Barre granite quarries, Barre, Vermont

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LOCATION

The Barre granite quarry district is located in the southeastern section of Barre Town, Washington County, Vermont, near the villages of Graniteville and Websterville. The quarried area extends slightly into the northeastern corner of Williamstown, Orange County. Figure 1 shows the general location of the quarry district and the various village entities within Barre Town.

From I-89 the area is reached by taking Exit 6 (Barre, South Barre) and following the access road 5 mi (8 km) to the intersection with Vermont 14 (Fig. 1). Cross Vermont 14 and follow Middle Road to Graniteville.

Figure 2 shows the locations of the quarries discussed in this field guide. Public viewing platforms are available at the edge of the Rock of Ages quarry (behind the Rock of Ages Visitors Center, 0.9 mi [1.5 km] east of Lower Graniteville) and the Wells-Lamson quarry (along the Websterville Road at the north end of the quarry). During the summer months, Rock of Ages operates a short train ride for tourists that gives an excellent view of the active Smith Quarry and the abandoned Duffee Quarry.

Access to the several other active and abandoned granite quarries in the area may be obtained only by making prior arrangements with the Rock of Ages Corporation and the Wells-Lamson Quarry Company. Both companies are accommodating to serious visitors and researchers who wish to do detailed sampling or mapping. The Pirie/Adam, Smith, and Wetmore & Morse quarries are especially interesting to visit. There are more than 70 inactive quarries in the Barre area, but most are now filled with water; in fact, many are a part of the local public water supply. Dale (1923) provided a map showing the locations and names of many of the quarries active at that time.

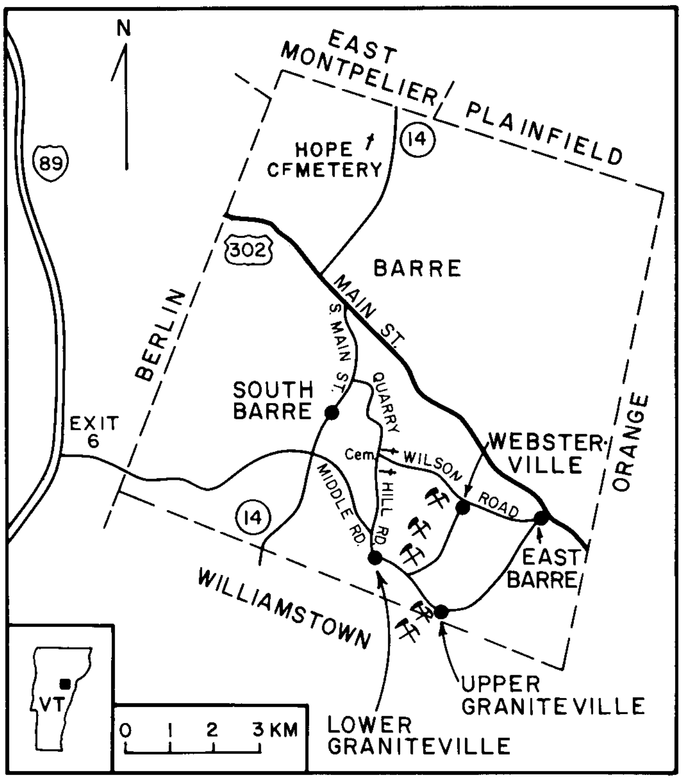

Figure 1. Location of Barre quarry district and numerous villages within the boundaries of Barre Town, Vermont.

SIGNIFICANCE

The Barre granite quarries expose a three-dimensional view of a small, well-studied pluton of the New Hampshire Plutonic Series. It is a Devonian talc-alkaline pluton formed by partial melting of Siluro-Devonian sedimentary rocks that had been folded and regionally metamorphosed during the Acadian orogeny and thus illustrates that the orogeny occurred rather suddenly in the region.

Contact relations with the Siluro-Devonian Gile Mountain Formation, internal igneous flow features, and various types of postconsolidation fracturing are very well displayed in the quarries. In addition, the Barre quarry district is one of the few localities in the Northeast U.S. where geologists and the public can observe the ancient and honorable tradition of quarrying large-dimension stone blocks.

