Geologic Site of the Month

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Beautifully Preserved Volcanic Debris in Bedrock, Western Head, Isle au Haut

44° 0’ 58” N, 68° 39’ 21” W

By
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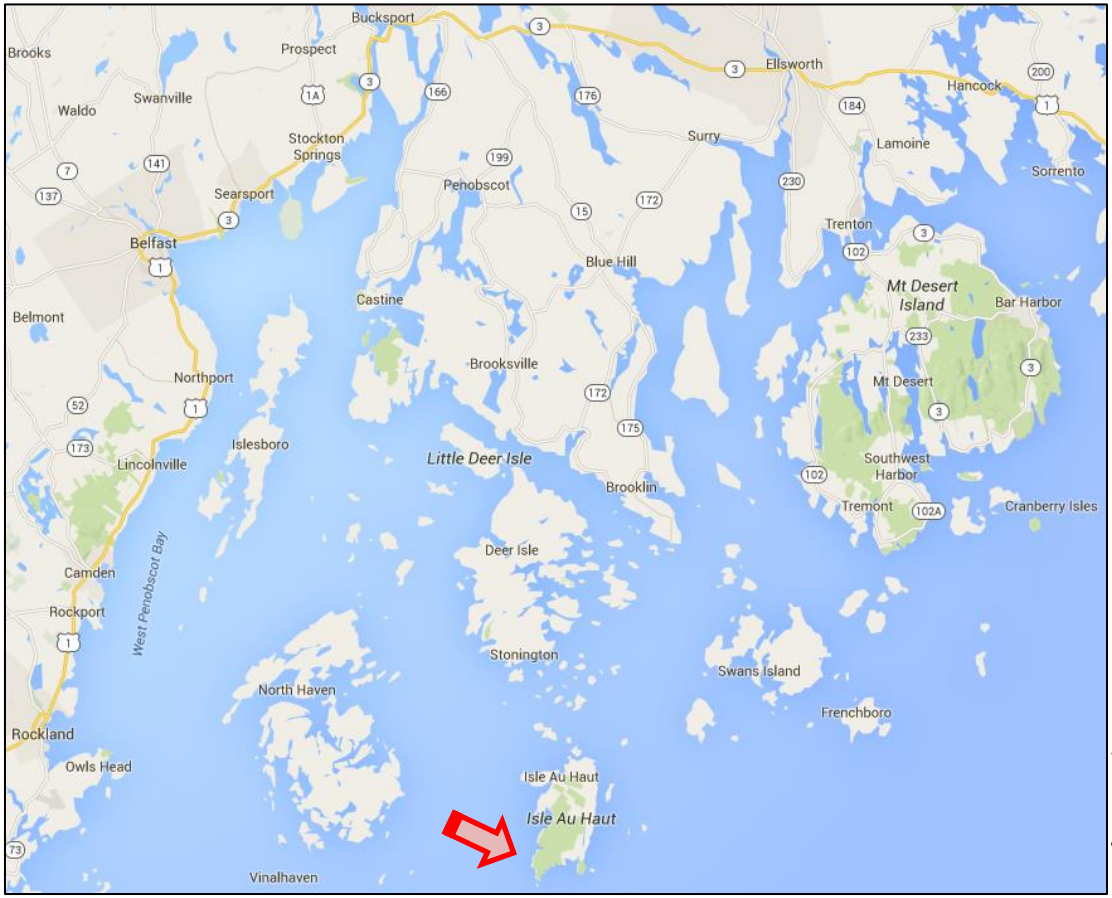
Introduction

Bedrock exposures along the west side of Isle au Haut island in mid-coast Maine display stunningly beautiful volcanic features produced in a huge series of explosive volcanic eruptions about 420 million years ago. It is one of several places along the Maine coast where volcanic rocks of this age are known, including Vinalhaven island, Swans Island, Mount Desert island, the Cranberry islands, and the Machias-Eastport area. The large, continuous outcrops along the coast of Western Head, Isle au Haut are perhaps the most spectacular because of the variety of volcanic structures, the large apparent thickness of the deposit, and the clean, wave-washed surfaces enhanced by centuries of natural weathering.

Location

Isle au Haut is a large outer island in eastern Penobscot Bay (Figure 1). A large part of the island belongs to Acadia National Park, including Western Head which can be reached by walking trails from the Duck Harbor campground.



