Multi-corehole thermal tracer tests using DTS to identify flow pathways in a fractured dolostone aquifer

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Jonathan Munn – PhD Candidate, University of Guelph

Beth Parker – Professor, University of Guelph

Thomas Coleman – Environmental Engineer, Silixa Ltd.

Carlos Maldaner – PhD Candidate, University of Guelph

Important Regional Aquifer

Silurian Dolostone Belt

N

Toronto

Guelph

Buffalo

Supplies groundwater to ~500,00 people

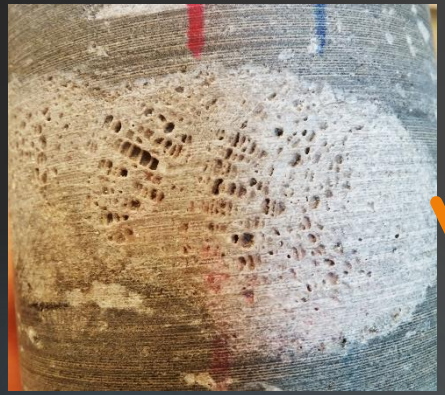
50 km

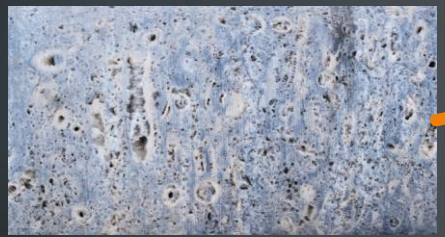
Flat-lying stratigraphy
(~0.25° dip to the SW)

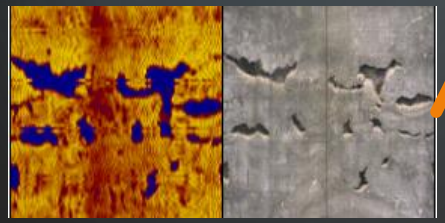
Guelph Formation

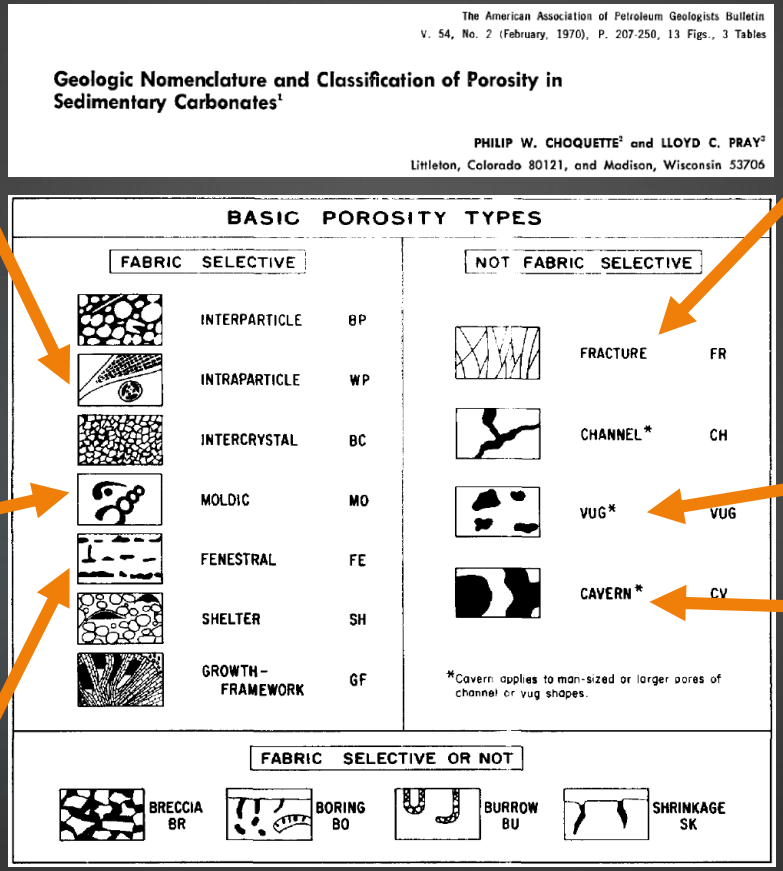
Many Types of Porosity in Carbonate Rocks

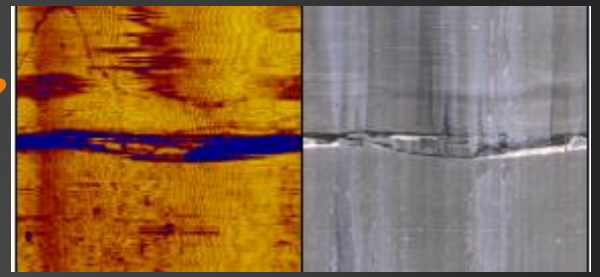
What types are important for GW flow in the aquifer?

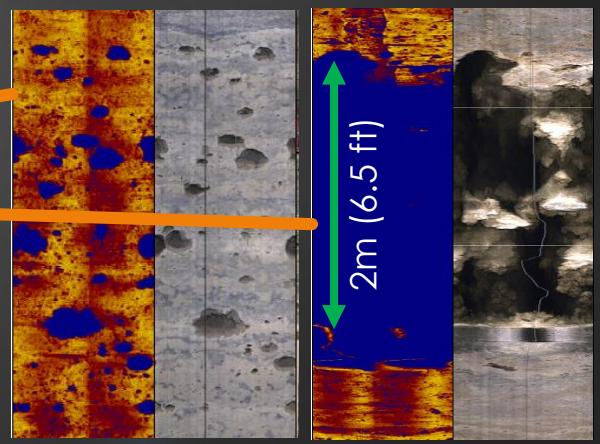








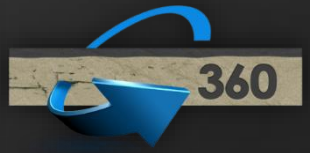




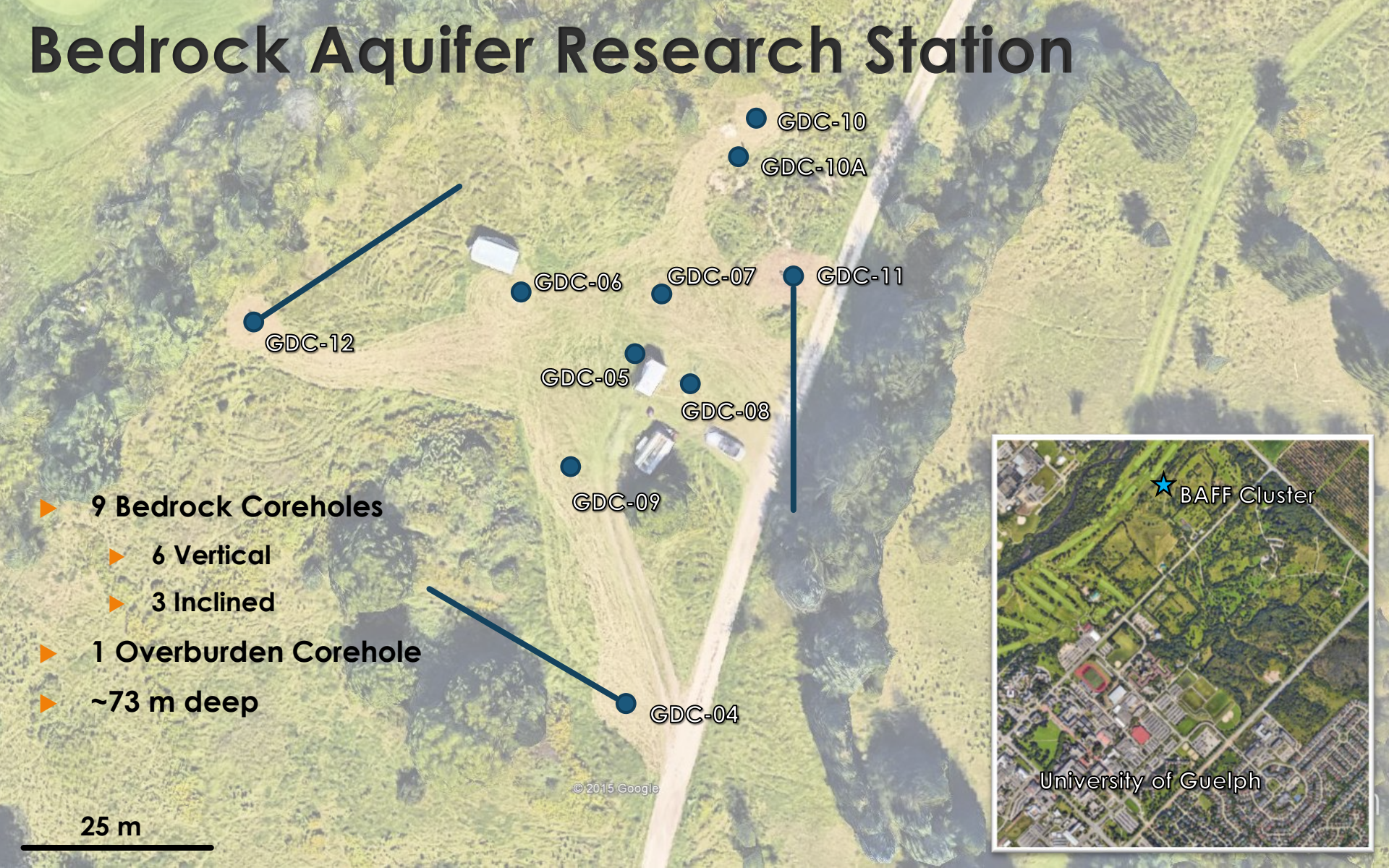
Porosity in carbonate rocks is complex and variable and determining what types are hydraulically important is challenging.

