DEPARTMENT OF CONSERVATION
Maine Geological Survey

Robert G. Marvinney, State Geologist

OPEN-FILE NO. 12-33

Title: *Bedrock Geology of the Great Pond 7.5' Quadrangle, Maine*

Author: *Chunzeng Wang*

Date: *2011*

Financial Support: Funding for the preparation of this map was provided in part by the U.S. Geological Survey STATEMAP Program, Cooperative Agreement No. 04HQAG0035.

Contents: 15 p. report and map

Bedrock Geology of the Great Pond 7.5' Quadrangle, Maine

Chunzeng Wang
University of Maine at Presque Isle

INTRODUCTION

The Great Pond 7.5' quadrangle lies within Hancock County of eastern-central Maine between 44°52'30" and 45°00' north latitude and 68°15' and 68°22'30" west longitude. The area has been intensively glaciated and consists of a few prominent hills and ridges that extend northeast-southwest and reach elevations as high as 1050 feet (Springy Brook Mountain in the southwest part of the quadrangle). Between the high hills and ridges are lowlands, broad plains, swamps, and lakes such as Great Pond in the north and some smaller ponds scattered throughout the quadrangle. The topographic relief is directly related to differential bedrock weathering and erosion; igneous intrusions stand high in relief forming rounded hills and prominent ridges, whereas metasedimentary and sedimentary rocks are low in relief forming rolling plains and lowlands.

Dense woods cover most of the area and bedrock exposures comprise less than 2% of the total area. The quadrangle is sparsely populated with almost all of the population scattered around the paved road that connects Route 9 in the south and the Dow Pines Recreation Area near Great Pond in the north. Lumber roads provide access to most of the quadrangle area.

The Great Pond 7.5' quadrangle has been mapped previously by several geologists including McGregor (1963), Stoesser (1966), Gilman (1974), Griffin (1976), Wones (1977, 1980), and Wones and Ayuso (1993). Early workers identified and described major rock types such as metasedimentary rocks, intrusive igneous rocks, and unmetamorphosed redbeds. More recent workers focused on the granitic plutons, such as the Lucerne pluton that occupies nearly one third of the quadrangle, and the Norumbega fault system that traverses the northwest part of the quadrangle and extends northeastward to eastern Maine and New Brunswick and southwestward to southwestern Maine.

The Lucerne pluton, one of the largest granitic plutons in Maine with an exposed area of 625 km^2, extends from the Great Pond area southwestward to Orland Township in the Penobscot Bay area. It has been well mapped and petrologically and geochemically studied by Wones (1980) and Wones and Ayuso (1993). However, because the Norumbega fault system occurs right on its northwest margin, the current understanding of its involvement in the Norumbega faulting remains unclear and problematic.

The Turner Mountain syenite, located in the northwestern part of the quadrangle, is another interesting pluton identified by all previous workers. It is interesting because, firstly, this type of igneous rock is rare in Maine, and secondly, it lies within the Norumbega fault system. It has been assumed to be Devonian in age without any radiometric dating and believed to have been emplaced prior to the earliest Norumbega deformation by all previous workers. However, no detailed mapping of this pluton has ever been carried out, so there is little information concerning the role it played during Norumbega faulting, its true relation to the Normbega faulting, and how it was emplaced.

The Norumbega fault system has been recognized recently as one of the largest transcurrent fault zones in the northern Appalachian orogen (Hubbard and others, 1995; Ludman and others, 1999). Detailed mapping and studies of the fault zone, however, have been conducted mostly in south and south-central Maine where amphibolite-facies ductile deformation along the fault zone dominates (Swanson, 1999a, 1999b; West, 1999; West and Hubbard, 1997; West and Roden-Tice, 2003; Hubbard and Wang, 1999), and eastern Maine where early medium-low greenschist facies ductile deformation and subsequent multistage reactivated brittle faulting characterize the branched fault zones (Ludman, 1998; Ludman and Gibbons, 1999; Ludman and others, 1999; Wang and Ludman, 2003, 2004). Obviously there is a gap between eastern and south-central Maine where the Norumbega fault system is least mapped and studied. This gap is also a transition between the middle-crust-level and shallow-crust-level deformation regimes. The Great Pond quadrangle lies within this gap and is essential to understanding the transition from one deformation regime to the other.

Although previous workers have identified and described the Norumbega fault system in the area, there is disagreement on its extent, the protoliths of the faulted rocks, and the nature of the faulting, and many details of the fault zone remain unclear. The mapping and laboratory work in this project can help reveal such unresolved details in a key part of the gap as its structure and deformation nature, and therefore improve our understanding of the deformation regime transition from the mid-crust level of south-central Maine to the shallow-crust level of eastern Maine.

This USGS STATEMAP project has produced a detailed map of the rocks within the Great Pond 7.5' quadrangle and revises our understanding of the relationships among them. Precise mapping and study of the Norumbega fault system in the northwest part of the quadrangle provides new insights into the structures within the fault system, the involvement of the Lucerne pluton and Turner Mountain syenite in Norumbega deformation, and the fault-related deformation of other rocks associated with the fault – especially the redbeds.

GEOLOGIC SETTING

Tectonically, eastern-central Maine is composed of several pre-Middle Devonian metamorphosed lithotectonic terranes; from west to east, the Late Ordovician-Early Devonian Central Maine Belt, the Late-Ordovician-Middle Silurian Fredericton Trough, and the Coastal Lithotectonic Block (Osberg, and others, 1985). By convention, metasedimentary rocks in the Great Pond area northwest of the Lucerne pluton are assigned to the Central Maine Belt whereas those to the southeast of the pluton are assigned to the Fredericton Trough. Both suites consist of thick piles of deep-water, dominantly sandy turbidites that were tightly folded and metamorphosed to lower greenschist facies conditions (chlorite-zone) during the Late Silurian to Early Devonian Acadian orogeny.

Devonian granitic plutons intruded the metamorphic terranes mentioned above and are major components of the Coastal Maine Magmatic Province. Portions of two of the largest plutons, the Deblois and Lucerne batholiths, crop out in the Great Pond quadrangle. The Deblois, about 1670 km^2 in area, is the largest in the Coastal Maine Magmatic Province. Its western lobe underlies the southeastern part of the Great Pond quadrangle. The Lucerne pluton is elongated in the direction of 210^o; it widens southwestward to Orland Township northeast of Penobscot Bay but narrows drastically toward the northeast, particularly in the vicinity of Great Pond.

The dominant structural feature in the region is the Norumbega fault system. Previous mapping unequivocally demonstrates the continuity of the fault zone for at least 450 km, from the Casco Bay region in southwestern Maine to central New Brunswick in Maritime Canada. It is recognized today as one of the largest and longest transcurrent fault systems in the northern Appalachians. In southwestern and south-central Maine the fault system is characterized by a wide zone of distributed dextral ductile shear with localized very high strain zones. Amphibolite facies assemblages and ductile shear fabrics indicate mid-crust ductile shearing immediately after early Devonian peak regional metamorphism. A complex displacement history, possibly continuous for almost 100 million years, has been inferred for the deeper segment in south-central Maine by West and Hubbard (1997) and West and Roden-Tice (2003). Two ductile shearing events have been recognized along the Norumbega system in south-central Maine and dated to ~380 Ma (at amphibolite facies) and ~290 Ma (at greenschist facies) respectively (West and Lux, 1993; West and Hubbard, 1997; West, 1999). Swanson (1999a) has proposed that the regional dextral shearing and accompanying upright folding, granitic intrusion, and metamorphism can be linked to a restraining-bend geometry along the Norumbega fault system in south-central Maine.

The shallow-crustal segment of the Norumbega fault system in eastern Maine, however, experienced a complex, multi-deformational history involving distinctive ductile and brittle phases (Ludman, 1998; Wang and Ludman, 2003, 2004). The initial greenschist-facies dextral ductile shearing began ~380 Ma and strain was largely partitioned into the Kellyland and Waite ductile shear zones (Ludman, 1998; Ludman and others, 1999). These fault zones, distinct from one another near the Maine-New Brunswick border, converge in the area just northeast of the Great Pond quadrangle. The Waite zone was later reactivated brittlely and three episodes of significant brittle faulting have been identified along the Waite composite fault zone (Wang and Ludman, 2003).

STRATIGRAPHY

Stratified rocks in the Great Pond quadrangle include metamorphosed older turbidites and unmetamorphosed younger redbeds. Traditionally, the metasedimentary rocks northwest of the Lucerne pluton are assigned to either the Vassalboro or Hutchins Corner Formation of the Late Ordovian-Early Devonian Central Maine Belt, whereas the metasedimentary rocks to the southeast are assigned to the Bucksport Formation of the Late Ordovician-Middle Silurian Fredericton Trough. Field mapping and observations, however, suggest that both formations are very similar in lithology and deformation features and could be also correlated to the Flume Ridge Formation that crops out in the area northeast of the quadrangle. All of these formations have been assigned an Ordovician-Silurian age by previous workers and this project has detected no evidence that would change this.

This report and the accompanying geologic map follow the conventional nomenclature and keep using Vassalboro Formation for the metasedimentary rocks to the northwest of the Lucerne pluton and Bucksport Formation for the metasedimentary rocks to the southeast of the Lucerne pluton. The two formations are nearly identical, each exhibiting a similar range of bedding types and lithologic proportions.

Vassalboro Formation (SOv)

The Vassalboro Formation (Perkins and Smith, 1925; Osberg, 1968; Osberg and others, 1985), later in part also called Hutchins Corner Formation (Osberg, 1988), is exposed to the northwest of the Norumbega fault system in the Great Pond quadrangle. The formation in the study area is interpreted as a

