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Stratigraphy and Structural Geology of the Bangor and Veazie 7.5' Quadrangles, Maine

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INTRODUCTION

The purpose of this study was to investigate the nature of the stratigraphy and bedrock structure within the Bangor and Veazie 7.5' quadrangles. The resulting bedrock geologic maps are associated with this report (Pollock, 2011a, 2011b). Prior to the present study there had been no detailed bedrock mapping of either quadrangle. Hussey and others (1967) treated all rocks comprising the greater Bangor, Brewer, and Hampden areas as undifferentiated "calcareous metasedimentary rocks." Osberg and others (1985) assigned these rocks to the Vassalboro Formation and the Bucksport Formation. Griffin produced reconnaissance geologic maps of the Bangor 15' quadrangle (Griffin, 1976a), of which the Bangor 7.5' quadrangle is the southeastern quarter, and the Orono 15' quadrangle (Griffin, 1976b), of which the Veazie 7.5' quadrangle is the southwestern quarter. In that study, Griffin mapped seven separate units of formational scale in the area of the Bangor and Veazie 7.5' quadrangles. In ascending stratigraphic order Griffin's units were: (1) Ordovician-Cambrian Copeland Formation (**O€c**) (or Copeland Schist); (2) an unnamed unit of Silurian age (**So**); (3) the "Kenduskeag unit" (**Sk**); (4) the Sangerville Formation (**Ss**); (5) an undifferentiated unit of probable Silurian age (**Su**); (6) the Vassalboro Formation (**DSv**); and (7) a Carboniferous to Permian age unit of dark red arkosic sandstone (**CPs**)*. Griffin (1976a, 1976b) interpreted the "Kenduskeag unit" to interfinger along its contact at several locations, with the "**So**" unit, the Sangerville Formation, and the Vassalboro Formation. Griffin's reconnaissance map (1976b) showed no outcrop control for the Carboniferous to Permian dark red arkosic sandstone, and no outcrops matching these characteristics were found in the Veazie sheet during the present study. Also, Griffin (1976a, 1976b) showed no regional structures except for a few broadly interpretive synclinal features. These are inferred based upon his map pattern and interpreted stratigraphic sequence.

To the south, Wones (1991) mapped the Orland 15' quadrangle and Kaszuba (1992) mapped the Brewer Lake 7.5' quadrangle which comprises the northwestern quarter of the Orland sheet. The Brewer Lake 7.5' quadrangle borders the Veazie 7.5' quadrangle to the south. Units mapped by both Wones (1991) and Kaszuba (1992) at the northernmost edge of the Brewer Lake sheet included the Vassalboro Formation, the Copeland Formation, the Schist of Rider Bluff (considered by Kaszuba to be a member of the Copeland), and the Bucksport Formation. The contacts do not exactly align with the contacts mapped in the Veazie sheet (Pollock, 2011b). In particular, neither the Copeland Formation nor the Schist of Rider Bluff are mapped in the Veazie quadrangle. Their Vassalboro Formation is mapped in the Veazie quadrangle as the Brewer Formation. The Bucksport Formation is extended northward into the Veazie quadrangle. An EDMAP project addressed these issues in detail (Preble and others, 2007).

GENERAL GEOLOGY

This study recognizes three formations in the Veazie quadrangle (Pollock, 2011b), two of which are also mapped in the adjacent Bangor 7.5' quadrangle (Pollock, 2011a). New names are proposed here for these two units. They are the Brewer Formation, a dominantly slate-rich unit, and the Bangor Formation, a dominantly sandstone unit. Internal stratigraphy of the Brewer Formation has not been defined due to poor outcrop exposure. The Brewer Formation underlies the thickly bedded metawackes of the Bangor Formation, which is subdivided into three members. The lowest metasandstone-rich member is here named the Penobscot River Member, the middle slate-rich member is named the Lover's Leap Member, and the upper meta-sandstone-rich member is named the Kenduskeag Stream Member.

The third formation, mapped in the Veazie quadrangle, is the Bucksport Formation. This formation traces approximately into the Bucksport Formation as shown to the south by Wones

* Letter symbols in boldface print indicate mapped units shown on geologic maps.

(1991) and Kaszuba (1992). It is dominantly a very fine-grained to medium-grained calcareous granoblastic and banded metasandstone with ancillary slate, phyllite, and very fine-grained biotite-quartz schist.