REGIONAL SETTING

The Connecticut Valley-Gaspé synclinorium in eastern Vermont is characterized by tightly folded phyllitic and calcareous metasediments of the Gile Mountain and Waits River formations. The metasediments are generally interpreted to have been deposited in the remnants of the Iapetus ocean. A series of more than 20 two-feldspar, two-mica granitoids, ranging in size from small dikes <0.6 mi (< 1 km) long to plutons >37 mi (>60 km) in diameter, intrude the metasediments in eastern Vermont. In general, the plutons are unzoned, internally uniform in composition, and not associated with igneous rocks more mafic in composition than diorite.

Contacts with the metasediments are mildly to strongly discordant. Metamorphic aureoles are associated with most of the intrusions (including the Barre pluton), indicating that the plutons were intruded after the peak of regional metamorphism. The regional metamorphic grade of the host metasediments ranges from garnet to kyanite grade in central Vermont. The regional metamorphic grade around the Barre pluton is staurolite grade.

Naylor (1971) obtained K-Ar dates on primary micas in

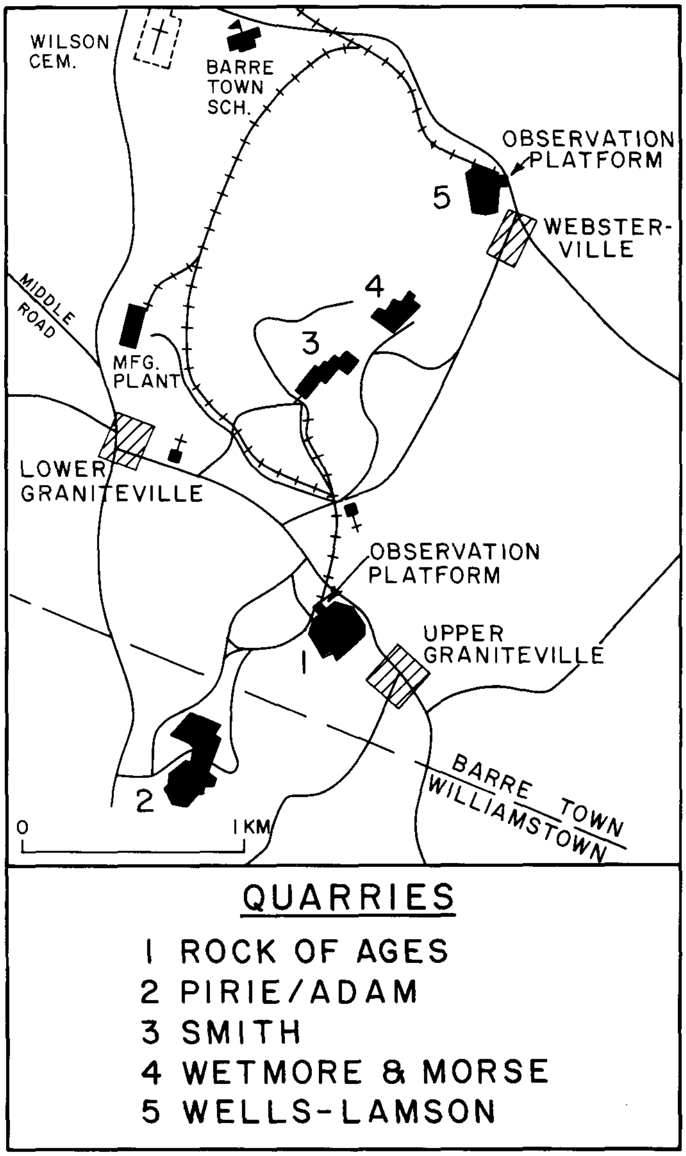

Figure 2. Sketch map showing quarry locations discussed in text.

several of the Vermont granitoids (including the Barre pluton) that clustered around 380 Ma. He concluded that the Acadian erogenic event in that part of the northern Appalachians must have been a brief but intense event, since the Devonian granitoids crosscut Devonian sediments that had been folded and regionally metamorphosed before intrusion.

