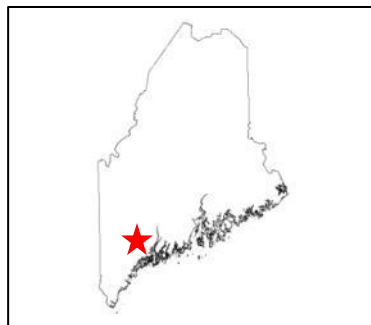


Maine Geologic Facts and Localities  
January, 2001

***Mount Apatite Park, Auburn, Maine***



44° 5' 38.45" N, 70° 17' 50.46" W

Text by  
Woodrow B. Thompson  
Maine Geological Survey



## Introduction

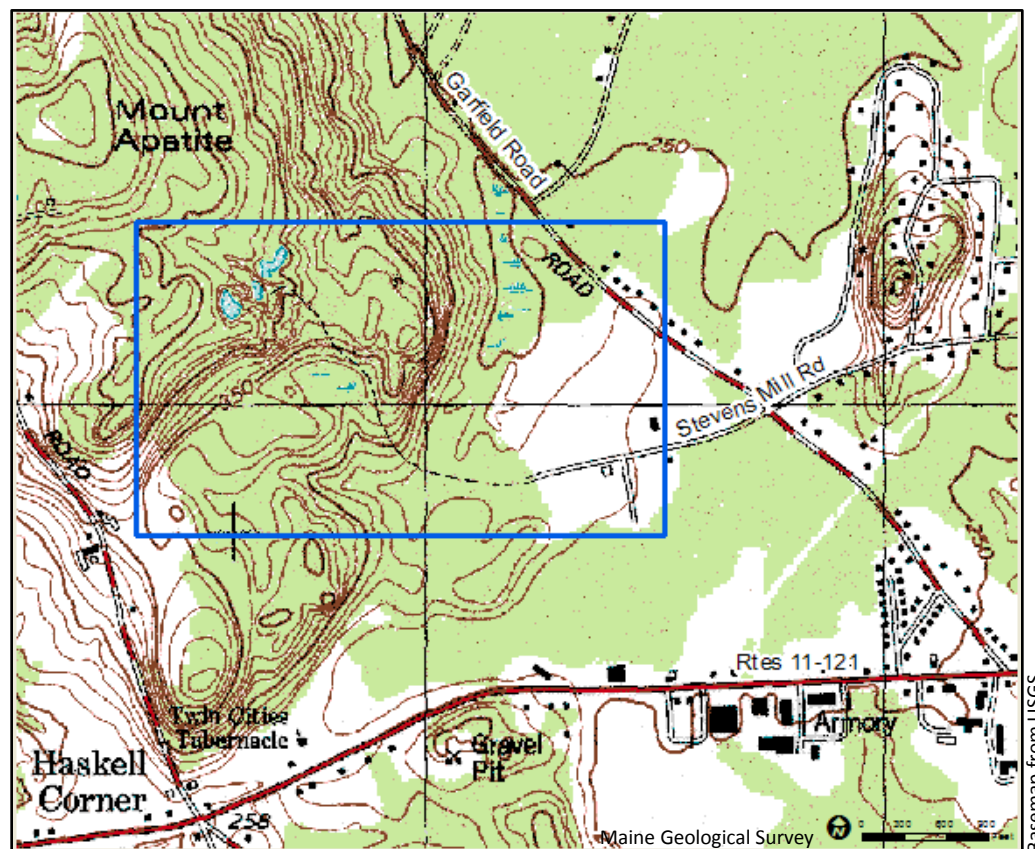
The Mt. Apatite quarries were important producers of commercial feldspar in the early 1900's. They played a prominent part in Maine's mining history. During the course of this mining activity, rare minerals and colorful crystals of green and pink tourmaline were found in both the Greenlaw and Maine Feldspar Quarries. These quarries also produced many large crystals of transparent smoky quartz. The complexity of the mineral assemblage at Mt. Apatite is matched by only a few other localities in Maine.

