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Title: Structural Characteristics of the Northwestern Boundary Fault in Northern Franklin and Somerset Counties, Maine

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Contents: 8 page report

INTRODUCTION

The Northwestern Boundary Fault (NWBF) bounds the Chain Lakes massif and Attean batholith (of Precambrian and middle Ordovician ages, respectively) along their northwestern contacts with Silurian calcareous strata, and slate and phyllite assigned to the Seboomook Formation. The NWBF has been recognized since the 1960's (Doyle and Hussey, 1967) as an extensive fault paralleling the strike of formational units and regional cleavage in the Boundary Mountains of western Maine and adjacent Quebec. Its extension along strike to the southwest, through the Eastern Townships of Quebec, and to the northeast (east of U.S. Highway 201) is still not resolved. Although the continuation of the NWBF system in Quebec may coincide with the Monroe Line in New Hampshire, its continuation to the northeast across the northern part of the Long Pond 15-minute Quadrangle in Maine is uncertain, for it appears to die out along strike within the Seboomook Formation along the northeasterly extension of the Moose River synclinorium. Reconnaissance mapping during the 1981 season will be directed in part to these questions.

During August of 1980, a field conference on the characteristics of the NWBF was held in the vicinity of Jackman. Participants were G.M. Boone (convenor), E.L. Boudette (U.S. Geological Survey), M. Bronston and S. Serra (Amoco, geophysicist and structural geologist, respectively), and D.S. Westerman (Maine Geological Survey). The motivation arose because E.L. Boudette, D.S. Westerman, and the present author each had arrived at different interpretations of net displacement: southeast over northwest thrusting; normal faulting with the northwest side down; and northwest over southeast thrusting, respectively (see previous NRC annual reports by Boone and by Westerman, 1978-1980). Boudette and Albee first had encountered the problem in their mapping of the Attean Quadrangle. Although they realized a tectonic break might be present, the field evidence was considered insufficient to warrant showing a fault on the published map (Albee and Boudette, 1972). My observations were confined to areas in the Attean and Skinner 15' Quadrangles, and those of Westerman in the Skinner and Chain Lakes 15' Quadrangles and Woburn and Megantic map areas in adjacent Quebec.

Exposures of fault surfaces of major and meso scales or fault contacts between formational units have not been found along the NWBF, although two localities contain exposures within a meter to a few meters of contacts. These are described separately in the next section.

Rock units directly involved along the trace of the NWBF in the areas covered by this report are as follows:

Seboomook Formation (Lower Devonian)
metalimestone and calcareous metaconglomerate (Upper Silurian)
Attean batholith (Upper Middle Ordovician)
Chain Lakes massif (Precambrian)

Description of Localities

1. U.S. Highway 201, approximately 4.3 miles north of Jackman. Road cuts on east side of highway, in vale occupied by East Branch of Sandy Stream and Coburn Pond, and 0.3 mile south of BM 1517.

Gray and greenish gray, silvery phyllite and cleaved metasiltstone, each with chocolate-brown-weathering, 0.5 to 1.0 cm thick layers, spaced 2 to 5 cm apart, within area mapped by Albee and Boudette (1972) as part of Seboomook Formation. Bedding is indistinct, but pervasive slaty cleavage is variously deformed, showing broad undulations in northwestward dip and pronounced chevron folding and microfault offsets of cleavage and metasiltstone lithons (fig. 1).