Map from Google Maps

Figure 1. Isle au Haut, east of Vinalhaven and southwest of Mount Desert Island, can be reached by passenger ferry from Stonington.

Bedrock Geology

This simplified bedrock map shows that most of the island is underlain by granite and gabbro, igneous rocks that formed by slow cooling of molten rock underground. Volcanic rocks, which are igneous rocks that form when molten rock erupts at the earth's surface, are present in two large areas along the western shore of the island. Analyses of particular mineral grains from the granite indicate that it solidified about 424 million years ago (Gerber and Chapman, 2015). The age of the volcanic rocks is not yet known, but where similar volcanic rocks occur on nearby Vinalhaven and Mount Desert Island, the volcanic rocks are about the same age as the accompanying granite. The granite and gabbro represent the underground portion of the volcanic system, and the volcanic rocks represent the surface portion, now exposed by millions of years of erosion.

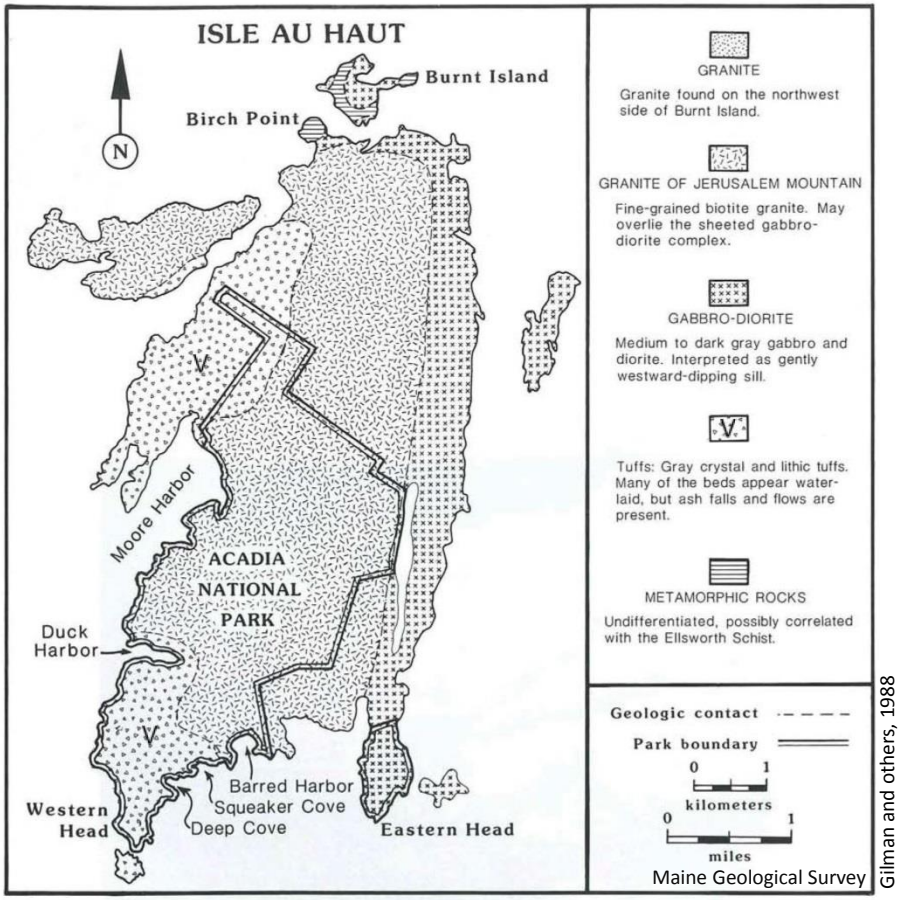


Figure 2. Generalized bedrock map of Isle au Haut. One large area of volcanic rock (V) is north of Moore Harbor. We are concerned here with volcanic rocks of the other large area, on Western Head, south of Duck Harbor. (Map from Gilman and others, 1988. For current map of Acadia National Park boundaries, see the National Park Service brochure.)

Volcanic Rocks

The volcanic rocks of Western Head were produced by violent, explosive eruptions that produced deposits of fragments ranging in size from tiny bits called volcanic **ash** (less than a tenth of an inch) to medium-sized pieces called **lapilli** (up to 2½ inches), to large fragments called **blocks** or **bombs** (over 2½ inches).

