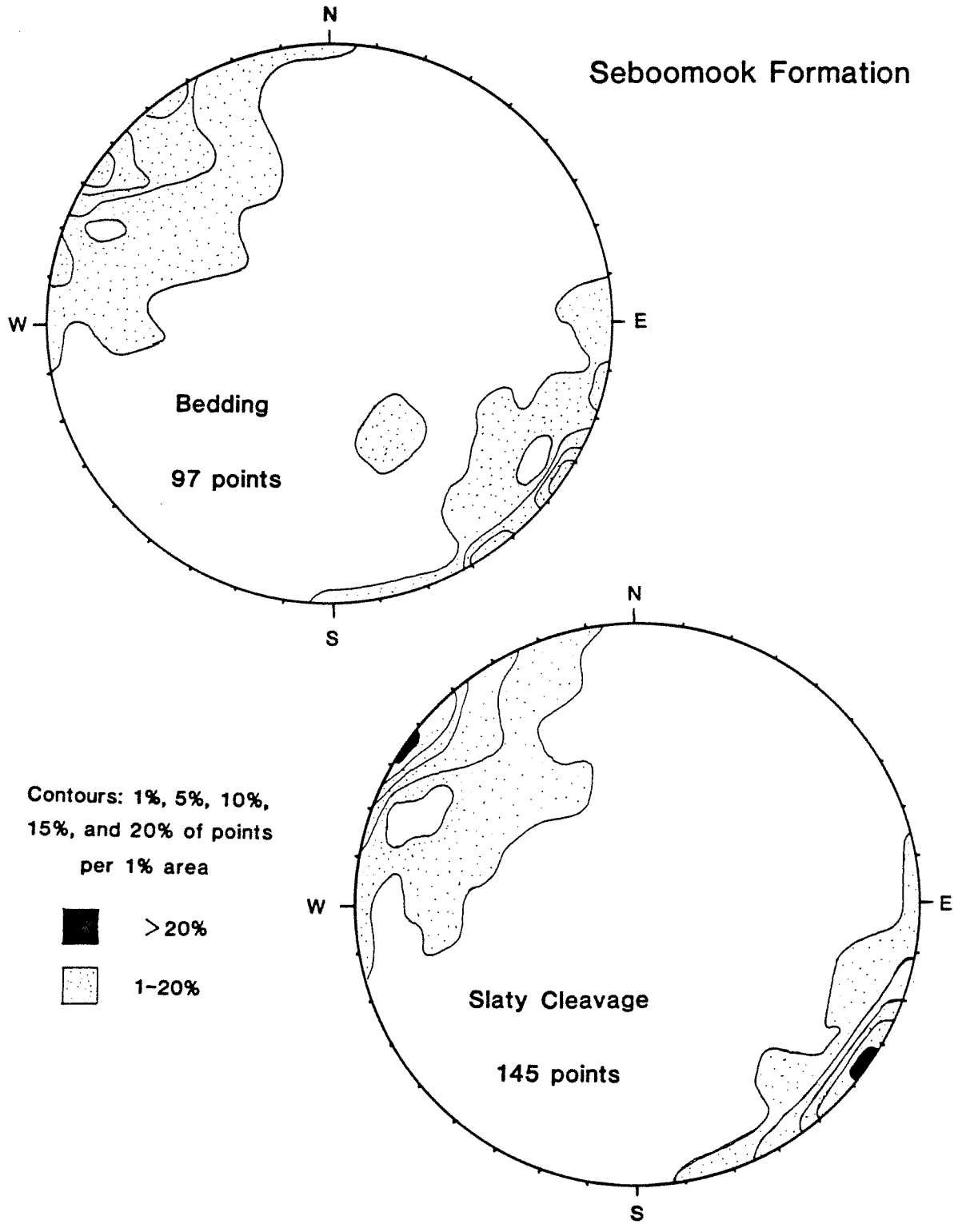

Figure 5. Pi-diagrams of bedding and slaty cleavage poles from the Seboomook Formation. Slaty cleavage is interpreted to be region S_2.