These quarries are among a small number of mineral collecting sites in Maine that offer a combination of good public access and the possibility of finding many different minerals. The ledges and boulders surrounding the quarry pits show interesting geological features, including basalt dikes cutting granite pegmatite, and interlayering of pegmatite with metamorphic rock. The coarse pegmatite shows large, easily visible examples of several common rock-forming mineral groups such as quartz, feldspar, and mica. Various features around the quarries illustrate former mining techniques and the linkages between Maine's geologic and human history.



### Location

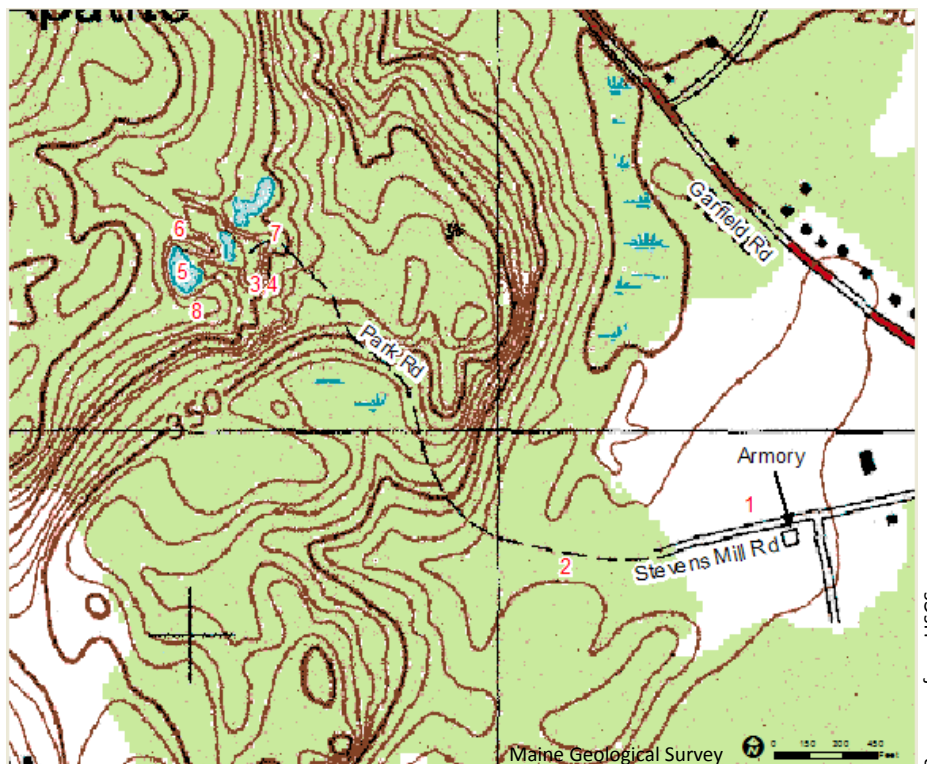
Town of Auburn in the Minot quadrangle. Abandoned quarries within the park are located on the southeast side of Mt. Apatite, north of Route 11/121, between Hatch Road and Garfield Road (see map).



**Figure 1.** Location map of the Mount Apatite quarries. The map of the highlighted area is on the next page.

### Directions

From junction of Routes 4/100/202 and 11/121 in Auburn, drive west on Rte. 11/121 for 1.9 miles. Turn right onto Garfield Road and go northwest for 0.50 mile. Turn left onto Stevens Mill Road. Go 0.20 mile and park outside gate (note National Guard armory on left). Walk the dirt road across large open field, then uphill through woods, for about 0.75 mile to the quarries. The Greenlaw Quarry and associated dumps are on the right (north) side of the road; the Maine Feldspar Quarry and dumps are to the left.



