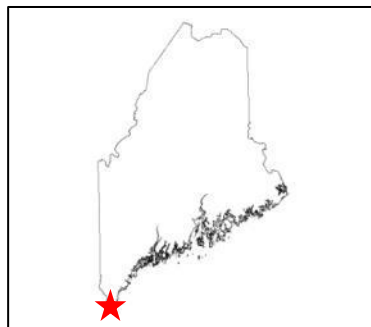


Maine Geologic Facts and Localities  
April, 2007

***Ancient Fault Rocks at Fort Foster Park, Kittery, Maine***



43° 03' 58.9" N, 70° 41' 08.00" W

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## Introduction

Have you ever been in a fault zone? Some parts of the world are riddled with active faults, places where the earth's bedrock breaks and moves repeatedly. People who live in such geologically active areas, such as Alaska, the Philippines, China, and California, are familiar with the main surface effect of sudden fault motion - earthquakes. But what happens to the rocks below the surface that are caught in a fault zone where earthquakes are generated?

One way to find out is to drill a hole two miles deep into an active fault, as in the [San Andreas Fault drilling project](#) sponsored by the National Science Foundation. Another way is to find a place where an ancient fault zone has been eroded, so that rocks which formed at depth can now be seen at the surface. One such place is in southern Maine, at [Fort Foster Park](#). The rocks here were in a major fault zone at a significant depth in the earth when they formed, probably between 270 and 300 million years ago (Swanson, 2007). In the expanse of geologic time since then, the overlying rock has been eroded, allowing us to examine rocks like those that would be found today several miles beneath the San Andreas fault.

**Important! This is a unique natural exposure that has been used for detailed geologic study and for teaching students. While photographs are encouraged, there is no reason or excuse for breaking or damaging these rocks. Please take care of this special place.**



Location

Fort Foster is at the southern tip of Maine, past the village of Kittery Point. Technically, it is on Gerrish Island, although this "island" is barely separated from the mainland by a narrow creek and wetland, and can be reached easily by car. The park, a former military installation, is owned and operated by the town of Kittery. Visitors are charged admission during the summer season. The rocks of interest are along the southeast shore, below the picnic pavilion



**Figure 1.** Air photo of the southern tip of Gerrish Island, Kittery, including Fort Foster Park. Width of view is approximately 0.2 miles.

## Picnic Pavilion



**Figure 2.** The picnic pavilion at Fort Foster Park can be rented for a fee from the town of Kittery, Maine. The rocks of interest are on the shore below here. This photo was taken off-season, in March, when walk-in visitors are allowed.



Shore Path



**Figure 3.** Shore path along the Atlantic Ocean at Fort Foster Park.

Foliation

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**Figure 4.** Rock that has been sheared by intense pressure may develop a thin layering parallel to the direction of shearing. While the edges of the foliation planes may appear as stripes on the rock surfaces, the foliation planes extend through the body of the rock. The rock here is a mylonite, which means that the foliation is very fine-grained due to deformation. The process of creating this type of foliation in a solid rock requires a shearing type of pressure, heat, and time. The colored plane is meant to illustrate the three-dimensional aspect of foliation planes. A large number of such foliation planes penetrate the entire body of rock.

Fault Zone

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**Figure 5.** Prof. Mark Swanson of the University of Southern Maine (red cap) has spent hundreds of hours over many years carefully photographing and describing thousands of details in this outstanding natural exposure. His research has documented a complicated array of features that formed in this ancient fault zone. The next several photographs will show examples of some of these fascinating features. (Geological Society of America field trip, March, 2007.)



Foliation Cut by Fault



**Figure 6.** The foliation in the upper part of this photo is cut off by a minor fault just above the pocket knife.



Layering Cut by Fault



**Figure 7.** Light and medium-gray layers in the lower part of the photo are cut off by a minor fault above the nickel.

Fold Cut by Fault



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**Figure 8.** Foliation in the lower part of the photograph was folded before being cut off by a minor fault below the nickel. In this example, the folding and faulting of rock are both related to the same geologic episode.

