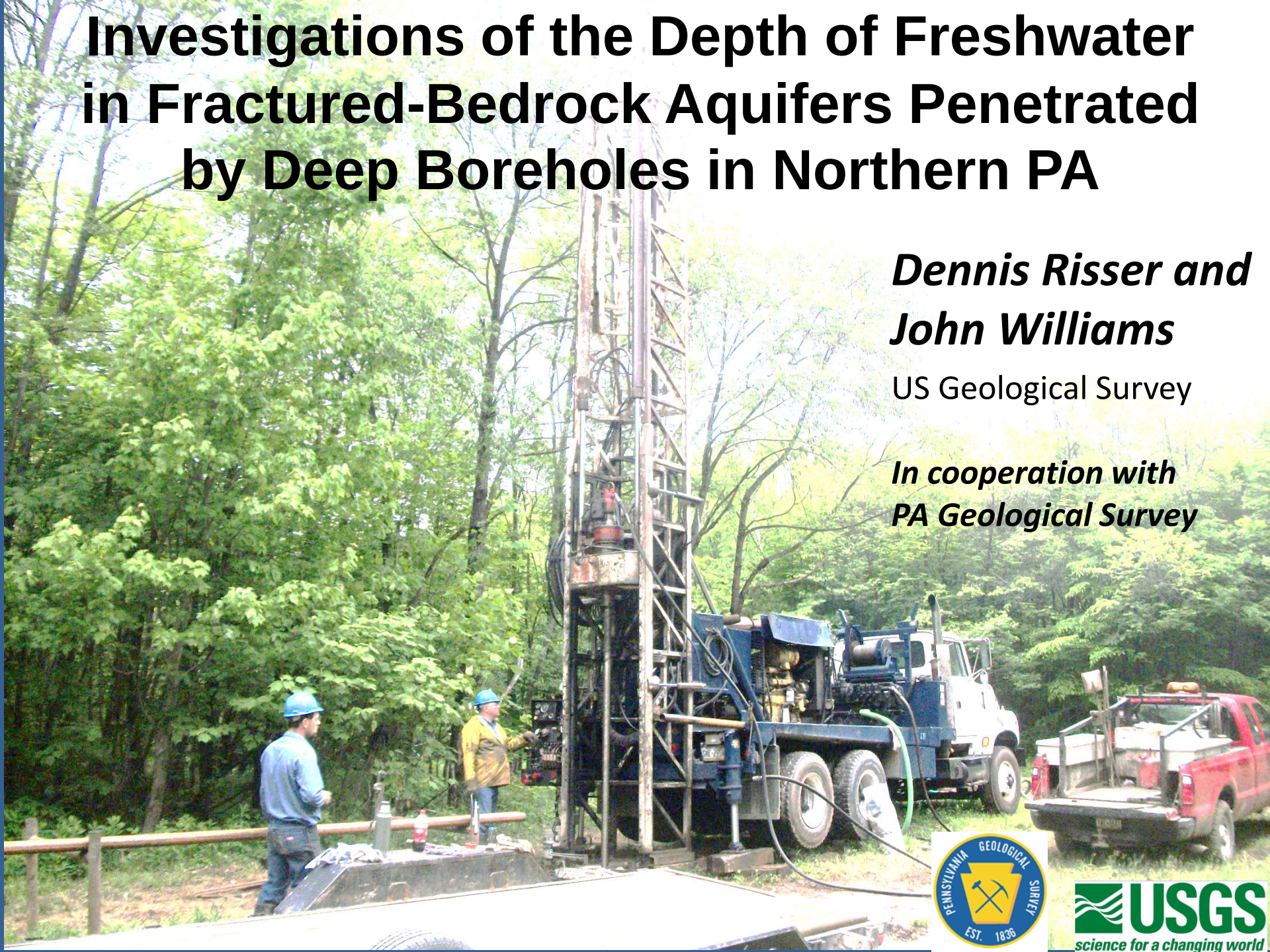
Investigations of the Depth of Freshwater in Fractured-Bedrock Aquifers Penetrated by Deep Boreholes in Northern PA



Dennis Risser and John Williams

US Geological Survey

In cooperation with PA Geological Survey

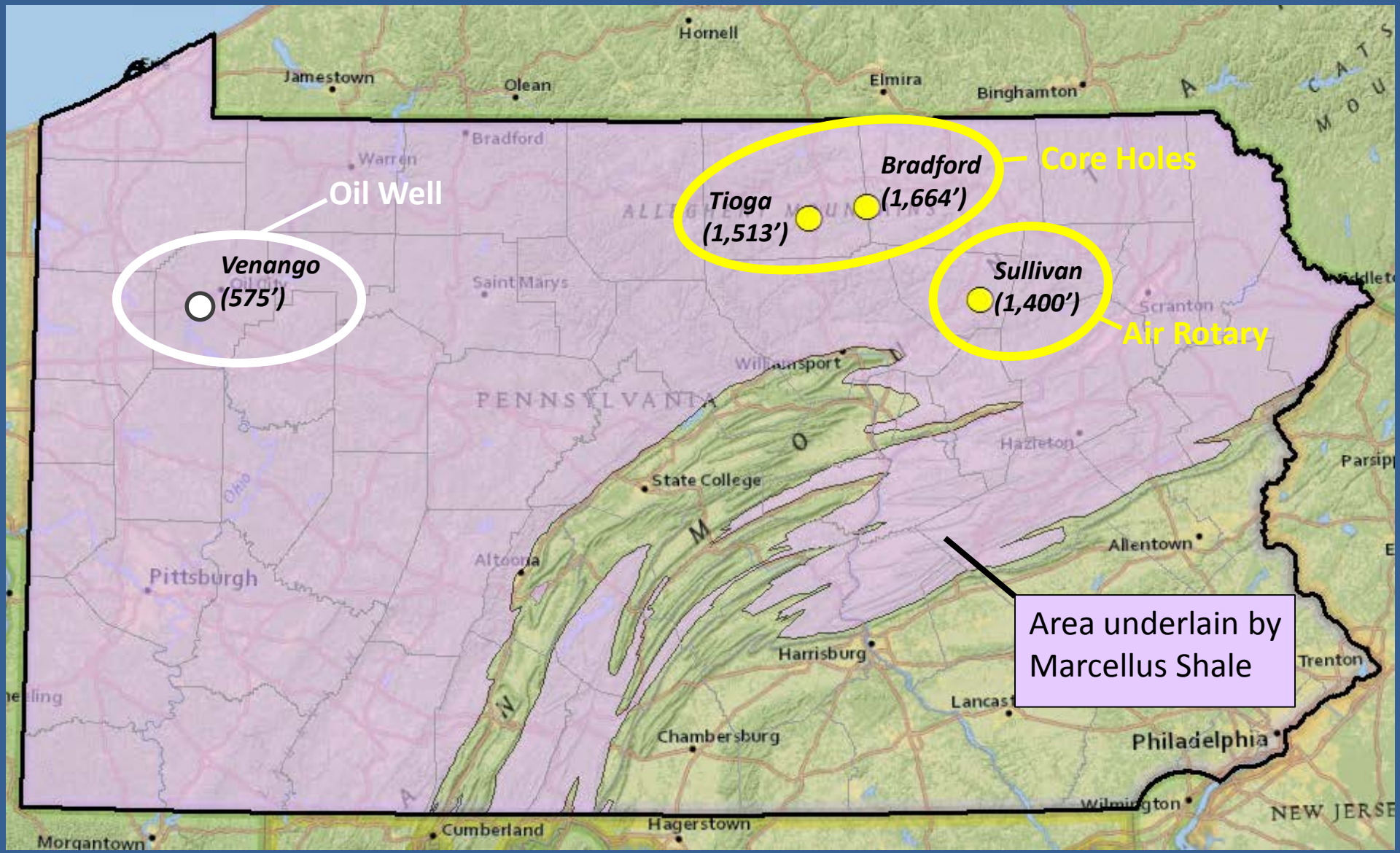
USGS science for a changing world

Study to Estimate Minimum Surface-Casing Depths of Oil and Gas Wells to Prevent Ground-Water Contamination

"Because of the poor quality and scarcity of ground-water data, the altitude of the base of the fresh ground-water system in the four study areas cannot be accurately delineated. "

