BOREHOLE GEOPHYSICAL DEMONSTRATION AT ALTONA FLAT ROCK

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INTRODUCTION

Geologic Setting

Altona Flat Rock (Flat Rock) is a 2,800 hectare field site located near Altona, New York. It is one of several sandstone pavements in the region that make up a discontinuous belt extending southeast into the Champlain valley from Covey Hill (at the New York and Québec border). The sandstone pavements were created by the denudation of overlying material during a catastrophic breakout of Lake Iroquois. Cambrian Potsdam Sandstone is exposed at the site. An exposed normal fault cuts through the site. Cold Spring Brook flows along the fault trace. The fault scarp is exposed clearly between the reservoir and Chasm Lake (Map 1 and Map 2). The downthrown block is to the north east of the fault.

The lack of surficial deposits makes the site an ideal location for studying fracture-flow hydrogeology. More than 25 bedrock wells from 12 to 140 meters depth have been installed at the site. Elevations and UTM coordinates for each well were measured using a survey-grade GPS. The wells are cased about one meter into bedrock. Below the casing, the wells are open to bedrock.

Potsdam Sandstone has two members; Keeseville and underlying Ausable. The Keeseville is a cream color, thinly bedded quartzitic sandstone (Williams et al 2010). The Ausable is a pink to gray coarse to medium arkosic sandstone (Williams *et al* 2010). The Altona Formation underlies the Ausable member of the Potsdam (Landing *et al* 2007). The Altona is argillaceous with hematite, arkosic sandstone, shale and dolomite (Landing *et al* 2007, Williams *et al* 2010).

Well 102

Well 102 is the deepest well at the site (Map 3). It is 140 m deep, fully penetrating the Cambrian units and extending into the Precambrian basement metamorphic and igneous rock. It has been used extensively for class demonstrations and undergraduate research. Several fractures in well 102 have been identified. Many of these fractures intersect wells nearby (Wells 500A, 500B and 103). Over the past several years, we have studied changes in chemistry of water in well 102 (Klein *et al*., 2013; Dorsey *et al*., 2014 and Mesuda *et al*., 2015). These changes in water chemistry occur due to changes in the relative contribution of groundwater from different sources flowing through different fractures. Well 102 is dominated by an upward flow of water originating in the Altona. Superimposed on this upward flow is a shallow flow system that is sensitive to surface events (precipitation and snow melt). In a 10 meter length of the borehole these two flow systems merge, resulting in rapid changes of water chemistry as conditions change.

Wells 500A and B are each 40 m deep and well 103 is 24 m deep. Despite sharing common fractures with well 102, the changes in borehole water chemistry have not been observed in the other wells. This suggests that an important driving mechanism for the changes observed in well 102 is the occurrence of upward flow from deeper in the well. The other wells are too shallow to intersect the upward flow system.

Borehole Geophysics Demonstration

This field trip will consist of a demonstration of borehole geophysical techniques at well 102. During the demonstrations we will log gamma, caliper, fluid temperature and resistivity and create an acoustical image of the borehole. We will also measure the vertical velocity of water flow within the borehole using a heat-pulse flow meter. An example of the well log is shown in figure 1.

We will use a Mt. Sopris® Borehole Geophysical system. The system includes a 500-m electric winch with a Matrix® computer interface. Every probe will be zero-referenced to the top of the well. Thus, the top of the well is 0 m depth. The depth of the probe is measured from its bottom. The processing software takes into account the actual location of the sensor(s), so the depths reported in the data are those of the sensor. As the probe is lowered (4-5 $m \cdot min^{-1}$), the probe will automatically take measurements at a pre-programmed depth intervals.

The fluid temperature and resistivity probe measures the temperature and electrical resistance of the fluid in the well casing. Abrupt changes in fluid temperature or resistivity may indicate fractures or lithological units that are contributing water to the well. In deeper wells (>150 m) it is possible to observe the thermal gradient of the crust in the well.

The gamma probe counts gamma rays emitted naturally from the bedrock as a part of gamma decay. This probe is particularly useful in separating shales and carbonates from other sedimentary rocks. The major sources of gamma particles in rocks are potassium, thorium, uranium and radium. The energies associated with these different gamma sources differ. Some probes are able to differentiate between the sources. The probe we are using is not able to differentiate. The gamma probe uses a scintillation crystal. The crystal lights up when exposed to gamma rays. A photomultiplier counts the number of times the scintillation crystal lights up. This number is converted to counts per second (cps).

Gamma logs are not a quantitative tool. The number of counts is not as important as the differences in counts at different depths in the borehole. Shales are often high emitters of gamma particles. The source of the gamma particles is K in clays. Carbonates are typically low gamma emitters. Quartz-rich sandstone would have a very low gamma count, while arkosic sandstone will be high.

Caliper log shows the diameter of the borehole. Three prongs are extended from the caliper probe at the bottom of the well. The probe is then raised to the surface, allowing the prongs to drag along the walls of the borehole. The probe is sensitive enough to detect fractures intersecting the borehole.

