STOP 3. Trap Rock Industries, Moore's Station Quarry

The quarry is located only about 5 minutes away from the park (fig. 25). We return to NJ Route 29 and head southeast for about a mile. The entrance of TRI's Moore's Station Quarry will be on our left. As a reminder:

HARD HATS ARE REQUIRED THERE, AND THERE WILL BE NO DIRECT CONTACT WITH HIGH WALLS IN THIS ACTIVE QUARRY.

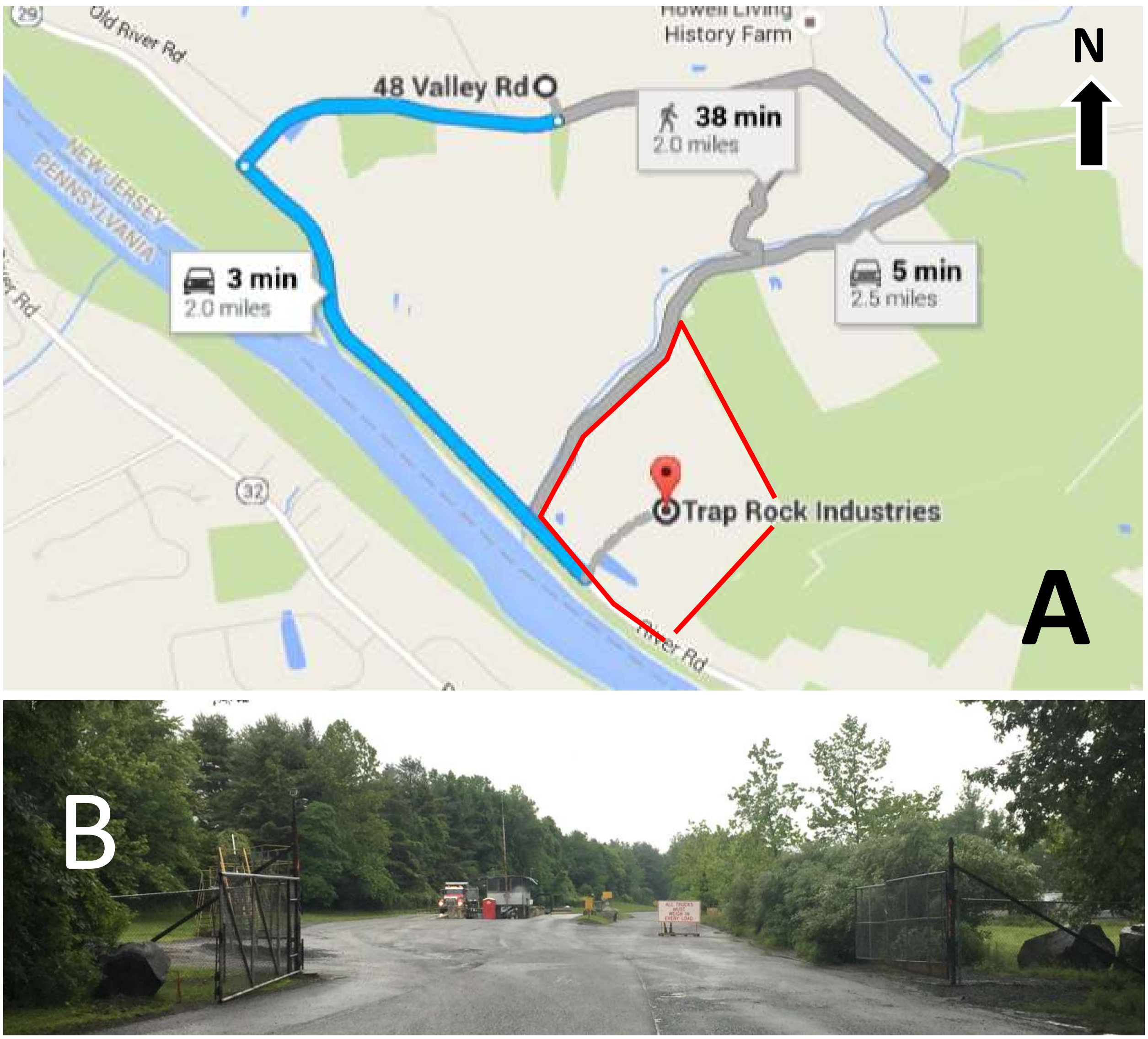


Figure 25. A. The route from Mercer County Park at 48 Valley Road to Trap Rock Industries' Moore's Station quarry. The Moore's Station quarry parcel is outline in red. **B.** Photo of the quarry's entry gate.