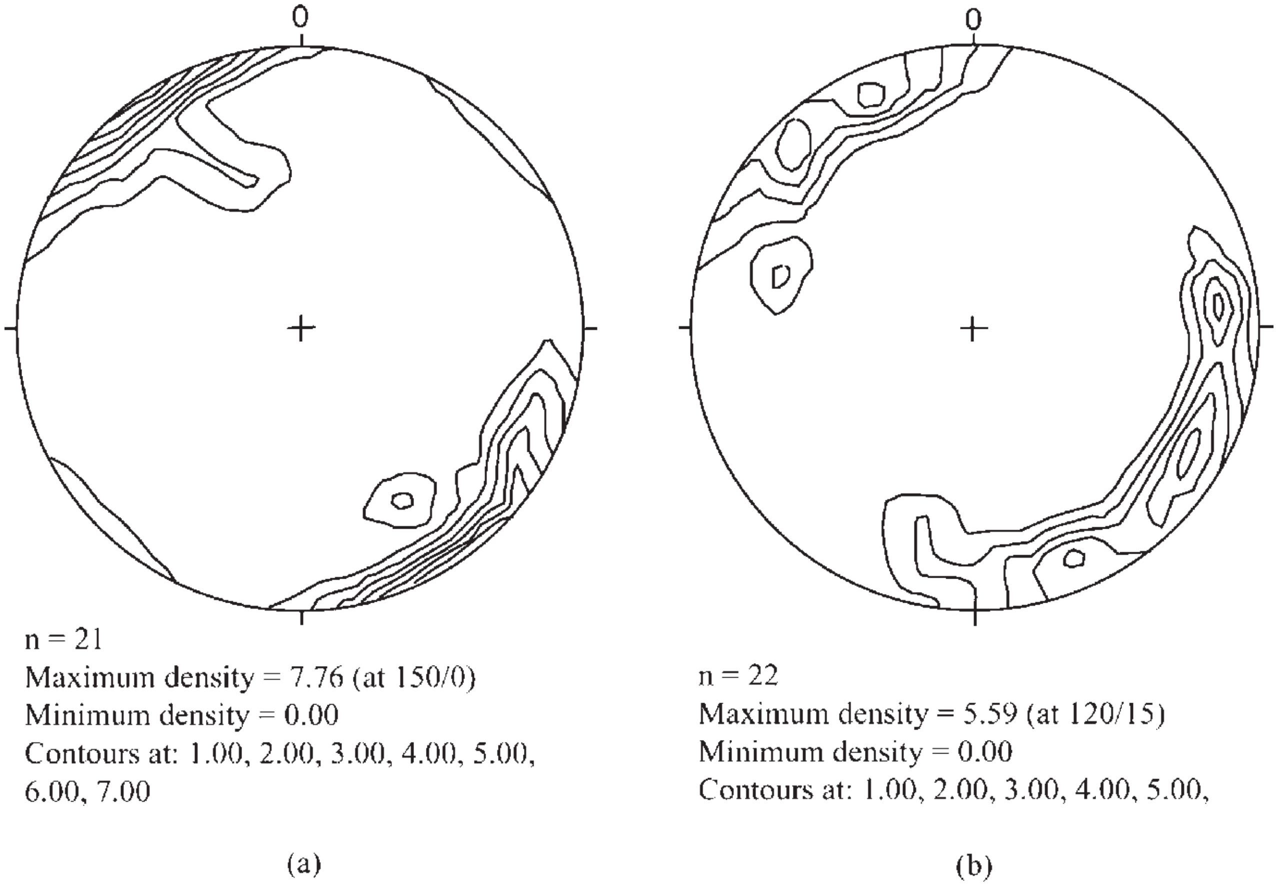


Figure 1. Equal-area stereograms showing poles to foliation/cleavage developed in metasedimentary rocks of Vassalboro Formation (a) and Bucksport Formation (b). See the text for explanation.

typical turbidite suite, composed predominantly of interbedded light gray, dark gray, and green-weathering medium to thick beds of feldspathic graywacke and subordinate, thin to medium horizons of pelite and siltstone. Calcareous siltstone layers are sporadically distributed throughout and locally weather to a rusty color where sulfide is abundant. Calc-silicate bands have been observed at higher-grade outcrops. Bed thickness generally varies from 1-2 cm up to 2 m thick. A general northeasterly strike at 45^o-65^o is prevalent throughout the area. Dips are medium to steep at an angle ranging from 45^o to 85^o to either northwest or southeast (Figure 1a).

The Vassalboro Formation was folded during the Acadian orogeny. Small-scale tight and isoclinal folds are observed throughout the area, but individual large-scale folds are not mappable. Axial-plane foliation or cleavage associated with the tight folding is penetrative throughout in the formation. Bedding is parallel or near-parallel to the cleavage at most outcrops.

The Vassalboro/Hutchins Corner Formation was metamorphosed to low greenschist facies during the Acadian folding and therefore occurs mostly as metasandstones with minor slate, dark gray phyllite, and thin layers of fine-grained schist, depending on metamorphic grade. Microscopically, the slightly metamorphosed and foliated graywacke and siltstone show typical clastic textures, with some strongly foliated with shape-preferred fabrics defined by aligned elongated quartz grains and muscovite flakes in the Norumbega fault system.

Adjacent to the Norumbega fault system, the Vassaboro Formation graywacke and pelite are thoroughly and strongly foliated, becoming slaty and locally strongly phyllitic, and quartz veins are common, suggesting its involvement in the early ductile shearing along the Norumbega system.

Bucksport Formation (SOb)

Sandwiched by the Lucerne and Deblois plutons in the Great Pond quadrangle is a sliver of the Bucksport Formation (Trefethen, 1950; Wing, 1957; Osberg and others, 1985). The Bucksport Formation in the area is also a turbidite suite and consists of predominantly dark-gray thick feldspathic graywacke beds and medium-thin layers of pelite. Interbedded medium to thin siltstones are locally calcareous and weather to a rusty color. Lithologically, the Bucksport is so similar to the Vassalboro Formation in the west and northwest and the Flume Ridge Formation to the northeast that it would be impossible to separate them

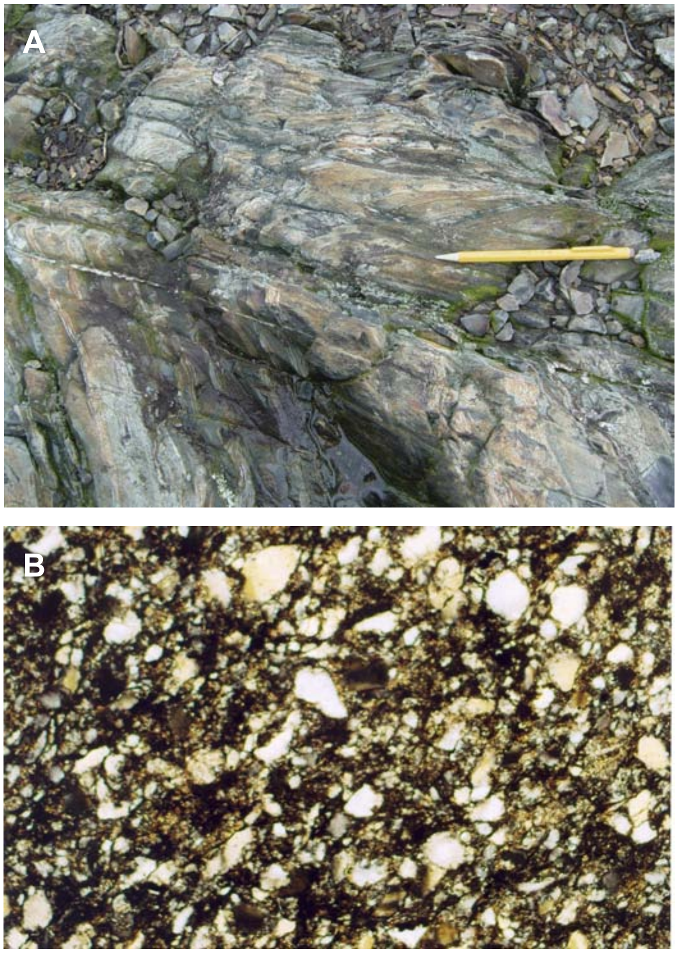


Figure 2. (a) Outcrop-scale fold with axial-plane cleavage developed within the Bucksport Formation. Pen pointing to north. Picture location at Stop 4157. (b) Photomicrograph showing hornfelsed graywacke of Bucksport Formation at contact with Lucerne granite. Numerous recrystallized, dark-colored, tiny biotite flakes occur throughout the rock. Rock sample #4226. Width of view is 3.5 mm. Cross-polarized light.

were it not for the presence of plutons and the Norumbega-related faults. The Bucksport was also tightly folded and metamorphosed to low greenschist facies during Acadian deformation. Outcrop-scale or mesoscopic tight and isoclinal folds are common (Figure 2a). Like the Vassalboro, both beds and axial-plane foliation/cleavage generally strike northeast and dip to either northwest or southeast (Figure 1b).

The only distinctive difference from the Vassalboro Formation is that the Bucksport Formation in the quadrangle is almost entirely hornfelsed by contact metamorphism caused by the emplacement of the Lucerne and Deblois plutons. Close to the contact the graywacke and pelite become dark-colored purplish black hornfels (Figure 2b). The dark color is due to the presence of numerous flakes of newly crystallized contact-metamorphosed biotite. Near the intrusive contact, diopside is present in the calc-silicate beds due to contact metamorphism. The calc-silicate beds are, however, only minor in the area and are best viewed in a large exposure along Route 9 in Aurora just south of the Great Pond quadrangle.

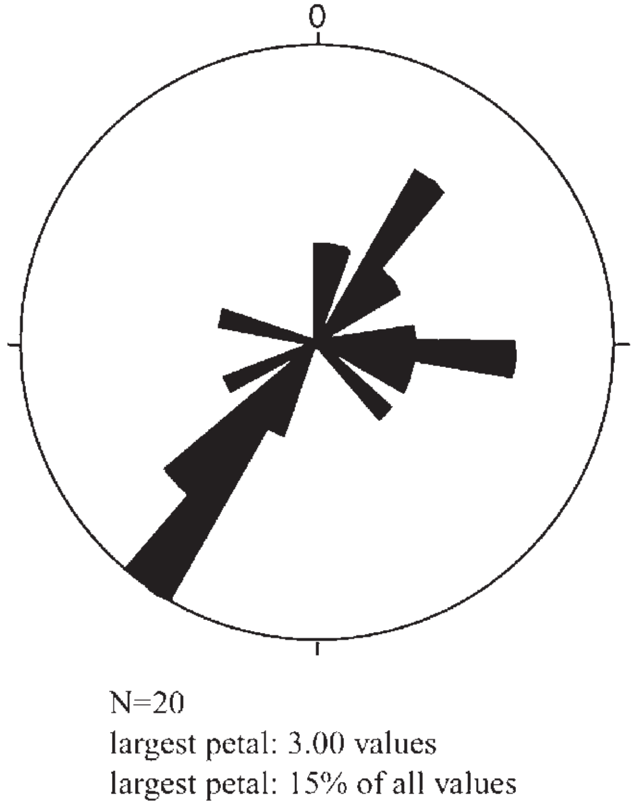
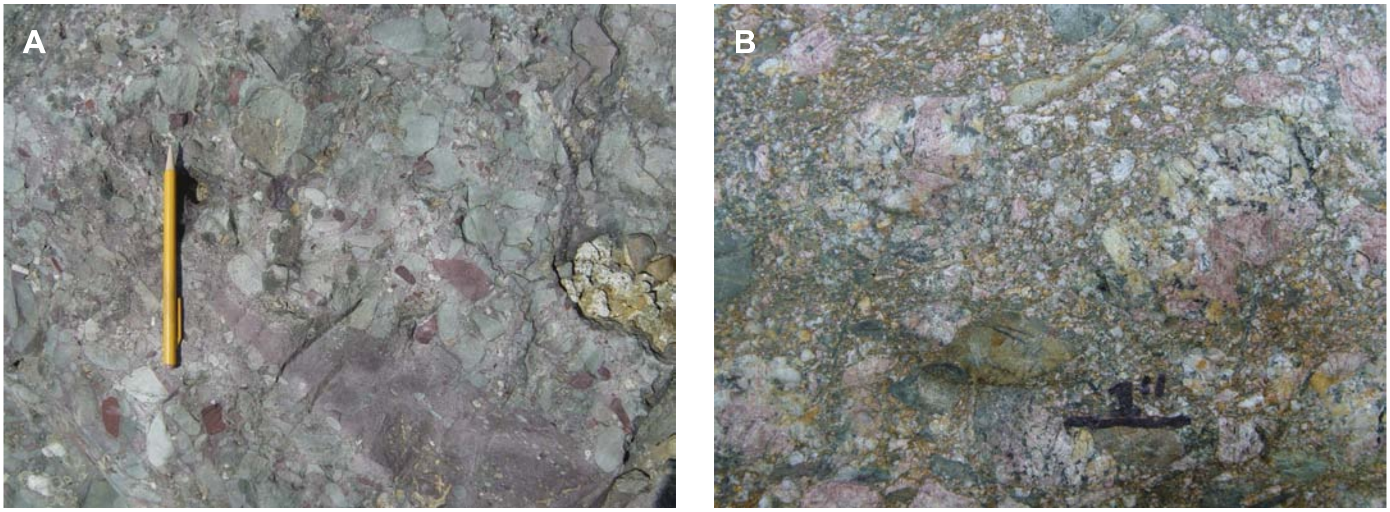


Figure 3. Strike rose diagram of redbeds. 10° classes. See the text for explanation.

