Paper #20233

Brine Availability Test in Salt, a Heated Borehole Experiment at the Waste Isolation Pilot Plant, New Mexico, USA

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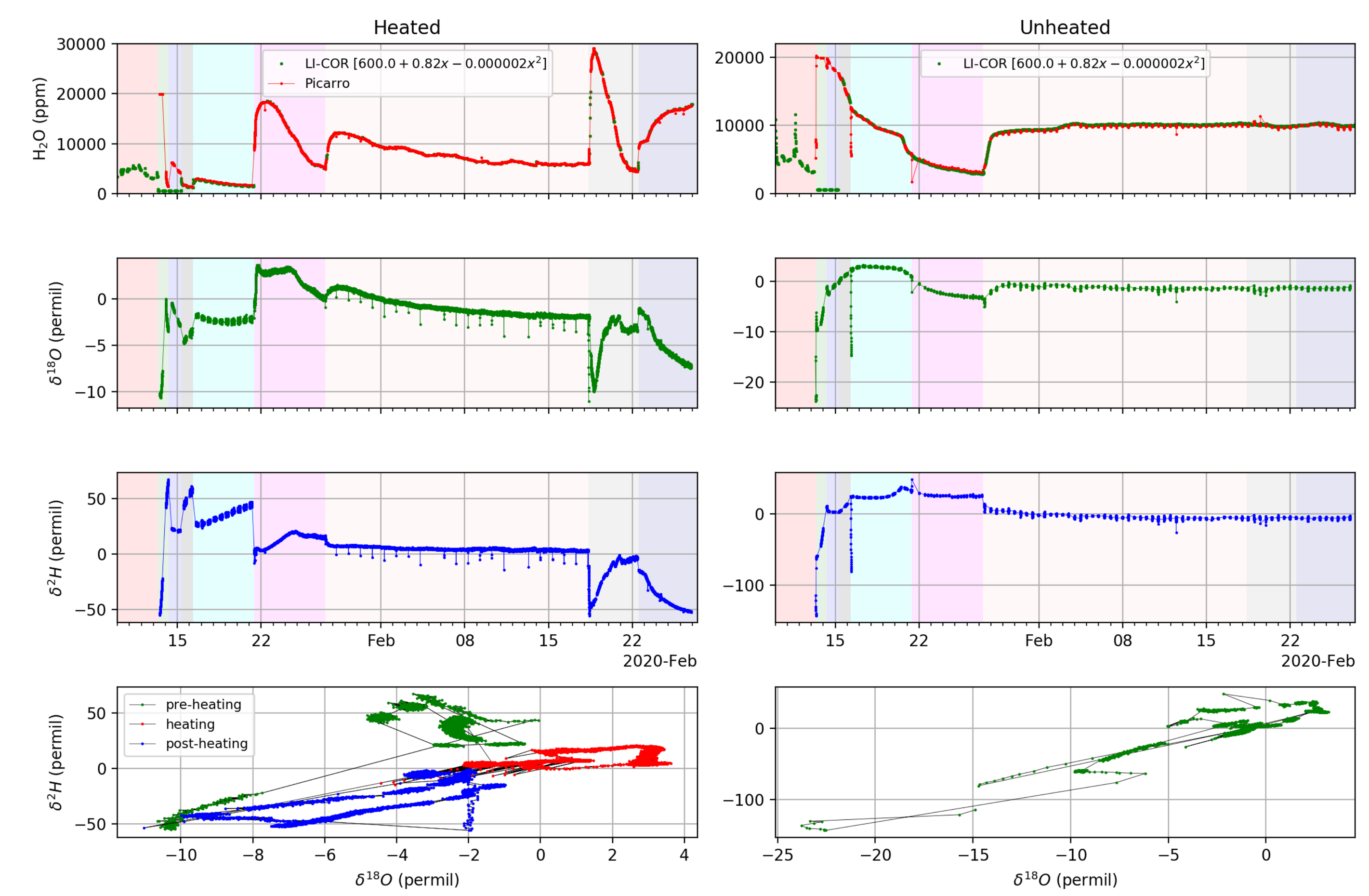
The Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico is a US DOE facility developed for long-term storage of transuranic (TRU) waste. Covering ~4000 hectares (~16 square miles), WIPP facilities are located in a Permian Period (250 MYBP) salt formation 600 m (~2000 feet) thick beginning 260 m (~850 feet) below ground surface. In addition to TRU storage, WIPP houses a unique Underground Research Lab (URL) with ongoing research that includes particle astrophysics, waste repository science, mining technology, low radiation dose physics, fissile materials accountability and transparency, and deep geophysics.