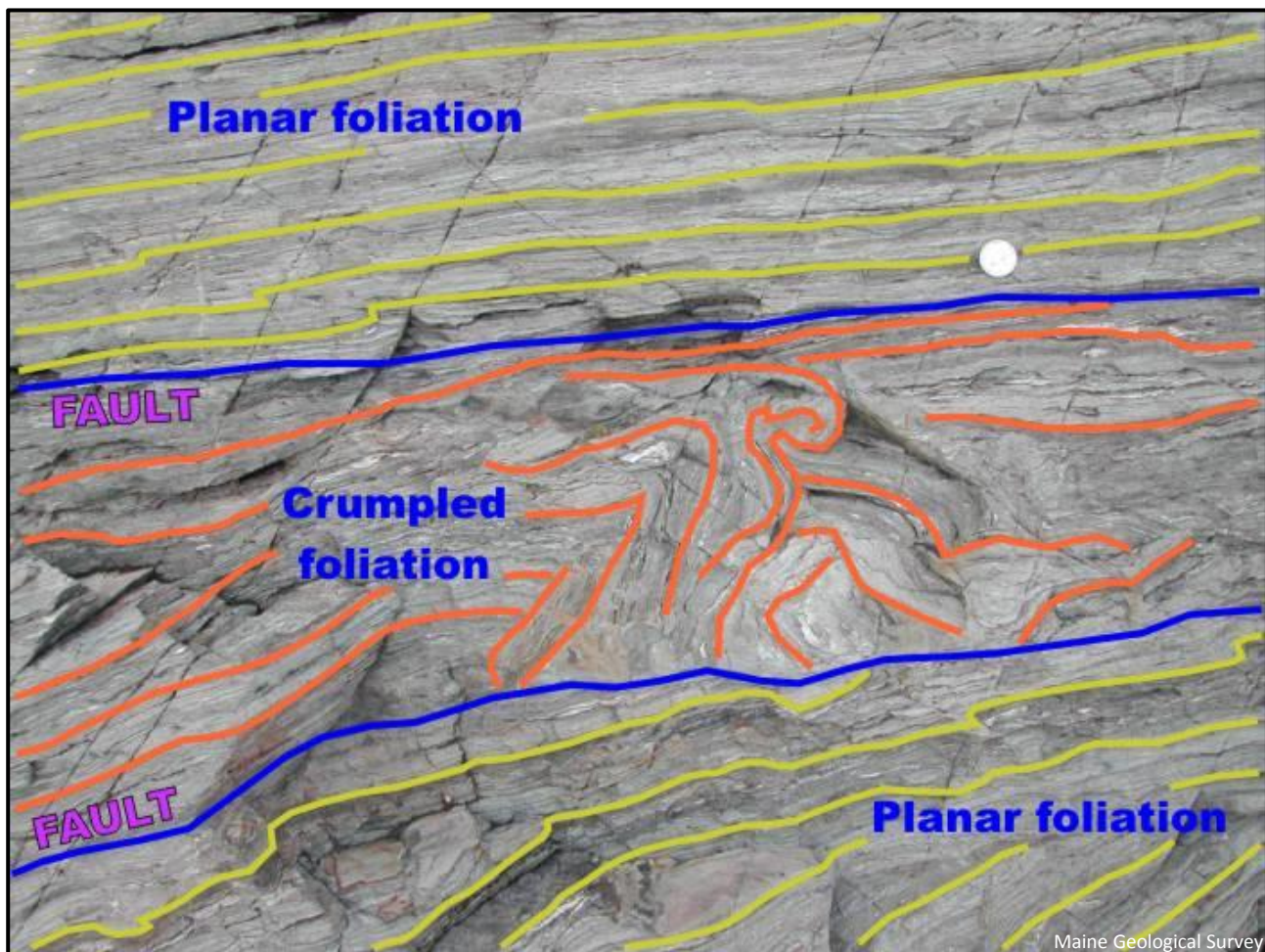


Crumpled Foliation

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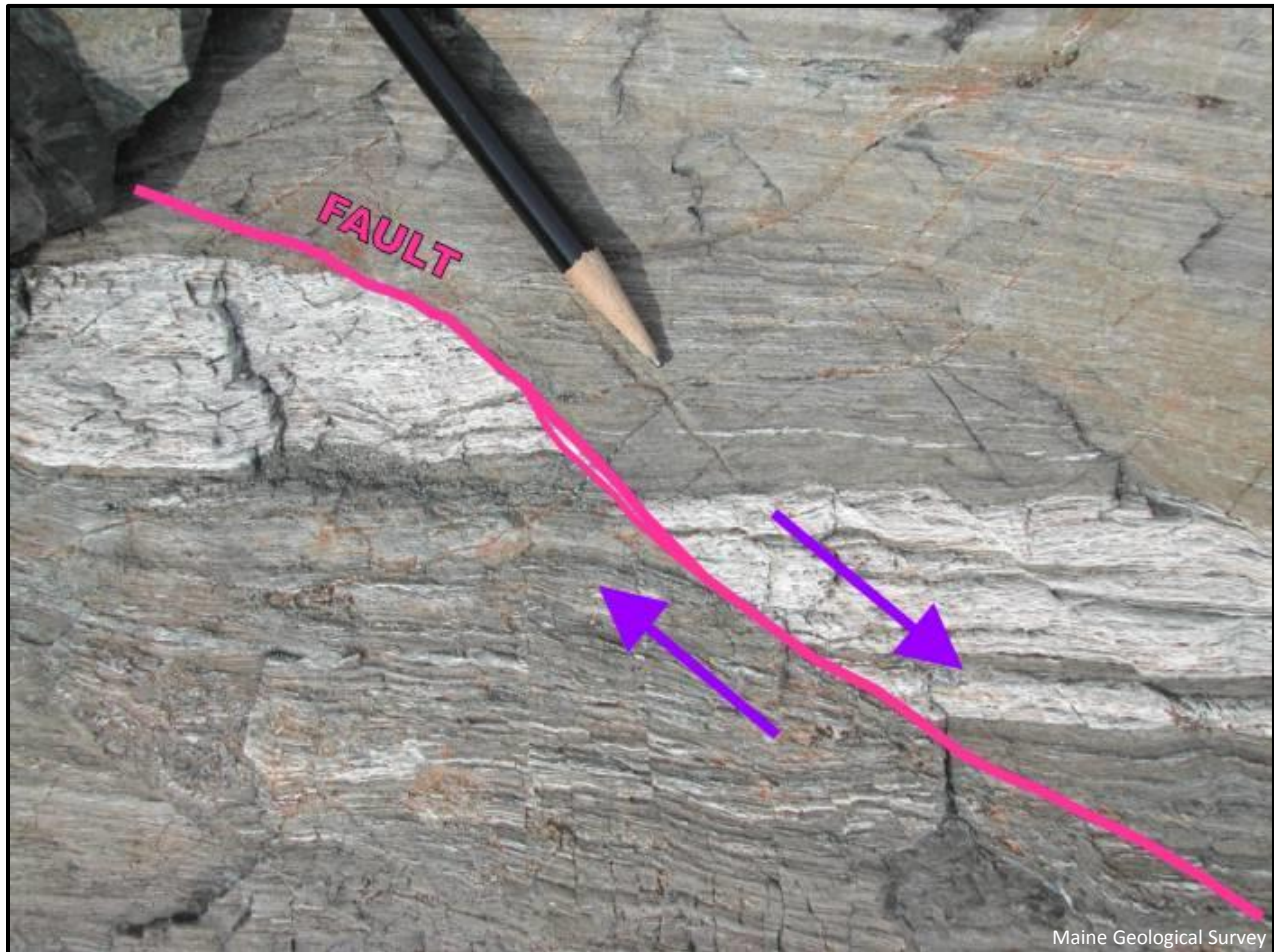
**Figure 9.** If the shearing force is not exactly parallel to the layers, some layers may be sheared off or crumpled as they move along fault surfaces. The crumpled area in the middle of this photograph is caught between two faults.