A fault is mapped as separating the Brewer Formation from the Bucksport Formation in the southeastern quarter of the Veazie quadrangle. More broadly, the preferred interpretation, at this writing, is that this fault sharply separates the rocks of the Vassalboro Group of the Central Maine Basin to the northwest, from rocks of the Fredericton Trough to the southeast.

Four dikes of igneous rock were discovered in the Bangor 7.5' quadrangle, including one porphyritic diabase dike and three felsic dikes. All dikes are less than 1 meter in width and are not traceable beyond the outcrops in which they occur. No igneous rocks were found in the Veazie quadrangle.

Major structural features in the area include an areally prominent northeast-trending syncline and three northeast-trending faults. The syncline crosses the central part of the Bangor quadrangle (Pollock, 2011a) and the northwestern quarter of the Veazie quadrangle (Pollock, 2011b). Two of the three faults either separate formations or separate members of the Bangor Formation. The third fault is a dextral shear zone within the Brewer Formation.

Minor structural features in the Bangor and Brewer Formations are common, and their nature and number vary from one outcrop to another. In the Bangor and Brewer Formations, folds are assigned to at least two generations of folding. Also in the Bangor and Brewer Formations there are two generations of cleavage. The first is a slaty cleavage, and the second is a fracture or spaced cleavage which is axial planar to the second set of folds. The Bangor and Brewer Formations contain numerous small-scale faults and joints. The small-scale faults do not exhibit any significant lateral persistence and cannot be shown at the 1:24,000 scale. Joints dominantly strike northwest and dip steeply both to the southwest and northeast, but other joint sets are present and their orientation differs from the dominant northwest-trending set.

Minor structural features in the Bucksport Formation in the southeastern quarter of the Veazie quadrangle include five separate fold styles. Their relationship to the fold generations in the Bangor and Brewer Formations is not certain.

STRATIGRAPHY AND CONTACTS

General statement

Three formations are mapped in the Bangor and Veazie quadrangles. Two of them, the Brewer Formation and Bangor Formation, are proposed and named here. The Brewer Formation is the lower unit, a slate-rich assemblage of thin-bedded to medium-bedded slates, metawackes, and metalimestone. The Bangor Formation is the upper unit, consisting of thickly bedded metawacke and minor slate and phyllite. The Bangor Formation is subdivided into three members, an upper and lower metawacke, and a middle slate and sandstone. These two formations are interpreted as part of the Vassalboro Group of the Central Maine Basin (Marvinney and others, 2010).

The third formation, the Bucksport Formation, is mapped in the southeastern quarter of the Veazie quadrangle. It is a thickly bedded very fine-grained calcareous quartz metawacke interbedded with sequences of slate or phyllite. Locally, the metawacke is a very fine-grained calcareous granoblastic schist and the metapelites are very fine-grained quartz-biotite schists. This formation is interpreted as part of the Fredericton Belt of coastal Maine.

Stratigraphic contacts

The contact between the Brewer and Bangor Formations is interpreted to be broadly conformable and gradational, with the Brewer Formation underlying the Bangor Formation. However, vertical beds which lack clear younging sense together with small upright isoclinal-scale folds near the contact between the two formations make the younging direction somewhat uncertain. Rocks similar in lithology to the Brewer Formation crop out locally in the Bangor Formation, and the Lover's Leap Member of the Bangor Formation is lithologically similar to rocks of the Brewer Formation except for the absence of thin metalimestone beds in the Lover's Leap. On the western limb of the regional syncline, the contacts between members of the Bangor Formation are conformable. On the eastern limb of the regional syncline, the Lover's Leap Member is not present in the Veazie quadrangle due to faulting. The contact between the Lover's Leap Member and the Kenduskeag Stream Member is exposed in the Veazie quadrangle along the southbound lane of Interstate 95 immediately south of the Kelly Road exit in Orono. In the Bangor quadrangle, contacts can be located accurately to within 100 meters along Kenduskeag Stream southwest of Husson University and along Souadabscook Stream along Paper Mill Road.

The contact between the Penobscot River Member and the Lover's Leap Member is interpreted as gradational. The transition can be most effectively argued on the southwest side of Kenduskeag Stream in the downtown Bangor area in the Bangor quadrangle. The transition, as currently understood, occurs over a few to possibly as many as 30-50 meters. The contact between the Lover's Leap and Kenduskeag Stream Members is both sharp and conformable; there is no recognizable transition between them.

