Trip B-2

MINERALIZATION AT THE KNOX UNCONFORMITY AND THE WESTERN ADIRONDACK PALEOSURFACE

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INTRODUCTION

The Ordovician Knox unconformity (Landing, 2003) is well exposed in the bed of Roaring Brook, on the eastern margin of Tug Hill in the Black River Valley. Here basal arkosic sandstones and minor pebble conglomerates of the middle Ordovician Pamelia Formation rest on middle Proterozoic feldspar-quartz gneiss. Immediately below the nonconformable contact, the gneisses show strong evidence of spheroidal weathering (Orrell and Darling, 2000) which is interpreted to be of middle Ordovician age because the spheroidal weathering diminishes with depth below the unconformity and other exposures of feldspar-quartz gneisses in the area show no evidence of modern-day spheroidal weathering.

The Knox Unconformity in New York State represents a period of subaerial exposure when upper Cambrian and lower Ordovician sediments were eroded from the region (Isachsen et al., 1991). Subsequent submergence resulted in deposition of the Black River and Trenton Limestones which was followed by a deepening foreland basin and subsequent collision during the Taconic Orogeny. Paleomagnetic studies demonstrate that this part of the North American continent was located in tropical to subtropical latitudes south of the equator (Niocaill, et al., 1997), an interpretation consistent with the development of extensive chemical (spheroidal) weathering of felsic gneisses.

The preservation of Ordovician age chemical weathering is significant because other mineralogical evidence (in the form of cryptocrystalline quartz + iron hydroxide veins) preserved in gneisses at Roaring Brook may have formed from chemical weathering as well. Similar microcrystalline quartz + iron hydroxide "rusty" veins are preserved in elevated regions of the Adirondack Mountains further to the east. The specific age of these veins is unknown but are herein interpreted as having formed during Ordovician chemical weathering.

On this trip, we will examine spheroidal weathering and cryptocrystalline quartz veins hosted by middle Proterozoic gneiss at Roaring Brook. We will then drive to and climb Bald Mountain, near Old Forge, NY (in the west-central Adirondacks) and examine several "rusty" quartz veins on the way to and at the summit. We will then discuss the eastward projection of the Knox unconformity over the west-central Adirondacks and the possibility that rocks at the summit of Bald Mountain and other summits in the area were located only a short vertical distance (10's of meters?) below a middle Ordovician paleosurface, and that gradually decreasing summit elevations in the western and central Adirondacks may, indeed, represent a partly eroded relict erosional surface (Whitney et al., 2002, p.5; Miller, 1910, p. 39). Lastly, we will discuss this evidence in light of Isachsen's model (1975; 1981) of Tertiary to Holocene doming of the Adirondack region.

SPHEROIDAL WEATHERING AT ROARING BROOK

Figure 1 shows spheroidal weathering preserved in middle Proterozoic felsic gneiss in the stream bed of Roaring Brook. The spheroidal weathering is characterized by closely spaced (3-4 mm) bands of iron-hydroxide, the bands extending a few centimeters into the gneiss (from the joints). Microscopically, the bands are characterized by fine-grained iron-hydroxide, calcite, serpentine? and chlorite? Locally, the bands are filled with medium-grained calcite, suggesting an open fracture at some point.

At Roaring Brook, the lowermost strata of the Pamelia Formation (Middle Ordovician) rest directly on top of Proterozoic gneiss. Spheroidal weathering occurs directly below the (well exposed) nonconformable contact, but is observed only during low water levels (normally late summer). The spheroidal weathering directly below the nonconformity and ~30 meters downstream (location of Fig. 1) are the only places where it is observed. Both are located within one vertical meter of the nonconformity. Exposures of felsic gneiss farther downstream, which are a few meters below the projection of the unconformity, show little or no evidence of spheroidal weathering. The proximal relationship between the nonconformity and the spheroidal weathering is interpreted as evidence of Ordovician age chemical weathering.