**Figure 2.** Location map. Red numbers refer to sites described in text.



### Logistics

**Permission:** Mount Apatite Park is owned and administered by the City of Auburn. It is open to the public, and no special permission to visit is required. Further information, including a detailed map of the park and its trail system, is available from the Auburn Parks & Recreation Department (207-333-6601 X2108). Another group of quarries (Pulsifer, etc.) are located on the west side of Mt. Apatite, but are not open to the general public and will not be discussed here. There are no toilet facilities at the quarries.

**Sampling:** Allowed. The park rules state that within the quarry and dump areas, "it is permitted to use hand tools to explore for mineral and gem specimens to a depth of two feet." Recommended equipment: knapsacks or pails, paper for labeling and wrapping mineral samples, sturdy geologist hammers (or equivalent) for breaking rocks, short-handled shovels or other tools for digging, safety glasses, first-aid supplies for cuts, heavy shoes, cameras, food and beverage.

**Exposure:** The quarry pits have steep rock walls, and some of them are flooded (Figure 3). Caution is necessary in exploring these areas. The big piles of waste rock (dumps) next to the quarries are good places to find mineral specimens, but be careful not to roll rocks downhill if people are below you. The remainder of the park is generally wooded and has a well-developed trail network.



**Figure 3.** Water-filled pit at Greenlaw Quarry.



### History of Mining

The Mt. Apatite quarries were excavated in a type of igneous rock called granite pegmatite (often simply called "pegmatite" in Maine). This is a coarse-grained variety of granite in which the individual mineral grains are very large. They may be several inches - or even more than a foot - in diameter. The most abundant minerals in the pegmatite are creamy white microcline (feldspar), glassy gray to white quartz, and flat sheets of shiny muscovite (mica). Muscovite is very distinctive because the larger pieces can be split easily into thin transparent sheets. This property is called cleavage. It occurs along planes of weakness in the molecular structure of a mineral. Muscovite and other species of mica have one direction of excellent cleavage, while the feldspars have two directions of cleavage (at right angles) which are not always obvious. Quartz lacks cleavage and breaks along jagged irregular fracture surfaces.

These quarries have a long history of mineral production. They were operated commercially as a source of feldspar during the early 1900's (Perham, 1987). This mineral is used for making china and other ceramic products. The feldspar from Mt. Apatite was hauled to a nearby mill built in 1897 at Littlefield Station in Auburn. Here it was ground to a fine powder and readied for industrial use. Besides the pits themselves, a few other remnants of quarrying are still visible. From the stone wall next to the entrance road, you can look down into an old trench cut in the bedrock. This probably was excavated to drain water from the quarries. Groundwater seeps into many of the quarries in Maine, and had to be drained or continually pumped out to keep the workings dry.



### Minerals at Mount Apatite

During feldspar mining the quarry workers sometimes encountered rare and unusual minerals. (The mountain is named after a phosphate mineral called apatite, which was found as beautiful deep purple crystals at the Pulsifer Quarry on the west side of the hill. See Figure 4).



Photo from the Maine State Museum

Maine Geological Survey

**Figure 4.** Purple apatite crystals, including specimens with apatites on quartz crystals, from Pulsifer Quarry.



### Minerals at Mount Apatite

These minerals might be put aside to be sold to museums and gem cutters, but in other cases the superintendents discouraged such activities because they did not want to slow down the mining operation. Crystals of some minerals such as beryl and garnet were encased within the solid rock. Other crystals, including quartz and valuable green and pink tourmalines, were found in cavities in the pegmatite. These "pockets" are natural open spaces where concentrations of gas or liquids containing rare elements remained late in the cooling history of the granitic magma. Fine transparent crystals had the best chance to form in this environment, though they were often shattered by explosive pressure changes as the rock cooled. King (2000) provides a detailed history of mining and mineral discoveries at Mt. Apatite.

Masses of lilac-colored lithium mica (lepidolite) typically occurred in the vicinity of tourmaline pockets. You may find pieces of this colorful mica on the dumps of the Greenlaw Quarry, which are strewn through the woods on your right as you enter the quarry complex. You will see lots of shallow holes that mineral collectors have dug in the rock piles.





