Thermal Energy Extraction from a Geothermal Reservoir: Numerical and Analytical Modeling Analysis

Jeremy Patterson, Michael Cardiff, Herb Wang, Kurt Feigl, and PoroTomo Team

Acknowledgements

Collaborators (PoroTomo Team):

ORMAT

SILIXA

WISCONSIN UNIVERSITY OF WISCONSIN–MADISON

Lawrence Berkeley National Laboratory

Lawrence Livermore National Laboratory

University of Nevada, Reno

COLORADO SCHOOL OF MINES EARTH • ENERGY • ENVIRONMENT

TEMPLE UNIVERSITY

Support:

The work presented herein was funded in part by the Office of Energy Efficiency and Renewable Energy (EERE), U.S. Department of Energy, under Award Numbers DE-EE0006760 and DE-EE0005510.

ORMAT Technologies, Inc. generously provided field site access, safety training, and data sharing to support this work.

Additional Support:

NSF

Cardiff: EAR-1654649 “CAREER: Understanding transport processes in fractured sedimentary rock through multi-frequency and multi-method investigations”

CENTER FOR HIGH THROUGHPUT COMPUTING

Outline

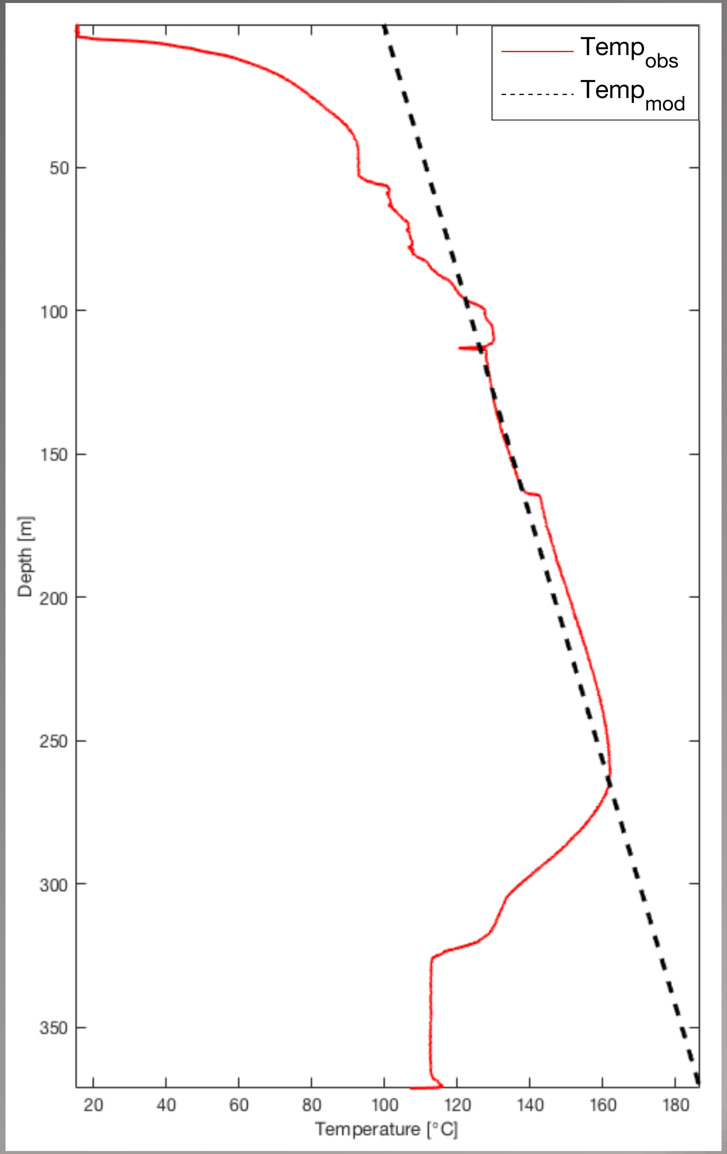
- PoroTomo Overview
- Study Area
- Thermal Characterization
- Hydraulic Characterization
- Conclusions
- Future Work

Big Picture Question:

- Can we constrain the thermal sustainability of a geothermal reservoir?

First Order Questions:

- Can we estimate the relevant thermal and hydraulic reservoir properties?
- How does fluid move through the reservoir?



Poroelastic Tomography by Adjoint Inverse Modeling of Data from Seismology, Geodesy, and Hydrology

- Project Objective
  - "…assess an integrated technology for characterizing and monitoring changes in the rock mechanical properties of an EGS reservoir in three dimensions with a spatial resolution better than 50 meters." (http://geoscience.wisc.edu/feigl/porotomo/)

Study Area

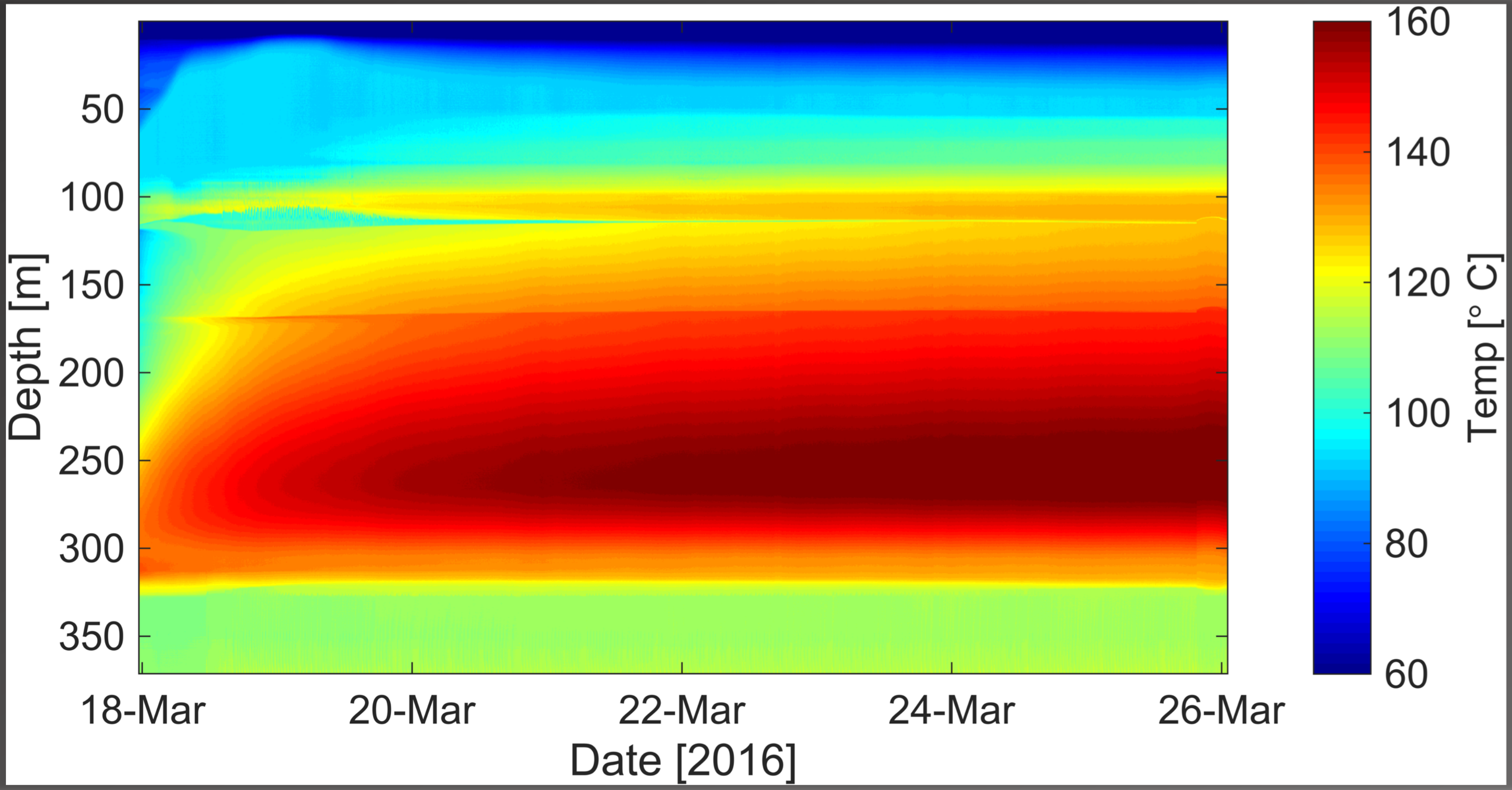
Brady Geothermal Field

- 75 km NE of Reno
- NE-SW trending high angle normal faults
- Shallow sedimentary units
- Deeper volcanic units

