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Title: Preliminary Report on the Geology of the Liberty 15' Quadrangle and Adjoining parts of the Burnham, Brooks, Belfast, and Vassalboro Quadrangles in South-Central Maine

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

Contents: 8 page report and map
ABSTRACT

The Liberty 15' quadrangle and adjoining areas straddle the structural belts of five basically dissimilar pre-Mid Paleozoic groups of metamorphosed bedded rocks. These groups, listed from northwest to southeast, are the: Merrimack, Casco Bay, Passagassawaukeag, Bucksport, and Appleton. Each group is separated from others by major NE-SW trending faults, several of which are in excess of 300 km long, and one is more than 600 km long. Cataclastic rocks, some relatively unhealed, are present within these faults. Data collected by Caswell (MGS open file report) show a high degree of correlation between water wells with very high yields and traces of many of these faults as well as the much shorter NW-SE trending fault near Liberty Village. A recommendation is made for further detailed study of these faults within the Liberty quadrangle and along their continuations both northeast and southwest.

STRATIGRAPHY AND LITHOLOGY OF THE METAMORPHOSED BEDDED ROCKS

General Statement. The metamorphosed bedded rocks in the area have been divided into five groups, all separated from one another by major NE-SW trending faults. At this time no correlation among these groups is agreed upon. From northwest to southeast, the five groups are:

Merrimack Group
Casco Bay Group
Passagassawaukeag Group
Bucksport Group
Appleton Group

Merrimack Group. Within the area of this report all rocks of this group have been included in the Vassalboro Formation of presumed Silurian age. This heterogenous unit is composed here of at least five potential subdivisions, but at the present time only two of them have been differentiated. The five subdivisions of rock types are:

1. Feldspathic biotite granofels with minor interbeds of biotite schist;
2. Biotite granofels with abundant interbeds of biotite schist;
3. Rhythmically layered biotite granofels and calc-silicate granofels;

These three rock type associations are lumped together on the geologic map as the principle part of the Vassalboro Formation (Sv). The two which have been differentiated are the:

4. Sulfide-rich metasandstone and metasiltstone (Svr); and
5. Mica-rich metapelite (Svp).
Casco Bay Group. Rocks of the Casco Bay Group are divided into five formations, and three of these are further subdivided into members. The stratigraphic sequence among the five formations has not been determined within the Liberty quadrangle, and thus they are here listed and described in order of their exposure from northwest to southeast.

Cushing Formation. In addition to the principle part of the formation composed of poorly- to well-foliated felsic metavolcanic rocks (O€cu), the following six members have been differentiated:

1. Marden Hill Member (O€cumh) composed of dominantly mafic metavolcanic rocks;
2. Prescott Pond Member (O€cupp) composed of weakly calcareous biotite granofels, rhythmically layered biotite granofels and calc-silicate granofels, and rare marble;
3. Beaver Ridge Member (O€cubr) composed of dominantly richly sulfidic rusty-weathering metasandstone, metasiltstone, metapelite, quartz-rich calc-silicate granofels, and highly leucocratic felsic metavolcanic rocks;
4. Whitten Hill Member (O€cuwh) composed of sulfide-bearing punky to rusty-weathering metasandstone, metasiltstone, and felsic metavolcanic rocks;
5. Wilson Cove Member (O€cuwc) composed of dominantly richly sulfidic hornblende- and grunerite bearing garnet amphibolite, and rusty-weathering thinly laminated metasandstone and meta-siltstone;
6. Sandy Pond Member (O€cusp) composed of aluminous leucocratic staurolite-garnet-kyanite granofels and schist, coarsely garnetiferous amphibolite, biotite-rich staurolite schist, calcareous biotite granofels, calc-silicate granofels, and minor marble.

Cape Elizabeth Formation. The bulk of this formation is metasandstone interbedded with metapelite. Typically the metasandstone is the dominant rock type. Pinstriping and segregation of micaceous minerals is common. In addition to the above, mapped as (O€ce), one member has been differentiated:

Hibberts Corner Member (O€cehc) composed of garnetiferous quartz-rich calc-silicate granofels and minor biotite granofels.

Spring Point Formation. This formation is composed of foliated metavolcanic rocks. Near the Cape Elizabeth Formation these are dominantly mafic, farther they are interbedded mafic and felsic, and near the Diamond Island Formation they are typically felsic. These have not been differentiated on the map, but are shown together as (O€sp).