### Minerals at Mount Apatite

The Greenlaw dumps are the most favorable area in which to find traces of green and blue-green tourmaline (Figure 5), though collectors have already gathered up most of the obvious pieces. Black tourmaline (resembling lumps of coal) is likely to be found, along with glassy dark-red chunks of garnet and fern-like growths of muscovite mica. Some of the pegmatite is "graphic granite" in which stringers of quartz form curious geometric intergrowths with feldspar.



Photo from the Maine State Museum

**Figure 5.** Green tourmaline crystals on pegmatite rock. Collected at Mt. Apatite ca. 1920.



### How did this pegmatite form?

The granite pegmatite at Mt. Apatite resulted from cooling and crystallization of a body of magma. This mass of molten rock was enriched in water and rare elements, giving rise to the variety of rare minerals found in the quarries. The source of the melts that produced the pegmatite veins in southwestern Maine continues to be debated: were they offshoots from magma intrusions that cooled and formed granite bodies such as the Sebago pluton (igneous model), or did they form when local metamorphic rocks were heated to the point that partial melting occurred (metamorphic model)? These two processes are not mutually exclusive, since magma from a distant source may intrude and melt the surrounding metamorphic rocks, producing locally derived granitic magma.

According to the traditional igneous model, during the cooling of a magma of granitic composition, many rare elements tend to concentrate in the final residual melt because they do not fit well in the structures of the ordinary rock-forming minerals formed earlier in the crystallization process. The presence of water both lowers the crystallization temperature of the melt and facilitates the migration of these elements and their concentration in the final parcels of magma, which may intrude fractures in adjacent rocks and finally solidify to form pegmatites.



### Igneous versus Metamorphic Models

Mineralogists who study the origin of New England pegmatites are comparing the chemistry of these rocks with the surrounding host rocks (commonly metamorphic) and with nearby granite plutons. The pegmatites in the Auburn area are part of a large swarm (Oxford pegmatite field) concentrated around the northeast margin of the Sebago pluton (Wise and Francis, 1992). This suggests a genetic relationship between the granite body and pegmatites.

Creasy (1979) has mapped the bedrock on Mt. Apatite as "heterotextural granite", a map unit which may include both pegmatite and regular granite complexly interlayered with metamorphosed sedimentary rocks. He concluded that the Sebago granite, and presumably the associated pegmatites as well, were derived from melting of the metamorphic rocks. Thus, Creasy's findings support the metamorphic model for the origin of the Mt. Apatite rocks. Simmons et al. (1995, 1996) likewise favor a metamorphic origin for Maine pegmatites, based on textural and geochemical evidence. Assuming the same age as the Sebago granite, the pegmatite on Mt. Apatite would have formed around 293 million years ago, in late Carboniferous time (Tomascak et al., 1996).



### Surficial Geology

The surficial sediments on Mt. Apatite are much younger than the bedrock. They probably formed during and just after the most recent glaciation, between about 25,000 and 13,000 years ago (Marvinney and Thompson, 2000). The bouldery material draping the hillside is rock debris (till) deposited directly from glacial ice. Till is a more-or-less random mixture of clay, silt, sand and rock fragments that the ice sheet eroded, transported, and then redeposited. Large angular boulders scattered across the ground often indicate the presence of till beneath the surface cover of soil and vegetation.