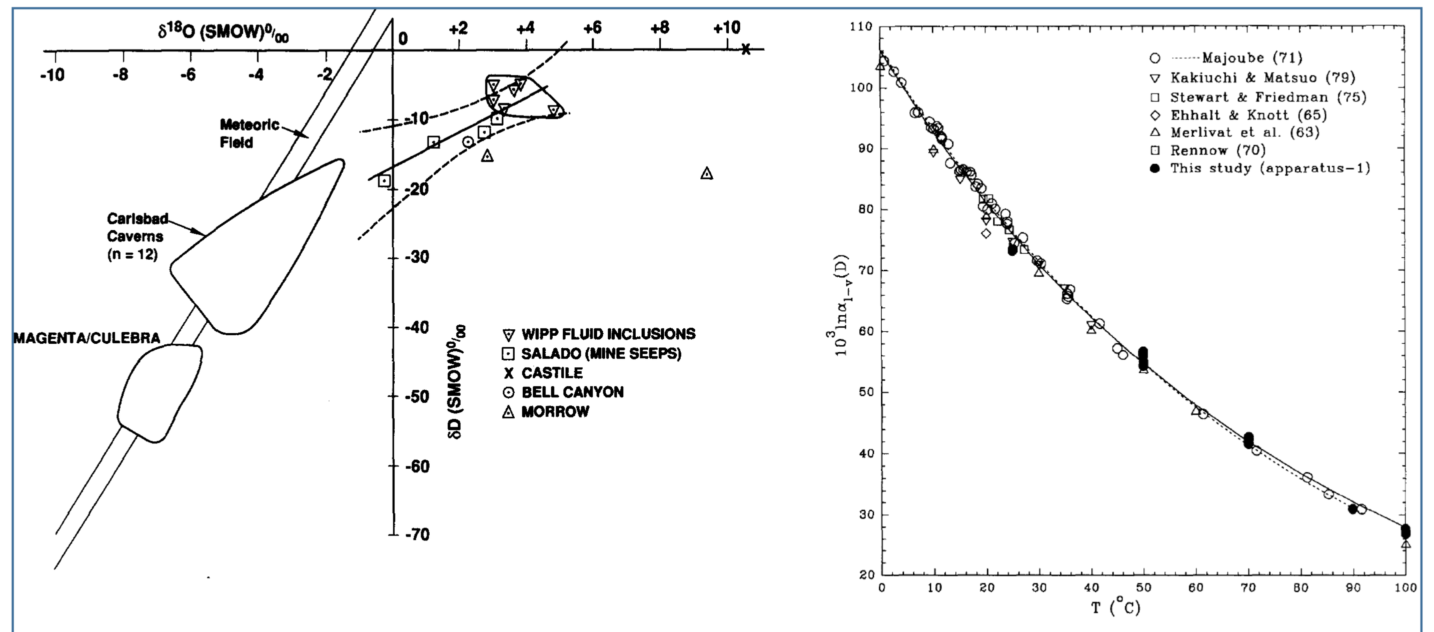
Salt formations are considered an ideal repository for heat generating nuclear waste (HGNW) due to their extremely low permeability, high thermal conductivity and self-healing capability. Uncertainties associated with brine chemistry and mobility near heat generating waste however, compel ongoing research to better understand and predict the long term behavior and evolution of storage facilities. Heat sources within salt may establish so called "heat pipes" where boiling of water vapor and subsequent condensing of steam within the formation create a multiphase convection system. While the presence of heated brine may corrode waste canisters the development of "heat pipes" may support storage efforts through the precipitation of salt around the canisters. To reduce these uncertainties and improve model forecasts for HGNW storage in salt, we are undertaking heated borehole experiments at the WIPP URL. The Brine Availability Tests in Salt (BATS) is a US Department of Energy Office of Nuclear Energy (DOE-NE) supported activity as part of the Spent Fuel and Waste Disposition (SFWD) Campaign where we are performing simultaneous heated and control experiments in adjacent horizontal boreholes in the WIPP Salt Disposal Investigation

To determine the effect of heating on movement of H_2O in salt, we are monitoring the concentration of H_2O as well as the isotopic content (^{18}O relative to ^{16}O ($\delta^{18}O$ permil)and ^2H relative to ^1H (δ^2H permil)) in continuous flow of Nitrogen through the sealed borehole. Continuous measurement of vapor phase H_2O isotopes during borehole heating will be impacted by several effects: 1) evaporation as liquid brine flows into the borehole and evaporates completely or partially into the dry N_2 stream; 2) H_2O from dehydration of hydrous minerals, that may enter the borehole; and 3) hydrous minerals that may form in the borehole (preferentially incorporating heavier isotopes).