Crumpled Foliation Highlighted

**Figure 10.** By carefully tracing the foliation, it is clear that the foliation has been broken and moved along the two faults indicated by blue lines. In many places the faults are nearly parallel to the foliation (yellow lines). But where the rock is constricted between closely spaced faults, the foliation can become crumpled (orange lines).



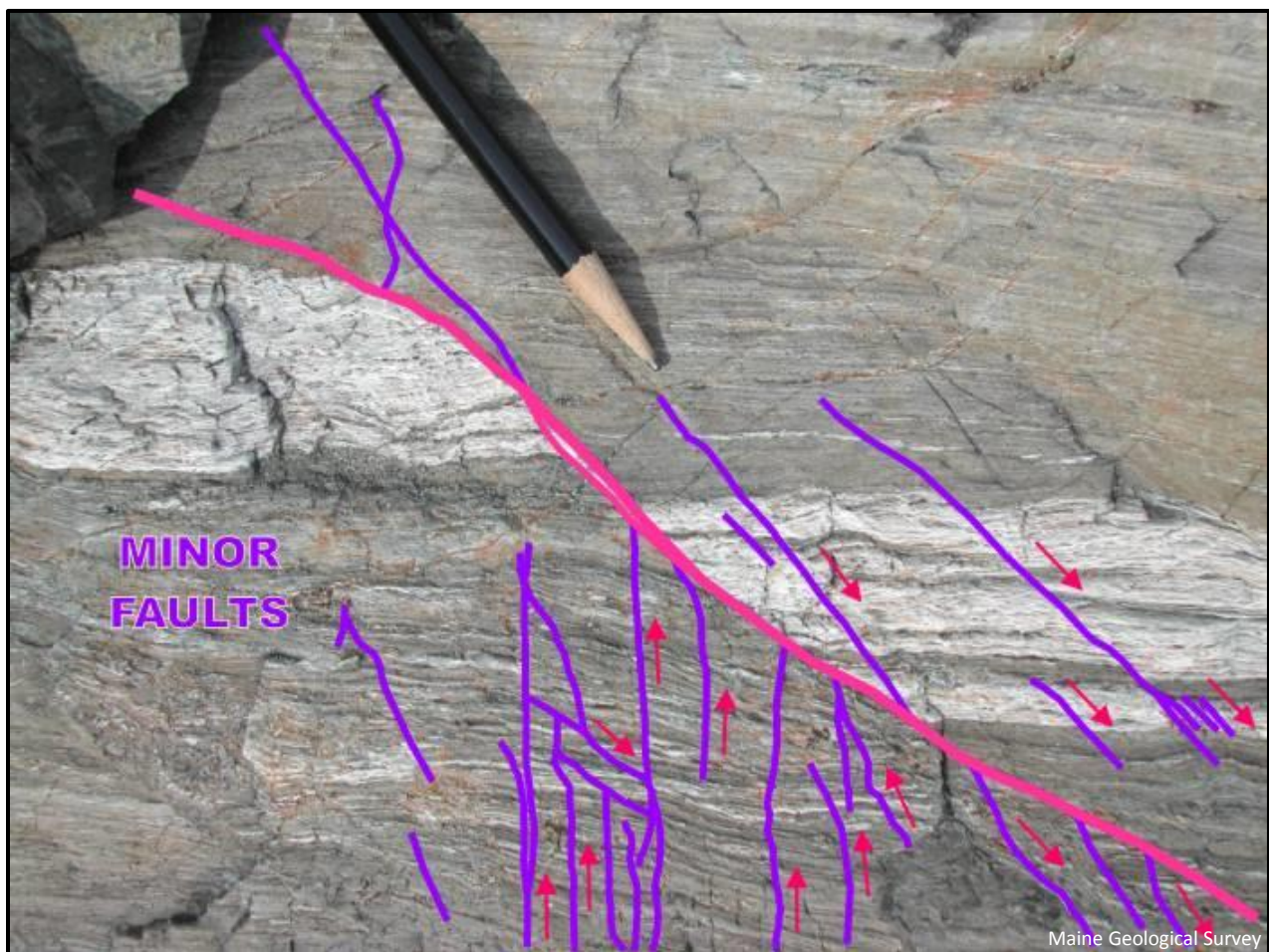
Offset Layers



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**Figure 11.** A fault cuts diagonally across this white layer. Rock to the right moved to the right; rock to the left moved to the left.