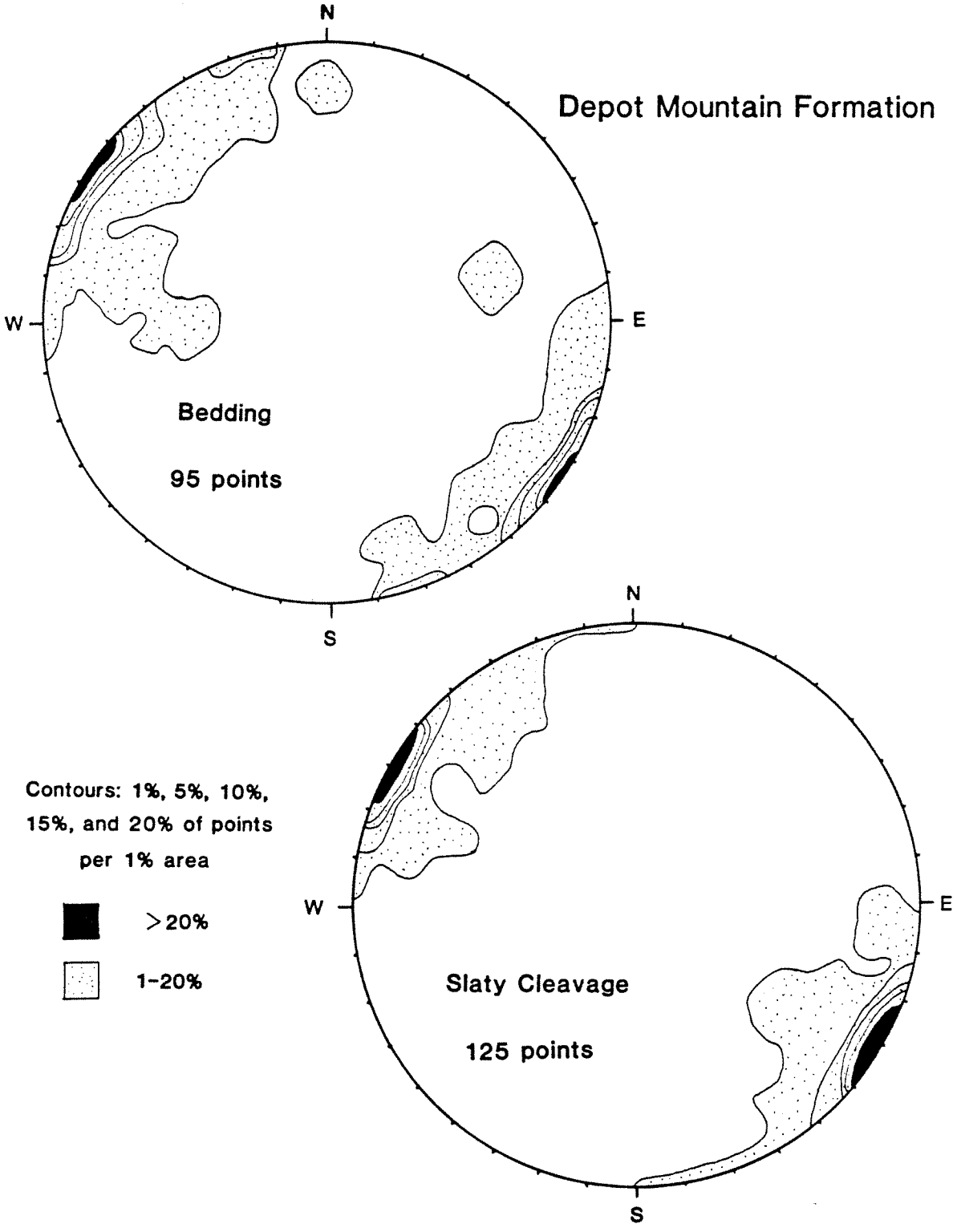

Figure 6. Pi-diagrams of bedding and slaty cleavage poles from the Depot Mountain Formation. Slaty cleavage is interpreted to be regional S_2.

Depot Mountain and Seboomook terranes.

The rocks of the Estcourt Road Formation are considerably more complex. In outcrop, a prominent foliation (regional S_1) is present in pelitic rocks with common transposition of sandstone/siltstone beds parallel to the foliation. De-limbed fold hinges found in outcrops showing bedding transposition are taken to be F_1 closures. In many outcrops the S_1 foliation and transposed bedding are folded by upright-to-overturned (northwest) folds (F_2) that plunge generally northeast and southwest at angles up to about 60°. The pi-diagram of S_1 foliation in the Estcourt Road Sequence (figure 7) shows considerably more variation in both strike and dip than either bedding or foliation in the younger units but still shows maxima corresponding to N 35° E fold trends in the younger rocks.

Interpretation

1. The first deformation involved only the Estcourt Road Formation and produced the prominent foliation (S_1) accompanied by widespread transposition of bedding parrallel to S_1 in isoclinal folds. F_1 closures are rare and "delimbed." This deformation is assigned to the TACONIAN OROGENY.

2. The second deformation caused the single cleavage, regional S_2, in the Depot Mountain, Fivemile Brook, and Seboomook formations that is axial planar to open to tightly appressed similar folds (F_2). The F_2 folds and S_2 foliation in the Estcourt Road Formation are here associated with this second deformation. This deformation is assigned to the ACADIAN OROGENY.

