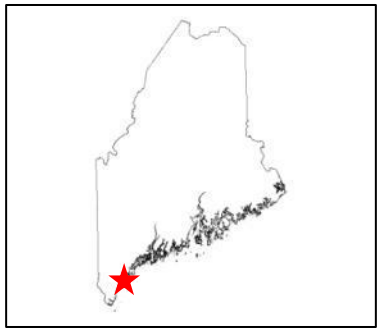
Geologic Site of the Month

September, 2012

Coastal Ledges of Kittery Formation, Granite, and Basalt East Point Sanctuary, Biddeford Pool



43° 26‘ 50.15“ N, 70° 20‘ 2.68“ W

Text by
Henry N. Berry IV

Introduction

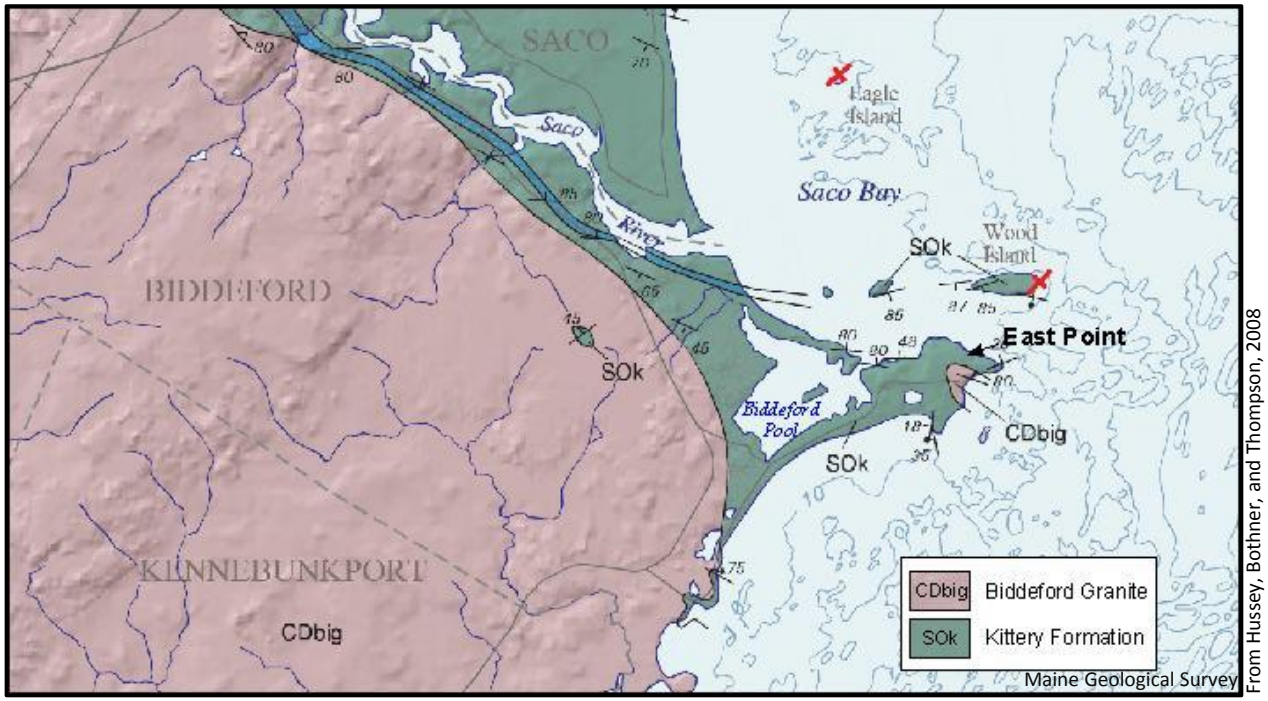
Three major rock types dominate the bedrock of southern Maine: broad units of metamorphosed sedimentary rock, large masses of intrusive igneous rock, and thin dikes of basalt. At East Point Sanctuary in Biddeford Pool, all three of these bedrock types can be found together. The geologic relationships that can be demonstrated in this small area are representative of a large part of York County.

