GEOLOGY ACROSS THE GREAT VALLEY:
from the Shawangunks to the Hudson Highlands

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Introduction

Orange County is a region of diverse geology, with bedrock ranging in age from Precambrian to Devonian, with structures ranging from klippe and overturned folds to relatively flat-lying strata, with geomorphic features varying from bedrock to glacial, and with fossils varying from the Otisville Eurypterid to the Sugarloaf Mastodon. Despite this diversity the county has not(with the exception of the Hudson Highland area) been the site of a great deal of geologic study.

On this field trip we will begin with the least deformed Silurian Bloomsburg and Shawangunk formations on the west side of the county near Port Jervis and traverse southeastward through succeedingly older and more deformed rocks of Ordovician and Cambrian age to the 1.1 billion year old Precambrian rocks of the Hudson Highlands following routes I-84 and 9W. We will not have time to see some of the interesting rocks and structures farther south along the New Jersey border but these have been discussed by Offield(1967) and Jaffe and Jaffe(1973).

Terminology

The problem of stratigraphic nomenclature, particularly along state boundaries and in complex areas, is frustrating both to beginners in geology and to old-timers. This area is no exception, especially when it comes to the Ordovician shale-graywacke sequence where no fewer than 10 different names may be found in the literature. An abbreviated stratigraphic column is given below showing the names and ages of the rocks we will see on this trip. Although the stratigrapher familiar with the area may cringe at what they regard excessive "lumping" of names(or even omission of some names between the Bloomsburg and Helderberg for example), and the geochronologist may frown at the lack of precision in the ages, I feel justified in leaving the details for other publications(many are listed in the bibliography). However I will try to explain some of the more significant usages I have chosen.

The Bloomsburg Red Beds is the name applied to the formation overlying the Shawangunk in Pennsylvania(Epstein and Epstein, 1972) while the High Falls Shale(or formation) has been applied in New York(Waines et al, 1983, and Fink and Schuberth, 1958). Since the formation as seen above Port Jervis(stop 1) is obviously not a shale and since it seems closely related to the stratigraphically equvalent formation described by the Epsteins, I have chosen to use the name Bloomsburg Red Beds.

The Ordovician shale-graywacke sequence, which I will refer to the Martinsburg formation, began as the Hudson River shales and since then has been variously referred to(in no particular order) as the Normanskill, Snake Hill, Austin Glen, Mount Merino, Bushkill aspect shale, Ramseyburg aspect shale, Pen Argyle aspect shale, and Taconic Affinity Shales(TAS) among others. See Waines et al(1983) as a starting place if you are interested in more detail. Since the Martinsburg is the most widely recognized name I have chosen to use it. As we traverse the county see if you can recognize distinctive, mappable lithologic variations in these rocks.

The Wappinger Group, a series of dolomitic to calcitic rocks, has been subdivided into a number of formations, however since we will not examine these rocks closely on this trip, I have chosen to use the group name.

The igneous/metamorphic rocks of the Hudson Highlands are quite variable. Helenek and Mose(1984) have mapped a number of different gneiss units. For this trip I will refer only to the Storm King Granite Gneiss which we will see at stop 8 and "other" gneisses which we will see at stop 9.

Simplified Stratigraphic Column

Devonian	Hamilton Group(sands, shales, silts)	
	Onondaga Limestone	
	Ulster Group	Esopus Shale(Grits)
		Glenerie Limestone
	Helderberg Group(limestones)	
Silurian	Bloomsburg Red Beds(High Falls)	
	Shawangunk Conglomerate	
Ordovician	Martinsburg Formation	
Camb./Ordov.	Wappinger Group(dolomite/limestone)	
Cambrian	Poughquag Quartzite(Hardyston)	
Precambrian	Storm King Granitic Gneiss and "other" gneisses	

Road Log

This road log will start at the beginning of the entrance ramp for I-84 at Exit 1 in Port Jervis, New York. It then goes eastward along I-84 to Newburgh then southward as far as Highland Falls. Mileages will be related to green interstate mileage markers when possible. Stop 4 will be made first during the field conference to avoid crossing the interstate with a group of people.