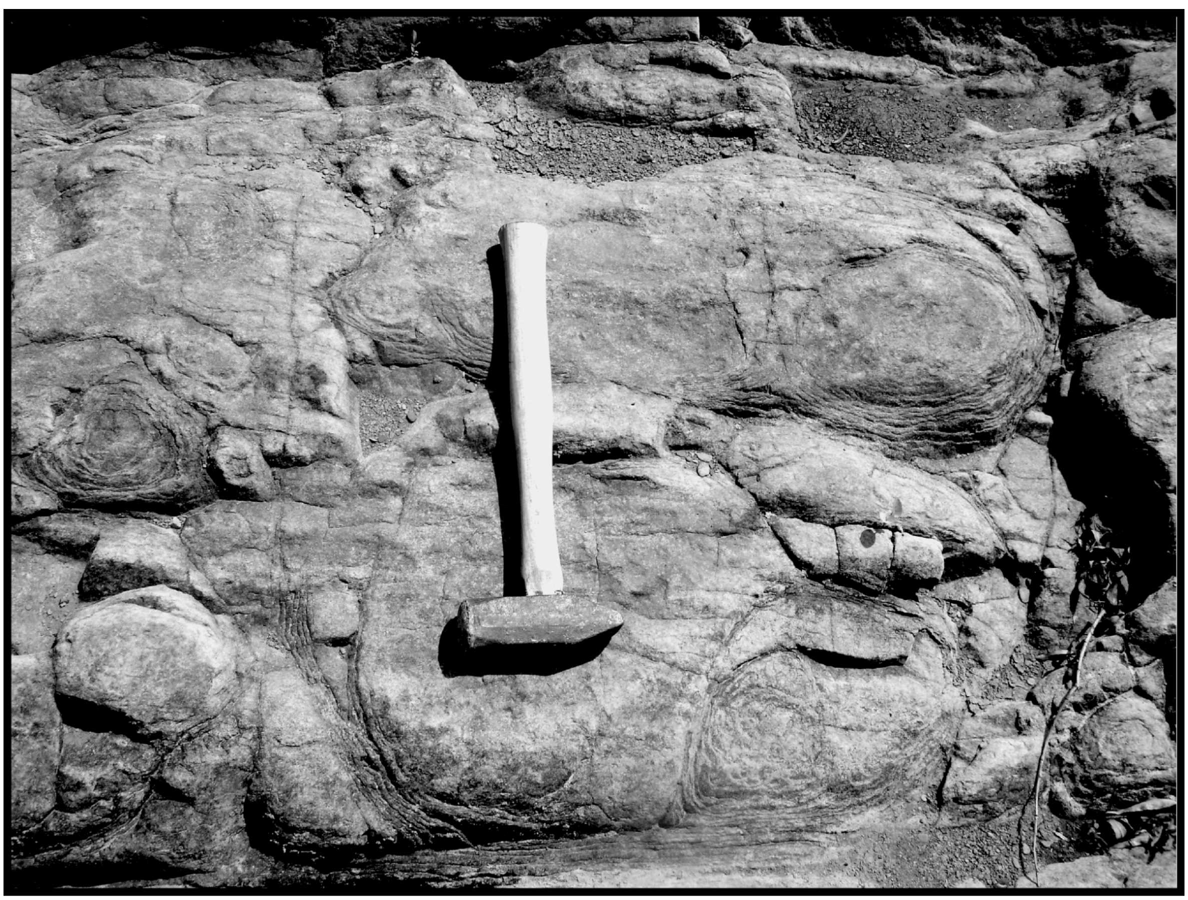

FIGURE 1—Vertical view onto surface of spheroidal weathering preserved in middle Proterozoic felsic gneiss just below the Knox unconformity at Roaring Brook (Stop 1). Hammer for scale.

RUSTY QUARTZ VEINS AT ROARING BROOK

About 100 meters northwest of this location, where Canaan Road crosses over Roaring Brook, exposures of felsic gneiss (under the bridge on the northwest side) contain smoothly worn, sub-horizontal, thin (2 - 4 mm) veins of dark greenish-gray to rusty-brown cryptocrystalline quartz and iron hydroxide (Fig 2A). In thin section, quartz grains are barely resolvable, averaging perhaps 2 to 5 micrometers across. Some goethite? lined micro vugs are present which are then filled with slightly coarser-grained quartz (Fig 2B). The cryptocrystalline quartz and iron hydroxide veins are located approximately 3 to 4 meters vertically below the projection of the unconformity.

