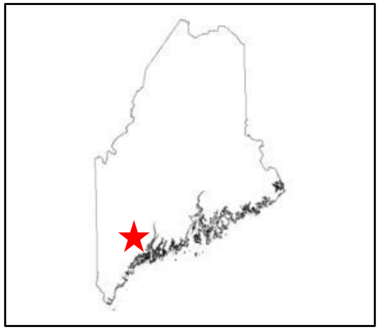
Geologic Site of the Month

July, 2010

Migmatite in New Gloucester, Maine



43 52‘ 46.19“ N, 70 19‘ 58.62“ W

Text by
Henry N. Berry, IV

Introduction

In 2005, a section of Maine Route 26 north of Turnpike Exit 63 (Gray) was rebuilt and relocated. One section of new road in New Goucester, about 1.3 miles north of the Maine Wildlife Park, required significant blasting of bedrock to reduce the road steepness. The resulting roadside rock cut exposures are the subject of this web site.

If you choose to visit on your own, please use extreme caution, because traffic moves fast on this new road. Do not park vehicles on Route 26. Instead, use the DOT Park and Ride Lot near the beginning of Sabbathday Road. The UTM coordinates for this parking lot are 0391688, 4866759 (NAD 27, Zone 19).

Glimpse into the Earth

These rocks are in the eastern part of a large region of granite shown on the 1985 Bedrock Geologic Map of Maine as the Sebago batholith (Figure 1).

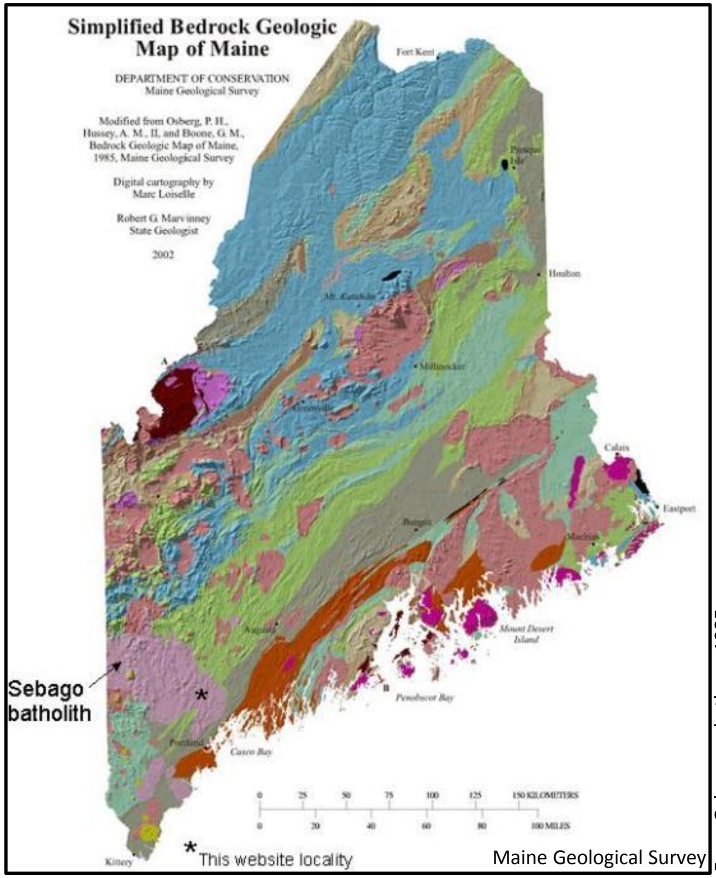


Figure 1. The Sebago batholith (shown in pink) covers a large area of southern Maine. Asterisk indicates the locality described in this web site.

Glimpse into the Earth

As the 1985 map suggests, the eastern part of the batholith is complicated, and contains a mixture of granite and metamorphic rocks (Figure 2). Granite is an igneous rock. It forms when other rocks are heated to sufficient temperature in the earth to partially melt; the melted rock then collects and flows into larger bodies of melt which then solidify into granite. Not all igneous rocks are granite, and not all granites are alike, but all igneous rocks form by solidification from molten rock.