Diamond Island Formation. This formation is composed of prominently rusty-weathering sulfidic and graphitic quartzite, mica schist, and minor metavolcanic rocks (O€di).
Scarboro-Jewell Formation. This formation is composed of dominant metapelite and metasandstone. Typically they are more aluminous than the rocks of the Cape Elizabeth Formation. They range from strongly rusty-weathering to completely non rusty-weathering. In addition to the principle part (0Gsj), one major member has been differentiated:

Kingdom Bog Member (0Gsjkb) composed of laminated biotite granofels and calc-silicate granofels; where deeply rusty-weathering this is shown as (0Gsjkbr).

Passagassawaukeag Group. Only one outcrop in the Liberty quadrangle has been positively identified as of this group. It is composed of locally rusty-weathering poorly laminated biotite granofels. Many layers contain megacrysts of quartz and feldspar, and the entire outcrop is cut by several generations of quartz veins. (pSp)

Bucksport Group. This unit is typically biotitic granofels interlayered with calc-silicate granofels. Locally calc-silicate granofels is rare, and the rocks resemble those of the Passagassawaukeag Group. Megacrysts of feldspar and quartz are common in this unit near the Lincoln Sill. (Pb)

Appleton Group. These are dominantly aluminous metapelites with inter-beds of laminated metasiltstone. (Da)

INTRUSIVE ROCKS

General Statement. The intrusive rocks in the Liberty quadrangle have been divided into four categories:

1. Gneissic intermediate rocks (gd);
2. Foliated felsic rocks (fqm);
3. Porphyritic shonkinite of the Lincoln Sill (ls);
4. Equigranular felsic rocks (eqm);

listed above from oldest to youngest, based on intrusive contacts.

Gneissic intermediate rocks. These are typically weakly foliated, locally with more than one foliation. Where gneissic banding is prominent, the melanocratic layers range from granodiorite to diorite and the leucocratic ones are typically granodioritic. Typical minerals are hornblende, biotite, epidote, sphene, andesine, microcline and quartz. (gd)

Foliated felsic rocks. This is typically well-foliated binary quartz monzonite and subordinate granite. These rocks intrude the gneissic intermediate rocks in a number of outcrops between the Sandhill Corner and Mountain Road Faults. An amoeboid body with similar rocks is mapped in the east part of the Liberty quadrangle and the west part of the Belfast quadrangle. A thin elongate body is present just southeast of the Lincoln Sill. They are also present as undifferentiated discontinuous patches in the complex in the south part of the Liberty quadrangle and the north part of the Waldoboro 15' quadrangle. (fqm)
Porphyritic shonkinite. This unmistakable rock composes the Lincoln Sill, which has a more complex shape than shown on earlier maps. The large phenocrysts of alkali feldspar are typically purplish in color due to minute inclusions of biotite. However, wherever the rocks are severely sheared and partly recrystallized, these megacrysts are white. The Lincoln Sill shows numerous examples of intrusive relationships into the foliated felsic rocks in the east part of the Liberty quadrangle. (ls)

Equigranular felsic rocks. These rocks form the bulk of a complex body which contains numerous inclusions of rocks of the Bucksport Formation, the Lincoln Sill, and of foliated felsic rocks. In addition pegmatite is abundant. Typically the equigranular rocks are of fine- to medium-grained gray binary quartz monzonite and granite. (eqm)

FAULTS

General Statement. Eight NE-SW trending faults have been recognized in the Liberty quadrangle and adjoining areas. From northwest to southeast they are the:

1. Dearborn Brook Fault
2. Fly Brook Fault
3. Jose Pond Fault
4. Hackmatack Pond Fault
5. Stantial Bog Fault
6. Sandhill Corner Fault
7. Mountain Pond Fault
8. Sunny Side Fault

In addition one NW-SE trending fault, the Liberty Fault, has been mapped. The contact between the Casco Bay Group and the Bucksport Group, between the Bucksport Group and the Appleton Group, and on both sides of the rocks of the Passagassawaukeag Group may also be faults. However, in the Liberty quadrangle these groups are separated by igneous intrusions.

Dearborn Brook Fault. This fault is easily picked out by the prominent lineament of brooks in the Vassalboro quadrangle. The fault is within the (Svr) and (Svp) members of the Vassalboro Formation which are intensely sheared and injected with quartz veins. In the Burnham quadrangle there is a prominent change of metamorphic grade across this fault, with the rocks on the southeast limb being at higher grade.

Fly Brook Fault. This fault is recognized in only a small part of the Burnham quadrangle. It forms a NE-SW trending lineament, and there is a very prominent change of metamorphic grade with the rocks on the southeast limb being at higher grade.