Buckwalter and Squillace, 1995, USGS WRIR 87-4136

Deep Holes Tested



Water-Bearing Fracture @ 90 Ft

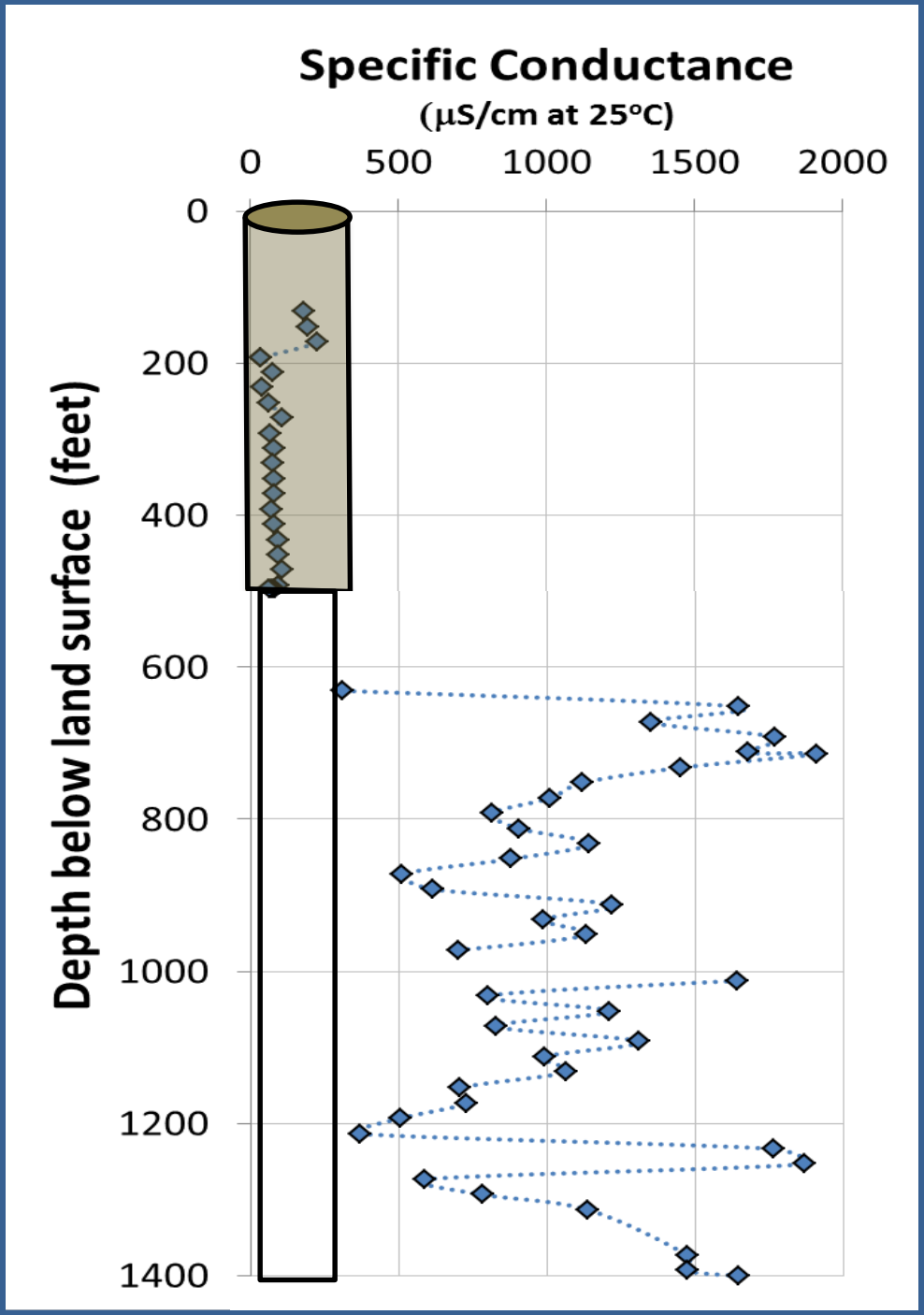
Approach

Observations During Drilling

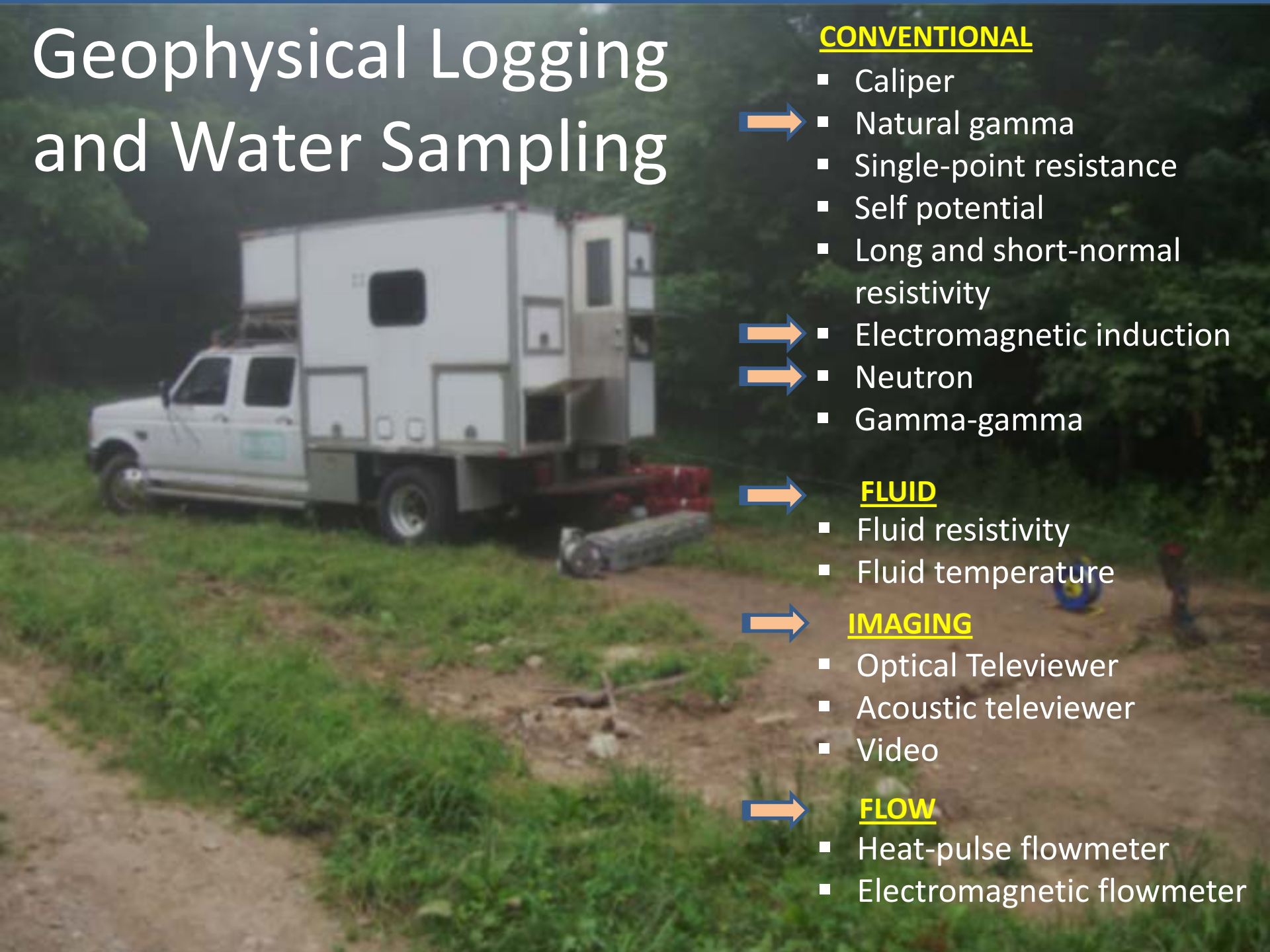
Geophysical Logging

Groundwater Sampling

Specific Conductance During Drilling Sullivan Co Test Hole



Geophysical Logging and Water Sampling



CONVENTIONAL

- Caliper
- Natural gamma
- Single-point resistance
- Self potential
- Long and short-normal resistivity
- Electromagnetic induction
- Neutron
- Gamma-gamma

