FIELD TRIP D
GEOLOGIC PHENOMENA IN THE SCHENECTADY AREA

by
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Stop 1 -- THE CLIFTON PARK ANTICLINE

Location

The outcrop is located at the top of a hill in the town of Clifton Park on N.Y. Rt. 146, 1.7 miles east of the intersection of Rts. 9 and 146. If approached from the east the outcrop lies 0.5 miles west of the intersection of Rts. 146 and 236.

Description

The Clifton Park anticline is an excellent outcrop for teaching purposes. At the one locality many structural and sedimentological features may be observed. It also is a prime example of the thrust faulting in the eastern part of the lower Mohawk Valley. There are only a few faults of this type in the area and they probably represent only small scale thrusting. Though associated with Taconic thrusting they are not part of the Taconic region itself but are west of the westernmost zone of that much discussed area.

The strata exposed at Clifton Park are assigned to the Normanskill formation and represent primarily the Austin Glen Graywacke member. Some black shales are interbedded with the siltstones and graywackes. The mud pebble conglomerate so common in the Normanskill may also be observed at this outcrop. No fossils have been reported from this exposure but the lithology is typical of this Middle Ordovician unit and fossils found in the near vicinity assure this age assignment.

The outcrop extends for about 600 feet on either side of the road. It is apparent from a rapid glance that the strata on the north side of the road do not match those on the south side. To gain the most from this exposure it is best to start your traverse at the west end on either side of the road and to walk toward the east and return in the opposite direction on the other side of the road. A series of thrust faults may be seen on either side of the road.

At the west end of the exposure on the south side of the road is a small thrust which may be observed to blend into a bedding plane fault to the east. Virtually all of the faults show mineralization along the fault plane. The mineralization usually consists of well slickensided calcite. No individual fault can be traced any great distance but there is no difficulty in detecting the faults nor in following them over a distance of several yards or more.

The entire section of strata on the south side appear to be less contorted than on the north. This is more apparent than real, however, for the whole area is part of an anticline plunging to the south.

Structural features on the north side of the road are quite different. Starting at the east end one may see beds dipping about 30° to the southeast followed by a small symmetrical anticline. About 25 ft. further west is a small faulted anticline. The fault here is a small thrust with a strong drag zone. Gouge may be seen in the fault plane itself. Another small but tight fold succeeds the fault to the west. About 75 ft. from the small fault is an interesting overturned anticline with an east limb dipping only a few degrees to the east and a west limb dipping 75° to 80° to the east. As a result the beds on the west limb are up-side-down.

For a distance of about 30 ft. is a zone of shattered siltstone which may represent one of the faults on the opposite side of the road. Still walking westward the last structure to be encountered is a symmetrical anticline whose limbs dip 30°. Jointing is obvious through the section.

In addition to the structural elements there are many sedimentary features to be seen on both sides of the road. Mud-pebble conglomerates, large ripple-marks, graded bedding and other features may be observed throughout. It is also interesting to note the result of unloading of the surface upon the siltstones and graywackes. Here, the beds have fractured and it is possible to see the difference between the beds which are actually several feet thick and the zone in which the beds appear thinner due to unloading.

Furthermore, it is obvious that the beds of siltstone and graywacke do not maintain a constant thickness as one traverses the outcrop.

Discussion

The primary cause of interest at the Clifton park anticline lies in the differences in strata and structural appearance on either side of the road. Some students have suggested that a fault, striking east-west is responsible for the disparity. This seems unlikely and is not needed to explain the exposure. On the contrary, an asymmetrical fold plunging to the southwest which was later cut by faulting seems to provide a simple and more adequate explanation. The explanation lies more in the asymmetry of folding followed by erosion than in any other factor. Certainly there is room for interpretation at this outcrop and we will welcome any comments.

Stop 2 -- GEYSER PARK AND THE "VALE OF SPRINGS"

Location

This area is a portion of the state-owned Saratoga Springs Reservation located just south of the city of Saratoga Springs, between N. Y. 9 on the east and N.Y. 50 on the west. Geyser Park is situated in the western half. Entrance to the Park is *via* a new road at the southern limits of the reservation which connects with both Route 50 and Route 9. The old entrance and approach to the Park, near the Hall of Springs, has been closed to vehicular traffic making it impossible to approach the park from the north. Visitors may, however, elect to park in that section of the reservation and walk down the hill into the upper section of the Park.