The Maine Audubon Society maintains a shore path at the East Point Sanctuary in Biddeford Pool. For directions and important information about visiting the site, go to the Saco Bay Trails web site. In particular, note that parking is very limited, pets are not allowed, and the privacy of neighborhood residents should be respected.

The recent bedrock geologic map of southern Maine (Hussey, Bothner, and Thompson, 2008 - 12.6 Mb pdf) shows that the Kittery Formation is the bedrock unit for a region along the Maine coast all the way from the New Hampshire line to Saco. The only significant interruption is a large body of granite, called the Biddeford Granite, which intrudes the Kittery Formation in a large area of Kennebunkport and Biddeford.

Regional Bedrock Geology

Figure 1 shows a portion of the bedrock map for the Biddeford area, including Biddeford Pool. The large main body of Biddeford Granite is roughly oval-shaped, approximately 6 miles by 10 miles across. Another small body of Biddeford Granite occurs along the coast east of Biddeford Pool, south of East Point. The bedrock at the point itself belongs to the Kittery Formation. In addition, dikes of basalt up to a few feet thick, are common, a few of which are represented on the map by red symbols. Many dikes of basalt intrude both the granite and the rocks of the Kittery Formation, as we shall see.



From Hussey, Bothner, and Thompson, 2008

Figure 1. Local bedrock map, showing Biddeford Pool and East Point.

What to See Here: Kittery Formation

The Kittery Formation is a thick sequence of layered sedimentary rocks that have been metamorphosed, or changed by heat and pressure. The layers, or beds, were originally sediments such as sand, silt, and mud, deposited in an ancient ocean basin (not the Atlantic), probably during the Silurian Period of geologic time. During metamorphism, the mineral composition and texture of the rock were changed, although the sedimentary layering is still well preserved. The most representative rock of the Kittery Formation is granofels, or metamorphosed sandstone, in medium to thick beds (Figure 2). The beds are distinguished from one another by having different colors, composition, and weathering character, among other things. The fresh rock is a bluish-gray, lavender-gray, or greenish-gray color. Individual mineral grains are very small, giving the rock a finely speckled appearance.

What to See Here: Kittery Formation

The wave-washed surface in Figure 2 displays the greenish-gray and lavender-gray layers that make up the formation. Although they are metamorphic rocks, the original sedimentary character is well preserved. Beds of sandstone and siltstone from 20 centimeters to over a meter in thickness are characteristic of the formation. Originally horizontal, the layers are now tilted steeply to nearly vertical. White, weathered pods are calc-silicate rock, which represents an impure limy sediment.

Photo by Henry N. Berry IV

Figure 2. A beautiful outcrop of the Kittery Formation.

What to See Here: Granite

The Biddeford Granite is a light gray to white, uniform rock (Figure 3). It may be cut by sets of cross-cutting fractures, but it is not layered. Weathered surfaces develop a pale brown to pinkish-brown hue. The rock is composed of mineral grains about 1⁄8 to 1⁄4 inch across, much larger than the mineral grains in the Kittery Formation. Most of the rock consists of the light-colored minerals quartz, plagioclase feldspar, and alkali feldspar. A few flakes of black mica (biotite) are scattered through it. As with all granite, this rock formed from a molten mass that melted somewhere at depth, intruded into the overlying rocks while still molten, and solidified while still underground. This process produced a rock with interlocked mineral grains of uniform size.

What to See Here: Granite

Figure 3 shows a large, uniform piece of granite bedrock with no fractures. Expansion and contraction of the outer surface due to hot and cold weather cycles over time, causes the outer surface to break away from the underlying rock in thin sheets. This natural weathering process is called exfoliation.

Photo by Henry N. Berry IV

Figure 3. A uniform outcrop of granite bedrock exhibiting exfoliation.

What to See Here: Basalt Dikes

Though they constitute only a small volume of the bedrock, the vertical sheets of basalt are easy to spot. They have a dark rusty-brown weathered surface, straight sides, and break into angular blocks (Figure 4). The dike is broken by a small fault, so that the dike in the foreground does not continue all the way to the vegetation, but is offset to the right. The fault creates an imperfection in the rock that is exploited by wave erosion to produce a small notch in the bedrock surface.