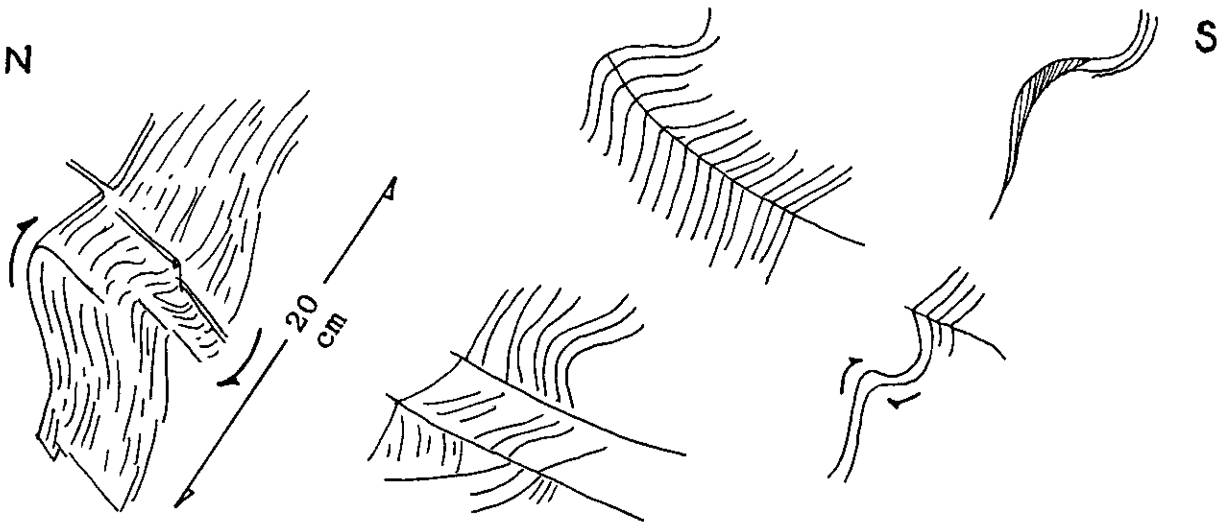

Figure 1. Deformed cleavage in Seboomook Formation, U.S. Highway 201, Attean Quadrangle.

These sketches, projected into N - S cross section, show that a) axial surfaces of chevron-folded cleavage consistently dip 35° to 45° south, but that b) the sense of rotation around fold axes is not consistent, although an argument might be made for a predominance of clockwise rotation as viewed eastward. Bearing and plunge of chevron axes average N80°E, 0°. N-S compression (σ_1 inclined) is evident.The zone of deformed cleavage is at least 400 meters wide, and the fault trace is believed to be marked by the Coburn Pond vale.

(Interpretive comments follow at the end of this report.)

2. North Branch, Wood Stream, ca. 2 miles west of Crocker Pond (NC ninth, Attean Quadrangle).

Gray phyllite (Seboomook Formation?) is strongly lineated owing to a) chevron-like intersections of transposed cleavage, b) small, 2 cm-radius cylindrical folds in the phyllitic foliation, and c) broad undulations. White, barren quartz veins are profuse, most occurring as thin reefs in the crenulations. The bearing and plunge of crenulation axes are N80°W, 35° to 45° NW.

3. Unnamed valley, 0.75 mile N10°W of Little Turner Pond, west-central ninth, Attean Quadrangle.

Medium- to coarse-grained, inequigranular Attean granitic rock, within approximately 100 meters of contact with Seboomook Formation: the Attean granite, northwestward to contact, picks up prominent sets of schistose shear surfaces, each a few millimeters in thickness, approximately 10 cm to 0.5 meter in length, and spaced several centimeters apart.

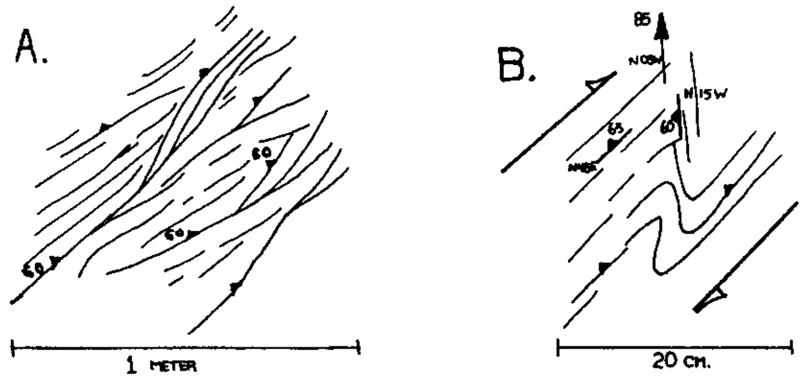

Figure 2. A: Spaced shear surfaces in protoclastic Attean granite. B: Map pattern of clockwise rotation in folded cleavage of Seboomook Formation. A and B bracket the fault contact at locality 3.

