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High Rates of Tracer Gas Transport in a Deep Fractured Basalt

Philip H. Stauffer

Sunday, September 22nd

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AGU100 ADVANCING EARTH AND SPACE SCIENCE

Geophysical Research Letters

RESEARCH LETTER
10.1029/2019GL082394

Evidence for High Rates of Gas Transport in the Deep Subsurface

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Key Points:

- Barometric pumping can induce significant gas flow and transport in deep fractured media
- Tracer testing helps characterize subsurface permeability, porosity, and diffusivity
- Simulations elucidate barometrically induced spreading of gas constituents in fractured rock

MOTIVATION

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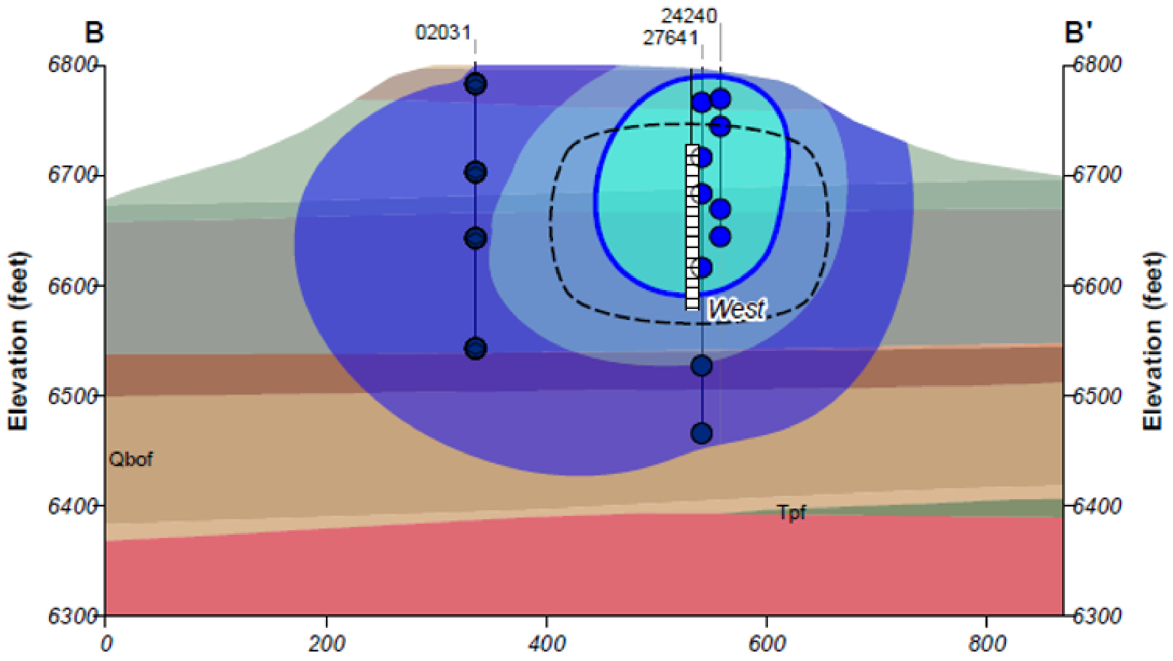
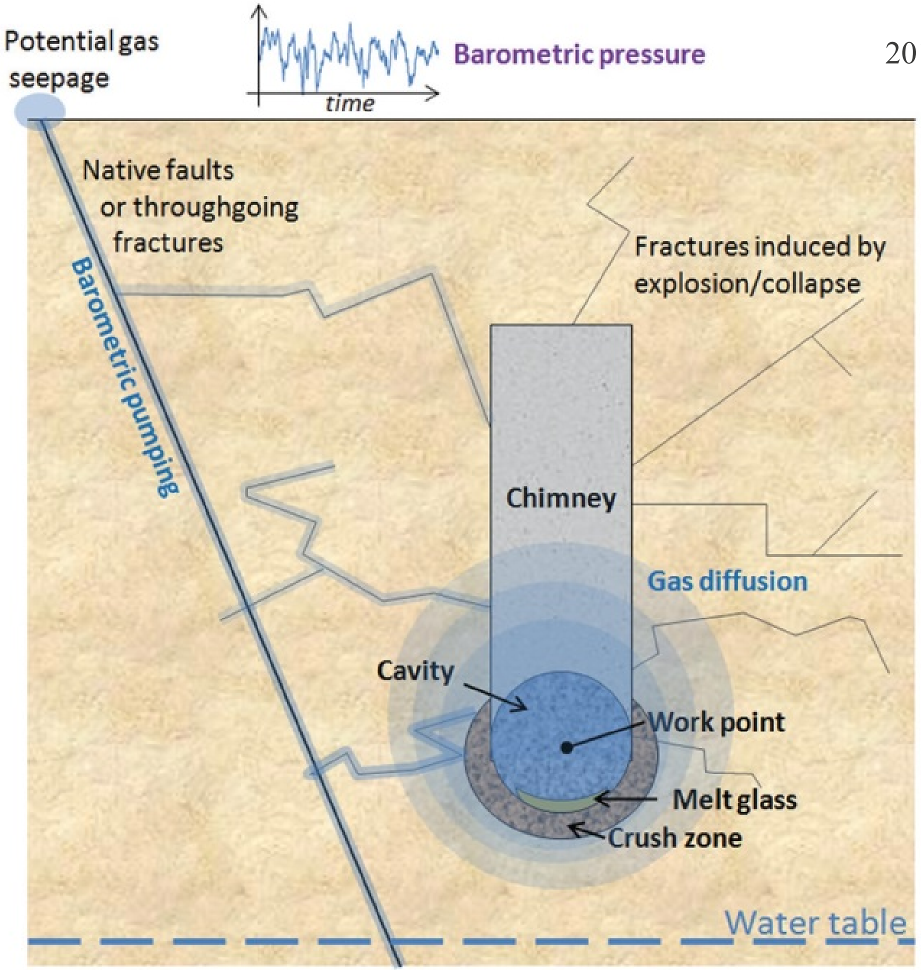
Deep vadose contaminant transport at Los Alamos



2019 Behar, H.R., . . . P.H. Stauffer, An investigation of plume response to drum failure and soil vapor extraction at Material Disposal Area L, Los Alamos, NM, *Vadose Zone J.,* 18(1), doi: 10.2136/vzj2018.04.0080.

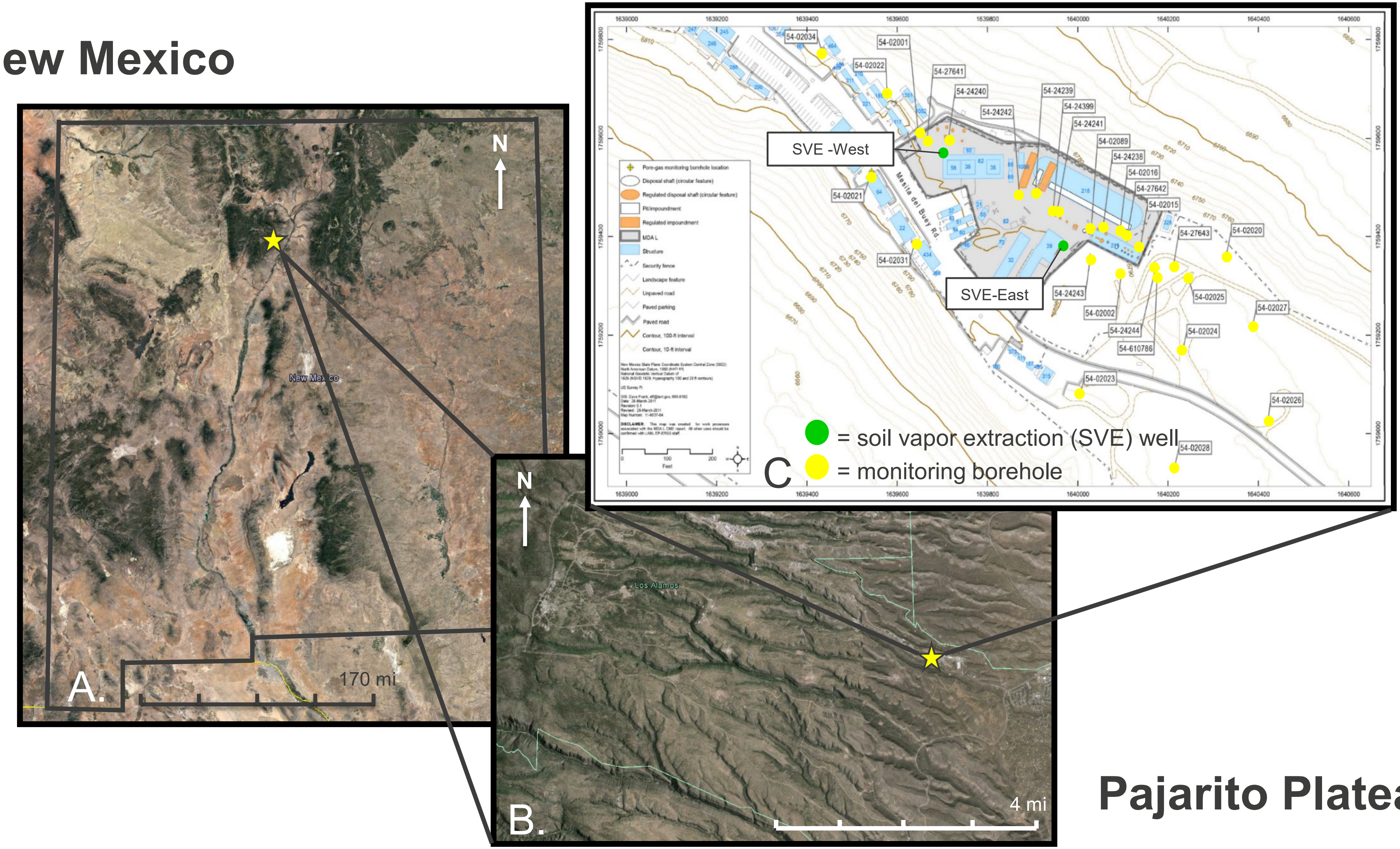
Radionuclide gas migration from underground nuclear tests



2019 Bourret, S.M., E.M. Kwicklis, T.A. Miller, and **P.H. Stauffer**, Evaluating the importance of barometric pumping for subsurface gas transport near an underground nuclear test site, ***Vadose Zone J.,*** March 14, doi: 10.2136/vzj2018.07.0134 .