FLUID

- Fluid resistivity
- Fluid temperature

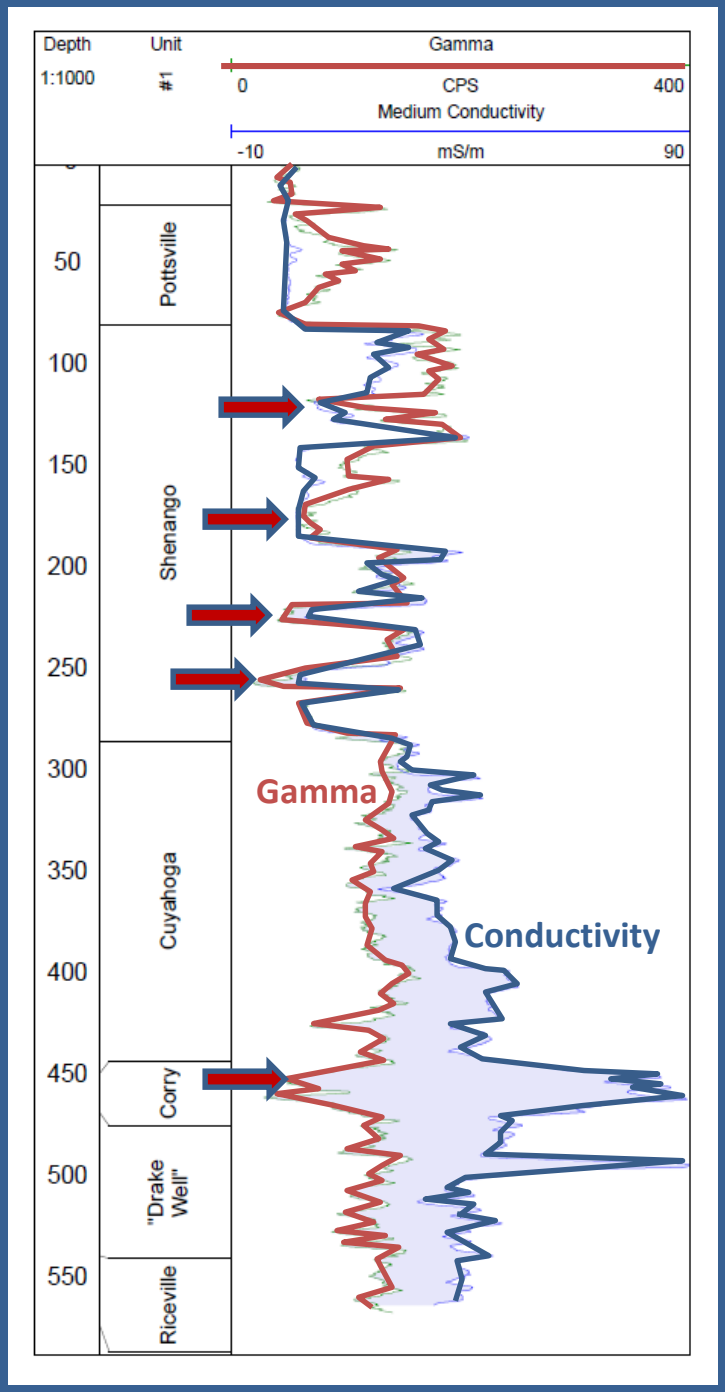
IMAGING

- Optical Televiewer
- Acoustic televiewer
- Video

FLOW

- Heat-pulse flowmeter
- Electromagnetic flowmeter

Natural Gamma & EM-Conductivity Overlay



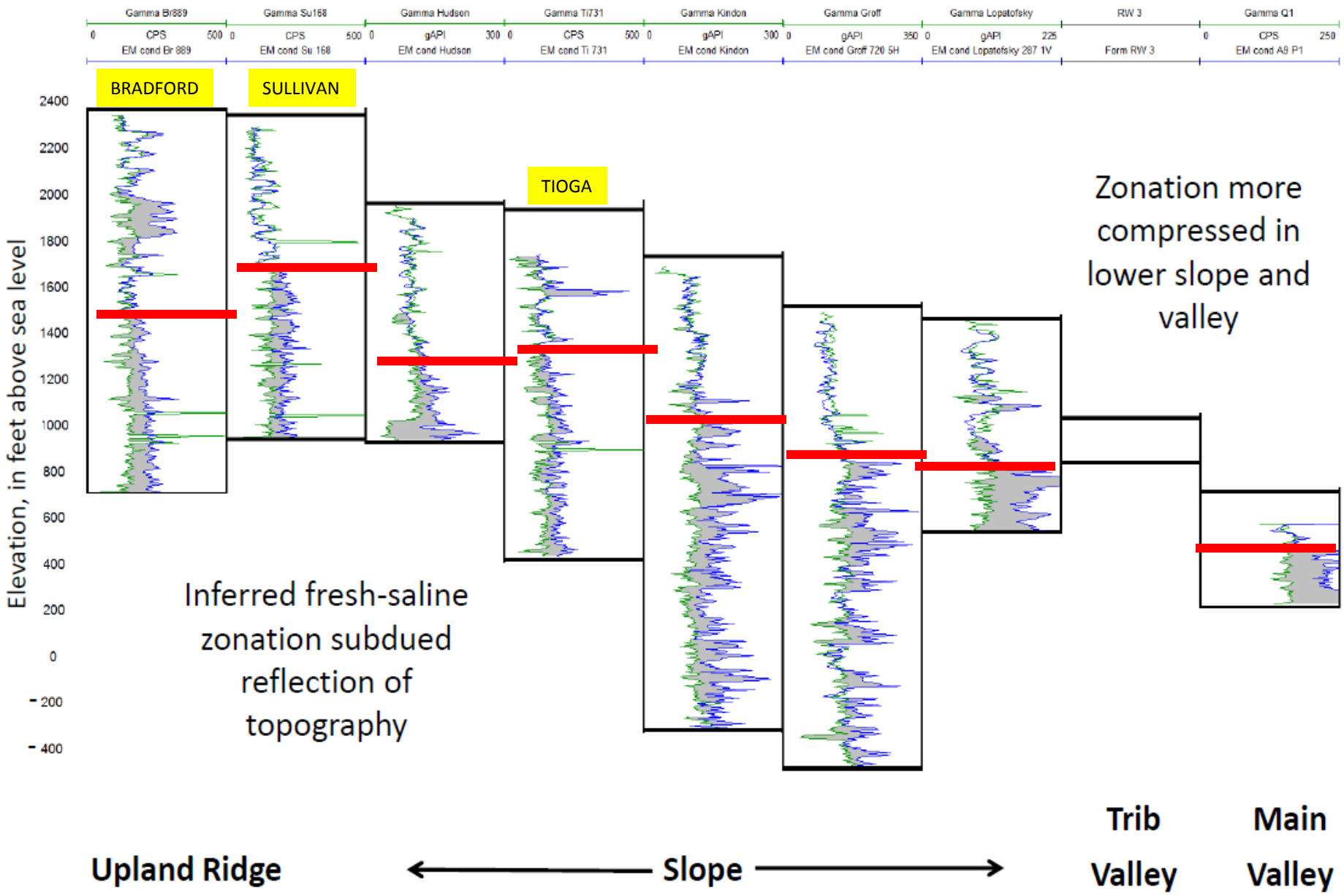
Depth below land surface, in feet

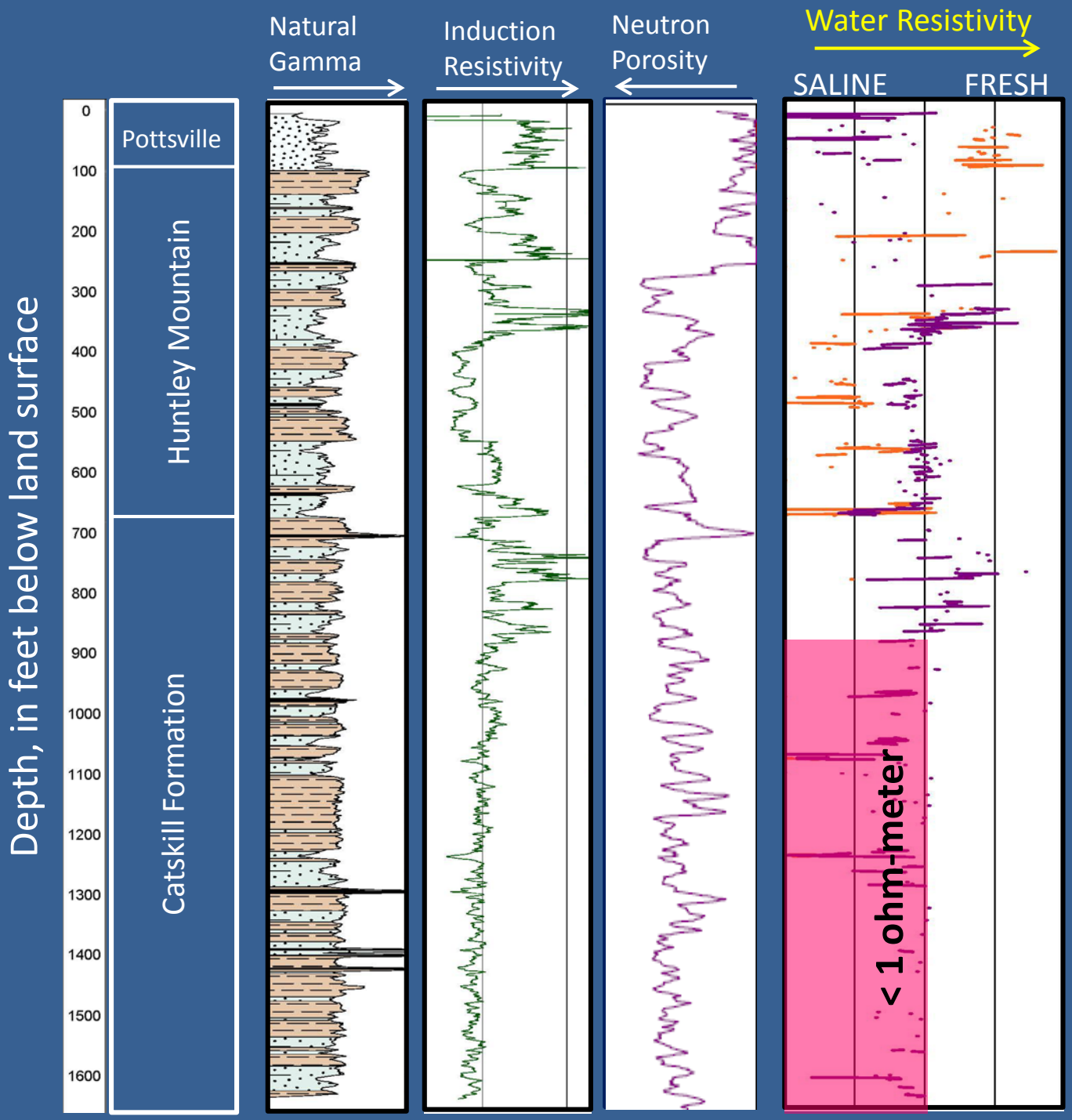
Low salinity in sandstone and shale

Increasing salinity in shale

High salinity in porous sandstone

Gamma and Induction Conductivity Logs

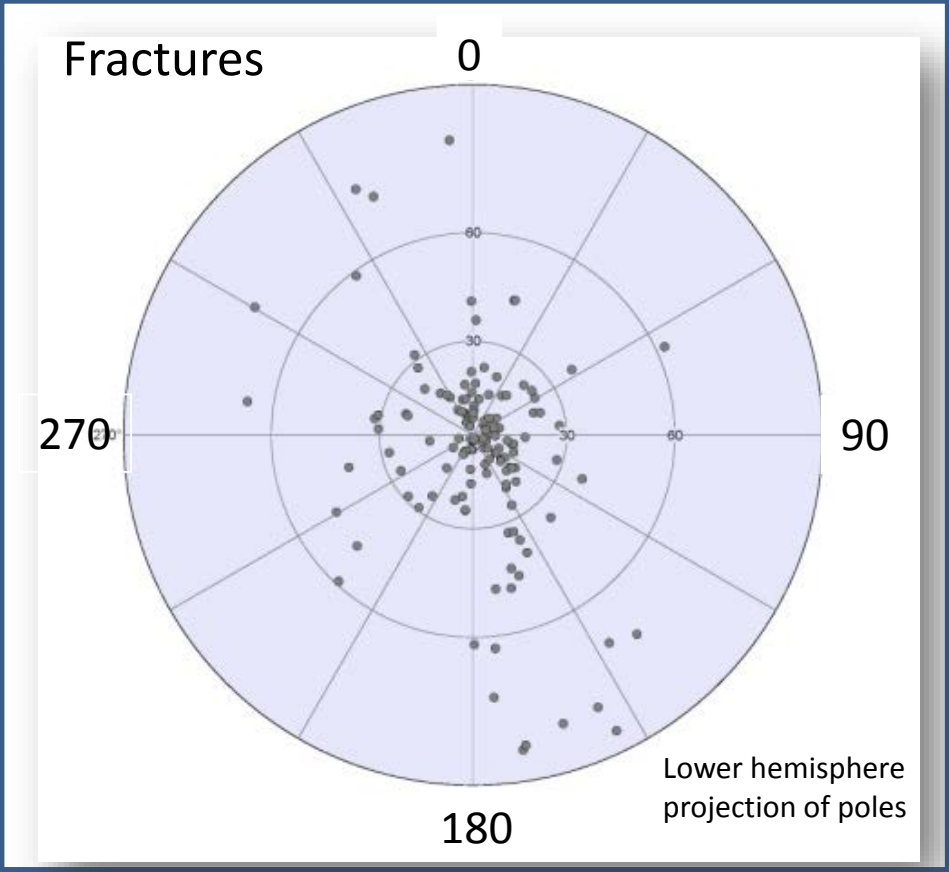


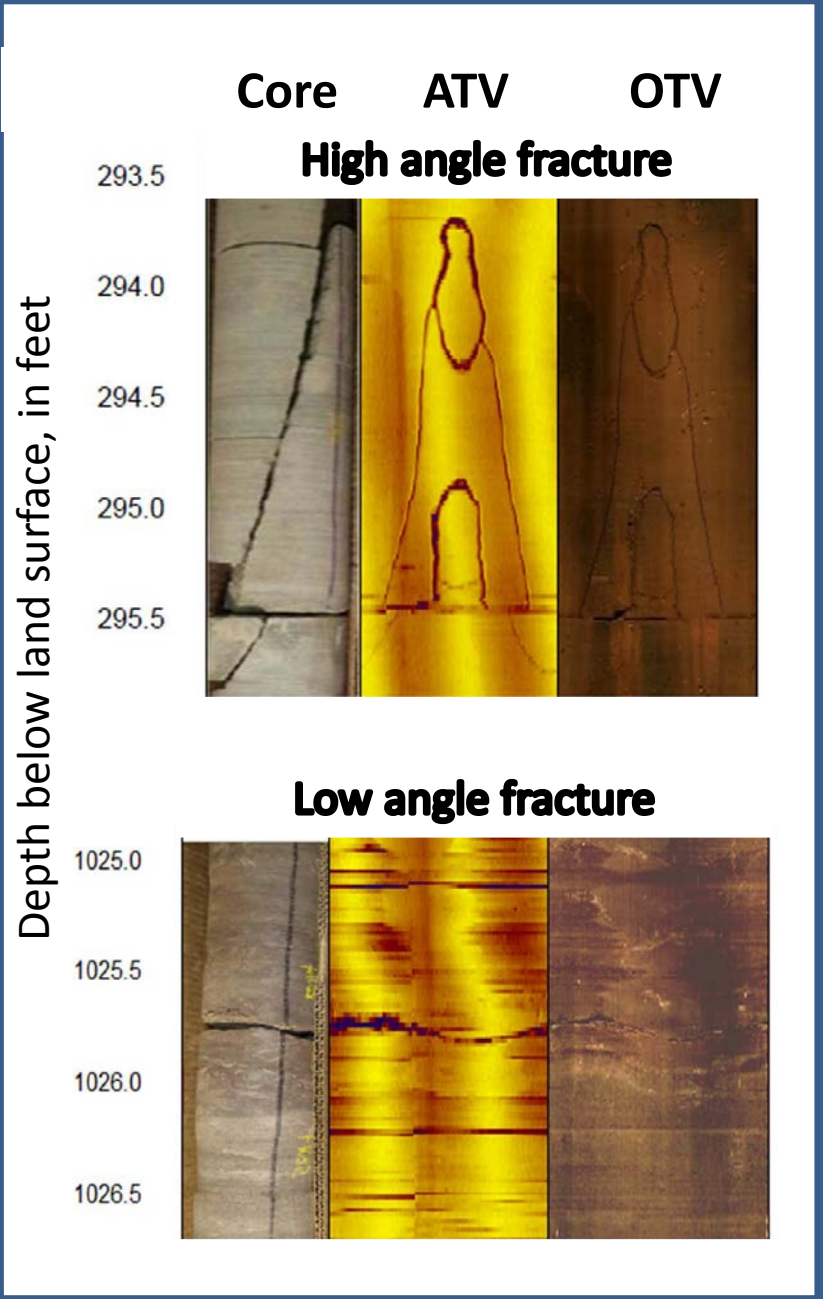