Minor Faults

**Figure 11.** In addition to the more obvious main fault (pink), there are abundant associated minor faults that affect the rock on one side or the other. A few of these are traced in purple. This shows that a large portion of the rock is affected to some degree by what appears to be a simple fault.



Offset Gray Layers



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**Figure 12.** Another fault cutting through the layering at a large angle.

Intersecting Small Faults



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**Figure 13.** The many small faults here are easy to find by trying to trace the white layers across the rock. Every small break and displacement is a fault.



Folded Layers



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**Figure 14.** Under certain conditions, rocks flow instead of breaking, as these delicately folded layers attest.



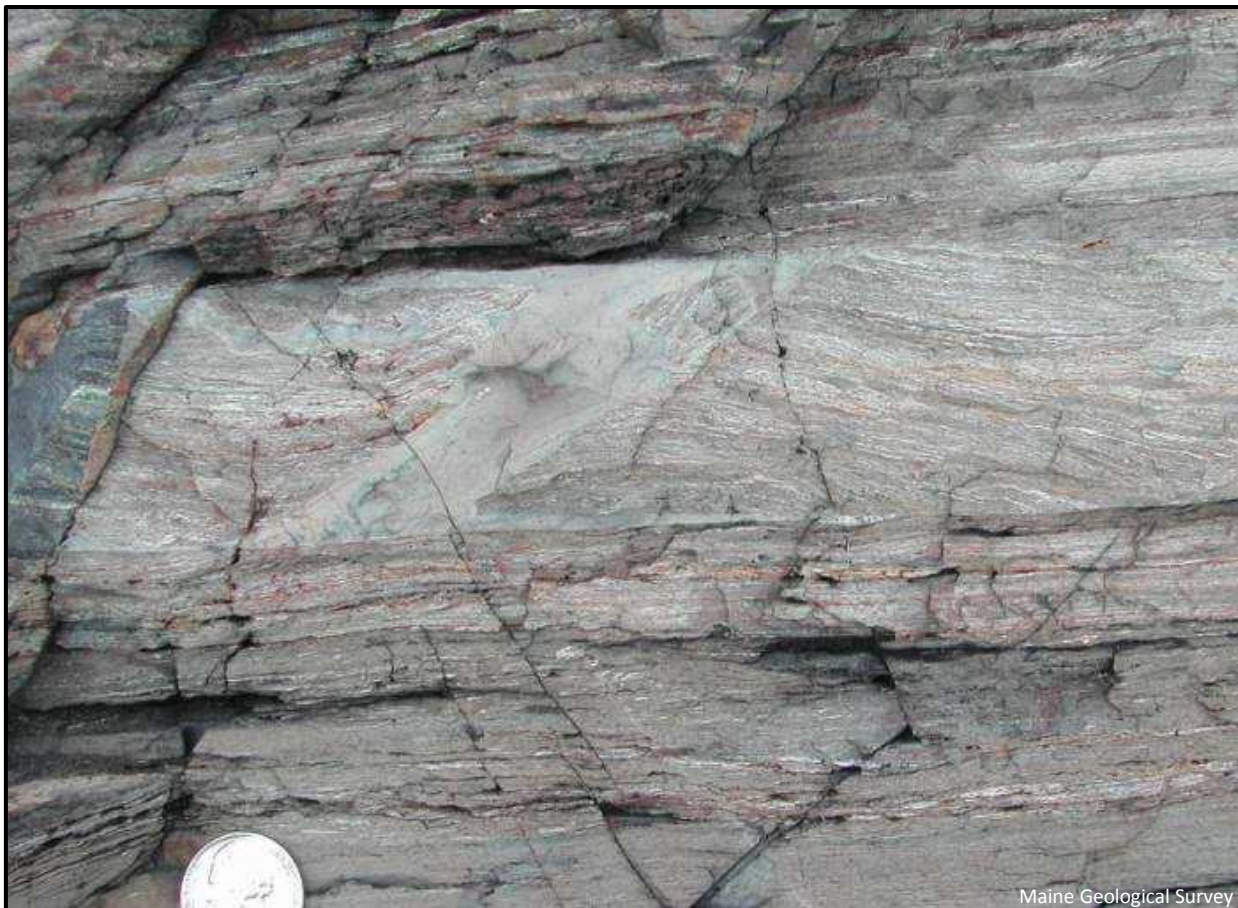
Pseudotachylyte Along Fault

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**Figure 15.** The inclined foliation in the upper part of this photograph is cut by a fault which extends across the photograph. The tapered band of rock just at that fault is called pseudotachylyte, which is rock that has been melted by the intense frictional heat produced during sliding on a fault.





