Geophysical Logging for Characterization of Fresh- and Saline-Water Flow Zones in the Fractured Bedrock of the Northern Appalachian Basin

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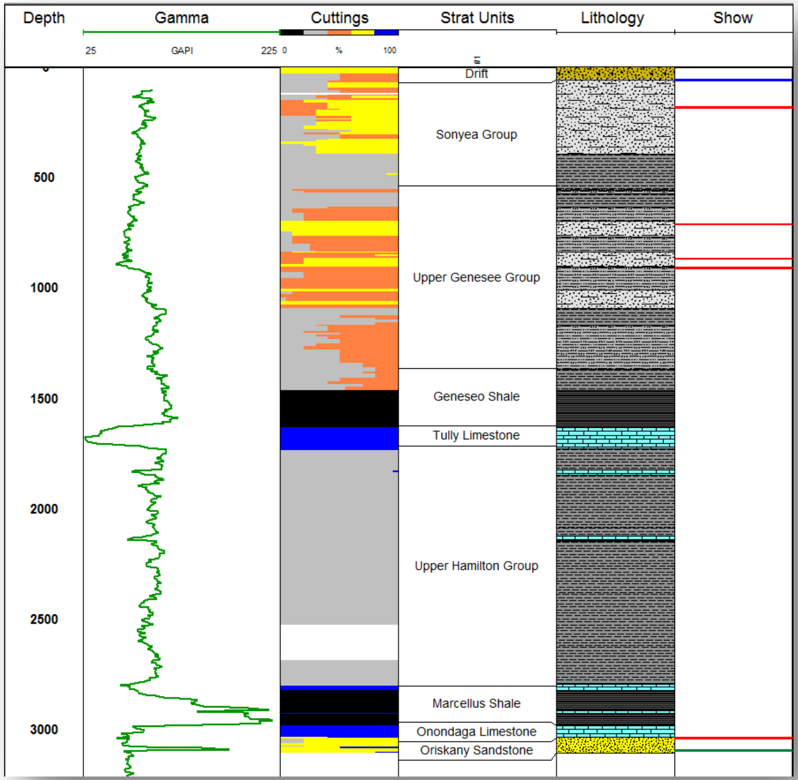
Historical Shallow Characterization at Gas-Well Pads

To protect drinking water aquifers during shale gas-play development in the northern Appalachian Basin, fresh- and saline-water flow zones in the fractured bedrock need to be isolated by casing and cement

Historically, characterization of the fresh- and saline-water flow zones relied on spotty information reported during drilling

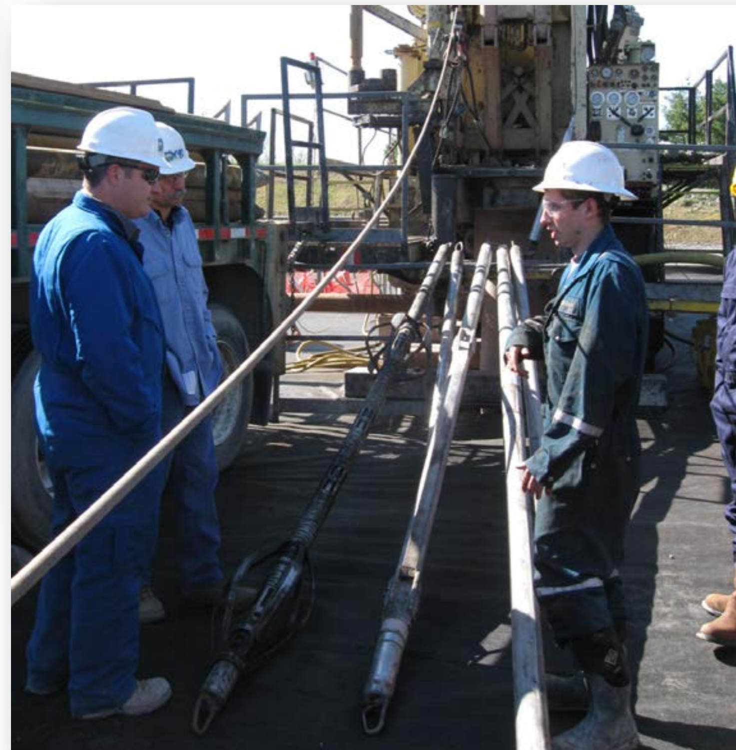
Geophysical logs not collected before the installation of surface casing, and other than nuclear logs, not collected up to land surface



RECORD	UNCONSOLIDATED	DEPTH IN FEET (TVD)	DEPTH IN FEET (TMD)	FORMATION NAME	DESCRIBE ROCK TYPE AND RECORD QUANTITY AND TYPE OF FRESH WATER, BRINE, OIL AND GAS
		0	0	....	Ground Surface (Elevation)
			1,890	Tully	
			1,996	Hamilton	
			2,974	Marcellus	
			3,087	Onondaga	