Features and Lithology

This area has the highest concentration of "springs" and "geysers" of any area in or around Saratoga. Altogether four "springs" and three "geysers" will be in operation upon the completion of a multi-million dollar reconstruction program.

The mineral waters discharged by the "springs" and "geysers" are representative of the Saratoga type mineral water; a highly saline water charged with varying amounts of carbon dioxide gas. Occurrences of this type mineral water is restricted to only one other locality in the United States.

The wells in the Park, some almost 1,000 feet deep, continuously discharge large volumes of water. The water is carried up in the well by the release of gas pressure in much the same manner as a warm and well-shaken bottle of soda ejects its contents when opened. This water pressure, passed through a small orifice at the top of some wells, produces the so-called "geysers" to be seen in the Park.

The large proportion of salts in the water, particularly carbonates, produces interesting tufa deposits in the form of cones, flows and terraces.

Geyser Brook, a non-carbonated, non-potable stream winds through the Park from the north, cutting a small valley and exposing the Canajoharie shales in several places. Rather poor specimens of some graptolites can be secured at several horizons in the shale.

Tour and Discussion

The first of three "geysers" to be observed is the Polaris "Geyser." All "geysers" are free flowing, but the force with which they leave the casing is regulated by using a small orifice. All of the "geysers" have been drilled and are actually wells which are allowed to run free. We have placed the word "geyser" in quotation marks since a true geyser is associated with hot water driven from the ground by steam pressure. Part of the cone of the Polaris has been created with stones piled around the casing, but a considerable amount of tufa (travertine) has been deposited since their initial operation.

The Park road eventually reaches a large parking lot, snack bar and comfort station. Further exploration will be on foot. Proceed across the bridge and turn right on the path. Just above the bridge is the Hayes Spring (well). The terminology becomes difficult at this point as both the spring and well apply. The impervious cap rock was pierced by a well in 1909. However, the water flows under its own pressure much as in a spring. Arguments could be collected in favor of an artesian well or spring. The reader is invited to choose one or the other. The Hayes is a pleasant water for those who are native to the area and who have acquired a taste for Saratoga type mineral water. It is well carbonated and moderately saline and popular with mineral water enthusiasts. A hole on the upstream side of the Fountain permits people to inhale the excess gas from the well and it is guaranteed to "clear your head." An analysis of the Hayes Well is appended for people with geochemical interests or for those who are just plain curious about what they are drinking. It is only fair to warn the drinker that many of the dissolved salts have had a reputation as "diuretics and cathartics," and they seldom fail to achieve this result when taken in any quantity.

The "geyser" a hundred feet or so upstream is appropriately named the Island Spouter "Geyser." Its waters ascend in a graceful flow to heights of thirty feet or more and is a much photographed object. The tufa cone and surrounding terrace is no more than 40 years old but in that time it has acquired a considerable thickness. The terrace is very slippery and the water tastes the same as the Hayes. Since another terrace is more accessible, it is not necessary at this point to get any closer to it than you are.

A much larger and more impressive tufa flow occurs a few hundred yards upstream where the overflow from the Orenda "spring" cascades over the bank and enters the brook below. This action results in a vertical structure approximately thirty feet high and two to five feet thick. This tufa flow is, in a sense, a miniature Yellowstone of the east, with the notable exception that it is almost 93 percent carbonates from cold water rather than siliceous matter (silicates) from hot water. According to Strock, the travertine is built up at the rate of 0.5 gram/liter of water. Literally translated to English units, it works out to be one pound in 240 gallons, or a potential two tons per million gallons.

The terrace is an interesting physical structure but the tufa itself has a few singular features. First of all, it is radioactive. Minute amounts of radon and other radioactive materials dissolved in the water become highly concentrated in the tufa. The tufa also affords an open-air, above ground exhibition of cave type travertine formation. The rapidity with which it forms causes it to be more coarse and granular but the laminations are readily visible. The rapid formation of tufa gives rise to a sort of "instant fossilization" process. Twigs and leaves are quickly coated with the carbonates and become a part of the fossil record. Loose pieces of tufa show excellent imprints and faithfully record the botanical activity near the terrace. With some luck one can occassionally find an insect accumulating a calcareous overcoat.

Some of the shales on either side of the terrace have a few graptolites. These would be Ordovician but identification is difficult because of an absence of detail. The best horizons seem to range from two to five feet above the level of the path.