Jose Pond Fault. Similarly to the Dearborn Brook Fault, the Jose Pond Fault contains intensely sheared and quartz vein injected rocks of the (Svr) member of the Vassalboro Formation. In addition, in the Liberty quadrangle it juxtaposes two different rock associations of the Vassalboro Formation. On the northwest limb there are typically biotite granofelses with abundant interbeds of biotite schist, whereas on the southeast limb the biotite granofelses are associated with rare interbeds of biotite schist.
Hackmatack Pond Fault. This is the fault which separates the Merrimack Group from the Casco Bay Group. It has not yet been seen in outcrop, but has been located to within 2 meters in several places. On the northwest side of the fault is exposed one of the three not yet differentiated rock types of the Vassalboro Formation (see types 1 thru 3 of page 1 of this report). On the southeast side is either the principle member of the Cushing Formation (06cu) or the Sandy Pond Member (06cusp). Intensity of deformation does not appear to increase with proximity to the contact. It is thus hypothesized that this is an early fault.

Stantial Bog Fault. Shearing was observed at the contact between the Wilson Cove Member of the Cushing Formation (06cuwc) and the Cape Elizabeth Formation (06ce) in several localities. Wide bands of vuggy vein quartz, containing angular fragments of the Wilson Cove Member, are present along this zone.

Sandhill Corner Fault. This is a wide fault zone, rather than a two-dimensional fault. Severely sheared rocks are present in a band ranging in across-strike width of up to 1 1/2 km, and mylonites are present in the central 1/2 km to 3/4 km. These mylonites range in color from dark gray, to purplish brown, to thinly laminated purplish brown and green. The first is derived from the typical metasandstone of the Cape Elizabeth Formation. The origin of the other two is less obvious. The high biotite content, which gives them the purplish brown color, is more typical of rocks of the Scarboro-Jewell Formation than of the Cape Elizabeth Formation. Similarly, calc-silicate rocks are more abundant in the Scarboro-Jewell section than in the Cape Elizabeth. Further work in adjoining areas is necessary before the origin of these rocks can be ascertained.

Mountain Road Fault. This fault zone is thinner and more poorly exposed than the Sandhill Corner Fault. Reconnaissance indicates that it approaches the Sandhill Corner Fault both in the Belfast quadrangle to the northeast and in the Wiscasset quadrangle to the southwest. The two faults are farthest apart in the southwest part of the Liberty quadrangle. There the bulk of area between them is occupied by the elongate igneous complex of intermediate composition gneisses (gd) intruded by foliated felsic rocks (fqm).

Sunny Side Fault. This fault, as described by Bickel (1971) from the Belfast quadrangle, is composed of a 30 meter wide belt of mylonite and less severely deformed cataclastic rocks. In the Liberty quadrangle it was traced for about 3 km and there lost in an area of poor exposure. Mylonites are very common along the northwest side of the Lincoln Sill. It is possible that they represent a continuation of this fault.

Liberty Fault. This fault is distinguished from the previous eight in that it has a NW-SE trend. It has not been observed in outcrop, but was drawn to account for the offsets in stratigraphic contacts across a line approximating the channel of the St. George River between St. George Lake and Stevens Pond.

In addition to the above-described faults, several additional contacts are believed by other workers to be faulted:

Casco Bay Group – Bucksport Group. In the Liberty quadrangle this contact would be between the Cape Elizabeth Formation (06ce) to the
northwest and the Bucksport Formation (pb) to the southeast. This contact has been intruded by a 100 meter offshoot of the Lincoln Sill. The shonkinite here is sheared and the feldspar phenocrysts lack the typical purplish color. Thus subsequent faulting is considered probable.

**Casco Bay Group - Passagassawaukeag Group - Bucksport Group.** In the Liberty quadrangle rocks of the Passagassawaukeag Group have been positively identified in only one outcrop forming a large inclusion in the body of foliated felsic rocks (fqm) in the east part of the area. Thus the relationship of rocks of this group to those both northwest and southeast cannot be determined here. However, the uniqueness of the rocks of the Passagassawaukeag Group as well as the shape of their map pattern both suggest fault contacts, possibly a horst.

**Bucksport Group - Appleton Group.** In the southern part of the Liberty quadrangle part of a lens-shaped body of foliated intermediate rocks, mapped as (gd), is present between rocks of these two groups. To the northeast, a thin body of foliated binary quartz monzonite and abundant pegmatite, both shown as (fqm), is found separating these groups. The relationship between these groups thus cannot be determined here. One or two faults are considered possible.

