TEMPORAL VARIATIONS IN A FRACTURE CONTROLLED SPECIFIC CONDUCTIVITY FRONT IN A BEDROCK WELL, ALTONA FLATROCK FIELD SITE (CHAZY, NY)

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Introduction:

Exposed bedrock at the Altona Flatrock field site (Chazy, NY) consists of Potsdam Sandstone denuded during a Lake Iroquois breakout. The site is ideally suited for the study of fracture flow hydrology because of the lack of over burden. One can clearly document the orientation and density of fractures exposed on the bedrock surface and cliff faces. We have over 25 wells at the site used for the study of fracture-flow hydrology. Elevation and UTM coordinates for each well were determined using a survey-grade differential GPS.

Well 102 is the deepest well (140 m), fully penetrating the Potsdam Sandstone and extending approximately 10 m into metamorphosed basement rock. Williams *et al* (2010) determined that much of the local groundwater recharge received by the Potsdam Sandstone occurs where it is exposed at the surface (such as Altona Flatrock). The lowest two members of the Potsdam Sandstone, Ausable and Altona, are present at Altona Flatrock (Landing *et al* 2007). The Altona underlies the Ausable. The Ausable is a pink to gray coarse to medium arkosic sandstone (Williams *et al* 2010). The Altona is argillaceous with hematite, arkosic sandstone, shale and dolomite (Landing *et al* 2007, Williams *et al* 2010).

As part of a continuing study of the hydrogeology of the Potsdam Sandstone we monitored hydraulic heads in two wells (102 and 103, Map 1) using Solinst® TL Loggers. In well 102 we also monitored specific conductivity at 30 m depth with a Solinst® TLC logger. Early August (2012) we observed a rapid rise in specific conductivity, from less than 10 $\mu S \cdot cm^{-1}$ to over 200 $\mu S \cdot cm^{-1}$ (Figure 1). This change in specific conductivity was due to the movement, past the logger, of a transition zone defined by low specific conductivity above the zone and high specific conductivity below the zone.

To better understand the mechanism driving this transition zone, we began a detailed study of temporal variations in specific conductivity profiles in the well. Between 9/11/12 and 11/26/12 we measure specific conductivity profiles approximately every week (Figure 2). During the study we observed the downward movement of this transition zone from a shallow fracture (24.24 m depth) to a deeper fracture (33.79 m depth).

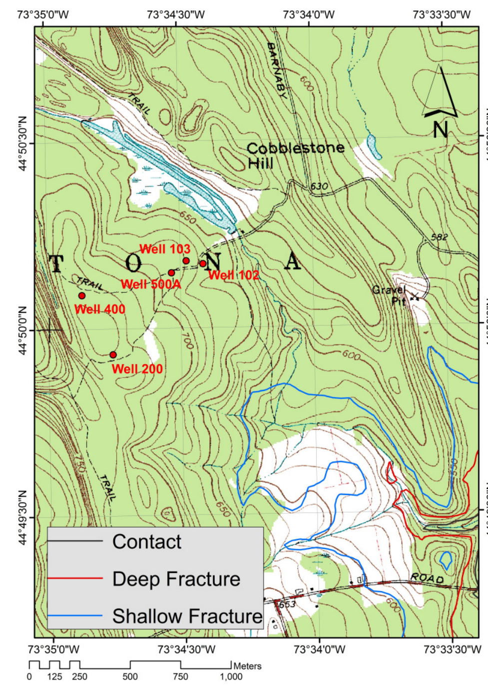
We hypothesize that the transition zone is controlled by changes in the relative amounts of water flow from the shallow fracture and deeper zones in the well. As the hydraulic head in the well decreases, the well-water chemistry is controlled by upward diffusion and/or advection of deeper water. In the fall, as precipitation increases, there is greater groundwater flow from the shallow fracture, allowing water from the shallow fracture to drive the transition zone downward.

Methods:

To identify changes in lithology and fracture locations we completed caliper, gamma and acoustical logs of the well (see well log). Caliper and gamma logs were measured once using Mt. Sopris® Matrix 2PGA1000 and 2PCA1000 gamma and caliper probes. We completed an acoustical image of the well using a Mt. Sopris® QL40ABI-Acoustical Borehole Imager between 13 and 42 m depths.