Further upstream the path terminates at a bridge which crosses Geyser Brook as it emerges from a stone culvert which once carried the water beneath the now abandoned roadbed of the Delaware and Hudson Railroad. This is a very interesting area following a heavy rain; a prime spot to study the Venturi effect on the velocity of liquids.

The pipe discharging water into the stream at the southern end of the bridge is actually the water from the Champion spring (well). The well has sufficient pressure to be a "geyser" and was for a long time, and it may again function as such. The water is noticeably sulphurous in taste and smell, the only water in the Park to have this characteristic. Since this is not typical of Saratoga Mineral Water, we can assume that the casing has been perforated by corrosion and ground water is entering from the shales. Considerable quantities of sulfur water are encountered throughout the Canajoharie and Snake Hill shales much to the consternation of suburban Saratogians. At Saratoga Lake the waters become heavily charged with hydrogen sulfide. Luther's White Sulfur Springs, at one time, was a small spa itself but is unfortunately eclipsed by more famous sulfur springs to the west at Richfield and Sharon Springs. All sulfur water seems to be a product of the Ordovician Shales which outcrop in the Mohawk Valley from Utica eastward.

A second Champion "Spring" flows from the bank about 50 feet beyond the bridge. After crossing the bridge, the path climbs up the west bank and enters a road which passes south along the bank, passing the Orenda "Spring" whose overflow is responsible for the tufa terrace previously inspected. An excellent view of the Island Spouter "Geyser" is obtained along the road just before it descends to stream level at the Hayes Well and the parking lot.

The Karista "Spring" is located a few hundred yards down stream on the west side of the brook from the bridge. Its mineral composition and gas content are much lower than either the Hayes or the Orenda. However, unless the visitor has a special interest in mineral water, it might be well to terminate the tour at the bridge and return to the parking lot.

The Saratoga Mineral Water Mystery

The manner in which this water was produced has excited the interest of many people and the theories seem to be directly proportional to the number of investigators. A few facts seem to have universal acceptance.

First, the water is in limestones and dolomites covered with the impervious layers of Ordovician shales which extend to the north, east and south. The Little Falls dolomite was given the credit for some time until Fisher and Hanson (1951) established the dolomite as Ordovician and renamed it the Gailor dolomite.

The water appeared at Saratoga because of an extensive fault (MacGregor) which forms a scarp north of Saratoga and then bifurcates as it approaches Saratoga. The eastern branch of the fault breached the shale and allowed the water to escape upward along the fault plane. This is graphically displayed at the north end of Saratoga Springs at High Rock Park. Route 9N traverses the top of the scarp and at the base approximately 30 feet of dolomite is exposed. High Rock Park is the site of the High Rock Spring, a true spring, which was known by the Indians long before Jacques Cartier first reported it in 1535. Only the tufa cone of this spring remains but a hundred yards to the north the Old Red continues to flow, having done so since 1774.

The control of the fault is striking. All springs and wells are always on the eastern side and the water issues forth at many places from Wilton, four miles north of Saratoga to Ballston Spa, seven miles to the south. Altogether some 200 springs and wells have produced Saratoga type mineral water, and always on the eastern side of the fault.

The source of the large mineral and gas content of the water has always been the difficult part of the problem.

Kemp (1912) looked to some deep-seated source for CO_2, Cl, Br and Fe. His ideas were deeply influenced by the presence of an old volcanic mass at Northumberland (Stark's Knob) some 15 miles northeast of Saratoga.

Strock (1944) on the basis of geochemical data, felt that the chemical content was in many ways related to sea water. As a result he placed the source in the Salina group, the extensive salt beds of Central-Western New York. Such beds extend eastward into Schoharie county, an area about forty miles to the southwest of Saratoga.

Ruedemann-Cushing (1914) suggested that Saratoga waters originated to the east of the region, aided in their movements up the bedding planes and fractures of the limestones and dolomites by a hydrostatic head established in the Green and Taconic Mountains.

The "volcanic exhalation" would doubtlessly furnish the CO_2 but in all probability furnish other gases as well. It leaves a question as to the mineral matter and overlooks the lack of any thermal activity which in most cases might be associated with deep-seated activity.

The virtual absence of all sulfates in the Saratoga water is difficult to correlate with the average chemical composition of sea water, either ancient or recent. Strock (1944) envisioned the water as coming down the Mohawk Valley and then moving northward. Unfortunately the dolomite outcrops long before it reaches the fault and in all probability would give up the water long before it reached the Saratoga fault. Then, too, it must be remembered that all wells and springs occur on the eastern side of the fault.