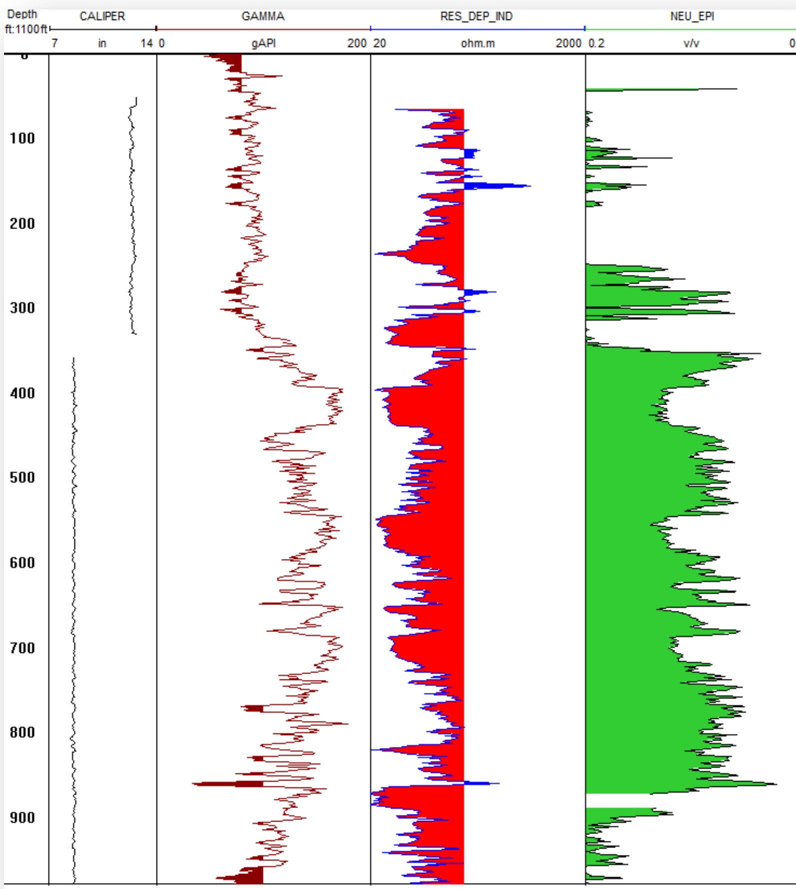
Current Shallow Characterization at Marcellus Multi-Well Pads

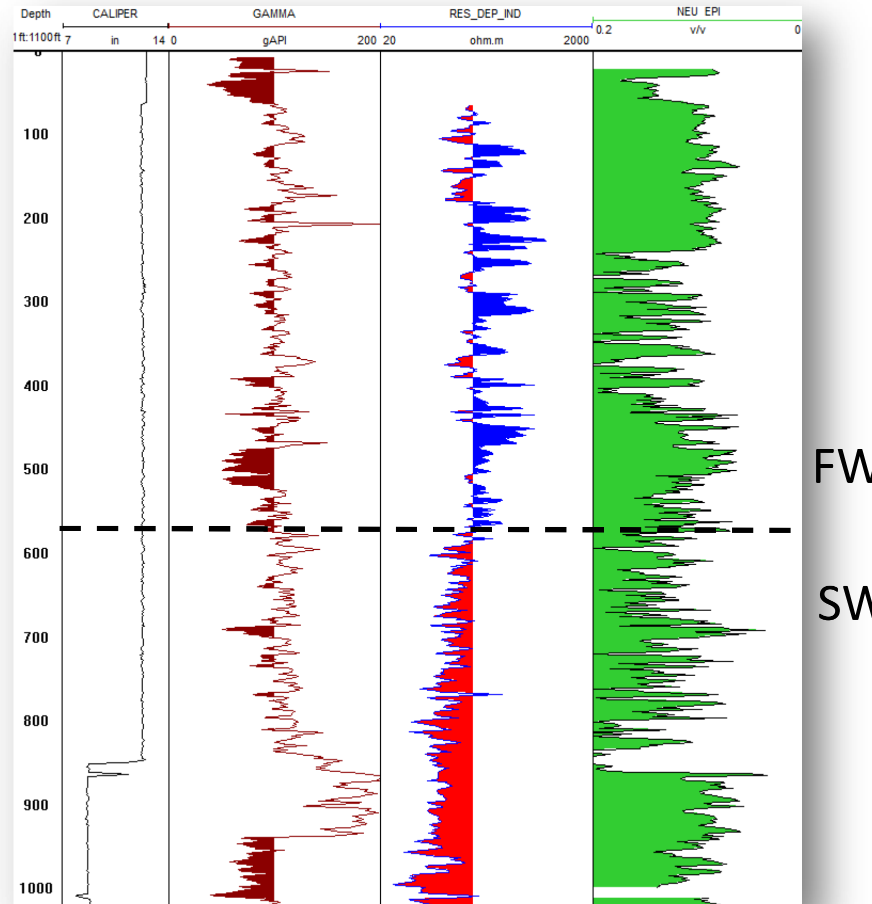
Topset rig drilling surface- and intermediate-cased intervals