BARRE AREA

Figure 3 is a generalized geologic map of the Barre area modified from Murthy (1957) and Doll and others (1961). The Barre pluton is contorted in outline but is approximately 1.9 mi (3 km) wide and 5 mi (8 km) long. The pluton is elongated parallel to the regional strike of the enclosing metasediments, the Gile Mountain Formation for the most part, and the Waits River Formation for a segment of the eastern contact. A much larger igneous body of similar composition, the Knox Mountain pluton, occurs a few miles northeast of the Barre pluton.

The Gile Mountain Formation is composed of fine-grained, dark gray mica schists and micaceous quartzites. The Waits River Formation contains similar rocks plus abundant caleareous schists. The stratigraphic relationships between the two host formations are complex and contradictory in places. Woodland (1977) and Fisher and Karabinos (1980) determined from structural analysis and graded bedding in the Royalton area, approximately 31 mi (50 km) south of Barre, that the Gile Mountain Formation is younger than the Waits River Formation and that the belt of Gile Mountain Formation in which most of the Barre pluton resides is the core of a north-plunging synform. Woodland (1977) has further suggested that the synform is the downward-facing nose of a recumbent nappe with an eastward root zone.

Contacts of the Pluton

Foliation of the metasediments near the Barre pluton is nearly vertical, strikes north-northeast, and more or less bulges around the igneous rock. The contacts of the pluton are thus semiconcordant with the foliation in most places. It appears that the pluton gently "shouldered" itself into position along zones of weakness in the country rock. Large xenoliths (>6 ft or >2 m) that appear not to have been reoriented are common, and septa of the metasediments (possible roof pendants) are present within the pluton.

A good pavement exposure of the contact occurs behind the storage garages at the south end of the Pirie quarry. The contact is exposed in places along the east walls of the Rock of Ages and Pirie quarries where quarrying terminated. A large septum of the Gile Mountain Formation roughly follows the road between Lower Graniteville and Websterville. Small outcrops along the road contain the contact and small dikes of granitic material invading the country rock. Contact with the same septum is visible along the east walls of the Smith, Wetmore & Morse, and Wells-Lamson quarries.

Composition

The Barre pluton is strikingly uniform in composition. It is a gray, fine- to medium-grained (1 to 5 mm) granodiorite. Note, however, that even among geologists the rock is widely known and commonly referred to by its commercial name, Barre granite.

In thin section, the rock is characterized by sericitized oligoclase laths (35 volume percent), partially chloritized reddish-brown biotite (9 percent), moderately to highly strained quartz (27 percent), and interstitial fresh-appearing microcline (21 percent). Primary muscovite (6 percent) is not common but does occur as disseminated ragged flakes. Common accessories include minute (<0.1 mm) zircon, apatite, sphene, metamict allanite, and opaques. Chayes's (1952) modal analyses on 21 samples from different quarries in the Barre district show little variation in modal abundances despite apparent visual variations in grain size and gray shades.

Aplites do not occur in the Barre pluton and pegmatitic veins are not common. The few pegmatites that occur are simple unzoned pegmatites composed of 4-6 cm creamy plagioclase, microcline, thin mats of muscovite and biotite, and interstitial quartz. A pair of semihorizontal pegmatite dikes, 3 ft (1 m) thick, occurs in the south wall of the Pirie quarry. A zone of pegmatitic material also occurs along the upper east side of the excavation for the Adam quarry. (Note: the Pirie and Adam quarries are converging as quarrying proceeds and may be considered one quarry by the owners.) The quarrymen refer to the pegmatitic material at the Adam quarry as "Gazeley," after the name of a quarry started in similar rock some time ago. Pegmatite veins are more abundant in the Knox Mountain pluton a few mi (km) to the northeast of the Barre pluton.