The origin of these veins is no doubt debatable, but I interpret them as having an origin related to Ordovician chemical weathering. Chemical weathering of feldspar (the dominant mineral in the hosting gneisses) normally yields silica according to the simplified reaction:

$$\textit{feldspar} + \textit{acid} + \textit{water} \rightarrow \textit{clay} + \textit{a dissolved cation} + \textit{silica} \qquad (1)$$

Product silica in reaction (1) can be in the form of silicic acid (H_4SiO_4) or precipitated quartz (chalcedonic or opaline). The exact mechanism of quartz precipitation is unknown. The sub-horizontal orientation (of the veins) is interpreted to reflect original pressure-release fracturing (sheeting) during middle Ordovician unroofing. Also, note the presence of three sets of steeply dipping joints preserved in the smoothly worn veins (Fig. 2A) indicating an age older than regional near-vertical jointing (i.e. pre-Alleghanian; Engelder et al., 2001).

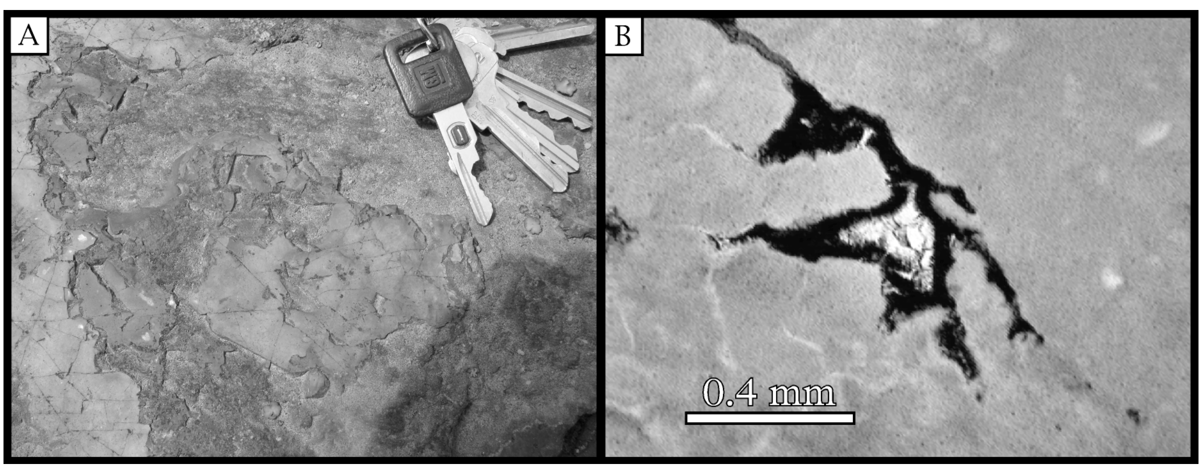

FIGURE 2—A) smoothly worn, sub-horizontal, cryptocrystalline quartz vein located where Canaan Rd crosses Roaring Brook (Stop 1). Note faint joints cross-cutting vein. Keys for scale. B) Photomicrograph of cryptocrystalline quartz vein showing vug lined with goethite? and infilled with coarser-grained quartz.

RUSTY QUARTZ VEINS ON BALD MOUNTAIN

This popular mountain summit is characterized by an unusually large amount of exposed bedrock and therefore offers a greater opportunity to observe features that might not be seen on most western Adirondack summits. Note that Bald Mountain is located about 42 km east of Roaring Brook, but similar quartz + iron hydroxide veins are found here.

At a number of places along the ridge trail and at the summit, steeply dipping, thin (2–10 millimeter wide) rusty quartz veins cut across feldspar-quartz gneiss (Fig. 3). Foliation in the gneiss strikes approximately N60E, but many of the rusty quartz veins strike northwest (Fig. 4). I know of no geological description of these veins except possibly a reference in David H. Beetle's (1948) book "Up Old Forge Way" where he (p. 95) describes, "…near the top, are thin rusty, veins of basalt." The rusty-brown color of the quartz + iron-hydroxide veins does, indeed, resemble typical rusty-brown weathering of basaltic rocks, but they are not basalt.

A total of 19 different rusty quartz veins were observed along the ridge northeast of and at the summit of Bald Mountain. *Yet, rusty quartz veins are rare, if not absent, in Adirondack gneisses at lower elevations*. I have searched for similar veins in exposed gneisses in western Adirondack rocks but have observed them only at or near mountain summits. For example, a few rusty quartz veins (3–4 mm wide) occur near the summits of Bare Mountain (~15 km southwest) at N 43.67501, W 75.07321 and Wakely Mountain (~32 km east) at N 43.73628, W 74.51366. A thin (1 mm) rusty quartz vein occurs at the summit of Stillwater Mountain (~17 km northwest) at N 43.86155, W 75.03381.