The Redbeds (Crb)

A narrow, northeast-striking slice of unmetamorphosed redbeds crops out between the Vassalboro Formation and the Lucerne granite in the northwest part of the Great Pond quadrangle. This unnamed redbed sliver is one of nine that occur along the length of the Norumbega fault system in eastern and eastern-central Maine, all of which are interpreted as having been deposited in sedimentary pull-apart basins generated by Late Devonian–Early Carboniferous Norumbega dextral strike-slip faulting (Wang and Ludman, 2003). The present steep dips of the redbeds indicate subsequent fault motions along the fault system. The redbeds occur today as steeply dipping beds of variable thickness that strike mostly northeast (Figure 3). They are bounded by faults on both northwest and southeast, and detailed mapping shows that they are in fault contact with both the Vassalboro Formation and Lucerne granite.

No fossils have ever been found within the redbeds. They are, however, traditionally assigned a Carboniferous age based on their correlation with the Carboniferous strata in New Brunswick and on the observation that they occur in the post-Acadian



strike-slip pull-apart basins and they are not metamorphosed. Wang and Ludman (2003) showed that the redbeds were deposited *after* 380 Ma ductile shearing and contain clasts of unmetamorphosed sandstones, supporting a Carboniferous, rather than Devonian age.

Lithologically the redbeds can be classified into two major members: one dominantly composed of red sandstone with significant amounts of pebble to cobble conglomerate and the other a combination of red sandstone and mudstone. The former occurs mostly in the northeastern part of the redbed slice whereas the latter characterizes the southwestern section. Bed thickness ranges from several millimeters up to 4-5 meters in both. The non-arkosic pebble conglomerate in the northeastern section is composed of mostly red sandstone and siltstone and gray sandstone clasts (pebbles) with some clasts (pebbles and granules) of coarse-grained granite and clasts from a green wacke of unknown origin (Figure 4a). These clasts vary in size from 0.02-20 cm long. The matrix is composed of detrital quartz, hematite, plagioclase, potassium feldspar, white mica, chlorite, and opaque minerals. Most clasts are rounded or sub-rounded but are poorly sorted, suggesting an origin as a near-source intermontane molasse. The red sandstone and siltstone consist of predominantly detrital quartz and feldspar with a fine-grained hematite matrix. Finely laminated mudstone is deep red in color and composed of extremely fine-grained white mica, quartz, and plagioclase.

Other distinctive lithologies of the redbeds are the arkosic granule conglomerate and coarse-grained arkose mostly found around Main Stream north of Great Pond and near Turner Mountain and Little Turner Mountain. The arkosic granule conglomerate is best exposed in Main Stream on the northern side of Great Pond. It is poorly sorted and composed of mostly fragmental and angular pink alkaline feldspar clasts sized up to 5-6 cm in length and fragmental quartz and plagioclase clasts. Some clasts are fragments of coarse-grained granite (Figure 4b). The red-pink coarse-grained arkose occurs as thin to medium

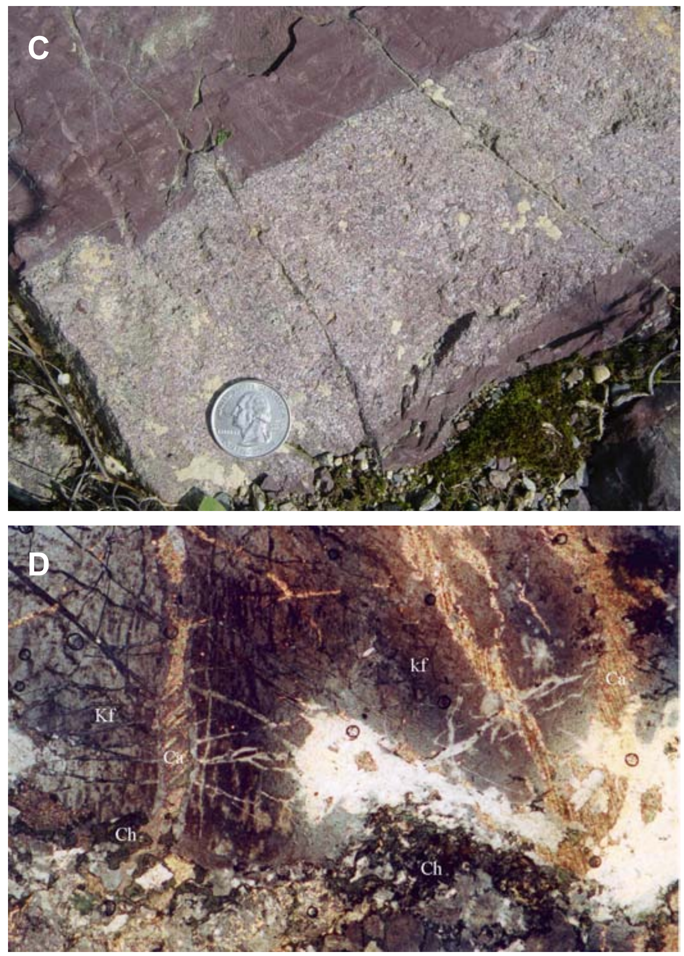


Figure 4. Pictures showing major lithological members of redbeds. See the text for more explanation. (a) Typical non-arkosic pebble conglomerate. Picture location at Stop 4080. (b) Arkosic granule conglomerate, consisting of mostly pink K-feldspar, quartz, and clasts of coarse-grained granite. (c) Layer of arkose sandstone and its soft deformation contact with mudstone. Picture location at Stop B10 at nearby The Horseback quadrangle. View facing north. (d) Photomicrograph of arkose sandstone showing perthite K-feldspar clasts and hydrothermal calcite and chlorite veins filling cracks. Rock sample #4083. Width of view is 3.5 mm. Cross-polarized light.

beds interbedded within finer red sandstone and mudstone sections (Figure 4c). It is composed of predominantly alkaline feldspar and quartz fragments around 0.5-4 mm in diameter.

Sedimentary structures such as scour and fill structures, cross-bedding, and graded bedding are common. Soft-sediment deformation is observed around contacts between coarse-grained beds such as arkose and fine-grained beds such as siltstone and mudstone (Figure 4c).

The arkosic nature of the redbeds demonstrates that their sediment was extremely immature, suggesting a source region proximal to coarse felsic plutons. Two possible local sources of alkali feldspars are the Lucerne granite or the Turner Mountain syenite in the region. The granite and syenite are largely composed of pink megacrystic potassium feldspars as stated in the later sections. Field and thin-section observations, however, suggest two reasons that the alkali feldspars in the arkosic conglomerate and sandstone are derived from the Lucerne granite: (1) the materials making up the arkosic conglomerate and arkose are granitic – the syenite contains a few very fine quartz and plagioclase grains, so the coarse quartz, plagioclase and granite clasts found with the alkali feldspar in the arkosic rocks (e.g. Figure 4b) can only come from the granite; (2) microscopic comparison of alkali feldspars from the arkose with those in granite and syenite show that perthite K-feldspar is prevalent in both arkose (Figure 4d) and granite (see Figure 5b) whereas the syenite contains few perthitic grains. The perthite in the arkose is therefore most likely derived from the Lucerne granite.

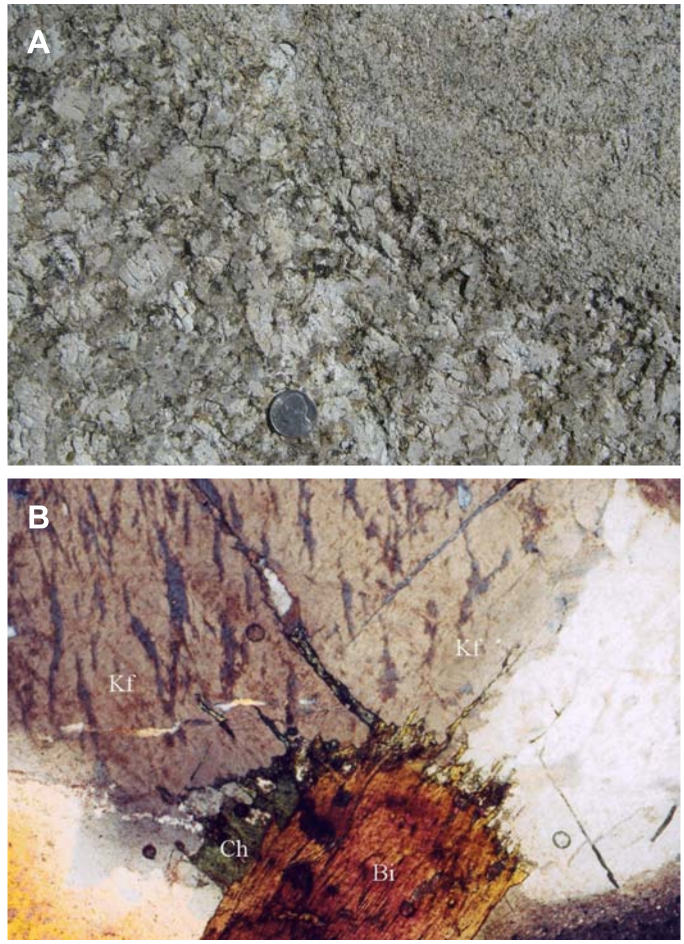


Figure 5. Lucerne granite. (a) Contact between main-phase regular megacrystic coarse-grained granite and a medium-grained granite dike. Picture location at Stop 4206. (b) Photomicrograph of typical Lucerne granite showing part of a perthite K-feldspar and other minerals. Cracks of the feldspar are filled by chlorite. Rock sample #4096. Width of view is 3.5 mm. Cross-polarized light.

IGNEOUS ROCKS

The Lucerne and Deblois plutons are the two largest granitic batholiths in eastern-central Maine. The Great Pond quadrangle however includes only a small portion of both plutons although they account for more than half of the quadrangle. The third igneous intrusion is the Turner Mountain syenite situated within the Norumbega fault system and adjacent to the redbeds north of the Lucerne granite in the western part of the quadrangle.

Lucerne pluton (Dgl)

Only the northeasternmost portion of the Lucerne pluton is exposed in the Great Pond quadrangle. There, it intruded the Vassalboro and Bucksport formations in Devonian times with a reported $^{207}Pb/^{206}Pb$ age of 380 ± 4 Ma (Zartman and Gallego, 1979). Several prominent mountains such as Black Cap Mountain, Morrison Pond Mountain, and Springy Brook Mountain west of Union River in the quadrangle are underlain by the Lucerne granite.