Fault contacts

The most significant fault is the northeast-trending fault which separates the Brewer Formation from the Bucksport Formation in the Veazie quadrangle. The fault is inferred to cut through the quadrangle but is not exposed. This fault is interpreted to be a relatively narrow feature, probably not more than 500 meters wide. Unequivocal shear fabrics are not present in

outcrops nearest to the location of the fault. However, the fault does separate rocks with apparently different structural and metamorphic histories.

On the southeast limb of the map-scale syncline in the Veazie quadrangle, the Lover's Leap Member is cut out by a fault. This fault is interpreted as being relatively minor from a regional point of view. The displacement, while probably not large, has not been estimated.

ROCKS OF THE VASSALBORO GROUP

Brewer Formation (new name)

1. General statement and area of exposure

This is the most widespread unit underlying the Brewer - Holden - Eddington area. It occupies the northwestern and southeastern parts of the Bangor 7.5' quadrangle and the central portion of the Veazie quadrangle. The Brewer Formation (**Sbr**) consists of four recognizable lithologic types. These are of variable occurrence and proportion, with the metalimestone being the least common and only locally observed. Extensive outcrops may contain all four lithologic types. However, most outcrops contain only two of the types described below.

2. Name and reference localities

The formation is named here for the city of Brewer. The best exposures are outcrops along Interstate 395 in Brewer near the eastern edge of the Bangor quadrangle.

3. Lithology

3a. Siltstone and claystone slate. This lithology is characterized by dark gray, grayish black or black, fine-grained to very fine-grained siltstone and claystone slate. In many places adjacent beds have different average grain size. Beds are typically thin, ranging between 1 and 10 cm, however thicker beds to 30 cm are present. Flaser lamination or thin flaser bedding is common, producing a "pinstripe" appearance. These flasers consist of thin laminae and very thin beds of quartz-rich metasiltstone or very fine-grained quartz-rich metasandstone. These laminae and beds locally pinch and swell and commonly are discontinuous. Flaser laminae and beds are usually devoid of sedimentary structures, but rarely parallel lamination or ripple lamination is present. Locally, the cleavage surfaces exhibit a rusty stain. Additionally, very fine-grained white mica occurs on cleavage surfaces.

3b. Rusty-weathering quartz-rich metasandstone. A medium dark gray to dark gray, well sorted, very fine-grained quartz-rich meta-arenite characterizes this lithofacies. Beds commonly range in thickness from 3 to 15 cm, but beds approaching or exceeding 1 m are locally present. Commonly, this lithofacies exhibits rusty weathering, with weathering rinds to 4 cm, depending upon bed thickness. Beds may be very slightly to moderately calcareous. Sedimentary structures are common, including the parallel-laminated (T_b) and ripple-laminated (T_c) turbidite intervals. Single turbidite intervals may characterize the entire bed or the intervals may be sequentially arranged.

3c. Feldspathic metawacke and quartz metawacke. These two lithologies are characteristically medium dark gray to dark gray. They are moderately poorly sorted wackes with grain sizes ranging from medium-grained to very fine-grained sand. Beds may exhibit textural gradation from medium (rare) or fine-grained sand to very fine-grained sand. These textural gradations may occur over the entire thickness of the bed or within the first 15 cm or so of the bed. Massive beds which lack textural gradation are common.

Compositionally, the rocks include: (a) feldspathic metawacke and less commonly (b) quartz metawacke. Both compositions are non-calcareous. Typical exposures of these two rock types might span several meters to a few tens of meters stratigraphically, but they do not occur together within an outcrop. The feldspathic metawacke is the more common of the two compositions.

Bedding thicknesses of both feldspathic and quartz metawacke are variable, ranging from approximately 30 cm to 2 m. Sedimentary structures are absent in most outcrops. Where present, they consist of parallel laminations which are transposed parallel to the dominant rock cleavage. Because rock cleavage in numerous outcrops is bedding-parallel or subparallel to bedding, it is difficult to ascertain the true sedimentary nature of the laminae. Ripple and/or convolute laminae are rare. Locally, sole markings, primarily groove casts, are present on the bases of thicker sand beds.

