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

OPEN-FILE NO. 80-35

Title: Report on Bedrock and Brittle Fracture Mapping in the Dover - Foxcroft/Dexter Area, Central Maine

Author: David S. Westerman

Date: 1980

Financial Support: Preparation of this report was supported by funds furnished by the Nuclear Regulatory Commission, Grant No. NRC-04-76-291.

This report is preliminary and has not been edited or reviewed for conformity with Maine Geological Survey standards.

Contents: 14 page report

ABSTRACT

Low, but persistent, seismic activity occurs in a wedge-shaped area north of Penobscot Bay, Maine, and this area corresponds with a regional flexure in in the trend of formational units. The trend of these units shifts from NE-NNE in the southern and western portions of the area to ENE in the eastern and northern portions. Large-scale topographic linears reflect this change in trend, which is easily seen on Landsat imagery. Smaller scale topographic linears trend NW-NNW and correspond positively with a set of brittle fractures, many of which exhibit evidence of left-lateral and extensional movement. These brittle fractures appear to be related to the regional flexure and, therefore, may be related to the seismic activity. No recent offsets were noted in the area.

INTRODUCTION

A wedge-shaped area north of Penobscot Bay, Maine, is known to be one of low, but persistent, seismic activity (Boston Edison Co., 1976; Barosh, 1978). The boundaries of this area extend north from Penobscot Bay to Millinocket (the Penobscot lineament zone of Barosh (1976) and earlier of Hobbs (1904)), across to Greenville, and south-southeast through Belfast to the north end of Penobscot Bay (the Dover-Foxcroft line of Lee and others (1977)). The study area for this report is located in the central portion of the seismically active "wedge" (Figure 1), specifically in the southern two-thirds of the Dover-Foxcroft Quadrangle, the southeastern quarter of the Guilford Quadrangle, and the northeastern quarter of the Pittsfield Quadrangle.

The purposes of this study were to investigate for possible relationships between topographic linears and brittle fractures in the bedrock, to analyze the brittle-fracture history of the region, and to conduct geologic mapping in an effort to determine the presence or absence of major faults. The method of investigation included the identification of topographic linears, followed by mapping both parallel and perpendicular to these features. Lithologic data, plastic deformation data, and brittle-fracture data were collected at each outcrop, with special effort made to determine movement directions on all measured surfaces. These data were plotted on appropriate map overlays (15-minute scale) and on stereograms. Analyses of the brittle-fracture histories included the distinction between data collected in close proximity to topographic linears and data collected between such linears.

GEOLOGIC SETTING

The study area is located within the southeast limb of the Merrimac Synclinorium, the stratigraphic relationships of which have been recently discussed by Pankiwskyj and others (1976). The youngest rocks in the area are Devonian or Silurian in age and belong to the Vassalboro Formation. These rocks consist primarily of massively bedded, weakly calcareous metasandstone