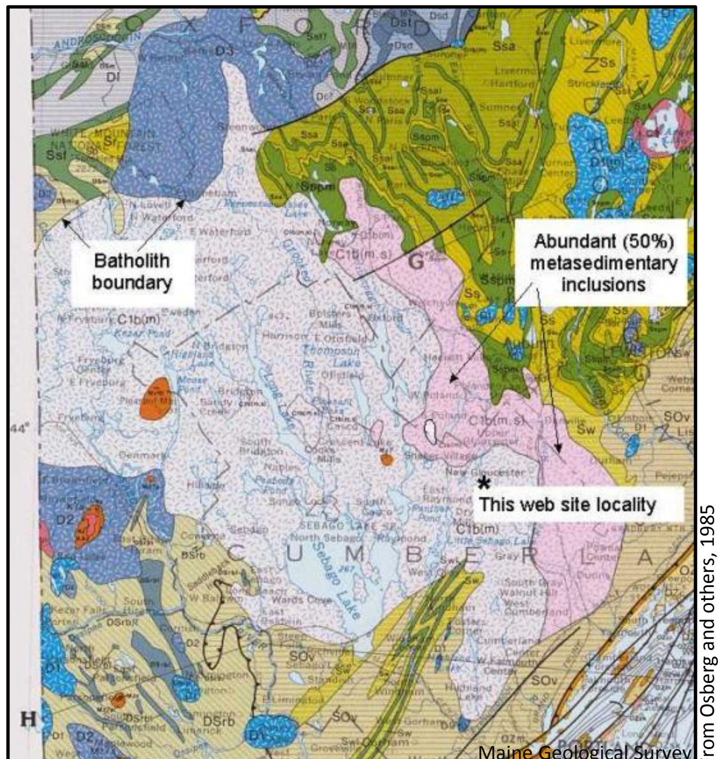


Figure 2. The 1985 Bedrock Geologic Map of Maine shows that a substantial area along the eastern side of the Sebago batholith includes abundant inclusions of metamorphic rock.

Glimpse into the Earth

Many roadside exposures in this area, such as the one in Figure 3, appear to consist mostly or entirely of light gray to white granite.

Figure 3. This outcrop on the east side of Route 26 consists almost entirely of granite.

Glimpse into the Earth

The vertical cuts beside the road, however, expose rocks beneath the surface, which show that there are many varieties of rock (Figure 4). The dark colored metamorphic rocks are what remain of the pre-existing rocks which were heated and partially melted. When igneous and metamorphic rocks are found together it is called migmatite.

Figure 4. A vertical cut through the rock shows that it is not solid granite, but contains layers and streaks of dark-colored metamorphic rock as well. This is across the road from the rock shown in Figure 3.

Migmatite

The proportion of light-colored granite to dark-colored metamorphic rock, and the shapes of the various types of rock are variable in the exposures, both along the rock face from one end to the other, and from bottom to top. A layered structure is dominant, with the layers generally horizontal, though careful tracing of individual layers shows that they may curve gradually up and down, and their thicknesses change from bulging to pinched.