They are oriented N30°E and N45°E, and dip ca. 60° NW (fig. 2A). Shear surfaces of each set here and there truncate surfaces of the other, and are therefore probably cogenetic. Outcrops of massive granite are locally interspersed with foliated granite.

Within a few meters of the fault, three foliations are evident:

N17°E, 55°NW
N40°E, 70°NW
N65°E, 60° NW

These bear the same relationship to each other as in the previous description.

Approximately 10 to 20 meters northwestward, the first outcrops of slate contain folded cleavage (fig. 2B) with dominant fold limbs N45°E, 65°NW, and shorter limbs, N15°W, 60°SW, with bearing and plunge of axes N05°W, 85°NW, showing thus, a map pattern of clockwise rotation around the axes.

4. Due north 0.4 mile from locality 3, quartz-veined phyllite is complexly polydeformed (fig. 3). Here at least two fold-axis orientations are found in tightly folded cleavage: one, consistently N75° - 80°W, 35° to 45° NW plunge; the other, variously N10° - 60°W, with 35° - 45° NW plunge, as shown by the open-patterned symbol. Fold limbs are variously steeply to vertically inclined, with axial surfaces of the more northwesterly folds overturned to the southeast.

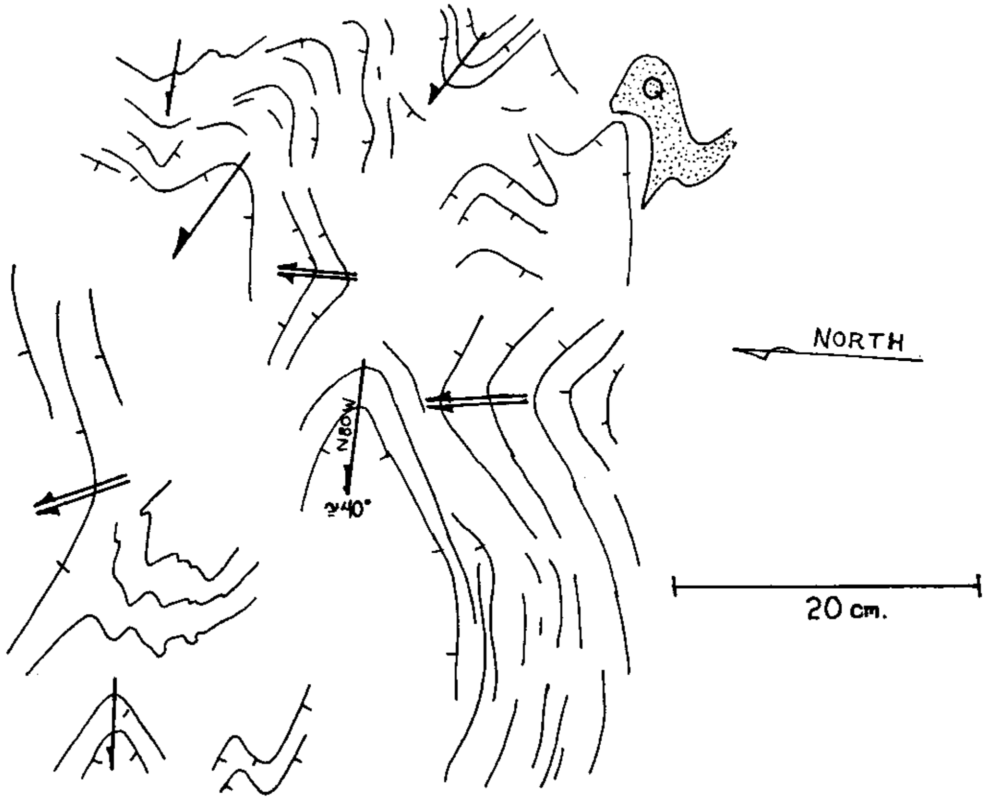

Figure 3. Map pattern of polydeformed cleavage in Seboomook Formation phyllite, ca. 10 meters north of NWBF at locality 4. The form lines show that the folded cleavage here is not of chevron geometry.