Petrophysical logging of topset holes

Petrophysical Logging Approach



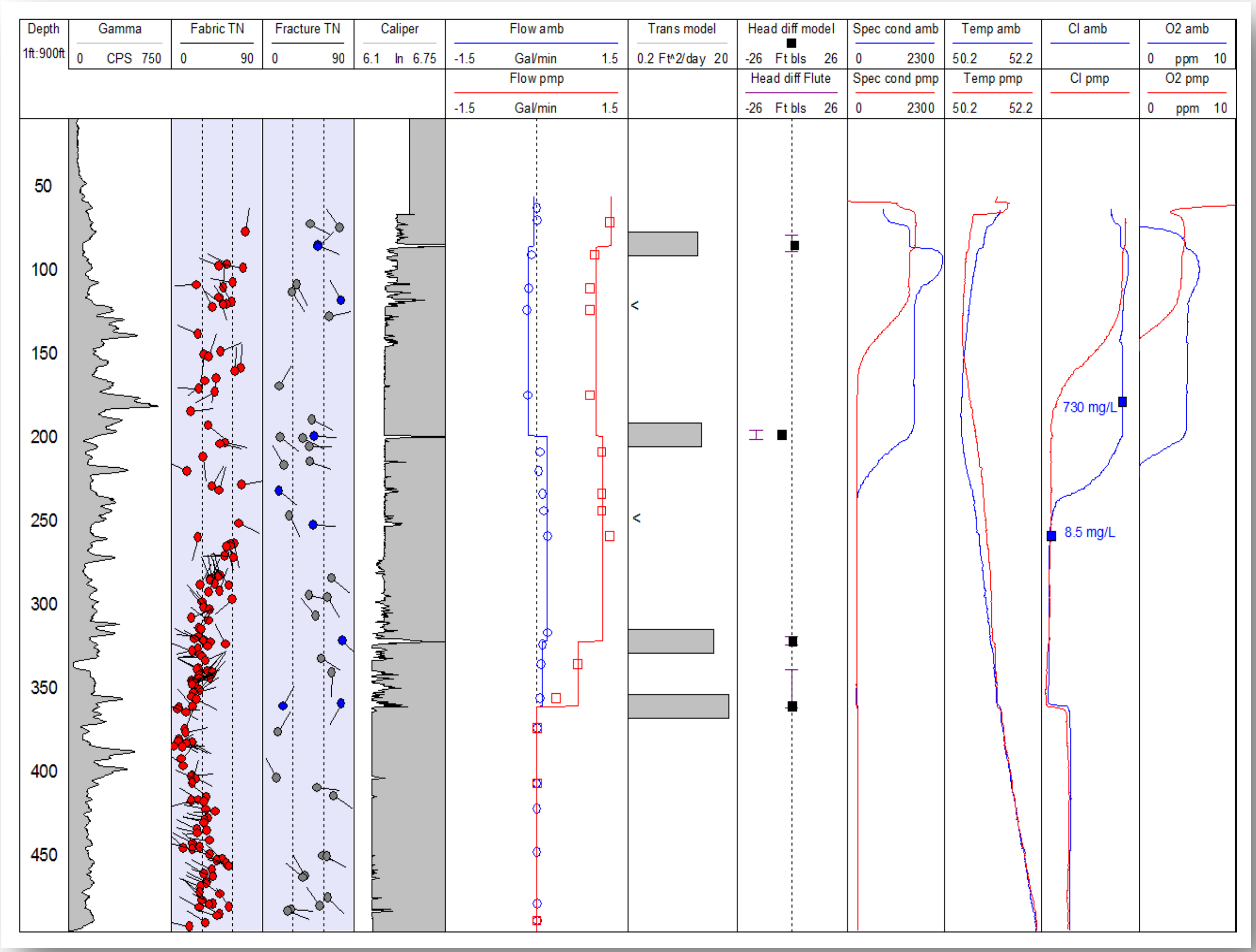


Gamma, induction resistivity, and porosity logging

Archie's Law to determine formation water resisistivity for sandstone intervals

Log data courtesy of Shell Appalachia

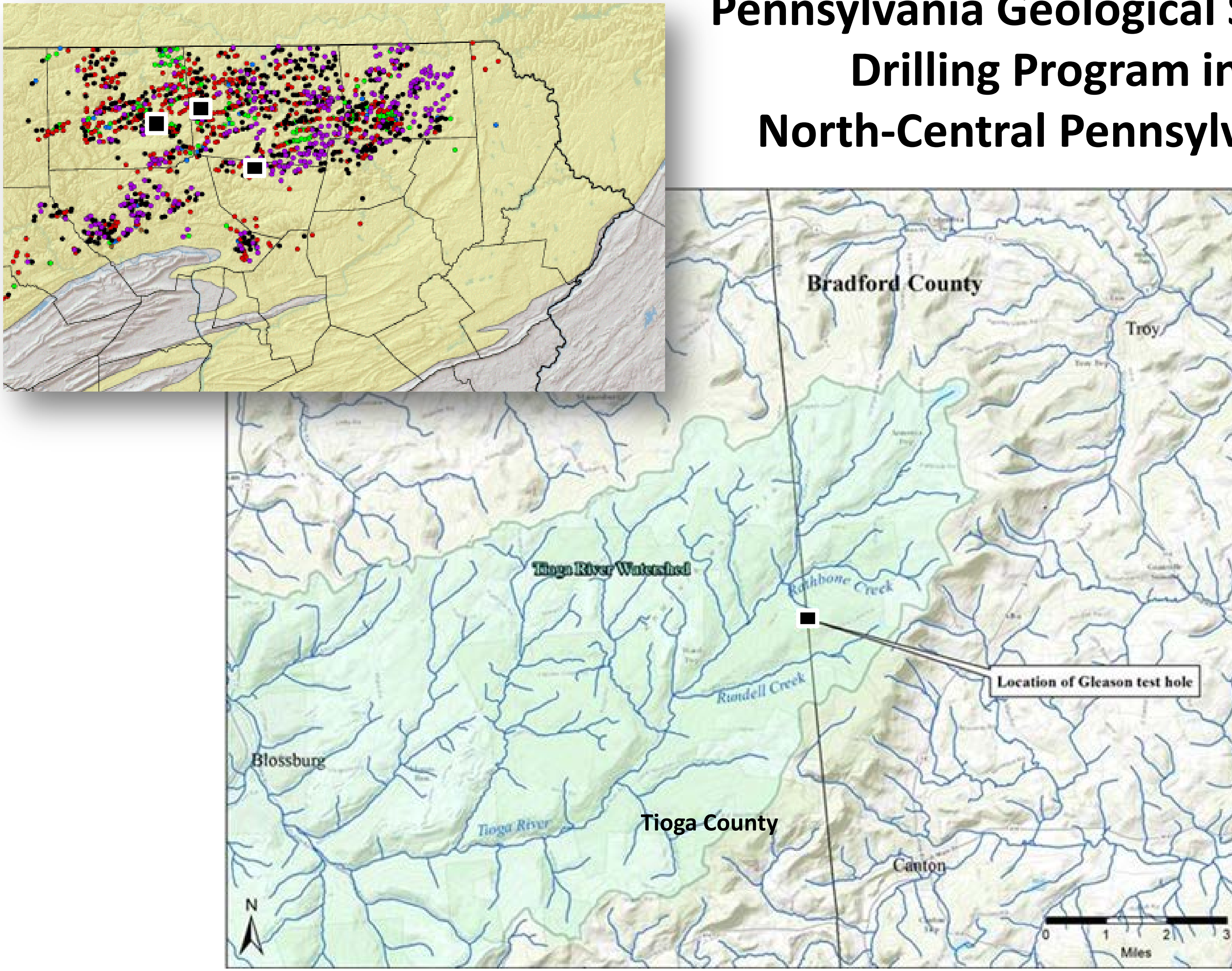
Integrated Geophysical Logging Approach at Fractured-Bedrock Sites