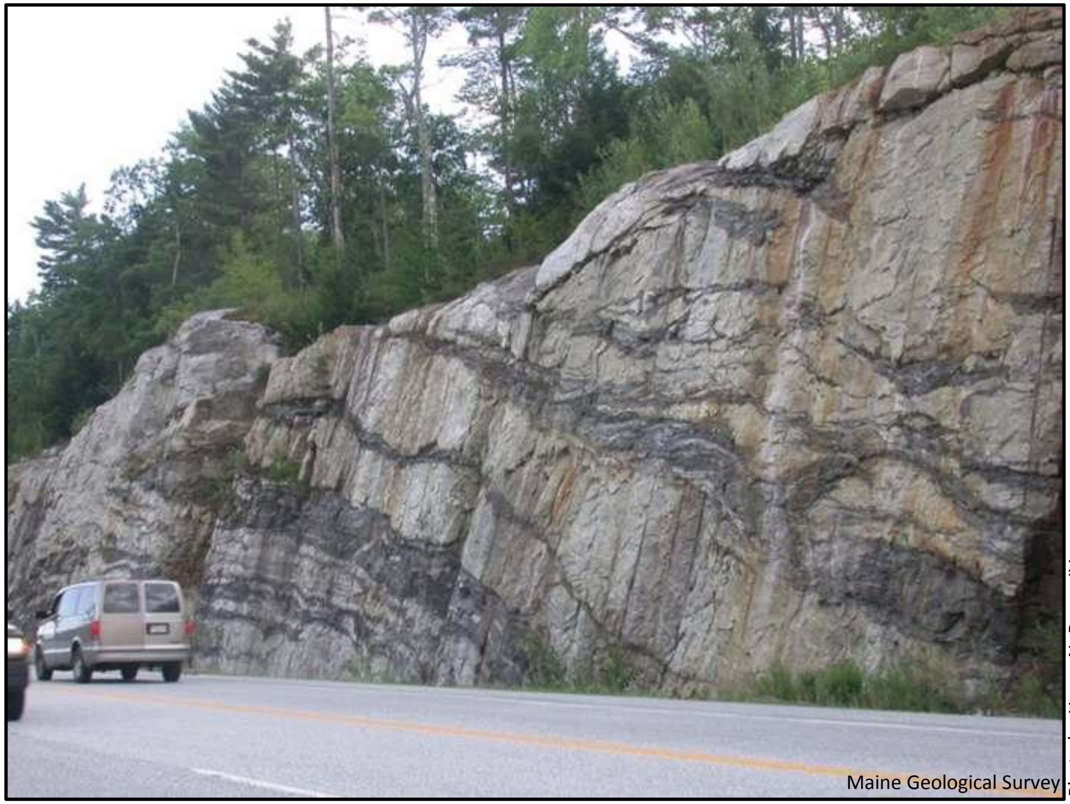


Photo by Henry N. Berry, IV

Figure 5. Migmatite with thick layers of granite.

Migmatite

In some places, the granite layers are thick (Figure 5); in other places thick layers of metamorphic rock dominate (Figure 6).

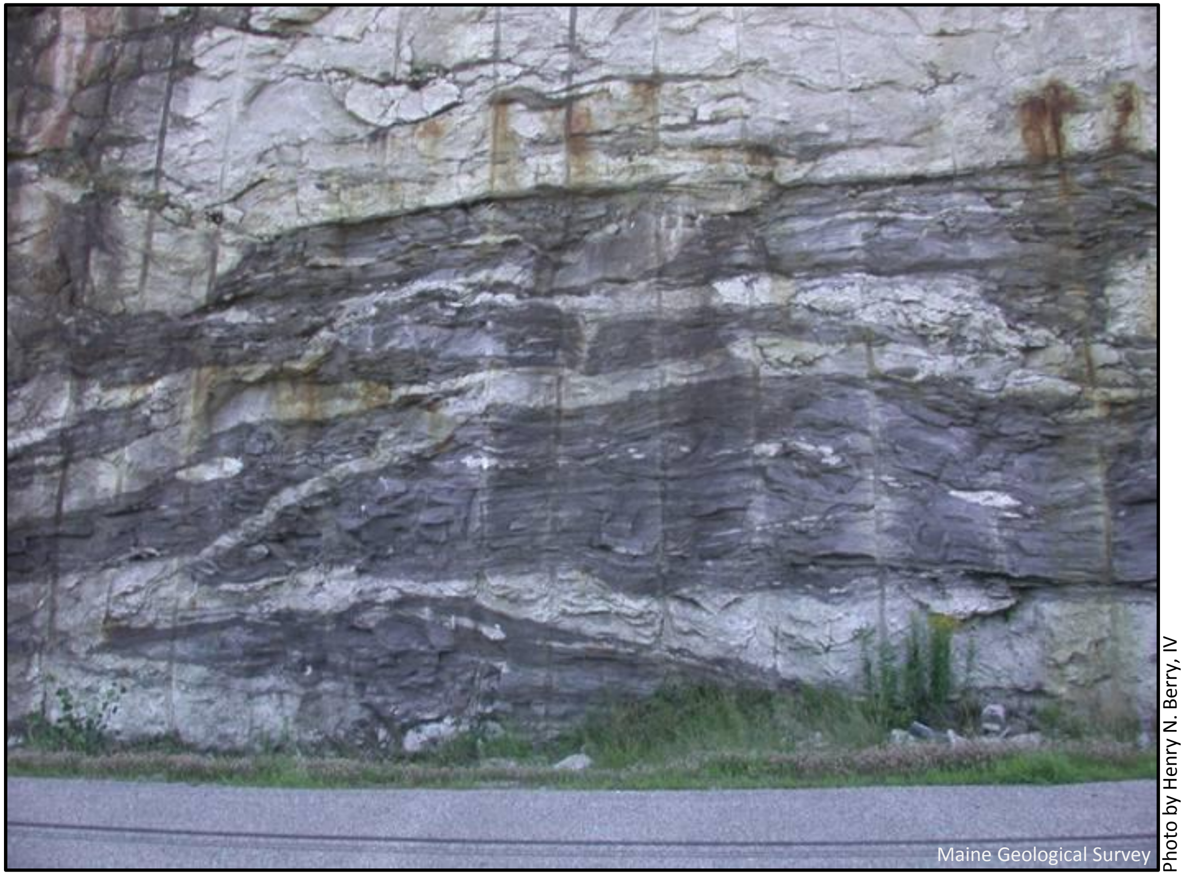


Figure 6. Migmatite dominated by thick layers of dark-colored metamorphic rock.