Specific conductivity profiles at well 102 were measured using a Mt. Sopris® Matrix 2PFA1000 Fluid Temperature and Resistivity probe. The depth of the transition zone was identified each time. Water samples were collected above and below the transition zone using a stainless steel water sampler. The sampler was lowered to the sample depth and opened from the ground surface. Samples were field-filtered using 0.45 µm membrane filters. Water samples were analyzed for major cations (Ca, Mg, Na, and K) using a Perkins-Elmer® ICP-OES.

Vertical water flow through the well was calculated using the displacement and travel time of the transition zone. The mid-point of the transition zone (average of the specific conductivity above and below the transition zone) was used as a reference.



Map 1: This topographic map (from USGS 1:24,000 West Chazy Quad, NAD27) shows the location of wells 102, 103, 200, 400 and 500A. We determined the orientation of the bedding plane fractures identified in well 102 (24.24 m and 33.79 m depth) using a three point solution. The depths at which these fractures intersect wells 103 and 500A are known from caliper logs. The strikes and dips of the fractures are 327° azimuth/5° NE. The contact between the Ausable and Altona was assumed to have the same orientation as the fractures. We projected where the fractures and contact outcrop in the vicinity of the well field. Some structural features were not accounted for, so projected outcrops are not entirely consistent with field observations (David Franzi, personal communication).

Results:

Hydrographs of well 102 (Figures 2a-2b) show that the hydraulic head in well 102 fluctuates over seven meters. The hydraulic head in well 102 was lower in elevation during our study than is typical. At the beginning of our study, the transition zone was at the same elevation as the shallow fracture. During the three months of the study the transition zone decreased in elevation to the depth of the deeper fracture. Previous work in 2009 shows that the transition zone can drop below the deeper fracture.

Between 9/25/12 and 10/16/12 the downward velocity of water in the borehole between the two fractures was 0.45 $m \cdot day^{-1}$ (6 $mL \cdot min^{-1}$ in a 6.00"/15.2 cm diameter well).

Analysis of major cations (Ca, Mg, Na and K) indicate that the waters above and below the transition zone had different concentrations of Ca and Mg (Figures 3 and 4). During the study the relative percent concentration of cations in the two waters became more similar.

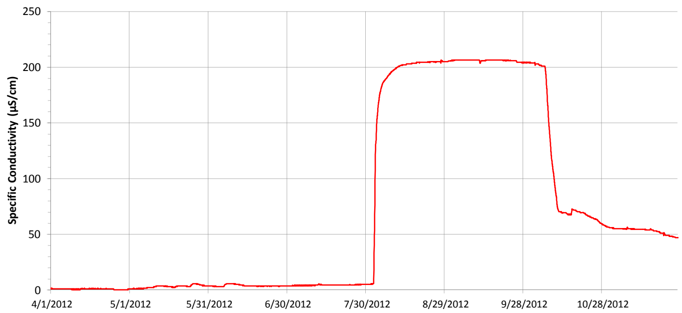
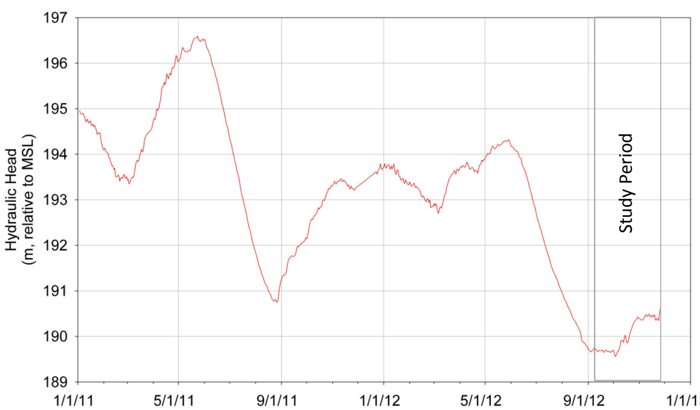


Figure 1: This figure shows changes in specific conductivity at 30 m depth in well 102. The change recorded by the logger shows the movement of the transition zone past the logger. In early August 2012 the transition zone moved upward to the shallow fracture. In early October the transition zone moved downward, stopping at the deeper fracture.