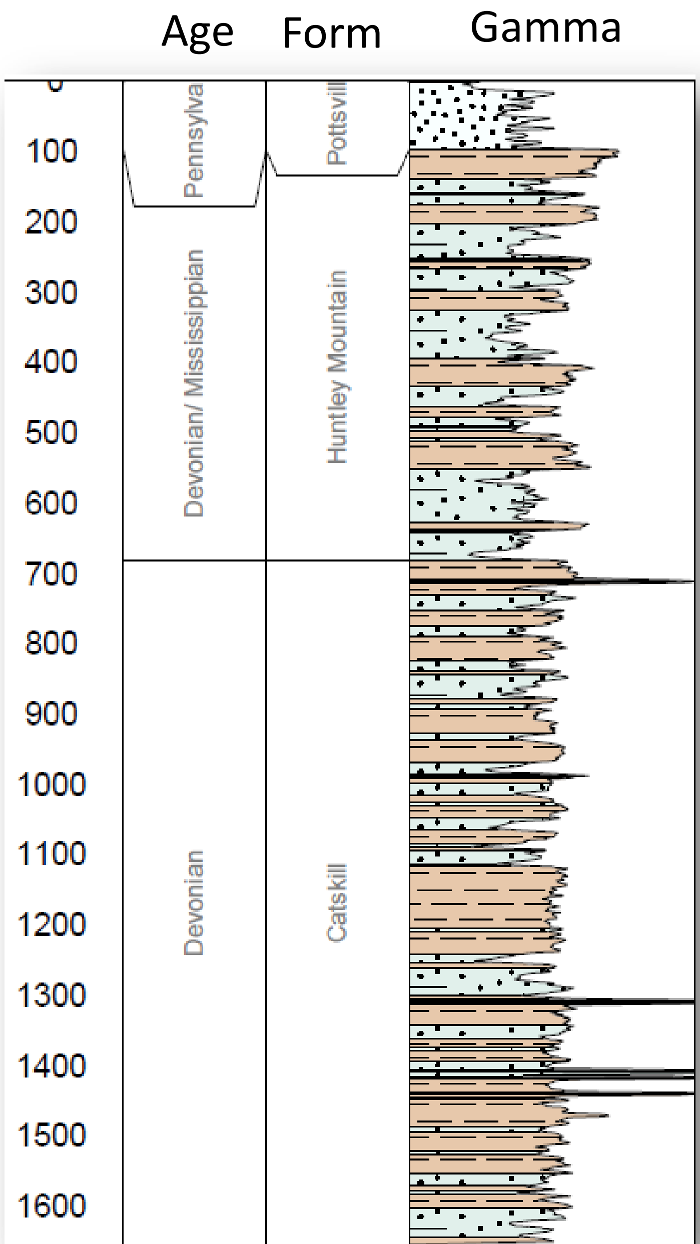
Borehole imaging, flowmetering, and fluid-property logging and sampling

Lithology, fabric, fractures, and flow-zone transmissivity, hydraulic head, and water quality

Pennsylvania Geological Survey Drilling Program in North-Central Pennsylvania



Opportunity to apply and compare geophysical logging methods in deep fractured-bedrock test holes in an area of intensive Marcellus gas development

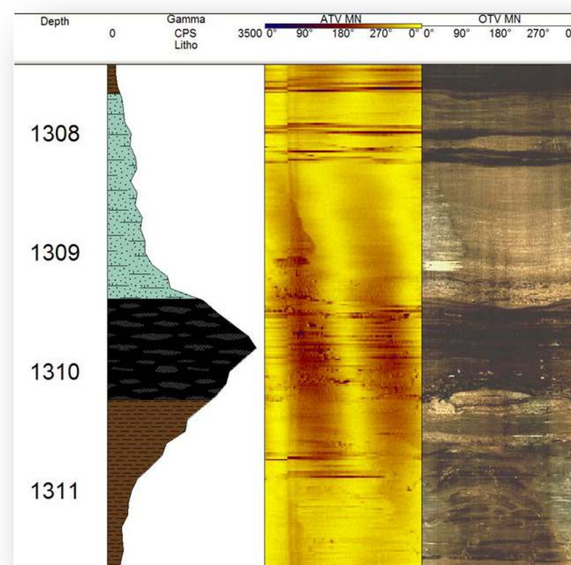


Gleason Corehole

1,664-feet deep corehole site in high-relief upland setting

Interbedded sandstone, siltstone, and claystone of Pennsylvanian, Mississippian, and Upper Devonian age