Fresh Water Depth From Archie's Law

Fracture Characterization

Most fractures are bedding parallel (dip 3° NW) with some steeply dipping fractures related to regional jointing



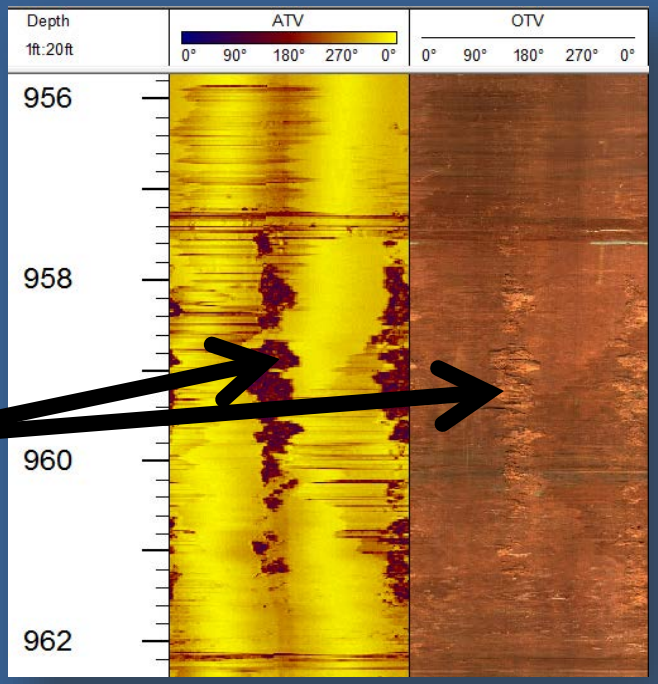


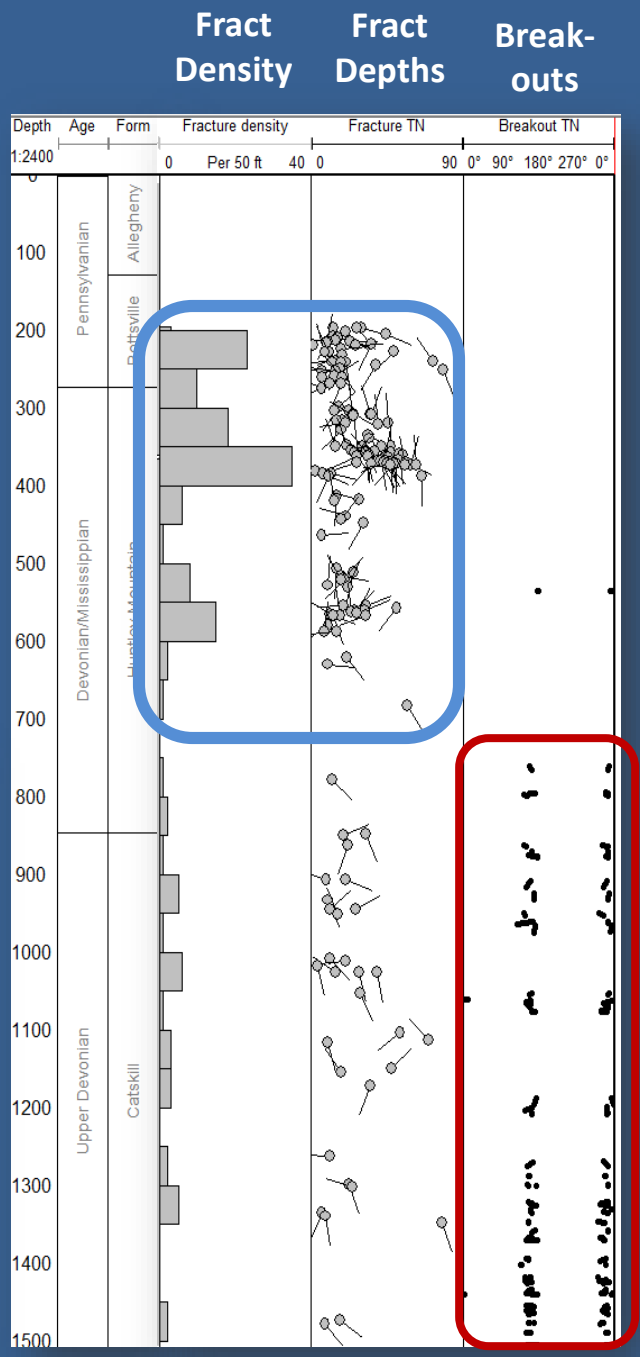
Breakouts

Breakouts formed by spalling of bedrock fragments from the borehole wall parallel to the direction of minimum horizontal stress

Breakouts present in mudstones below 800 ft

Breakout orientation indicated that the direction of maximum horizontal stress was N75E, which was consistent with regional estimates.