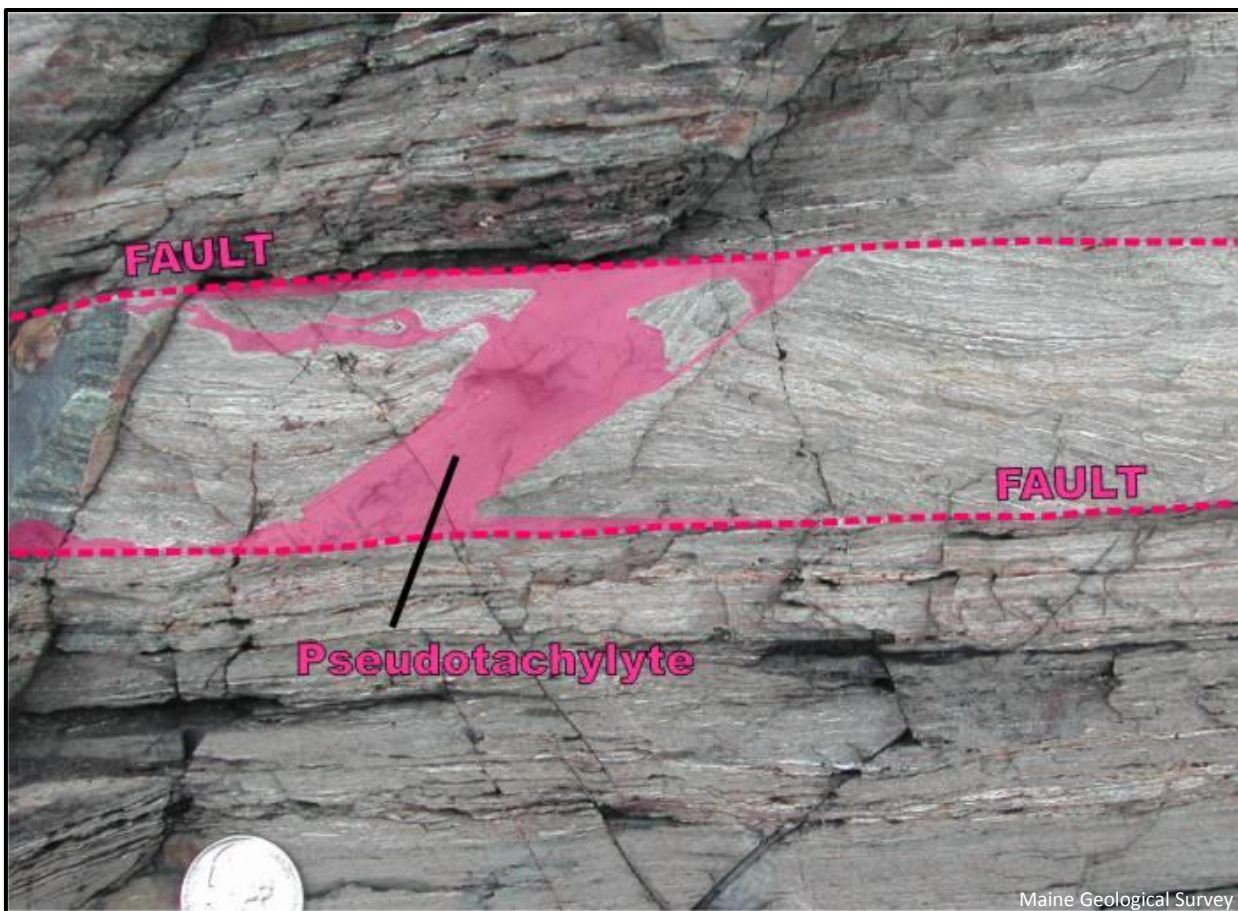
Pseudotachylite

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**Figure 16.** Pseudotachylite (sue' doe tack uh lite) is a special kind of rock that is produced along a fault by frictional heating. Sudden fault motion can generate incredibly high temperatures which instantaneously melt a small volume of rock. The melted rock is injected into fractures in the adjacent rock, then solidifies. Most pseudotachylite veins are very thin, measured in the millimeters. Though small, they are important. The presence of pseudotachylite is evidence that there were sudden fault motions that produced sizable earthquakes in the geologic past.



Pseudotachylyte Highlighted

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**Figure 17.** Notice that thin bands of pseudotachylyte formed along the two fault surfaces. At the same time, the rock between the two faults was broken apart, allowing the molten rock to be injected as a fluid, which instantly froze in place. The angular rock fragment to the upper right was engulfed, and the molten rock fluid shot through the irregular channelway to the upper left. This is dramatic evidence for ancient earthquake-producing sudden fault motion.



Foliated Granite



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**Figure 18.** This light-colored rock is also intensely deformed by the fault-related activity, but it was originally a coarse-grained granite, which produces a rock different from those in the previous photographs.

Foliation in Granitic Rock



**Figure 19.** This light-colored granite contains the same type of intense foliation as the other rocks (see Figure 4).



Sheared Feldspar in Granite