Carbonaceous zones correlated with gamma spikes, source of thermogenic methane

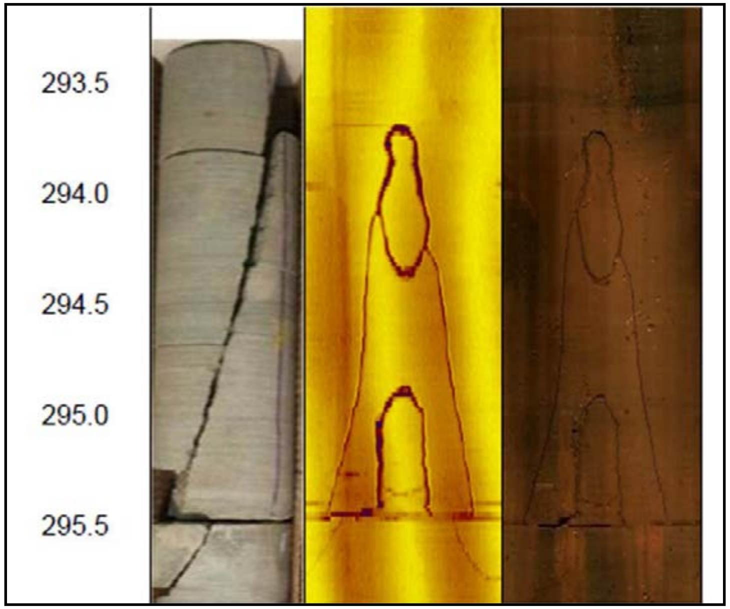


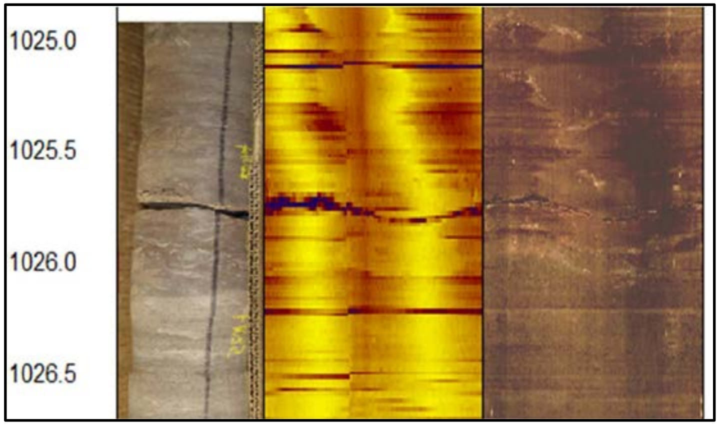
Fracture Characterization

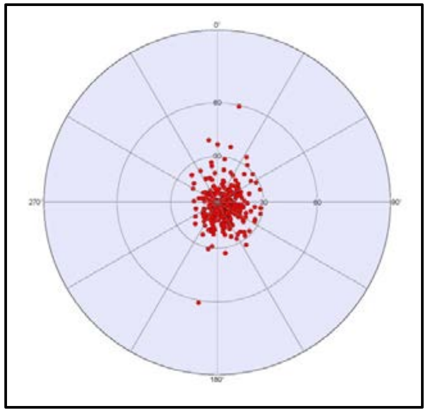
Distribution and orientation of fractures determined from analysis of acoustic and optical televiewer logs that provide oriented 360 degree view of corehole wall

Most fractures bedding parallel with some steeply dipping fractures related to regional jointing