Tioga Co. test hole

Water-Yielding Fractures and Fluid-Flow Zones

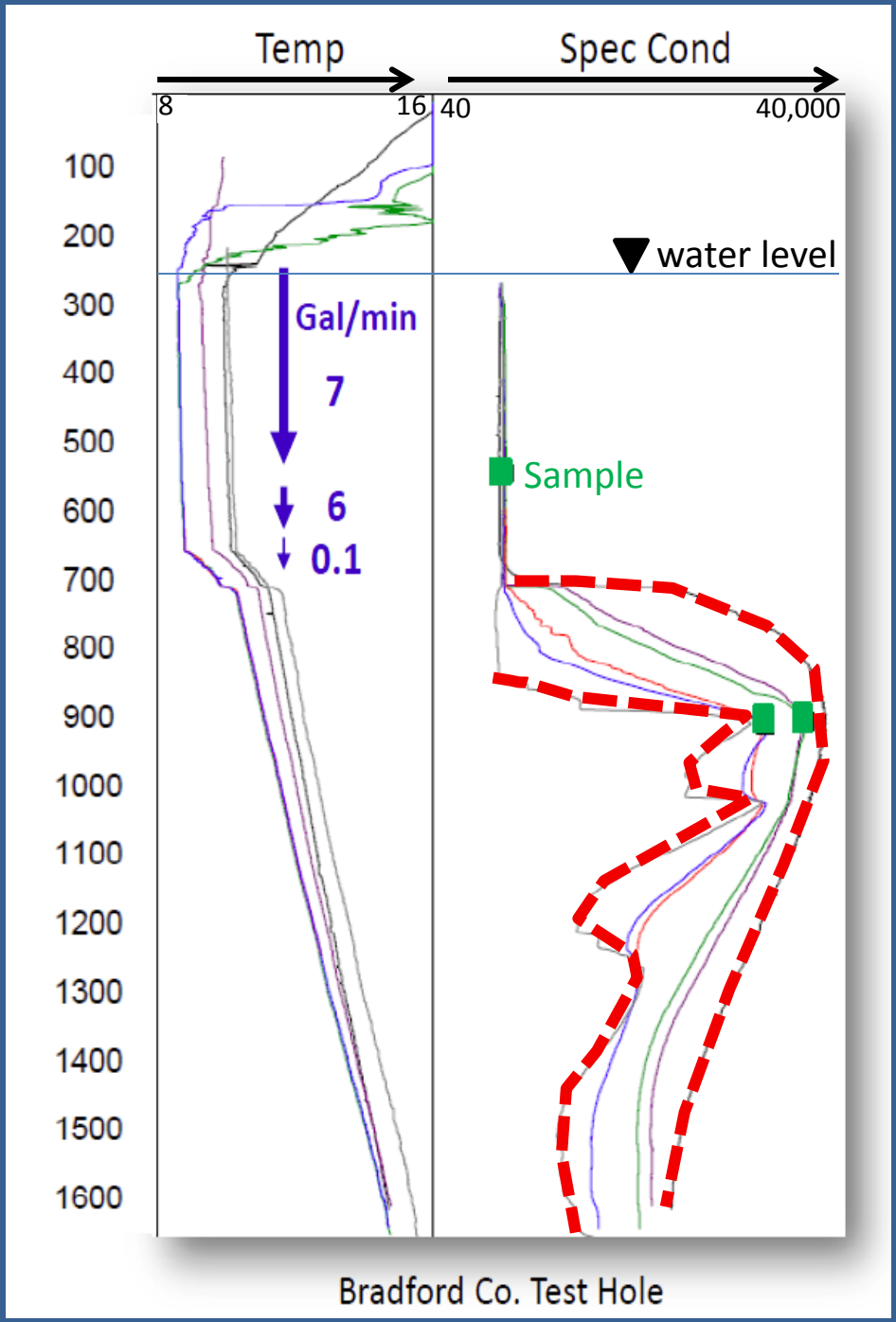
INFLOW ZONES

From multiple fractures from 50 to 294 feet

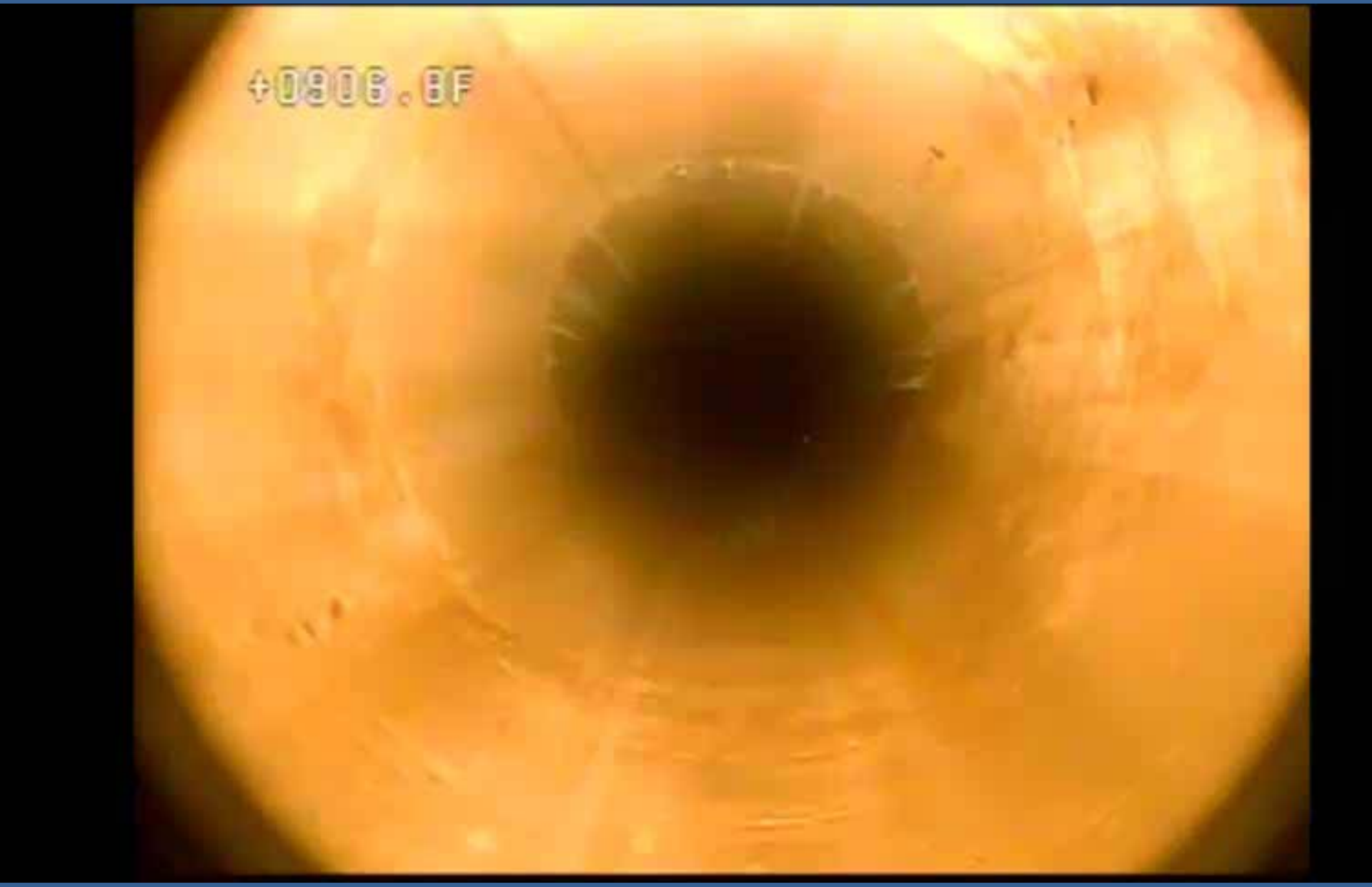
OUTFLOW ZONES

To fractures at 553, 661, and 712 feet.

Most outflow to fracture at 661 feet.