5. Approximately 0.5 mile west of Little Turner Pond, Attean Quadrangle.

Foliated and strongly retrograded Attean granitic porphyry is in small-scale (?) fault contact with more equigranular rock suggestive of the common granofels lithology of the Chain Lakes massif. Although the areal extent of the granofelsic rock is not known, nor is its origin (large xenolith or fault slice?) the divergence of shear splays (fig. 4) indicates a right-lateral and northwest-over-southeast sense of displacement.

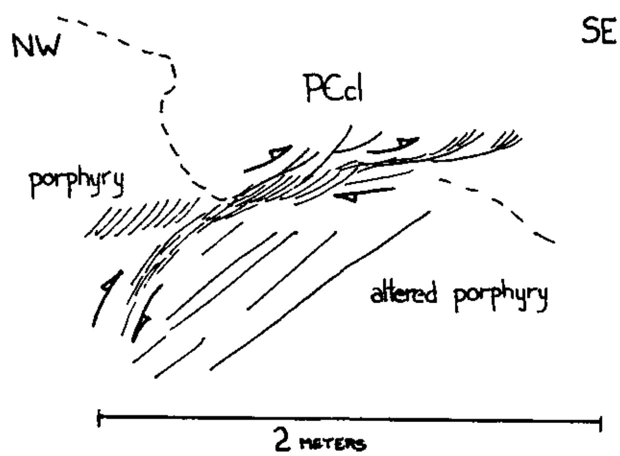

Figure 4. Geometry of splayed shear surfaces, granitic porphyry against granofelsic rock.

6. Saddle in ridge crest, 0.3 mile north of survey point at 1852' elevation, between East Branch of Gulf Stream and unnamed tributary of Wood Stream; western Forsythe Twp., EC ninth, Skinner 15' Quadrangle.

D. S. Westerman has mapped here a normal fault separating greenish gray and gray phyllite and slate bounded to the southeast by poorly cleaved, well-bedded metalimestone, from strongly retrograded, subequigranular Attean granitic rock on the southeast side of the fault. The limestone here preserves a steeply dipping fracture (fault?) surface, approximately 60 meters along strike, by several meters high, along which cobble- and boulder-sized, variously angular to poorly rounded blocks of limestone, low-grade calc-silicate rock, porphyritic medium- to fine-grained granite, and sillimanitic granofels assignable to the Chain Lakes massif are found cemented by secondary calcite and quartz. Unlike exposures in the previously described localities, the rocks in the vicinity of the fault surface are lacking in polydeformed cleavage and, in the Attean, in anastomosing shear surfaces and foliation. Orientation of cleavage in the slate and phyllite of the Seboomook Formation departs in the vicinity of the fault from the regional N55°E, locally to N30°E, but dip of cleavage is unchanged, 50° to 60°NW. Bedding in slate and metalimestone is upright, and generally dips 40° to 45° NW, thus showing a simple bedding - cleavage relationship.