Thermal Characterization

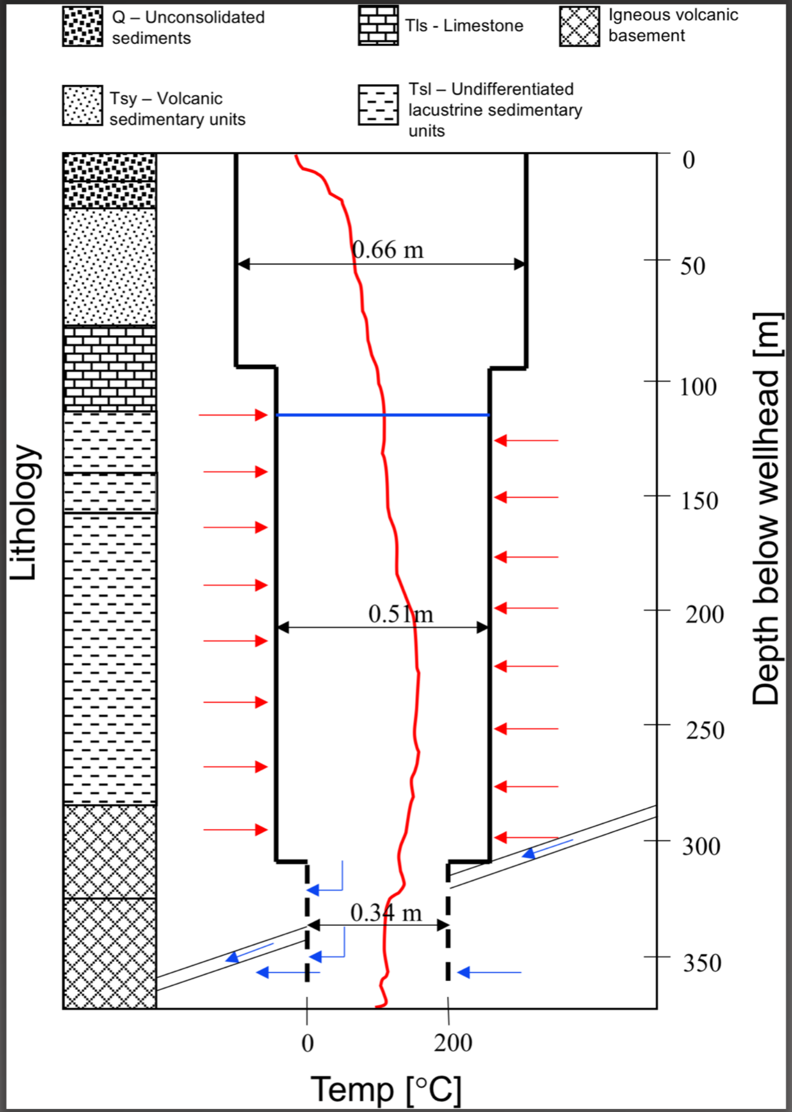
Borehole DTS

- Sampling interval
  - Spatial – 0.12 [m]
  - Temporal – 60 [s]
- Borehole temperature recovery
- Inverted geotherm below 260 m



Adapted from *Patterson et al., [2017]*

Thermal Characterization



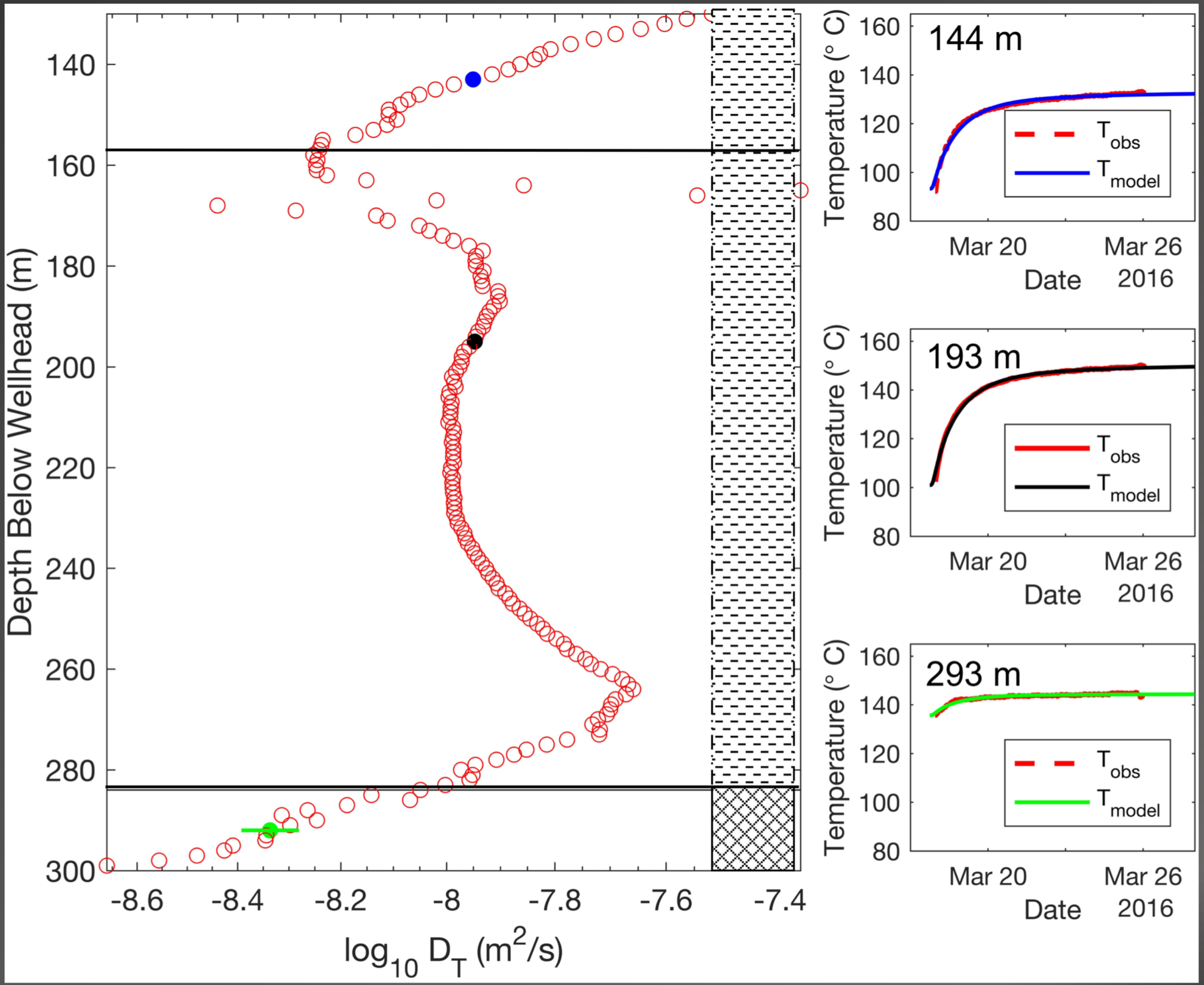
Patterson et al., [2017]

Borehole schematic

- Vertical temperature profile along borehole
- Radial heat diffusion into borehole
- Fluid filled and cased portion of borehole (~125 – 300 m depth)
- Conceptual model for numerical heat transfer model