The effects of glacial erosion are nicely displayed on the large horizontal ledge surface next to the trail, where it passes between the quarry pits (Figure 6). During the maximum phase of the last glaciation, the ice flowing across this area was several thousand feet thick. Sand particles and rock fragments at the base of the glacier were dragged over the ledge under great pressure, "sand papering" the rock surface until it was flat and smooth. In this case the ledge is actually polished - notice how it reflects sunlight when viewed at certain angles. Individual rocks dragged across the ledge produced parallel scratches. The narrow ones are called striations, while the deeper and broader furrows are called grooves. These scratch marks are oriented from NNW (340 degrees) to SSE (160 degrees), parallel to the flow of the glacier. By themselves, they do not tell us which way the glacier moved, but they indicate two possibilities: toward the north-northwest or toward the south-southeast. From other types of evidence, such as the transport direction of rocks from known sources, we can safely infer that ice flow in this part of Maine was generally southward, and 160 degrees is presumed to have been the direction of ice flow across Mt. Apatite.



Suggested itinerary, activities, and discussion questions

As you walk westward across the field, examine the sand plain in the field near the armory (Site 1 on location map). *If this sand was deposited by a flowing stream, what does its fineness suggest about the stream velocity (fast or slow)? Compare the topography of the sand plain with the dunes where you enter the woods (Site 2). How do they differ? (Keep in mind that there has been some human disturbance of the ground in this area.) If the insides of the dunes were exposed, what characteristics you look for to tell if they were formed by wind or water?*

Walk west on the woods road leading to the quarries. Just beyond a small wetland (on left), the road starts to climb. Note the boulders on the hillside (part of the glacial till), in contrast to the sand on the valley floor. If time permits, examine a few of these boulders and see if they resemble the rock types exposed in the quarries. *Are there any erratic boulders that were glacially transported from other bedrock source areas?*

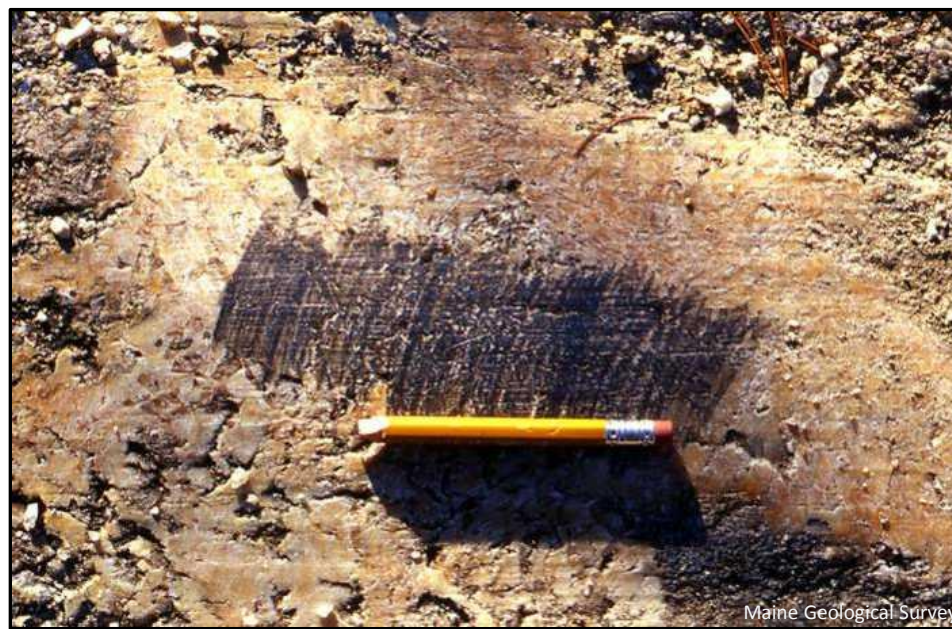
Continue uphill, staying on the main road until reaching the quarries. You will come to a short stone wall on the left side of the road (Site 3). From this point is seen a trench that was cut into bedrock during quarry operations. Perhaps this was done to drain water from the quarry pits? There are very few buildings or other structures remaining at the old mine sites in Maine, so it is challenging to try to reconstruct details of the mining operations from clues that can still be seen. This is the domain of industrial archaeology. *Can you find other evidence of mining techniques around the quarries, such as drill holes in the rock or support structures for booms used to hoist the freshly mined feldspar?* Some good historical photos of Mt. Apatite mining have been reproduced by King (2000). For those interested in mining history worldwide, a useful Web site is maintained by the [Mining History Network](#).