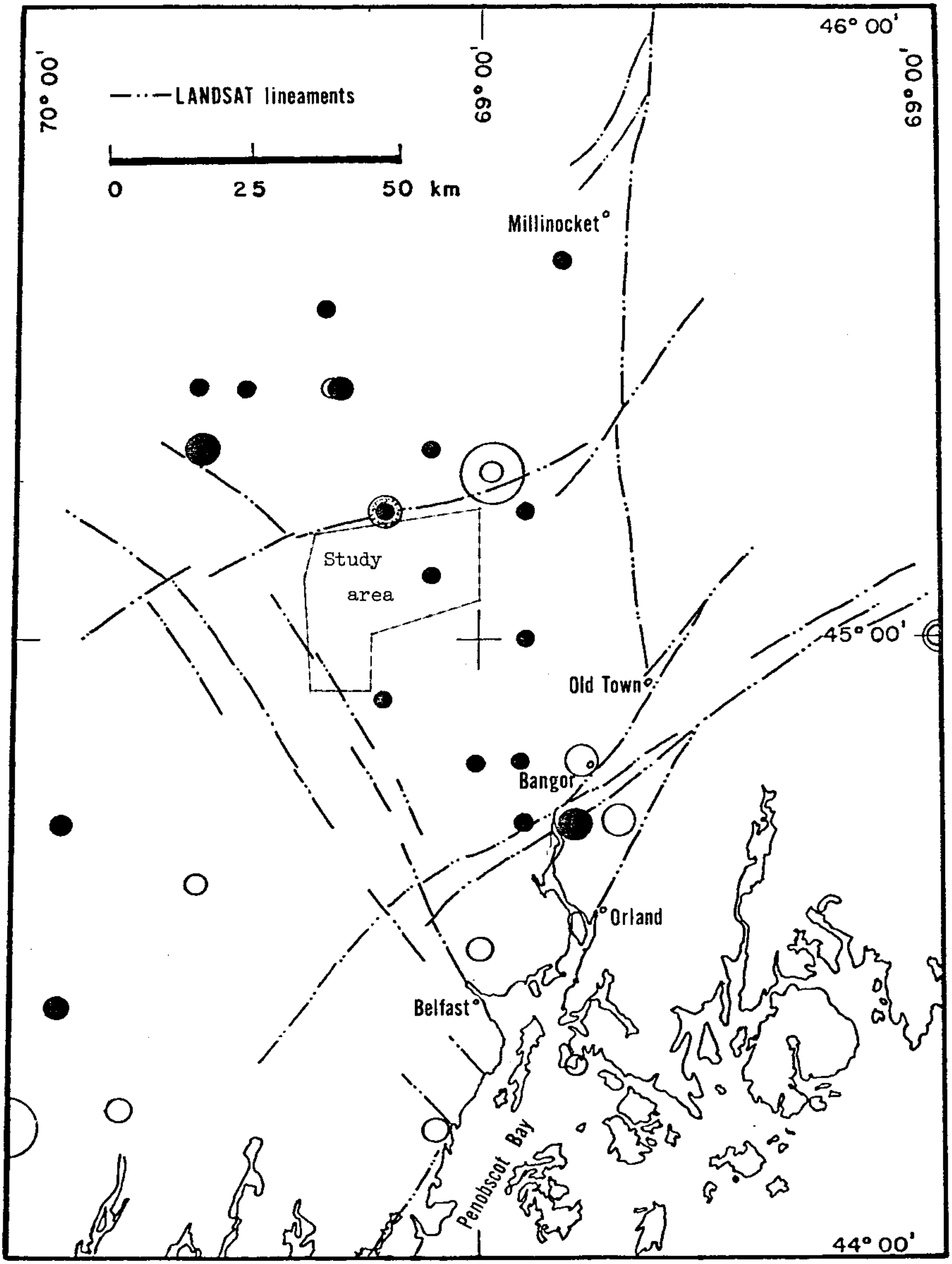


Figure 1. Wedge-shaped area of low, but persistent, seismic activity (Boston Edison Co., 1976; Figure 16 of Barosh, 1978)

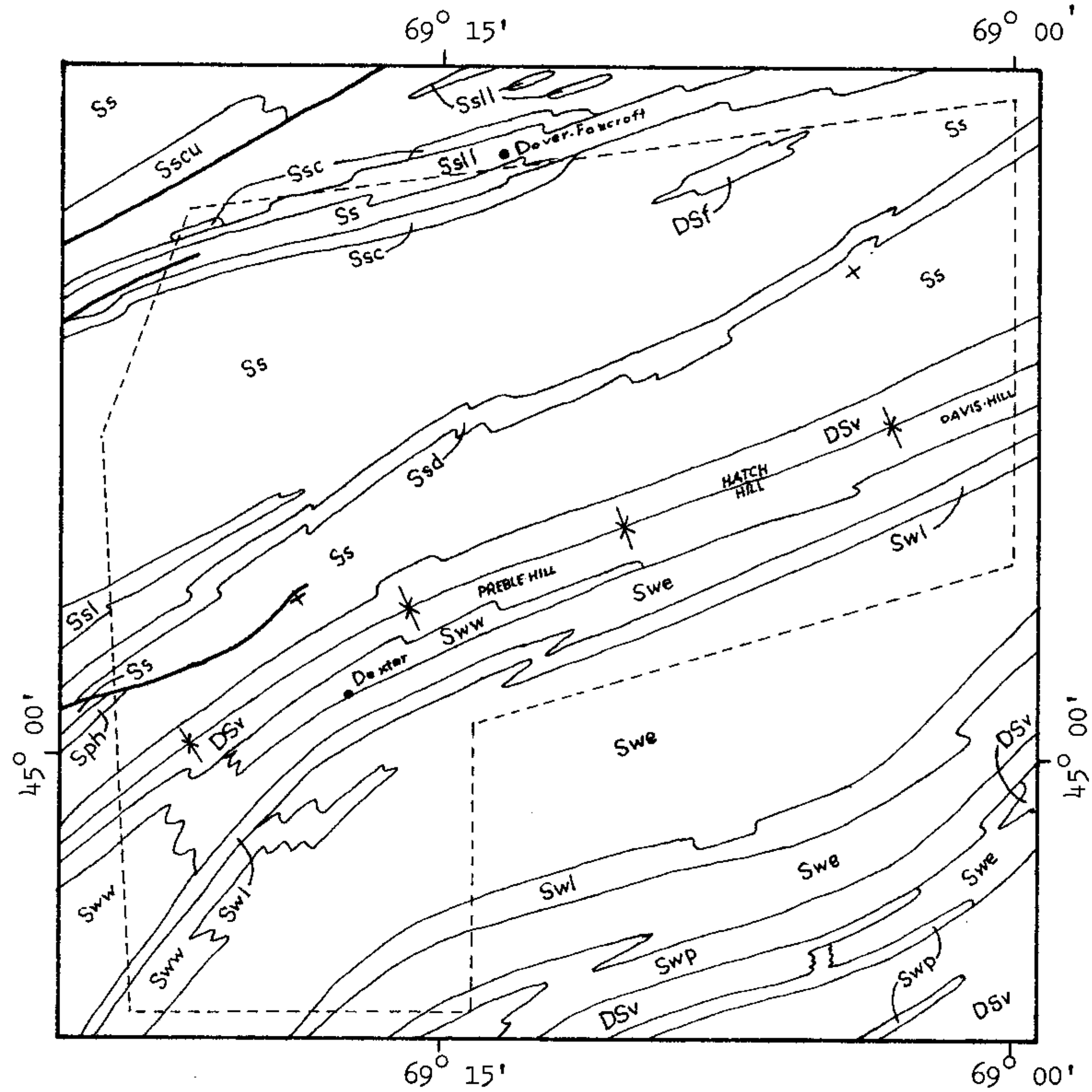
with minor interbeds of massive metapelite. They are exposed in the core of the Currier Hill Syncline of Ludman (1969), the northeastern extension of which passess through the central portion of the study area (Figure 2). This syncline effectively divides the southeast limb of the Merrimac Synclinorium, and is flanked on both sides by primarily anticlinal structures in which rocks of Silurian age are exposed. The rocks of the Waterville Formation, as redefined by Osberg (1968), are exposed on the southeast flank of the Currier Hill Syncline, and rocks of the Sangerville Formation are exposed on the northwest flank (Pankiwskyj and others, 1976). Pankiwskyj and others (1976) suggest, on the bases of both lithologic and fossil correlation, that the Sangerville Formation is equivalent to the Waterville Formation.