Photo by Henry N. Berry IV

Figure 4. This brown-weathering dike intrudes across the bedding of the Kittery Formation.

What to See Here: Basalt Dikes

Each vertical sheet, called a dike, formed when magma filled a fracture as it was opening. The rock itself is a dark gray to black igneous rock that has very small grains, entirely visible only under magnification. In some places, the rock contains scattered larger grains of feldspar (Figure 5). This texture of two dominant grain sizes, is called porphyritic. A porphyritic texture may be produced by a two-stage crystallization process, in which the larger crystals began to form first, at a deeper level in the earth, and then the rest of the rock crystallized rapidly into very fine crystals at the time the dike was emplaced into colder rocks.

Photo by Henry N. Berry IV

Figure 5. Close-up view of one of the dark-colored dikes where it is not covered by the brown weathering rind.

What to See Here: Structural Features and Cross-cutting Relationships

The main structural features of the bedrock are the bedding in the Kittery Formation (Figure 6, Left), the fractures in the granite (Figure 14), and the long, straight dikes (Figure 6, Right).

Photos by Henry N. Berry IV

Figure 6. (Left) The beds in the Kittery Formation here are tilted away from the viewer and a bit to the left (north-northwest). Wood Island Light is built on the next outcrop of Kittery Formation. (Right) The contact between a dike (brown rock to the left) and the Kittery Formation (gray rock to the right) is a structurally weaker zone in which the rock is more easily broken and eroded by the sea. This produces a prominent "step" in the outcrop surface.

What to See Here: Structural Features and Cross-cutting Relationships

In addition, minor faults cut the rock in a few places. These structural features control properties of the rock such as weathering and groundwater flow. Cross-cutting relationships demonstrate the geologic history by which the various features formed. The oldest rock is the Kittery Formation. After the layers had formed, they were deformed by folding (Figure 7).

Photo by Henry N. Berry IV

Figure 7. Light and dark gray beds of the Kittery Formation are folded, together with white quartz veins that have formed in some beds. This sort of folding occurs during metamorphism, when the rocks are at high temperature and pressure at depth in the earth.

What to See Here: Structural Features and Cross-cutting Relationships

The Biddeford Granite intruded later, as demonstrated by fragments of Kittery Formation enclosed by the granite (Figure 8). The fragment enclosed in granite is called a xenolith, or "foreign rock". This relationship indicates that the Kittery Formation is older than the granite.

Photo by Henry N. Berry IV

Figure 8. A xenolith in the Biddeford granite. The layers in the xenolith indicate that it was a sedimentary rock, probably a piece of the Kittery Formation.

What to See Here: Structural Features and Cross-cutting Relationships

Finally, the basalt dikes intruded into both the Kittery Formation and the granite (Figure 9). This relationship indicates that the dike is younger than the granite. The dike rock is basalt, a very fine-grained, dark-colored rock. Modern beach sand partly covers the bedrock.

Photos by Henry N. Berry IV

Figure 9. (Left) A dike of dark-colored rock cutting through granite. (Right) The brown-weathering dike in the middle of the photo cuts sharply across the bedding in the Kittery Formation, nearly at right angles.

What to See Here: Coastal Ledges, Beaches, and Bluffs

Modern geologic processes continue to shape the coast. Storm waves loosen and move blocks from the bedrock preferentially along structurally weaker zones such as dikes, faults, and fractures. Pocket beaches form in small recesses between rocky headlands (Figure 10). For some reason, the bedrock surface at this place has been eroded deeply enough that it is completely covered by sediment, mainly cobbles and pebbles. The bedrock headlands restrict the transport of beach sediment along the shore, which allows this beach to be quite different from the next beach to the south (Site A) which is on granite bedrock.

Photo by Henry N. Berry IV

Figure 10. View toward the southwest from the path.

What to See Here: Coastal Ledges, Beaches, and Bluffs

The beaches may be made of sand or cobbles, but whatever the sediment it is moved by waves of sufficient energy up and down the beach face (Figure 11). Storm waves move the stones up the beach, leaving ridges, or "berms", at particular elevations. Lower berms are reworked by later storms, so the higher berms represent older storms. Most of the stones on the beach are light gray, greenish-gray, and lavender-gray rocks eroded from the Kittery Formation. Compare the color with the bedrock in the foreground, except that any chemical weathering stains are worn away from the cleaner beach stones by wave action.