**DISCUSSION OF AND CORRELATION WITH WORK DONE IN ADJACENT AREAS AND RECOMMENDATIONS FOR FURTHER STUDIES**

Work by others, eight completed or in progress, in adjacent areas includes the following:

- **Wiscasset Quadrangle** (Hatheway, 1969)
- **Waterville Quadrangle** (Osberg, 1968)
- **Vassalboro Quadrangle, N part** (Osberg, 1968)
- **Waldoboro Quadrangle, NE part** (Norton, unavailable)
- **Belfast Quadrangle** (Bickel, 1971)
- **Brooks Quadrangle** (Bickel, unavailable; Osberg, unavailable; Griffin, 1973)
- **Bucksport Quadrangle** (Griffin, 1976; Osberg, unavailable; Wones, not yet received)

It is regretful that the preliminary results of a number of investigations were not made available to me by the workers. Much of the correlation and discussion took place during field trips. What follows here is a summary of what is known and what still remains unsolved:

1. Of foremost importance are the set of subparallel long NE-SW trending faults. Extending from eastern New Brunswick to southern Rhode Island, and probably emerging in Newfoundland and in the Carolinas, these faults are chronologically the last major structural features to be imposed on the coastal states and provinces. Faults can be recognized without detailed knowledge of stratigraphy of the rocks they cut, but they cannot be dated or their displacement determined until stratigraphic details have been worked out. The age(s) of the NE-SW trending faults has not yet been consistently determined.
Several of them displace Carboniferous sediments in New Brunswick. Yet the extension of the Mountain Road Fault shows no offset on the presumably early Devonian Blinn Hill Granodiorite in the Wiscasset quadrangle. Wones (1976 personal communication) finds displacements of more than 25 km on one such fault in the Great Pond quadrangle, but a mere 100 meters on another.

Many faults in Maine have associated with them water wells with significantly higher yield than wells distant from faults. This indicates that the fracturing caused by faulting has not become healed. Other evidence also points in this direction. Trends of seismic aftershocks during the 1 July 1967 Augusta earthquake coincided with NW-SE trending line. This suggests that other such lines may also be seismically active; for instance, the Liberty Fault. The valley of the St. George River between St. George Lake and Stevens Pond coincides with a lineament of high yielding wells. Deformation of Pleistocene till on Sears Island shows that with changes of vertical stress the strain may take place along one of the old faults.

2. The relationship of the Vassalboro Formation to the well-dated Waterville Formation is still in doubt.

3. Rocks mapped as the Vassalboro Formation south and southeast of the Togus pluton are sufficiently different from those north of the pluton to warrant the question as to whether they should be considered part of the same formation. Basically, to the north these rocks are dominantly biotitic granofelises with different amounts of biotite schist. To the south and southeast, these are rhythmically interlayered biotite granofels and calc-silicate granofels. This is one of the problems encountered in the Liberty quadrangle.

4. Rocks mapped as the Bucksport Formation in the Bucksport and Orland quadrangles (Wones, 1976 personal communication) may in fact be two similar units of different ages.

5. The Vassalboro Formation and the Bucksport Formation have commonly been correlated. Yet only the rhythmically interlayered biotite granofels and calc-silicate granofels of the Vassalboro Formation resemble the Bucksport Formation. This added to the problems noted in paragraphs 3 and 4 above makes further work very important.

6. In the Wiscasset quadrangle, the Cape Elizabeth Formation to the northwest is separated from the Bucksport Formation to the southeast by two thin, but consistently present units—Cod Cove Schist and Edgecomb Gneiss. The former bears some resemblance to rocks of the Passagassawakeag Group. The latter is not unlike some of the thoroughly sheared rocks of the Lincoln Sill in the Liberty quadrangle. If one of the other of these is correct than there is a major fault in this area which changes strike from NE-SW to N-S toward the south.

It is here recommended that mapping of bedrock geology be continued or commenced in all quadrangles which have the major NE-SW trending faults. Work should concentrate on detailed examination of the rock units affected by the faults. Only in this way can the age of the faults and the amount of displacement be determined. It is suggested that two full field seasons be devoted to this, with either two or three principle senior investigators,
each having one or preferably two junior assistants. The task of the assistants would be generally to locate outcrops and to guide the more experienced investigator to them. It is recommended that funds be made available for the preparation of petrographic thin sections. One hundred (100) thin sections per investigator per season is considered adequate. Aerial photographs should be available to supplement topographic maps and to point out lineaments. Color photographs would be especially useful to point out differences in vegetation and in ground temperature as a function of unhealed fractures.

This writer is interested in spending up to fifteen (15) weeks in the field in the summer of 1977, and up to twenty-five (25) in the summer and fall of 1978. The ten extra weeks in 1978 are provisional to his request for sabbatical leave from the University of Hawaii being approved.

REFERENCES CITED


Osberg, P. H., 1968, Stratigraphy, structural geology, and metamorphism in the Waterville-Vassalboro area, Maine: Bull. 20, Maine Geological Survey, 64 pages