This STOP will be a relatively quick drive through – more a sight-seeing tour with one mineral-collecting opportunity near point B (fig. 26). It is expected that this STOP should take about 30 minutes. This quarry has thick, excavated exposures of red-bed hornfels (fig. 27) that rival anything that seen in the New Jersey part of the Newark Basin. This quarry is developed in the west end of the Baldpate Mountain dolerite body (figs. 18-22) in a manner reported by Herman and others (2013) as part of their work in detailing the plumbing geometry of the complex system of intrusive bodies in the center of the basin that are part of the Central Atlantic Magmatic Province (CAMP; Marzoli and others, 1999).

The Moore’s Station quarry has a long and storied history. According to Mindat.org, an on-line Mining and minerals database:

“This is a large quarry located at the northwest end of Baldpate Mountain, adjacent to Rt. 29 and Pleasant Valley Road. It is very near the Delaware River. The quarry was abandoned in 1932, the same year the nearby Delaware and Raritan Canal went out of business, and lay dormant for 50 years. It was reactivated by Trap Rock Industries in 1982 and called the "Moore’s Station Quarry. …This quarry is cut by splays from the Hopewell Fault. Some of the common members of the prehnite - zeolite mineral assemblage, typical of the New jersey trap rocks are present although significant collecting has not been possible in the large scale, industrial atmosphere that prevails at this site.”

According to correspondence from Mercer County addressed to the NJ Water Supply Authority (on file at the offices of the NJGWS), the County purchased the 166-acre property from TRI, Inc. subject to the stipulation that TRI retains the right to continue quarrying activities for a period of 25 years, terminating in 2022. The property is currently part of the 1,200-acre regional nature area and passive recreation park known as the Ted Stiles Preserve at Baldpate Mountain. The County is in the early stage of planning for future recreation use of this site, and evaluations are underway to see if this site might fit into New Jersey’s future reservoir needs. A seen in figure 28A, the quarry is very deep, with over 6 benched levels and a range in elevation of about 120 m (~400 feet) from the nearby uplands on Baldpate Mountain down to the floor (~0m elevation). Current estimates are that the quarry is capable of holding about 2 billion gallons of water (written communication from Mercer County Division of Planning to the New Jersey Water Supply Authority dated 04-29-2015 on file at the NJGWS.).

As we drive into the main quarry area, we see the northeast wall in the distance, and the structural arrangement of the igneous layering relative to the overlying hornfels, as pictured in figure 27. A 3D display in GE of the igneous layers, sedimentary beds, and steeply dipping normal- and oblique-slip faults measured in outcrop within and around the quarry is shown in figure 26B. The Early Jurassic dolerite is steeply dipping to the right in the NE wall and the hornfels dip gently northwest and to the left. The dominant fracture pattern seen in the