3d. Micritic metalimestone. Metalimestone is the least common of the four lithologic types in this formation, and it is not everywhere present. It consists of dark gray to grayish black, extremely and uniformly fine-grained metalimestone. Beds weather to various shades of dark brown and brownish black. Locally these beds are highly weathered. Bedding is characteristically less than 4 cm thick. No sedimentary structures have been observed in this lithofacies.

4. Internal stratigraphy

The Brewer Formation has not been divided into members. Extensive glacial deposits coupled with very small, uninformative outcrops of slate, and multiple small folds with poor topping senses or with top reversals due to small-scale folds have not allowed an internal stratigraphy to be developed at this time.

Feldspathic and quartzose metawacke locally occur as prominent cycles or lenses within the dominant thinly bedded slate and metasandstone. Several of these cycles are potentially mappable at the 1:24,000 scale. Further work may allow these metasandstone occurrences to be mapped as lenses or as limbs of small synclines.

5. Thickness

The thickness of the Brewer Formation is unknown. The stratigraphic base is not exposed within the Bangor or Veazie 7.5' quadrangles. Also, unknown structural complexities as indicated by numerous reversals of sedimentary tops and small-scale folds do not allow for a reasonable thickness estimate at this time.

6. Age

No body or trace fossils have been recovered from the Brewer Formation. A Silurian (?) age is inferred from regional relationships (see below).

Bangor Formation (new name)

1. General statement and area of exposure

This is the second most extensive unit in the study area. It occupies approximately 1/3 of the Bangor and Veazie 7.5' quadrangles, preserved in a northeast-trending syncline through downtown Bangor. Unpublished reconnaissance mapping by the author indicates that the Bangor Formation extends north into the Old Town 7.5' quadrangle as well. The full map extent of this formation is not known, but it is probably a unit of regional importance. The Bangor Formation is divided into the lower Penobscot River Member (**Sbpr**) which has two recognizable and mappable facies, a middle Lover's Leap Member (**Sbl**), and an upper Kenduskeag Stream Member (**Sbk**).

2. Name and reference localities

The formation is named for the city of Bangor, Maine. Significant exposures of the Penobscot River Member, here named for the Penobscot River, are present along the western bank of the river in Veazie, and both banks of the river in Bangor and Brewer. The Lover's Leap Member is here named for the prominent cliff of that name on the northeast bank of a right bend in the Kenduskeag Stream, 1800 feet east of the I-95 bridge in Bangor. The Kenduskeag Stream Member is here named for Kenduskeag Stream, Bangor.

3. Lithology

3a. Penobscot River Member. Medium dark gray to dark gray, very fine-grained to medium-grained feldspathic metawacke comprises the majority of this member. Muscovite, some of which is detrital, is locally common. Thin beds of metasiltstone and, less commonly, claystone slate are interbedded with the metawackes. Beds are typically of variable thickness, ranging from 5 centimeters to slightly more than 2 meters. The Penobscot River Member has two facies which are differentiated on the basis of bedding thickness and matrix content. The lower facies (**Sbpt**) is very thick to thickly bedded and matrix-poorer, while the upper facies (**Sbpm**) is medium bedded and matrix-richer. The bedrock map shows the approximate distribution of these two facies in the northern portion of the Veazie quadrangle (Pollock, 2011b). Lack of outcrop in the vicinity of the Bangor Mall and points southwest into the Bangor 7.5' quadrangle make extension of the contact problematic.

In the lower facies (**Sbpt**), in the immediate vicinity of the Penobscot River, beds are thick to very thick (1 m to 2+ m). Beds are typically devoid of sedimentary structures, although parallel lamination and elongated pipe-like structures similar to well documented dewatering features, are locally common. Ripple cross-lamination is rare. Graded bedding is present, but the graded textures commonly range from a fine-grained sand at the base to a very fine-grained sand at the top. Shale or slate rip-up clasts occur locally and may be present at any position in the bed. Flame structures associated with load or flute casts are rare.