Migmatite

In detail, the granite cuts across the metamorphic layers to form an interconnected network (Figure 7).

Photo by Henry N. Berry, IV

Figure 7. Granite forms a network of veins and layers through the migmatite.

Migmatite

In extreme cases, granite has engulfed the metamorphic rocks so that only disconnected wisps remain (Figure 8). These sorts of relationships would be difficult to see by looking down on the tops of bedrock outcrops normally found in woods and fields.

Photo by Henry N. Berry, IV

Figure 8. Migmatite in which granite has engulfed the metamorphic rocks, leaving disconnected remnants.

Interaction between Granite and Metamorphic Rock

The metamorphic rocks have an internal fabric that was probably produced by heat and pressure which affected them as solid rocks, before the rock melted. Similar fabric is found in metamorphic rocks well outside the granite. Therefore, some of the mineral alignment and folding in the metamorphic rocks is probably older than the granite. On the other hand, there are structural features produced by heat and pressure which affect both the granite and the metamorphic rocks together. These features indicate that the granite was not emplaced quietly and passively, but in a dynamic environment. Igneous and metamorphic rocks are deformed by the same folds (Figure 9-10).

Photo by Henry N. Berry, IV

Figure 9. Thin layers of folded granite in the metamorphic rock.

Interaction between Granite and Metamorphic Rock

Figure 10. Close-up showing granite and metamorphic rocks deformed together.

Interaction between Granite and Metamorphic Rock

And, beautifully scalloped edges show that some of the metamorphic rocks were soft and malleable due to heat and pressure at the time that the molten granite was flowing around them (Figure 11).

Figure 11. Scalloped contacts between the dark-colored metamorphic rock and the light-colored granite indicate that the metamorphic rock was being deformed while the granite was still molten.

Granite Types

There are several different varieties of granite at this locality. The most obvious variable is the size of the mineral grains that comprise the rock. Rocks with large mineral grains are said to be coarse-grained (Figure 12, Figure 14).

Photo by Henry N. Berry, IV

Figure 12. Coarse-grained granite.

Granite Types

Those with small mineral grains are said to be fine-grained (Figure 13). The predominant minerals of all true granites are feldspar and quartz. In the rocks here, the feldspar is milky white and the quartz is clear to translucent gray. Black mica (biotite) is almost always present, but in small amounts.

Photo by Henry N. Berry, IV

Figure 13. Fine-grained granite.

Granite Types

Red garnet has been found in a few of the rocks here (Figure 14). Two granites of different grain size may have similar mineral compositions, and two granites of similar grain size may have different mineral compositions.

Photo by Henry N. Berry, IV

Figure 14. Coarse-grained granite with garnet.

Interaction among Granite Types

According to the fundamental rule of cross-cutting relationships, an igneous rock which cuts across another rock is younger than the other rock. At this field site, coarse-grained and fine-grained granites are found in many different relationships, suggesting either a complicated process or a complicated history of granite formation, or both. In some places, the fine-grained granite clearly cuts across coarse-grained granite (Figure 15).

Photo by Henry N. Berry, IV

Figure 15. Fine-grained granite (on the right) cuts across coarse-grained granite and metamorphic rock. The pencil is aligned with streaks in the fine-grained granite, parallel to the contact, that formed when it flowed into place. There is a concentration of coarse black mica (biotite) along the contact.

Interaction among Granite Types

In some places, veins of coarse-grained granite cut through fine-grained granite (Figure 16).

Figure 16. Thin veins of coarse-grained granite cut through fine-grained granite. (The vertical grooves are drill holes from the blasting work.)

Interaction among Granite Types

In many places, especially in the coarse-grained granite, there are granites of different grain sizes mixed together in patches that merge with each other without distinct boundaries (Figure 17).

Photo by Henry N. Berry, IV

Figure 17. Granite with different grain sizes from place to place, in irregular patches with diffuse boundaries.

Interaction among Granite Types

Some thick and fairly straight layers of very coarse-grained granite cut through fine-grained granite (Figure 18), although in this particular case, their boundary is not clean, and suggests that the two rocks were molten at the same time (Figure 19).

Photo by Henry N. Berry, IV

Figure 18. A thick layer of very coarse-grained granite (called pegmatite), which cuts diagonally through fine-grained granite. The pegmatite contains coarse flakes and books of white mica (muscovite).

Interaction among Granite Types

Figure 19. Close-up of the edge of the pegmatite in Figure 18. Notice that the minerals of the pegmatite and the fine-grained granite are intergrown along the contact, and a small patch of pegmatite is surrounded by fine-grained granite. Together these observations suggest that the granite had not completely solidified when the pegmatite intruded.