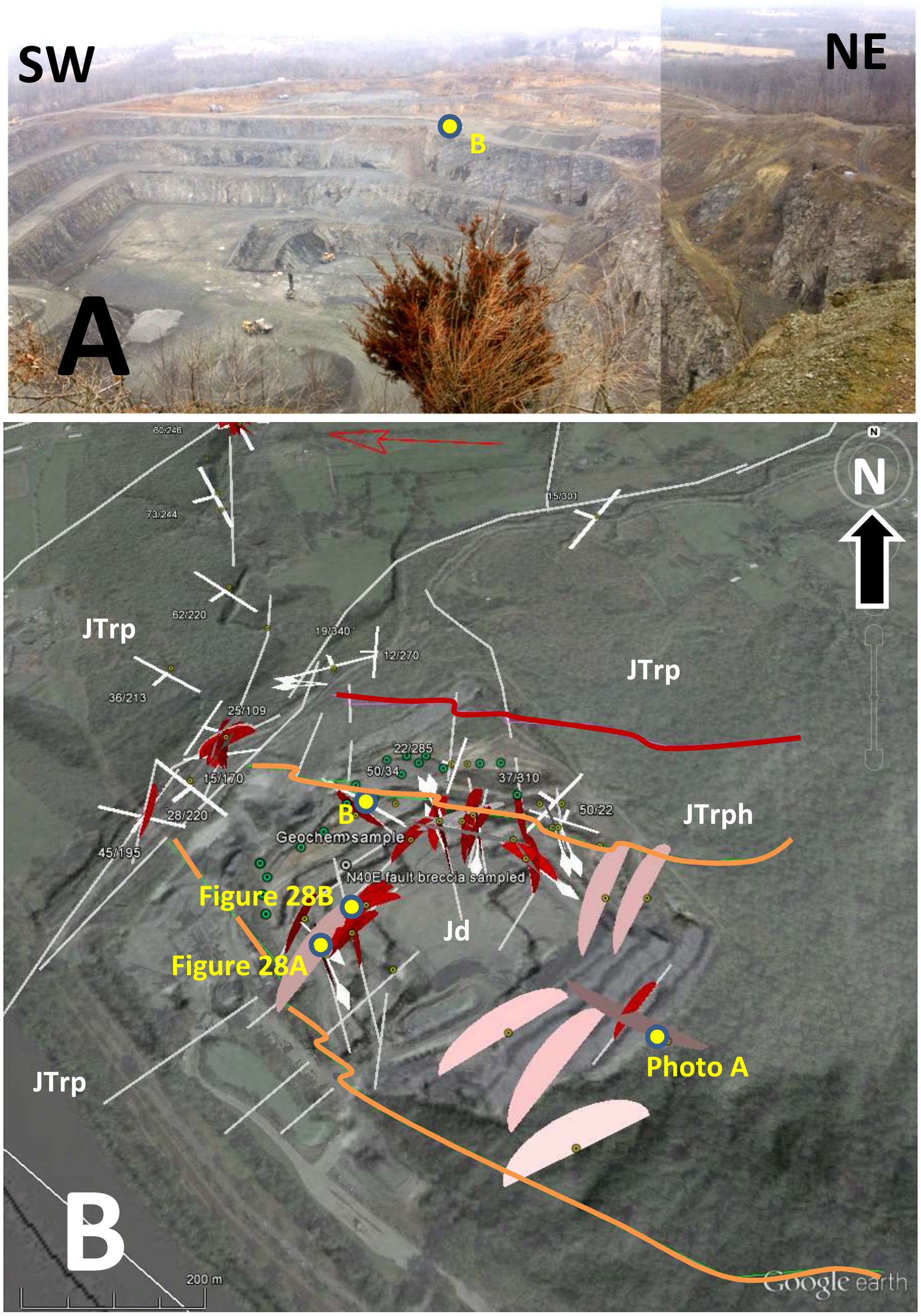
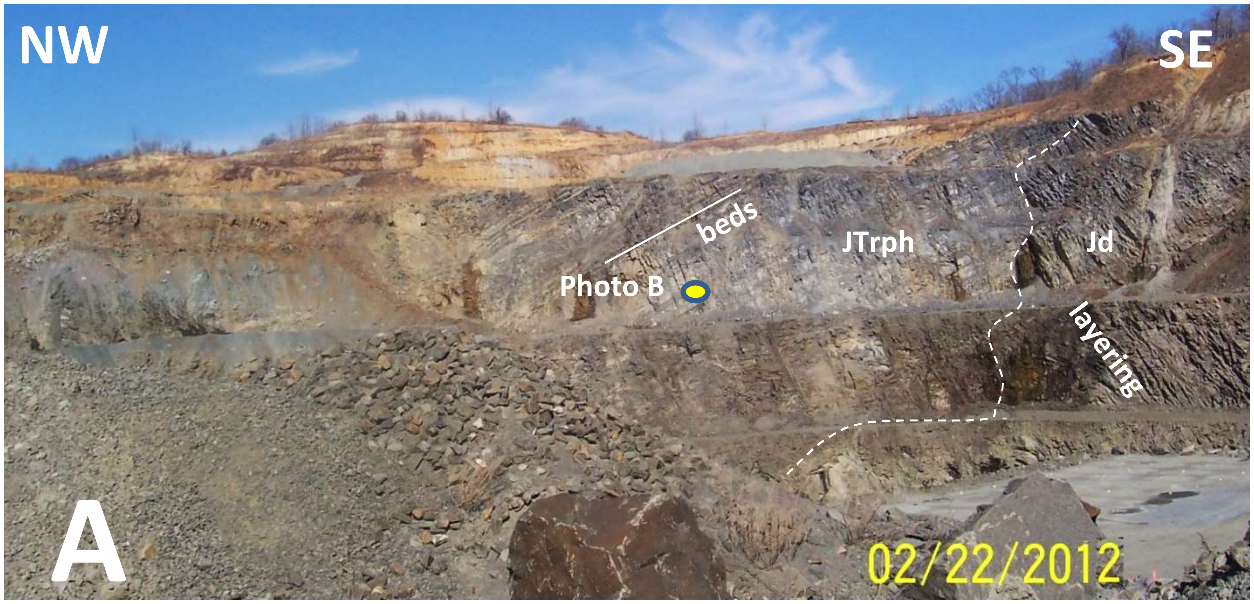


Figure 26. A. February 2012 overview of the Moore's Station quarry, looking SW from the ridge crest on Strawberry Hill (fig. 22). **B.** Obliquely tilted overhead view of the Moore's Station quarry showing some 2D and 3D structures. The PASDA grayscale hill-shade image overlay is set at 80% transparent. White bed symbols have dip/dip azimuth notation. Green points are the locations of TRI test borings. White points are NJGWS field stations. The white lines are fault traces, orange lines are trap (Jd) contacts, and the dark red line is the upper hornfels contact. The pink 3D ellipses represent compositional layering in dolerite-trap that generally dips SE to NE. The red 3D ellipses represent fault planes. White 2D arrows show slickenline trends and plunge directions. Fault movement is mostly down to the E-SE for most fault blocks although N-W fault slips occur. The northern Jd-JTrph contact is indicated where the trap nonconformably plunges beneath Passaic Formation hornfels, as seen in figure 27A. Point B is near where the Buses will park for mineral collecting from the gravel berms.