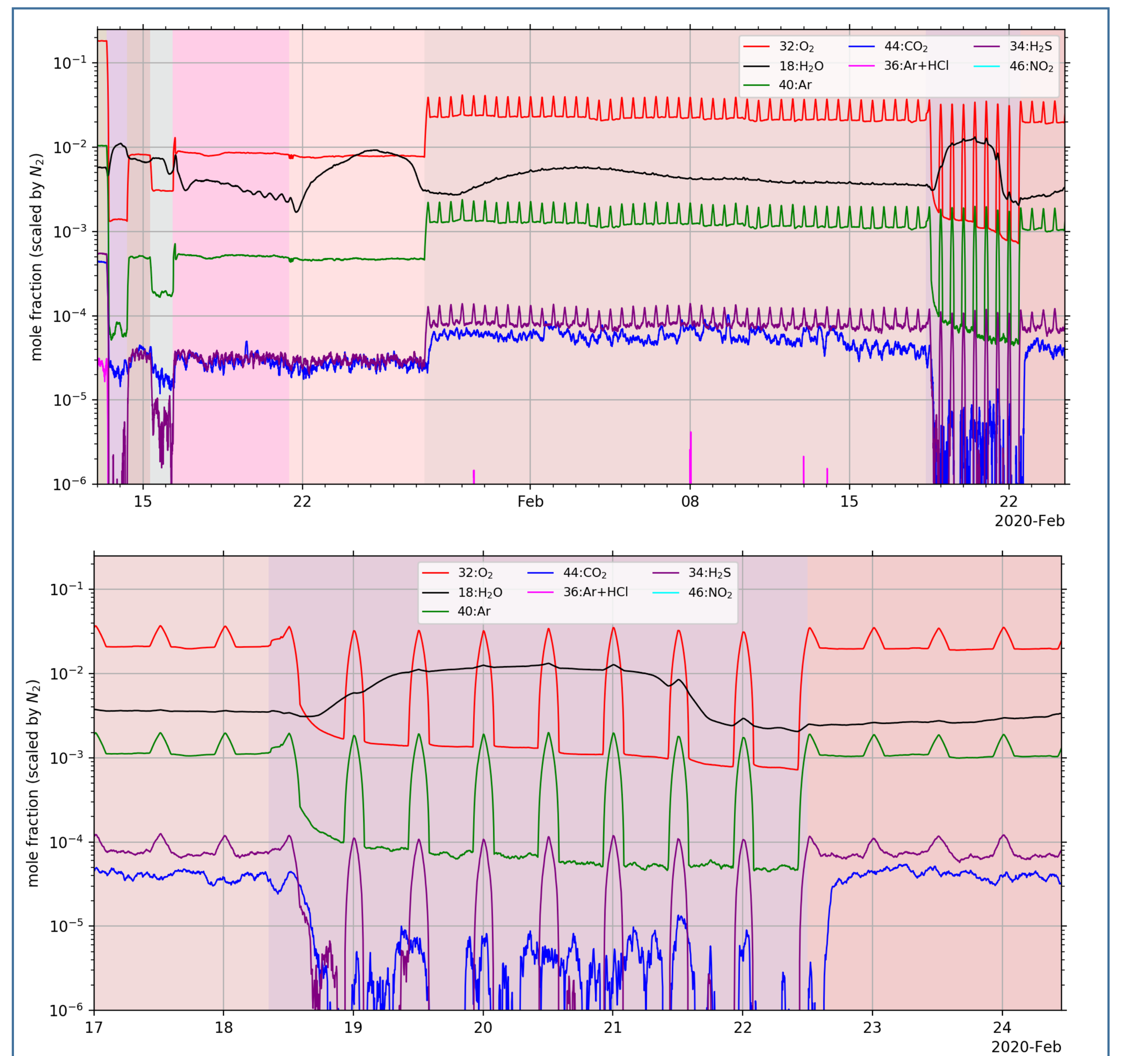


Left: H_2O vapor concentration as well as $\delta^{18}O$ and δ^2H in the heated and unheated boreholes as a function of time. Color changes indicate heater on and off as well as changes in gas flow to optimize analytical performance.