In the upper facies (**Sbpm**), which lies west of the Penobscot River, sequences of thinly bedded metawacke and slate are interbedded with sequences of thickly bedded, graded, structureless or parallel-laminated metawacke. Within the thinly bedded sequences, the thinly bedded metawackes commonly exhibit parallel laminations and/or ripple cross-laminations. Convolute laminations are locally present. These structures may comprise the entirety of a bed, or they may be stacked, with ripple cross-laminations overlying a parallel-laminated interval. Thick metawacke beds commonly exhibit textural grading from fine-grained to very fine-grained sand. Additionally, some beds are structureless, or have a graded or structureless interval underlying a parallel-laminated interval. Centimeter-scale clasts of slate interpreted as rip-ups are common near the bases, or occur as isolated clasts within metawacke beds. Rarely, the soles of thicker beds exhibit flute or groove casts.

3b. Lover's Leap Member. The middle member is very similar to the siltstone and claystone slate of the Brewer Formation. Locally, this member contains calcareous, medium dark gray to dark gray, well-sorted, very fine-grained quartz-rich meta-arenite identical to the second lithology of the Brewer Formation described in section 3b above.

3c. Kenduskeag Stream Member. The upper member is characterized by medium to dark greenish gray, very fine-grained to fine-grained feldspathic metawacke. These rocks are also micaceous. Beds are of variable thickness, generally between 15 cm and 45 cm. Beds greater than 1 meter in thickness are uncommon. In addition to coloration differences, metawacke beds in this member are less well graded, and there is an overall lack of parallel lamination, rip-up clasts, and sole markings. Greenish gray slate and phyllite are interbedded with the metawackes. These finer grained beds typically range in thickness between 3 and 40 cm. Sedimentary structures include graded beds, ripple cross-lamination, and rare flute and groove casts.

4. Thickness

The thickness of the Penobscot River Member is estimated to be between 1400 and 1600 meters. The Lover's Leap Member is estimated to have a maximum thickness of 200 meters. Faulting along the southeastern limb of the syncline causes this unit to be cut out. The exposed portion of the Kenduskeag Stream Member is estimated to have a maximum thickness of approximately 300 meters. The stratigraphic top of this member is not preserved in the Veazie or Bangor quadrangles, and portions of the member exhibit an irregular thickness due to faulting along the eastern contact.

5. Age

No body or trace fossils have been recovered from the Bangor Formation. A Silurian (?) age is inferred from regional relationships (see below).

Regional correlation of the Brewer and Bangor Formations

Reconnaissance mapping by John Griffin (1973), summarized by Pankiwskyj and others (1976), established the general continuity of metasedimentary rocks from the Augusta-Vassalboro area to the Bangor area and beyond. These rocks were grouped under the name Vassalboro Formation on the Bedrock Geologic Map of Maine (Osberg and others, 1985), even though the reconnaissance mapping had shown that it could be subdivided locally. Since that time, the detailed interpretation of the stratigraphic relationships has changed, and the stratigraphic nomenclature has been revised in the Augusta-Vassalboro area (Osberg, 1988; Tucker and others, 2001; Marvinney and others, 2010). This recent work has not changed the fundamental concept of a single sedimentary basin of Silurian to possibly late Ordovician age, extending from the fossiliferous rocks of the Waterville area to Bangor. It has, however, caused some of the formation names used on earlier maps (Griffin, 1976a, 1976b, for example) to be revised or obsolete.

A solution to the nomenclature problem was presented by Marvinney and others (2010), who proposed that the Vassalboro be elevated to the rank of Vassalboro Group, allowing formations to be mapped locally within the Vassalboro Group. Following this proposal, the Brewer and Bangor Formations are included here in the Vassalboro Group. The local formation names used by Griffin (1976a, 1976b) in the Bangor area, including Sangerville Formation, Vassalboro Formation, and Kenduskeag unit, are discontinued here. The new Kenduskeag Stream Member of the Bangor Formation coincides, in part, with Griffin's informal "Kenduskeag unit." The similarity of name empasizes the sandstone-rich nature which Griffin described, but a new name is warranted because of the substantially different map pattern, and stratigraphic context of the Kenduskeag Stream Member as currently conceived.