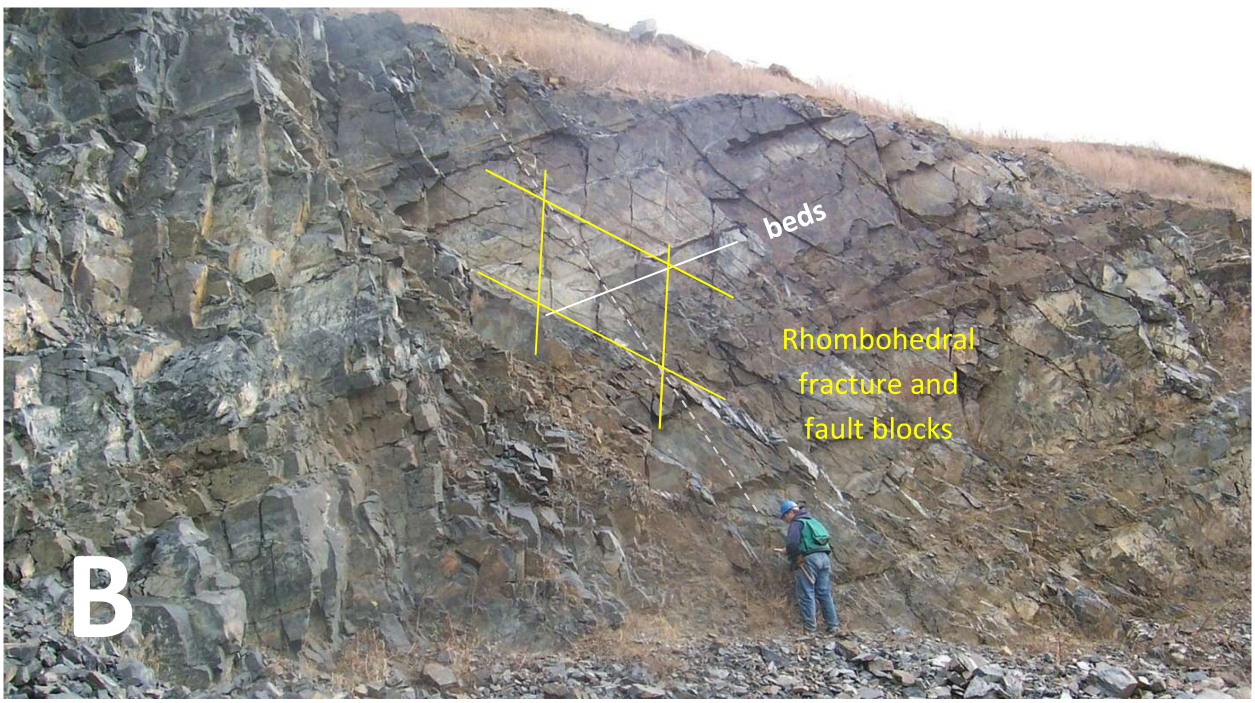


Figure 27. A. Northern view of the gray, brown, and purple hornfels of the Passaic Formation, dipping moderately west with the steep SE-dipping diabase cropping out beneath it to the right. **B.** Passaic Formation hornfels dipping gently NW showing a rhombohedra fracture geometry stemming from overlapping sets of tension fractures developed during the Mesozoic rifting (see cross-section in fig. 15 and Herman, 2009).

dolerite dips steeply southeast and reflects pervasive cooling fractures that formed parallel to compositional layering and that locally interacted with conjugate shear planes and other cooling fractures to impart sigmoidal shear structures to the igneous layering (fig. 30). These same relationships are observed in TRI's Pennington quarry (Herman and others, 2013). The structural form of igneous layering and sedimentary bedding are very well exposed here and provides evidence of the mechanics of magmatic stoping (Day, 1914), the process by which magma was intruded into the sedimentary section.

For example, figure 19 traces LiDAR lineaments in the Lambertville Sill striking at 30°-60° angles relative to the encompassing sedimentary-bedrock ridges. These traces also likely correspond to compositional layers representing individual magma pulses that were injected into the sedimentary section along developing, crustal fractures that were aligned normal to regional tension at that time (S2 structural phase of Herman, 2009). This means that for the Lambertville Sill, as for Baldpate and Pennington Mountains, igneous layering commonly strikes and dips at high angles relative to the upper nonconformity. This normal alignment of compositional layering with bounding nonconformities is also seen in the Mt. Rose dike leading to the Rocky Hill dolerite body (Herman and Curran, 2012) and the Stockton dolerite body hosting TRI's Lambertville quarry (Herman and others, 2013). The mechanics of magmatic stoping therefore includes compositional layers that were inserted into steeply dipping, extension fractures that developed within focused horizons during tensional rifting.