Site Location

New Mexico



Material Disposal Area L (MDA L), LANL

Pajarito Plateau

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Site Stratigraphy

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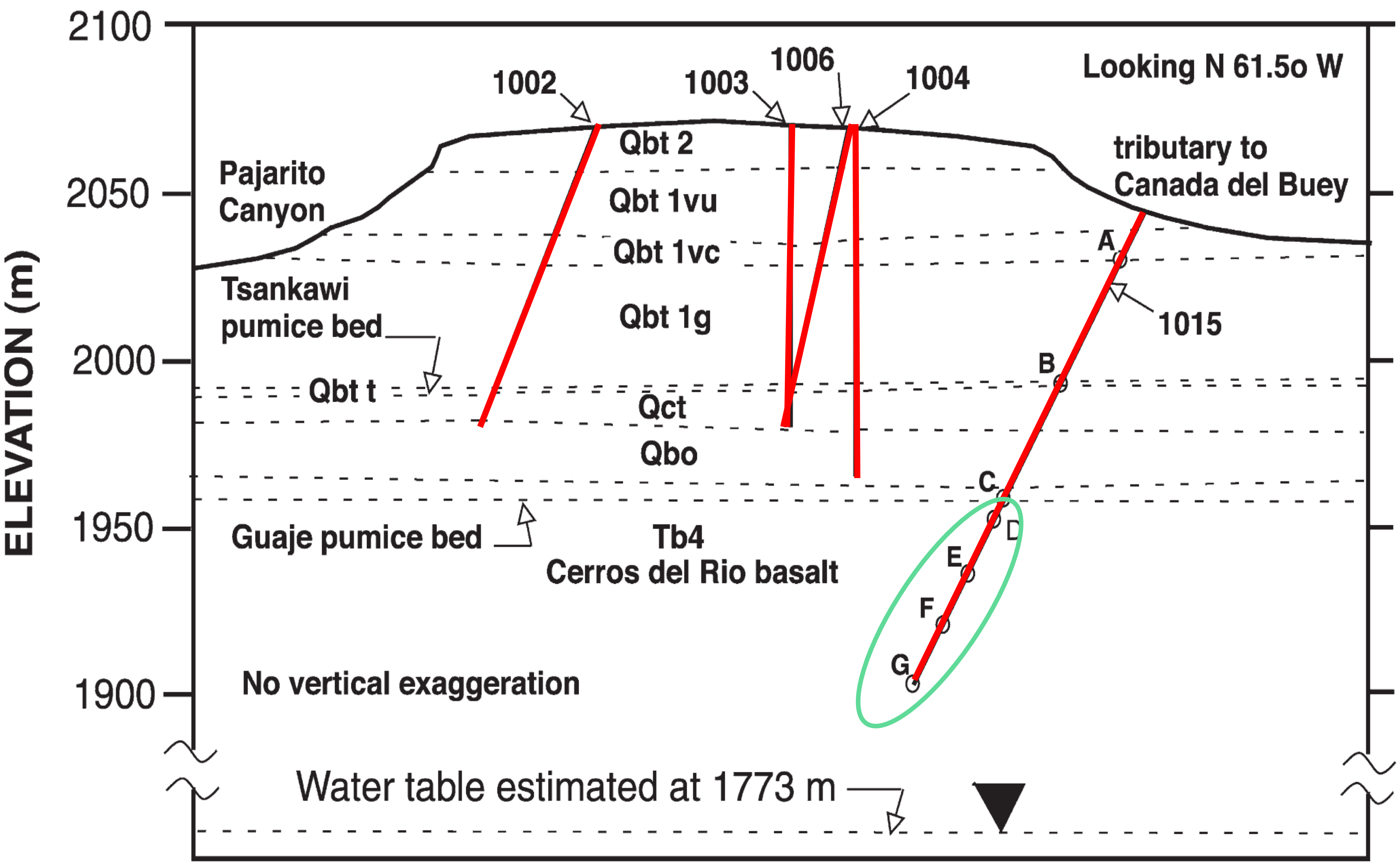

Stauffer, P.H., Birdsell K.H., Witowski M.S., Hopkins J.K. 2005. Vadose zone transport of 1,1,1-trichloroethane: conceptual model validation through numerical simulation. Vadose Zone Journal. 760-773.

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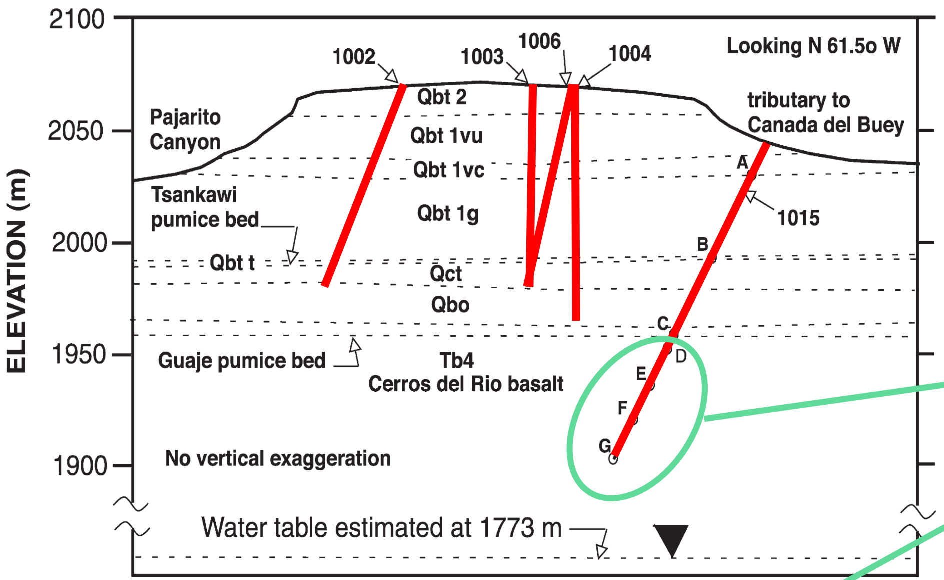
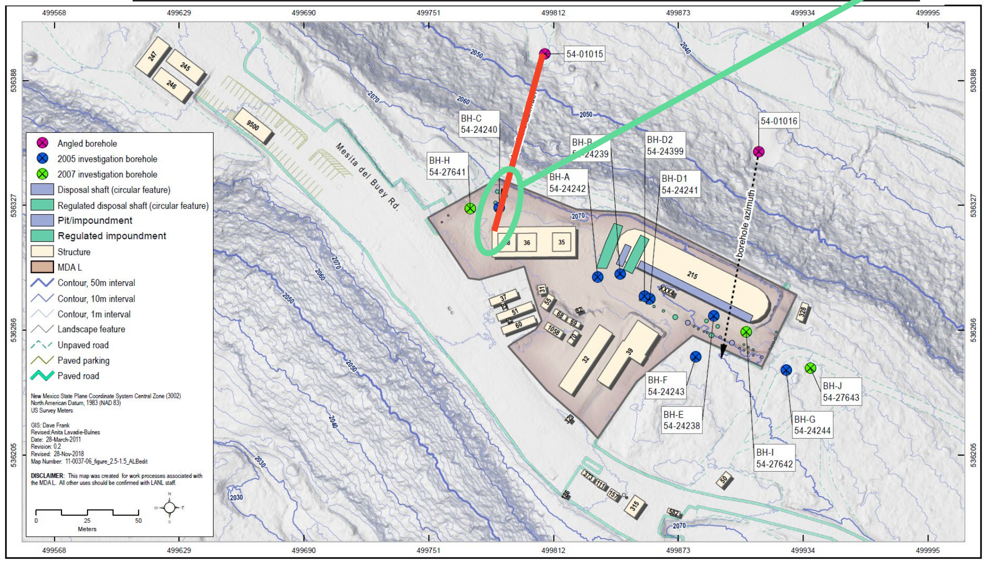
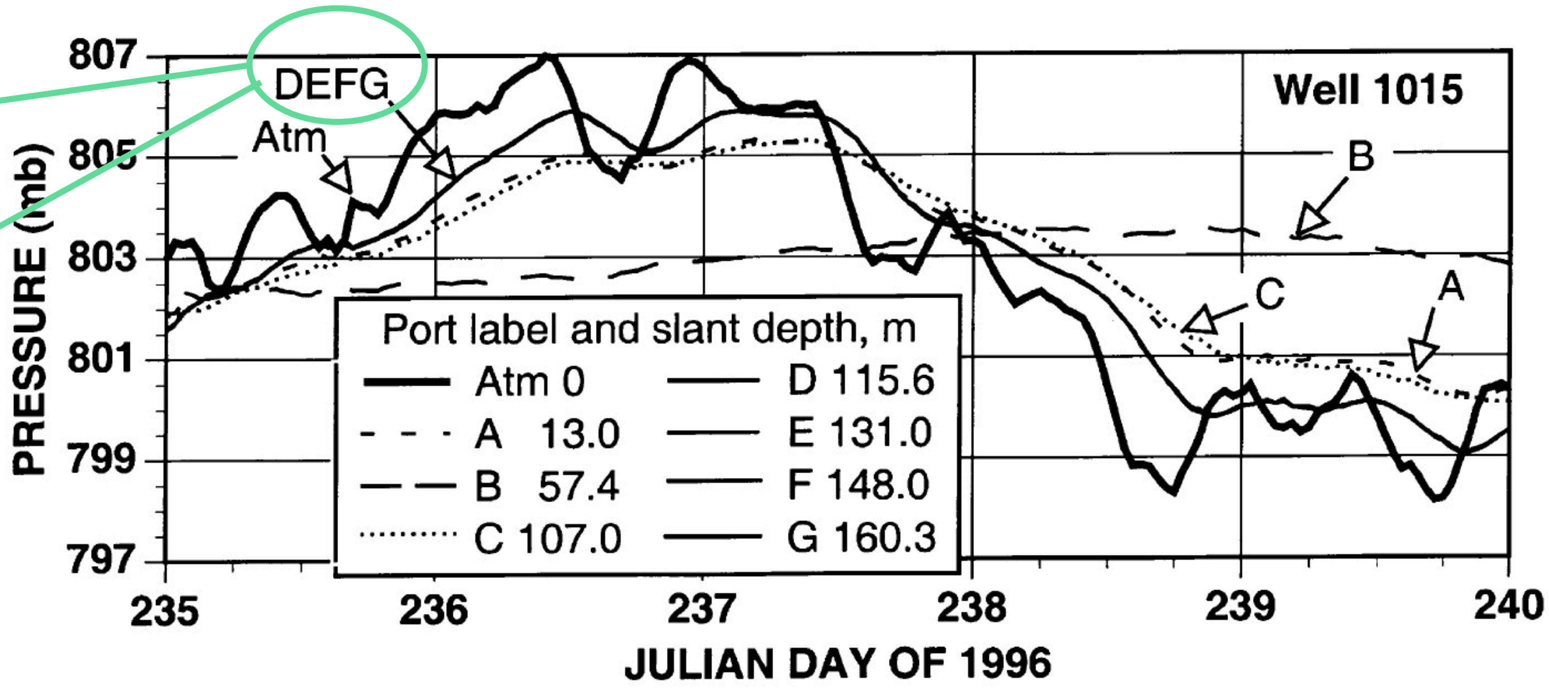
Site Description





Basalt is nearly in phase and of the same amplitude as the atmosphere.