Detailed and reconnaissance mapping has been previously done in the study area by Griffin (1973) and open-file bedrock geology maps by that author are available at the Maine Geological Survey. One of the principle mapping efforts of Griffin was the subdivision of the major formations into members. The detailed stratigraphic descriptions of Pankiwskyj and others (1976) are in close agreement with, and incorporate, those subdivisions, although their map distributions of these units differ in detail. Lithologic mapping by this author resulted in additional discrepancies. This appears to be due to the frequency of repetition of individual members of formations, and formations themselves, relative to the scale of mapping. This problem, a common one in multiply-deformed metamorphic terrains such as exist throughout much of Maine, appears to result from three possible conditions, perhaps in combination. These are: (1) the deposition of similar lithologic horizons separated in time and space, (2) the repetition of individual horizons as the result of folding, and (3) the repetition of individual horizons as the result of faulting. Although no major faults were identified in the study area, the possibility of their presence is indicated by the frequent changes in lithology along strike. Lithologic mapping by this author was insufficient to significantly modify the maps of earlier workers.

ANALYSES OF PLANAR FRACTURE SURFACES

Bedding - The primary lithologic layering of the metasedimentary units exposed in the study area was observable in nearly all outcrops. This layering, termed bedding (S_0), is generally characterized by having steeply-dipping fracture surfaces (S_1) which parallel the bedding. The nature of these surfaces varies as a function of rock type, primarily grain size, ranging from joint-like fractures in the more massive, coarse-grained units to a schistose, phyllitic or slaty cleavage in the fine-grained units. Rarely, isoclinal fold noses were observed, leading to the common interpretation that the steep dip of the beds parallel to S_1 is the result of an initial isoclinal folding episode.

The variation in orientation of the S_{0-1} surfaces can be seen in the map view (Figure 2), with a prominent change from N. 32° E. in the southwestern portion to N. 58° E. in the central and eastern portions. These variations are further illustrated in stereographic projection (Figure 3), in which the poles to the surfaces have been plotted on the lower hemisphere and then



EXPLANATION

× Diabase

DSf Fall Brook Formation

DSv Vassalboro Formation

Sph Parkman Hill Formation

Ss Sangerville Formation
- Ssl metalimestone member
- Ssll lower metalimestone member
- Ssc metaconglomerate member
- Sscu upper metaconglomerate member
- Ssd Dover member

Swe Waterville Formation, eastern facies

Sww Waterville Formation, western facies
- Swl metalimestone member
- Swp Pittsfield member

Formational contact
Fault
Currier Hill synclinal axis
Boundary of the study area

5 0 5 Miles
Scale 1 : 250,000

Figure 2. Geology of the Dover-Foxcroft and Dexter area (after Pankiwskyj et al., 1976)

contoured. The change in trend, a flexure of regional scale, has been previously noted by Lee and others (1977), who termed the hinge of the flexure "the Dover-Foxcroft line". Barosh (1978) pointed out the prominence on Landsat imagery of this flexure, observing the pattern as a giant drag fold cut off at its eastern margin by the Penobscot lineament zone.

In most instances, the S_{0-1} surfaces have a greater degree of roughness in one direction than in any other. The sense of movement is invariably right lateral, but does not appear to be reflective of movement parallel to strike. The preferred direction of roughness is due to movement on a transecting cleavage (S_2) which trends more northerly and formed during an episode of right-lateral deformation. Quartz veins trending parallel to bedding and exhibiting the effects of later folding episodes are common in the pelitic units.

<u>S_2 Fractures</u> - Following the initial isoclinal folding of the rocks in the region and the development of the associated fractures, some of the rocks received a second set of fractures generally seen as closely-spaced, pervasive cleavage marking the axial planes of tight "Z" folds. In most places where these folds are observed they are present over the whole area of the outcrop and only rarely exhibit a reversal in sense. Where reversals are observed they can be seen to be small drag folds on the crossing limbs of the "Z" folds. The surfaces of the S_2 foliation vary from a micaceous, rough fracture cleavage indicating right-lateral movement to very closely spaced joints with no indication of movement on their surfaces.

Variations in the orientation of S_2 surfaces are illustrated in Figure 4. The dominant trend is N. 32° E. with high angles of dip. This trend corresponds with the N. 58° E. trend of bedding in the central and eastern portions of the study area. The dominant trend of S_2 surfaces in the southwestern portion of the area is N. 13° E. where bedding trends N. 32° E.. The extent of variation in the orientation of S_2 is greater than is that of S_{0-1}, due to refraction of S_2 as it passes through beds of varying grain size. The trend of S_2 is generally more northerly in the finer grained rocks.

The fold axes associated with the S_2 surfaces typically plunge to the south-southwest at moderate to steep angles, suggesting that the dominant movement along the fold planes was right lateral, but shallowly plunging axes were also observed. These would indicate a component of vertical movement, east rising relative to west.

<u>S_3 Fractures</u> - A third generation of fracture surfaces associated with recognizable deformation was observed in several localities. These surfaces (S_3) characteristically appear as joints, with smooth planar surfaces, but they constitute the axial planes of "S" kink folds and indicate left-lateral movement during their formation. These fractures occur with two trends, N. 36° W. and N. 68° W., both with steep dips (Figure 5). The strongest concentration of S_3 surfaces was observed in the vicinity of Preble Hill, approximately 4 miles northeast of the center of Dexter. It is interesting to note that the only local economic prospect known to the author is located near this zone of deformation. This prospect, the Preble Hill Silver Mine, consists of three pits associated with a quartz vein containing galena, pyrite and spalerite (?). One of the pits is reportedly on the order of 100 feet deep. The quartz vein varies in orientation, having a general trend of N. 80° W., 60°N.

The occurrence of S_3 fractures is rare in the southwestern portion of the study area, where they were observed to trend N. 47-65° W., and dip steeply to the north. In the central portion of the study area, where these surfaces were commonly observed, the two dominant trends occurred both together and independently. One occurrence of S_3 kink surfaces was located in the easternmost portion of the study area.