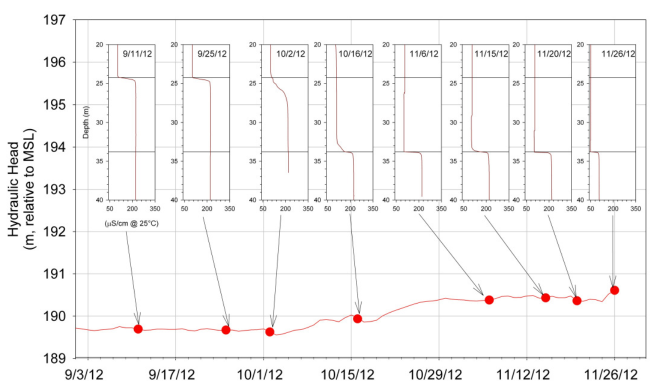


Figure 2a and 2b: These are hydrographs of well 102 showing daily average hydraulic head. Hydraulic head measurements were recorded every 15 minutes. Hydraulic head elevations peak in late May and early June. An annual minimum occurs in early September. Figure 2b shows the hydraulic heads during our study. Each specific conductivity profile is shown with the corresponding hydraulic head. The fractures are shown with solid lines.

Discussion:

At the beginning of the study, the transition zone was located at the shallow fracture. We have not documented how the transition zone moved to this fracture. We assume that the cycle we observed during these three months occurs annually. It appears that downward movement must be dominated by advection. The increase in concentration (as determined by specific conductivity) in the column of water in the well was in the same direction the transition zone moved. Hence, diffusion would have been in the direction opposite the movement of the transition zone. The increasing depth of the transition zone between 9/25/12 and 10/2/12 must be an effect of increase flow into the well from the shallow fracture (6mL·min^{-1}).

Since the transition zone seems to have stopped moving (at least temporarily) at the deep fracture, this suggests the fracture is discharging water from the borehole. This is consistent with previous measurements of ambient velocity (Williams *et al* 2010). It remains to be seen, which of two processes, diffusion or advection, controls the upward movement of the transition zone.

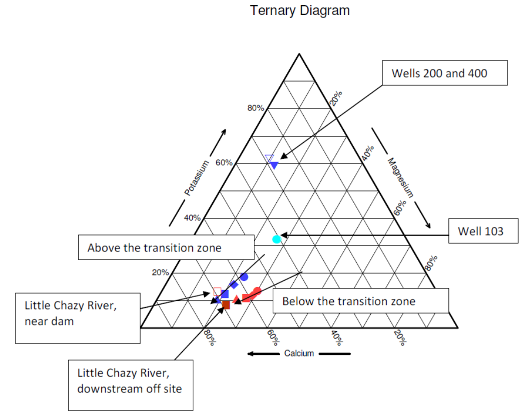


Figure 3: The ternary diagram shows the relative percent meq·L^{-1} concentrations of major cations (Ca, Mg and K). Samples collected above the transition zone are indicated by purple symbols (●, ◆, ■, ▲). Samples below the transition zone are red symbols (●, ◆, ■, ▲). The corresponding dates for the symbols are 9/11/12, 9/25/12, 10/2/12 and 10/16/12 respectively. For comparison, relative cation concentrations for adjacent wells and surface water samples from the Little Chazy River are shown. Two water samples were collected from the Little Chazy River. One sample was collected upstream of where the contact between the Ausable and Altona outcrops. The second sample was collected downstream of the contact.

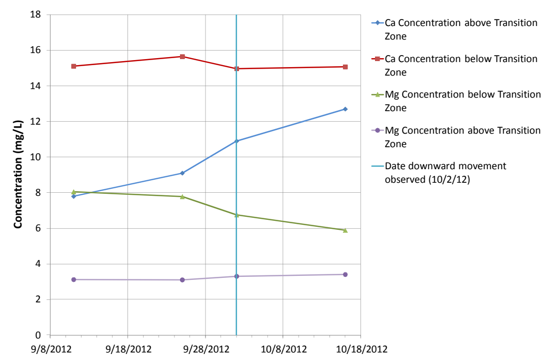


Figure 4: This figure shows changes in concentrations of Ca and Mg (mg·L^{-1}) during the months of September and October.