The eastern basin theory seems to have fewer "ifs" and more positive evidence. The limestones and dolomites are buried at depth and covered by thick and impervious shales. The upturned edges of these beds, raised in the Taconic disturbance, collects the water. The limestones and shales are reasonably competent and withstood the compression of the Taconic disturbance without difficulty until it grounded out against the crystalline base of the Adirondacks. The north-south lineation of the fault would tend to substantiate this idea. This places the source of the water in the dolomites and limestones. Considerable amounts of sodium, calcium and magnesium salts are available plus the halogens which are noticeably high in the water. The Hoyt limestone beneath the dolomite contains a vast cryptozoon population which suggests shallow seas and possibly intermittent periods of dryness whereupon some elements would crystallize out and into the calcareous material of the sea floor. Any acid bearing ground water introduced into these carbonates would immediately begin an attack on the carbonates which in turn would begin the production of CO_2. This gas, sealed in the acquifer by the shale above and brought up in pressure by a hydrostatic head, would produce a strong carbonic acid system which would increase with further solution until reasonably high pressures were developed. More than ordinary solution would occur, unlike the conventional solution as observed in other limestone areas. The water, driven westward by a hydrostatic pressure, reaches the fault and is carried up the thousand or more feet by the sudden release of the gas pressure.

Colony (1929) in his report to the Saratoga Springs Commission examines all previous ideas and debates them in far more detail. Although the mineral water industry has declined seriously, the controversy as to its source and origin has flourished. Anybody with a new theory??

Selected References

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Analyses of the Hayes Well
Hypothetical combinations of elements in parts per million

Ammonium chloride	38.24
Lithium chloride	24.07
Potassium chloride	465.40
Sodium chloride	5,941.82
Potassium bromide	30.00
Potassium iodide	1.25
Sodium sulphate	trace
Magnesium sulphate	none
Sodium metaborate	trace
Sodium nitrate	trace
Sodium nitrite	trace
Sodium bicarbonate	712.76
Calcium bicarbonate	2,849.13
Barium bicarbonate	30.88
Strontium bicarbonate	trace
Ferrous bicarbonate	10.82
Magnesium bicarbonate	1,626.90
Alumina	.74
Silica	10.80
Total Solids	11,742.81

Stop 3 -- STARK'S KNOB

Stark's Knob is a protuberance of volcanic rock located north of the town of Schuylerville, New York. It was named after General John Stark of the Revolutionary Army that hindered Burgoyne's retreat to the north (Woodward, 1901). It is found 1.2 miles north of Schuylerville just west of New York State Highway #4.

The Knob is a mass of basalt about 200 feet high and is surrounded by Ordovician Normanskill shales. The rock has been quarried for road metal resulting in exposure of the interior of the rock mass. In describing the Knob and locating its features, it will be convenient to refer to the quarried face on the east and the natural face, which is a steep cliff, on the west. Prior to quarrying, the Knob was probably ovoidal or circular. It may be noted that basalt is also found on the south side of the dirt road located south of the Knob.

Standing at the base of the quarried face one can see a mass of dark basalt broken by many fractures and fault planes. A prominent fault or fracture extends upward along the middle of the quarried face. A less obvious fault exists about 50 feet up slope from a small circular well or pool at the base, near the southern corner of the quarried face. One can also see pillow lava or lava ball structure displayed all over the quarried face. The western natural face is almost vertical on its north end and is partially covered by talus on its southern end. The southern portion of the Knob is unquarried and is extensively covered by brush and trees. A foot path extends over the crest of the Knob. At the summit, a plaque offers the history of the area and a presumed explanation of the geology.

Rock Types

The basaltic Knob is surrounded by slaty shales of the Normanskill formation. The shales are blue-gray and weather to buff and locally rusty-red. Cleavage is well displayed, and bedding is obscure.

The shale-basalt contact is exposed on a small hump at the base of the Knob along the dirt road leading to the quarry. The contact is also exposed along the northern end of the Knob at the edge of the quarry where it curves eastward, and in a small patch near the summit along a path leading down the talus slope of the natural face. No apparent macroscopic contact metamorphism of the shales has been observed. Some of the shales at these contacts may be fault slices or inclusions in the basalt.