The Lucerne pluton is a coarse-grained to megacrystic leucocratic biotite granite, rich in potassium feldspar. It is bounded or truncated on the northwest by the Norumbega fault system. Detailed mapping has revealed that the Lucerne granite was involved in the early Norumbega ductile shearing and its northwest margin was ductilely sheared and strongly mylonitized. A zone of granitic mylonite and ultramylonite derived from the Lucerne pluton occurs next to the redbeds and Turner Mountain syenite is mapped here as an independent unit (Dgl(m)). The following paragraphs describe the undeformed Lucerne granite (Dgl) and the ductilely sheared granite (Dgl(m)) respectively.

Undeformed Lucerne granite (Dgl)

The undeformed Lucerne granite is characterized by a massive and extremely coarse-grained appearance and distinctive pale-white and pink potassic feldspar megacrysts. It is composed mostly of white-pink perthitic microcline and white sodic plagioclase megacrysts up to 8 cm in length set in a coarse-grained matrix of subhedral albite and anhedral quartz, biotite, and minor hornblende (Figures 5a and 5b), with a typical “seriate texture” (Wones, 1980). Rapakivi albite rims on alkali feldspar

Figure 6. Ductilely sheared and mylonitized Lucerne granite. (a) Typical granitic ultramylonite showing strong mylonitic foliation. Picture location at Stop 4144. Pen pointing to north. (b) Photomicrograph of ultramylonite showing quartz ribbons composed of sub-grains and feldspar porphyroclasts. The ultramylonite is superimposed by cataclasis due to subsequent brittle faulting. Rock sample #4136. Width of view is 3.5 mm. Cross-polarized light.

megacrysts are observed but not common. Local variations include areas characterized by porphyritic textures. The largest piece of porphyritic granite was found near the southeast contact, on the southeast side of Spring Brook Pond around the southwest corner of the quadrangle where phenocrysts of alkali feldspar up to 5 cm and smaller plagioclase occur in a medium-grained more mafic matrix. The contacts between the porphyritic and coarser grained megacrystic rocks appear to be gradational. Abundant tourmaline-rich quartz and tourmaline veins up to several centimeters in width are present in the porphyritic granite at the same location.

According to Wones (1980) and Wones and Ayuso (1993), the Lucerne granite is a calc-alkaline granite and chemically metaluminous to mildly peraluminous.

Outcrop-scale medium-grained granite dikes intruding the main phase of the Lucerne granite have been observed throughout the pluton in the Great Pond quadrangle (Figure 5a). The width of the dikes ranges from several centimeters to about 1 m. They are composed mostly of white sodic plagioclase, white potassic feldspar, and quartz. Ferromagnesian minerals such as biotite are scarce. The dikes are also ductilely sheared within the Norumbega ductile shear zone, indicating that they are pre-Norumbega in age.

Primary flow foliation defined by alignment of euhedral to subhedral feldspars has been observed along the east and southeast margin of the pluton. Foliation strikes 010^{o}-015^{o}, parallel to the contact of the pluton, and dips nearly vertically. No plastic deformation has ever been noticed in quartz grains where flow foliation is observed.

Ductilely sheared and mylonitized-and-ultramylonitized Lucerne granite (Dgl(m))

A ductile shear zone about 1.5 km in width was described by previous workers along the Norumbega fault system between the Lucerne pluton and the redbeds and Turner Mountain syenite in the northwest part of the Great Pond quadrangle. However, the ductile shear zone and the sheared rocks were mapped as a faulted sliver of Precambrian-Ordovician "Passagassawakeag gneiss" (Wones, 1980: Wones and Ayuso, 1993; Osberg and others, 1985). Based on detailed mapping, correlation with the Kellyland and Waite ductile shear zones of the Norumbega fault system in eastern Maine, and microscopic observations, this project concludes that the ductilely sheared rocks are granitic mylonite and ultramylonite derived from the Lucerne pluton.

Most of the sheared rocks within the ductile shear zone are fine-grained and extremely fine-grained ultramylonite (Figure 6a) due to extremely high-strain grain-size reduction. Microscopically, the grain-size reduction is seen to have been achieved predominantly by dynamic recrystallization and dislocation and sub-grain rotation of quartz grains (Figure 6b). Quartz grains are sheared into quartz ribbons up to 10 cm long. Feldspar crystals however are cataclasized into progressively smaller fragments, suggesting a deformation temperature below $450^{o}C$ (Simpson, 1985; Tullis and Yund, 1985). Aggregates of fine fragmental feldspar porphyroclasts are progressively stretched to become feldspar bands as well. Some ultramylonite shows a laminated structure caused by alternating quartz ribbons and feldspar bands, resembling foliated metasedimentay rocks. This was presumably the reason for mapping these fault rocks as Precambrian-Ordovician gneiss.

Coarser-grained mylonite occurs as interbedded thin horizons and lenses within lower-strained domains in which granitic texture and composition are distinguishable in the field (Figure 6c). The least sheared, foliated granite or protomylonite, defines a narrow transition zone between the undeformed granite in the southeast and the mylonitic and ultramylonitic granite. The width of this transition zone is uncertain but estimated to be less than 300 m. This slightly sheared granite is characterized by alignment of euhedral-subhedral feldspar crystals (Figure 6d)

Figure 6 (continued). Ductilely sheared and mylonitized Lucerne granite. (c) Mylonite with lenses or bands of less strained coarser-grained granite. Picture location at Stop 4147. Pen pointing to north. (d) Least sheared and foliated Lucerne granite. View facing north. Picture location at Stop 4059.

which are barely deformed either plastically or brittlely. Quartz grains are only partially plastically deformed or locally dynamically recrystallized to form short ribbons wrapping around feldspar crystals.

The granitic mylonite and ultramylonite are significantly affected by brittle reactivation of the Norumbega fault system. Brittle faulting and cataclasis was concentrated mostly along the northwestern margin of the zone of granitic mylonite and ultramylonite, forming a through-going brittle fault that acts as a boundary between that zone and the Turner Mountain syenite and redbeds. The mylonite and ultramylonite next to the fault were completely brecciated and cataclasized within a zone at least 40 m wide (Figure 6b). Related outcrop-scale and microscopic fractures including faults and joints are well developed within the zone of mylonite and ultramylonite.

Deblois pluton (Dgd)

The Deblois pluton, the largest pluton in the Coastal Maine Magmatic Province has intruded several lithotectonic belts/terranes including the St. Croix, Coastal Volcanic, and Fredericton belts, and has been divided into two lobes, the western and eastern lobes referred to by previous studies (e. g., Ludman and others, 1999; Wang and Ludman, 2003). Both lobes extend northward with the eastern lobe terminating at the northeasterly-striking Kellyland ductile shear zone and the western lobe being dextral ductilely sheared and elongated into a fault sliver called "the Third Lake Ridge granite" (Wang and Ludman, 2004) sandwiched between the Kellyland and Waite ductile shear zones. Only the westernmost margin of the western lobe crops out in the eastern and southeastern parts of the Great Pond quadrangle. Granite in the western lobe was dated at 393 ± 17 Ma by Rb/Sr whole-rock methods (Loiselle and others, 1983).

The Deblois pluton is most commonly a potassic-feldspar-rich, two-feldspar, hornblende-biotite granite characterized by a coarse-grained appearance, distinctive potassic feldspar megacrysts, and a seriate texture. Texturally and mineralogically it is very similar to the Lucerne granite. However, outcrops of the pluton in the quadrangle show a less megacrystic appearance, probably a marginal facies on its western margin. Feldspar crystals are mostly less than 3 cm in length and are more uniform in size. Medium- and fine-grained granitic dikes less than 1 m wide are common within the pluton as well.

The Deblois granite around the Baker Ridge area contains more rapakivi feldspars than other granite in the quadrangle. Irregular and ovoid salmon-colored alkali feldspar megacryst cores, with irregular embayed margins overgrown by a creamy white plagioclase rapakivi mantle are a conspicuous texture of the coarse-grained granite in this area (Figure 7a). Interestingly, spectacular rapakivi feldspars are also present within mafic inclusions (Figure 7b).

It must be pointed out that although granites of both Lucerne and Deblois (western lobe) in the area northeast of Great Pond and around the Baker Ridge are poorly exposed, the known exposures support a speculation that both plutons are most likely "connected" in the area—they could either intrude in the area as a single magma body or just meet there as separate intrusions. Although previous mappers indicate a septum of metasedimentary rocks between the two bodies near the Norumbega fault system, there is no evidence for it in the field and it is hard to find room for metasedimentary rocks between the bodies. Secondly, it is hard to distinguish between the two plutons because they are so similar, with only the exception of the dominantly rapakivi granite around Baker Ridge. Thirdly, hills and ridges in this area are prominently tall and rounded, reflecting a signature of typical granite-type topography that is so

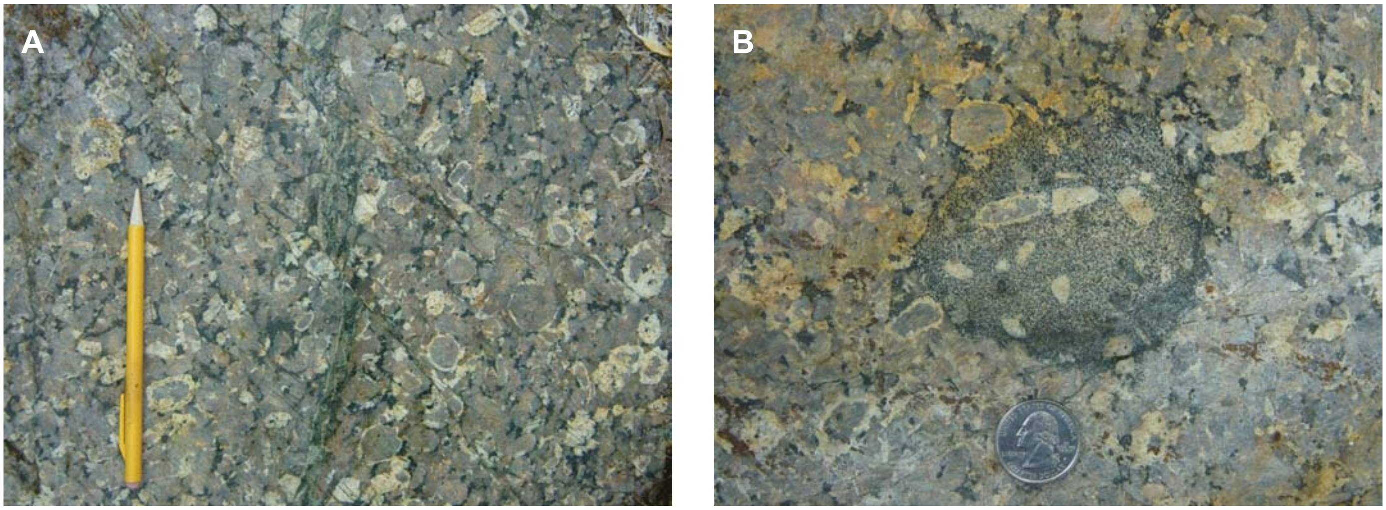


Figure 7. Typical Deblois rapakivi granite around Baker Ridge. (a) North-northeast-striking small-scale brittle-ductile shear zones and subsequent minor brittle faults. Pen pointing to north. (b) Rapakivi feldspar occurring within a mafic enclave. Location of both pictures at Stop 4103.

impressive in the quadrangle and nearby quadrangles. Based on these observations, the accompanying map does not show any separation between the plutons in the area around Baker Ridge, in the northeastern part of the quadrangle. It is suggested that both granite plutons are simply two lobes of a super-pluton that are just like the eastern and western lobes of the Deblois pluton.