This talk will show:

How DTS and thermal tracer tests can provide insight as to what types of porosity are hydraulically active (using field data)



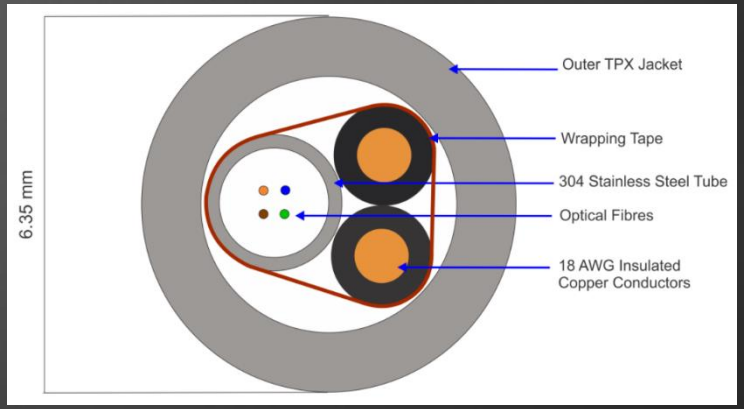
Bedrock Aquifer Research Station



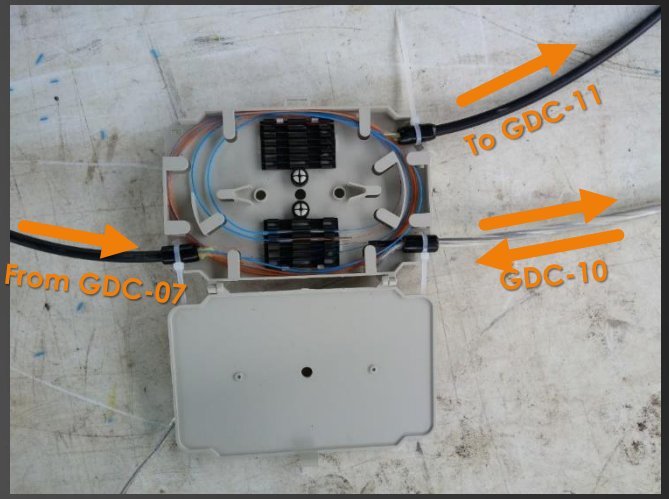
- 9 Bedrock Coreholes
  - 6 Vertical
  - 3 Inclined
- 1 Overburden Corehole
- ~73 m deep

Deployed FO throughout entire cluster

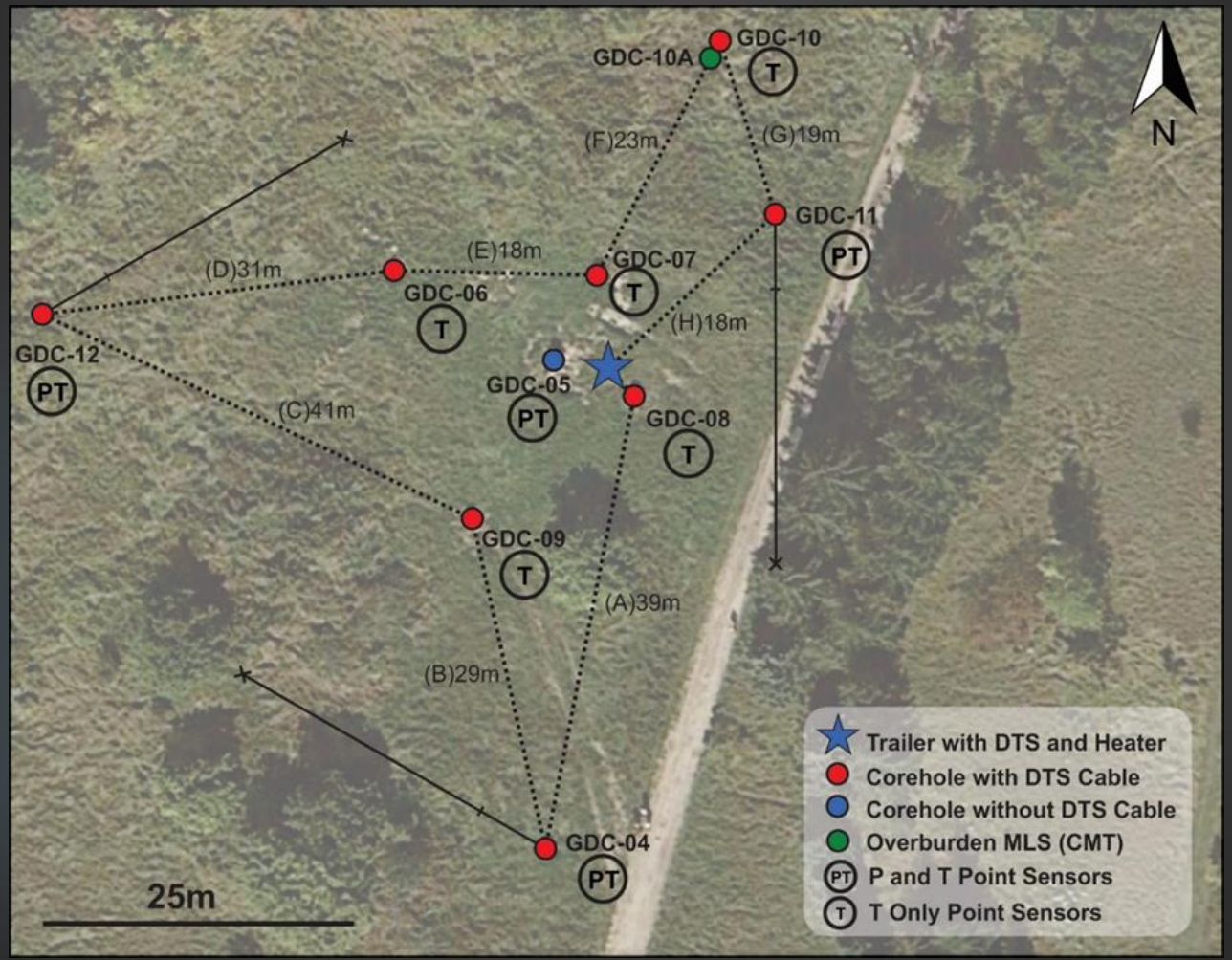
- Composite FO cable
  - Two 18 AWG copper conductors
  - Two singlemode fibres
  - Two multimode fibres



Surface cables spliced to borehole cables to form continuous loop



Large continuous FO network (1755 m)