Internal Fabrics

Primary igneous flow patterns are faintly visible at most locations in the quarries. Balk (1937) measured the attitude of the lineations and concluded that there are several domelike intrusions represented in the quarries. In general, the flow patterns in the currently active quarries appear to dip gently to the southwest.

From the observation platform at the Rock of Ages quarry, prominent flow lines can be observed at the northeast corner of the quarry, about 15 ft (5 m) below an unused red hoist building. Another area of pronounced flow features occurs near the top of the Smith quarry at the U- 1 derrick location. Here, the flow lines are wavy and commonly cross-cutting.

Xenoliths are common near the contacts of the pluton. They are particularly common in the southeastern limb of the body and can be seen in all stages of assimilation by the magma in the Rock of Ages and Pirie quarries. From the observation platform at the Rock of Ages quarry, one can observe large (6 to 15 ft; 2 to 5 m) xenoliths and biotite schlieren in the east wall of the quarry, and toward the bottom of the south end of quarry. Xenoliths are much less common in the Smith, Wetmore & Morse, and Wells-Lamson quarries, which are located in the central portion of the pluton.

Structure

Two styles of jointing are present in the Barre quarries: high-angle joints with a northeast strike, and sheeting joints that follow the topography. One type of joint is generally more prominent in each quarry.

In the Rock of Ages and Pirie/Adam quarries, a prominent set of joints strikes northeast and dips steeply eastward. The dip is about 70° in the Rock of Ages quarry and about 45° in the Pirie/Adam quarry. Joint surfaces commonly contain slickensides and are marked by greenish chloritized alteration products. Sheeting and cross-jointing are poorly developed in the Rock of Ages and Pirie/Adam quarries.

In contrast, high-angle joints are much less common and more widely spaced in the Smith, Wetmore & Morse, and Wells-Lamson quarries. These quarries, located on the flanks of Millstone Hill, are characterized by well-developed sheeting joints that are subparallel to the topography of the hill. The spacing between sheeting joints gradually thickens from <4 in (< 10 cm) near the surface to >15 ft (>5 m) in the quarries.

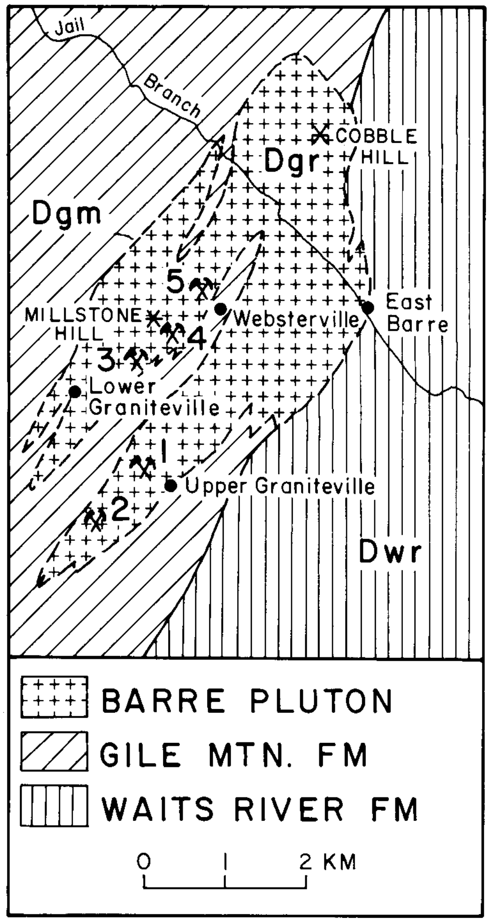

Figure 3. Generalized geologic map of Barre area. Numbered quarries are the same as shown in Figure 2. (Modified from Murthy, 1957, and Doll and others, 1961.)

Sheeting is generally thought to be formed during unloading as the rock is brought to the surface. It appears that because the southeast limb of the Barre pluton had a prominent set of high-angle joints along which the unloaded stresses could be relieved, the formation of sheeting was not favored. In the central part of the pluton, on the other hand, high-angle joints are not well developed, and in situ stresses during unloading could be relieved only by propagating sheeting joints.