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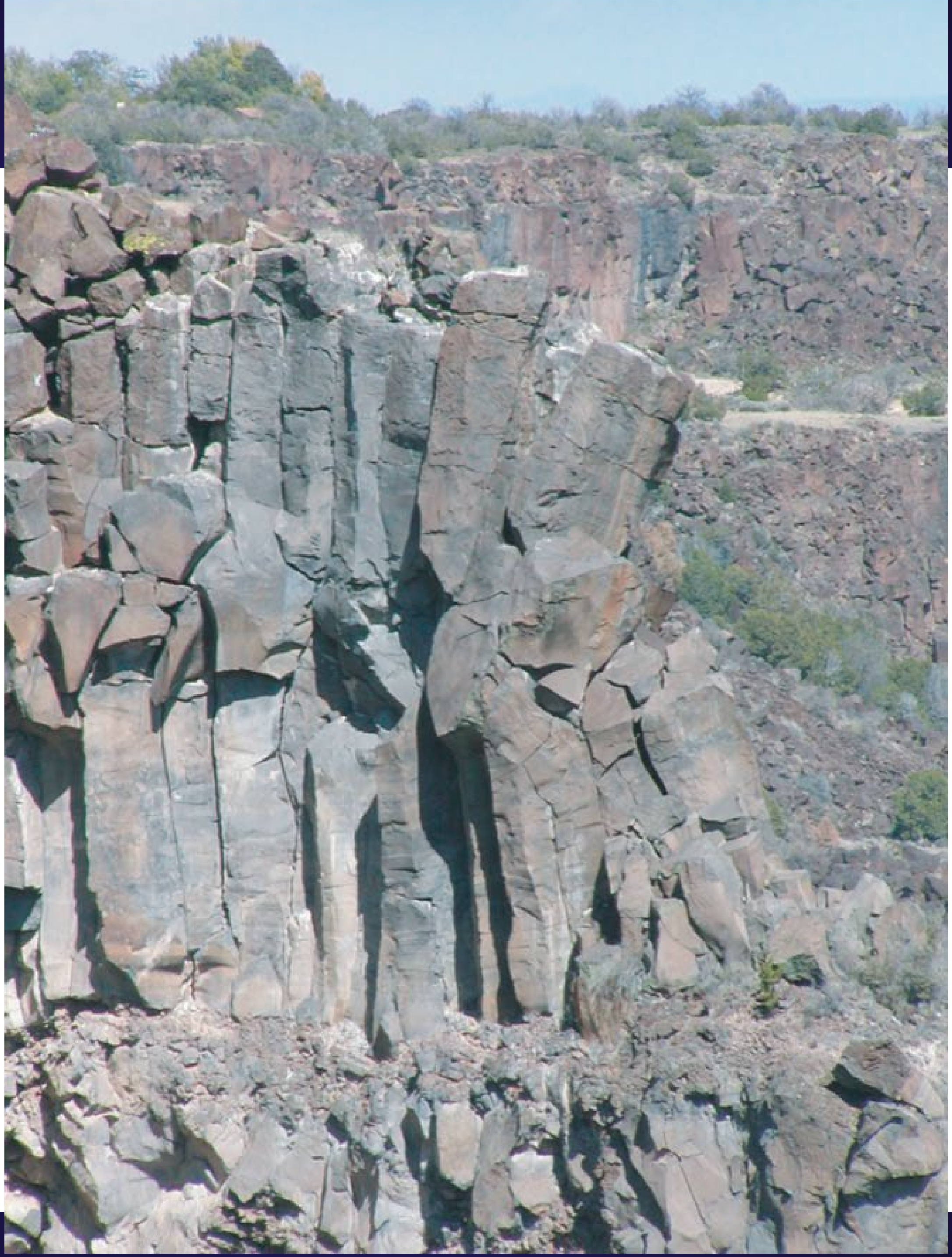
Cerros del Rio Basalt

Massive columnar sections
Fracture porosity
High permeability

Thinner interflow breccia
Rubble porosity 35%
High permeability



2017 Tracer test in the Cerros del Rio Basalt

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Tracer Experiment April 2017

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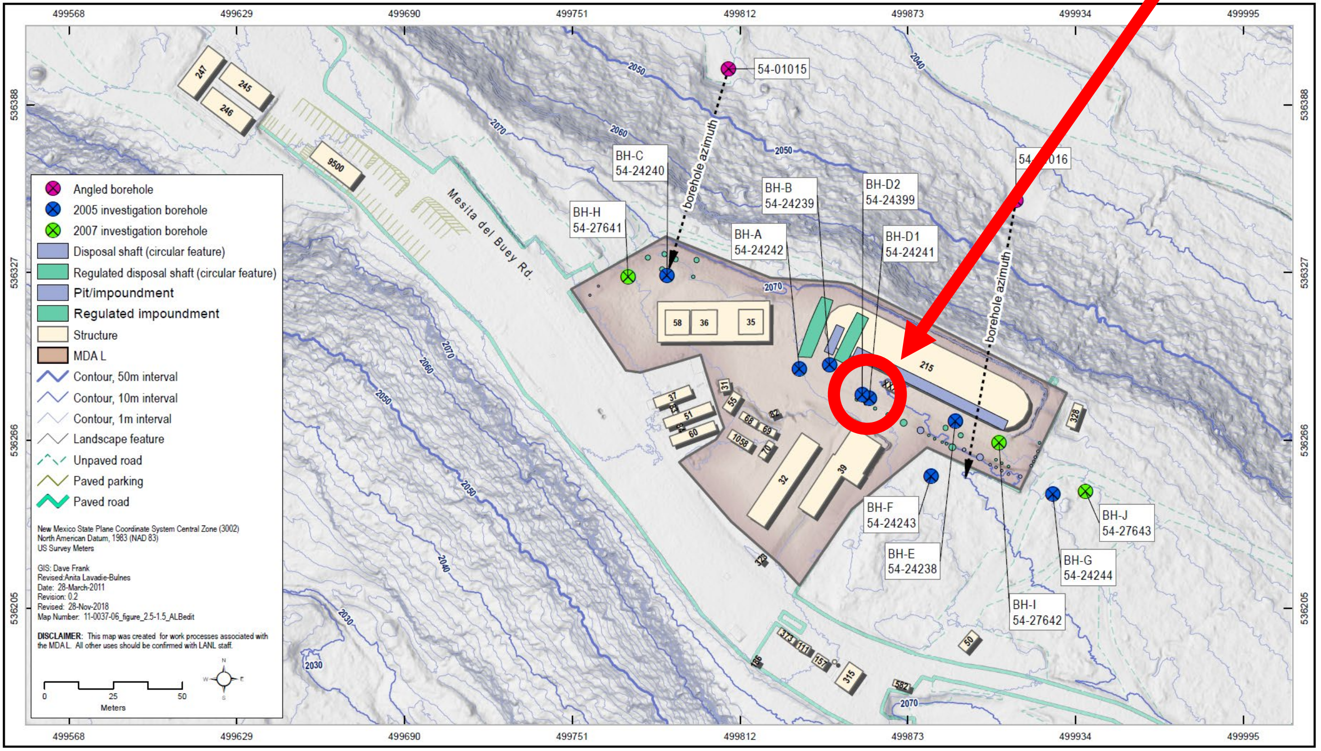
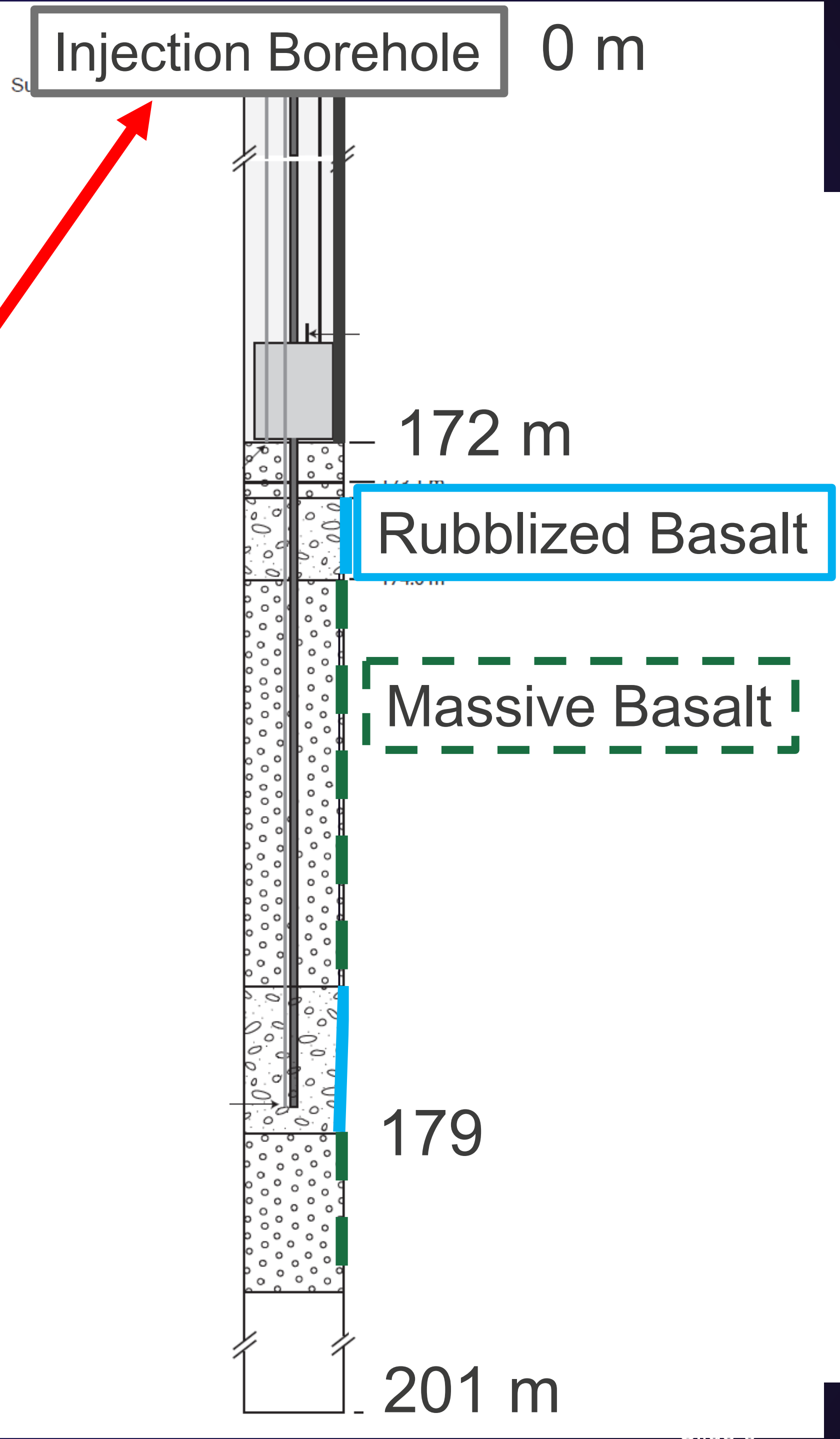
Sulfur Hexafluoride injection into the Cerros del Rio Basalt





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Tracer Experiment April 2017