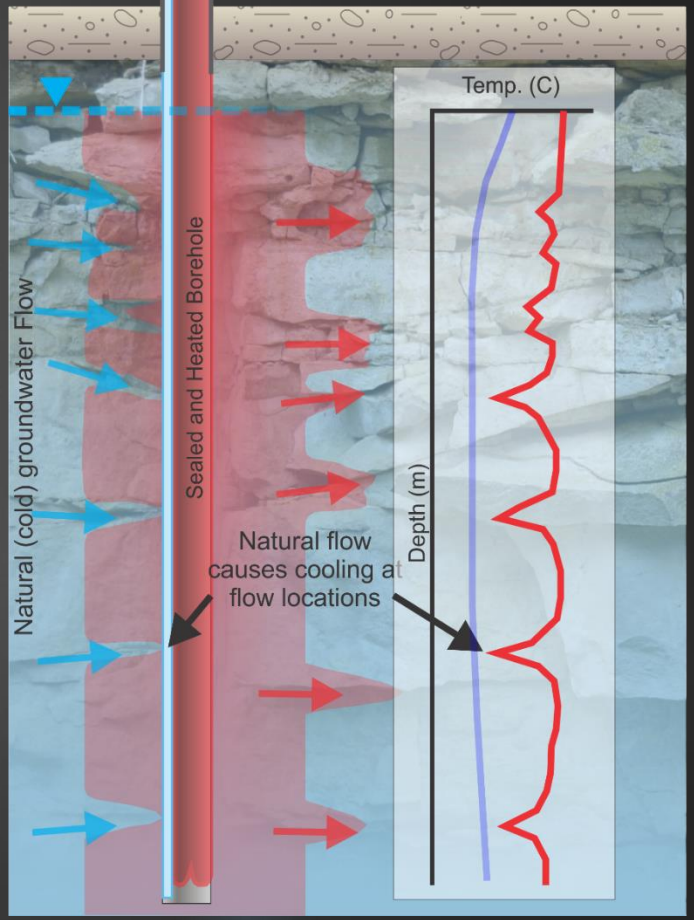


Active DTS Testing

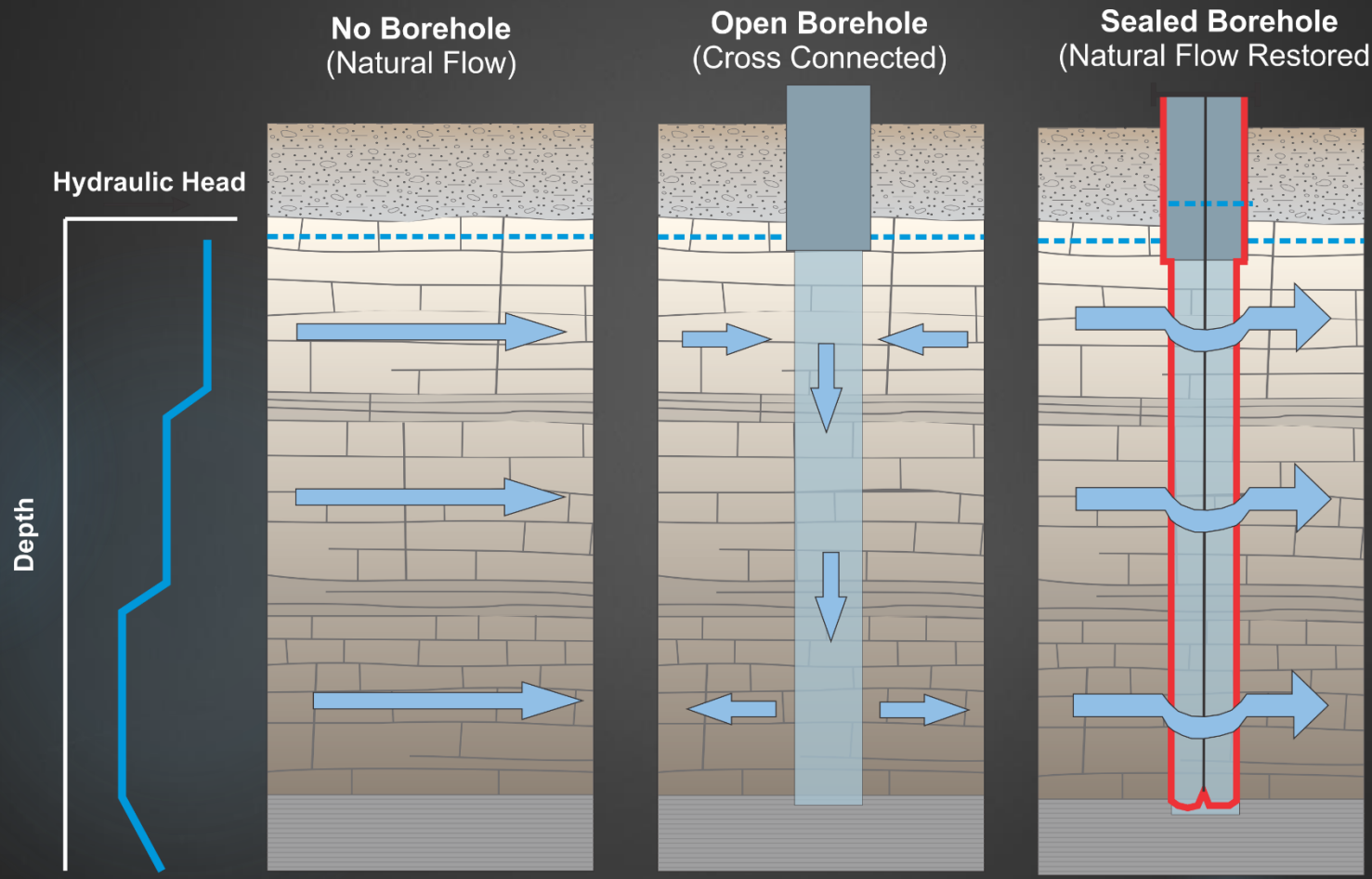
Natural Groundwater Flow

Active DTS Testing

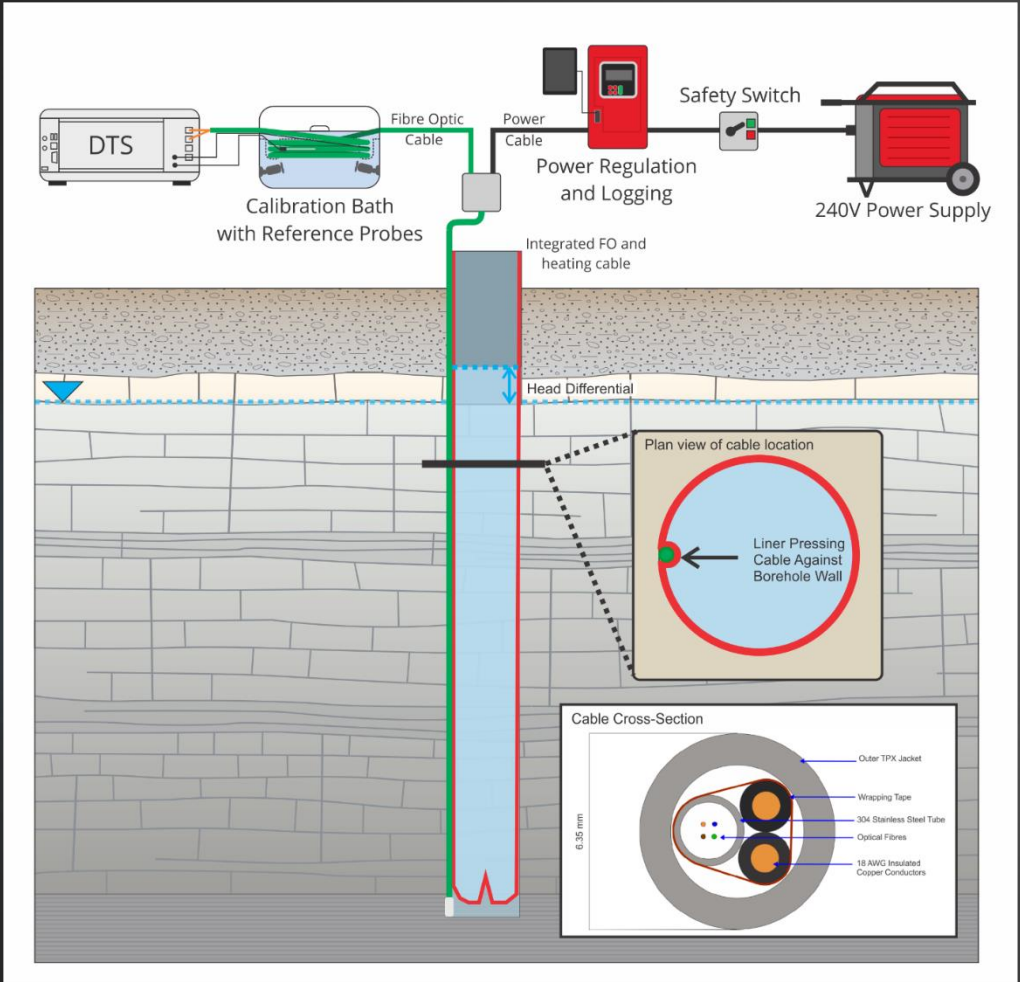
- Building on early work by Dr. Pete Pehme (wireline ALS Profiles)
- Heat the Fibre Optic Cable within sealed corehole
- Continuously record temperature during heating and thermal recovery (i.e. cooling)
- Look for zones of enhanced cooling resulting from ambient groundwater flow
- Expand upon previous studies to test multiple boreholes simultaneously