Total Miles	Miles from last point	
0	0	Entrance ramp to I-84 eastbound at Port Jervis(near the junction of N.J. 23 and U.S. 6). The cliff behind you is the sands and shales Lower Devonian Esopus formation(sometimes called the Esopus Grits in this area).
0.4	0.4	Enter I-84 at mile marker 1. Between mile markers 1 and 2 the ridge visible to the left(north) side of the interstate is Trilobite Ridge, a famous collecting locality composed of the Lower Devonian Glenerie Limestone.
2.4	2.0	The redbeds on the right are the sands and shales of the Silurian Bloomsburg Red Beds.
2.7	0.3	**STOP 1:** [Approximate mile marker location 3.3] Stop at the parking area. The view northwest from this overlook is across the valley of the Neversink River which flows in a valley composed of Devonian carbonates(the Onondaga Limestone) lying between the Shawangunk Ridge (to the right) composed of middle Silurian clastics and Allegheny Front(across the valley), composed of Devonian clastic strata of the Hamilton Group. The confluence of the Delaware and Neversink Rivers is to the left in Port Jervis. The

Delaware River can be seen to the southwest as it flows along the west side of the Shawangunk Ridge.

The rock cut to the west of this parking area is in the redbeds of the Silurian Bloomsburg Redbeds(or High Falls Formation) which strike approximately N.40°E and dip 25-30° NW at this location. They consist of fine red sands, silts and shales, often with mud cracks and gray reduction spots, interbedded with coarse, gray-green sands showing trough cross-bedding. There are noticeable carbonate grains in the coarse cross-bedded sands. The Bloomsburg, which is conformable with the underlying Shawangunk conglomerate(stop 2), is inferred to be an alluvial deposit with the coarse beds reflecting channel deposits and the finer redbeds being floodplain deposits. It was shed westward from the mountains of the Taconic Orogeny, which existed to the east, into a sea which existed to the west. This formation grades downward into the basal Shawangunk conglomerate which unconformably overlies earlier(pre-Taconic Orogeny) sediments.

Things to look for at this stop include:

1. Good cross-bedding in the coarse gray sands.
2. Carbonate grains in the coarse gray sands(what is their origin?).
3. Gray reduction spots in the redbeds. Some vertical reduction spots may follow burrows.
4. Pebbles of fine red silts/shales in the coarse gray sands.
5. Mud cracks in the finer sediments.
6. Invertebrate tracks. I have seen these at one other locality, but not here.

3.5 0.8 Mile marker 4. Elevation 1272 feet.

3.6 0.1 **STOP 2:** [Approximate mile marker location 4.2]

This location is at the angular unconformity below the middle Silurian Shawangunk formation and the underlying mid-Ordovician Martinsburg formation. At this locality the angular discordance is very slight which is the same as I have seen at other exposures of the unconformity in Orange County.

The basal Shawangunk is a quartz-pebble conglomerate with a sandy matrix which grades upward into a coarse sand with fewer and smaller pebbles. Some feldspar fragments are visible in the upper coarse sand areas. The limonite stain on the Shawangunk results from oxidation of pyrite which may be seen as minute grains in the matrix of the conglomerate. The Shawangunk has been interpreted as a beach deposit(Fink and Schuberth, 1962) and as a braided stream deposit in a complex transitional marine-continental environment(Epstein and Epstein, 1972).

Between the Shawangunk and the Martinsburg is a brown clay layer which may be seen in other exposures of the unconformity in this area. Waines(Waines, Shyer and Rutstein, 1983) has speculated on the origin of this layer and has called it a paleosol, although there are several other plausible origins. The other possibilities will be discussed on the outcrop.

Walking around the outcrop to the right(west) you may note some glacial smoothing of the dip slope and along a trench behind the outcrop you can see an exposure of slickensides on a fault plane which strikes N.60°W and dips about 65°NE. The slickensides plunge about N.40°W at 30°. According to Fink and Schuberth(1962) tear faults like this are more common farther south in New Jersey. There are also several quartz veins on the dip slope and they strike N.70° $\pm$ 10°W.

Things to look for at this stop include:

1. The clay layer at the unconformity.
2. Pyrite grains in the Shawangunk.
3. Slickensides on the tear fault.
4. Glacial smoothing and quartz veins on the dip slope.
5. Variation in quartz pebble size and quantity. An interesting question is what is the source of the quartz pebbles since they are not common in the underlying Martinsburg.

5.2 1.6 The swamp in the median and to the right(south) is an example of drainage interruption due to the highway. A beaver lodge is sometimes visible in this swamp.