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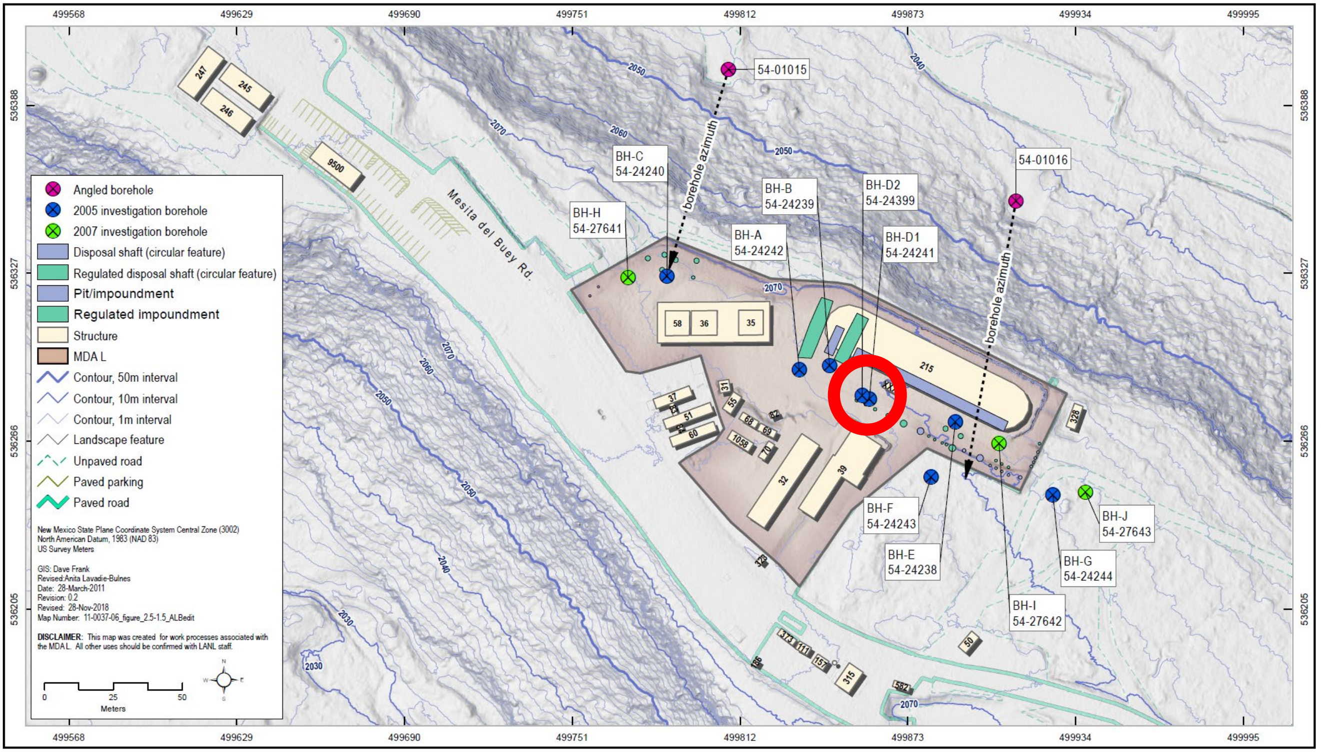

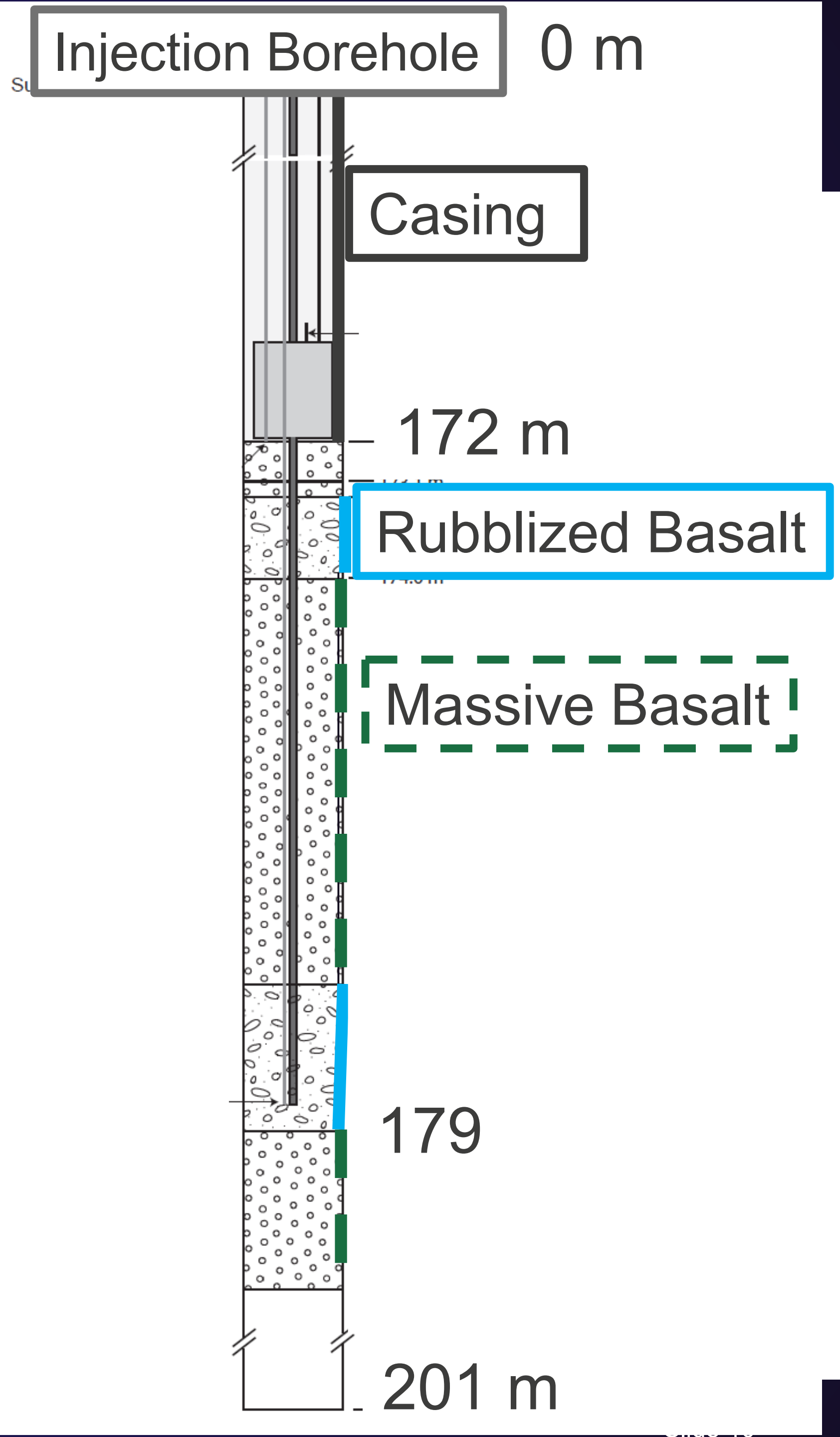

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Tracer Experiment April 2017