Borehole Liners Restore Natural Gradient Conditions



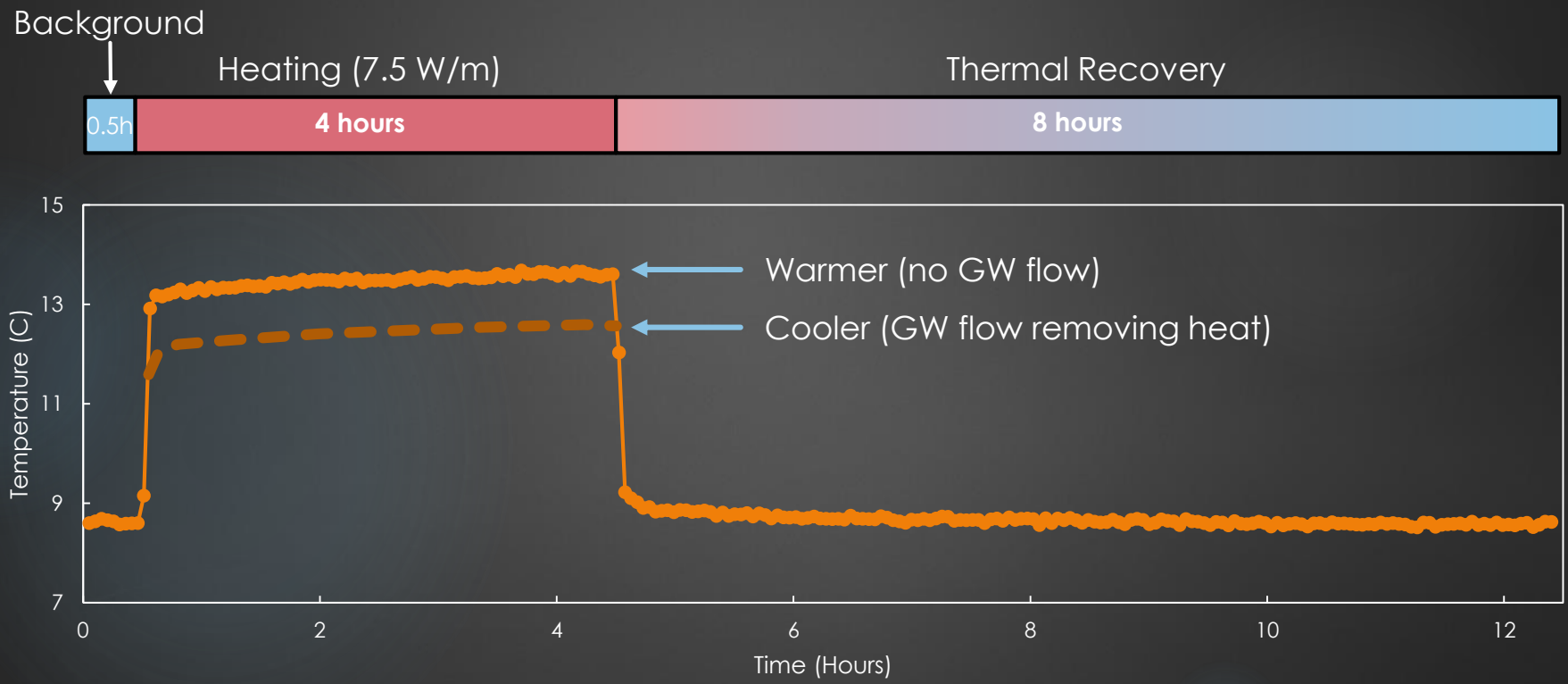
Active DTS Equipment Schematic



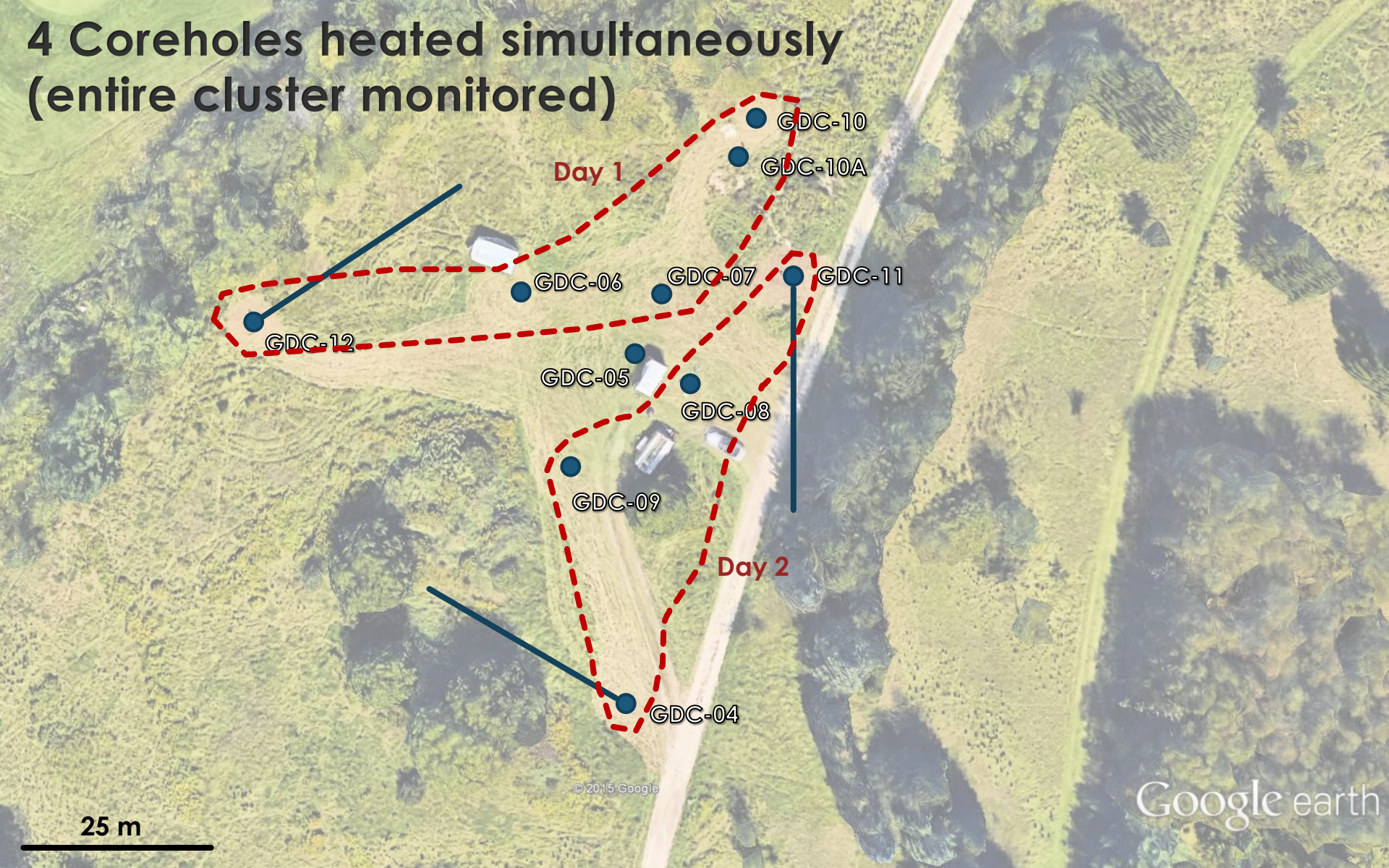
- DTS and calibration bath (cooler)
- Composite FO cable (w/copper conductors)
- FLUTe liners to seal coreholes
- Power source (Honda 7000 Generator)
- Power Controller (Control Concepts)
- Tablet to record power output