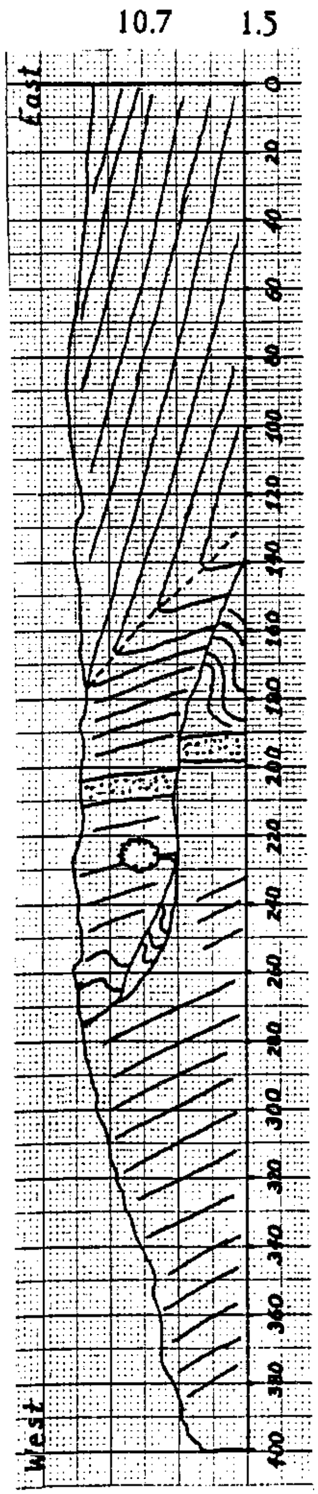
9.2 4.0 **STOP 3:** [Approximate mile marker location 9.8]

This is the first of four stops in the mid-Ordovician Martinsburg formation which will emphasize different types of structural deformation and sedimentary features.

At this location you can see more or less horizontal beds in the Martinsburg at each side of a section of almost vertical beds. The deformed structure is approximately 225 feet wide and varies from N.25°E., dip 82°SE on the south side of the highway to N15°E. and vertical on the north side. This seemingly isolated segment of almost vertical beds could be several things: an isoclinally folded anticline or syncline, a monocline downthrown to the northwest or to the southeast, a rotated fault block or possibly something else. The graywacke beds in the Martinsburg often show graded bedding so it is possible to determine the original bed tops in the vertical section. It appears the bed tops are all facing the northwest(thus eliminating the isoclinal fold possibility) and they show an obvious upward curvature at the west end of the tilted section. This suggests a monoclinal flexture downthrown to the northwest, but similar indications of folding at the southeast end of the tilted section are not apparent. I suspect the monocline has been cut off by faulting at the southeast end but the evidence is not clear.

A second question is when did the deformation occur. Conventional thought would relate it to the Taconic Orogeny of late Ordovician time, but Epstein and Lyttle(1986), based on work done in 15 areas along the Taconic Unconformity from Pennsylvania to New York, suggested that post-Taconic faulting had cut both the Martinsburg and the overlying Shawangunk. Compare this style of deformation with the other styles of deformation you will see in the Martinsburg at stops 4 and 6 and ask yourself whether this high-angle faulting might represent a different episode of faulting.

Things to look for at this stop include:
1. Grading in the graywacke beds.
2. Slickensides on the bedding planes of the vertical beds. Try to determine sense of motion of the slip.
3. Evidence for folding/faulting at the east end of the deformed section.



Stop 4: [Approximate mile marker location 11.3]

This cut is on the north side of the west-bound land of I-84[Note: During the field conference this will be the first stop so that we will not have to cross the highway].

At this location the Martinsburg shows a typical "suddenness" of intense deformation. Beneath the overpass and to the east of the overpass the beds are relatively flat and seemingly undisturbed, but about 130 feet west of the overpass the bedding is sharply deformed by an overturned anticlinal fold which has been cut by a thrust fault. This thrust fault and associated drag folding extends 140 feet further west where it curves upward to the top of the road cut in a characteristic listric-fault fashion. The fault and associated drag folds strike about N.40°E and dip SE. Be sure to compare this style of deformation, which I consider to be unquestionably Taconic, with the style of deformation you see at Stops 3 and 6 in the Martinsburg.

This is a good location to examine slaty cleavage in the shale layers. It strikes N.40-60°E and dips 25° SE, but does not penetrate the graywacke layers. This is a good stop to show students that slaty cleavage is a pressure phenomena unrelated to primary bedding.

The sketch at the left extends west from the overpass to the west end of the cut.

Things to look for at this stop include:
1. Slaty cleavage between the graywackes.
2. Synclines and overturned anticlines produced by drag folding.
3. The listric thrust fault. Try to estimate the amount of offset if you can find a suitable marker.