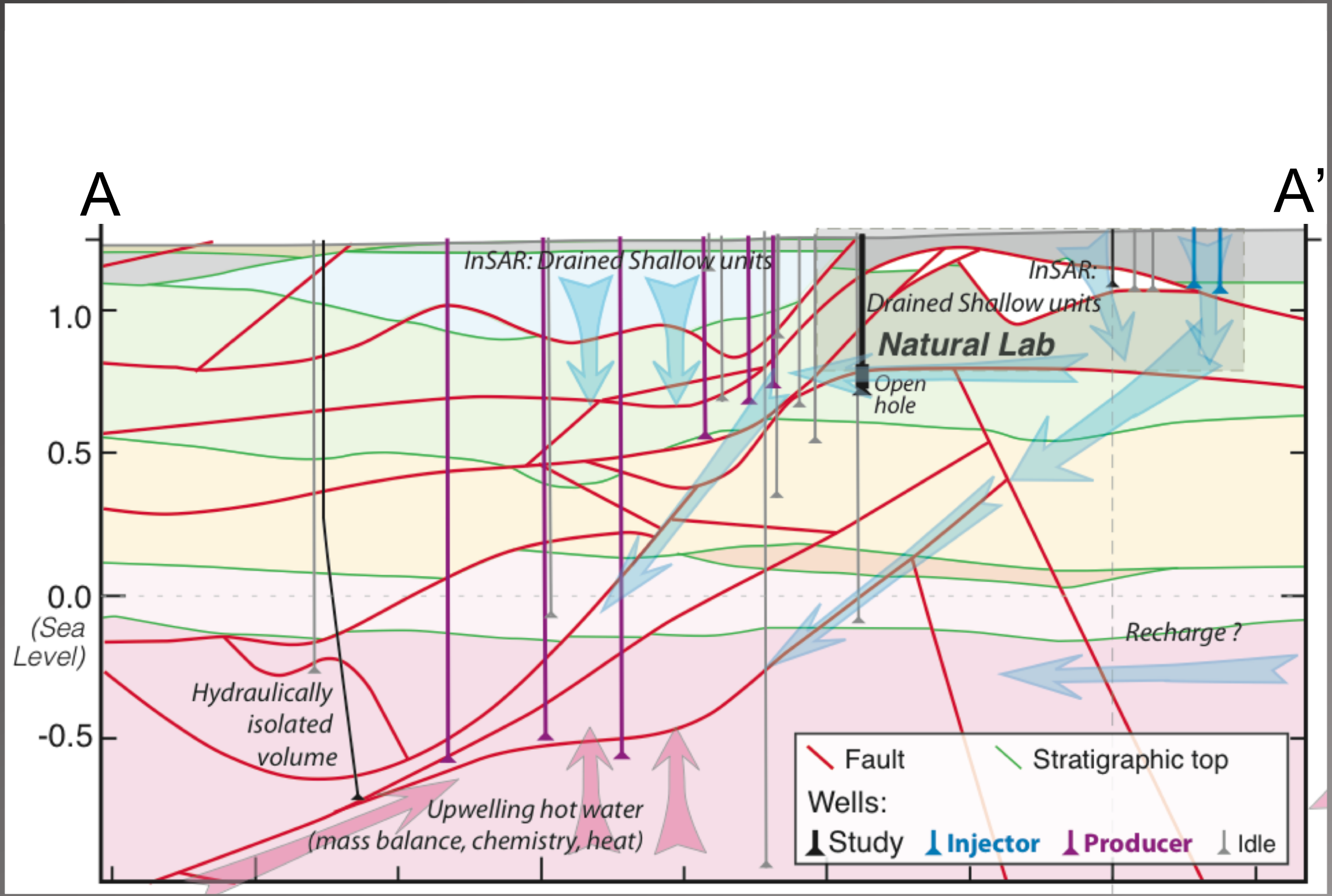
Parameter estimation results:

- Thermal diffusivity depth profile
- Major changes correlated with lithologic changes
- Estimated diffusivity lower than lab reported values



Patterson et al., [2017]