Turner Mountain syenite (MzCtm)

The Turner Mountain syenite crops out around Turner Mountain and Little Turner Mountain in the western part of the quadrangle. The syenite has long been identified by previous workers (Stoeser, 1966; Gilman, 1974; Griffin, 1976; Wones, 1977, 1980; Wones and Ayuso, 1993) as an independent intrusion and the only syenite found in central-eastern and eastern Maine. Although it is confined by the post-Acadian Norumbega fault system, it has been assumed by previous workers to be only a small member of the Silurian-Devonian Coastal Maine Magmatic Province, and has never received serious attention.

The syenite intrusion, at least 2 km^2 in area, is tabular in shape and extends about 2.75 km along the strike of the Norumbega fault system. Most of the syenite crops out in the Great Pond quadrangle, although somewhat less than 10% does lie in The Horseback quadrangle to the west. Because it is more resistant to weathering than all other surrounding rocks, it stands high in relief and forms Turner Mountain in the southwest and Little Turner Mountain in the northeast.

The Turner Mountain syenite is texturally and mineralogically quite homogenous. It is a deeply weathered dark brown to black porphyritic hornblende-biotite syenite. Its weathering surfaces are lighter in color and are characterized by large pink euhedral potassic feldspar phenocrysts commonly 2-6 cm long (Figure 8a). Potassic feldspar phenocrysts are mostly homogenous (Figure 8b) with only a small percentage showing perthitic intergrowths. They sit in a medium-grained to coarse-grained groundmass composed of mostly subhedral orthoclase and plagioclase feldspars, biotite, and hornblende (Figure 8c). Fine-grained interstitial anhedral quartz in the groundmass makes up less than 5% of the rock. Small and darker inclusions of medium-grained to fine-grained alkaline and more mafic rocks have been observed. The homogenous porphyritic texture of the whole intrusion may indicate a shallow emplacement environment.

A finer porphyritic phase with lesser amounts of large potassic feldspar phenocrysts but more medium-grained groundmass crops out sporadically around the margin of the syenite intrusion, probably representing a narrow marginal phase. Small inclusions of metasedimentary rock were observed in this finer porphyritic phase.

The late stage Norumbega brittle faulting affected the Turner Mountain syenite significantly, as syenite around its northwest and southeast contacts is extensively brecciated and cataclasized. Feldspar phenocrysts are cracked or fractured into smaller fragments (Figure 8d). Hydrothermal secondary minerals such as chlorite, calcite, and sericite are common and occur mostly as tiny veins filling cracks within feldspar crystals (Figure 8d).

The syenite intrusion is surrounded on the north and west by the tilted Carboniferous (?) redbeds (Crb) and on the east and southeast by the granitic mylonite and ultramylonite zone (Dgl(m)). A brittle fault separates the zone of granitic mylonite and ultramylonite from the syenite and redbeds. However, a contact metamorphic aureole ranging from 5-10 m in width was found next to the syenite in the redbeds at several outcrops on the northwest side of Turner Mountain. The contact between the syenite and the redbeds at these outcrops is only slightly modi-

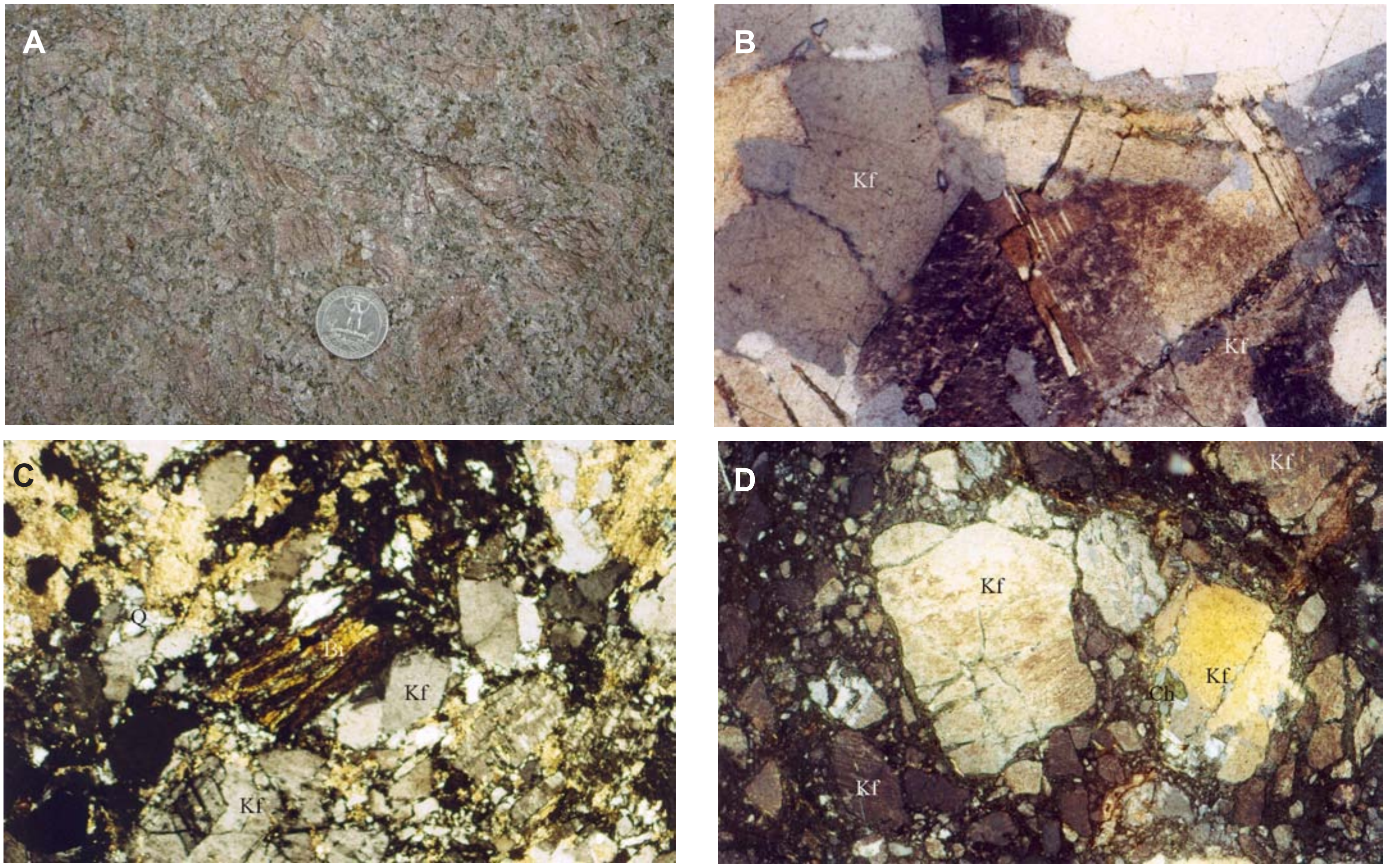


Figure 8. Turner Mountain syenite. (a) Typical porphyritic Turner Mountain syenite on a weathered surface. Picture location at Stop 4047. (b), (c), and (d) are photomicrographs of the syenite. Width of view for each one is 3.5 mm. Cross-polarized light for all of them. (b) Homogeneous potassic feldspar and microcline. (c) Interlocking texture of the medium-grained groundmass made of mostly potassic feldspar, plagioclase, and biotite which has been significantly altered into chlorite. Quartz is finer and scarce. (d) Cataclasized/brecciated syenite with chaotic texture. Microscopic veins of hydrothermal calcite and chlorite fill the cracks and interstitial areas. (b) and (c) are from rock sample #4118 whereas (d) is from #4255-1, next to a fault.

fied by brittle faulting (Figure 9a). Red siltstones within the aureole become pale green biotite hornfels (Figures 9a and 9b) due to conversion of hematite into biotite by increasing heat most likely from the syenite magma. The biotite hornfels are characterized by numerous newly-nucleated microscopic tiny biotite and some hornblende crystals (Figures 9b, 9c, and 9d). The clastic texture could be completely replaced by crystalline texture due to re-crystallization (Figures 9c and 9d). The biotite hornfels were later affected by superimposed brittle faulting, resulting in formation of numerous microscopic hydrothermal chlorite and calcite veins (Figure 9c) throughout the contact zone.

The intrusive contact relation with the redbeds demonstrates a hitherto unsuspected post-redbed age for the syenite. Moreover, the syenite intrusion has long been mapped as a fault sliver within the Norumbega fault system, but no ductile deformation is observed within the intrusion at all, suggesting that it might have intruded the Norumbega fault system between the early phase of ductile shearing and onset of very late-stage brittle deformation. The brittle reactivation of the Norumbega system and transtensional regime for the development of the pull-apart redbed basin (Wang and Ludman, 2003) may have facilitated the emplacement of the Turner Mountain syenite. Radiometric dating is needed to confirm the age of the syenite.

STRUCTURAL GEOLOGY

Deformation structures within metasedimentary formations

Rocks of both the Vassalboro and Bucksport Formations were folded, foliated, and metamorphosed during the Acadian orogeny. The regional metamorphic grade is low greenschist facies and original bedding (S_0) is well preserved. The bedding generally strikes northeast and dips toward either northwest or southeast due to repeated Acadian folds (Figure 1). However, because of poor exposure, tightness of folding, and lithologic similarity, regional-scale folds within both formations are not mappable.

In the field, however, outcrop-scale folds are abundant. Most of them are isoclinal and intraformational with well-devel-