12.1 1.4 Underpass with wind generator to left(north).

16.2 4.1 Entrance to rest area.

17.6 1.4 **Stop 5:** [Approximate mile marker location 18.2]

This is a brief stop to examine recent(1968?) deformation in the Martinsburg. Notice the drill holes on the south side of the highway. They have been offset by slippage in an up-dip direction to the northwest. I was told by Cliff Lloyd, who brought this site to my attention, that most of this deformation took place shortly after completion of the highway and that for a time the highway department had been quite concerned about it. I have stopped here a number of times since 1973 and there has been no noticeable change since that time. You can see that there are several slippage planes, each deformed by a thrusting motion, probably related to stress relief following excavation of the road cut. For a recent article on this phenomena with a list of reference see Bell(1985). He lists references to other such features in the Appalachians.

Across the road you can see another thrust fault(Taconic) which strikes N.20°E and dips 35° SE.

Things to look for at this stop include:

1. Amount of offset on the recent faults.
2. Drag-folding on the thrust fault.

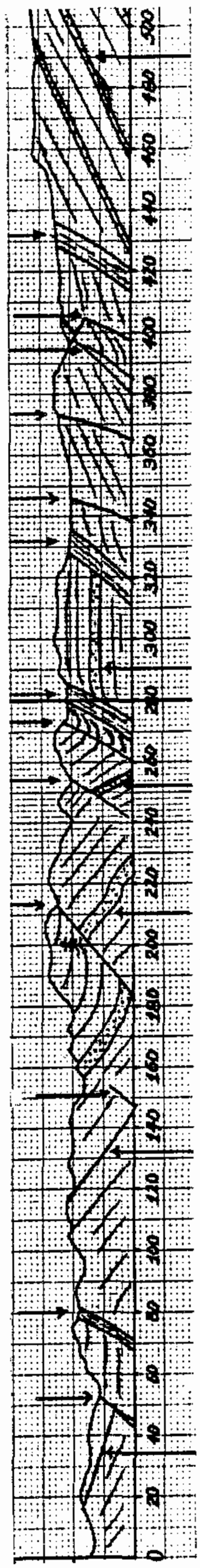
25.6 8.0 Bridge over the Wallkill River.

27.0 1.4 Gravel flows on the right(south) side of the highway.

The gravel, intended to prevent slumping of the underlying material, has itself flowed downslope. These flows have noticeably enlarged over the past few years. Do you think the motion is partly within the gravel, or is it merely slipping over the substrate? Compare this with the cuts at 34.0 and 35.3.

30.9 3.9 **Stop 6:** [Approximate mile marker location 31.5]

This long road cut shows a number of interesting features, both structural and sedimentological, in the



Martinsburg formation. The diagram at the left extends along the cut on the south side of the highway westward from the overpass for 500 feet.

Structure: On the south side of the highway there are a number of faults which cut the strata. Examination of the drag folds and the offset of the strata at 200 feet show that these are mainly normal faults. This deformation does not seem to match the thrusting which was evident at stops 4 and 5. While it would be nice to see a normal fault offseting a thrust fault, I nevertheless believe this is a post-Taconic period of faulting. Whether these faults, downthrown to the southeast, are related to the deformation at stop 3(downthrown to the northwest) I can't tell.

North of the highway and east of the overpass are a pair of adjacent anticlines offset by a fault, and plunging in opposite directions. This in an interesting spot to have students test their powers of observation.

Sediments: The Martinsburg is a classic flysch deposit with the graywackes of the Martinsburg being classic turbidites(turbidity current deposits)(McBride, 1962). Turbidites are considered to have an "ideal" sequence of structures which has been called a *Bouma* cycle after the Dutch sedimentologist who described them in 1962. A complete Bouma cycle consists of the five divisions shown in the diagram below. Often some of the divisions are missing but the ones that are present are always in the same order. Proximal deposits(near their origin point) are more likely to have a significant A division whereas more distal deposits may consist only of divisions C, D, and E. Examine the graywacke beds closely and try to identify the various divisions of the Bouma cycle. Are these proximal or distal deposits?

Things to look for at this stop include:

1. Faults. What type? Amount of offset.
2. Drag folds along faults.
3. Oppositely plunging anticlines on north side of the highway.
4. Bouma cycles in the graywackes. Identify each division present. Are the turbidites proximal or distal?