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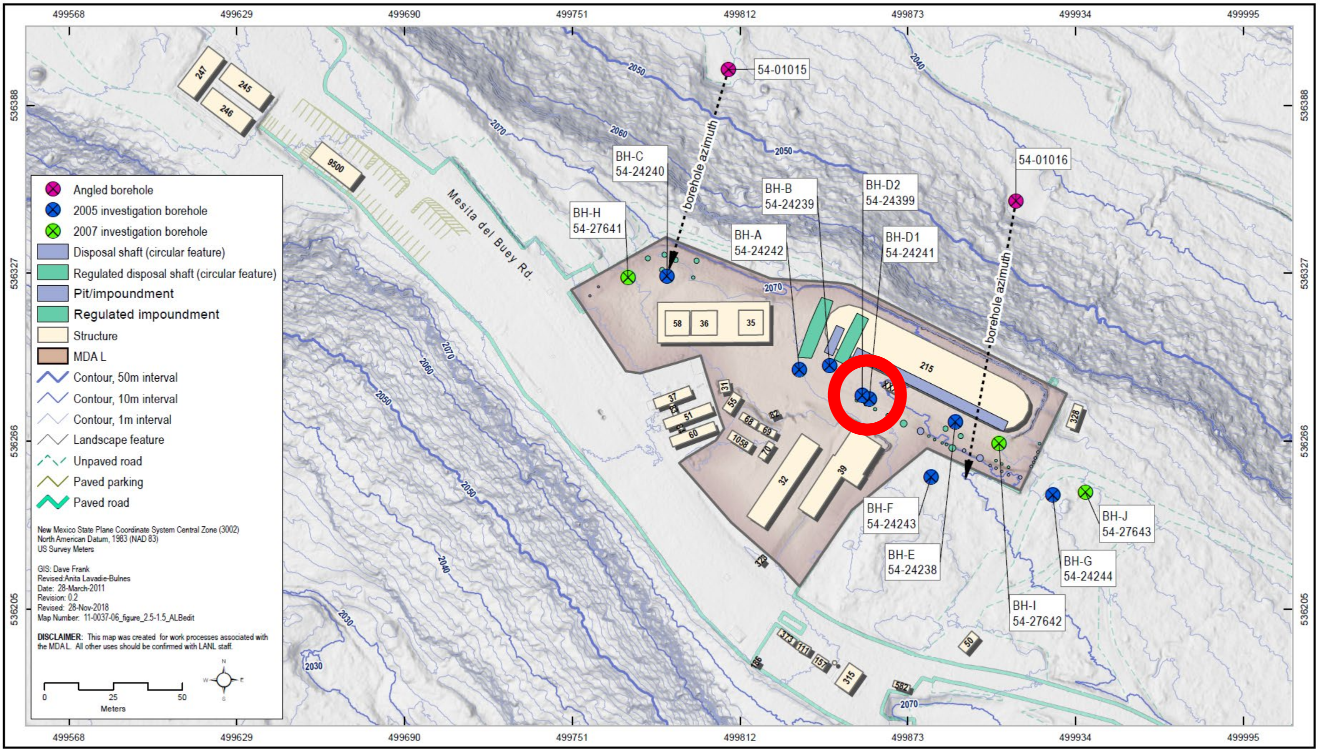
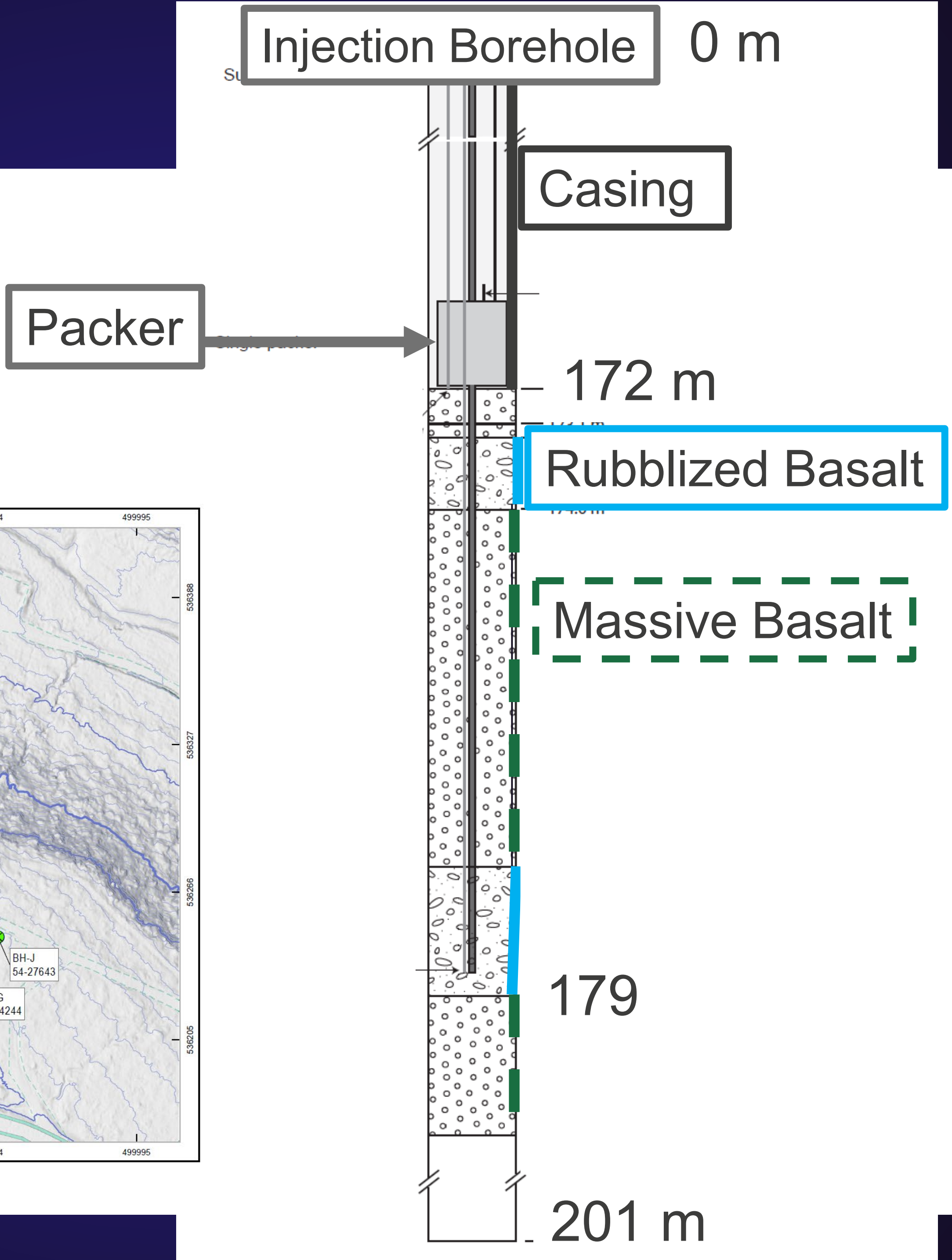
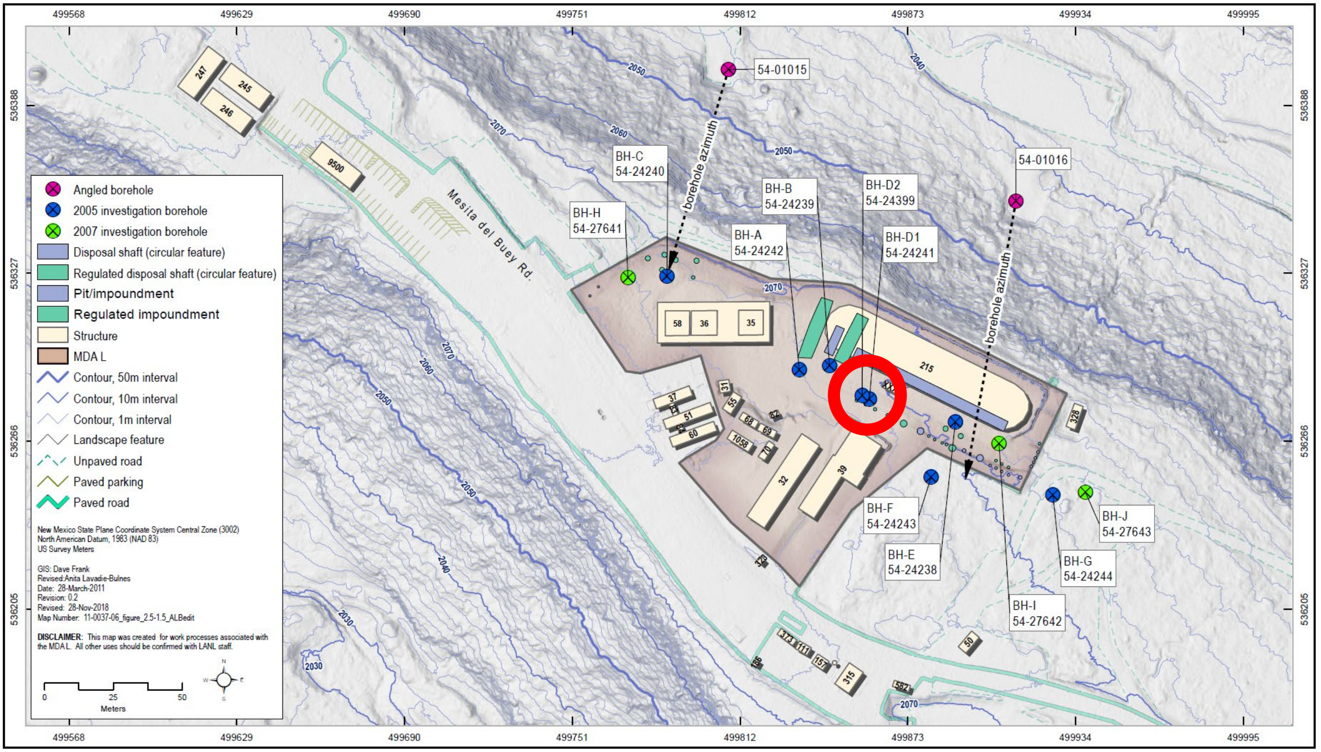
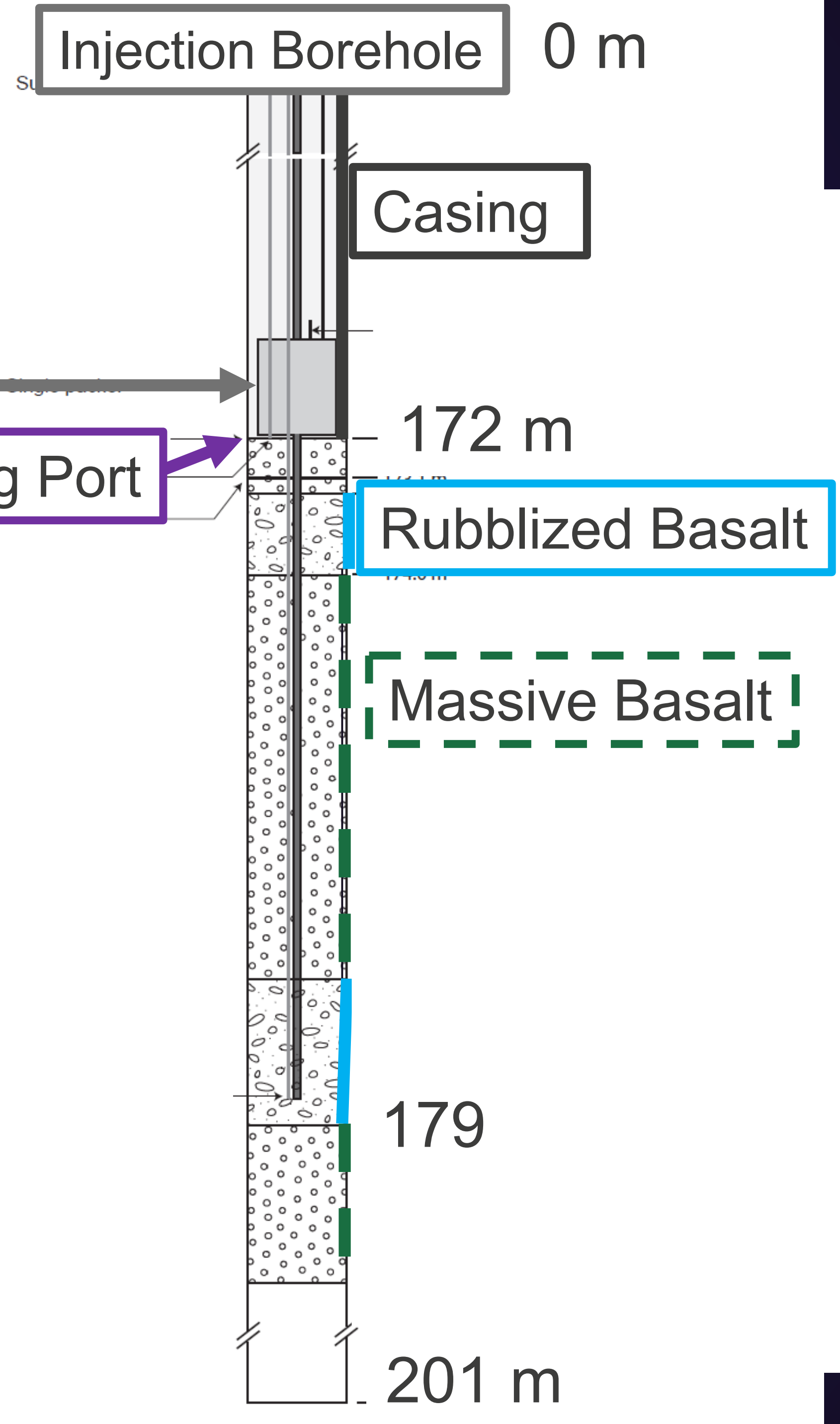




Tracer Experiment April 2017

Sulfur Hexafluoride injection into the Cerros del Rio Basalt





Tracer Experiment April 2017 – Tracer Details

5 g of SF_6 injected

Mixed in 1 L of air → Pump reversed to sample

10 min air purge

Innova 1412i Photoacoustic Gas Monitor, installed in the field at MDA L, April 2017.

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Tracer Experiment April 2017 – Tracer Data

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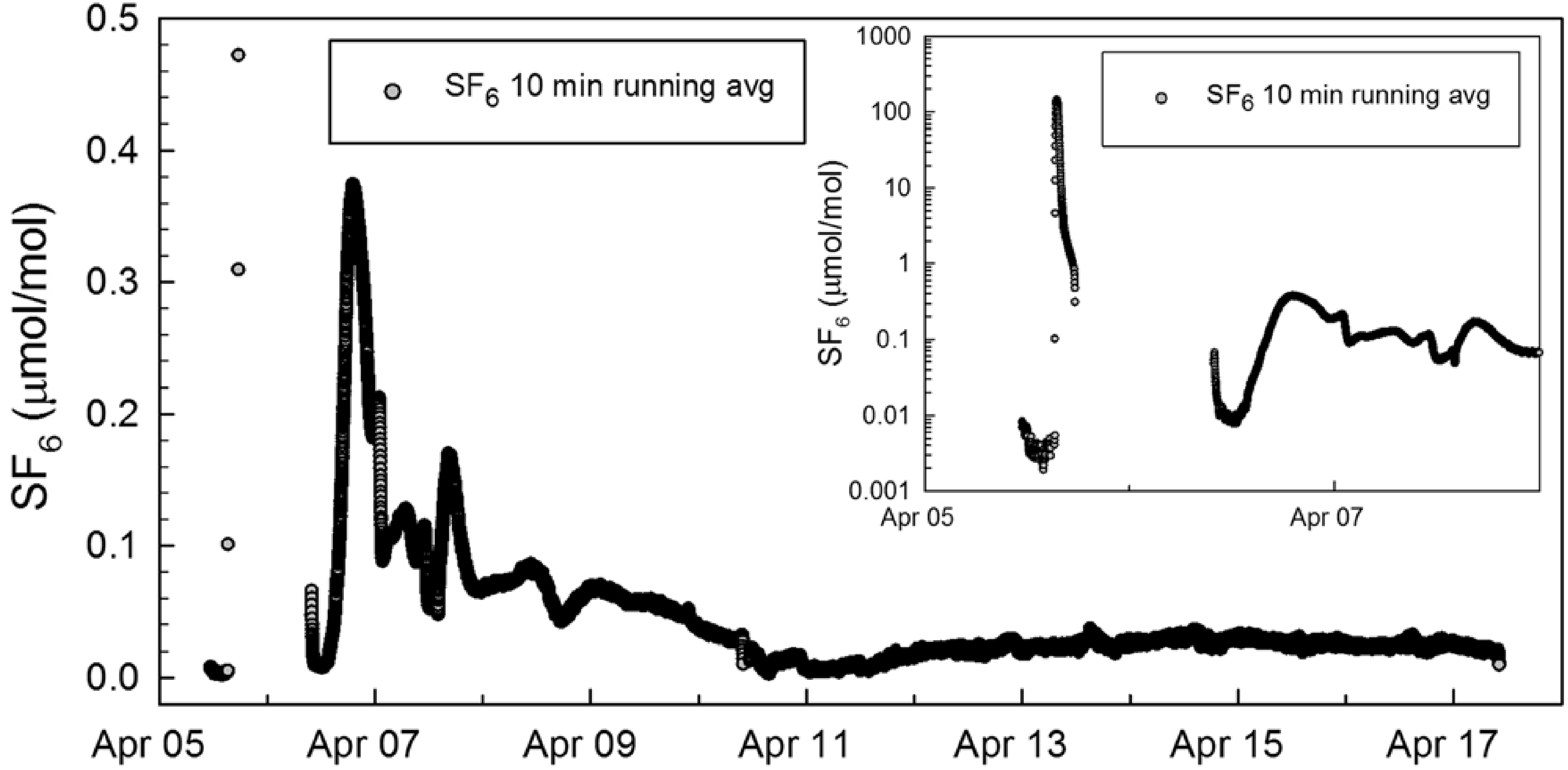
Tracer initially spikes, disappears, then returns, drops then increases.