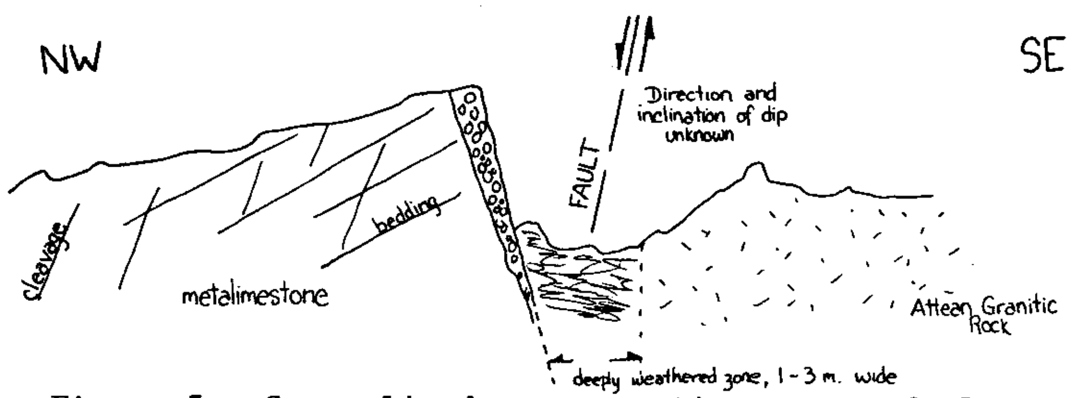

Figure 5. Generalized cross section across fault at locality 6, Skinner Quadrangle. Length of section, approximately 30 m.

Interpretation

Hypotheses to explain the features described must take into account that localities 1 through 6, as well as others, lie very much on line-of-strike, leaving disturbingly little cross-strike width in which to postulate coincidence of separate faults unrelated in tectonic style as well as origin. Posthumous fault systems along which recurrent, and possibly tectonically unrelated movement has occurred, provide perhaps the most obvious of possible models. This model has been applied rather commonly to intra-plate continental faults documenting a long and complex history of movement. One drawback of the model is the imprecision in the concept as regards length of time between disparate senses of motion, or how much change in orientation of stress vectors is required to pass from the conceptual model of a genetically coherent, evolving fault system to that of unrelated posthumous motion on pre-existing fault surfaces. Rather than pursuing this problem, it is more instructive to invoke a second model as an end-member of the first, namely of a series of episodic movements on a fault in response to continuous change in stress vector orientations. A third model, suggested by Serra and Bronston, is based on predominantly strike-slip motion on a steeply dipping or vertical master fault representing a simple shear component of a stress system in which σ_1 is horizontal and at a Hartman or smaller azimuthal angle to the fault trace (fig. 6A).