Joints With Quartz - Approximately 17 percent of the joints measured in the study area had quartz on their surfaces. The thickness of the coating was generally 1-2 mm, ranging up to 1 cm. The three dominant trends of these joints are N-S with moderate to steep dips, N. 35° W. with steep dips, and roughly E-W with moderate to steep dips (Figure 6). No portion of the study area was observed to have a particularly high concentration of such joints or a strongly preferred orientation.

Joints With No Mineralization or Associated Movement Indication - The highest percentage of joints in the study area trend N. 32° W. with nearly vertical dips (Figure 7). A large majority of the joints trend between N. 10° W. and N. 75° W., also dipping steeply. Joints of moderate dip followed these trends throughout the study area. The surfaces of the joints are generally planar and smooth, and the spacing varies considerably. Joints associated with deformation tend to be more closely spaced than those showing no indication of movement, but closely spaced joints (2 to 5 cm) were seen in several localities. Such joints are in most cases parallel to a local topographic linear feature and will be discussed below.

RELATIONSHIP OF TOPOGRAPHY TO BRITTLE FRACTURES

The largest scale linear topographic features in the study area trend parallel to the map pattern of the different lithologic units and, therefore, parallel to the S_{0-1} fracture surfaces. These features include two prominent topographic lows separated by a ridge passing through Dexter. The ridge extends SW from Dexter and extends ENE to include Preble Hill, Hatch Hill, Bull Hill and Davis Hill, roughly tracing the axis of the Currier Hill Syncline. These large-scale topographic linears are due to the differential erosion of formational units determined by their rock type and the extent of development of S_1 fracture surfaces. The ridge system appears to be due in part to the relative abundance of quartz veins with parallel strike in the pelitic portions of the underlying units.

The second most prominent set of topographic linears form valleys transecting the ridge system (Figure 8). The general trend of these valleys, which contain small tributaries to the major drainage network, is NW to NNW. This trend corresponds very closely with one set of S_3 surfaces (Figure 8), one set of quartz-coated joints, and one set of "clean" joints. There is an additional positive correlation between these topographic linears and the degree of development (spacing) of the brittle fractures.

The N. 36° W. trend of the transecting valleys and the corresponding brittle fractures may be related to the regional flexure of the formational units. Both tend to suggest an overall left-lateral sense of deformation which postdates the development of the "Z" folds and their associated S_2 fractures. With one exception near Hatch Hill (Figures 2 and 8), the S_2 fractures do not appear to have a prominent topographic expression and can be seen to have been involved in the subsequent deformation. This is illustrated by their rotation on a regional scale along with the S_{0-1} surfaces (Figure 8).

RELATIONSHIP OF BRITTLE FRACTURES TO SEISMICITY

Barosh (1978) suggested the possibility of a relationship between the existence of low, but persistent, seismic activity in the Dover-Foxcroft/Dexter area and the regional flexure of the underlying bedrock. The results of this study suggest a structural correlation between the flexure and the NW trending set of brittle fractures, which can be seen as the youngest deformational features in the area. Many of these fractures show evidence of left-lateral motion ("S" kinks) and extensional motion (quartz filling and downdip movement perpendicular to the hinges of the kinks). The ages of these fractures is presumably great, and no evidence has been observed to indicate post-Pleistocene movement in the bedrock of the region. If the seismic activity is related to the reactivation of an ancient fracture system with a surface expression preserved, the youngest system (NW trend, left lateral) appears to be the most likely candidate.