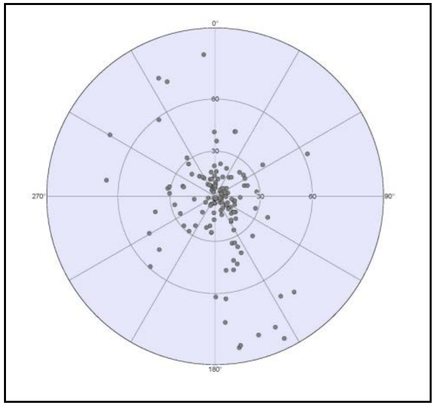
Core ATV OTV



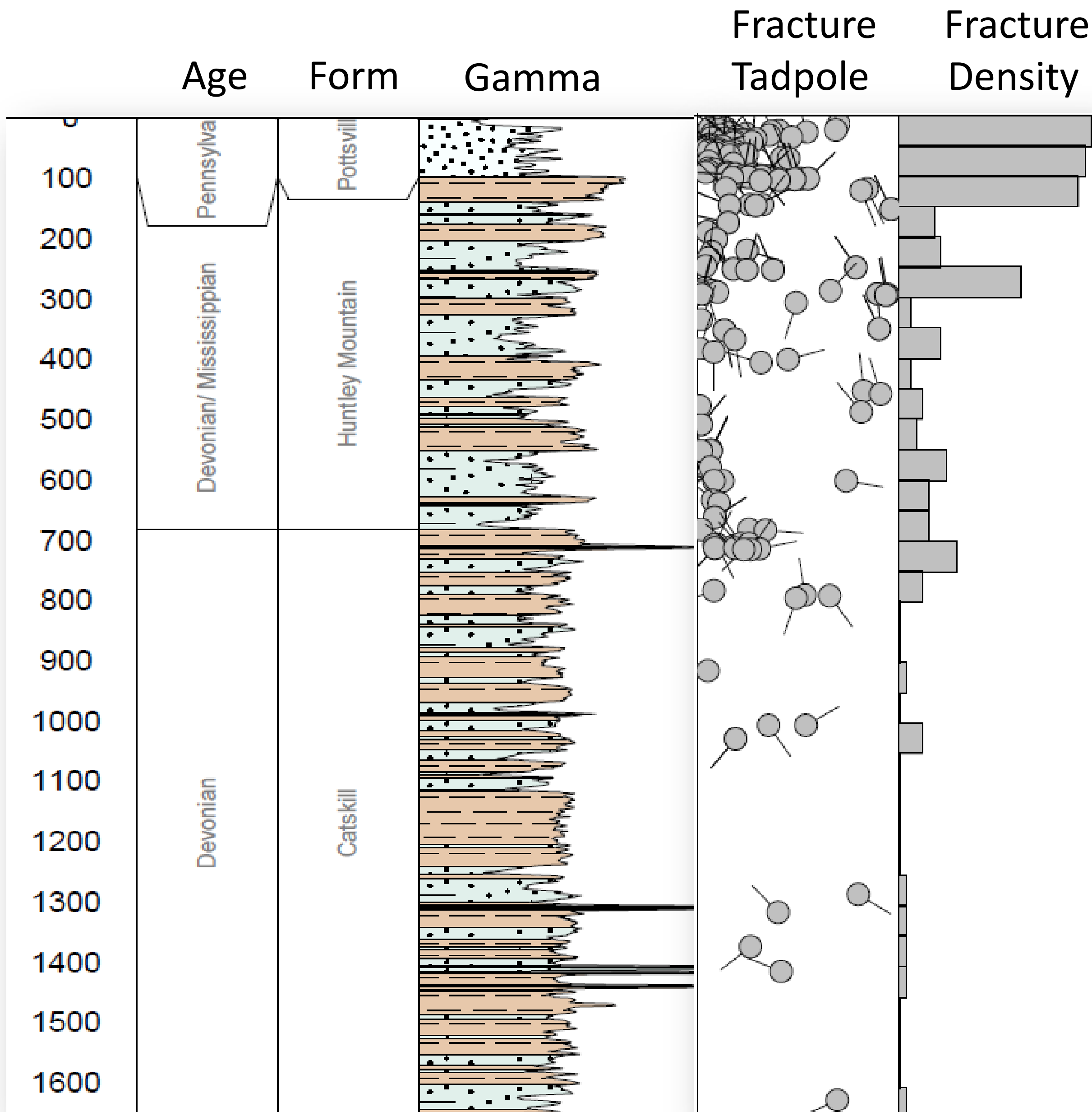




Bedding

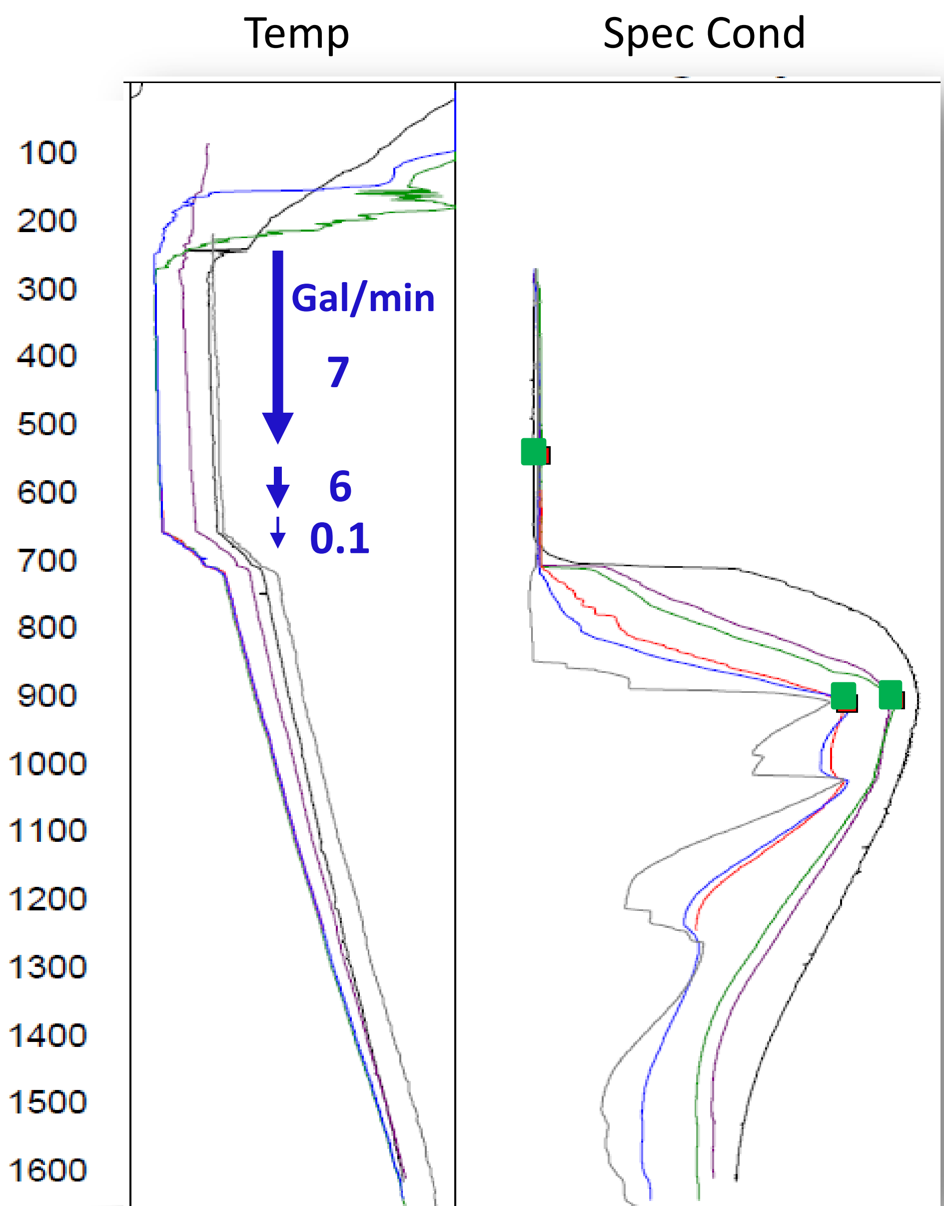


Fractures



Majority of fractures above 300 feet and few fractures below 800 feet

Flow-Zone Characterization

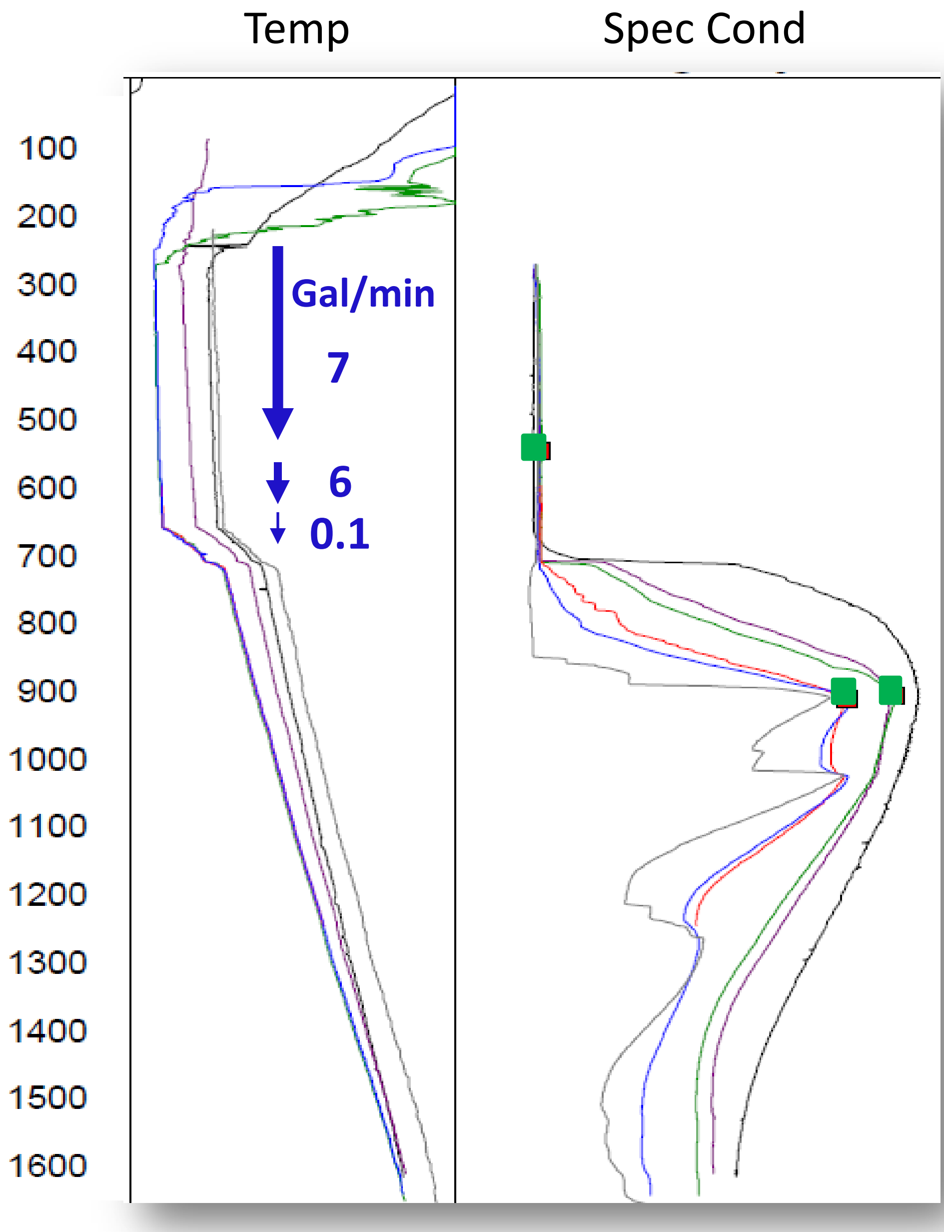


Integration of the fracture analysis with interpretation of the fluid-property, flowmeter, and video logs

Inflow of fresh water from multiple fractures between 50 and 294 feet, cascading water above composite water level at 270 feet

Outflow of fresh water to fractures at 553, 661, and 712 feet with most outflow at the 661-foot zone

Flow-Zone Characterization



Temperature log gradient approached geothermal gradient below 712 feet indicating little transmissivity below this depth

Inflow of saline water with thermogenic methane from fractures at 915, 1,026, and 1,310 feet delineated by specific conductance logs and characterized through specific-depth sampling

