Geology Exercise Comments:  (F. Dudás, 8/31/09)

Attached are two different drawings of what this outcrop (in this case, roadcut) looks like. The drawings differ in emphasis: what you see as important depends on the use you wish to make of the observations!

In both cases, the drawings should have a direction indicator (where is North?), and a scale (approximate). My drawings are missing a scale!

One drawing emphasizes features related to general geologic mapping: what and where are the major rock types, what are the major rock units, and where are the major structures.

The major rock types are a gray gneiss, that in this location, is called the Rangeley Formation, and makes up the majority of the outcrop, and a mica schist that is called the Smalls Falls Formation. The Smalls Falls Formation is exposed as a sliver of rock overlying the northern end of the exposed road cut. If you didn’t walk the full length of this outcrop, you probably missed seeing the Smalls Falls Fm. A subordinate rock type is granitic pegmatite that forms small dikes and pods in several places. The gray gneiss and mica schist are metamorphic rocks, whereas the granitic pegmatite is an igneous rock.

The major rock units are the Rangeley Formation and the Smalls Falls Formation.

The major structures exposed in this roadcut are (1) the contact or boundary between the Rangeley Fm and the Smalls Falls Fm (I didn’t look at this in detail, to see what kind of boundary this is!), (2) the major fault that cuts upward and to the north, and (3) a smaller fault that cuts almost vertically into the rock face on the south end of the outcrop. Both of the faults are zones where water is flowing out of the rock face. The faults indicate that the rocks were exposed to significant strain while they were cool enough to break in a brittle fashion. The gneiss, particularly, shows smaller-scale deformation as swirls and undulating foliation – features that indicate deformation by flow while the rocks were warm enough to be ductile. The brittle deformation features are later than the ductile deformation features, because the faults are not themselves deformed.

The presence of granitic pegmatite indicates that the temperature and pressure to which this package of rocks was exposed exceeded the conditions required for the beginning of melting. The presence of aluminum-rich minerals suggests that the original rocks, from which these metamorphic rocks formed, were rich in clay – their precursors were probably sedimentary rocks. The presence of large and relatively abundant tourmaline in the granitic pegmatites suggests that these were originally marine sediments – tourmaline is rich in the element boron, and, among the major geochemical reservoirs in the crust of the earth, seawater is the only one that has significant amounts of boron!

The second drawing emphasizes features that are important to geological engineering – where the fractures are, where the water is flowing through the rock, where rock bolts have been used to stabilize loose blocks.
The detailed drawings are specific to my interests as a geochemist. The presence of xenoliths (xeno = foreign, lith = rock; in other words, rocks that are foreign to the bulk of the host rocks) indicates that the gray gneiss unit, the Rangeley Fm, has a complex history prior to the metamorphic episode that made it into gneiss. The xenoliths are a record of this earlier history. Without more detailed study of these foreign fragments, I can’t tell what their geologic significance might be. Features around the xenoliths – the ductile deformation of the gneiss - tell me a little bit about the conditions that existed during metamorphism.

The quartz vein in the smaller, irregular fault, contains the mineral pyrite. This is an iron sulfide – FeS₂ – that is progressively breaking down due to exposure to water and oxygen in the atmosphere:

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2 \text{FeS}_2 + 5 \text{H}_2\text{O} + 7.5 \text{O}_2 = 2 \text{FeO(OH)} + 4 \text{H}_2\text{SO}_4
\]

pyrite goethite sulfuric acid

Goethite (named for the famed German naturalist and, incidentally, writer, Goethe!) is the rust-colored mineral that gives this roadcut its rusty color. The sulfuric acid formed in this reaction is the same thing that causes the problems with “acid mine drainage” and “acid rain.” Note that the reaction generates 2 moles of acid per mole of pyrite! The other mineral that forms in this environment is jarosite, a yellowish mineral that incorporates both iron and sulfate: KFe₃(SO₄)₂(OH)₆; it also scavenges some potassium that is dissolved in the water. The presence of jarosite probably buffers the pH of the “acid mine drainage” to about 1.8.
A similar sketch could be made emphasizing hydrologic features. Thus, for example, the faults and the contact between the Smalls Falls Fm. and the Rangeley Fm. are channels where water preferentially flows. These waters precipitate some iron oxides, hydroxides and sulfates, as well as some silica or carbonates.
This is schematic. The exact spacing of blast holes and rock bolts is not shown by this sketch. The engineering geology sketch should also take account of the differences in rock type because the Rangeley Fm. gneiss is much more competent than the rocks of the overlying Smalls Falls Fm., but I have chosen to show those only on the general geology sketch. This sketch does not show numerous other, smaller faults and fractures.
Detailed sketches of some geological features

**Detail of xenolith in gneiss:**

![Diagram of xenolith in gneiss]

The foliation in the host gneiss indicates that the metamorphic environment during formation of the gneiss was in the ductile regime (rocks bend, rather than break, typically at T > 400°C, at depths > 10 km below surface).

**Detail of sulfide-bearing quartz vein, filling fault:**

(near south end of roadcut)

Faulting - the breakage of rocks - demonstrates deformation in the brittle regime. The age of this fault and fault-filling vein is younger than the gneiss, but is otherwise not constrained. It could be as young as the glacial period.

Breakdown of pyrite by oxidation forms sulfuric acid - the typical "acid mine drainage" reaction.