Where the shales have been faulted, their character changes. This may be seen at the base of the quarry area and on a linear mound or hump which trends east-west at the base of the Knob on its southeasterly side (south of the quarry area). This mound will be discussed in the section on structure. The shales, which apparently have been faulted, do not show such prominent fissility as displayed in shales farther from the Knob. The rock has curved, platy surfaces and weathers rusty-red.

The basalt occurs as pillows, balls or ovoidal structures embedded in a matrix. Both the lava balls and the matrix are liberally penetrated by calcite veins. The pillows range from approximately an inch to four feet along the greatest dimension. They display radial jointing in the outer portions. The lava pillows are surrounded by a dark, foliated, shaly matrix. This matrix concentrically surrounds and winds through the space between the pillows. Some pillows have a dark, glassy coating which in some places appears to be part of the matrix and at others, part of the pillow. Lava balls and limestone inclusions are beautifully displayed on the quarry face. Balls of varied sizes and shapes are randomly grouped. The balls show coarser grained interiors with a fine grained rind on the surface. In rare cases they display characteristic pillow structure including the tail-like feature.

On the southeast unquarried portion of the knob the basalt does not show ball-structure as clearly. This rock is very porous, apparently due to leaching of calcite or some other mineral. There are many large and small holes in which lady bugs may be found hibernating during cold weather. This porous rock crumbles when struck by a hammer. Massive patches of basalt in which faulting is manifested by planes with slickensided calcite also occur on the unquarried portion of the knob. On both the quarried and natural faces the lava pillows contain amygdules. Many pillows, however, show no amygdaloidal structure.

Limestone inclusions may be found readily in the lava balls. The limestone is medium to dark gray and is medium to fine grained. The limestone weathers to buff or tan, surrounded by a darker portion near contact with the basalt. Fracturing along calcite veins may give the appearance of a limestone inclusion. Care must be taken to make sure one is looking at an authentic inclusion.

On the natural face the limestone is especially different from the quarried face. Here the inclusive nature of the limestone is less apparent and the limestone may actually be in the matrix. Locally a limestone matrix with basalt fragments appears as a breccia. The limestone itself is porous and is almost entirely calcite. An extremely small amount of fine, unidentified, insoluble residue was obtained from this limestone.

Structural Geology

The only secondary structures that can readily be seen in the basalt are fractures and faults. On the quarry side there are many ledges, over which one may walk, which exhibit slickensided calcite. Locally, calcite veins offset by fractures can be found. Along the crest over the quarry face there are fractures which are parallel or semi-parallel. Calcite veins occupy some of the fractures. Along this same crest and on the natural face the fractures are closer spaced than on the quarry side. Throughout the knob, calcite and quartz crystals occupy large fractures. Irregular calcite veins pervade the basalt and are not apparently related to fractures.

Faulting is manifested in the slickensides found along the calcite veins. At least some faulting must have taken place after the deposition of the calcite. There is one large fault plane or fracture striking N 50°W and dipping 52° NE on the quarry side. It is covered with talus and vegetation making investigation difficult. Another prominent fault striking N 45°W and dipping 32° NE is exposed above the small well just south of the quarry area. The rock here is crushed, folded and has a peculiar shaly appearance and is probably gouge. There is basalt above the fault and talus below. Intersecting this fault almost perpendicularly is another fault which strikes N 65°W and dips 79° NE. The fault surfaces here have very prominent slickensides.

The linear mound or hump mentioned previously strikes N 55°E and plunges away from the Knob near the bottom of its southeast slope. The hump is about 12 feet across and 70 feet long. The rock exposed here is slaty shale but, as mentioned before, is different from the surrounding Normanskill shales.

Problems of Stark's Knob

This report is, of course, brief, superficial and almost entirely descriptive. It does not propose nor support any genetic theories for Stark's Knob. However, one cannot help but question the origin of this rock, and how it, unlike any other in the State, could have occurred here.

The main question concerning the origin of Stark's Knob is whether it is a volcanic neck, indigenous to this locality, or an allochthonous mass faulted in from some other area.

Cushing and Rudemann (1914) hesitantly support the theory that the knob is autochthonous and was intruded where it stands. Never the less, they acknowledge the apparent lack of contact metamorphism and the absence of any inclusions, especially shale, other than the limestone.

The irregular, fine grained calcite veins contrasted to the coarse, crystalline and slickensided ones may indicate more than one period of calcite precipitation. The pillow-type structure is similar to known subaqueous pillow lavas, hinting at under-sea extrusion of the basalt precipitating calcium carbonate dissolved in the water.

Bibliography

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