Suggested itinerary, activities, and discussion questions

Just past the stone wall, there is a smooth flat ledge in the clearing on the right side of the road (Site 4). This is a great place to see glacially abraded and polished bedrock, with striations produced by stones dragged across the ledge at the base of the ice sheet. Although there are many such glacially smoothed ledges in Maine, weathering has often destroyed the striations on rock surfaces that have been exposed for a long time. Pegmatite ledges such as this one contain quartz and other hard minerals that tend to preserve striations better than crumbly rock types. Sometimes we can reveal striations that are not immediately evident. Take a hard pencil (H3), pick a very smooth place on the ledge (on polished quartz or the creamy white feldspar), and rub the pencil transverse to the visible striations. This is like taking a charcoal rubbing from a gravestone image.

With a little practice and close scrutiny, you will see that the striations show as white lines in the areas smudged by the pencil lead (Figure 6). (Hint: keep a sharpener handy!) Geologists often use this technique on smooth ledges where the striations are not so obvious as they are here.



**Figure 6.** Pencil rubbing of glacially polished ledge surface reveals narrow glacial striations.

Suggested itinerary, activities, and discussion questions

The group of pits on the north (right) side of the road are the Greenlaw Quarry. The single large pit to the south is the Maine Feldspar Quarry (Site 5). Walk down to the water's edge in the Maine Feldspar Quarry and look across to the high west wall. This face shows metamorphic rock overlying lighter-colored pegmatite.



Photo by Maine Geological Survey

Maine Geological Survey

**Figure 7.** Contact between gray metamorphic rock and white pegmatite in wall of Maine Feldspar Quarry.



Suggested itinerary, activities, and discussion questions

Continuing up the road between the quarries brings you to a set of stone steps. Just to the right of these steps is a low rock face that at first resembles a stone wall (Site 6; Figure 8). Look closer at this densely fractured bedrock, and you'll see that it's a dark, fine-grained rock called basalt. The basalt forms a vertical vein crosscutting the surrounding pegmatite, with a trend of 055 degrees (NE). Igneous rock veins such as this one are called dikes. Looking closely at the dike, remnants of pegmatite are still attached to the side facing you. Compare the grain size of the basalt with the pegmatite. *What does this suggest about cooling rates in the two magma bodies? Which is younger, or did they crystallize at the same time?*



Photo by Maine Geological Survey

**Figure 8.** Side of vertical basalt dike (center) exposed in ridge between Maine Feldspar and Greenlaw Quarries.



Suggested itinerary, activities, and discussion questions

Note that the stone steps have been imported from somewhere outside the quarry. They are made of fine-grained gray granite and have drill holes on the edges. These granite slabs look like the foundation stones of many older houses and barns in the area, and may have come from a former home site. Farmers in southern Maine often exploited local granite ledges, or even large boulders, to obtain foundation stone. They took advantage of natural fractures in the rock to facilitate breaking off the slabs. Drill holes in hilltop ledges are evidence of this activity.

Climb the steps to a viewpoint on the north side of the road. This overlooks another old quarry pit which is mostly dry. Look at the boulders placed next to the pit rim. One of them shows a black basalt dike cutting through pegmatite. The margin of the dike shows very fine-grained texture due to chilling in contact with the adjacent rock. *Are there any other rock types among the boulders here?*



Suggested itinerary, activities, and discussion questions

Return back down the road, past the rock wall, and turn left to visit the rock piles next to the Greenlaw Quarry (Site 7; Figure 9). This is a good area to gather a collection of minerals for yourself or your school. Unknown minerals can be brought home and researched with the help of mineral identification guidebooks. Keep in mind that the photographs in many nature guides tend to show ideal or beautifully crystallized minerals, which unfortunately are not typical of what we usually find!