Deployment Photos

Temperature profile at single interval on FO cable



4 Coreholes heated simultaneously (entire cluster monitored)



Preliminary Results

Temperature with time for full network

Heat On

Heat Off

GDC-08

GDC-04

GDC-09

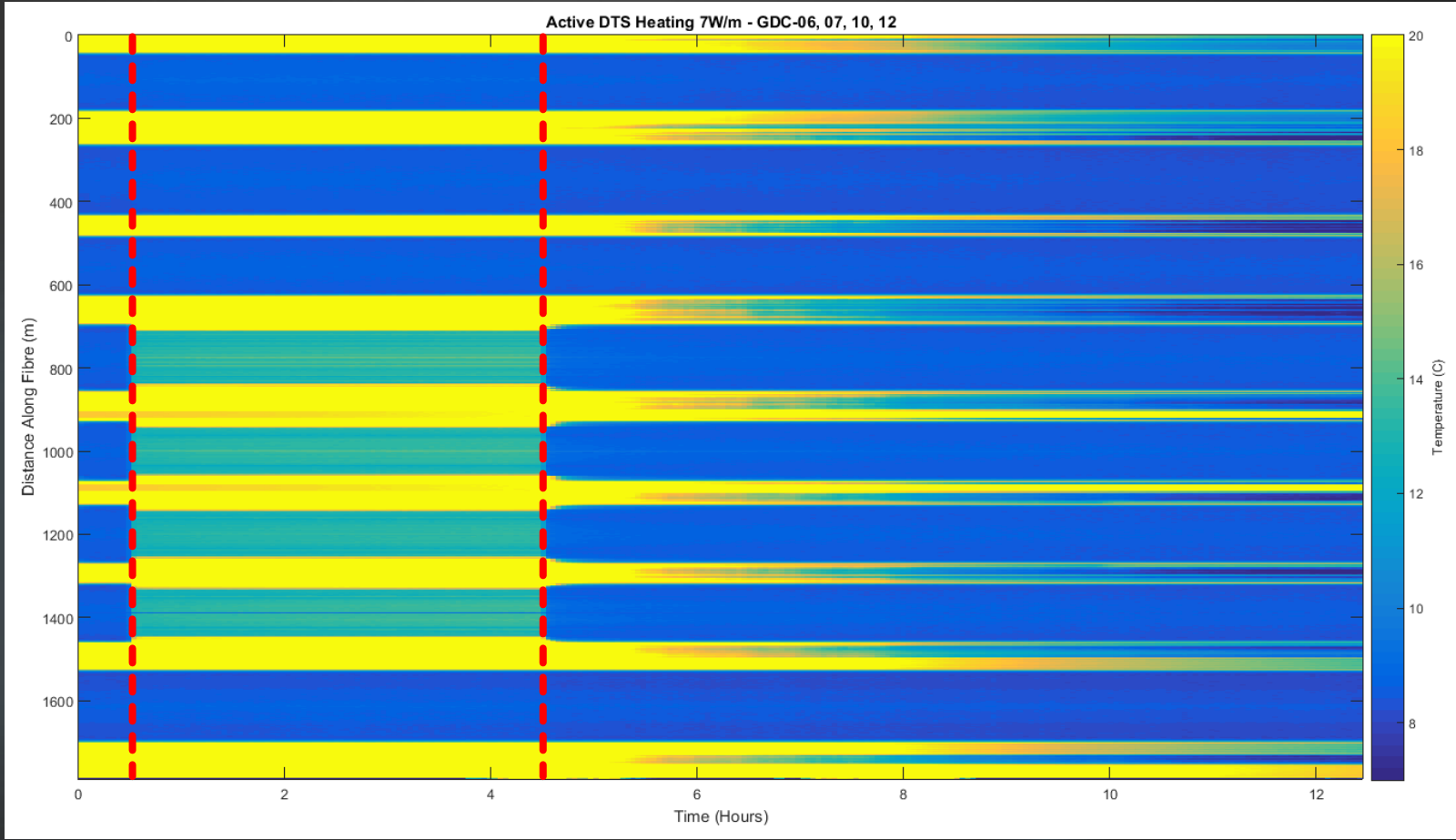
GDC-12

GDC-06

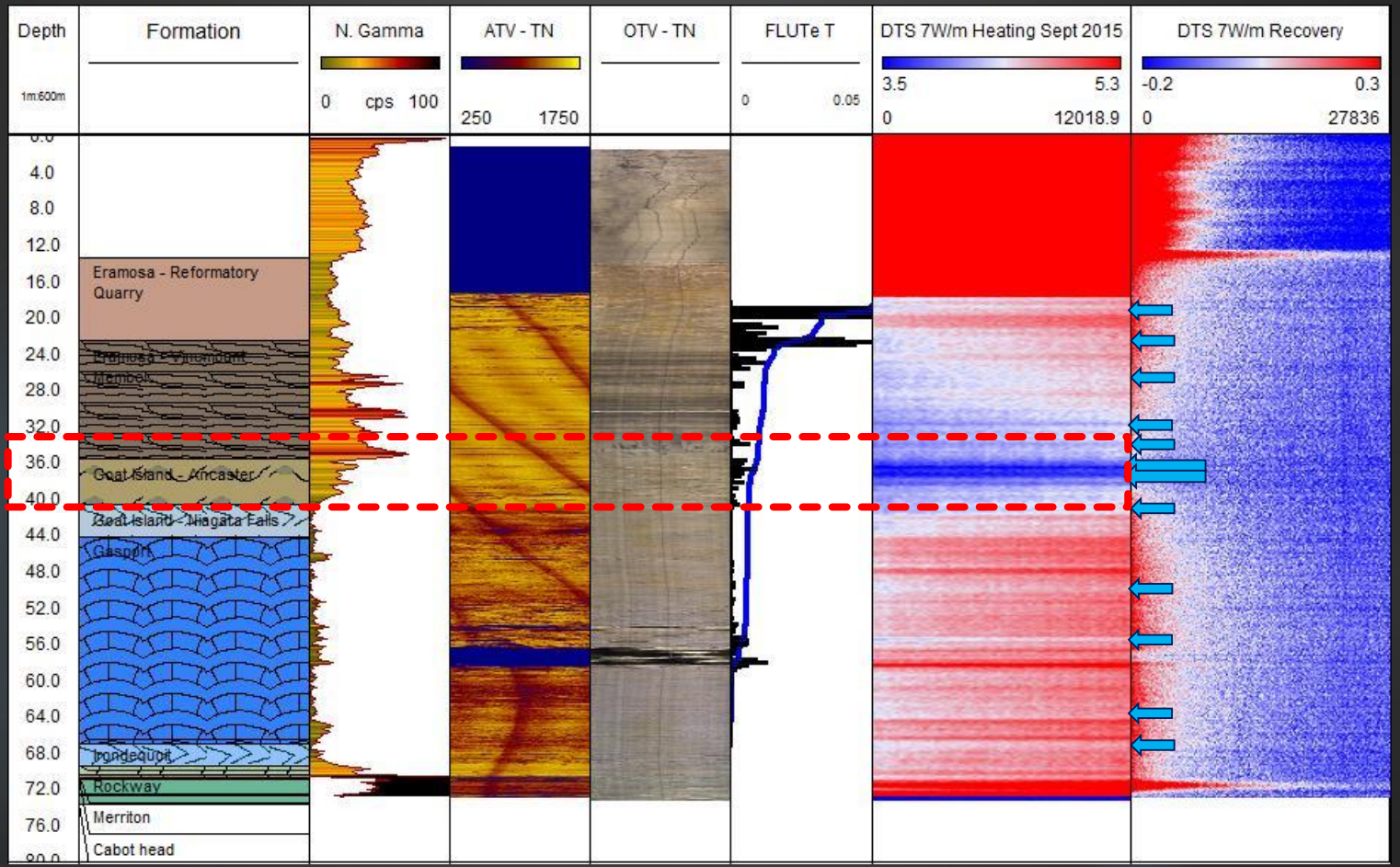
GDC-07

GDC-10

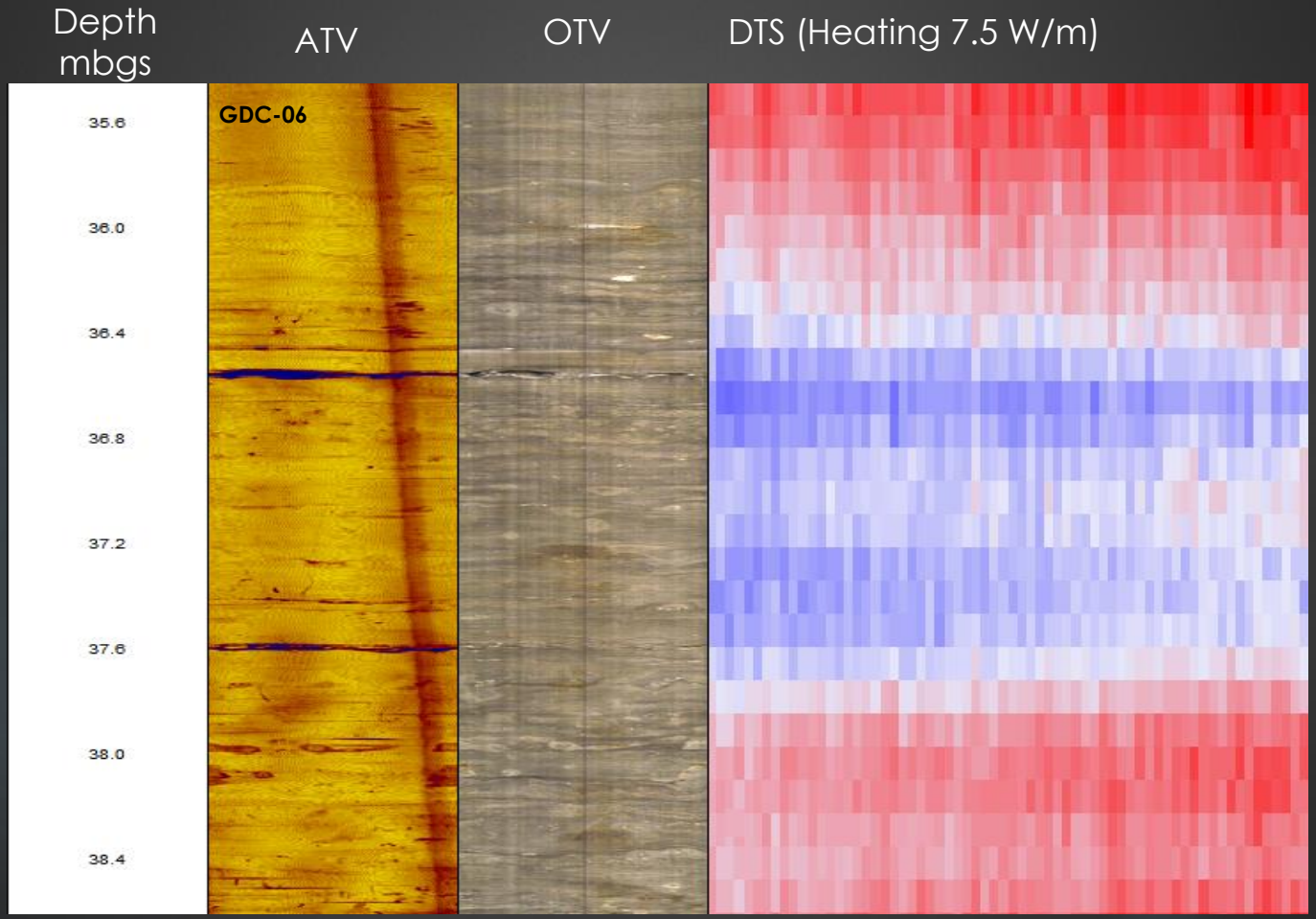
GDC-11



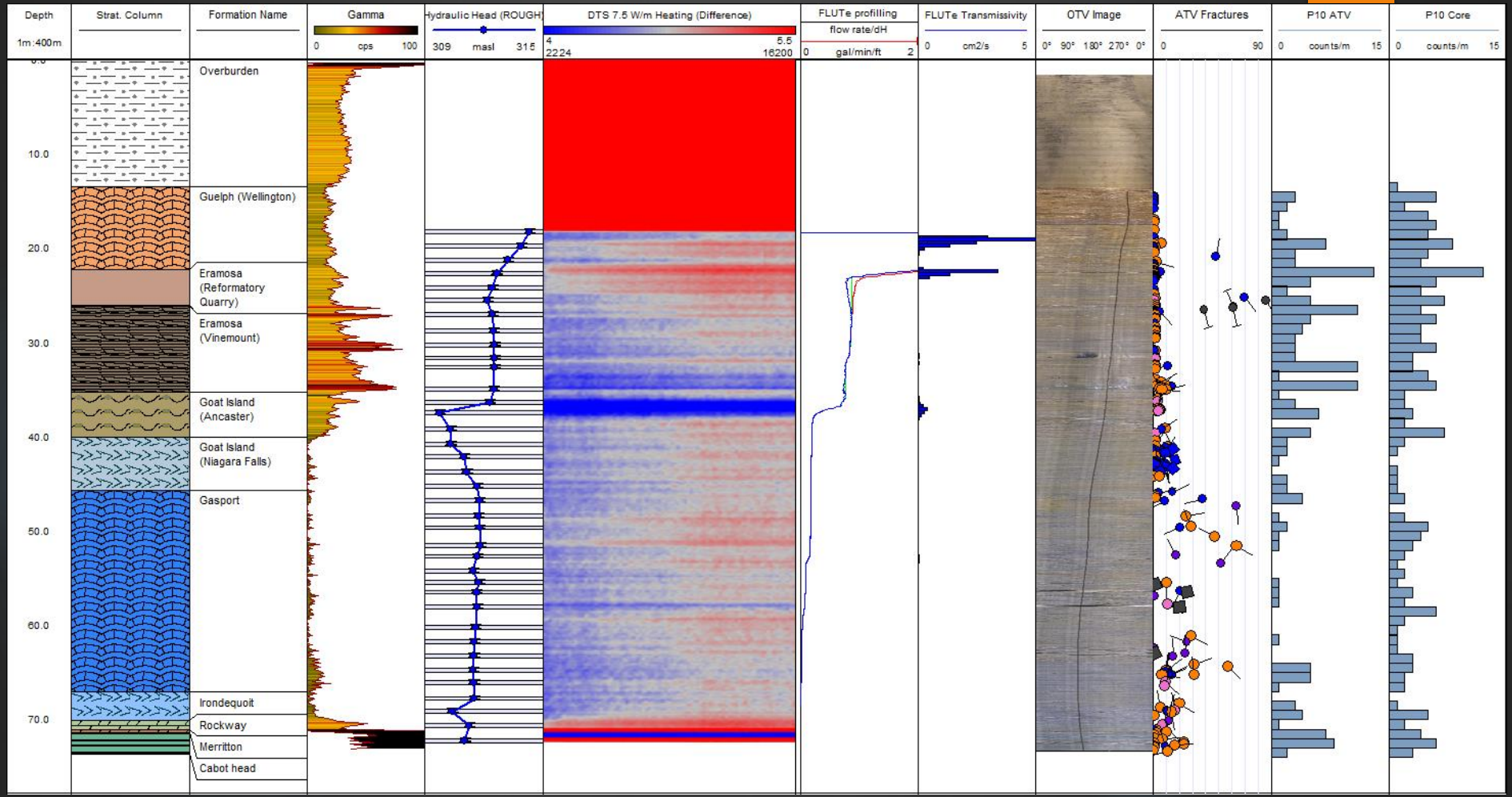
Major ambient flow at common features in nearly all coreholes:



Most dominant flow feature:
2 fractures in Goat Island Formation

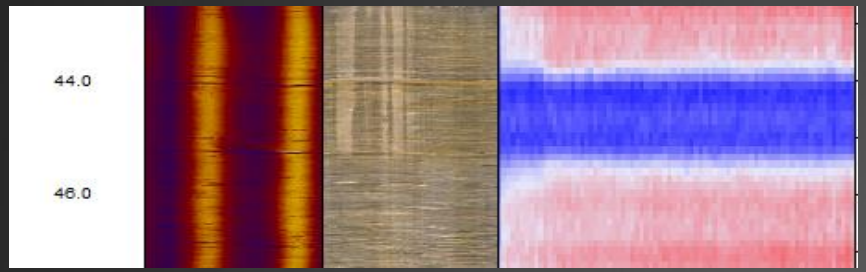


Flow zones corroborate well with other datasets

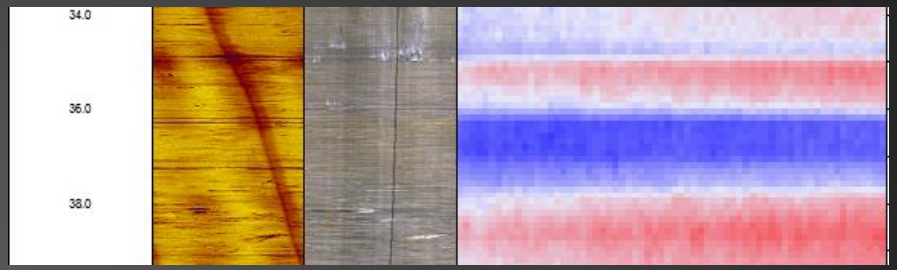


Same fractures and flow observed across entire site

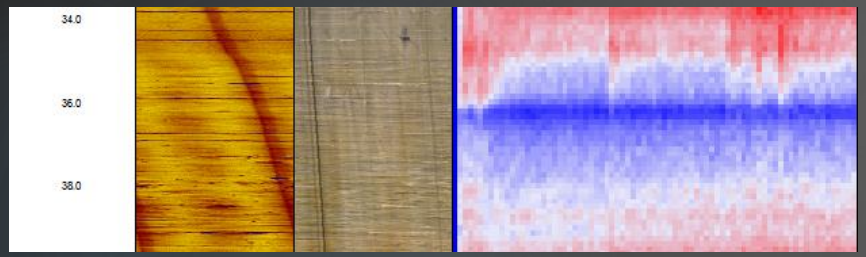
GDC-04



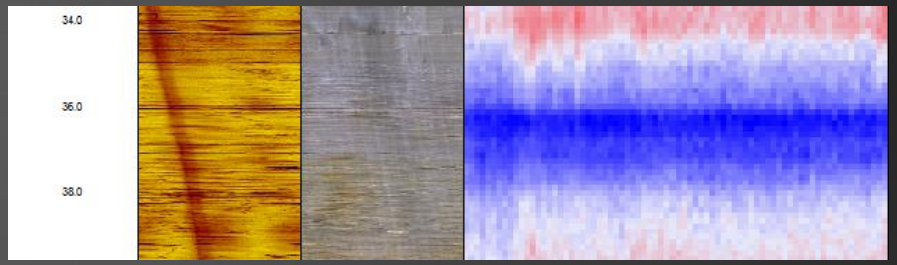
GDC-05



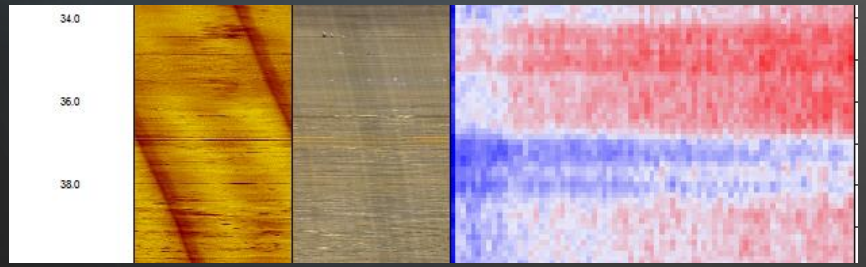
GDC-07



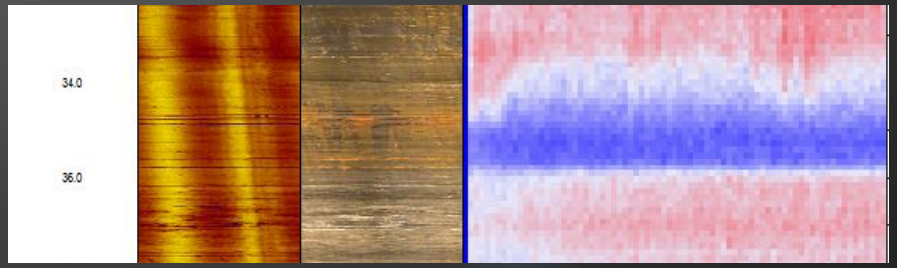
GDC-08



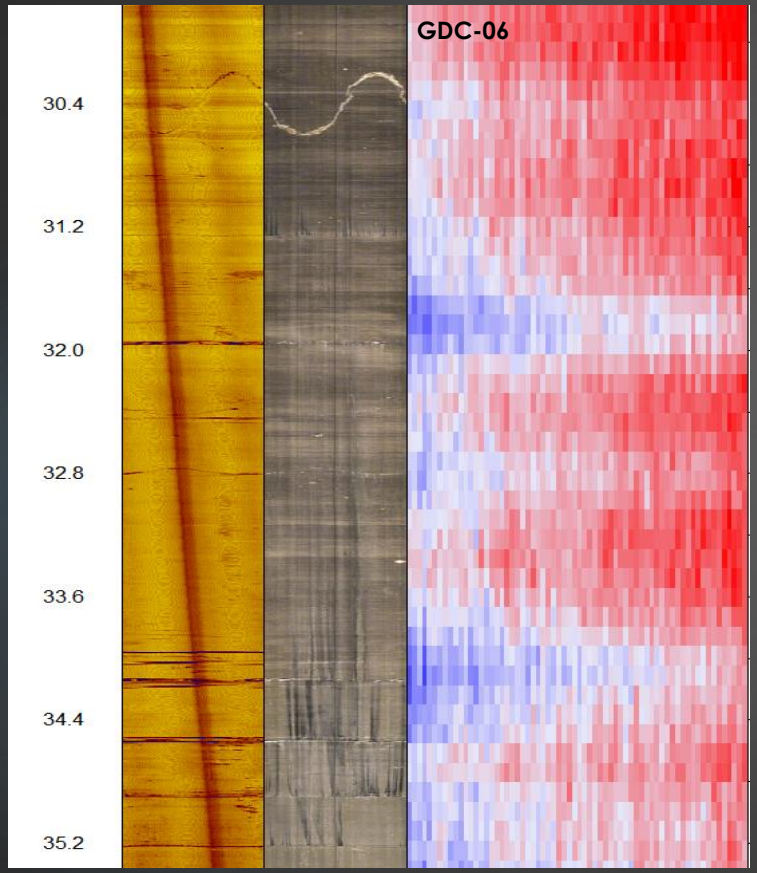
GDC-09

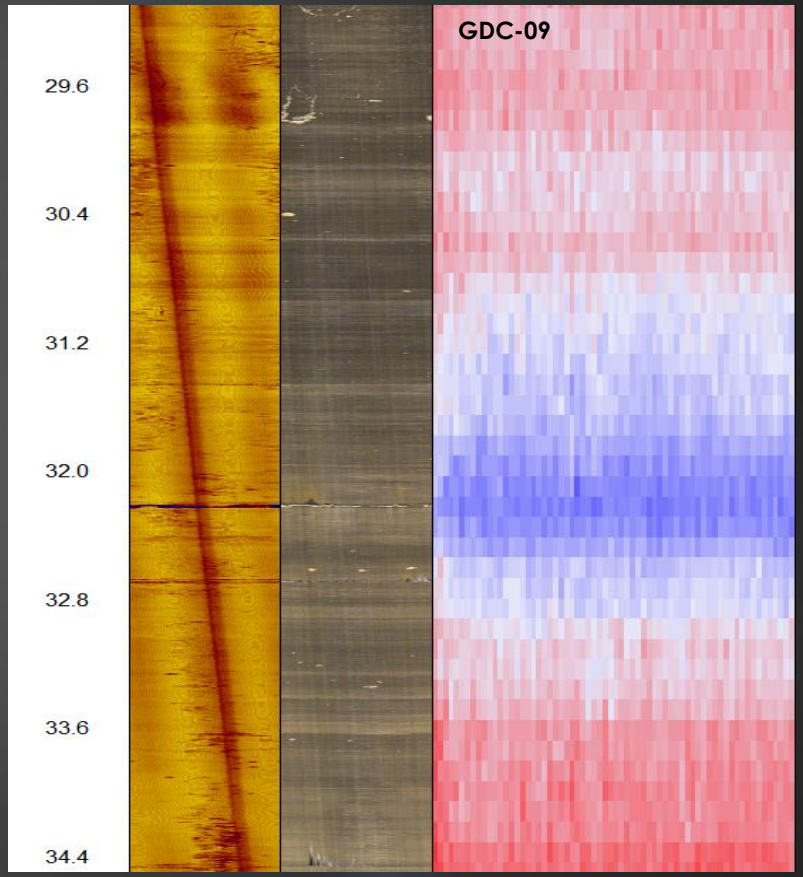


GDC-10

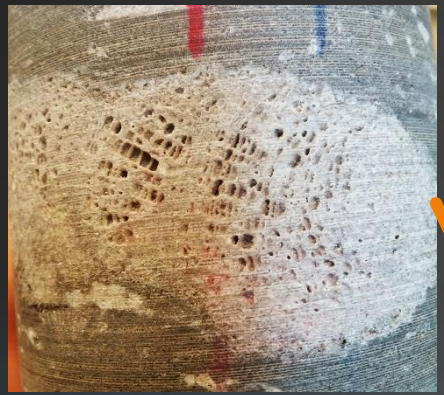


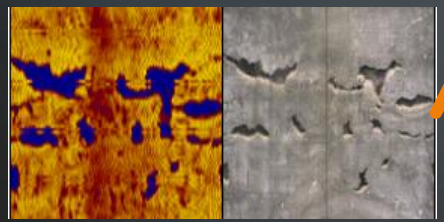
More examples of flow along fractures

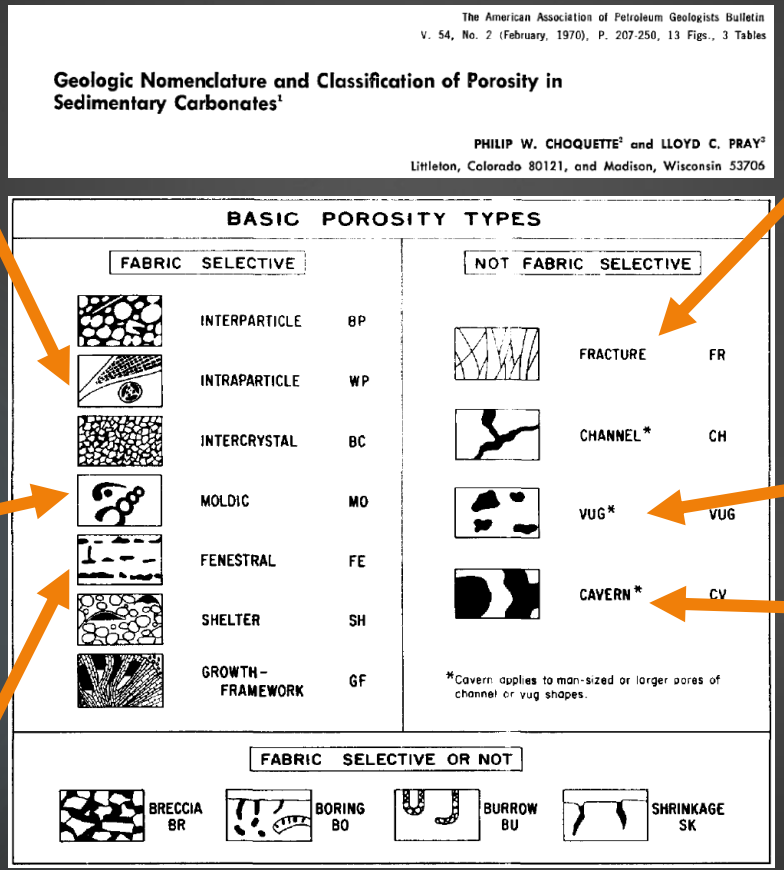


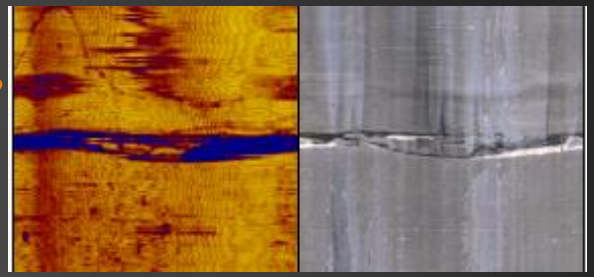


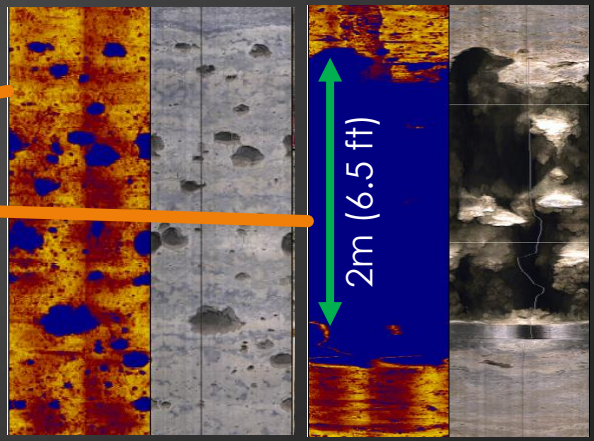
Porosity Types in Carbonate Rocks



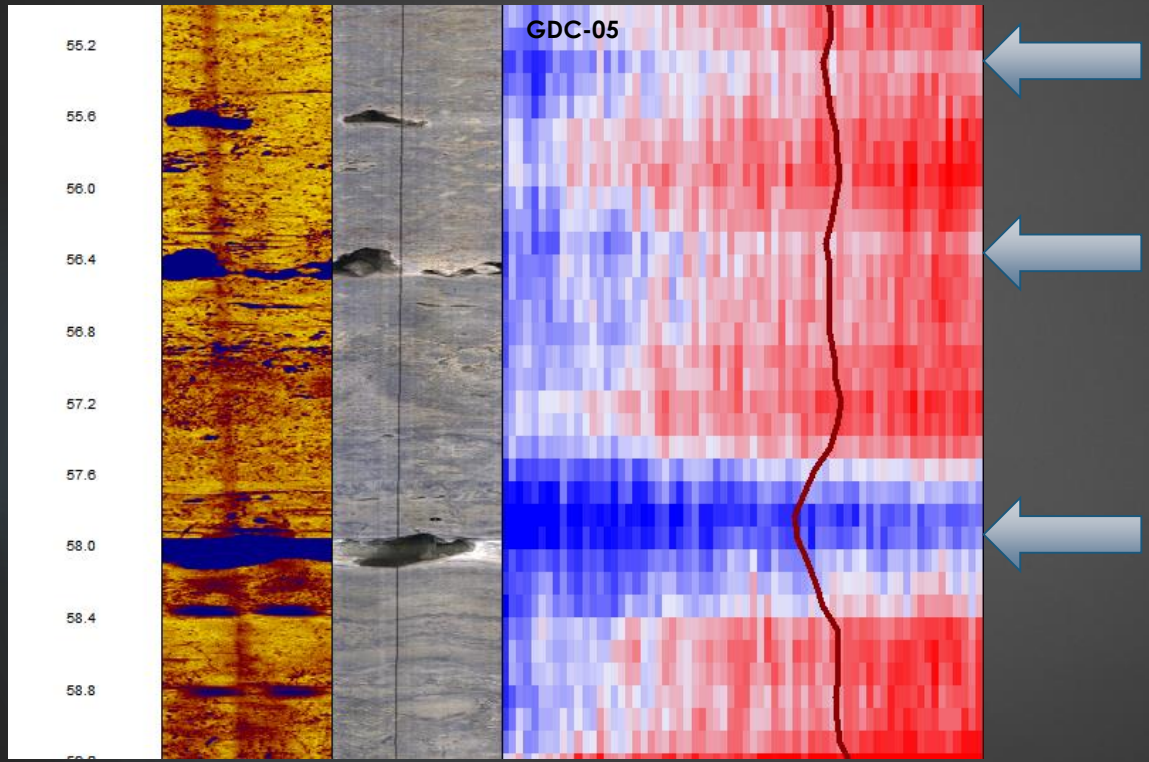