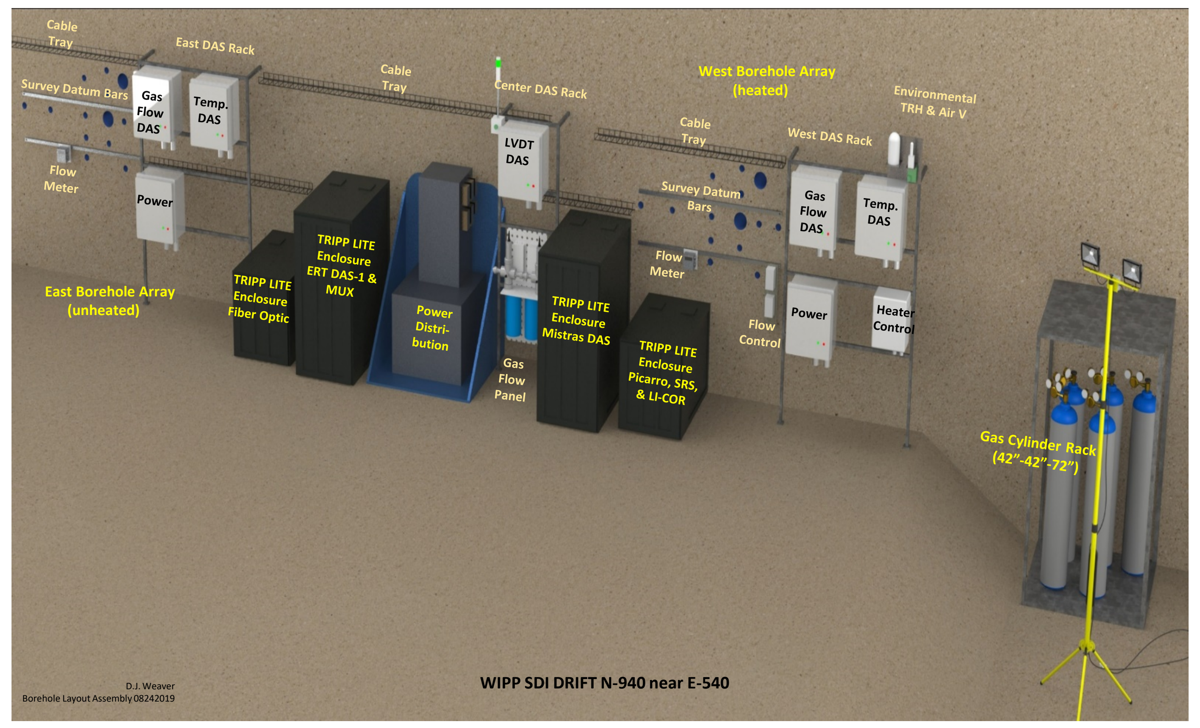
Jan-13-2020 09:38 AM # 1: gas on (2 L/min)
Jan-14-2020 07:14 AM # 2: gas -> 200 mL/min
Jan-15-2020 07:24 AM # 3: gas -> 500 mL/min
Jan-16-2020 07:23 AM # 4: gas -> 150 mL/min
Jan-21-2020 09:40 AM # 5: heat on
Jan-27-2020 08:14 AM # 6: gas reduced (H:50, U:25)
Feb-18-2020 08:15 AM # 7: heat off (leak)
Feb-22-2020 12:01 PM # 8: gas spent, leak stops



Literature values for Left: isotopic values of local natural waters (including fluid inclusions in WIPP salt) from Lambert, 1992, and Right: $^2H/^1H$ equilibrium fractionation as a function of temperature from Horita and Wesolowski, 1994.