FIGURE 3—Vertical rusty quartz vein in felsic gneiss located ~10 meters south of Bald Mountain fire tower. Vein is approximately 8 mm wide. Hammer for scale.

The rusty quartz veins are characterized by microcrystalline quartz and iron-hydroxide. The iron-hydroxide is identified only by its brown, rusty color and flakey texture in thin section. Its specific mineralogy is unknown at the time of this writing but may likely be goethite. The iron-hydroxide does not occur as a staining of earlier formed quartz; it is intergrown with quartz and is interpreted to have formed syngenetically. The relative amount of quartz and iron-hydroxide are variable such that veins dominated by quartz are more resistant than surrounding gneisses (like that shown in Fig. 3) whereas iron-hydroxide rich veins are less resistant than surrounding gneisses.

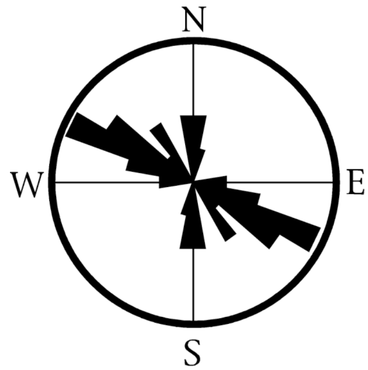

FIGURE 4—Rose diagram showing the strike of 19 rusty quartz veins measured on Bald Mountain. Dip is steep to vertical. Note prominent NW strike. Petal (or bin) size = 10^o. Rose diagram created using R. Allmandinger's "Stereonet v 6.3 X" available at http://www.geo.cornell.edu/geology/faculty/RWA/programs.html

In thin section, the quartz and iron hydroxide grains are microcrystalline, averaging perhaps 15 to 30 micrometers across. In many of the veins, sharply angular fragments of coarser-grained (60 to 300 micrometers) quartz are present (Fig. 5A). Badly decomposed feldspar with a similar texture and grain size is locally present. The *coarser* quartz grains locally contain fluid inclusions of a similar composition and liquid-vapor phase ratios to that of typical fluid inclusions in quartz from Adirondack rocks (Lamb et al, 1991; Darling and Bassett, 2002; McLelland et al., 2002) and, therefore, are interpreted to have originated from the host gneisses. However, the coarser grains are *occasionally* rounded (Fig. 5B) which supports the idea that the veins may have originated, in part, as sandstone (or neptunian) dikes. Sand-filled dikes have been described in Proterozoic rocks of the Adirondack lowlands (Selleck, 2005).

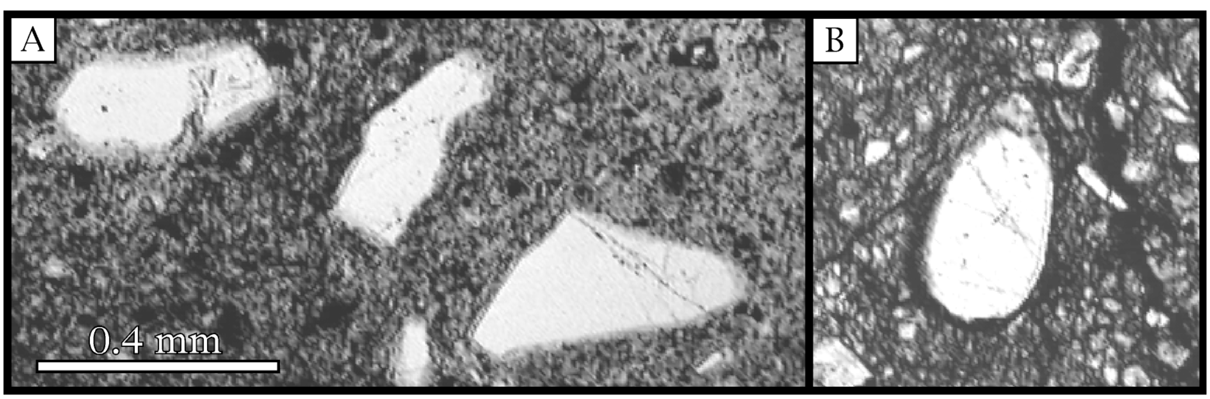

FIGURE 5—A) photomicrograph of rusty quartz vein showing microcrystalline matrix comprising quartz and iron hydroxide and angular fragments of coarser-grained quartz. B) similar photomicrograph showing a rounded grain of quartz (scale same as in A).