More precise correlation of the Brewer and Bangor Formations with formations in the Augusta-Waterville area is not warranted at this time. One possibility is that the sand-rich and shale-rich units mapped locally as formations may not be laterally continuous across such large distances. It is tempting to correlate the Bangor Formation with the Mayflower Hill Formation, since they are both sandstone-rich units that rest stratigraphically upon pelite-rich units. However, the sequence of members in the Bangor Formation has not been recognized in the Mayflower Hill, and the sulfidic pelite at the base of the Mayflower Hill has not been recognized at the Bangor-Brewer contact. Furthermore, the Brewer Formation is across strike to the southeast of the main belt of Waterville Formation, calling their correlation into question. Perhaps detailed mapping between the Bangor and Waterville areas will clarify the distribution of lithofacies within the Vassalboro Group.

ROCKS OF THE FREDERICTON BELT

Bucksport Formation

1. General statement and area of exposure

This formation crops out within the southeastern quarter of the Veazie quadrangle. In comparison to the Brewer Formation, outcrops are both large and abundant. Rocks of the Bucksport Formation (**SOb**) display structural and metamorphic features that are somewhat different from those of the Vassalboro Group, possibly reflecting different structural and metamorphic histories.

2. Reference localities

There are several readily accessible outcrops around the village of Holden. Abundant outcrops are present on the southern parts of Mann Hill, Holden.

3. Lithology

3a. Metasandstone. These rocks include fine-grained to medium-grained calcareous quartz metasandstone and granoblastic schist. The protolith probably was a fine-grained to very fine-grained calcareous quartz-rich sandstone. These rocks now exhibit a well developed granoblastic texture. The dominant planar fabric of the rocks varies between thinly laminated and strongly foliated. The laminations or foliations are commonly folded. There are two types of this calcareous metasandstone. The first type exhibits definitive laminations which consist of dark gray, non-calcareous quartz-rich laminae alternating with tan-weathering, medium gray to medium dark gray, calcareous quartz-rich laminae. Differential weathering produces a striped rock of alternating dark gray and tan laminae. The second type is texturally similar, except that the alternating

bands are not present. This type is also slightly to moderately calcareous. Very fine grains of biotite are present locally in both types. Bedding where unequivocally identified ranges from medium (30± cm) to thick (~75 cm).

3b. Phyllite. The phyllite is a rusty-weathering, dark gray to black phyllite locally with well developed sulfidic stains. Textural variations in the phyllite suggest the protolith ranged from a silty claystone to a fine-grained siltstone. Also, several outcrops appear to be transitional from phyllite to very fine-grained biotite-quartz schist. Phyllite cleavage surfaces commonly exhibit a rusty stain. Cleavages are also moderately irregular, suggesting a phacoidal cleavage.

3c. Slate. Slate is a minor rock type and is found as thin to medium interbeds in the metasandstone. Commonly the slate exhibits thin, tan-weathering, non-calcareous metasiltstone laminae. These laminae are typically parallel, ranging in thickness from less than a millimeter to approximately 10 millimeters. Ripple forms in the silts are rare. Because of the alternating tan-weathering silts and grayish black slate, the beds have a "pinstripe" appearance. These sequences are interpreted to be mud turbidites.

4. Thickness

Because many outcrops lack demonstrable bedding and have a relatively uniform lithology, together with regional uncertainties due to (a) multiple deformations; (b) possible metamorphic grade increases; (c) a fault-bounded western contact; and (d) no contact along the eastern edge of the Veazie quadrangle, no thickness estimate is provided at this time.

5. Age

No body or trace fossils have been recovered from the Bucksport Formation. A Silurian-Ordovician (?) age is inferred from regional relationships (Tucker and others, 2001).

6. Regional correlation and stratigraphic assignment

In the Orland 15' quadrangle, Wones (1991) specifically notes two lithologies of the Bucksport Formation that probably correlate with lithologies in the Veazie quadrangle. Notably, Wones describes rocks with 10 cm to 1 m thick beds that are rusty-weathering, pyrite-pyrrhotite-bearing chlorite-quartz-plagioclase schist. More importantly however, Wones (1991) describes schists in which calcareous layers are interbedded with non-calcareous layers. Specifically Wones describes these as "rock layers" that contain fine-grained quartz, muscovite, chlorite, and plagioclase "interbedded" with layers composed of quartz, plagioclase, chlorite, calcite, and muscovite. The presence of alternating non-calcareous and calcareous layers combined with interbeds of rusty-weathering phyllite in the Veazie quadrangle and rusty-weathering schist in the Orland 15' quadrangle, together with the alignment of outcrop belts, make for a strong argument that the term Bucksport should be applied to these rocks.