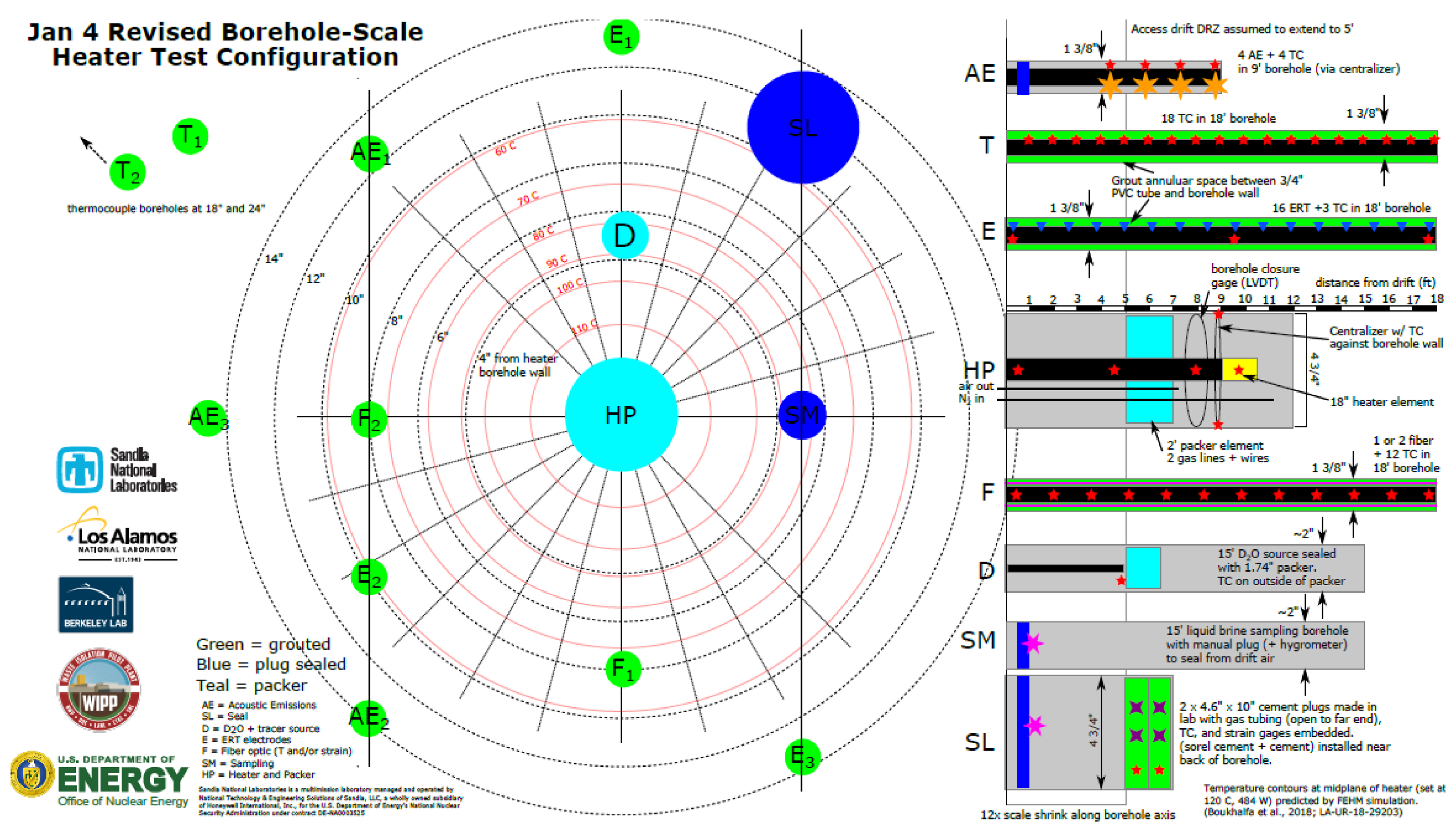


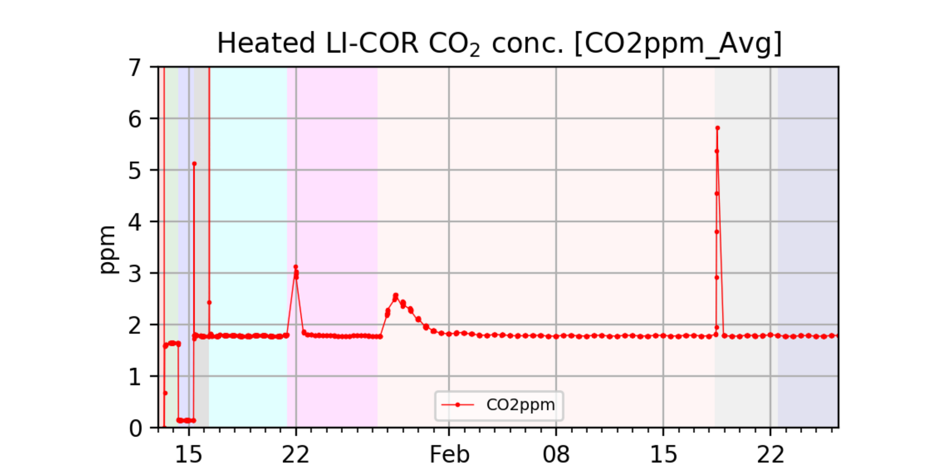
Trace gas analyses normalized to N_2. Top: Complete period of heating. Bottom: Detailed observations at time of heater turn-off.