The relative percent concentrations of cations (Figure 3) show that the waters above and below the transition were mixing during our study. In early September waters above and below the transition zone were different (Figures 3 and 4). By late October Ca and Mg in both water were approaching similar concentrations. The difference, in composition between the two waters in early September suggests different sources. Cation concentrations in the deeper water may be affected by dolomite in the Altona. The composition of water above the transition zone was similar to the water sample collected upstream in the Little Chazy River (above the contact). The water below the transition zone had similar composition to the water sample collected downstream in the Little Chazy, below the contact. Mixing of the waters may be due to downward advection of shallow groundwater and some upward diffusion of cations from deeper waters.

Conclusion:

The preliminary results of this study suggest that the specific conductivity profile in the well is a function of changes in hydrology and relative contributions of flow to and from fractures intersecting the well. We speculate as groundwater recharge increases in the shallow zone, flow from the shallow fracture increases, driving the transition zone deeper. When the hydraulic head is lower, the water in the well is affected by upward diffusion of cations from deeper zones in the well. The study is continuing in order to document the upward movement of the transition zone. We are also developing an advection/diffusion model of the movement of the transition zone using Stella®.

References Cited:

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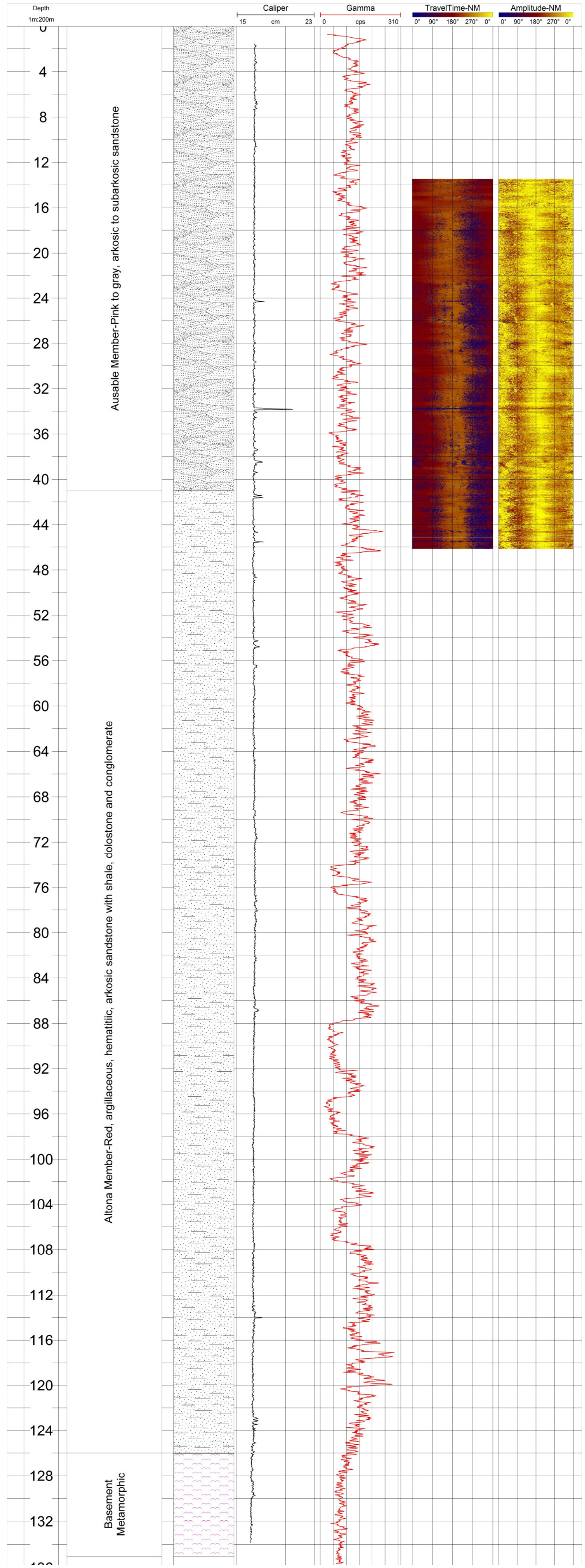
Depth
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Ausable Member-Pink to gray, arkosic to subarkosic sandstone
Altona Member-Red, argillaceous, hematitiic, arkosic sandstone with shale, dolostone and conglomerate
Basement
Metamorphic