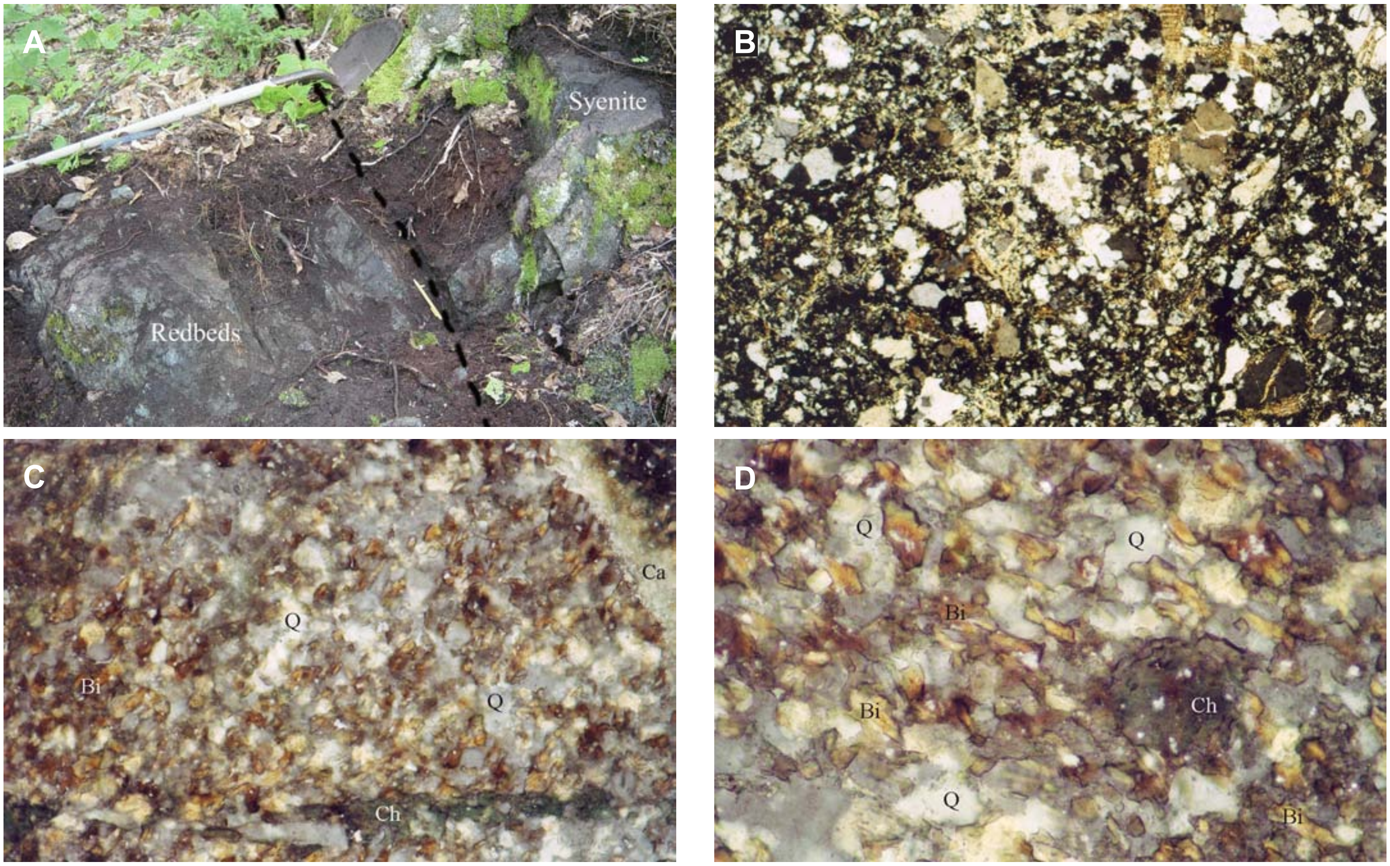


Figure 9. (a) Outcrop of intrusive contact between the Turner Mountain syenite on the right and the pale green hornfelsed siltstone "redbeds" on the left. Picture location at Stop 4255. View facing northeast. (b), (c), and (d) are photomicrographs of the biotite hornfels next to the contact. Width of view is 3.5 mm for (b), 1.8 mm for (c), and 0.9 mm for (d). Cross-polarized light for all of them. (b) is from rock sample #4255-2 whereas (c) and (d) from # 4257. See the text for more explanation.

oped axial-plane cleavage (Figure 2a). Axial-plane cleavage (S_1) is penetrative throughout both formations; it is mostly parallel to original bedding (S_0) or locally slightly oblique to original bedding. Measurements of foliation in the quadrangle show a northeast trend with steep dips to either northwest or southeast (Figure 1).

Rocks of the Vassalboro Formation next to the redbeds were involved in the early Norumbega ductile shearing to become strongly foliated phyllonite as discussed earlier. Quartz veins and boudins are common within the phyllonite. The width of the phyllonite zone is estimated to be less than 500 m.

Only minor brittle faults were observed within the metasedimentary rocks. Joints are common and most of them strike northeast and southeast (Figure 10).

Deformation structures within granite plutons

The northwestern margin of the Lucerne granite pluton was involved in the early Norumbega ductile shearing and became the prominent zone of mylonite and ultramylonite mentioned above that will be discussed in more detail in the next section. The rest of the Lucerne granite and the Deblois granite within the Great Pond quadrangle are, however, not significantly deformed at all except for minor and outcrop-scale shears and faults observed at some stops.

Outcrop-scale minor ductile and half-ductile (ductile-brittle) shears occur within both Lucerne and Deblois plutons (Figure 7a). Most of them strike north and northeast and show a dextral shear sense, suggesting their association with the early dextral ductile shearing along the Norumbega fault system. They are always truncated or crosscut by minor brittle faults that strike mostly northeast and southeast (Figure 7a).

The Norumbega fault system

The most significant deformational structural feature within the Great Pond quadrangle is the Norumbega fault system. The fault system extends 2-3 km across the redbeds and the ductilely sheared Lucerne granite. It has a prolonged history involving early ductile deformation along the contact between the Vassalboro Formation to the northwest and the Lucerne granite pluton to the southeast, and subsequent brittle reactivation that is

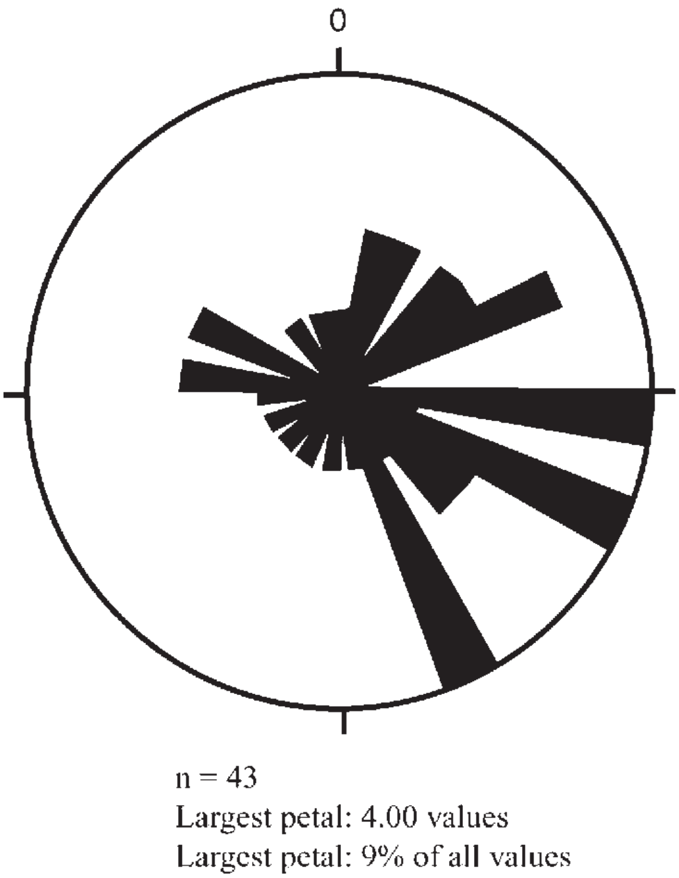


Figure 10. Strike rose diagram of joints. 10° classes. See the text for explanation.

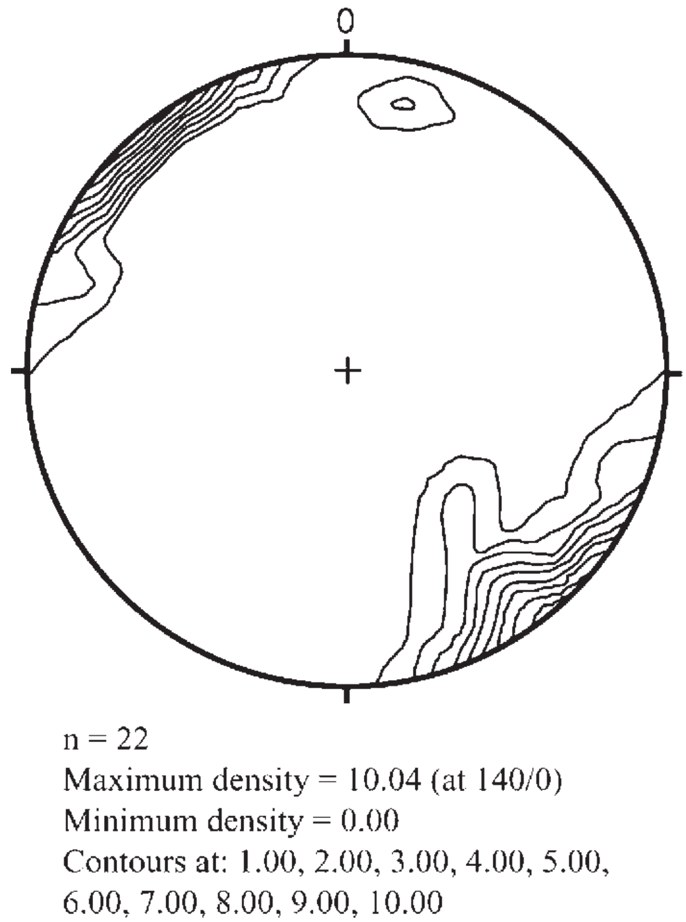


Figure 11. Equal-area stereogram showing poles to mylonitic foliation developed in the granitic mylonite and ultramylonite zone. See the text for explanation.

presented as through-going brittle faults and pull-apart redbed basins.

Early ductile shearing and the ductile shear zone

As discussed early, the northwest side of the Lucerne granite pluton within the quadrangle was involved in the early Norumbega ductile shearing and the megacrystic coarse-grained granite was ductilely sheared into mylonite and ultramylonite. This ductile shear zone is about 1.5 km wide and extends northeast and southwest into adjacent quadrangles.

To the northeast in the nearby Gassabias Lake and Fletcher Peak quadrangles, the Kellyland ductile shear, one of the branches of the Norumbega fault system in eastern Maine, also follows the contacts between granitic intrusions and their metasedimentary country rocks. However, intensity of ductile deformation in the Great Pond quadrangle is much higher as evidenced by a much wider zone of very high-strain granitic mylonite and ultramylonite described in the previous sections.

The granitic mylonite and ultramylonite are characterized by well-developed and penetrative mylonitic foliation defined by quartz ribbons and feldspar cataclasis bands (Figure 6). The foliation strikes northeast around 45^{o}-55^{o} and dips mostly toward the northwest at a very steep angle within the high strain zone (Figure 11). Southeastward, in the transition zone of less sheared, low strain, and slightly foliated granite (protomylonite granite as discussed earlier), the foliation strikes more northerly to around 010^{o}-015^{o}, indicating a dextral shear drag effect.

Other classes of shear-sense indicators observed within the ductile shear zone in the granite also suggest a dextral strike-slip motion, being consistent with its coeval eastern Maine and south-central Maine ductile shear extensions (Ludman, and others, 1999; Swanson, 1999b; Wang and Ludman, 2004).

Fault reactivation and brittle faults

Significant brittle fault reactivation has been observed along the length of the Norumbega fault system in eastern-central and eastern Maine by previous studies (Wones, 1977, 1980; Wones and Ayuso, 1993; Ludman, 1998; Ludman and others, 1999; Wang and Ludman, 2003). Wang and Ludman (2003) identified three episodes of subsequent brittle fault reactivation that were superimposed on early ductile shear zones in nearby eastern Maine in the northeast.