Photo by Stephen M. Dickson

Figure 11. View of a pebble beach with storm berms.

What to See Here: Coastal Ledges, Beaches, and Bluffs

The bluffs of sediment at the head of the beach and resting on the coastal ledges, are actively being eroded, exposing bare sediment and undercutting sod and plant roots (Figure 12).

Photo by Henry N. Berry IV

Figure 12. Bluff erosion has undercut the sod and exposed roots. Wood Island Light, in the distance, has stood unmoved on solid bedrock for more than 200 years.

Where to Visit

Four areas of geologic interest, labeled Site A through Site D, are indicated on the index map (Figure 13) and on the Google Earth file.

Figure by Henry N. Berry IV

Figure 13. Index map of areas of geologic interest.

Where to Visit: Site A

Site A is an area of Biddeford Granite bedrock (Figure 14). This is the best place to inspect the granite. The granite contains fragments of the Kittery Formation, which sank into the molten rock before it solidified. Also, the granite is intruded by basalt dikes, which must be younger.

Aerial photo from Google Earth

Figure 14. Site A. Area of Biddeford Granite bedrock.

Where to Visit: Site B

Site B is an area of Kittery Formation intruded by several basalt dikes (Figure 15). This is the best place to see the dikes. A small body of granite intrudes the Kittery Formation near the north end of the outcrop, near the beach.

Aerial photo from Google Earth

Figure 15. Site B. Area of Kittery Formation intruded by several basalt dikes.

Where to Visit: Site C

Site C is a pocket beach made of smooth, rounded pebbles and cobbles (Figure 16). Most of the cobbles are light gray rock derived from the Kittery Formation, although some stones of granite and other rock types are mixed in. Notice the ridges (berms) at certain elevations, produced by storm waves. The bluff at the head of the beach is eroding, providing sediment to the beach.

Aerial photo from Google Earth

Figure 16. Site C. Pocket beach of smooth, rounded pebbles and cobbles.

Where to Visit: Site D

Site D is the large outcrop of ledge that extends to the point (Figure 17). It is dominantly Kittery Formation, intruded by a small body of granite toward the south end, and a large basalt dike just below the point of land. Many minor structural features such as folds and faults deform the bedding in the Kittery. The bluff at the point, though not very high, is extremely unstable.

Aerial photo from Google Earth

Figure 17. Site D. A large outcrop of ledge.

Google Earth File

Geologic features of the East Point Sanctuary are presented in an interactive Google Earth file. The file includes polygons showing geologic units and placemarks showing photo localities superimposed on the high-resolution air photo image. You will need to install Google Earth on your computer to view this data. For help using Google Earth go to the Google Earth Help Center.

Geology of the East Point Sanctuary - KML file which opens Google Earth

Using the file. Check the box beside **Photo localities** to see Placemarks where geologic photos are available. Double-click on the name of a Site to zoom to that site. Double-click on numbered Placemarks for oriented snapshot view. Single-click on numbered Placemarks to see photos and captions. Check the box beside **Geology** to display colored polygons showing outcrops of granite and Kittery Formation, red lines highlighting basalt dikes, and purple lines highlighting faults and fractures.

References and Additional Information

Hussey, Arthur M., II, Bothner, Wallace A., and Thompson, Peter J., 2008, Bedrock geology of the Kittery 1:100,000 quadrangle, Maine and New Hampshire: Maine Geological Survey, Geologic Map 08-78, scale 1:100,000 (View map - 12.6 Mb pdf). (Paper copies available from MGS for $6. Ordering instructions)

Sinson, David A., Nestor, Rebecca A., Dickson, Stephen M., Kelley, Joseph T., 2002, Coastal bluffs in the Biddeford Pool quadrangle, Maine: Maine Geological Survey, Open-File Map 02-174, scale 1:24,000. (View map - 2.4 Mb pdf) (Paper copies available from MGS for $5. Ordering instructions)

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