Behavior was predicted by pre-test simulations

Tracer Experiment April 2017 – Down-hole Pressure Data

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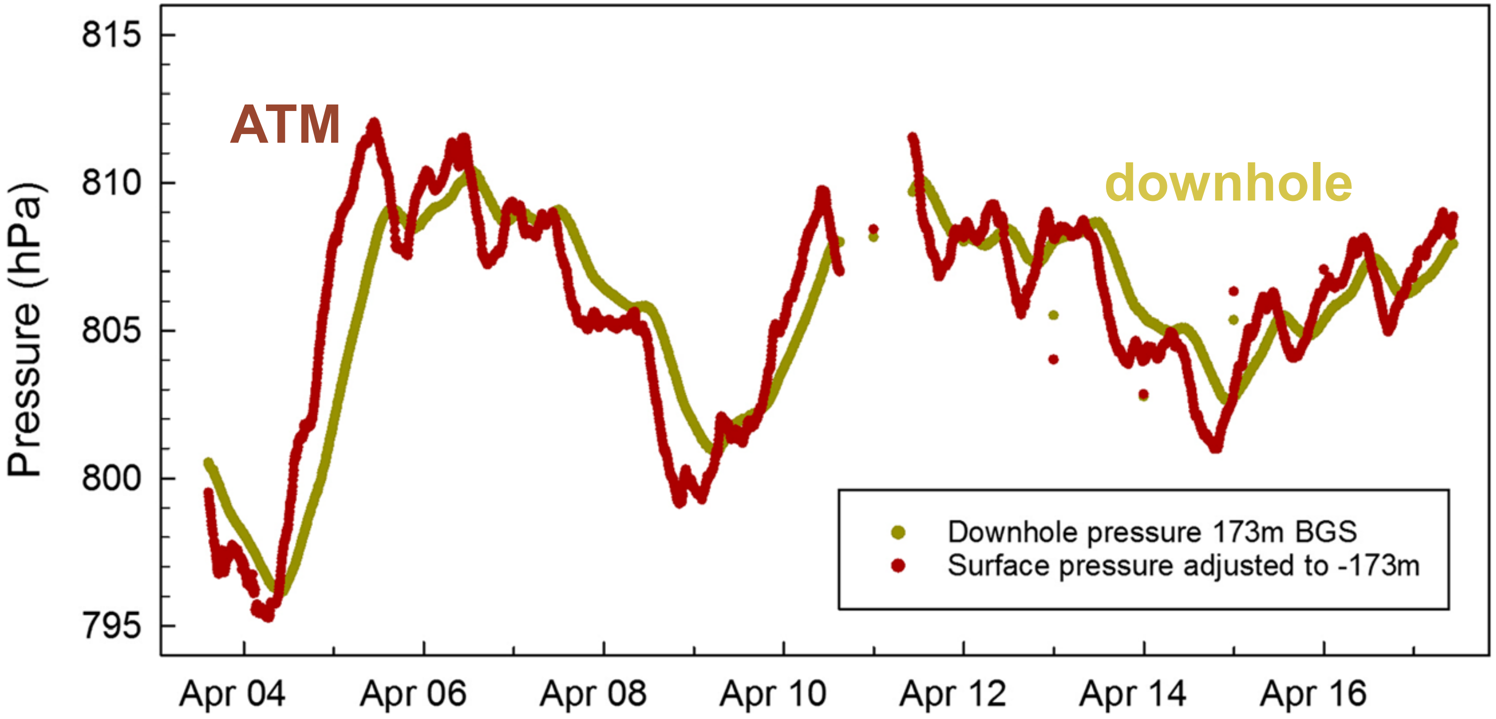
Pressure gauge measuring below the packer



Basalt is nearly in phase and of the same amplitude as the atmosphere.

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Numerical Model of the Tracer Test

FEHM

Finite Element Heat and Mass Transfer Code

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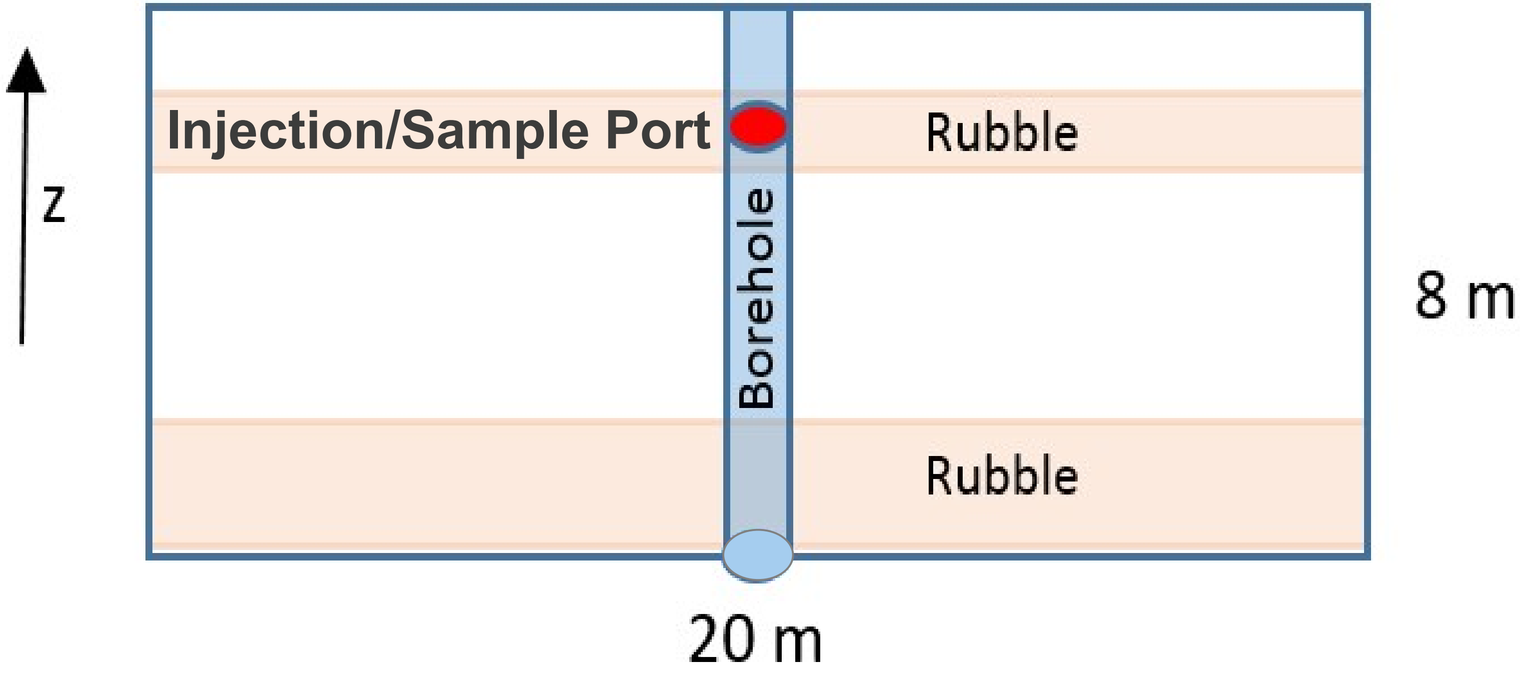
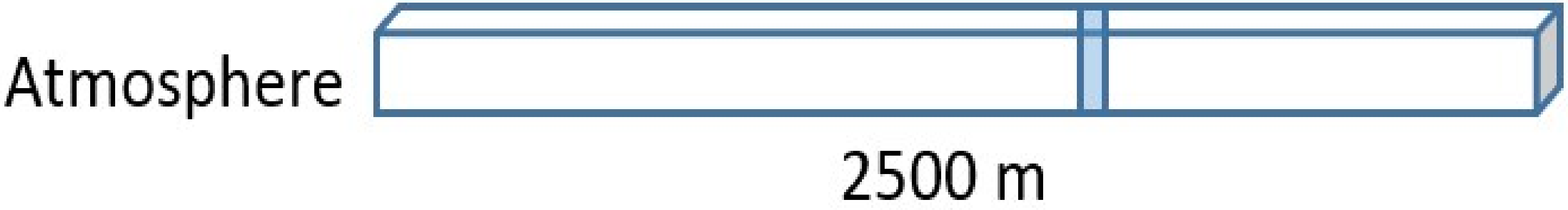
3-D long narrow slice of basalt