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**Figure 20.** Original feldspar grains are partly preserved, though distorted into tapered shapes by deformation of the rock. The asymmetry of this grain indicates the direction of shearing. Rock in the upper part of the photo flowed to the right, in relation to rock in the lower part of the photograph.

Rotated Feldspar in Granite



**Figure 21.** This feldspar grain rotated clockwise as the rock in the upper part of the photograph moved toward the right.



Basalt Dike Cutting Faulted Rocks

**Figure 22.** This band of dark colored rock is basalt, an igneous rock that flowed up through a fracture in the rock as magma, and solidified in place. All the fault-related features of the previous photographs are in the light-colored rocks in this picture, and do not affect the basalt. This relationship demonstrates that the faulting episode occurred long ago, and ended before the basalt was emplaced.

References and Additional Information

- Hussey, Arthur M., II, 1980, [The Rye Formation of Gerrish Island, Kittery, Maine; a reinterpretation](#); The Maine Geologist; Newsletter of the Geological Society of Maine, v. 7, no. 2, p. 2-3.
- Swanson, Mark T., 1988, Pseudotachylite-bearing strike-slip duplex structures in the Fort Foster Brittle Zone, southern Maine: Journal of Structural Geology, v. 10, p. 813-828.
- Swanson, Mark T., 2006, Pseudotachylite-bearing strike-slip faults in mylonitic host rocks, Fort Foster Brittle Zone, Kittery, Maine. In Abercrombie, R., McGarr, A., Kanamori, H., and DiToro, G., editors, Earthquakes: Radiated energy and the physics of faulting: American Geophysical Union Monograph Series, vol. 170, p. 167-180.
- Swanson, Mark T., 2007, Structure of Late Paleozoic brittle dextral strike-slip faults in coastal Maine exposures. In Peter Thompson (editor), Guidebook to field trips in New Hampshire, adjacent Maine & Massachusetts: Northeastern Section, Geological Society of America, Durham, N.H., Trip F-2, p. 3-18.