Interaction among Granite Types

And in some places, thin layers of fine-grained granite cut cleanly across all the other granite types, indicating that it is the youngest rock, at least in this particular place (Figure 20).

Photo by Henry N. Berry, IV

Figure 20. A thin layer of fine-grained granite cuts diagonally through the rock from lower left to upper right, with sharp contacts and fairly uniform thickness. It is younger than all the other rocks in this photograph, although perhaps only slightly younger.

Interaction among Granite Types

Taken together, these relationships suggest that many of the granite types were probably molten and actively moving through the rock at the same time, but that some are clearly younger than others.

Much of the volatility in the melting environment may be ascribed to the metamorphic rocks, which yield fluids when heated. Mixing of fluids rich in water or carbon dioxide with granitic magma can significantly and suddenly influence the grain size and mobility of the magma.

Younger Diabase Dikes

In addition to the migmatites described above, these bedrock exposures contain several thin, nearly vertical dikes of black rock, which cut straight through everything else (Figure 21). They are fine-grained igneous rocks called diabase, or basalt. They formed when magma from deep in the earth was forced upward through fractures.

Photo by Henry N. Berry, IV

Figure 21. A vertical dike of black rock (diabase) cuts across the migmatite.

Younger Diabase Dikes

In contrast to the granites, which intruded when the metamorphic rocks were hot, the diabase dikes intruded through cold, brittle rock and did not interact with the wall rocks. This is illustrated by the straightness of the vertical walls, and the consistent thickness. Some dikes do have small jogs or offsets (Figure 22), but these occur around imperfections in the host rock, where it did not break open cleanly.

Photo by Henry N. Berry, IV

Figure 22. This is a jog in the diabase dike where the walls did not open cleanly. The fracture along the right edge of the dike continued straight upward for only a short distance and then stopped for some reason, and another fracture to its left opened and continued upward. The thin layer of metamorphic rock in the granite probably caused the interruption.

Younger Diabase Dikes

Close inspection of the sides of the diabase dikes shows that the contacts with the host rock are sharp and brittle (Figure 23). The very fine (microscopic) grain size of the diabase, and the brittle fracturing of the granite both indicate that the granite was cold at the time the diabase intruded. Similar diabase dikes in southern Maine are dated at about 200 million years old, which is about a hundred million years younger than the granite.

Photo by Henry N. Berry, IV

Figure 23. Left edge of a diabase dike, in sharp contact with coarse-grained granite. The diabase fills a vertical fracture which opened in the granite. There is a similar vertical fracture in the granite just to the left which could have opened, but didn't. The diabase is a sheet, which continues into the rock, away from the road.

Importance

These extensive roadside exposures allow for detailed study of the character and relationships between the metamorphic rocks and the granitic melt, and also among the several varieties of granite. These studies lead to an understanding of geologic processes during the time of melting and intrusion. A series of geology students at the State University of New York College at Buffalo, under the direction of Prof. Gary Solar, and at the State University of New York at Oswego, under the direction of Prof. Paul Tomascak, have been studying these exposures in detail, both through careful descriptive field studies and a variety of laboratory studies. Some of this work has been presented at professional meetings by LaFleur and others (2008), Nyitrai and others (2009), and Bohlen and others (2010). These studies are gradually telling the story of how granite formed at this place. Similar meticulous studies have been done at other sites in the region (Hayes and Solar, 2006; Gulino and others, 2001; Kalczynski and Solar, 2008; Thalhamer and Solar, 2010).

This site is also important in understanding the nature of the Sebago batholith, a dominant feature of southern Maine geology, and the largest plutonic complex in Maine. Since the time of the 1985 State bedrock map, several workers have shown that the batholith is more complicated than had been appreciated previously. Quadrangle mapping, especially east of Sebago Lake, delineated several varieties of granite (Creasy, 1996; Creasy and Robinson, 1997). The regional map was redrawn to emphasize the area of migmatite east of the granite (Berry and Hussey, 1998). Several chemical and isotopic studies demonstrated a variety of melt sources and ages among the granites and migmatites (Tomascak and others, 1996a, 1996b; Cirmo and others, 2006; McAdam and others, 2009). As these lines of research evolve, regional interpretations of the history and significance of the Sebago batholith are continually reassessed (Tomascak and others, 1996a, 1996b; Creasy and others, 1998; Guidotti and others, 1998; Solar and Tomascak, 2001, 2002; Tomascak and Solar, 2001; Tomascak and others, 2008).

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