8 m vertical x 20 m wide x 2500 m long

0.07 m radius borehole

1 m spacing within 100 m of the borehole





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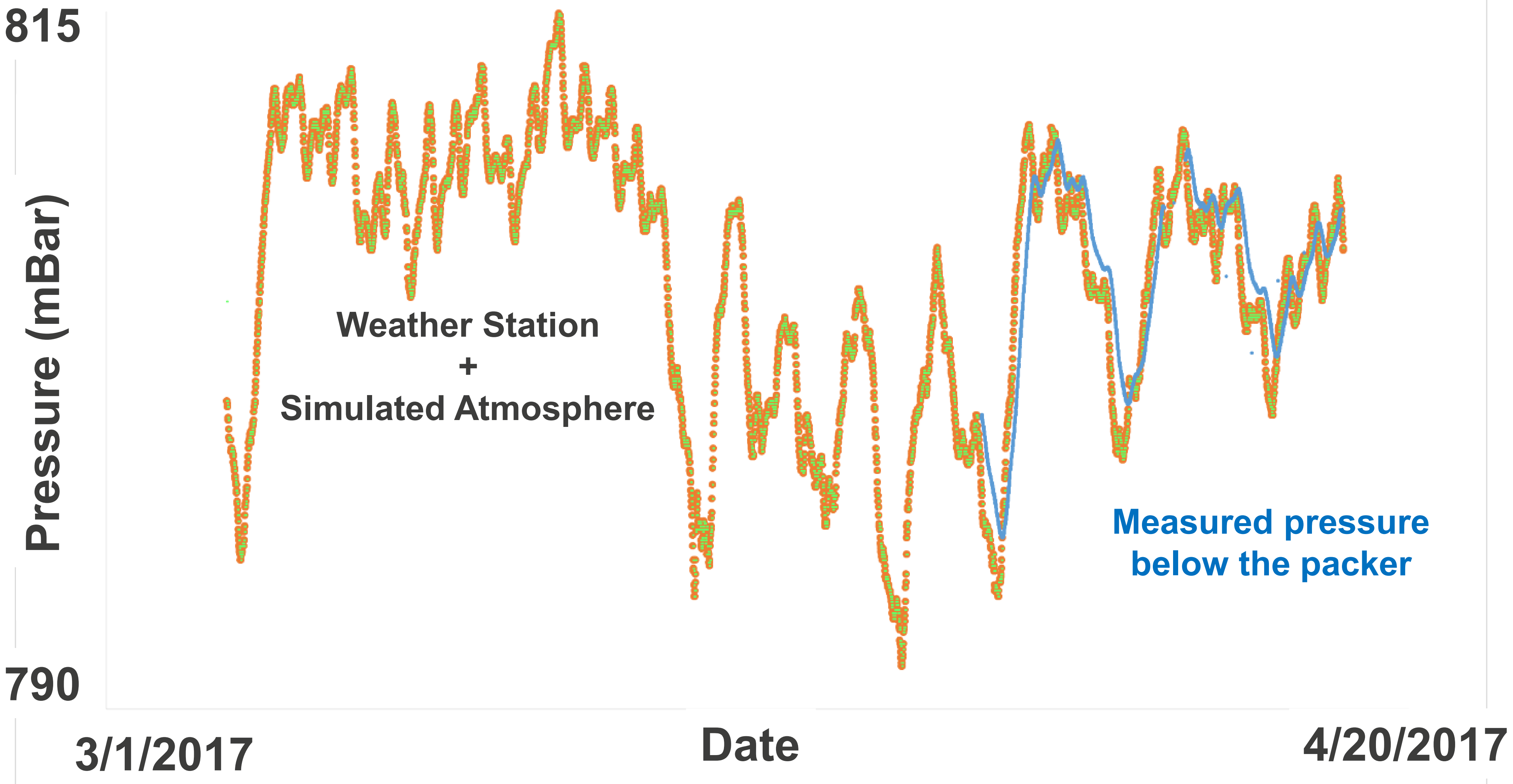
Simulation Spin-up to atmospheric pressure

1 month of atmospheric pressure data used to create the initial state



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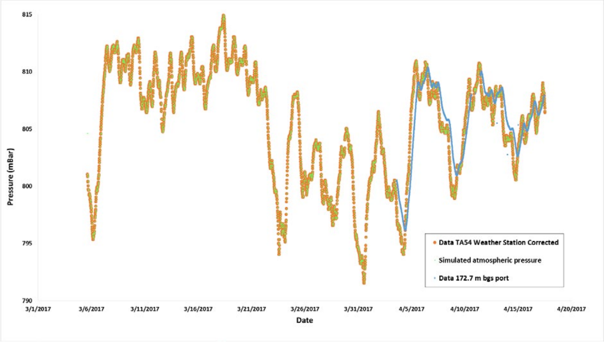
Parameters – calibrated to fit pressure and tracer data

Basalt permeability on order of 1000 darcies

Basalt porosity 35% rubble 0.4% massive fractured (4 mm fracture per m)

Lateral boundary for pressure drive at 1000 m from the sampling port

Atmospheric boundary



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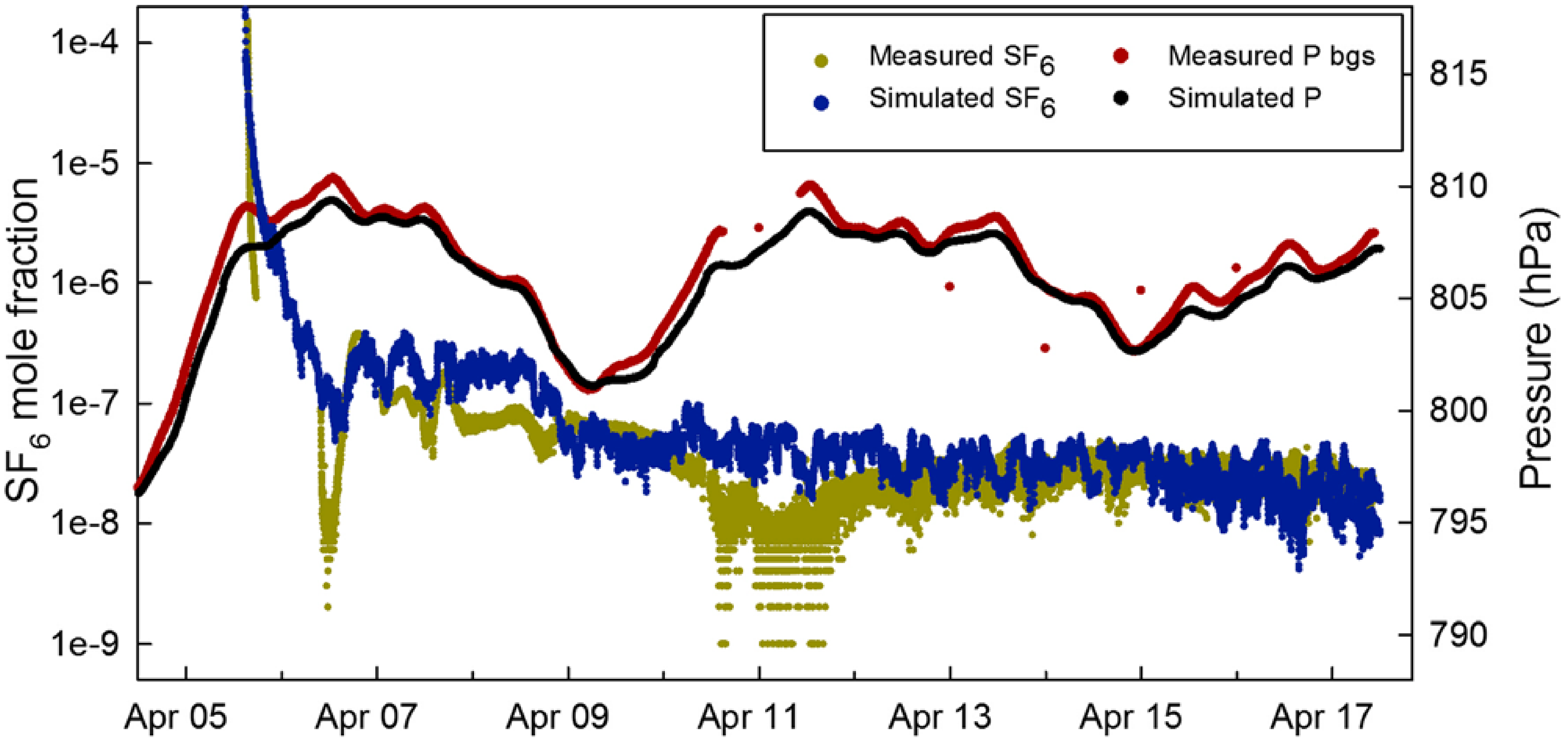
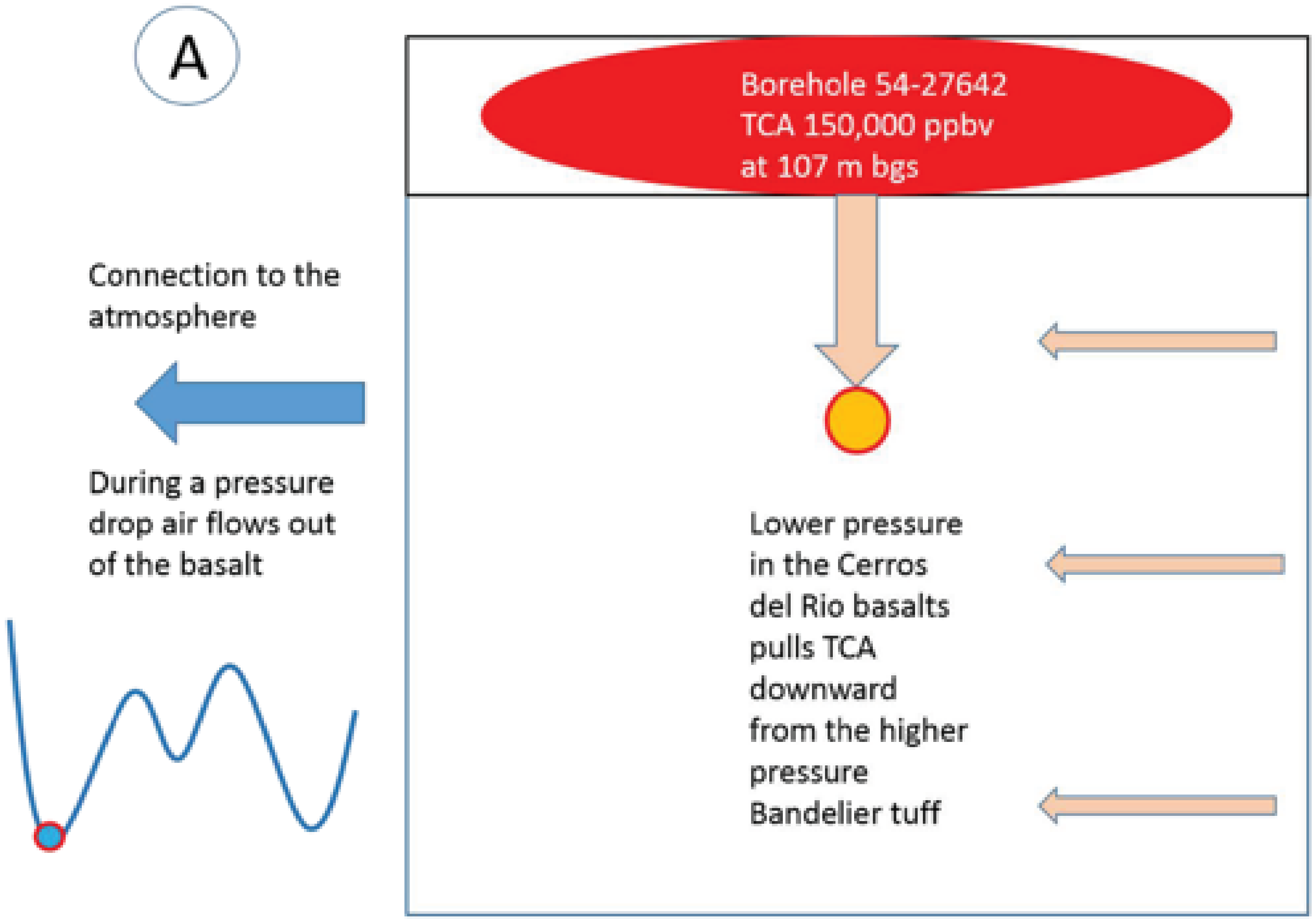
Results – Matching downhole pressure + tracer concentratoin