Rocks composed of volcanic fragments are called are called **pyroclastic** rocks, from Greek word roots pyro- (from *puros* meaning heat or fire) and clast (from *klastos* meaning broken in pieces). Pyroclastic rocks are named on the basis of their fragment sizes: a rock dominated by ash is called a **tuff**; a rock dominated by blocks or bombs is called a **breccia**, and rocks with mixtures of sizes are given combined names such as lapilli-tuff or tuff-breccia. The following photos show examples of pyroclastic rocks from Western Head.

Figure 3. Volcanic rock composed of rock fragments. Because the fragments are mostly less than 2½ inches across, this rock would be named a lapilli-tuff. The fragments have irregular shapes, and have different colors. Christine studies the fragments.

Volcanic Rocks

Figure 4. A high cliff of tuff-breccia with large blocks. The faint horizontal streaks suggest these rocks flowed before they had fully solidified. Aaron and Sheila scamper by.

Volcanic Rocks

Figure 5. A fragment of volcanic rock embedded in lapilli-tuff. The delicate, folded layering within the fragment is called flow-banding, which develops as highly viscous molten lava flows. After the flow-banded rock had solidified, it was blown apart by an explosive eruption and embedded in this pyroclastic deposit. (Pencil point for scale.)

Volcanic Rocks

Figure 6. Very fine-grained, light colored tuff containing irregular dark blobs. Their shapes suggest that the blobs erupted while still molten. The light and dark colors show that this volcanic system contained molten rock of different compositions, presumably melted at the same time from different sources at different depths. The light colored rock is probably rhyolite and the dark colored rock is probably basalt, although a chemical analysis would be required to be sure.

Volcanic Rocks

Figure 7. These light colored wispy structures are called **fiamme**, from the Italian word for flames, because their flattened, tapered shapes are reminiscent of tongues of flame. They form as fragments of **pumice** — frothy volcanic glass — become flattened by the pressure of the enclosing ash deposit during the eruption and emplacement of the pyroclastic deposit. This is a classic structure found in modern volcanic deposits such as welded tuffs or ignimbrites.

Volcanic Rocks

Photo by Henry N. Berry IV

Figure 8. Natural weathering brings out the internal beauty of these rocks, which makes the coastal ledges on Western Head so special. The shapes of the fragments show up in shades of light gray, pinkish-gray and white because of the microscopic grains of feldspar, a mineral that weathers to a chalky white material. Beneath the thin weathered surface veneer, the rock inside is dark greenish-gray to black, as shown in the upper part of this photo where the rock has been broken. Black on the inside, white on the outside!

Volcanic Rocks

Figure 9. A volcanic layer of tuff-breccia, with a chaotic mass of dark angular blocks embedded in light colored volcanic ash. This would not have been a good place to be at the time it erupted.

Volcanic Rocks

Figure 10. The large pyroclastic block of gray volcanic rock to the right of Chris is several feet across.

Volcanic Rocks

Figure 11. Gently curved, nearly horizontal layers exposed in this 20 foot cliff show that rock here is an accumulation of pyroclastic deposits produced by a series of explosive eruptions, rather than a single event. Dave studies the rock below, and Myles is exploring the upper reaches.

Volcanic Rocks

Figure 12. Close-up of the layering at the site in Figure 11. The layers are similar to each other, and they are not very distinct, which implies they were deposited one after another without much time between eruptions. The blue lines approximate the layering.

Intrusive Igneous Rocks

While most of the deep underground parts of the volcanic system are preserved in the granite-gabbro complex on the central and east side of Isle au Haut (Figure 2), there are a few places at Western Head where molten rocks intruded up into the overlying volcanic pile and solidified before reaching the earth's surface. The steeply inclined sheet of black rock in Figure 13 intruded as molten basalt which flowed readily into a widening fracture in the pyroclastic volcanics. The light colored igneous rock in Figure 14 was more viscous and intruded in a different way, by breaking its way through the volcanic rocks and incorporating blocks of rock into it before it eventually solidified. These features indicate that at least some of the volcanic rocks had solidified while molten rock beneath the surface was still active.

Figure 13. The steeply inclined sheet of dark igneous rock is more highly fractured than the light colored volcanic rocks around it, making it easier for the surf to break it up, and leaving a narrow cleft eroded into the weathered outcrop surface. The dark rock solidified from molten rock which forced its way into a fracture in the volcanics and solidified. This type of vertical fracture could have been part of the feeder system to volcanic flows at the overlying surface, now long since eroded. We will never know.