It's convenient to think of the injection process as magma rising through subsidening crust that is forming extension fractures to accommodate crustal stretching, rather than magma forcefully stoping into bedrock along a specific stratigraphic layer at low angles and uplifting suprajacent beds in the process. Magma is first injected from a subvertical feeder dike laterally into a thick, semi-consolidated sedimentary pile at a depth where lithostatic pressure equals magmatic injection-pressure. But as the injection process continues, the magma stopes upward at moderate to steep angles along rhombohedral-shaped, overlapping faults that we repeatedly see developed in transtentional crustal environments involving at least two phases of non-coaxial extension (figs. 24 and 25; Herman and others, 2009; 2013; Henza and others, 2009). A point to emphasize here is that dolerite intrusions in the Delaware Valley are igneous bodies with composite geometric form having igneous layers paralleling encompassing sedimentary beds in some places, but with angular nonconformance elsewhere. In the case of Baldpate Mountain, injection of this western limb appears to reflect an eastern source, because layering dips eastward to where the medial dike segment springs in a normal direction from the trace of the Hopewell fault, near a major fault branch (figs. 18-20). Similar intrusion geometry is seen for the Pennington trap body (fig. 18) and both intrusions have been shown to reflect fault-mediated ascent of CAMP dolerite from lower stratigraphic sections to the northwest into higher sections to the southeast (Husch and others, 2009; Herman, 2013).

Figure 28. Outcrops along upper- and lower-level benches looking west towards the east face cuts noted in figure 26, where igneous layering dips moderately SE (upper right to lower left). In photo **A**, some rusty, layer-sub-parallel faults occur in upper-level faces near land surface where meteoric groundwater infiltrated fault surfaces and zones coated and impregnated with iron-rich minerals including chlorite, epidote, and sulfides In photo **B**, the sigmoidal interaction of cooling joints with shear fractures belies synchronous magmatic injection and normal shearing.

For STOP 3, we will drive through the quarry and out on the 1st or 2nd - level benches where mineralized hornfels are excavated (photo B on figure 27A) and where the berms contain excavated, mineralized hornfels. Figure 29-31 and table 3 provide some details of the mineralized horizons and mineral specimens that have been documented at, and that we have collected from, this quarry. A list of minerals in table 3 below is tallied from www.mindat.org and expanded with chemical formulae and abstract descriptions adapted from Deer and others (2013) and Wikipedia. All of these minerals have petrogenesis in volcanogenic igneous settings associated with the mineral infilling of voids, amygdales, and veins in ore-bearing environments from transport during low-temperature hydrothermal circulation including sulfur and copper.

Table 3. List of minerals reported from TRI Moore's Station quarry on www.mindat.org

Mineral	Chemical Formula	Comment
Calcite	$CaCO_3$	
Chabazite	$(Ca,K_2,Na_2)_2[Al_2Si_4O_{12}]_2 \cdot 12H_2O$	Zeolite tectosilicate
Heulandite	$(Ca,Na)_{2-3}Al_3(Al,Si)_2Si_{13}O_{36} \cdot 12H_2O$	Zeolite tectosilicate
Stilbite	$[NaCa_4$ or $Na_9](Si_{27}Al_9)O_{72} \cdot 28(H_2O)$	Zeolite tectosilicate
Natrolite	$Na_2Al_2Si_3O_{10} \cdot 2H_2O$	Zeolite tectosilicate
Apophyllite	$(K,Na)Ca_4Si_8O_{20}(F,OH) \cdot 8H_2O$	Hydrated sheet silicate
Prehnite	$Ca_2Al(AlSi_3O_{10})(OH)_2$	Chain silicate – metamorphic-facies mineral
Schorl **(Tourmaline)**	$(Ca,K,Na,[\ ])(Al,Fe,Li,Mg,Mn)_3(Al,Cr,Fe,V)_6(BO_3)_3(Si,Al,B)_6O_{18}(OH,F)_4$	Trigonal Boron silicate
Pyrite	FeS_2	Isometric cubic
Marcasite	FeS_2 (white pyrite)	Orthorhombic
Chalcopyrite	$CuFeS_2$	Isometric hextetrahedral w/ perfect cleavage
Sphalerite	$(Zn,Fe)S_2$	

Note: [ ] An empty, double bracket denotes that the following combination of chemicals form repeating units in the chemical formulae.