Implications – Contaminant Plume Migration

Atmospheric pressure drops will pull the plume into the basalt



10x to 100x more mixing in the basalt than standard diffusive theory

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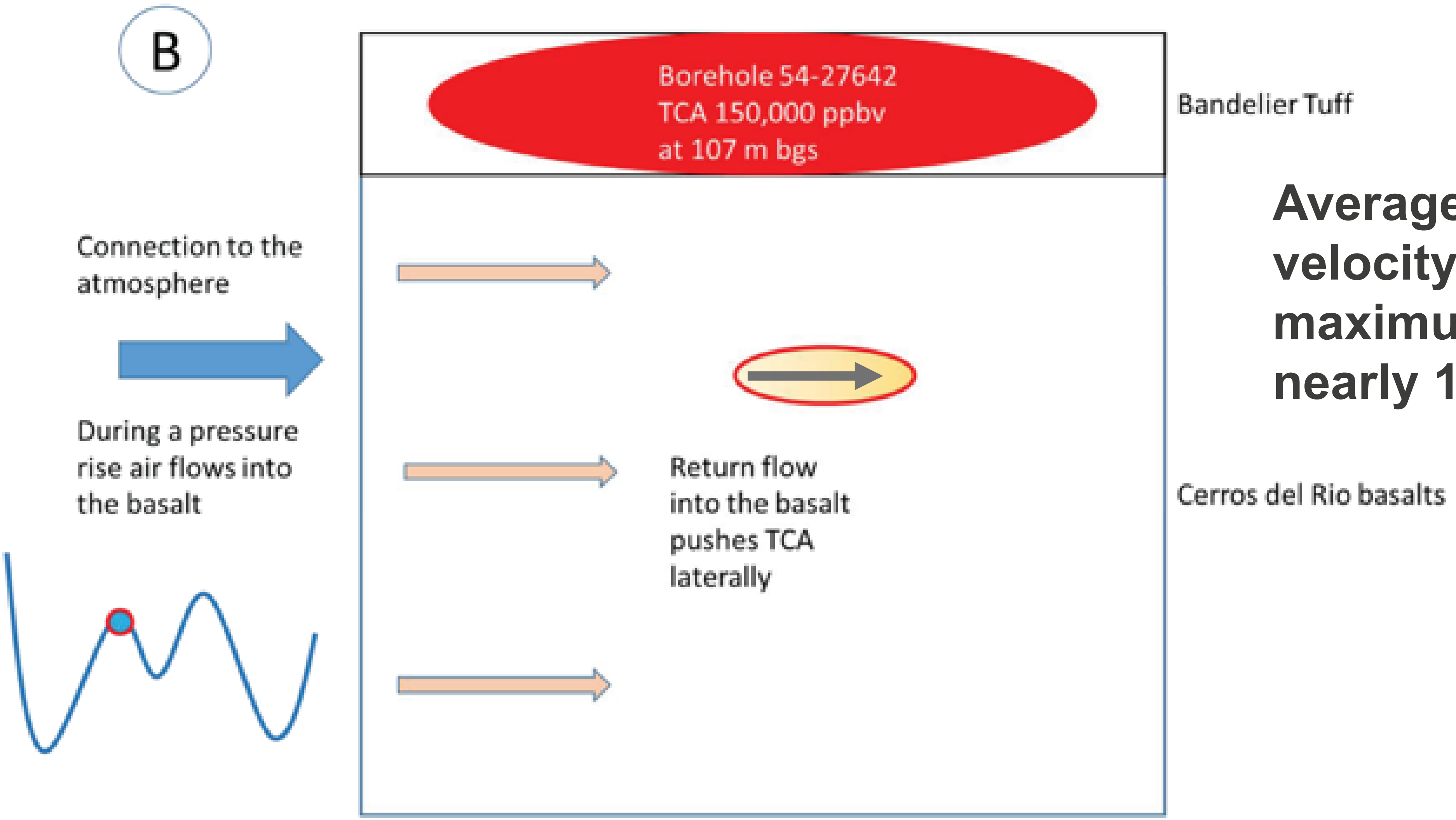
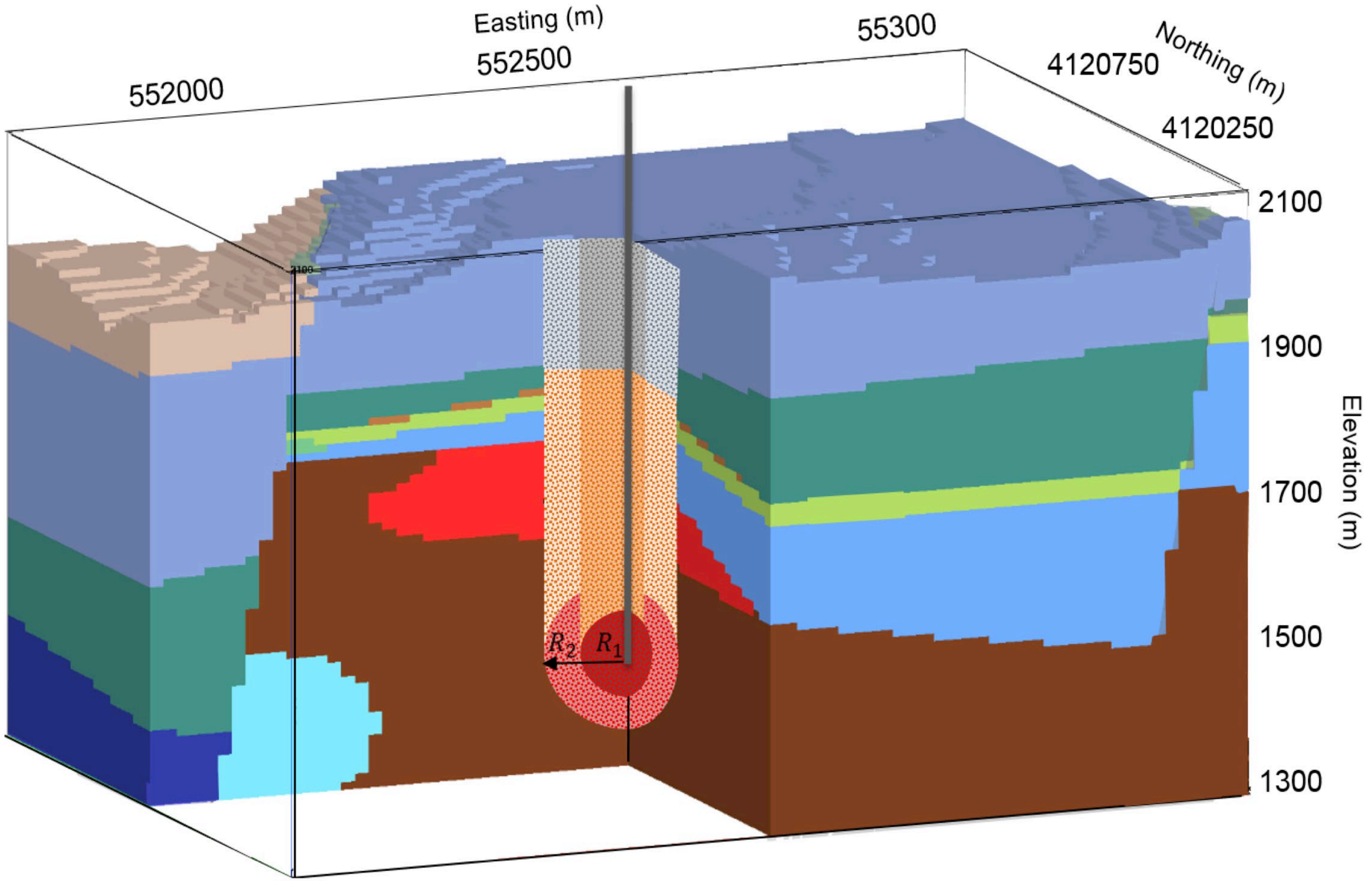
Implications – Contaminant Plume Migration

Atmospheric pressure high pushes the plume back into the basalt



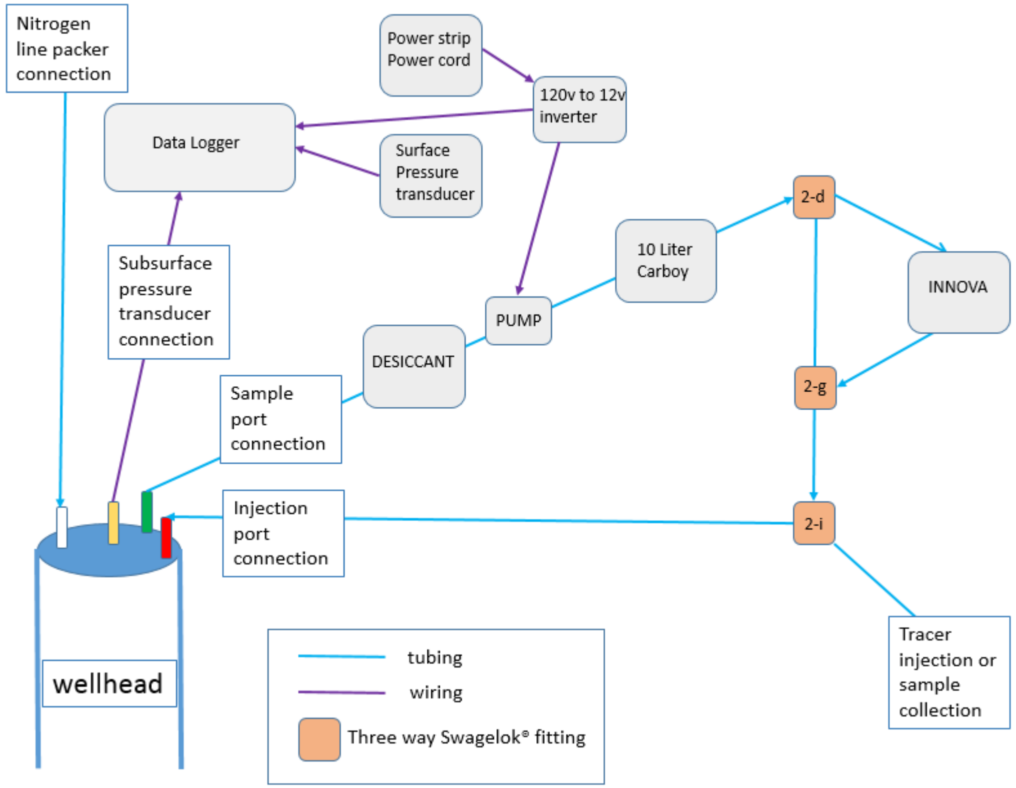
Average linear velocity reaches maximums of nearly 1000 m/day

Implications – Nuclear gas transport



Basalt layer could provide a fast-path to the atmosphere, increasing probability of observing gas seepage

Questions ?



Nitrogen line packer connection
Power strip Power cord
120v to 12v inverter
Data Logger
Surface Pressure transducer
2-d
10 Liter Carboy
INNOVA
Subsurface pressure transducer connection
PUMP
DESICCANT
2-g
Sample port connection
Injection port connection
2-i
wellhead
tubing
wiring
Three way Swagelok® fitting
Tracer injection or sample collection