Saline Seep

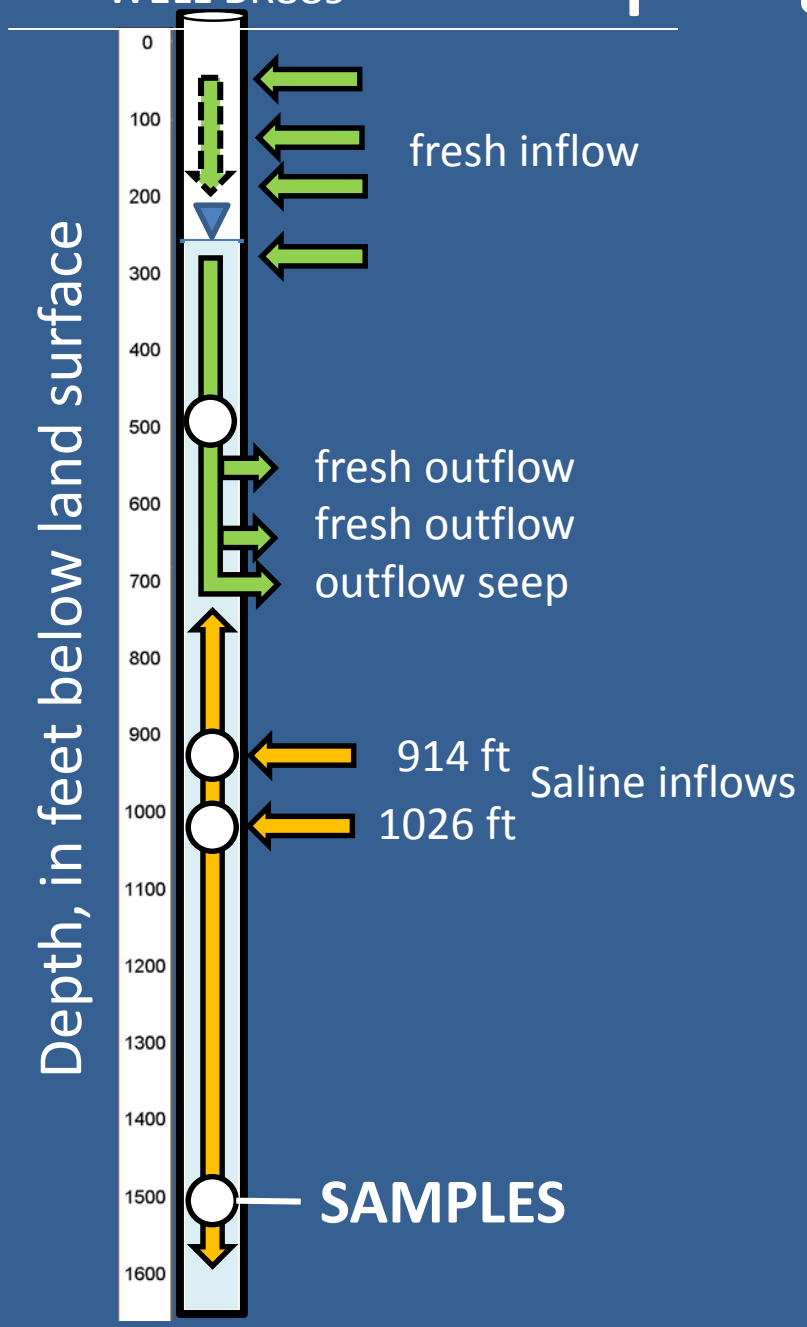


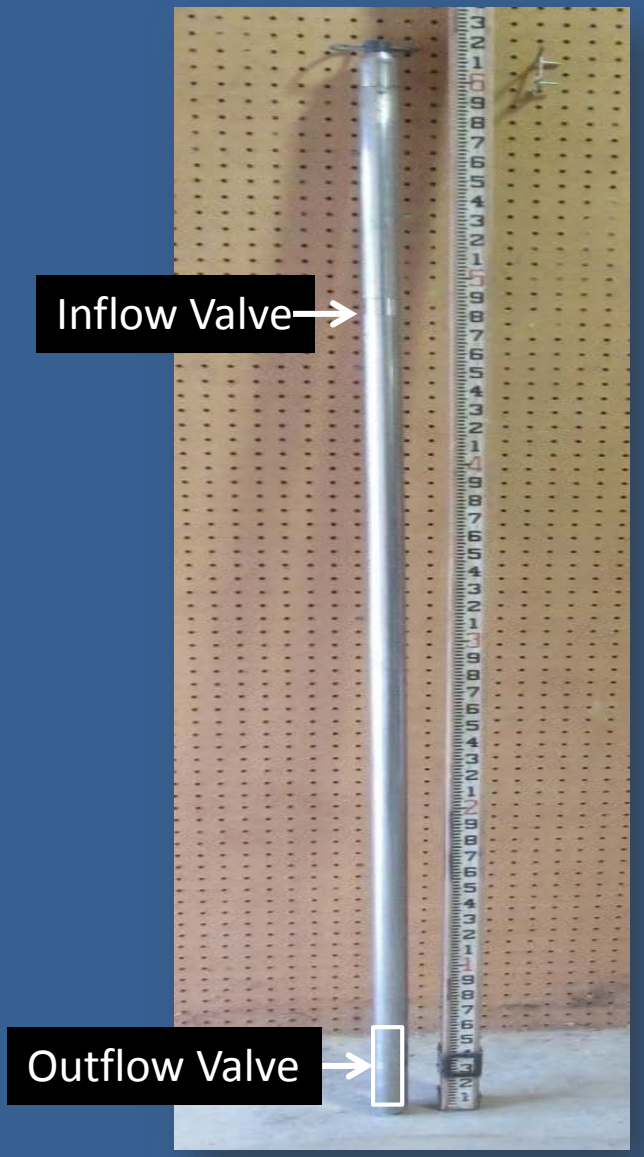
Water Sampling

Open hole with Wire-line point sampler

Isolated Intervals with Packers

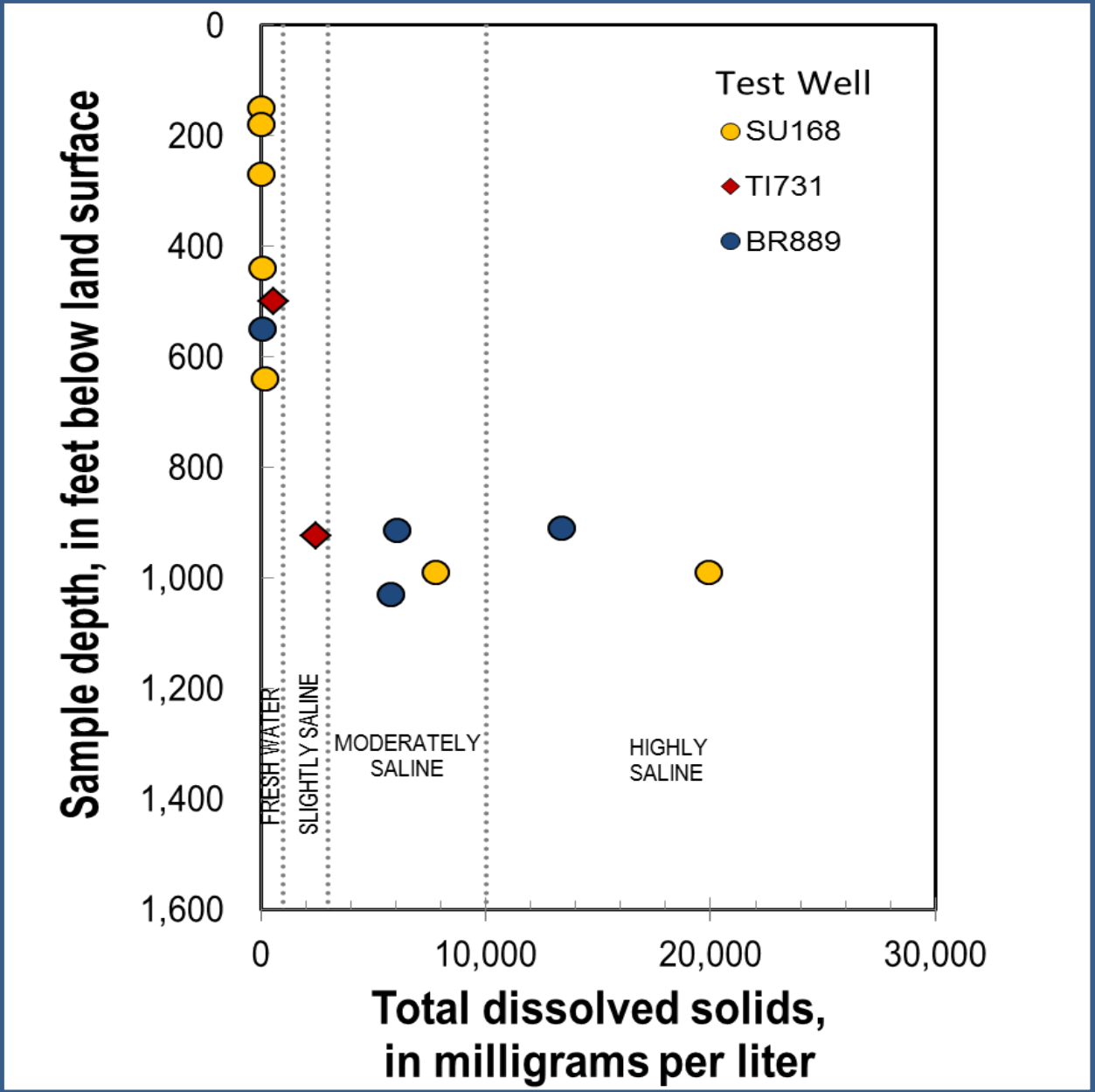
Sampling with Point Sampler



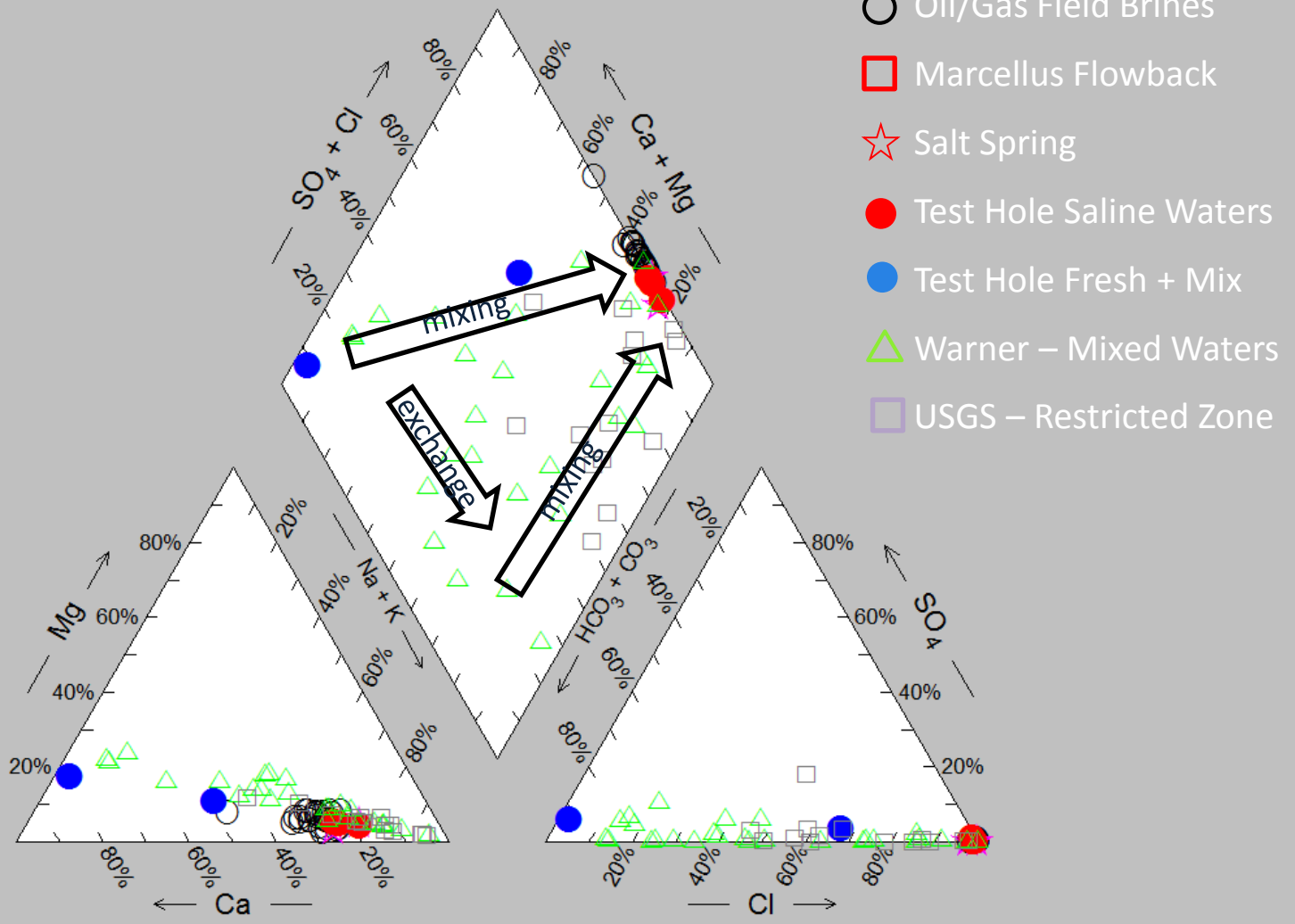


Source of Methane Bubbles

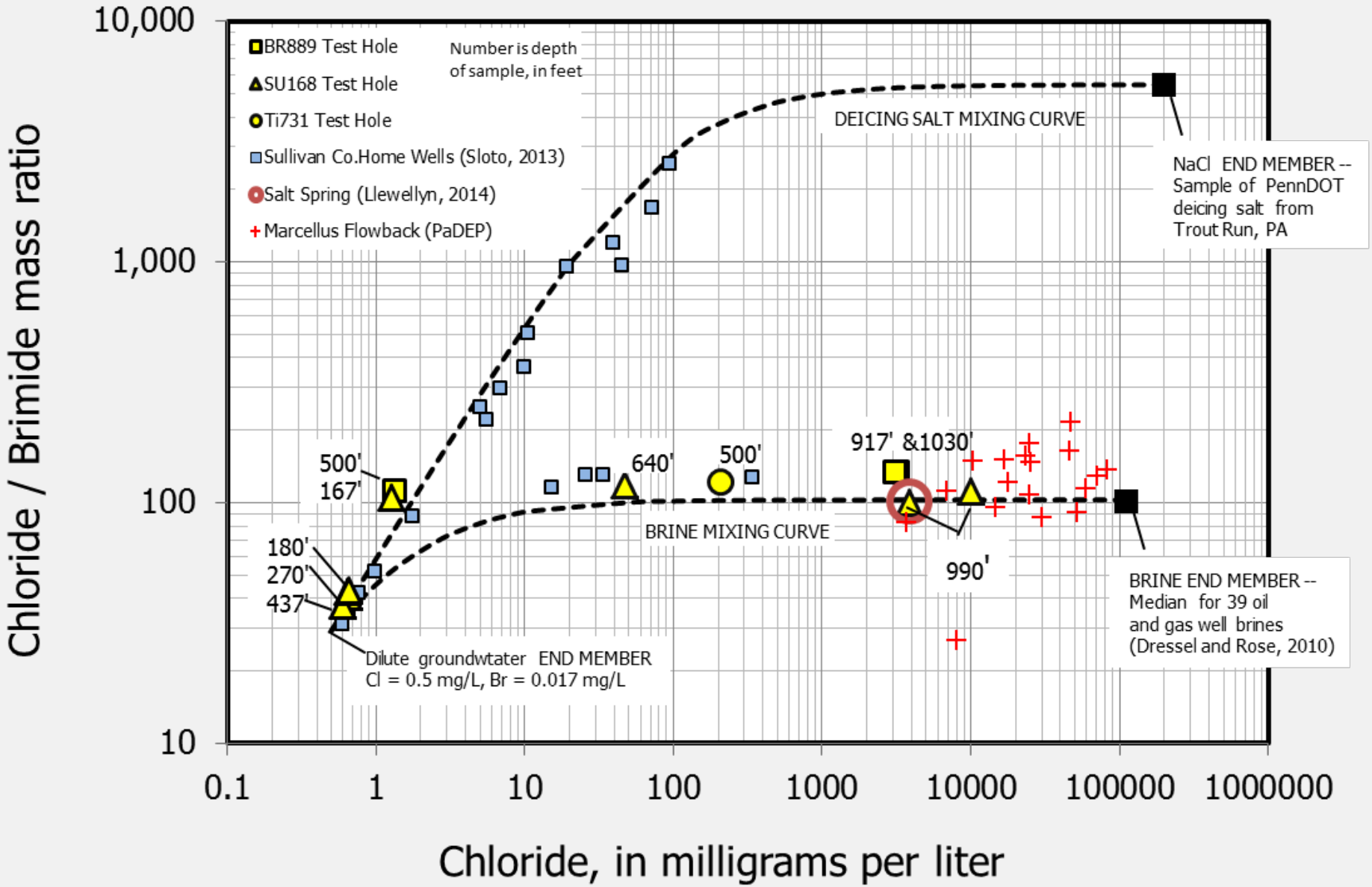
Salinity of Water Samples