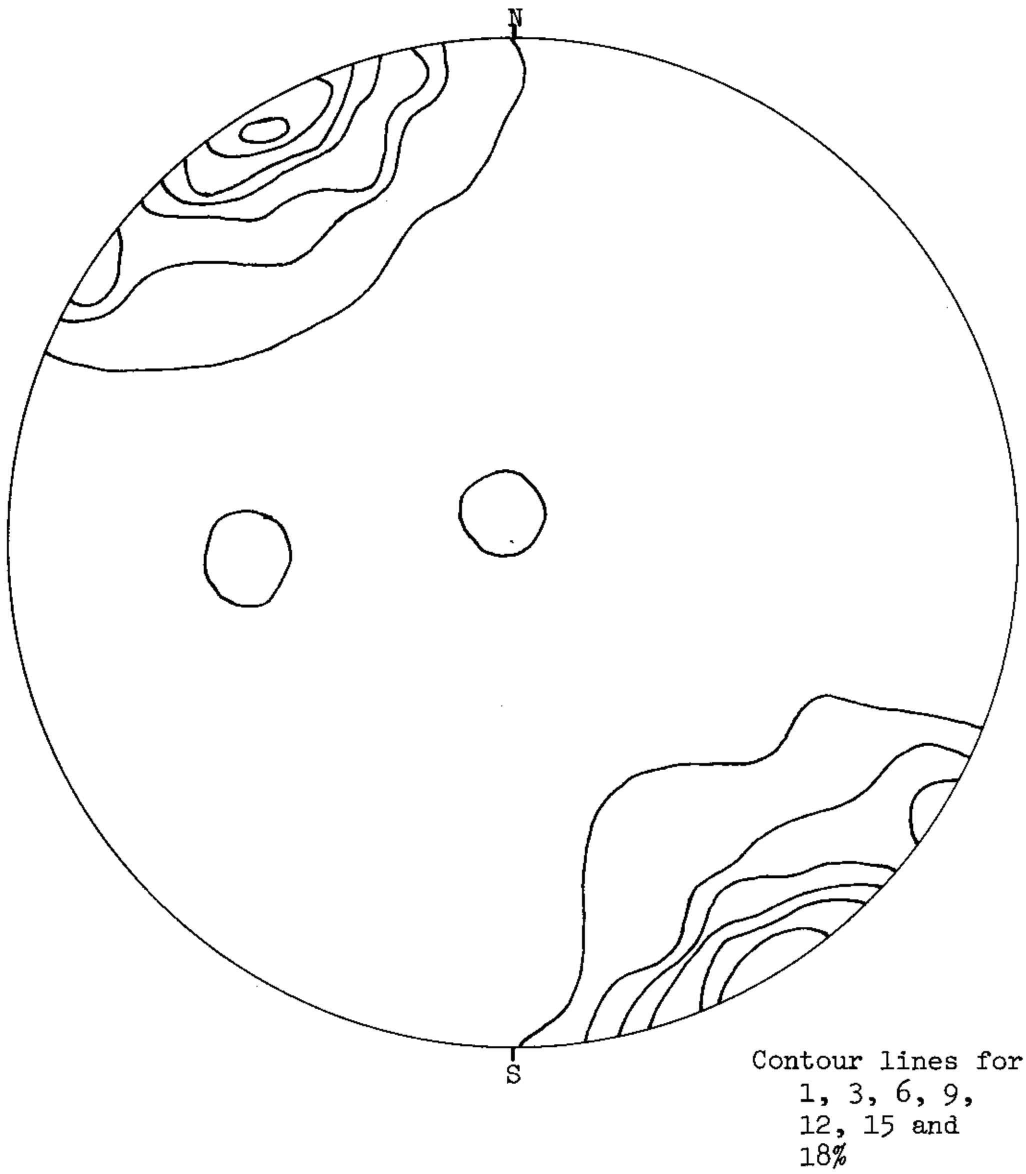


Figure 3. Contour diagram of S_{0-1} surfaces - Bedding and