In the Great Pond quadrangle, multiple brittle fault reactivation episodes also characterize the Norumbega fault system. Field structural relations show that the earliest through-going brittle fault motion took place along the mylonitic contact between the Lucerne granite and the Vassalboro Formation. This brittle fault later evolved into a transtensional pull-apart basin in the Great Pond and the neighboring Horseback quadrangles due to dextral strike-slip faulting. According to previous studies (e.g. Wones and Ayuso, 1993; Wang and Ludman, 2003), the 700-1400 m wide pull-apart basin extends from about the northeast corner of the Great Pond quadrangle southwestward for nearly 30 km to the Chemo Pond area, northwest of Clifton. After deposition of redbeds within the pull-apart basin, and probably emplacement of the Turner Mountain syenite within the redbeds, there was another episode of brittle faulting that was most likely compressional and dip-slip so that the contacts between the redbeds, the granitic ductile shear zone, and the Vassalboro Formation are now fault contacts and the redbeds are steeply tilted. An estimated 40 m wide zone of breccia and cataclasite separating the granitic mylonite and ultramylonite zone from the syenite and redbeds is of a prominent fault. The northwestern contact of the syenite intrusion was also modified by minor southeasterly-dipping thrust faults (e.g. Figure 9a).

In the field, slickenlines on secondary fault surfaces showing dip-slip, strike-slip, and oblique-slip motions are common, suggesting multiple and probably minor motions of brittle faulting along the fault zone for a long while.

GEOLOGIC HISTORY

In the Great Pond quadrangle, the earliest recorded geologic history began with the deposition of the Central Maine turbidite sequence (the Vassalboro Formation) and the Fredericton Trough turbidite sequence (the Bucksport Formation) within an ocean basin during late Ordovician and Silurian time. The Acadian orogeny in Late Silurian through Early Devonian times closed the ocean and folded these sequences and regionally metamorphosed their strata to low greenschist facies assemblages.

The Lucerne and Deblois granitic plutons, possibly two lobes of a super-pluton, were emplaced shortly after the Acadian folding and metamorphism at around 380 Ma. Slow cooling and crystallization of the granitic magmas produced the impressive megacrystic coarse-grained texture seen today within each pluton. The metasedimentary rocks around pluton contacts and roof pendants are hornfelsed.

The initial dextral ductile shearing of the Norumbega followed the contact between the newly crystallized Lucerne pluton and the metamorphic country rocks in the Great Pond quadrangle area, producing a 1.5 km wide high strain and ductile shear zone on the northwest margin of the Lucerne pluton. This shearing was coeval with others observed throughout the whole Norumbega fault system in Maine. It ductilely sheared the megacrystic coarse-grained granite into mylonite and extremely fine-grained ultramylonite. Within the ductile shear zone the metasedimentary rocks of the Vassalboro Formation were ductilely sheared into phyllonite. The phyllonite extends southwestward into the nearby The Horseback quadrangle and becomes spangled quartz muscovite schist, a schistose mylonite in the Hopkins Pond quadrangle.

Multiple brittle faulting events caused by fault reactivation following the early ductile shearing along the length of the Norumbega system have been identified in the Great Pond quadrangle. The very early through-going brittle fault motion took place along the mylonitic contact between the Lucerne granite and the Vassalboro Formation. This brittle fault later evolved into a transtensional pull-apart basin due to dextral strike-slip faulting. Gravels, sand, silt, and clay of proximal sources were transported into the pull-apart basin, forming an immature suite of poorly-sorted pebble conglomerate and arkosic granule conglomerate, with finer-grained arkose, sandstone, siltstone, and mudstone. The Turner Mountain syenite probably was emplaced during the opening of the pull-apart redbed basin because it intruded the redbeds and favored an extensional environment. The syenite magma might have followed the southeast boundary fault of the pull-apart basin, forming a shallow and typical porphyritic igneous intrusion.

Later brittle faulting which was most likely compressional and reverse, created a breccia and cataclasite zone at least 40 m wide along the boundary between the granitic mylonite/ultramylonite and the redbeds. The southeast and northwest margins of the syenite were cataclasized due to this brittle faulting.

CONCLUSIONS

A significant improvement in our understanding of the bedrock geology in the Great Pond 7.5' quadrangle has been made with this USGS STATEMAP project, including:

The nature, geometry, and deformational features of the Norumbega fault system in the quadrangle are better understood. A much more precise and accurate bedrock geologic map has been compiled.

The previously defined "Passagassawakeag gneiss" sliver in the quadrangle turns out to be a 1.5 km wide granitic mylonite and ultramylonite zone derived from the Lucerne pluton and produced by early Norumbega ductile shearing. The high-strained ductile shear zone is much wider than to the northeast in eastern Maine.

The Turner Mountain syenite, a shallow porphyritic alkaline intrusion, bears an intrusive contact relation with the Carboniferous (?) redbeds, demonstrating a hitherto unsuspected post-redbed age. The transtensional tectonic environment with respect to the pull-apart basin formation would have facilitated the shallow emplacement of the syenite magma. Another probability that the syenite might have been emplaced during the early Mesozoic Atlantic opening is not excluded. If its post-redbed age is confirmed by future radiometric dating, it would become the first and the youngest syenite pluton in central-eastern and eastern Maine and the only pluton controlled by the brittle reactivation of the Norumbega fault system.

Mapping in the Baker Ridge area suggests a physical connection between the Lucerne and Deblois plutons. Probably both granite plutons are simply two lobes of a super-pluton that are just like the east and west lobes of the Deblois pluton. This is consistent with another suggestion that the northeasterly-striking sliver of significantly hornfelsed metasedimentary rocks of the Bucksport Formation sandwiched by both Lucerne and Deblois plutons could be a thin roof pendant of the super-pluton.

Geologic history of the bedrock and the evolution of the Norumbega fault system in the quadrangle area are better understood and constrained. The initial and early Norumbega ductile shearing juxtaposed along the contact between the Lucerne granite and the Vassalboro Formation metasedimentary rocks, producing a prominent mylonite and ultramylonite zone. Subsequent later shallow and near-surface brittle fault reactivation localized along the mylonitic contact between the mylonitic granite and the phyllonitic Vassalboro metasedimentary rocks, producing a pull-apart redbed basin and probably facilitated the emplacement of the Turner Mountain syenite intrusion.

ACKNOWLEDGMENTS

This report and the accompanying bedrock geologic map of the Great Pond 7.5' quadrangle are the products of a USGS STATEMAP project funded through the Maine Geological Survey. I am very grateful to Dr. Robert Marvinney and Dr. Henry Berry IV of the Maine Geological Survey for their great help and support. Special thanks go to my field assistant Geoffery Nazzaro for his company and hard fieldwork with me in mosquito-infested Maine woods and streams. I thank Dr. Allan Ludman of Queens College for his logistical support and discussions in the field. His review and corrections of the manuscript make this report read much better. Another thanks to Dr. Patrick Brock of Queens College for his help on thin section studies and to Dr. Cecilia McHugh of Queens College for her help on photomicrography.

REFERENCES

Gilman, R. A., 1974, Geologic mapping in the Ellsworth, Great Pond, Lead Mountain, Tug Mountain, and Wesley quadrangles, Maine: Maine Geological Survey, unpublished report and map.

Griffin, J. R., 1976, Reconnaissance bedrock geology of the Great Pond quadrangle, Maine: Maine Geological Survey, Open-file Map 76-22.

Hubbard, M. S., and Wang, H., 1999, Temperature variability during shear deformation: an interpretation of microstructures along the central Norumbega fault system, Maine, *in* Ludman, A. and West, D. P., Jr. (editors), Norumbega fault system of the Northern Appalachians: Geological Society of America, Special Paper 331, p. 25-40.

Hubbard, M. S., West, D. P. Jr., Ludman, A., Guidotti, C. V., and Lux, D. R., 1995, The Norumbega fault system, Maine: mid-shallow level crustal section within a transcurrent zone: Atlantic Geology, v. 33, p. 109-116.

Loiselle, M., Erikkson, S., Wones, D. R., and Sinha, A. K., 1983, Timing and emplacement of post-Acadian plutons in central and eastern Maine: Geological Society of America, Abstracts with Programs, v. 15, p. 187.

Ludman, A., 1998, Evolution of a transcurrent fault system in shallow metasedimentary rocks: the Norumbega fault system, eastern Maine: Journal of Structural Geology, v. 20, p. 93-107.

Ludman, A., and Gibbons, S., 1999, Multistage shearing of the Deblois granite in the Kellyland fault zone, eastern Maine, *in* Ludman, A. and West, D. P., Jr. (editors), Norumbega fault system of the Northern Appalachians: Geological Society of America, Special Paper 331, p. 41-58.

Ludman, A., Lanzirotti, A., Lux, D., and Wang, C., 1999, Constraints on timing and displacement of multiple shearing in the Norumbega fault system, eastern Maine, *in* Ludman, A. and West, D. P., Jr. (editors), Norumbega fault system of the Northern Appalachians: Geological Society of America, Special Paper 331, p. 179-194.

McGregor, J., 1963, Geology of the southeast part of the Great Pond quadrangle, Maine: Maine Geological Survey, unpublished report, 10 p.

Osberg, P. H., 1968, Stratigraphy, structural geology and metamorphism of Waterville-Vassalboro area, Maine: Maine Geological Survey, Bulletin 10, 64 p.

Osberg, P. H., 1988, Geologic relations within the shale-wacke sequence in south-central Maine, *in* Tucker, R. D., and Marvinney, R. G. (editors), Studies in Maine geology; Volume 1 – structure and stratigraphy: Maine Geological Survey, p. 51-73.

Osberg, P. H., Hussey, A .M., II, and Boone, G. M., 1985, Bedrock geologic map of Maine: Maine Geologic Survey, (scale 1:500,000).

Perkins, E. H., and Smith, E. S. C., 1925, Contributions to the geology of Maine, No. 1; A geologic section from the Kennebec River to Penobscot Bay: American Journal of Science, v. 209, p. 204-228.

Simpson, C., 1985, Deformation of granitic rocks across the brittle-ductile transition: Journal of Structural Geology, v. 7, p. 5030511.

Stoesser, D. B., 1966, Geology of a portion of the Great Pond quadrangle, Maine: M.S. thesis, University of Maine, Orono, 87 p.

Swanson, M. T., 1999a, Dextral transpression at the Casco Bay restraining bend, Norumbega fault system, coastal Maine, *in* Ludman, A. and West, D. P., Jr. (editors), Norumbega fault system of the Northern Appalachians: Geological Society of America, Special Paper 331, p. 85-104.

Swanson, M. T., 1999b, Kinematic indicators for regional dextral shear along the Norumbega fault system in the Casco Bay area, coastal Maine, *in* Ludman, A. and West, D. P., Jr. (editors), Norumbega fault system of the Northern Appalachians: Geological Society of America, Special Paper 331, p. 1-24

Trefethen, J. M., 1950, Bucksport-Orland map area: New England Intercollegiate Geological Conference, 42nd Annual Meeting, Bangor, Maine.

Tullis, J. A., and Yund, R. A., 1985, Dynamic recrystallization of feldspar: a mechanism for ductile shear zone formation: Geology, v. 13, p. 238-241.

Wang, C., and Ludman, A., 2003, Evidence for post-Acadian through Alleganian deformation in eastern Maine: multiple brittle reactivation of the Norumbega fault system: Atlantic Geology, v. 38, p. 35-51.

Wang, C., and Ludman, A., 2004, Deformation conditions, kinamatics, and evolution of shallow crustal ductile shearing in the Norumbega fault system in the Northern Appalachians, eastern Maine: Tectonophysics, v. 384, p. 129-148.