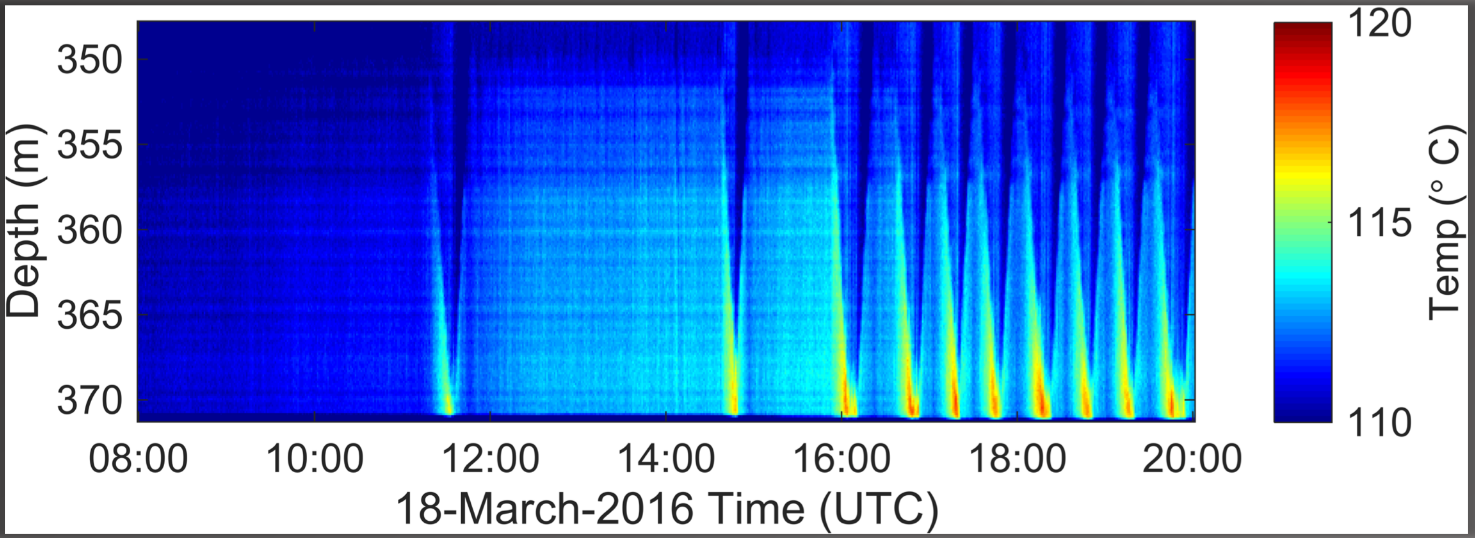
Subsurface Fluid Flow

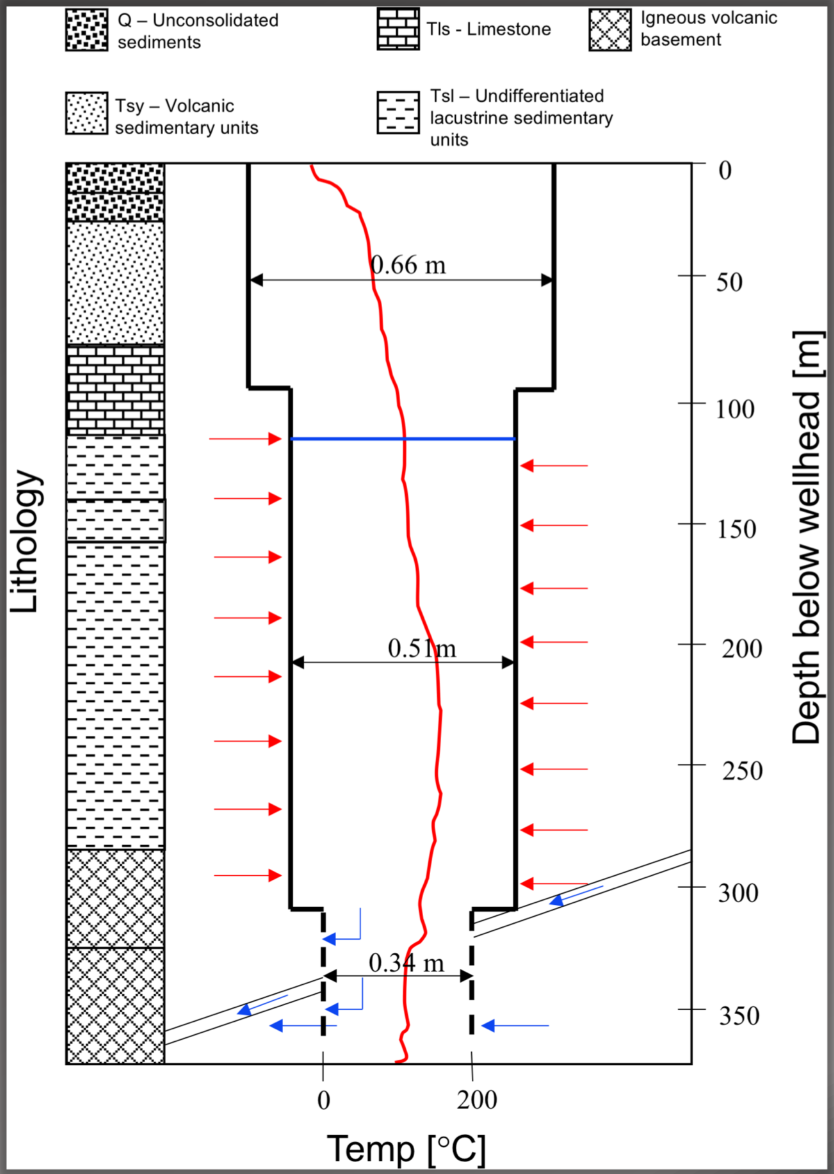


Adapted from *Feigl and Team*, [2018]

Evidence for fault-driven groundwater flow:

- **Borehole advection**

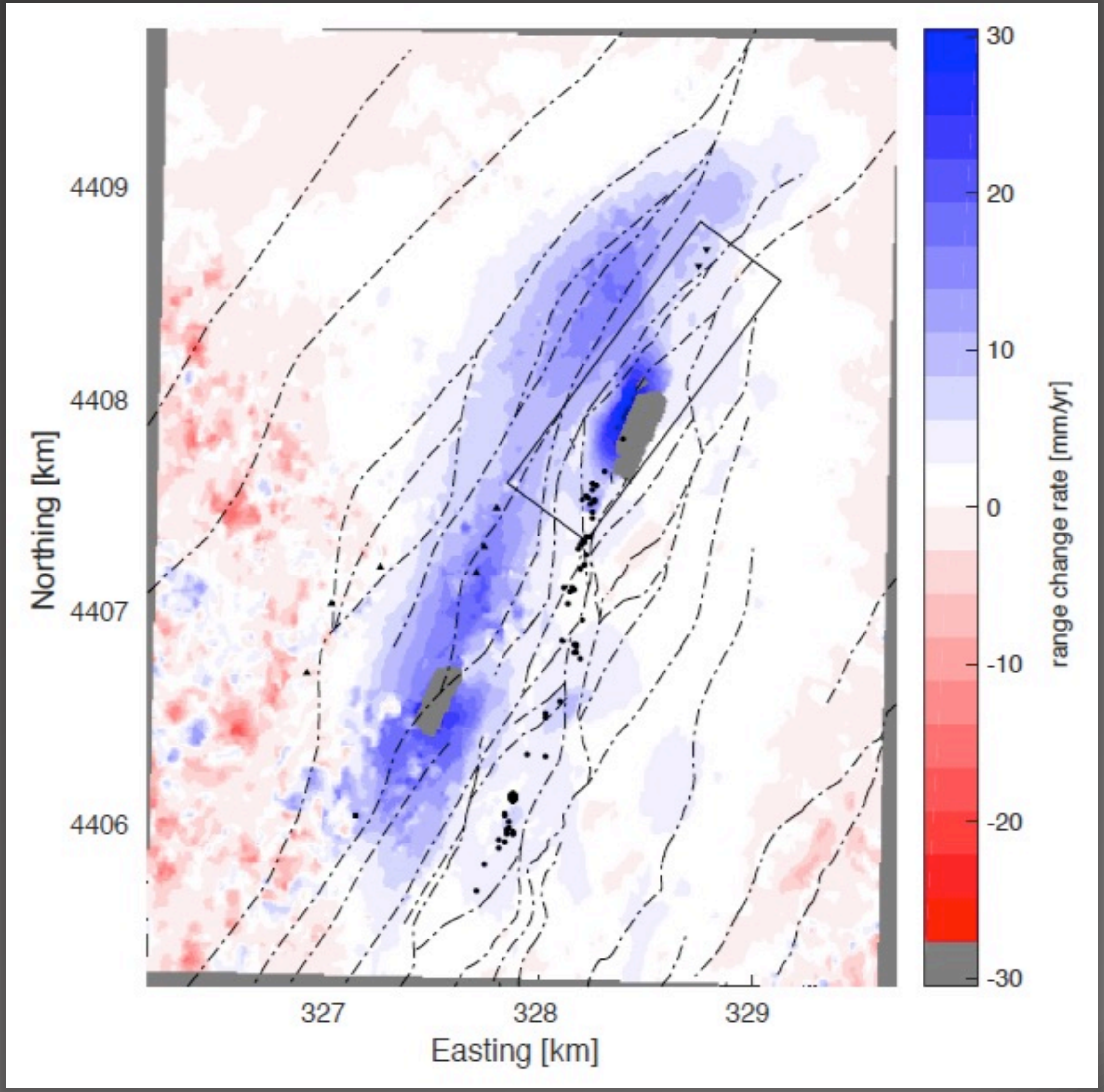




Adapted from *Patterson et al.*, [2017]

Evidence for fault-driven groundwater flow:

- Borehole advection
- **Ground subsidence**

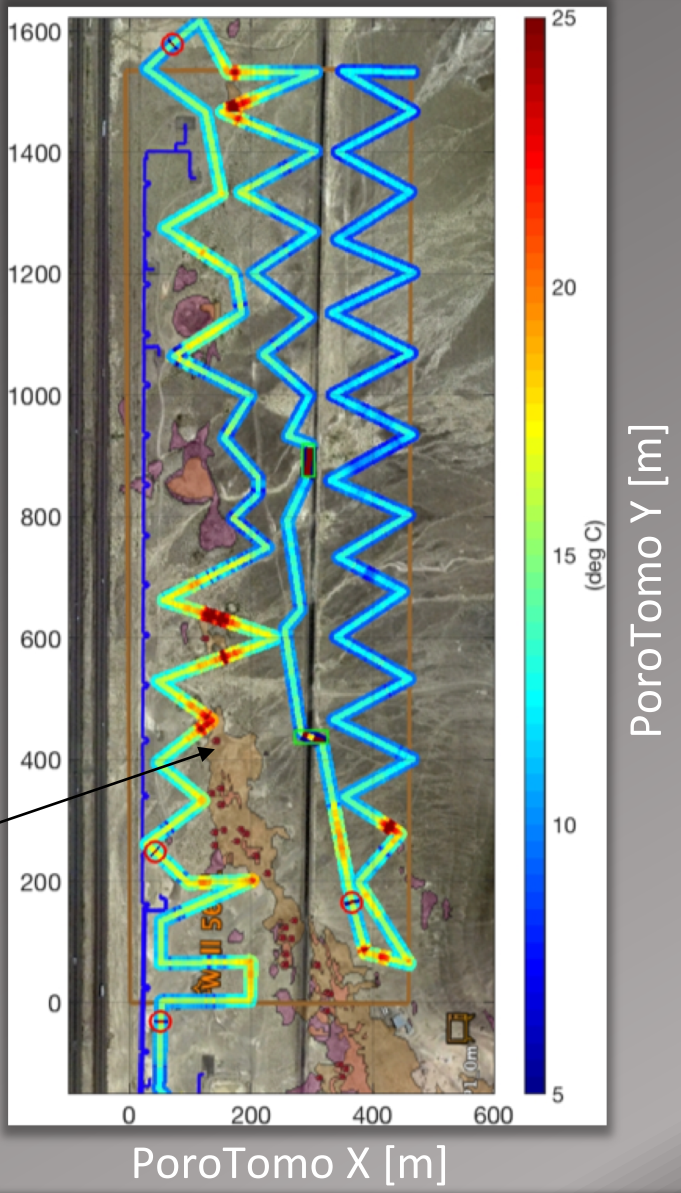


Adapted from *Reinisch et al.*, [In Review]