bedding plane cleavage.

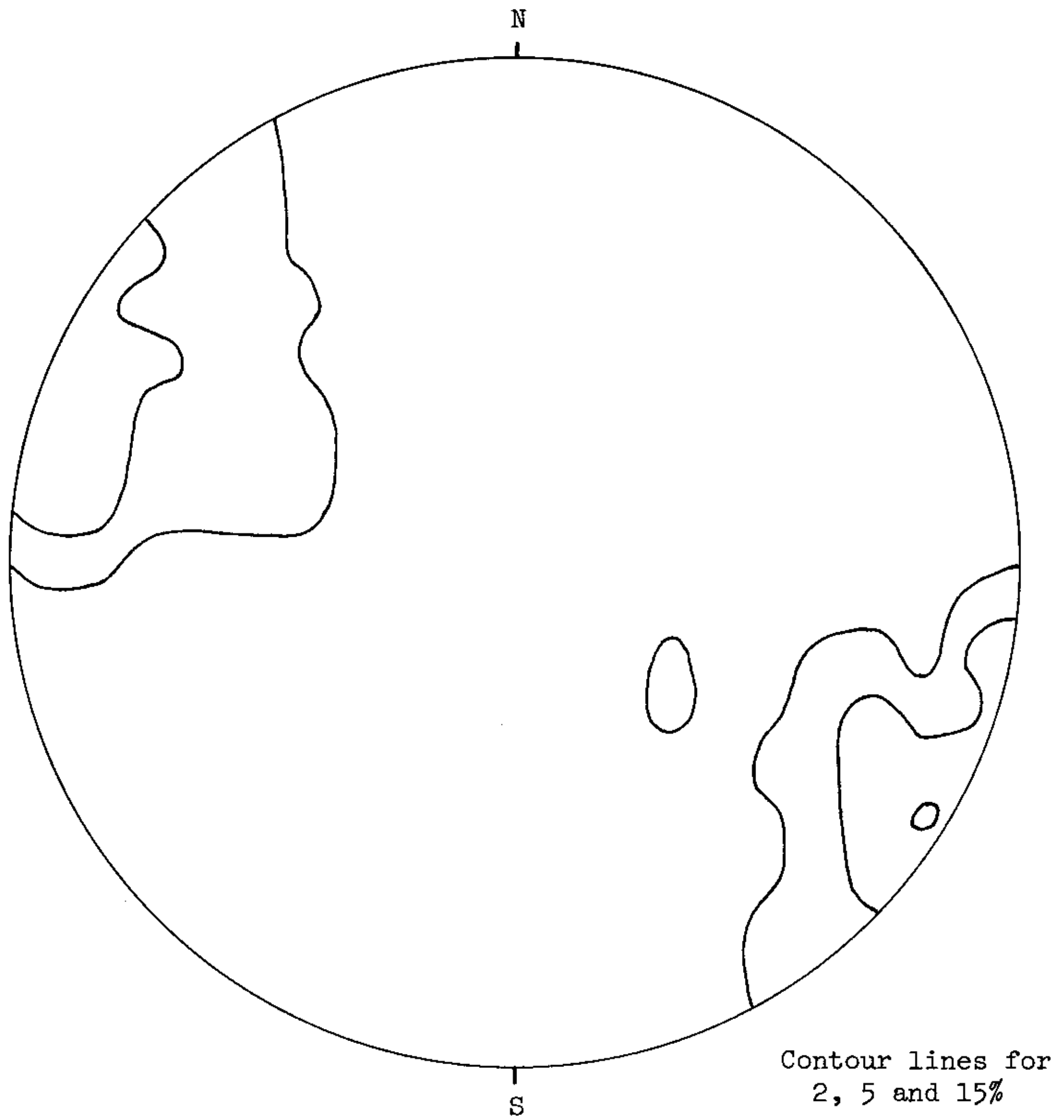
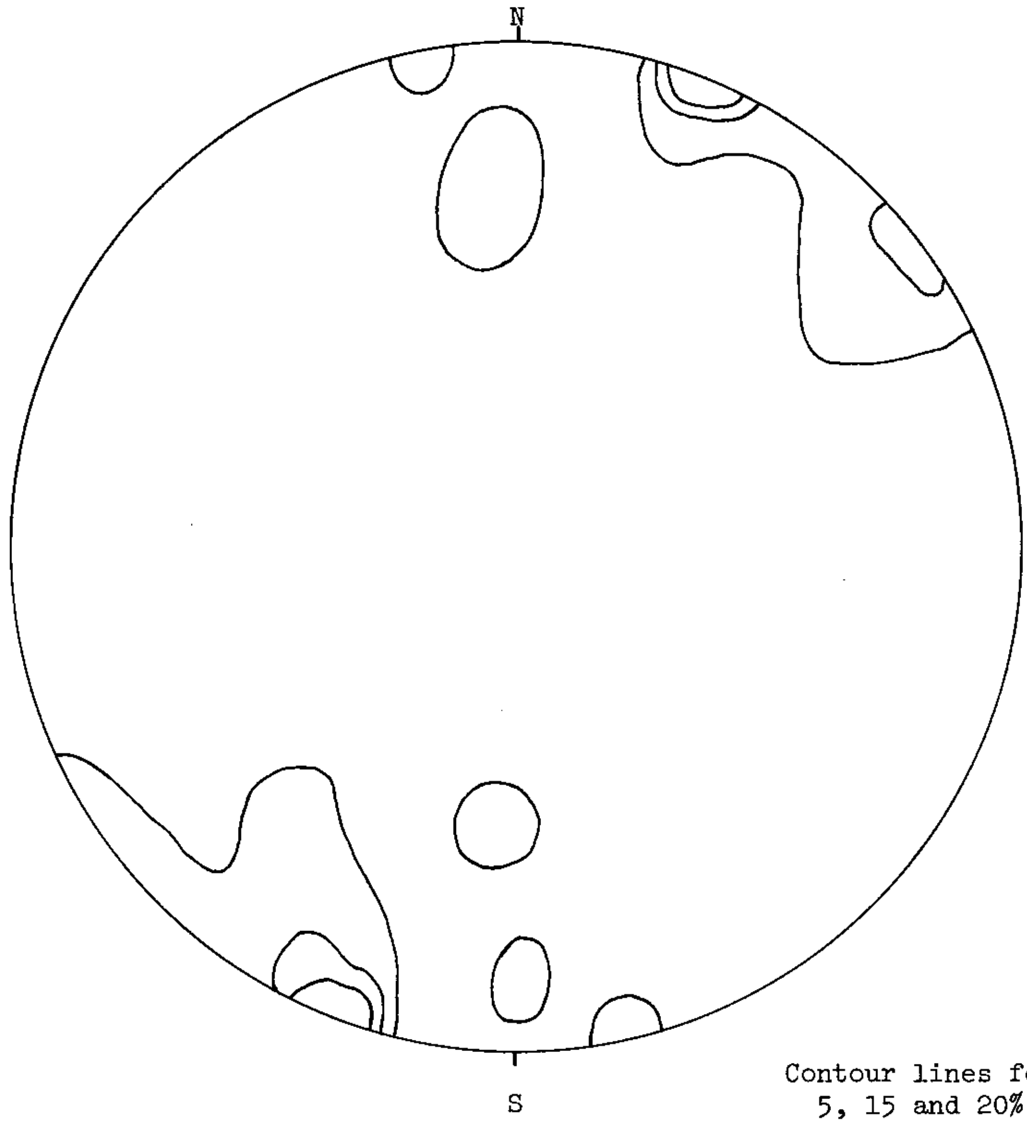