The acoustical borehole imager scans the interior of the borehole using RADAR. The return time and reflected energy are recorded. The probe is also equipped with an accelerometer and magnetometer so that one can determine its orientation in three-dimension space. The resulting image from the probe is the wall of the borehole splayed open. Magnetic south is referenced along the center axis of the image. Magnetic north is referenced along the two edges. Fractures, foliations or changes in lithology often result in changes in return energy and travel times. The changes will appear in the image as changes colors. Planar features that intersect the well at perpendicular angles will be shown as bands of alternating colors perpendicular to the long axis of the figure. Features intersecting the borehole at other angles will appear as a sine wave, with a distinct peak and trough. Since the orientation of the probe is known, it is possible to determine the orientation of the strike and dip of planar features intersecting the borehole. By comparing the acoustical borehole image to the caliper log, one can distinguish between filled fractures, open fractures or foliation.

The heat-pulse flow meter measures vertical fluid flow in the borehole. Two thermistors, one above and one below a heating element monitor ambient fluid temperatures. Baffles direct water flow through the probe, past the sensors and heating element. From the surface, we trigger the heating element to heat for an instant. If there is vertical flow, one of the two thermistors will indicate an increase in ambient temperature. The time between firing the heating element and observing the peak increase in ambient temperature is used to calculate the water velocity or discharge.

FIELD GUIDE AND ROAD LOG

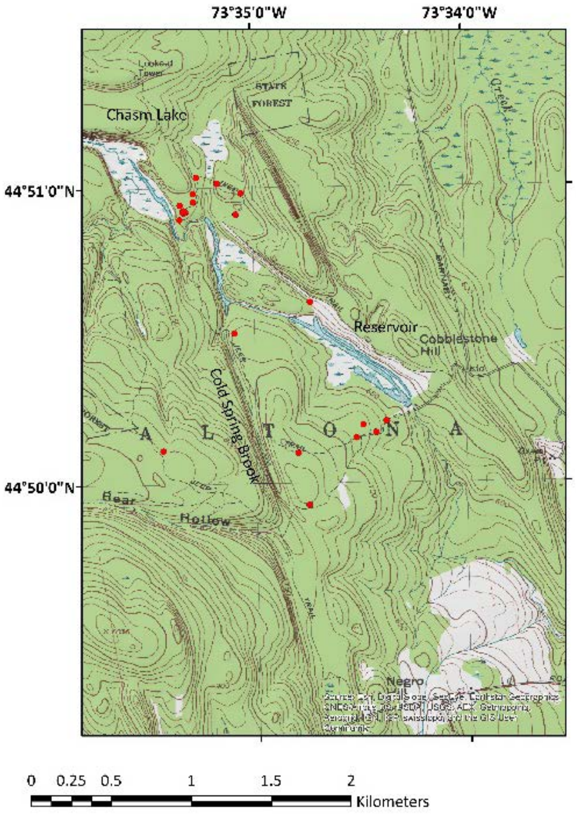
Meeting Point: Southeastern parking lot of Hudson Hall on the SUNY Plattsburgh campus. The lot is located at the corner of Beekman and Broad Streets at the northwest corner of the intersection.

Meeting Point Coordinates: 44.696°N, 73.467°W

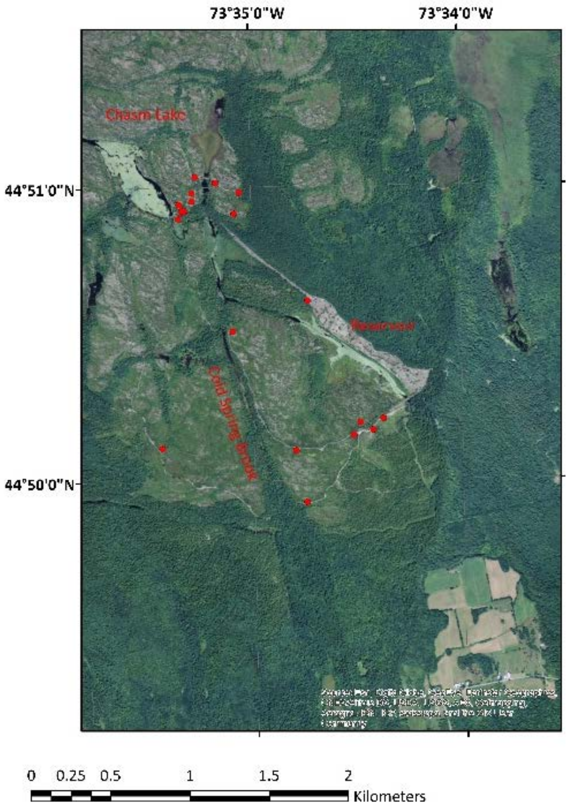
Meeting Time: 8:30 AM (The demonstration will continue during the entire morning at the well. You are free to arrive and leave the demonstration at your convenience. If you wish to arrive later than 8:30, please travel directly to the well location.)