The Rider Bluff Member of the Copeland Formation does not extend northward into the Veazie quadrangle.

INTRUSIVE ROCKS

In the course of mapping, four dikes of igneous rock were noted in outcrop, all in the Bangor 7.5' quadrangle. One is a porphyritic diabase. The other three are felsic aphanites, with sparse tabular or elongate mafic grains as microphenocrysts. The microphenocrysts are tentatively thought to be chlorite or biotite. Overall, the felsic dikes appear to be rhyodacitic in composition, although they have not been analyzed.

All four dikes are thin. The diabase is less than 2 meters wide. The felsic dikes are less than a meter in width. They are approximately parallel to bedding and cleavage.

No igneous rocks were found in the Veazie quadrangle.

STRUCTURAL GEOLOGY

Map-scale faults

Three map-scale faults were identified, all in the Veazie 7.5' quadrangle. The most significant of these is the fault which separates the Brewer Formation from the Bucksport Formation. No outcrops of the fault were located and the trace is not precisely located due to extensive glacial cover. However, this fault clearly separates two units of differing lithology, and with apparently different metamorphic and structural histories. Motion on the fault is not known due to lack of exposure of the fault zone itself. Strain markers or kinematic indicators do not appear to be widely distributed in outcrops closest to the inferred trace. I interpret the boundary to be a relatively narrow (i.e. < 500 m wide based upon limited outcrop control) and sharp fault zone.

To the northwest of that fault, and approximately parallel to its trace is a dextral shear zone. Serendiptously, the location of this shear zone is controlled by three outcrops which are aligned on strike. One outcrop has kinematic indicators which unequivocally demonstrate right-lateral movement. These shear-sense indicators are confined to a well indurated zone approximately 1.5 m wide. Adjacent to this shear zone are slates which appear disrupted, but which lack good shear-sense indicators. They also appear more weathered, so they may be within the shear zone. These outcrops lack bedding, are poorly jointed, and exhibit irregular (rotated?) cleavage.

The third map-scale fault crops out along the boundary between the Penobscot River and Lover's Leap Members of the Bangor Formation. The fault is exposed in small outcrops along the southbound lane of Interstate 95 south of the Hogan Road exit in the Bangor 7.5' quadrangle. This fault lacks clear kinematic indicators.

Minor faults and brittle fractures

The Veazie 7.5' quadrangle contains numerous outcrop-scale brittle fractures and faults which are not shown on the 1:24,000-scale map because of their small size or lack of lateral persistence. These brittle fractures and faults are approximately parallel or sub-parallel to cleavage or bedding. Displacement has been determined along a few of these faults; it is small, generally less than a few meters. Most commonly these faults appear as zones with ubiquitous, irregular small-scale quartz pods, lenses, and veins, whose origins are difficult to interpret. Rarely is there any definitive motion indicator. Slickensides and other lineations related to movement are uncommon.

Joints

Joints are ubiquitous in the Bangor and Veazie 7.5' quadrangles. The majority of these are not extensive, with small surfaces, and do not cut across bedding boundaries. Most are closely spaced with spacings less than 30 cm. Thicker-bedded metawackes may exhibit larger joints by virtue of the thicker beds. Multiple joint sets which intersect at high angles are commonly present. The dominant joint set strikes northwest and dips steeply to the southwest and northeast. Less prominent joint sets have a variety of orientations. Shallow-dipping joints are most common in areas of thick-bedded metawacke.

Map-scale folds

An areally prominent syncline is the major structural feature in the Bangor 7.5' quadrangle. It continues northeastward into the Veazie quadrangle. This syncline, as mapped, is asymmetric with a northwest-dipping axial surface. The orientation of the northwestern limb varies along strike from nearly vertical to overturned with northwest dips. The southeastern limb has been modified by the fault between the Penobscot River and Lover's Leap Members of the Bangor Formation. Multiple small-scale folds in the vicinity of the Penobscot River suggest that the syncline is complex overall.

Minor folds in the Brewer and Bangor Formations

General Statement

Small folds in the Brewer and Bangor Formations are related to at least two generations of folding. The first generation of folding is associated with the dominant slaty cleavage. The second generation is associated with an axial planar spaced or fracture cleavage. First generation folds are uncommon. Second generation folds are most common in the southeastern half of the Bangor 7.5' quadrangle, but are present over the entire quadrangle.