Intrusive Igneous Rocks

Figure 14. A more viscous, light colored intrusion that incorporated fragments of volcanic rocks from below and carried them into place and solidified. Notice that the angular fragments are darker colored and thinly layered, which makes them different from the adjacent light colored pyroclastic rocks. This demonstrates that the blocks are out of place, and were carried along by the moving magma.

Relics of a Bygone Era

There is no doubt that the huge volume of volcanic rocks on Isle au Haut, apparently exceeding 3 kilometers thick (Whitman and others, 2015), record a dramatic event in Earth's history. For the past 200 million years, the crust of Maine has been geologically quiescent, drifting on the passive continental margin of North America, but in an earlier time, long before the Atlantic Ocean opened and before the supercontinent of Pangea had been assembled, the rocks tell of a chain of active volcanos of dramatic proportions. Recent efforts to reconstruct the plate tectonic setting of the time, about 424 million years ago, suggest the volcanic activity occurred on a continental margin above a deep ocean trench where oceanic crust was being subducted into the mantle (Piñán Llamas and Hepburn, 2013). The neighboring ocean at that time, the Rheic Ocean, has long since closed and no longer exists. The size of some of the volcanic eruptions may have reached supervolcano status, a select group worldwide, although with only fragmentary evidence preserved here, it may be difficult to prove (Seaman, 2013). Nevertheless, the volcanic rocks on Western Head, Isle au Haut are beautiful to behold, and challenge the imagination. Students at the University of Massachusetts are continuing to study the Isle au Haut volcanics (Whitman and others, 2015).

References and Additional Information

Geologic research papers related to the Isle au Haut volcanics

Chapman, Marshall, 1996, Petrogenesis of a silicic magma chamber periodically invaded by basaltic magma; the Isle au Haut igneous complex, Maine: Ph.D. dissertation, University of Massachusetts, Amherst, 238 p.

Chapman, Marshall, and Rhodes, J. M., 1992, Composite layering in the Isle au Haut Igneous Complex, Maine; evidence for periodic invasion of a mafic magma into an evolving magma reservoir: Journal of Volcanology and Geothermal Research, v. 51, nos. 1-2, p. 41-60.

Gilman, Richard A., Chapman, Carleton A., Lowell, Thomas V., and Borns, Harold W., Jr., 1988, The geology of Mount Desert Island; a visitor's guide to the geology of Acadia National Park: Maine Geological Survey, Bulletin 38, 50 p., 2 maps, scale 1:50,000. http://www.maine.gov/dacf/mgs/explore/bedrock/acadia/B-38.pdf

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Smith, George Otis, Bastin, E. S., and Brown, C. W., 1907, Description of the Penobscot Bay quadrangle, Maine: U. S. Geological Survey, Geologic Atlas, Folio 149, 14 p. (scale - 1:125,000). http://pubs.er.usgs.gov/publication/gf149

Whitman, Megan L., Seaman, Sheila J., and Chapman, Marshall, 2015, Eruptive history and geochemistry of the Isle au Haut volcanic series, coastal Maine: Geological Society of America Abstracts with Programs, vol. 47, No. 3, p. 121. https://gsa.confex.com/gsa/2015NE/webprogram/Paper251942.html

References and Additional Information

Visiting Isle au Haut

About the town: http://isleauhaut.org/welcome

Acadia National Park brochure: http://www.nps.gov/acad/planyourvisit/upload/IsleAuHaut-2011-small.pdf

Ferry service from Stonington: http://www.isleauhaut.com

Cool information about volcanic rocks

Volcanic rocks on Vinalhaven, Maine (Maine Geological Survey): http://www.maine.gov/dacf/mgs/explore/bedrock/sites/mar98.pdf

Yellowstone Volcano Observatory (U.S. Geological Survey): http://volcanoes.usgs.gov/observatories/yvo

Cascades Volcano Observatory (U.S. Geological Survey): http://volcanoes.usgs.gov/observatories/cvo

Supervolcanoes: https://en.wikipedia.org/wiki/Supervolcano

Continental volcanic arcs (Columbia University): http://www.columbia.edu/~vjd1/subd_zone_basic.htm