West, D. P., Jr., 1999, The timing of displacements along the Norumbega fault system, south-central and south-coastal Maine, *in* Ludman, A. and West, D. P., Jr. (editors), Norumbega fault system of the Northern Appalachians: Geological Society of America, Special Paper 331, p. 167-178.

West, D. P., Jr., and Hubbard, M. S., 1997, Progressive localization of deformation during exhumation of a major strike-slip shear zone: Norumbega fault system, Maine: Tectonophysics, v. 273, p. 185-201.

West, D. P., Jr. and Lux, D. R., 1993, Dating mylonitic deformation by the $^{40}Ar/^{39}Ar$ method: an example from the Norumbega fault system, Maine: Earth and Planetary Science Letters, v. 120, p. 221-237.

West, D. P., Jr., and Roden-Tice, M. K., 2003, Late Cretaceous reactivation of the Norumbega fault system, Maine: Evidence from apatite fission track ages: Geology, v. 31, p. 649-652.

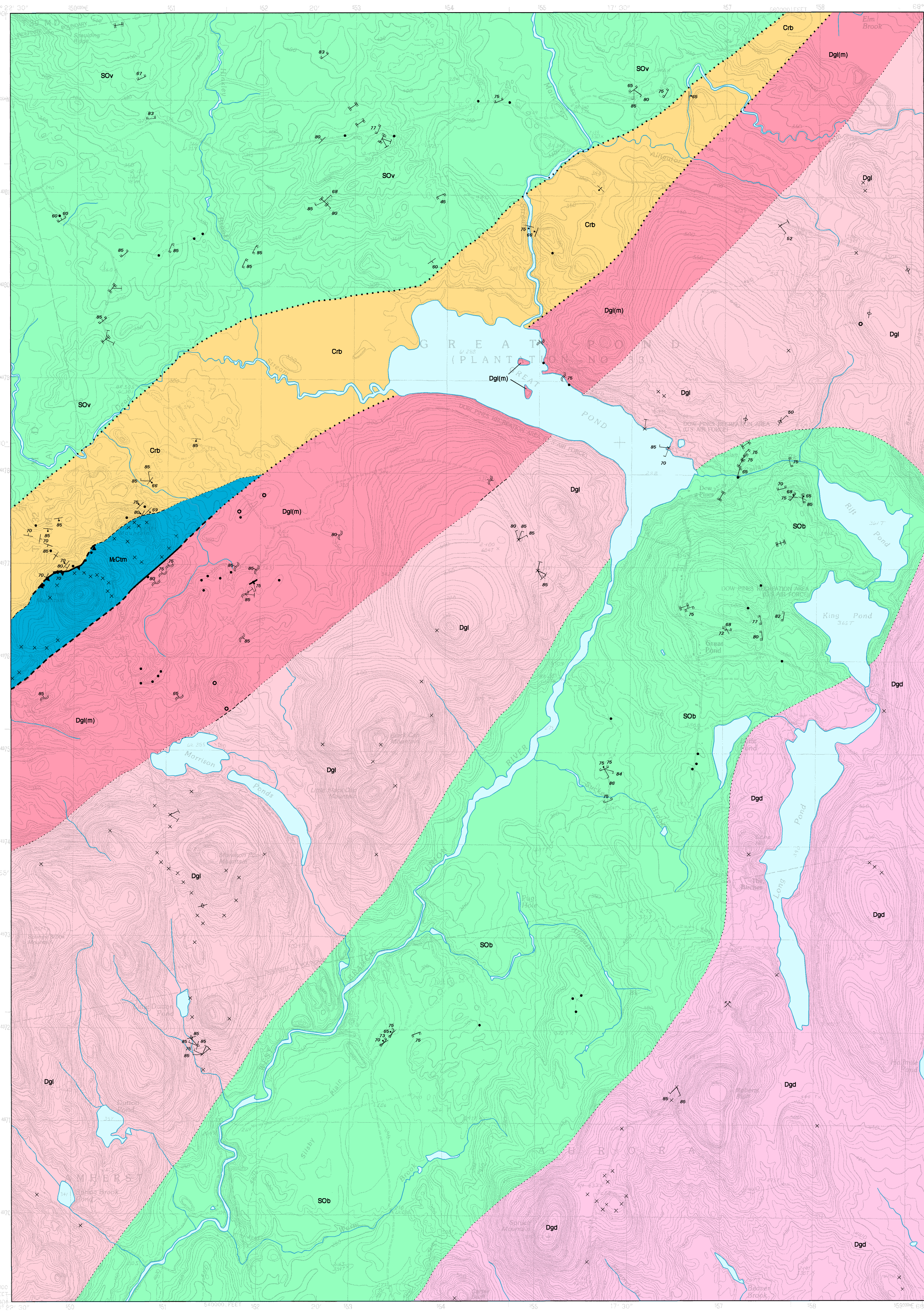
Wing, L. A., 1957, An aeromagnetic and geologic reconnaissance survey of portions of Hancock and Penobscot Counties, Maine: Maine Geological Survey, Geophysical and Geological Survey no. 1, 10 sheets.

Wones, D. R., 1977, Bedrock geologic map of part of the Great Pond quadrangle, Maine: Maine Geological Survey, unpublished map.

Wones, D. R., 1980, Contribution of crystallography, mineralogy, and petrology to the geology of the Lucerne pluton, Hancock County, Maine: American Mineralogist, v. 65, no. 5-6, p. 411-437.

Wones, D. R., and Ayuso, R. A., 1993, Geologic map of the Lucerne granite, Hancock and Penobscot Counties, Maine: U.S. Geological Survey, Miscellaneous Investigations Series Map I-2360.

Zartman, R. E., and Gallego, M. D., 1979, USGS (D)-BUB-8 (Sample 139), USGS (D)-BUB-9 (Sample 140), USGS (D)-BUB-10 (Sample 141), and USGS (D)-ORA-301 (Sample 142), *in* Marvin, R. F., and Dobson, S. W., Radiometric ages: compilation B, U. S. Geological Survey: Isochron/West, no. 26, p. 18-19.



EXPLANATION OF UNITS

Intrusive Rocks

Mesozoic-Carboniferous(?)

MzCtm — **Turner Mountain pluton.** Deeply weathered, dark brown to black porphyritic hornblende-biotite syenite. Characterized by large, pink, euhedral potassic feldspar phenocrysts commonly 2-6 cm long sitting in a medium- to coarse-grained groundmass composed of mostly subhedral orthoclase and plagioclase feldspars, biotite, and hornblende. The syenite intruded the Carboniferous(?) redbeds but its absolute age remains undetermined.

Devonian

Dgd — **Deblois pluton.** A potassic-feldspar-rich, two-feldspar, hornblende-biotite granite characterized by an extremely coarse-grained appearance, distinctive potassic feldspar megacrysts with rapakivi texture, and a seriate texture.

Dgl — **Lucerne pluton.** A potassic-feldspar-rich, two-feldspar, hornblende-biotite granite characterized by a extremely coarse-grained appearance and distinctive pale-white and pink potassic feldspar megacrysts set in a coarse-grained matrix of subhedral albite and anhedral quartz, biotite, and minor hornblende.

Deformed Intrusive Rocks

Devonian(?)

Dgl(m) — **Mylonitized and ultramylonitized Lucerne granite.** Derived from typical Lucerne megacrystic massive granite. Characterized by fine-grained and extremely fine-grained texture due to grain-size reduction during extremely high strain and plastic deformation. The rocks have a well-defined mylonitic foliation.

Stratified Rocks

Carboniferous(?)

Crb — **Unnamed redbeds of conglomerate and sandstone.** Composed of thin to thick beds of red, pebble to cobble conglomerate, arkosic granule conglomerate, arkose, quartz sandstone, and mudstone. Arkosic conglomerate contains mostly clasts of coarse-grained granite, quartz, and potassic feldspars.

Silurian-Late Ordovician(?)

SOb — **Bucksport Formation.** A typical turbidite suite consisting of predominantly dark-gray, thick beds of feldspathic graywacke and medium to thin beds of pelite. Interbedded medium- to thinly bedded siltstones are locally calcareous and weather to a rusty color.

SOv — **Vassalboro Formation.** A typical turbidite suite, composed predominantly of interbedded light gray-, dark gray-, and green-weathering medium to thick beds of feldspathic graywacke and subordinate, thin to medium beds of pelite, siltstone, and calcareous siltstone.

EXPLANATION OF SYMBOLS

- Outcrop of mapped unit.
- Outcrop of non-foliated plutonic rock.
- Large or abundant float blocks, presumed to represent underlying bedrock.
- Active quarry.
- 20 — Strike and dip of bedding, stratigraphic topping direction known. (upright, vertical - ball toward top)
- 20 — Strike and dip of bedding, topping direction unknown. (inclined, vertical)
- 20 — Strike and dip of igneous flow foliation. (inclined, vertical)
- 20 — Strike and dip of metamorphic foliation or cleavage. (inclined, vertical)
- 20 — Strike and dip of mylonitic foliation. (inclined, vertical)
- 20 — Strike and dip of fault plane.
- 20 — Strike and dip of joint. (inclined, vertical)

EXPLANATION OF LINES

Stratigraphic or intrusive contact. (well constrained, approximately located, inferred)

Thrust fault, teeth on upper plate. (well constrained, approximately located)

Fault, motion unspecified. (well constrained, approximately located, inferred)

GEOLOGIC TIME SCALE

Geologic Age		Absolute Age*
Cenozoic Era		0-65
Mesozoic Era	Cretaceous Period	65-142
	Jurassic Period	142-200
	Triassic Period	200-253
Paleozoic Era	Permian Period	253-300
	Carboniferous Period	300-360
	Devonian Period	360-418
	Silurian Period	418-443
	Ordovician Period	443-489
	Cambrian Period	489-542
Precambrian time		Older than 542

* In millions of years before present. (Okulitch, A. V., 2004, Geological time chart, 2004: Geological Survey of Canada, Open File 3040 (National Earth Science Series, Geological Atlas) - REVISION.)

Bedrock Geology of the Great Pond Quadrangle, Maine

Bedrock geologic mapping by
Chunzeng Wang

Digital cartography by:
Robert A. Johnston
Susan S. Tolman

Robert G. Marvinney
State Geologist

Cartographic design and editing by:
Robert D. Tucker
Henry N. Berry IV

Funding for the preparation of this map was provided in part by the U.S. Geological Survey STATEMAP Program, Cooperative Agreement No. 04HQAG0035.

Maine Geological Survey

Address: 22 State House Station, Augusta, Maine 04333
Telephone: 207-287-2801 **E-mail**: mgs@maine.gov
Home page: http://www.maine.gov/doc/nrimc/index.htm

Open-File No. 12-33
2012

This map accompanied by a 15 p. report.

SCALE 1 : 24,000

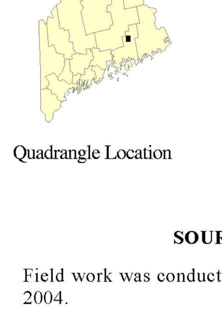
1 — 0 — 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 — 0 — 1 KILOMETER

CONTOUR INTERVAL 10 FEET

TRUE NORTH



Quadrangle Location

SOURCES OF INFORMATION

Field work was conducted by Chunzeng Wang during the summer of 2004.

Topographic base from U.S. Geological Survey Great Pond quadrangle, scale 1:24,000 using standard U.S. Geological Survey topographic map symbols.