Evidence for fault-driven groundwater flow:

- Borehole advection
- Ground subsidence
- **Hydrothermal Deposits**

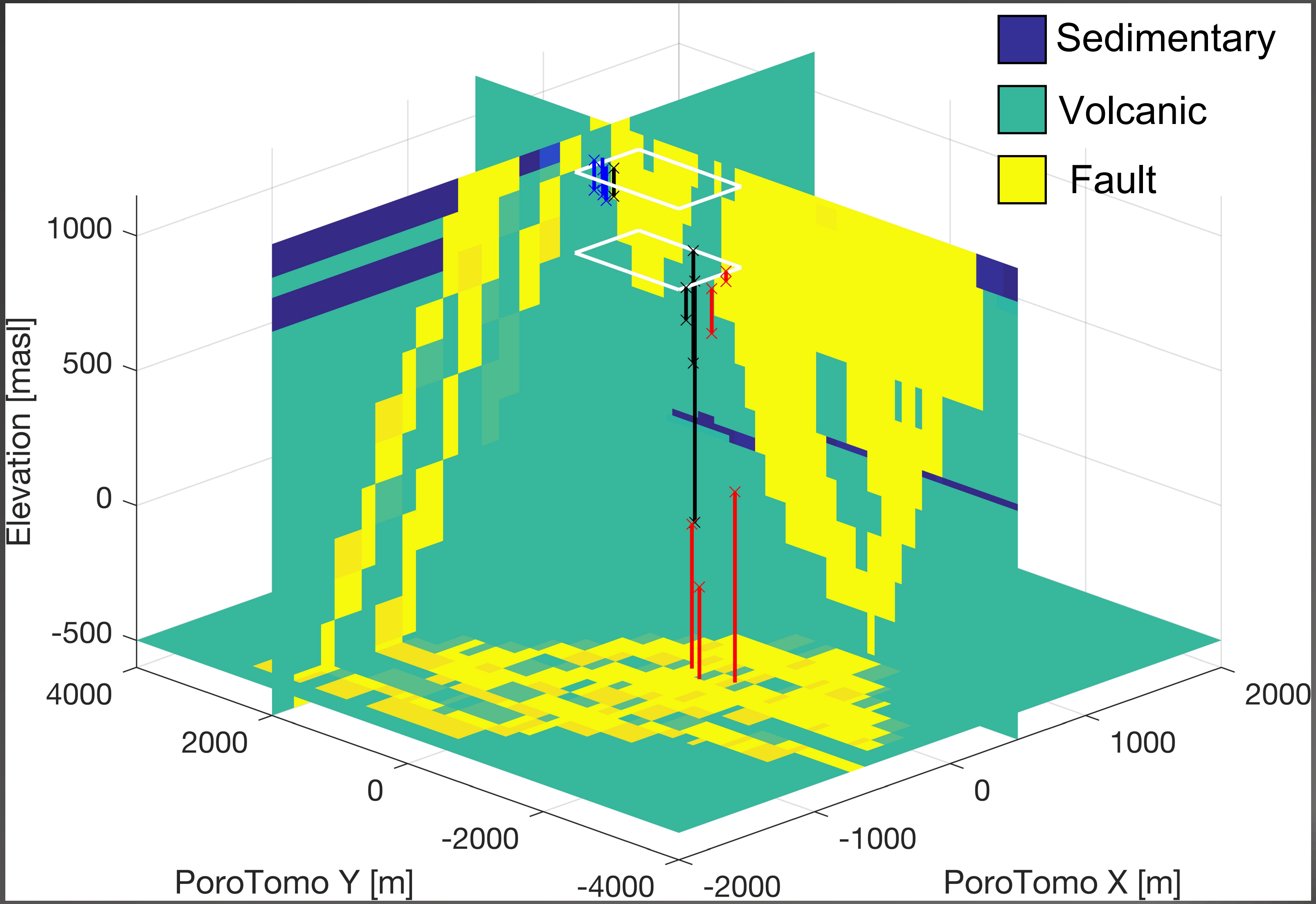
Hydrothermal Deposits



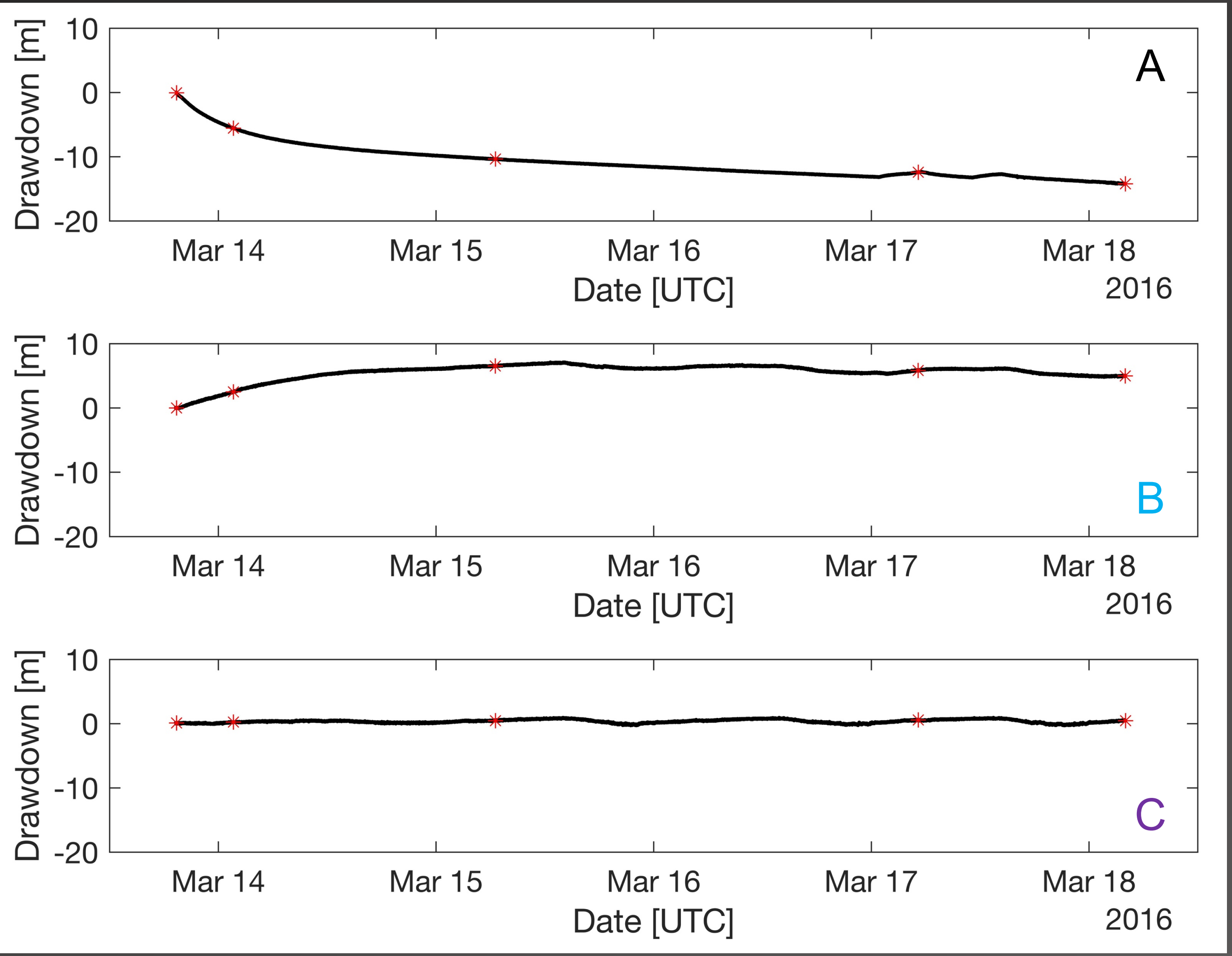
Adapted from *Miller et al.*, [2018]