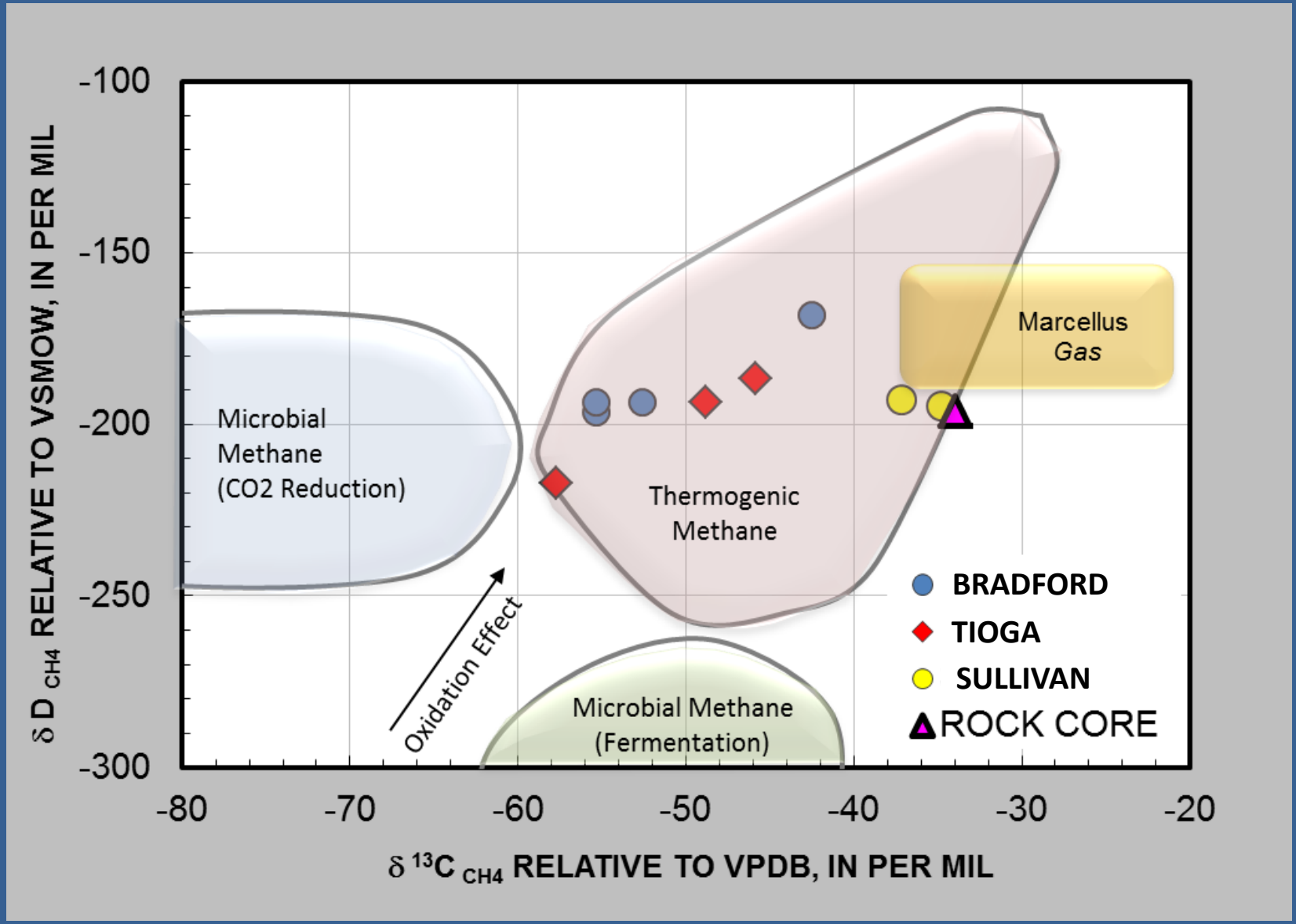
Major Ion Composition



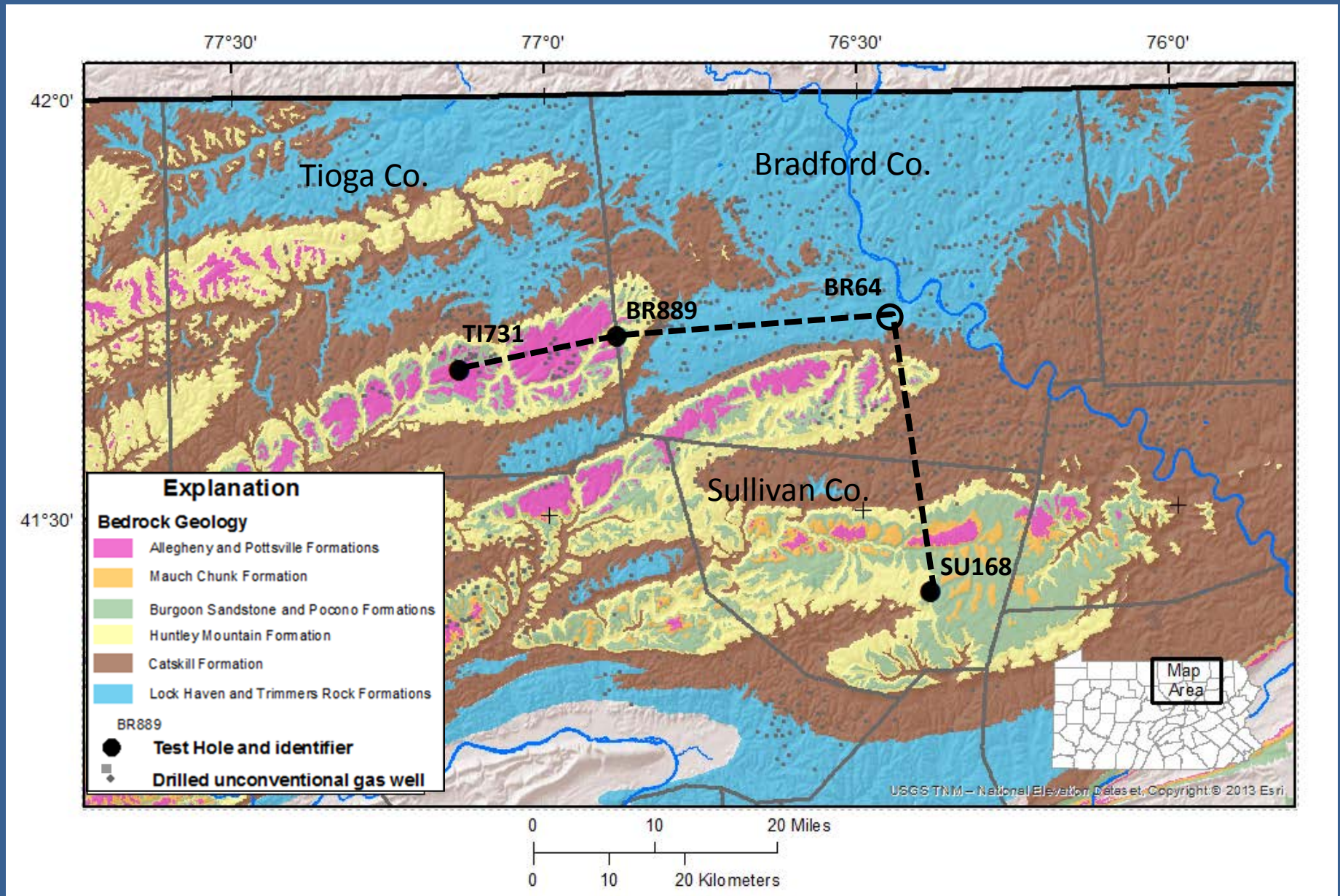
Chloride/Bromide Ratios



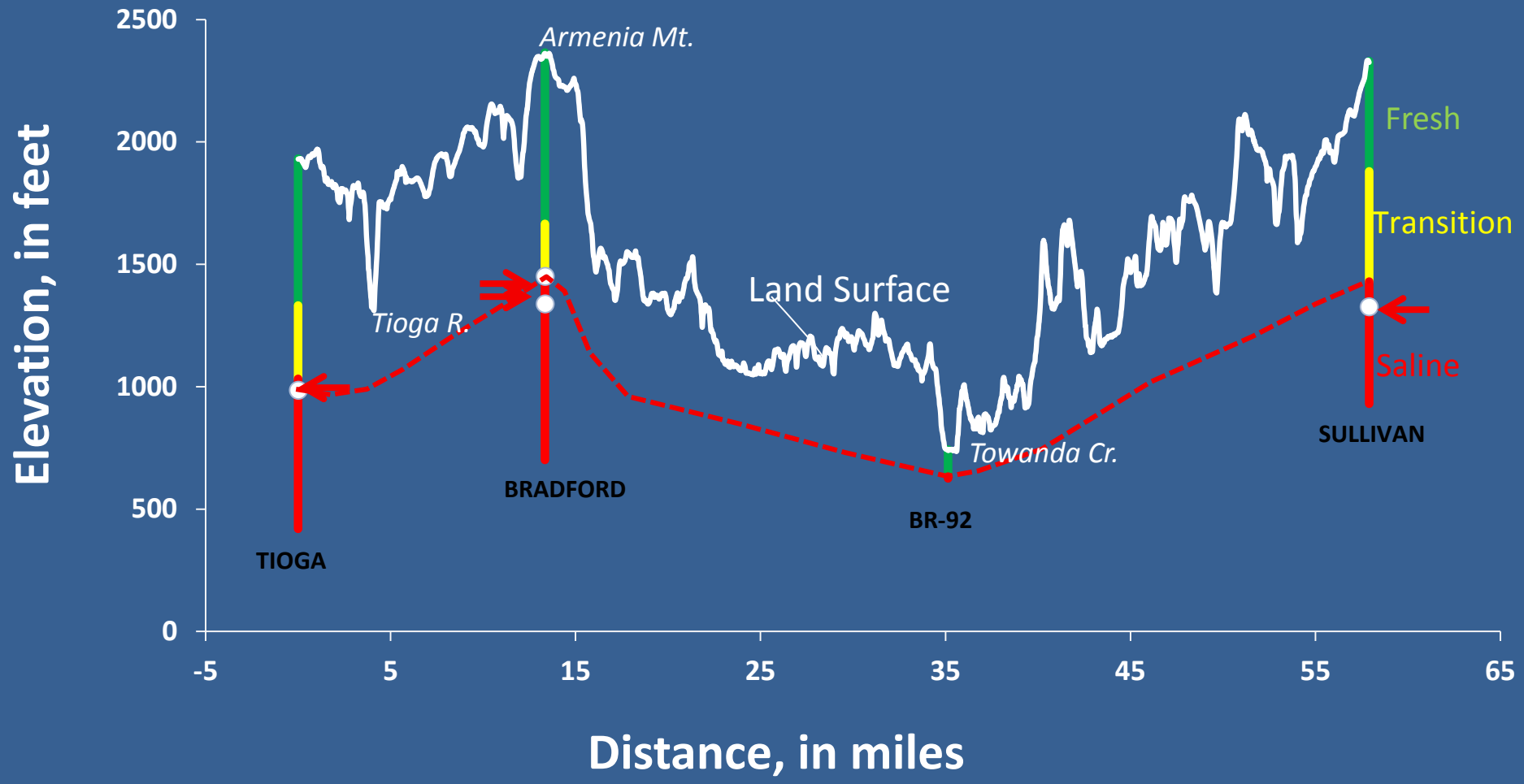
Thermogenic Isotopic Signature of Methane



Trace of Cross Section



Cross Section Showing Saline Water



Summary

- Geophysical, flowmeter, and video logging suites, along with water samples provided consistent and complimentary information for characterizing fresh- and saline-water zones in fractured bedrock of northern Pa.

- Saline water having thermogenic methane and chemical characteristics similar to diluted basin brines is present 700-800 feet beneath uplands and is much shallower beneath valleys.

- Discrete-zone monitor wells are needed to better characterize water chemistry.

Groundwater seeping from fractures in the Catskill Formation , Susquehanna County, PA