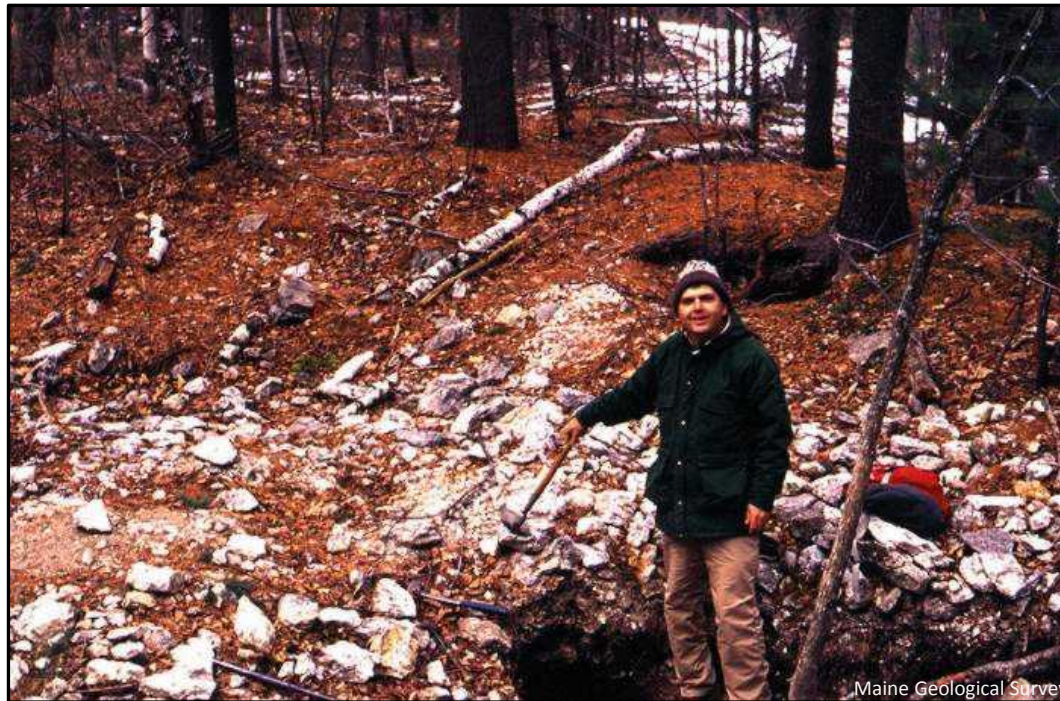


Photo by Maine Geological Survey

**Figure 9.** Digging for minerals in dump at Greenlaw Quarry (on New Year's Eve!).

Suggested itinerary, activities, and discussion questions

The common minerals at the Greenlaw are described above. They include milky and smoky quartz, feldspar species (microcline and albite), muscovite mica, black tourmaline, and garnet. Two other micas - black biotite and purple lepidolite - can be found, along with fragments or small crystals of green and blue tourmaline. You may be lucky and also find some of the many rarer minerals that have been discovered here. To access another collecting site, continue back down the road and turn right (south) to the huge dump pile from the Maine Feldspar Quarry (Site 8; Figure 10). Many garnets are found here. Thompson et al. (1998) list 39 mineral species that have been reported from the Greenlaw and Maine Feldspar Quarries.



**Figure 10.** Large dump next to Maine Feldspar Quarry.

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### Additional Information and Acknowledgements

Looking at exhibits in museums, and at shows and stores where minerals are sold, is a good way to get acquainted with them. Students may find that an interest in minerals leads to a career in the earth sciences or a satisfying lifelong hobby. Local mineral clubs conduct meetings and field trips, and club members are usually very helpful to beginners wishing to learn more about the hobby and mineral recognition.

Prof. William B. Simmons (Department of Geology and Geophysics, University of New Orleans) reviewed the text and provided helpful comments on the origin of pegmatites. We are especially grateful to the City of Auburn for keeping this important Maine mineral locality open to the public.