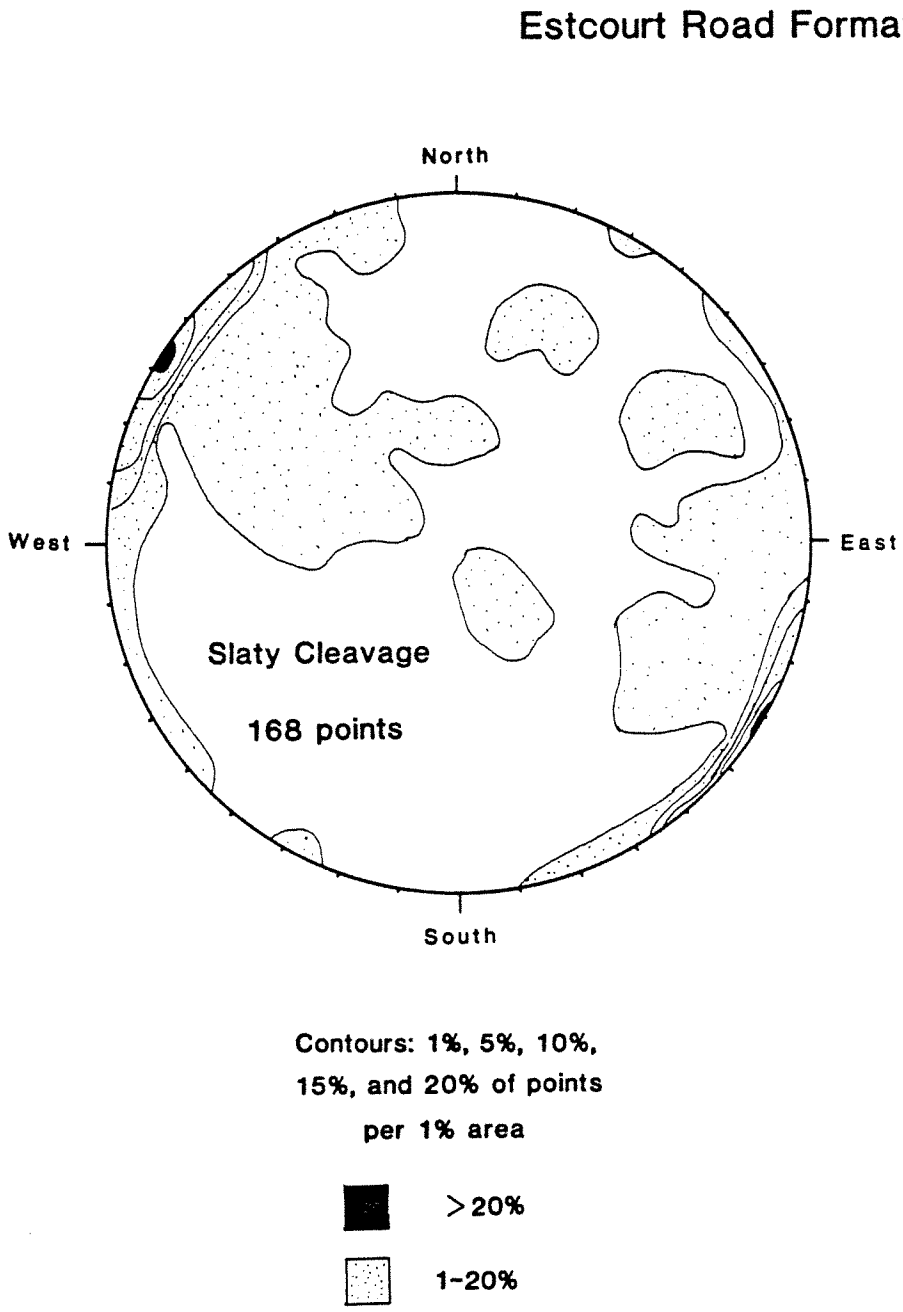

Figure 7. Pi-diagrams of prominant slaty cleavage poles from the Estcourt Road Formation. The slate cleavage is interpreted to be regional S_1 folded by F_2 folds.

3. The development of the major faults is the third major deformational event. The strike faults predate the cross-faults and are inferred to be of late Acadian origin. Early movements on the Dead Brook Fault may be related to the overturned F_2 folds in the Estcourt Road Formation.

MAGNETIC TRAVERSES AND SOIL GEOCHEMISTRY

Shown in Plate 1 are lines of magnetic traverses (MT 1 through MT 9) and areas of anomalously high soil base metal concentrations that are discussed in Roy 1980a and by others in that same report to which the reader is referred. The magnetic traverses proved quite useful in supporting the geological interpretations in portions of the region where volcanic rocks are present. The upper greenstone lentils within the Fivemile Brook Formation in the Twomile-Fivemile brooks area are based entirely on the presence of magnetic anomalies. in traverses MT 4 and MT 5.

ACKNOWLEDGEMENTS

Mr. Daniel L. Carey provided excellent service as field assistant during the course of the 1981 field season and began a study of his own (MS thesis at Boston College) of the shales of the Jemtland Formation in northeastern Maine. Mr. William Schwartz began his MS thesis work on the Silurian Volcanic rocks of the upper St. John region and provided some preliminary information on those rocks for inclusion in this report. Mr. Mike Myster, Allagash District Forest Ranger, provided recent airphotos covering the Beau

Lake and Rocky Brook quadrangles and was of great assistance to members of the MGS project during the rain and flooding of August 5-8.

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