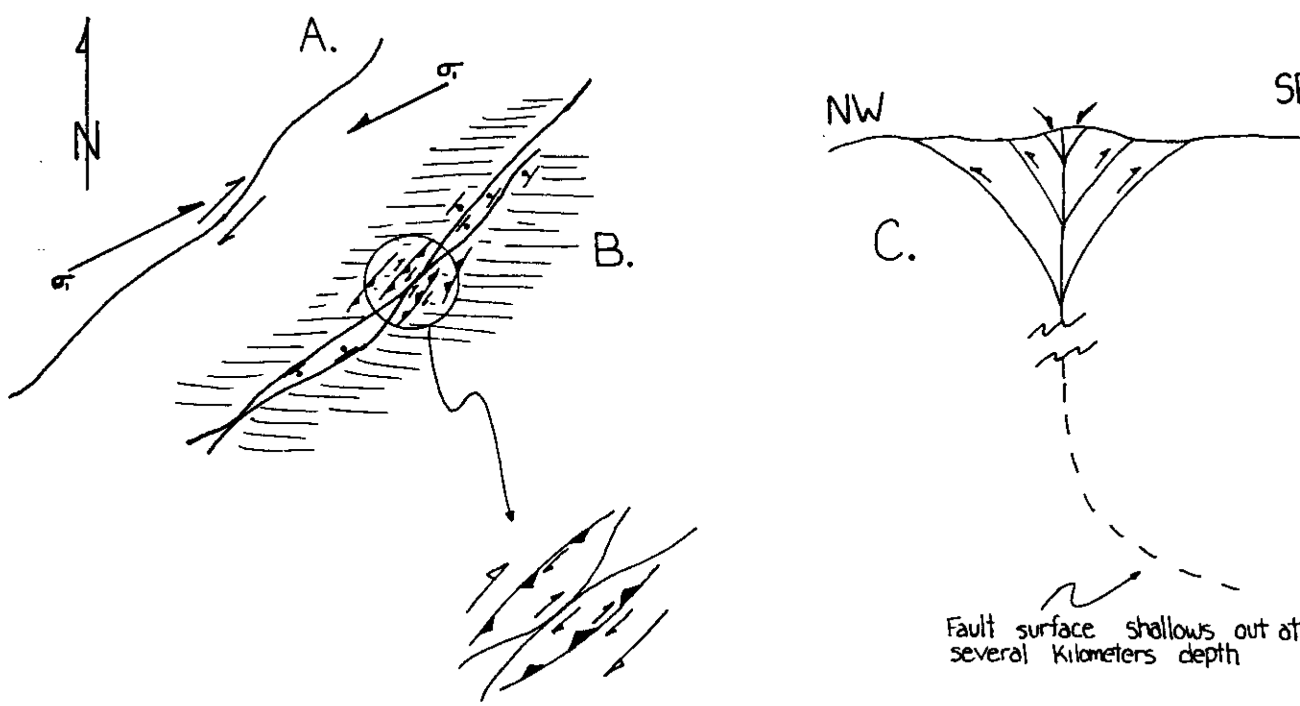

Figure 6.

The more the fault surface departs from linearity, the greater will be the contrast in faulting locally along the strike of the master fault. Lateral surface width of subsidiary faulting is variable, depending upon tensile and compressive strengths, depth, temperature, fluid pressure, strain rate, initial lithologic inhomogeneity, and depth of erosion (fig. 6 B, C). Far from merely being a convenient eclectic hypothesis to account for the assemblage of disparate structures described, faults with subsidiary "fleur de lys" geometry such as here discussed are well documented in modern orogenic belts by surface mapping, exploratory drilling, and seismic data.

Although we cannot document the existence of fleur de lys subsidiary fault geometry along the NWBF, we favor this model as being the simplest hypothesis to explain the field observations as we have mutually studied them. The quasi-horizontally disposed compressional geometries inferred for localities 1, 4, and 5 would be confined to locations in time and space when, and where, opposing salients of each wall of the master fault create localized compression (fig. 6B), producing polydeformed structures in the orientations expected in domains of coherent deformation or protoclasis, while at higher structural levels fleur de lys thrusts would be expected to develop in domains of brittle deformation. Map patterns of dextral rotation (as in slate, locality 3, fig. 2B) would be widespread proximal to the master fault as well as to subsidiary thrusts where they pass laterally into zones of coherent, homogeneous deformation (ends of thrusts, enlarged portion of fig. 6B). Steep plunge of cleavage folds (fig. 2B) and of intersecting shear surfaces (fig. 2A) would be expected adjacent to the strike-slip master fault where compression across the fault was less intense. Less steep plunges of cleavage folds (locality 4, fig. 3) and of splayed shear surfaces (locality 5) may be more typical of subsidiary, inward-dipping thrusts of fleur de lys geometry (fig. 6B, C). Normal faults (locality 6, fig. 5) would be expected when and where recesses in each wall come into juxtaposition across the master fault (normal fault symbols, fig. 6B, and keystone sense of antithetic displacement, as is shown directly over master fault trace in cross section, fig. 6C).

Structures at meso and minor scales may become obliterated by subsequent strike-slip or dip-slip components of movement, but it would be unlikely that all features expressing one or another sense of fault displacement would be preferentially destroyed.

We believe that confirmation or refutation of this synthesis of our observations will probably be achieved only by extensive investment of refined geophysical as well as further surface geologic study of the NWBF system.

A possible modern analog involving strike-slip and thrust sense of motion may be the Alpine fault, southern New Zealand, where arc-related rocks of the South Island impinge against continental crust of the Indian plate (Allis, 1981).

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