The mineralogy and texture of the rusty quartz veins coupled with the observation that they are most abundant at western Adirondack mountain summits suggest they have an origin related to chemical weathering similar to what is observed at Roaring Brook. This may be significant because it would represent evidence that the projected eastward extension of the Knox unconformity over the western and central Adirondacks (from the Black River Valley) is located at an elevation not far above (~10's of meters?) the present-day summit of Bald Mountain.

A MIDDLE ORDOVICIAN PALEOSURFACE?

If one looks southeastward from the summit of Bald Mountain, the summits of the western and central Adirondacks decline in elevation towards the west. A composite panoramic image of this western Adirondack vista (as viewed from Bald Mountain) is shown in Figure 6. A much better panoramic view (created by Mr. Carl Heilman of www.carlheilman.com) can be viewed at www.naturepanoramas.com/14001114.html.

A plane can be drawn through western Adirondack summits to show the westward decline in elevation, and Whitney et al. (2002, p. 5) suggested that this plane lies close below a Cambrian erosion surface in the Fulton Chain-of-Lakes area. They also noted that the plane projected close to the Precambrian / Paleozoic contact in the Black River Valley to the west. Miller (1910, p. 39) described the Precambrian surface of the southwestern Adirondacks as a peneplain and suggested that the region had been an extensive smooth surface near sea level prior to Paleozoic sedimentation.

FIGURE 6—View looking east (left), southeast (center) and south (right) from Bald Mountain summit showing the summits of the western Adirondacks declining in elevation to the west. Fourth Lake (left), Third Lake (center), First and Second Lakes (right). Little Great Range at distant horizon between Third and Fourth Lakes.

The plane connecting western Adirondack summits (Whitney et al., 2002, p. 5) is herein interpreted as a *middle Ordovician paleosurface* which I suggest extends from the "Little Great Range" comprising Squaw, Snowy, Lewey, Blue Ridge, and Pillsbury Mtns (west of the Indian Lake fault) westward to the Knox unconformity in the Black River Valley. In large-scale topographic maps of the Adirondacks, the paleosurface, as defined above, is striking, with more extensive erosion and higher summits in the Little Great Range and less eroded (but still abnormally high elevations) in the West Canada Lakes region. The fact that rusty quartz veins have been observed near the summit of Wakely Mountain supports this idea, however, I was unable to locate rusty quartz veins on the summits of Black Bear Mountain and Blue Mountain.

Using Surface III+ software (Kansas Geological Survey; www.kgs.ku.edu/Tis/surf3/surf3Home.html) the slope of the western Adirondack paleosurface can be approximated by regressing a simple "trend surface" through the highest elevations of the region (as defined above). As illustrated in Figure 7, first and second order regressions result in a planar and a concave downward curved paleosurface, respectively, but both result in a generally westward dipping paleosurface decreasing in elevation about 11 to 12 meters per kilometer. However, the subsurface slope of the unconformity west and south of the Black River Valley, which can be estimated from deep drill holes in central NY, dips southwestward at a slope of about 12-13 meters per kilometer in the region just east and south of Lake Ontario and 25-26 meters per kilometer immediately south in the Mohawk Valley (Rickard, 1973; Isachsen, 1975).

The elevation of the Precambrian surface, particularly in areas farther southwest reflects a Cambrian erosion surface as upper Cambrian and lower Ordovician sedimentary rocks rest unconformably on Proterozoic gneiss (Rickard, 1973). However, even if the thickness of the upper Cambrian and lower Ordovician sediments are taken into account, the slope of the Knox unconformity is at least *equal to* or *steeper* in the subsurface (farther to the southwest) than its inferred position over the western and central Adirondacks.