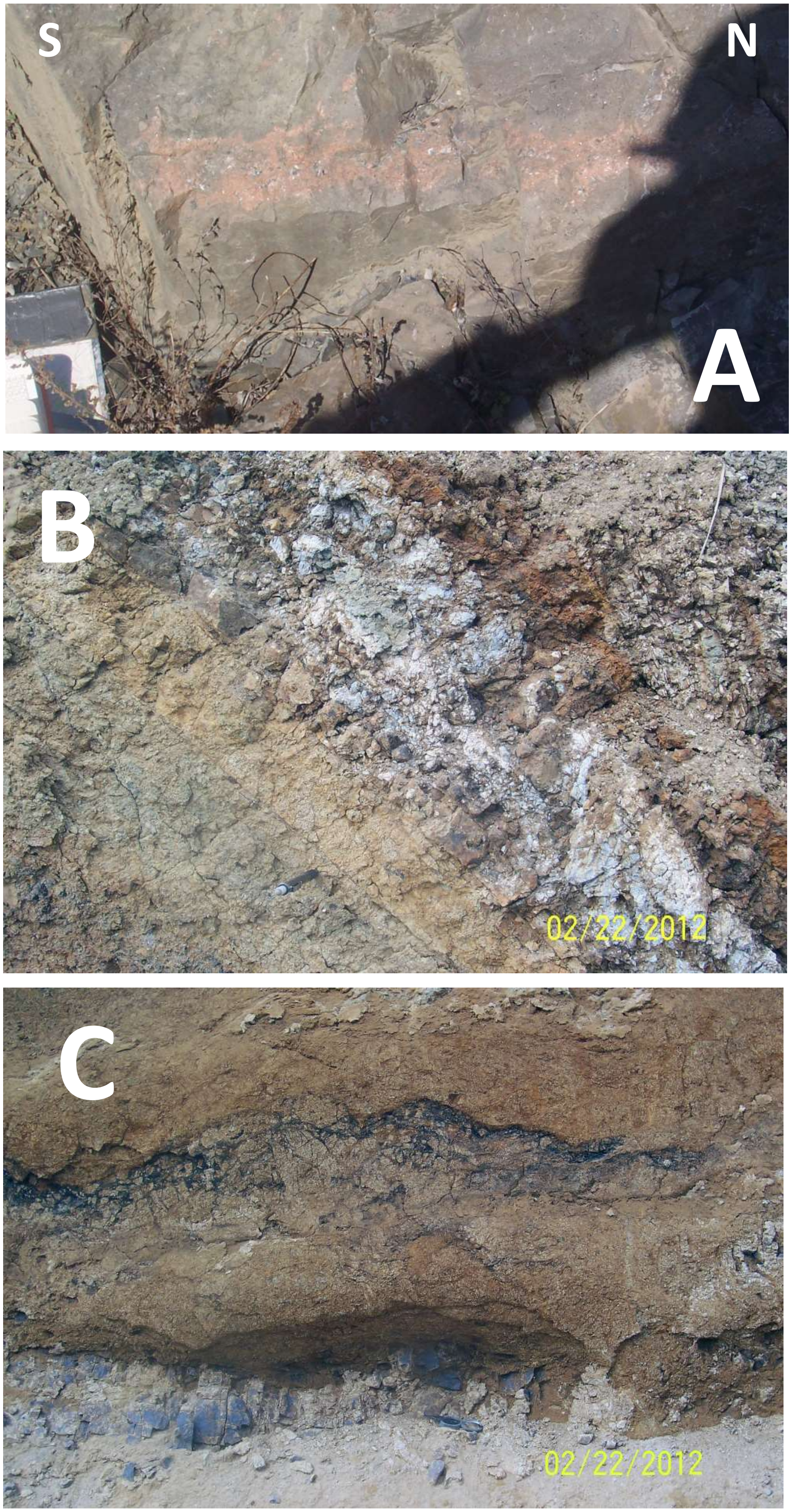