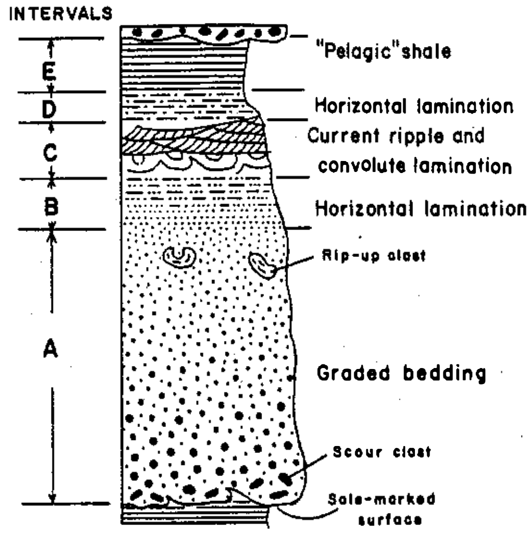


Diagram showing ideal sequence of structures (Bouma cycle) in a graded bed. (After Stanley, 1963, Jour. Sed. Petrology, v. 33, Fig. 2.)

33.1 2.2 Another long outcrop of Martinsburg.

34.0 0.9 Slumping in road cut to right. This cut was given no special engineering protection to prevent mass wasting. Compare this with the cuts at 27.0 and 35.3.

35.3 1.3 Gravel drainage zone around top of road cut to right. Highway engineers apparently decided to intercept the water which would percolate down the slope and cause mass wasting and drain the water off to the side. The lack of slumping or flow compared to cuts at 27.0 and 33.0 suggests it was effective.

36.2 0.9 **Stop 7:** [Approximate mile marker location 36.8]

This is one of perhaps 14 small(?) klippe, or allochthonous blocks of Precambrian Hudson Highlands material which was thrust northwestward during the Taconic Orogeny and then isolated from the parent mass by later erosion(other interpretations have been made but this is the one I like).

Toward the east end of the road cut you can see the Cambrian age Poughquag Quartzite, which at this location is noticeably conglomeratic. The pebbles are mainly quartz and the matrix contains substantial amounts of pyrite. Oxidation of the pyrite has caused the pervasive limonite staining of the rock. Toward the western end of the cut the Poughquag overlies Precambrian granitic gneisses in a classic non-conformity. The gneisses have been severely weathered and are almost unrecognizable at the first casual glance. The attitude of the unconformity shows that the Poughquag extended above the level of the cut on the north side of the highway and has been eroded away so that only gneissic material is exposed. This transgressive Cambrian sand marks the inundation of the continent following rifting of the continent after the Precambrian Grenville Orogeny. It probably represents a beach environment.

The outcrop across the entrance ramp to the northwest(onto I-84 west) is Martinsburg, so the basal fault below this thrust block **must** be located between the two cuts north of the highway, however I have never seen reference to it by anyone who noted it during the building of the highway.

Things to look for at this stop include:

1. The non-conformity at the base of the Poughquag.
2. The granitic gneiss below the unconformity.
3. Variations in pebble content in the Poughquag.
4. Evidence for faulting in the Poughquag.
5. Pyrite in the matrix of the Poughquag.

38.1 1.9 Road cut though Cambro-Ordovician age Wappinger Group Dolomites. These represent a stable shelf environment which existed here following the transgression of the Poughquag. They persisted until the downwarping of the continental margin began during the subduction and closing of Iapetus which preceded the Taconic Orogeny. They are overlain by the flysch deposits of the Martinsburg which are subduction-related (Isachsen, 1980). For additional information on these carbonates see Friedman(1975).

38.3 0.2 Exit right(south) off I-84 at Exit 9 to stoplight. Turn right at stoplight onto 9W south for 1 block.

38.35 0.05 Stoplight. Turn left onto N. Plank Road.