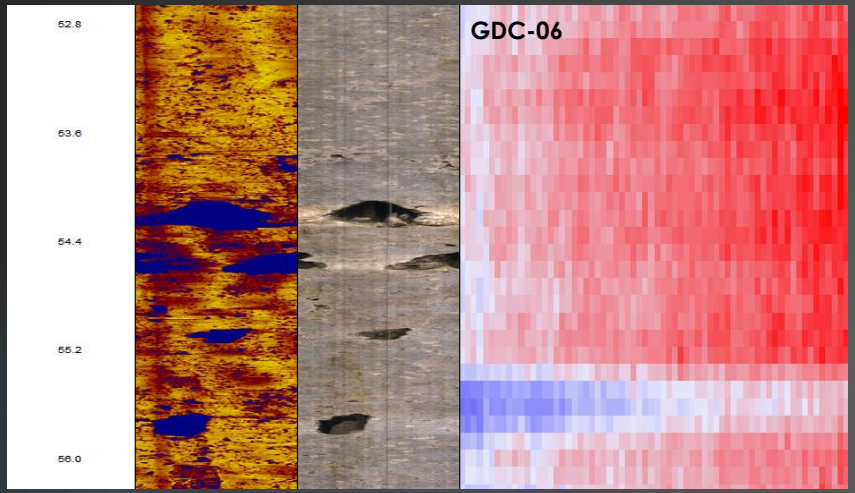


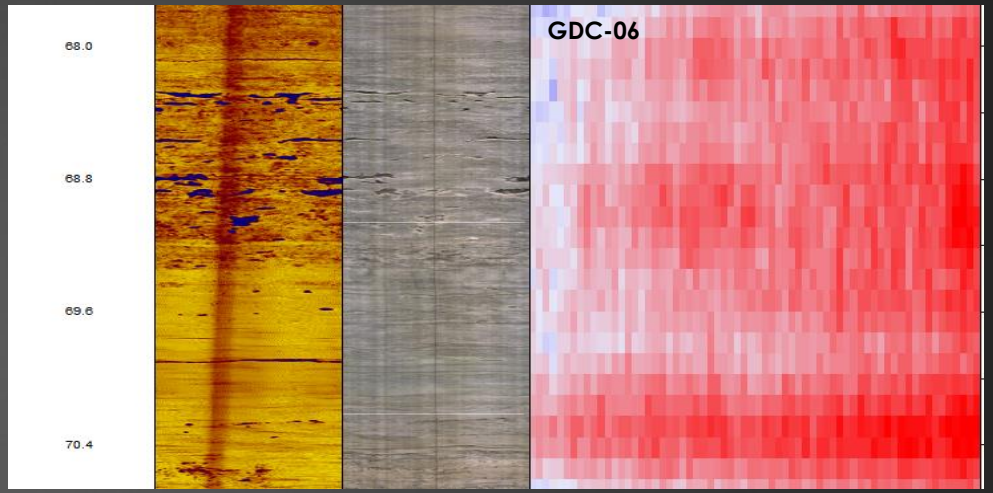
Evidence of flow through vugs/channels

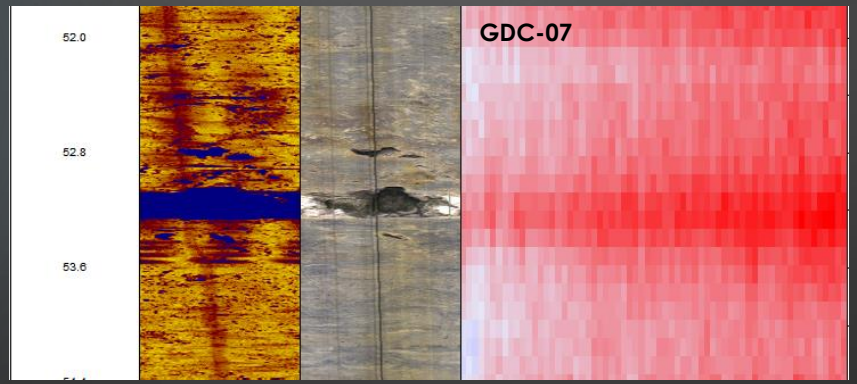


Distinct cooling at certain vugs/channels

Not all vugs/channels show active flow







Key Points

- Active DTS in sealed coreholes provides an efficient and effective way to identify hydraulically active flow in multiple coreholes (simultaneously)
- Observed active groundwater flow along major fractures that extend across the entire site
- Active flow observed in solution features (vugs/channels)
- Results are repeatable and consistent across site

Future/Ongoing Work

- Quantification of observations (flux)
  - Account for rock thermal conductivity contrasts
- Optimize field techniques
  - Head in FLUTe liner
  - Cable Designs
  - Heat output
- Cross hole testing

Thank you – Questions?