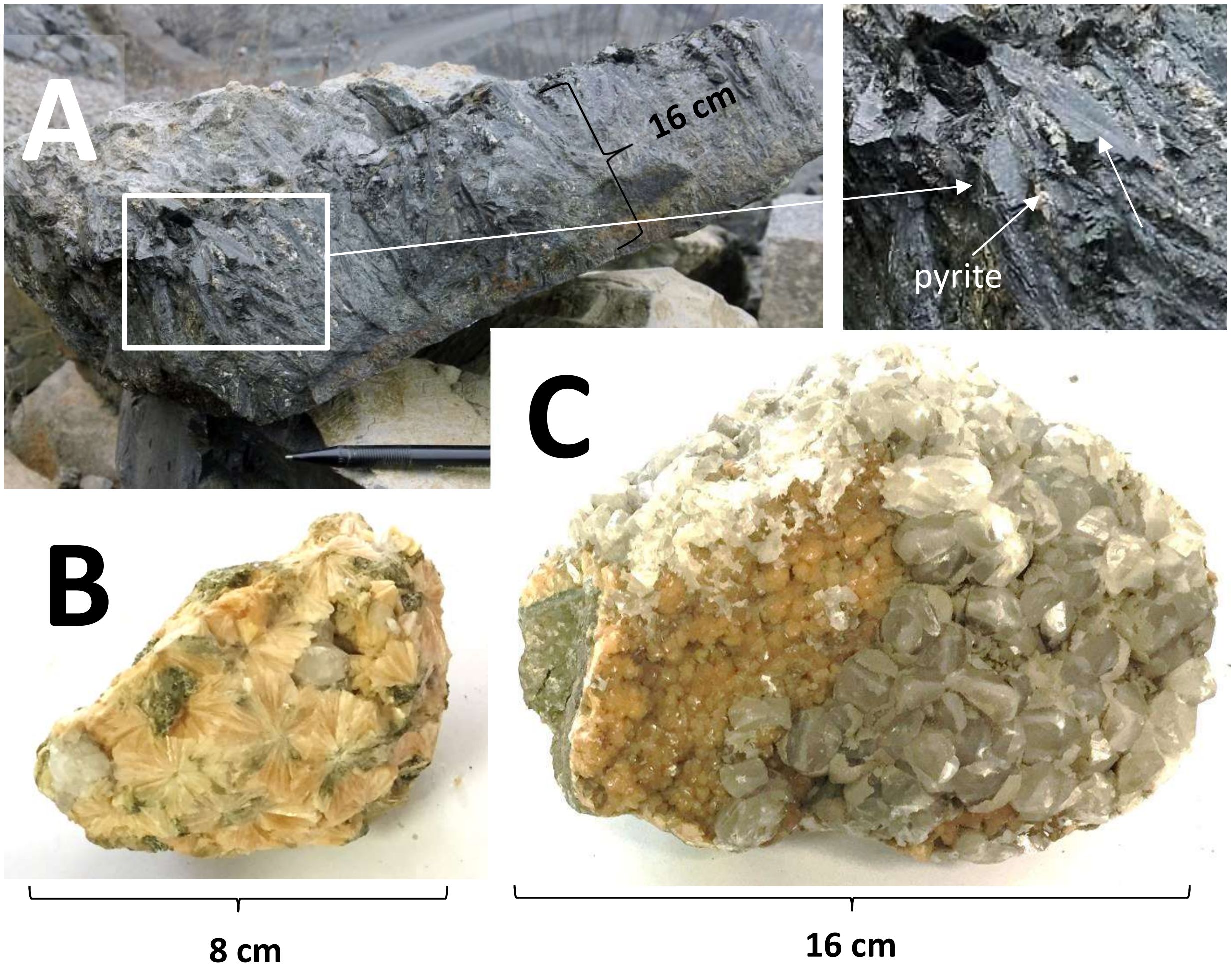