38.8	0.45	Stoplight. Make second right onto Leroy Place(not Liberty). Continue along this road - it will change its name first to Water Street then to River Road as it parallels the Hudson River.
40.2	1.4	Stop sign at Washington Street. Continue straight ahead on River Road.
40.3	0.2	Stop sign at Renwick Street. Continue straight ahead on River Road.
41.1	0.7	Start of oil tank area for Port of Newburgh on the left. Several of the homeowners in the area complained of devaluation of their property as this tank farm expanded. Would you agree?
41.8	0.7	Continue up hill following 9W south signs.
42.2	0.4	Curve left onto access ramp for 9W south.
43.0	0.8	Bridge over Moodna Creek. Continue south on 9W.
46.3	3.3	The hill in front of you marks the beginning of the Hudson Highlands. The road leaves the valley of Martinsburg sediments, crosses the northwest border fault of the Highlands thrust block and starts up the Precambrian gneissic material. The first outcrop is visible on the left shortly after you start up the hill.
47.9	1.6	**<u>Stop 8:</u>** Overlook at Storm King. [Note: During the field conference this will follow stop 9 so that we will be able to park at the overlook.] This cut is an excellent exposure of the Storm King granite gneiss, at this location a two-feldspar, hornblende granite gneiss. The gneissic structure is shown by lineation of the amphiboles and a similar elongation of the quartz(Lowe, 1958, indicates there is "no clearly preferred space-lattice orientation" of the quartz). There are a number of pegmatitic zones in the granite and these have a similar mineralogy to the surrounding finer-grained areas. The pegmatite zones sometimes follow the strike of the lineation in the

gneiss and at times cut across the lineation suggesting they are either late-phase crystallization or later remobilization of the material. The Storm King was first thought to be a late intrusion into the gneisses(Lowe, 1958) but is now suggested to be an early Grenville intrusion(Helenek and Mose, 1984, give a date of 1140 m.y.).

The overlook to the east provides an impressive view over the Hudson River.

Things to look for at this stop include:

1. Large hornblende crystals in the pegmatitic zones.
2. Orientation of the pegmatitic zones relative to the lineation of the gneiss.
3. Nature of the lineation.
4. A cross-cutting, epidote-filled fracture.
5. View from the overlook.

48.7	0.8	The proposed Storm King pumped storage reservoir site is on the right(west) side of the highway.
51.8	3.1	Exit right to Rt. 218 toward Highland Falls.
51.9	0.1	**<u>Stop 9:</u>** This cut exposes some of the "other" gneisses of the Hudson Highlands, and one of the best dikes you could ask for.

The gneisses are quite varied in composition and in several places show coarse-grained remobilized zones. Garnets are abundant locally but they are usually fractured and are difficult to remove from the gneiss. You can see how distinct the Storm King gneiss is from these other gneisses.

The dike, which is visible on both sides of the road cut, strikes across the road cut at N.47°E and dips approximately 70°NW but it curves markedly on the right(east) side of the cut. Close examination of the dike shows it to be mafic(dioritic to gabbroic) with accessory pyrite. There are excellent chilled margins with knife-edge sharp contacts with the country rock(best seen on the east side of the cut). There are also several apophyses(tongues) extending into the country rock. About 2 meters above road level on the east side of the cut, you can see two small light-colored intrusions into the chilled margin of the dike.

These obviously came from the dikes' still molten interior and thus are autointrusions, one of the clearest examples I have ever seen.

Facing the dike on the east side of the cut, you should notice the dark(mafic) band about 7 cm wide which parallels the right contact **inside** the chill margin. This mafic zone does **not** exist along the left contact but there is visible a zone parallel to the contact and inside the chilled margin characterized by coarse blebs of light and dark minerals. Similar zones are visible in the dike on the other side of the cut but they are harder to see because of groundwater which normally drains along the margins on that side. These dissimilar zones present a problem. Why is the dike not symmetrical? I am tempted to believe the mafic zone on the right is an example of crystal settling of the mafics and the blebby zone on the left represents the last stages of crystallization of the dike, but if this is true it would seem to require a significant upward rotation of the dike since its crystallization. I have not seen or read of a similar feature on other dikes in the area(Mack, 1962; Ratcliffe et al, 1983; and others).

Differential weathering is noticable at the top of the dike where the spheroidal weathering of the mafic dike is in sharp contrast to the minimal weathering of the surrounding gneisses.

The engineering techniques used to minimize the hazard of falling rocks are also worth mentioning. On the west side of the cut you can see rock bolts, a ledge and a fence(chicken-wire conglomerate). What you can't see is that they have replaced the guard rail on that side 3 times in the past 15 years and still there are dents visible **on top** of the rail. The fault zone visible above the ledge was the source of a major fall several years ago. A fracture pattern on that side of the cut dips into the cut so it is virtually impossible to totally prevent rock falls here.

Things to look for at this stop include:

1. Intrusive features such as chill margins on the dike, autointrusions in the dike, and apophyses from the dike.
2. Mafic and blebby zones in the dike.
3. Spheroidal weathering at the top of the dike.

4. Remobilized zones and garnets in the gneisses.
5. Evidence of falling rocks and engineering techniques to prevent them.

End of Road Log

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