Distance in miles (km)		Route Description
Cumulative	Point to Point	
0.0 (0.0)	0.0 (0.0)	Meet at the parking lot south of Hudson Hall on the campus of SUNY Plattsburgh at the corner of Broad and Beekman streets. Proceed from the parking lot, turn left on to Beekman St.
0.9 (1.4)	0.9 (1.4)	Continue to the end of Beekman St., turn left on to Boynton Ave. Boynton Ave. will change to Tom Miller Rd.
1.4 (2.2)	0.5 (0.8)	Turn right on to Quarry Road. Continue north on Quarry Rd. After you cross the intersection with state route 374, Quarry Rd. becomes HW 22. Continue north on 22.
6.7 (10.7)	5.3 (9.9)	Turn left onto O’Neil Rd and proceed west and follow the road as it turns north.
10.8 (17.3)	4.1 (7.4)	Turn left onto West Church and proceed west.
11.6 (18.6)	0.8 (1.3)	Turn right onto Barnaby Rd. There isn’t a street sign for Barnaby. The turn is also identified by a sign pointing to Parker’s Maple House. Continue north on Barnaby

Distance in miles (km)		Route Description
Cumulative	Point to Point	
12.7 (20.3)	1.1 (1.7)	Barnaby Rd. becomes a seasonal gravel road, continue on Barnaby.
13.8 (22.1)	1.1 (1.8)	Barnaby Rd. turns sharply to the right before an orange gate. Continue through the gate on the gravel road.
14.1 (22.6)	0.3 (0.5)	The gravel road passes in front of a cabin. You may park at the cabin if you wish. If your car has low clearance, it will be best for you to park near the cabin. It is just a brief 300 m walk to the well continuing on the road.
14.3 (22.9)	0.2 (0.3)	Continue on the road past the cabin (either driving or walking). After you cross the bridge on the Little Chazy River you will be on the Potsdam Sandstone. At 14.3 miles or 22.9 km from the starting point you will be at the well. If you drive, please proceed past the well, the road passes through a clearing where there will be plenty of room to park. (44.836°N, 73.574°W)



Map 1: This topographic map shows well locations at Altona Flat Rock. The topographic expression of the normal fault is clearly visible along Cold Spring Brook.



Map 2: Orthophotograph of Altona Flat Rock showing well locations.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Map 3: Detail orthophotograph map of wells located near Well 102.

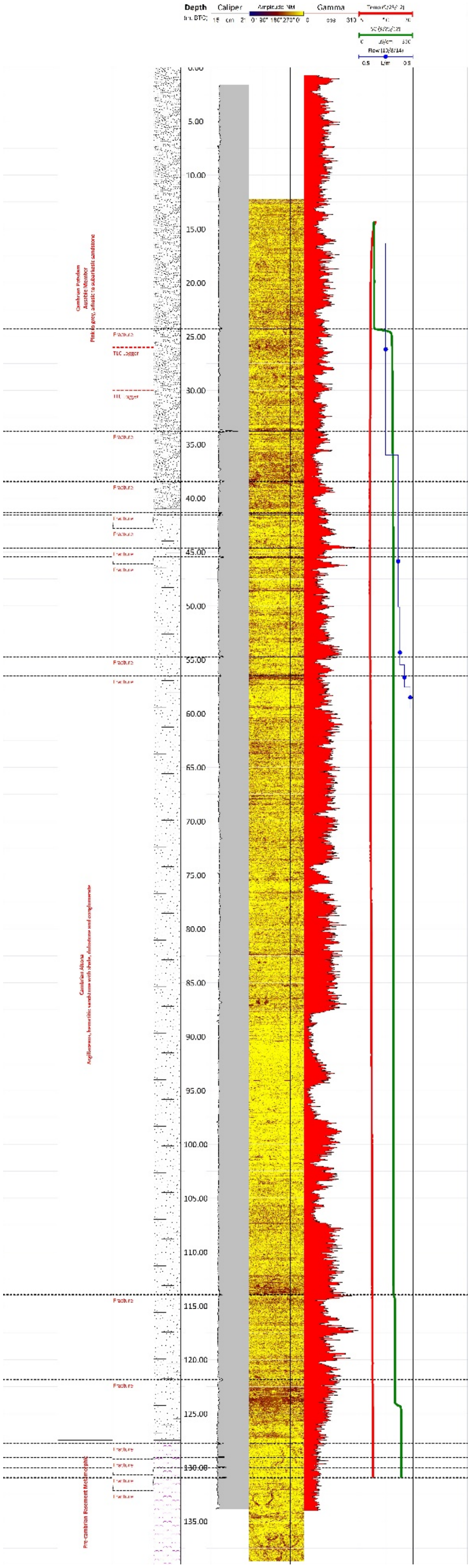


Figure 1: This is a typical well log from well 102. Known lithology is indicated on the left. Fractures are identified by dashed lines extending across the logs. Depths are measured in meters relative to the top of the well casing. The amplitude log has been filtered for better clarity. The gamma log shows decreases in counts per second (cps) as the borehole passes through dolomitic layers in the Altona. At the same depths the acoustical log shows high energy reflectance, which is consistent with carbonates. Fluid temperature shows little variation, however, the fluid resistivity log (measure as specific conductivity) shows a sudden change corresponding with one the fractures. The velocity log shows and upward velocity from deep in the well (+). This velocity decreases to below detection limit between the two shallow fractures suggests that water is removed from the borehole through these fractures.

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