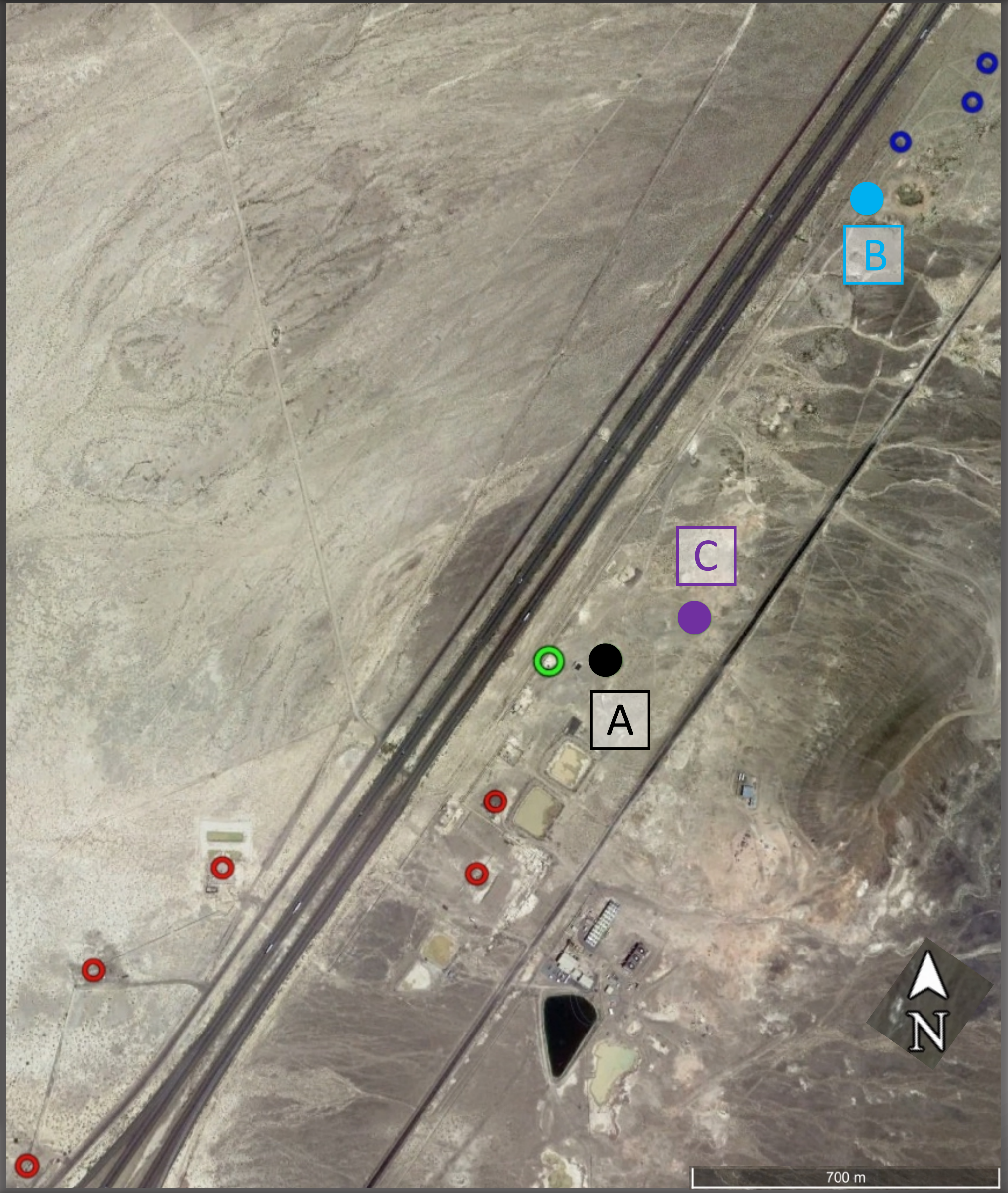
Groundwater Flow Model

- 7 km x 13 km x 6 km
- Discretization
- 3 Hydraulic Property Zones
- Zoned Parameter Estimation



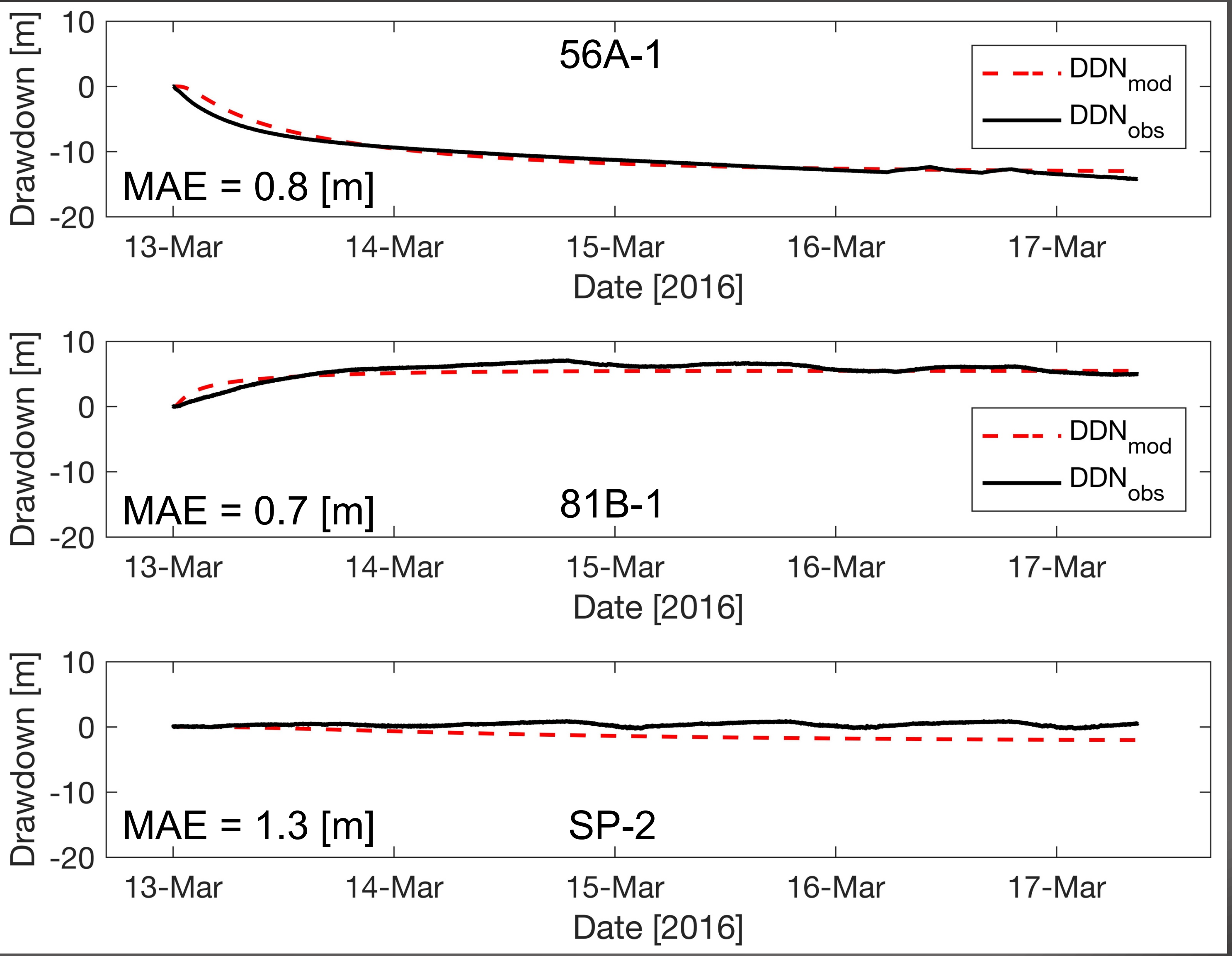
Hydraulic Characterization





Hydraulic Characterization

Lithology	K [m/s]	S_s [m^{-1}]
Sedimentary	4.1×10^{-2}	7.0×10^{-8}
Volcanic	2.7×10^{-4}	3.5×10^{-8}
Fault	1.7×10^{-8}	1.8×10^{-6}