Rock bursts, i.e., the spontaneous cracking of the granodiorite during quarrying, is a common phenomenon in the Barre quarries (White, 1946). The rock bursts are due to release of in situ stress and are more common in sheeted than in unsheeted quarries. Nichols (1975) found that the strain relaxation time for a quarried block of Barre granite was several days. It is interesting to note that quartz in thin sections from the central quarries appears less strained than quartz in thin sections from the southeastern quarries.

Several Mesozoic lamprophyre dikes intrude the Barre pluton. The dikes are generally 3 to 5 ft (1 to 1.5 m) wide and have a northeast strike similar to that of the high-angle joints. A pair of narrow dikes can be observed in the north wall of the Rock of Ages quarry on strike from the observation platform. One of the dikes is continuous under the face below the platform.

Economic Geology

The Barre pluton has been quarried for dimension stone continuously since the 1830s. The quarry industry became a major economic force in the Barre area after the Civil War, when the railroad was constructed and when, at about the same time, the market for cemetery monuments shifted from marble to the more durable granite. Most granite blocks produced in Barre today are manufactured into cemetery monuments. Other products include building facings, surface plates (precision ground flat tables for machine bases and inspection surfaces), and paper rolls. The paper rolls are cylinders up to 30 ft (10 m) long and 6 ft (2 m) in diameter, which are used to dewater crushed pulp in the manufacture of newsprint. The Barre district is one of the major producers of granite products in the United States.

Quarrymen are natural practitioners of rock mechanics in that they use jointing and the microstructure of the granite to split out regular rectangular blocks. In the dimension stone industry, the three directions in which a block of granite will split commonly are called “rift,” “grain,” and “headgrain” (or “hardway”), in order of decreasing ease of splitting. The three directions of splitting are termed “rift,“ “lift,” and “head” in the Barre district only.

The rift is parallel to the sheeting in most quarry districts; in Barre, however, the rift is a nearly vertical plane that has a strike roughly parallel to the strike of the high-angle joints. It is independent of primary igneous flow features in the rock. The rift is defined by a set of open and partially healed intergranular microcracks that can be recognized in oriented thin sections (Douglass and Voight, 1969). Dale (1923) recognized that planes of secondary fluid inclusions in quartz are aligned with the rift of several commercially quarried granites. With practice, the rift in the Barre granite can be recognized in blocks and in outcrop by looking for minute cracks with a preferred orientation in quartz grains.

The optimum block size from the Barre quarries is 175 to 200 ft^3 (5 to 6 m^3), a size that permits the mass manufacture of cemetery monuments. Waste (called “grout” in the industry) is unusable stone that is undersized, irregularly shaped, fractured, or is “blemished” by xenoliths (“knots”), veins (“sand lines”, “streaks”), or strongly pronounced flow features (“waves”). Saleable recovery from the Barre quarries varies from 25 to 40 percent. More than 700,000 ft^3 [20,000 m^3] of granite blocks are produced by the Barre district quarries annually. The quarry blocks are separated into five grades, depending on their color and texture. The darker gray, finer grained granite from the Rock of Ages and Pirie quarries commands the highest price. By the time the granite is processed into a finished product, the total recovery is said to be 15 percent.

The waste is discarded in huge piles since there is no economic use for it. The market for crushed stone is too small in the Barre area to make much use of the grout. The granite is too fine grained and the feldspars contain too much iron for separation into individual mineral products for the industrial minerals market.

The manufacturing process for the granite products is fascinating to most geologists, although it is too detailed to be described here. There is an observation platform at the Rock of Ages manufacturing plant in Lower Graniteville where one can see large automated polishing machines and also stone cutters hand-trimming granite monuments. Some of the smaller granite fabricators in the city of Barre also permit serious visitors. In addition, a visit to Hope Cemetery located on the west side of Vermont 14 just north of the city of Barre is highly recommended for those who are interested in seeing spectacular carved granite monuments.

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