Figure 4. Contour diagram of S_2 surfaces - Fracture cleavage associated with "Z" folds.



Contour lines for
5, 15 and 20%

Figure 5. Contour diagram of S_3 surfaces - Joints associated with "S" kink folds.

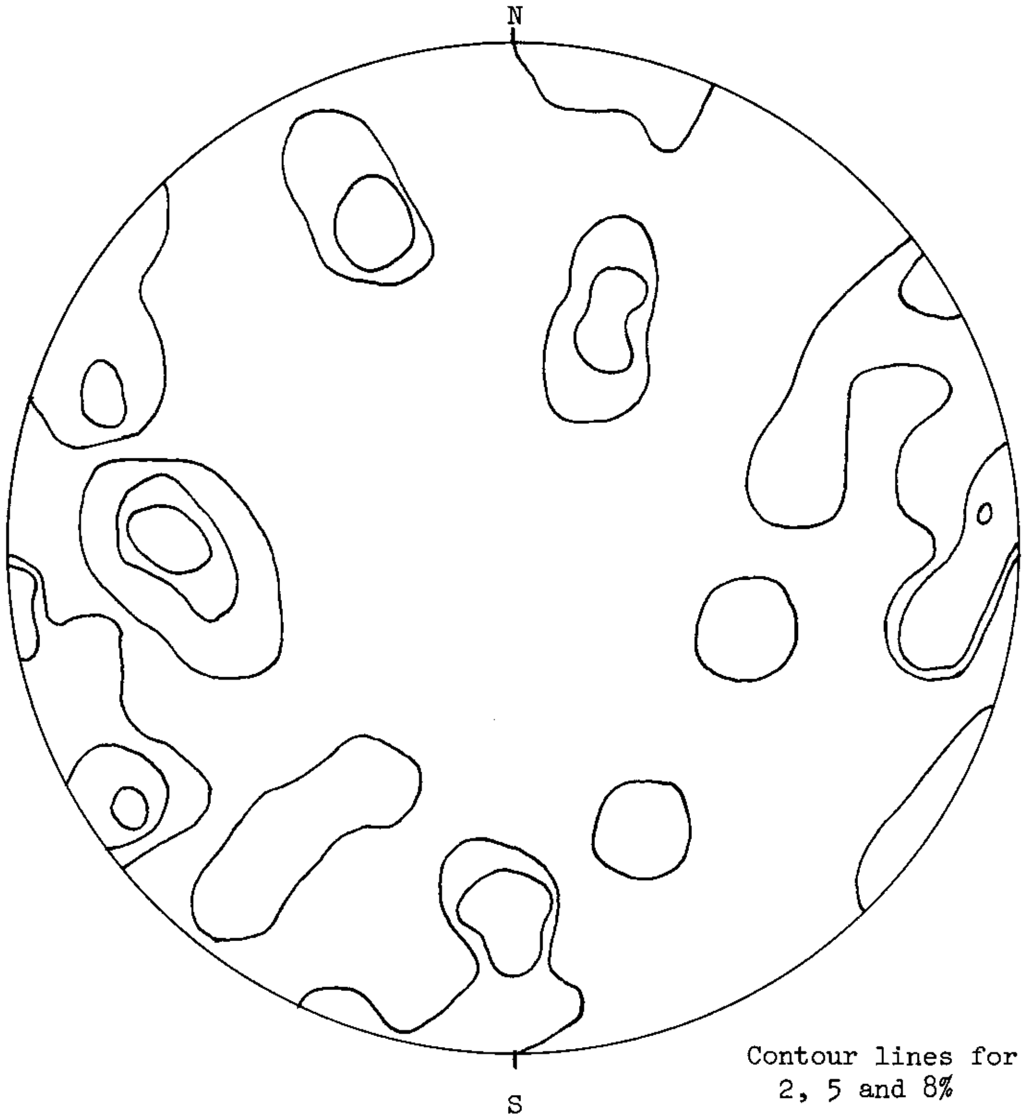


Figure 6. Contour diagram of quartz-coated joints.

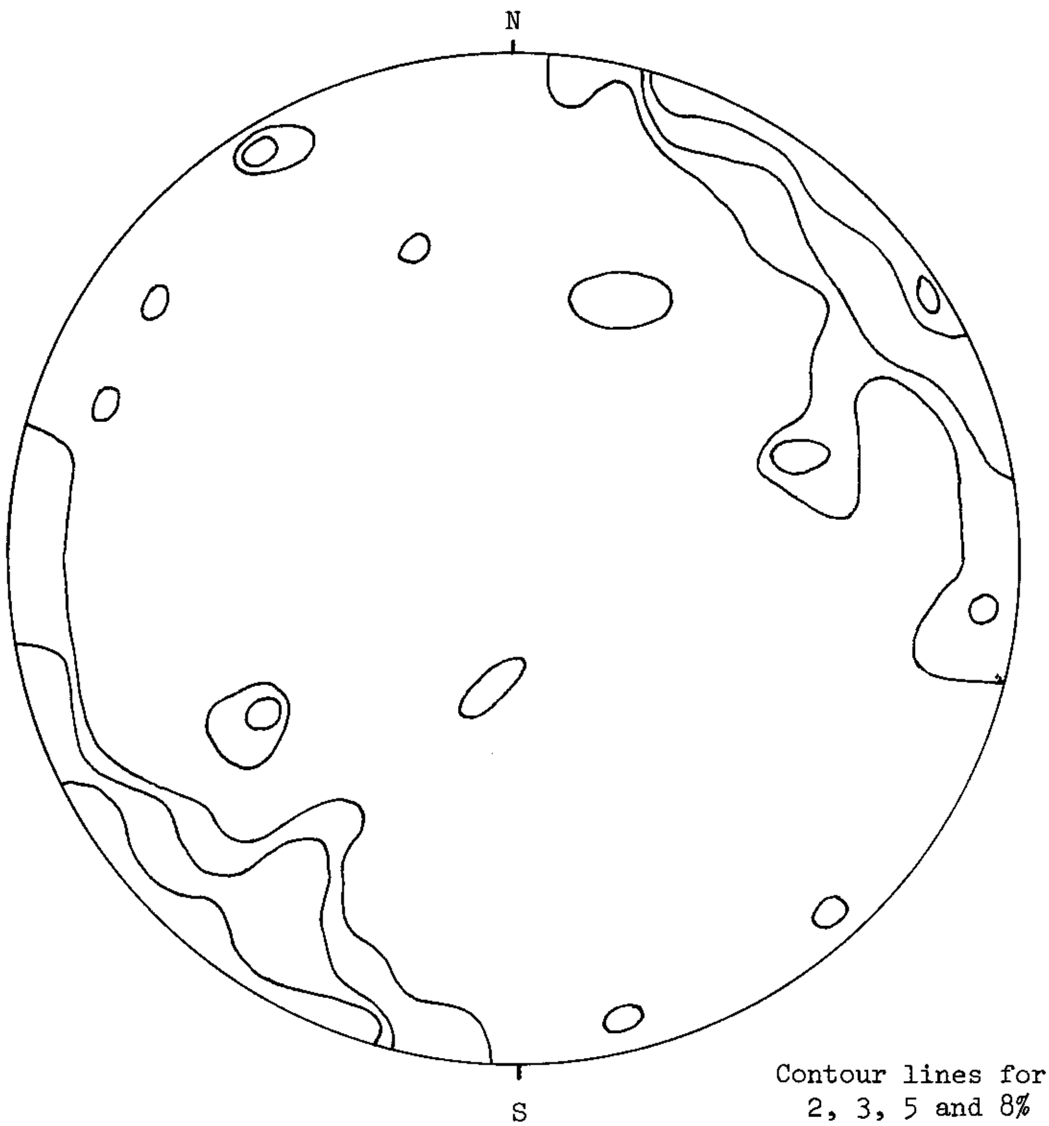


Figure 7. Contour diagram of joints with no mineralization or associated movement observed.