Parameter estimates indicate:

- Specific storage estimates indicate confined behavior
- Faults may act as barrier to flow

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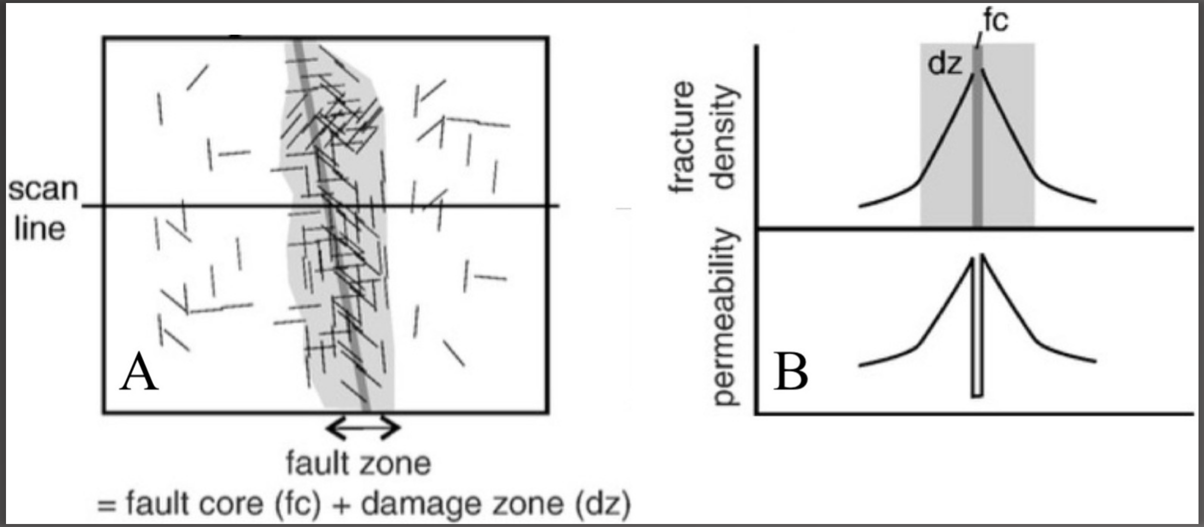