First generation folds

These folds typically have northeast-trending axes with northwest-dipping axial surfaces. Generally, these folds are asymmetrical with synclines having a nearly vertical or overturned northwest limb and a moderately to steeply dipping southeast limb. These folds mimic the style of the larger scale syncline. Plunges of the folds vary within the map area. Currently, three plunge orientations are recognized. These are: (1) a nearly horizontal to shallow northeast plunge; (2) a moderate plunge to the northeast; and (3) a moderate plunge to the southwest.

Second generation folds

These are currently recognized as medium (1-2 meter wavelength) to small (<15 cm) folds which fold the dominant slaty cleavage. Fold axes are commonly subhorizontal with northeast-southwest trends. Plunges, where determined, are to the northeast. Axial surfaces of these folds are subhorizontal or have shallow dips either to the southeast or northwest.

Cleavage in the Brewer and Bangor Formations

General statement

Two generations of cleavage are recognized in the Brewer and Bangor Formations. The first of these is an area-wide slaty cleavage that equally affects all units. The second cleavage is a spaced (fracture) cleavage which is superimposed upon the first cleavage. Spaced cleavage, recognized as most prominent in the southeastern half of the Bangor 7.5' quadrangle, is relatively uncommon in the Veazie quadrangle. It occurs in slates and in the metasandstones where bedding is less than 1 meter thick. In general, the character of the cleavage is dependent upon the rock type. Cleavages in slates in the Brewer Formation range from a good planar slaty cleavage with little or no rusty stain, to a moderately planar or slightly curved (not folded) slaty cleavage with rusty stain, to an irregular slaty cleavage with locally pronounced rusty stains. This irregular slaty cleavage is curved, producing phacoidal cleavage. Cleavages in slates of the Bangor Formation are typically planar cleavages devoid of rusty stains.

Likewise, cleavages in the sandstones are variably developed. Some metasandstones exhibit a faint or very weakly developed rock cleavage, while other metasandstones exhibit a very strongly developed pressure solution cleavage.

Refraction of cleavage or curved cleavage within metasandstone beds, and refraction of cleavage across metasandstone-slate bedding planes are common.

Slaty cleavage (first generation)

Slaty cleavage is a regionally prominent structural element that strikes northeast-southwest and almost universally dips

steeply to the northwest. In sandstones this cleavage may be manifested as a pressure solution cleavage. Locally, however, interpretation may be equivocal. Thicker metasandstone beds may exhibit parallel sedimentary lamination, and cleavage may be bedding-parallel or bedding-subparallel. Hence, correct interpretation is difficult because sedimentary laminations may be "enhanced" by bedding-parallel pressure solution cleavage.

Spaced (fracture) cleavage (second generation)

This cleavage is axial-planar to the second generation folds. Spacing between cleavage planes is typically 1 cm, but ranges from approximately 4 mm to 15 mm. This cleavage has a variable strike with dips dominantly in the southeast and northwest quadrants. This cleavage is not everywhere developed. Most commonly it is seen in beds ranging from approximately 15 to 75 cm in both formations. Locally, the spaced cleavage is an axial planar fan cleavage to the second-generation fold set.

Minor folds in the Bucksport Formation

Five distinct fold styles are recognized in the Bucksport Formation of the Veazie quadrangle. In sequence from oldest to youngest these are: (1) An overturned to partially recumbent fold set with subhorizontal fold axes and shallowly dipping axial surfaces. This fold set is locally accompanied by a folded cleavage which is axial planar to these folds. (2) Steeply plunging folds with steep to near vertically plunging fold axes and steep axial surfaces; (3) Gently plunging tight chevron-style folds with steeply dipping axial surfaces; (4) Gently plunging open concentric folds with steeply dipping axial surfaces; (5) An open concentric fold set with shallow fold axes and shallow to sub-horizontal axial planes. This fold set is rare and is locally accompanied by an axial planar or fan spaced cleavage.

Fold axes of the chevron folds in the Bucksport Formation are oriented approximately parallel to the first generation folds in the Brewer and Bangor Formations. The youngest fold set in the Bucksport Formation, concentric-style folds with shallow dipping axial planes and associated spaced cleavages, is consistent with the second generation folds in the Brewer and Bangor Formations.

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