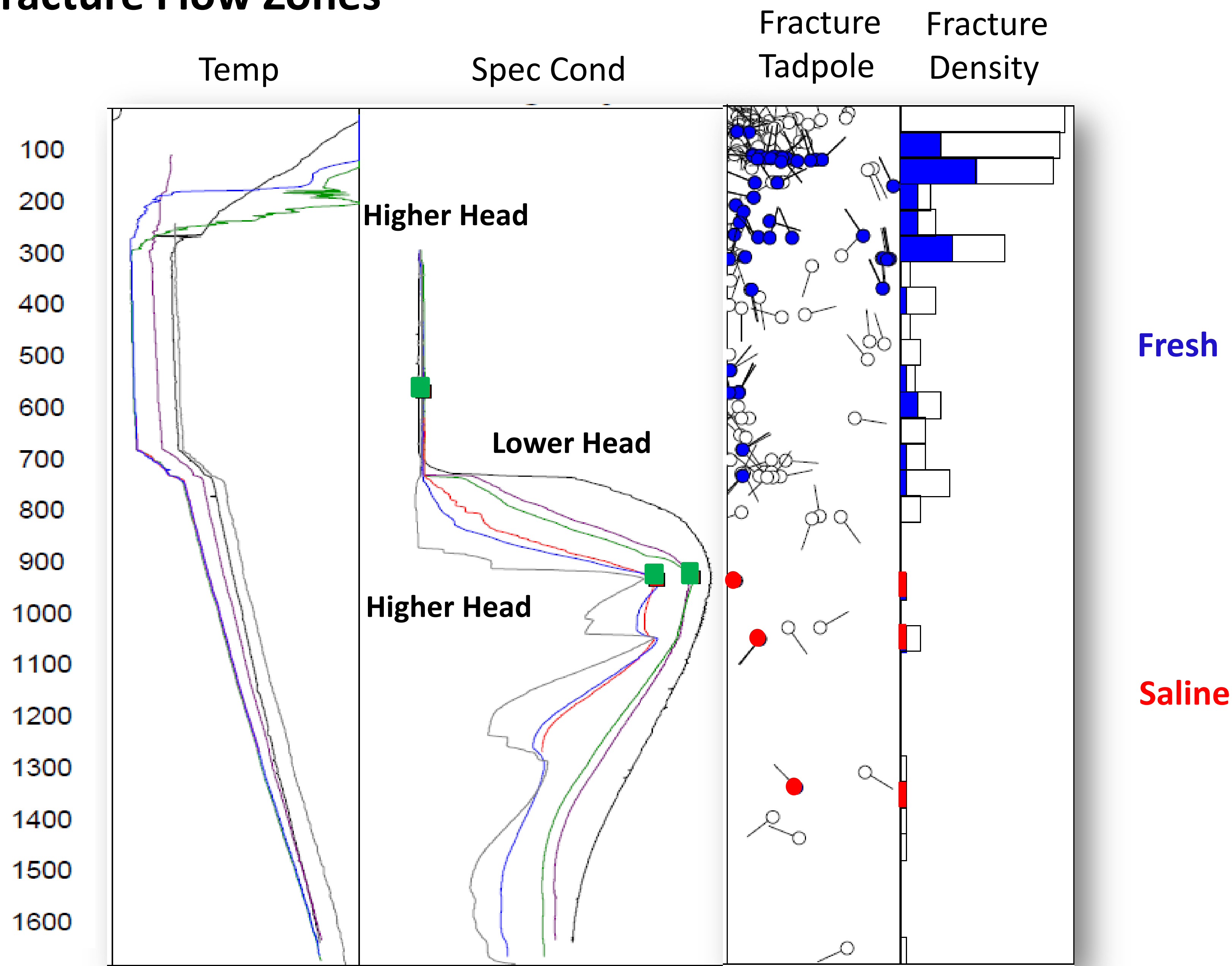
Borehole Camera Videos

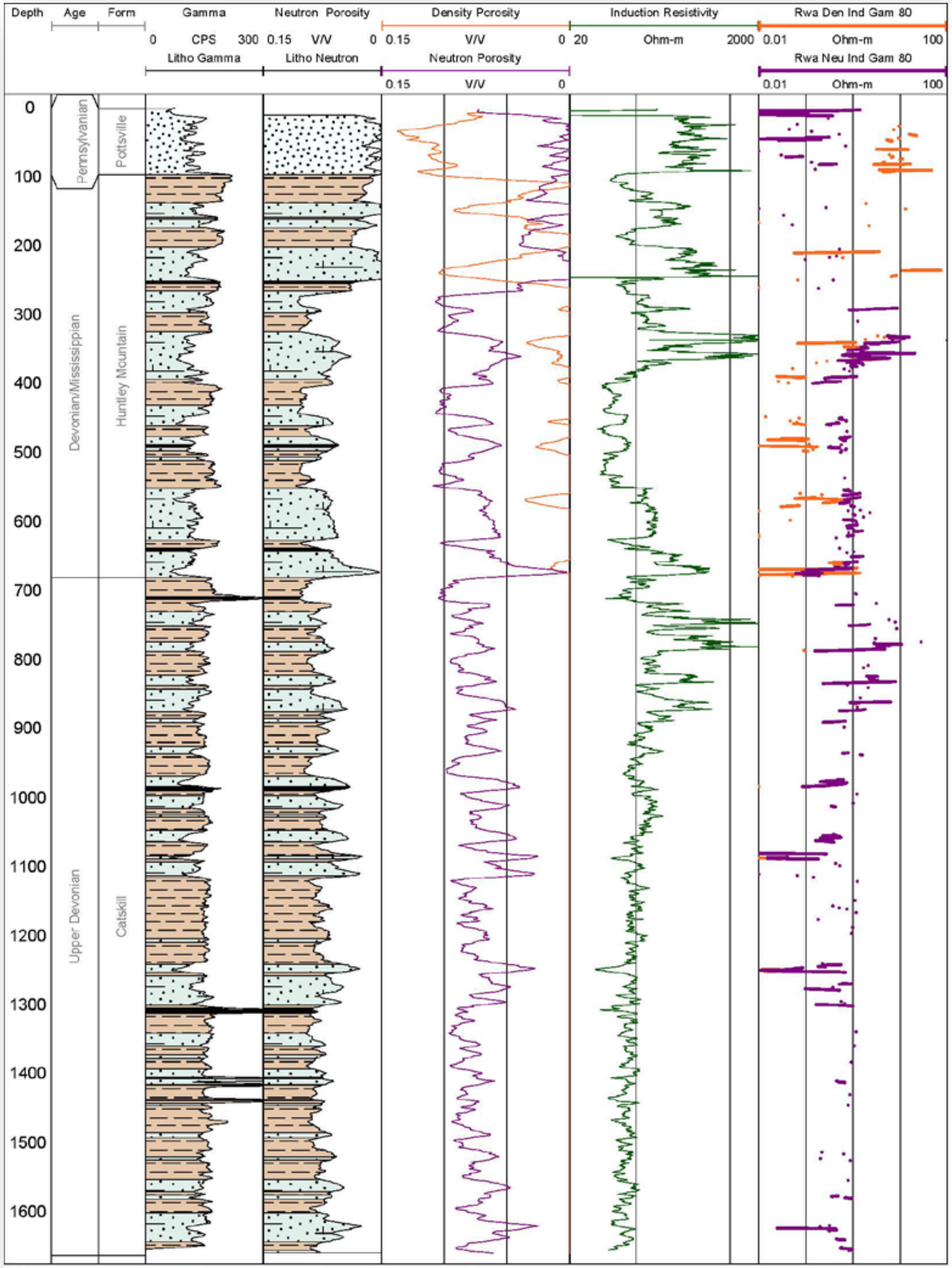
Fresh-water inflow zones above composite water level at 270 feet

Fresh-water outflow zone at 661 feet

Saline-water inflow zone at 915 feet

Fracture Flow Zones





Petrophysical Logs

Highly variable above 880 feet

Suggests saline formation water below between 880 feet

Consistent with fresh-water flow zone at 712 feet and saline water-flow zone at 915 feet

Summary and Conclusions

Better characterization of the fresh- and saline-water flow zones in fractured bedrock is needed to protect drinking water aquifers during shale-gas development

An integrated geophysical logging approach that included imaging, flowmetering, and fluid-property logging and sampling in addition to petrophysical logging was successfully applied in a deep corehole in an area of shale-gas development

Consideration should be given to adding fluid-property and video camera logs to the petrophysical logging suite currently being collected from topset wells at multi-well pad sites

Application of the complete integrated geophysical logging approach would be beneficial for the design and installation of discrete-zone monitoring wells at multi-well pad sites and investigation of domestic water-wells potentially impacted by shale-gas development.