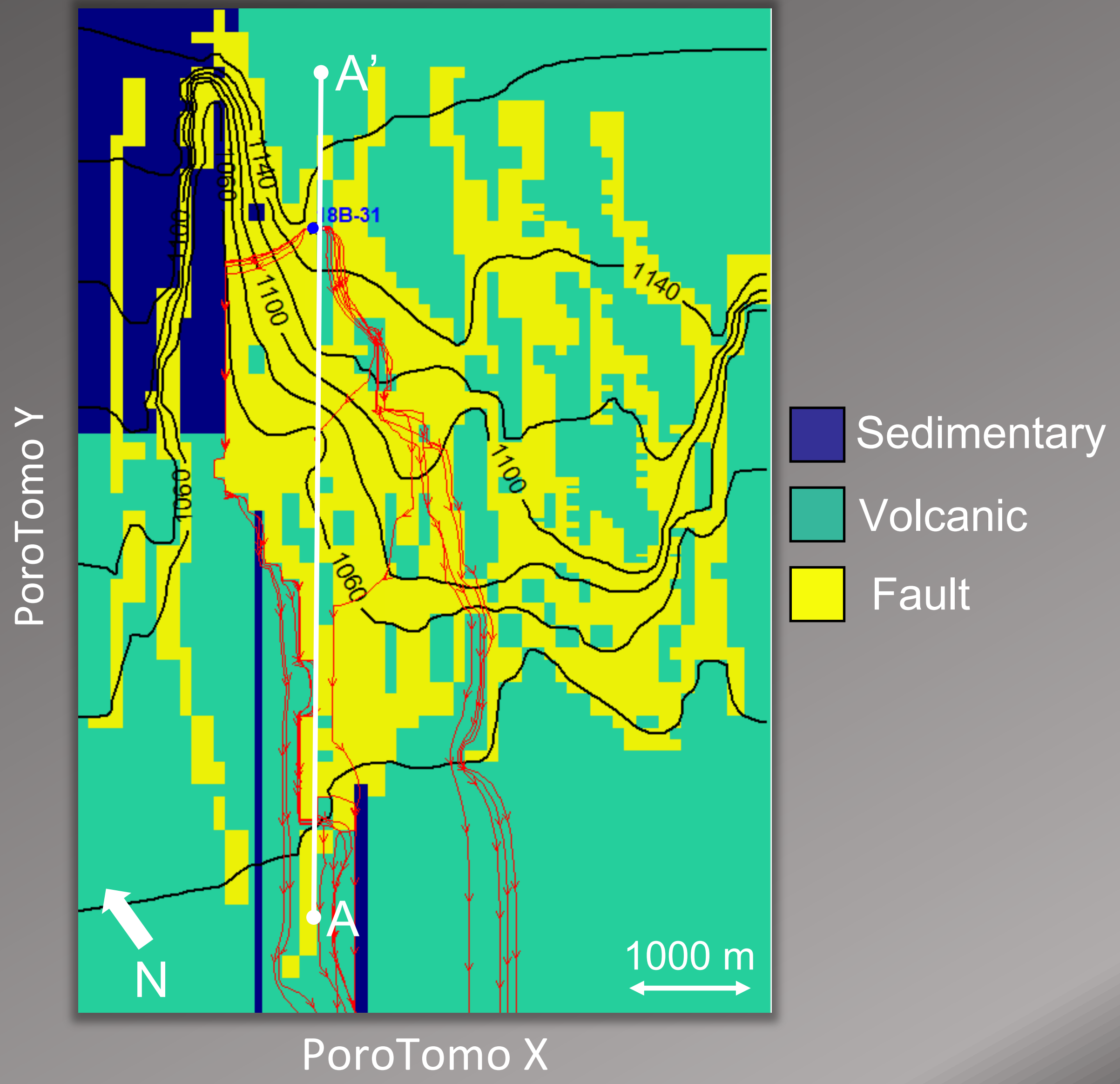
Two component fault zone

- Low permeability fault core
- Higher permeability damage zone

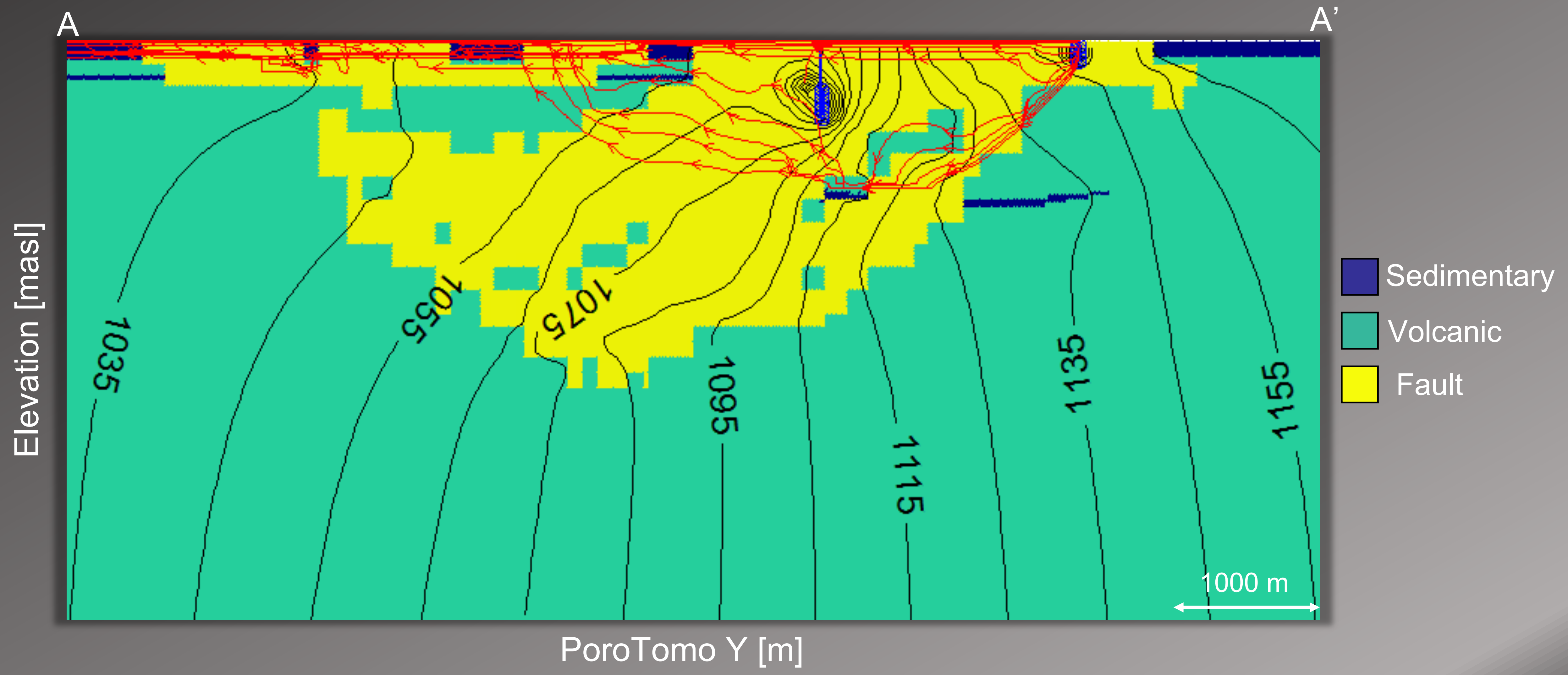
Adapted from *Bense et al.*, [2013]

Plan View (100 m depth)

- Advective transport from injection well
- Flow paths show planar flow following fault traces



Flow Characterization

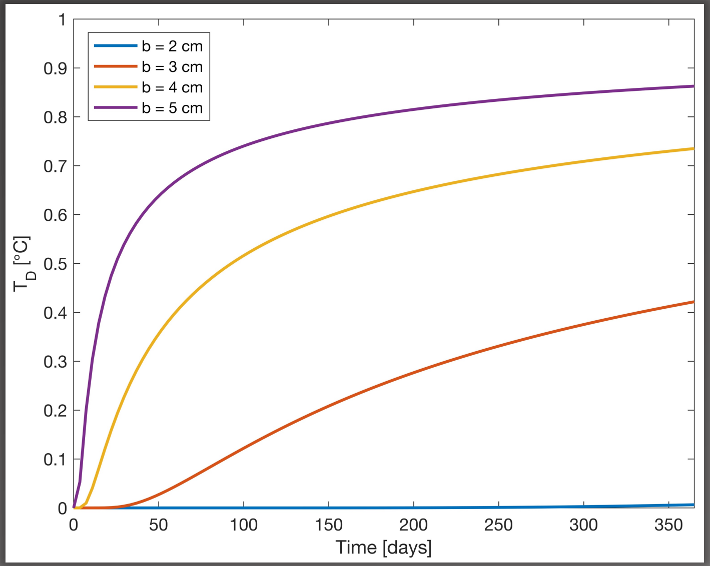


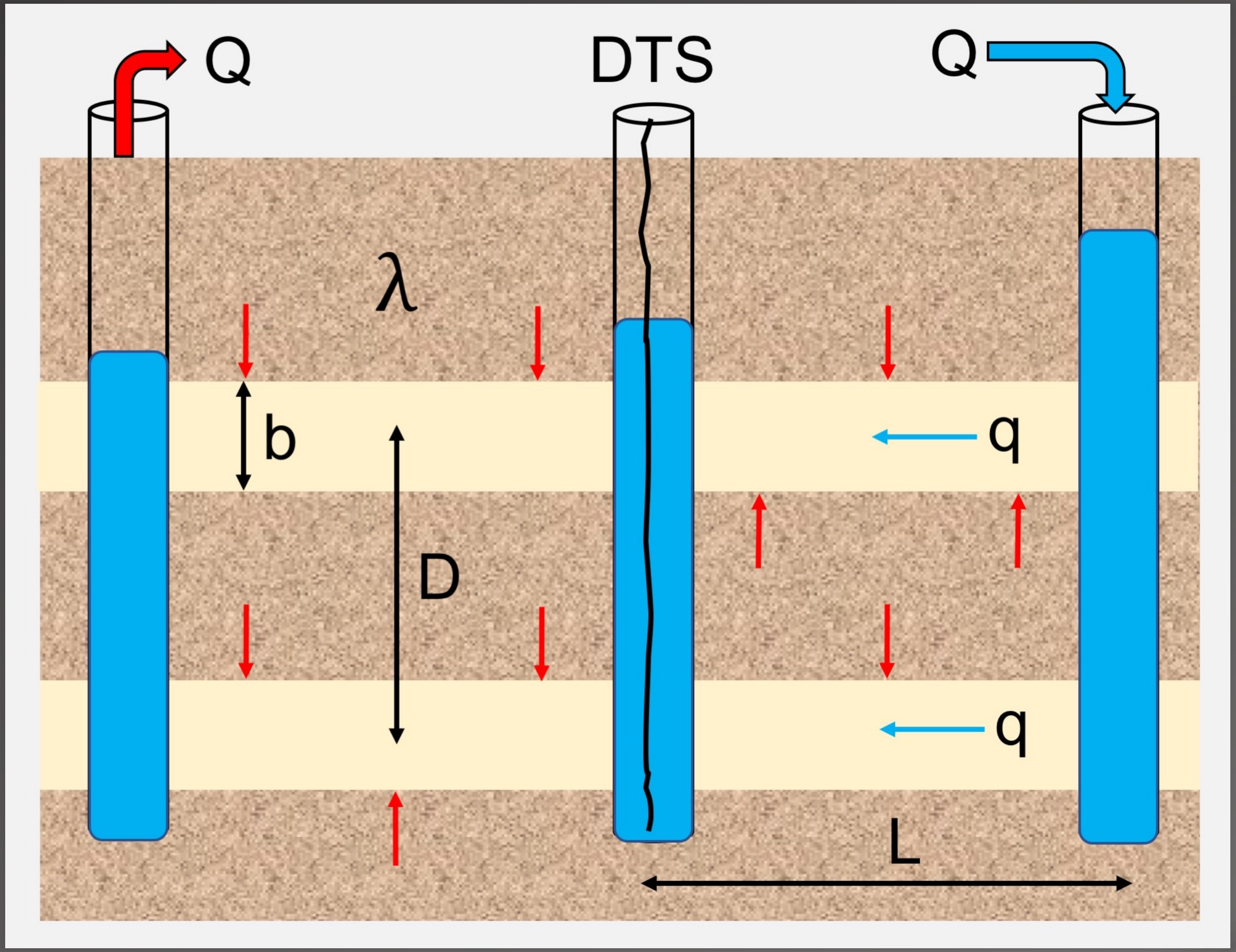
Conclusions

- Thermal characterization determines thermal diffusivity estimates which are consistent with expected values based on rock types.
- Hydraulic characterization implies individual faults act as barriers to groundwater flow
- Geophysical, visual observations, and advective transport simulations indicate fault-driven groundwater flow system.

Analytical Modeling

- Energy consumed vs energy produced?
- Hydraulically active faults?
- Parameter sensitivity?





Questions?