Figure 29. Outcrops along the upper benches on the northern and western face cuts showing epithermal mineralization associated with emplacement of trap into the Passaic Formation. Looking West in all photos.

A. In some places, melt lenses a few inches thick that are enriched in alkali-feldspar invaded Passaic red beds immediately above the nonconformity.

B. A light-greenish-blue supergene enrichment zone lying beneath a gossan cap was temporarily exposed on the uppermost bench of the east side of the quarry during removal of the hornfels cover to expose workable trap rock.

C. Manganese dendrites weather out along fractured horizons in saprolitic hornfels that were permeated with hydrothermal fluids from the nearby igneous intrusion. Upper bench on western limits of the quarry near the westernmost borings shown in figure 26B.



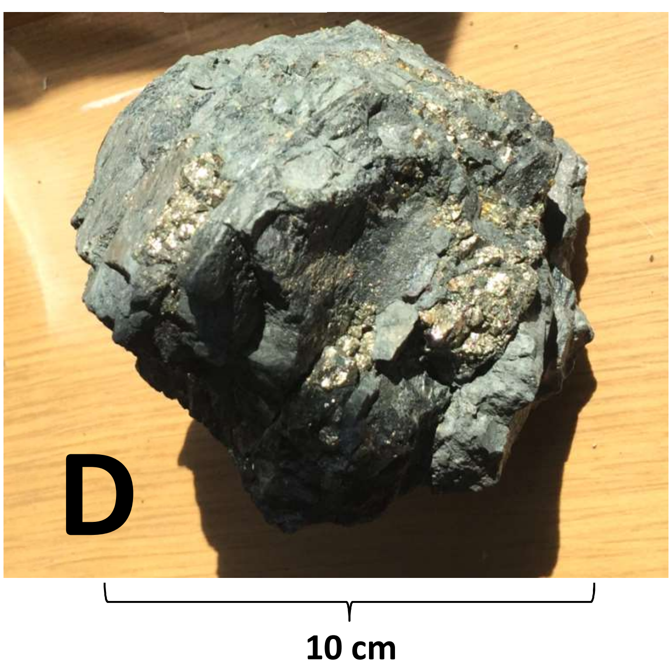
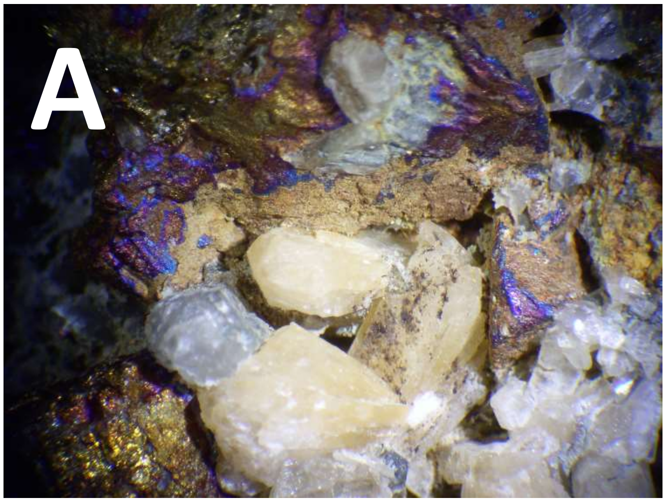
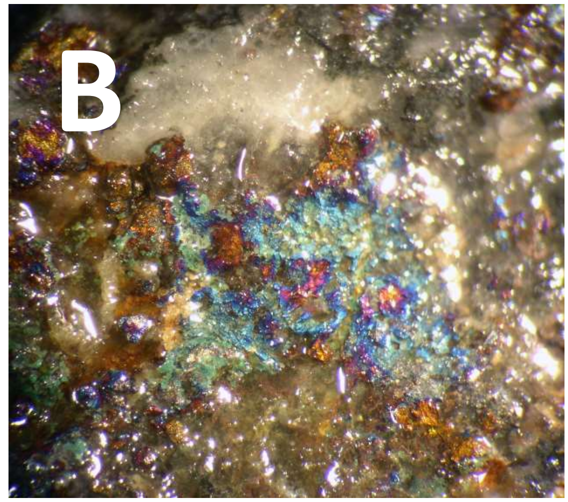


Figure 30. Photos of NJGWS hand samples from Moore's Station quarry. **A.** Loose slab of mafic pegmatite layer with bladed pyroxene and interstitial pyrite. **B and C.** Stilbite, a salmon-pink zeolite (table 3) shows either an acicular, radiating habit (**B**) or has a medium-grained, dog-tooth drusy form in mineralized veins within the dolerite (**C**). Stilbite first forms on cavity walls and is overgrown by gray, subhedral, dog-tooth calcite as seen to the right, the later, drusy calcite coating of all preceding minerals. **D.** Gray mudstone hornfels with sulfide veining and infiltration (mostly subhedral pyrite).

With respect to our work, we commonly find calcite, prehnite, stilbite, pyrite, and chalcopyrite (figs. 30 and 31).





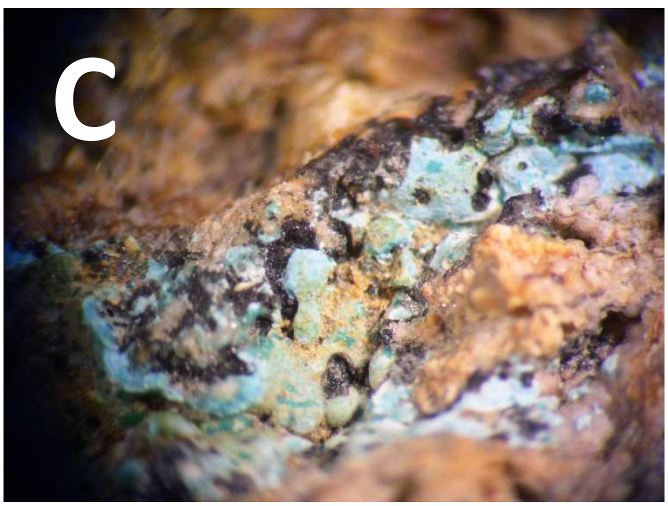


Figure 31. Photomicrographs of secondary minerals filling vugs in dolerite.

A. Euhedral Stilbite (tan), calcite (white), and chalcopyrite (metalliferous). ~ 7.5X

B. Chalcopyrite bleb~25X

C. Anhedral to euhedral chalcocite altering to malachite(?) ~30X

After picking through the berms for about 20 minutes, we will return to the buses and head to STOP 4.