The difference in slope of the surface of the Precambrian rocks has traditionally been attributed to the deep erosion of the Adirondacks and the inference that a steeply sloping paleosurface has long been eroded away (Miller, 1910). If, however, the *middle Ordovician paleosurface* has not been deeply denuded and is preserved in the present-day western and central Adirondack summits, as interpreted here, then the difference (or similarity) in slope would seem to argue against the hypothesis that the Adirondack uplift resulted from largely vertical crustal movements in the Tertiary to Holocene (Isachsen, 1975, 1981). Such uplift should have steepened the middle Ordovician paleosurface in the Adirondacks as compared to areas outside the Adirondack dome assuming an originally flat unconformable surface (Isachsen et al., 1991, p. 44).

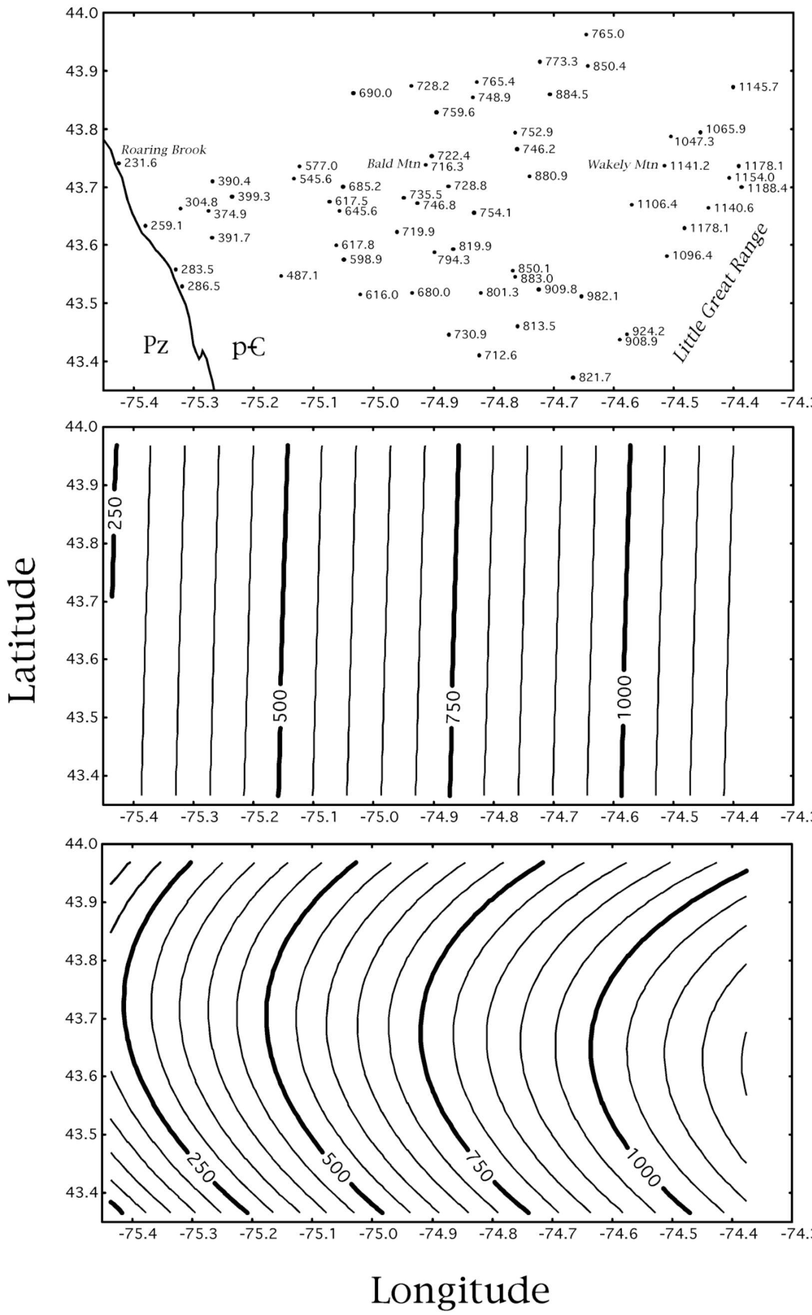

FIGURE 7—The western Adirondack paleosurface defined by bedrock-cored summit elevations on Proterozoic metamorphic rocks (top). Note locations of Roaring Brook, Bald Mtn, and Wakely Mtn. First order regression of data (middle) resulting in west-dipping plane. Second order regression of data (bottom) resulting in concave downward, west-dipping, curved plane. Scale: at 43.75^{o} latitude, one degree longitude = 80.4 km.