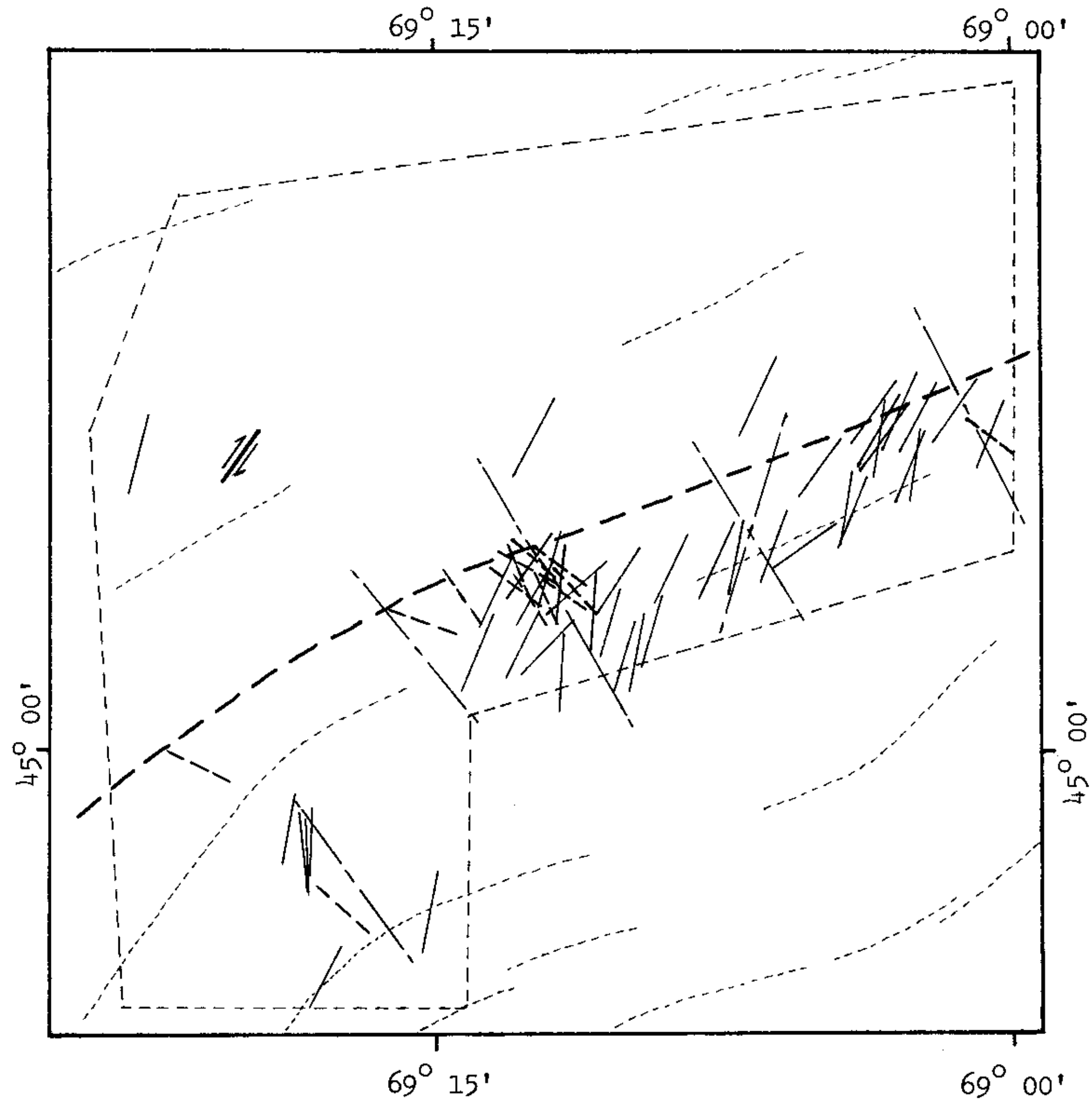


Figure 8. Relationship between cross-cutting prominent topographic linears and brittle fractures having indications of movement.

- – – – – Cross-cutting topographic linears
- - - - - - Formational contact trends
- ——— S_2 trends associated with "Z" folds
- — — — S_3 trends associated with "S" folds
- ⇌ Small-scale fault surface with slickensides
- — — — Currier Hill synclinal axis

REFERENCES CITED

Barosh, P.J., 1976, Compilation of faults and selected lineaments in the northern Appalachian region: U.S. Geological Survey Open-File Report 76-843.

______ 1978, The Penobscot lineament zone, Maine: New England Seismotectonic Study report, Weston Observatory, Boston College, 52 p.

Boston Edison Co., 1976, Epicentral locations of historical earthquakes of intensity IV or greater and all instrumental events: Boston Edison Company, Pilgrim Unit No. 2, 1:1,000,000 scale map.

Griffin, J.R., 1973, A structural study of the Silurian metasediments in central Maine: Ph.D. dissertation, University of California at Riverside, 157 p.

Hobbs, W.H., 1904, Lineaments of the Atlantic-border region: Geological Society of America Bulletin, v. 15, p. 483-506.

Lee, F.T., O'Leary, D.W., and Diehl, S.F., 1977, Preliminary analysis of lineaments and engineering properties of bedrock, Penobscot Bay area, Maine: U.S. Geological Survey Open-File Report 77-886, 23 p.

Ludman, Allan, 1969, Geology of the Skowhegan Quadrangle, Maine: Ph.D. dissertation, University of Pennsylvania, Philadelphia, 325 p.

Osberg, P.H., 1968, Stratigraphy, structural geology and metamorphism of the Waterville-Vassalboro area, Maine: Maine Geological Survey Bulletin 20, 64 p.

Pankiwskyj, K.A., Ludman, Allan, Griffin, J.R., and Berry, W.B.N., 1976, Stratigraphic relationships on the southeast limb of the Merrimac Synclinorium in central and west-central Maine: Geological Society of America Memoir 146, p. 263-274.