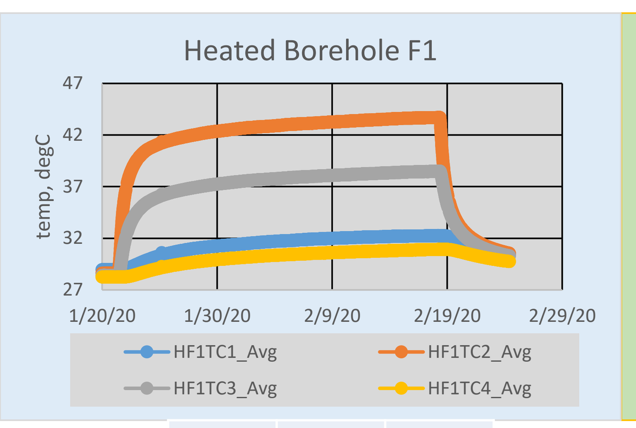
Above from left to right: Cartoon schematic of the BATS layout, photo of the heated borehole array, and insertion of the heater with the packer system.

Right: detailed schematic of the heated borehole array. Unheated array is identical except for heating element. Individual boreholes accommodate a variety of sensors, sampling capabilities or tracer introduction. HP (heater packer), AE (acoustic emissions), T (thermocouple), E (electrical resistivity), F (fiber optic,) D (tracer e.g. gas, liquid, deuterium), SM (liquid sample), SL (seal). Heating element is a 750 W helios quartz lamp.

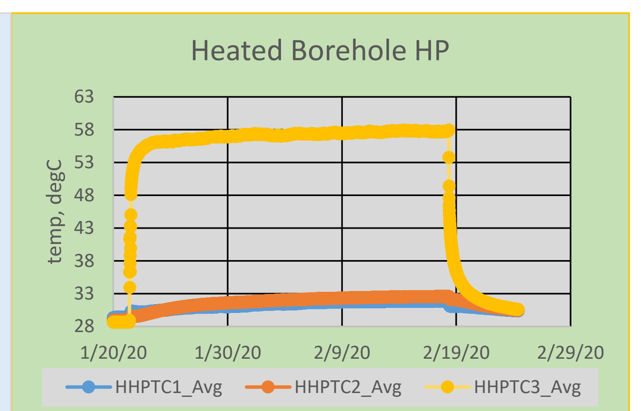




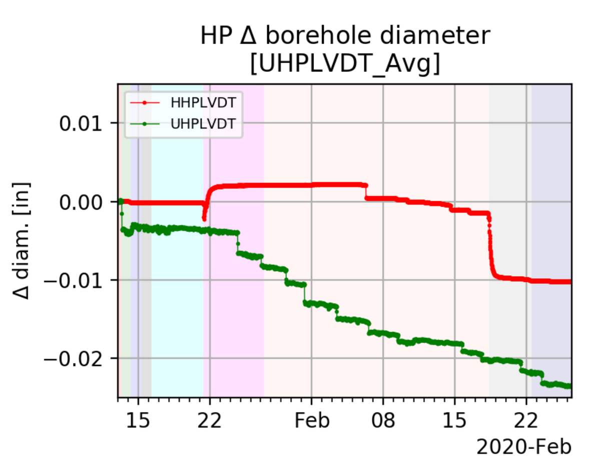
Carbon dioxide in continuous flow sample stream of the heated borehole. Unheated hole CO_2 (not shown) was constant at ~2 ppm.



	m	ft
HF1TC01	1.14	3.75
HF1TC02	2.29	7.50
HF1TC03	3.43	11.25
HF1TC04	4.57	15.00



	m	ft
HHPTC1	0.61	2.00
HHPTC2	1.22	4.00
HHPTC3	2.22	7.28



Above left and center: Example temperatures at given depths in specified boreholes under 120 degrees heating.
Above right: Borehole closure monitoring using a linear variable differential transformer (LVDT) system.

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