ACKNOWLEDGEMENTS

I am grateful to Drs. David Barclay and Gayle Gleason for reviewing this manuscript and providing helpful comments. I thank S. Darling, H. Darling, E. Rounds, A. Chenoweth, and P. Martínez de la Vega Mansilla for their assistance in locating and collecting samples at western Adirondack summits.

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ROAD LOG FOR TRIP B-2

MINERALIZATION AT THE KNOX UNCONFORMITY AND THE WESTERN ADIRONDACK PALEOSURFACE

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0	0.0	Start from the corner of Graham Ave and Gerhart Dr. on the SUNY Cortland campus. Head downhill on Graham Ave.
0.1	0.1	Turn right onto Groton Ave.
0.5	0.4	Continue straight through Main St. staying on Clinton Ave.
1.2	0.7	Turn left onto Pomeroy St. at major intersection.
1.4	0.2	Pass under Interstate 81.
1.5	0.1	Turn left onto the Interstate 81 on-ramp heading north.
30.4	28.9	Exit right onto Interstate 481 (it heads only east from here).
40.2	9.8	Take Exit 6 for the NYS Thruway. Get ticket at toll booth and head toward Albany on Interstate 90 East.
65.2	25.0	Get off the Thruway at Exit 33 (Verona). Take Rt. 365 East toward Rome. As you approach Rome, continue passed the Rt. 49 exit that heads into Rome, and stay on Rt. 365 East.
76.8	11.6	Take exit for Barneveld / E. Dominick St.
77.4	0.6	Take right onto E. Dominick St (heading east toward Barneveld).
79.4	2.0	Turn left (this is still Rt. 365 East). Pass through the towns of Floyd and Holland Patent.
91.1	11.7	Turn left in downtown Barneveld (this is still Rt. 365 East).
92.0	0.9	Turn right onto Rt. 12 / 28 North on-ramp. Head North on Rt. 12 / 28.
101.9	9.9	Rts. 12 & 28 split. Continue straight (North) on Rt. 12.
116.3	14.4	Traffic light in Port Leyden (continue North on Rt. 12)
128.4	12.1	Take right onto Canaan Rd just before crossing bridge over Roaring Brook.
128.5	0.1	Pull off Canaan Rd on left side next to Roaring Brook.

STOP 1. THE KNOX UNCONFORMITY AT ROARING BROOK.

Get out of the vehicles and walk down the stream bank to the reddish-colored exposures along the bed of Roaring Brook (watch out for poison ivy!). These are feldspar-quartz gneisses that strike N40E. Note the development of spheroidal weathering between joint sets in the gneiss (Figure 1).

Walk ~30 meters upstream. The lowermost strata of the Pamelia Formation are exposed in the stream bed. More spheroidal weathering occurs directly below the (well exposed) nonconformable contact, but is observed only during low water levels (late summer, normally).

Walk back to Canaan Road and walk northwestward (~100 meters) until you cross a small bridge (over Roaring Brook). Walk down to the exposures of gneiss under the bridge (on the northwest side). Note the presence of smoothly worn, sub-horizontal thin (2 - 4 mm) veins of dark greenish-gray to rusty-brown cryptocrystalline quartz and iron hydroxide.

128.5	0.0	Turn around, and head back to Rt. 12.
128.7	0.2	Turn left onto Rt. 12 south.
140.9	12.2	In the village of Port Leyden, turn left at the traffic light onto E. Main St.
141.4	0.5	Turn right onto River Rd at "T" intersection.
141.6	0.2	Turn left onto Moose River Rd.
155.3	13.7	Turn left onto Rt. 28 North (at McKeever). Pass through Thendara and Old Forge.
170.6	15.3	Turn left onto Rondaxe Rd.
170.7	0.1	Turn left into Rondaxe Trailhead Parking area.

STOP 2. RUSTY QUARTZ VEINS ON BALD (RONDAXE) MOUNTAIN.

Walk southwestward on the trail to Bald Mountain. As you approach the summit along the ridge trail, look for thin (2–10 millimeter wide) rusty-brown veins cutting across feldspar-quartz gneiss. One rusty-brown vein (striking N49W) is offset on an unmineralized joint (striking N20E) about 50 meters northeast of the tower. Veins can be found both NE and SW of the Bald Mountain fire tower.

Return to vehicles, head back to Route 28 south and back to Cortland.

END OF FIELD TRIP