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U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY | SPENT FUEL & HIGH-LEVEL WASTE DISPOSITION

Brine Availability Test in Salt (BATS) FY25 Final Closeout

Spent Fuel and High-Level Waste Disposition

Prepared for

U.S. Department of Energy

Office of Nuclear Energy

By Sandia National Laboratories

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Name/Title of Deliverable/Milestone/Revision No.	Brine Availability Test in Salt (BATS) FY25 Final Closeout
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Carlos Lopez [signature] 7/7/2025

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CONTENTS

REVISION HISTORY

This report is the final FY25 closeout BATS experiment status reports.

The FY20 BATS report details construction of the BATS 1 arrays and the first round of heating (SAND2020–9034R). The FY21 report details further data collection during periods without active heating and results of gas tracer tests conducted between boreholes (SAND2021–10962R). The FY22 report detailed decommissioning of the BATS 1 heated array and construction of the BATS 2 heated array (SAND2022–12142R). The FY23 and FY24 reports described the data collection in the new BATS 2 heated array and the original unheated array from BATS 1 (SAND2023-08820R and SAND2024-12338R). This FY25 report describes the final data collection after DOE-NE canceled the work in May 2025.

Thanks to Carlos Lopez for technically reviewing the closeout report.

ACRONYMS

AE	acoustic emissions (also BATS boreholes)
BATS	Brine Availability Test in Salt
CBFO	Carlsbad Field Office
DFOS	distributed fiber optic sensing
DOE	Department of Energy
DOE-EM	DOE Office of Environmental Management
DOE-NE	DOE Office of Nuclear Energy
DSS	distributed strain sensing
DTS	distributed temperature sensing
ERT	electrical resistivity tomography
FY	fiscal year (October-September)
HP	BATS central heater/packer borehole
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratory
MPFM	multiparameter flowmeter
RH	relative humidity
SFWD	Spent Fuel & Waste Disposition
SFWST	Spent Fuel & Waste Science and Technology
SIMCO	Salado Isolation Mining Contractors
SL	BATS seal borehole
SN	serial number
SNL	Sandia National Laboratories
SRS	Stanford Research Systems
TC	thermocouple
TCO	WIPP Test Coordination Office
TRH	temperature and relative humidity
US	United States
WIPP	Waste Isolation Pilot Plant (DOE-EM facility)

SPENT FUEL AND HIGH-LEVEL WASTE DISPOSITION/SALT RESEARCH AND DEVELOPMENT

This fiscal year 2025 (FY25) closeout report summarizes the final experiments conducted and data collected in phase 2 of the Brine Availability Test in Salt (BATS 2). The design and interpretation of the test was previously funded by the US Department of Energy's Office of Nuclear Energy (DOE-NE) Spent Fuel and Waste Disposition Program, under the Disposal Research and Development (R&D) program of the Office of Spent Fuel & Waste Science and Technology (SFWST) but they are not funding it anymore (since May 2025). The experiment was located underground at the Waste Isolation Pilot Plant (WIPP), southeastern New Mexico, which is a DOE Office of Environmental Management (DOE-EM) site managed by the Carlsbad Field Office (CBFO). DOE-EM funds the WIPP Test Coordination Office (TCO), which provided critical implementation support for the continued execution of BATS. A high-level summary of processes expected in a salt repository are given in Kuhlman & Mills (2025).

1 CLOSEOUT DATA FROM BATS 2

1.1 HEATER-PACKER BOREHOLE

Dry UHP N_2 gas is circulated through the interval isolated behind the HP packer. The gas inflow location is at the back of the borehole (i.e., the inlet gas is directed to the area behind both heater reflectors through a 0.25-inch [6.4 mm] stainless steel tube), and the gas outflow location is on the back of the packer. The mass flowrate of N_2 gas into the interval behind the packer is controlled by an Omega flow controller between the N_2 gas bottle regulator (set to approximately 20 psi [1,379 mbar] gauge pressure) and the packer. The flowrate of gas out of the packer-isolated interval is measured immediately downstream of the packer with an Omega multi-parameter flowmeter (MPFM), which measures mass flowrate, temperature, and pressure.

1.1.1 HP: GAS STREAM PRESSURE AND FLOWRATE TIME SERIES

Figure 1 shows the time series of gas stream mass flowrate (i.e., the active flow controller between the gas source and the HP packer, and the passive mass flowmeter downstream of the packer) averaged every 10 minutes by Campbell CR1000X dataloggers.

The legends and titles in Figure 1 and subsequent figures use the naming convention of variables in the data spreadsheets produced by the WIPP TCO. In these variables, the BATS 2 heated or BATS 1 unheated arrays are indicated by a starting letter "H" or "U". The next letters relate to the BATS 2 borehole (in this case "HP"). Finally, "GQUp" and "GQDown" refer to gas "G" flowrate "Q" up and downstream of the packers in the heated and unheated arrays (see Figure 1).

In most time series plots, the minor tick-marks indicate weeks (each Monday). The colored dots indicate individual 10-minute average values, while lines of the same color are used to connect dots but may not be representative of the value between averages.

The colored vertical stripes are common across all time-series figures and are associated with key testing events listed in Table 1. The heating events, BATS 2h through BATS 2k, occurred in FY25; they are new since the last annual data report (i.e., below dashed line in table). The heater events are labeled with letters above the top edge of Figure 1 for clarity of explanation but are not labeled with letters on subsequent figures.

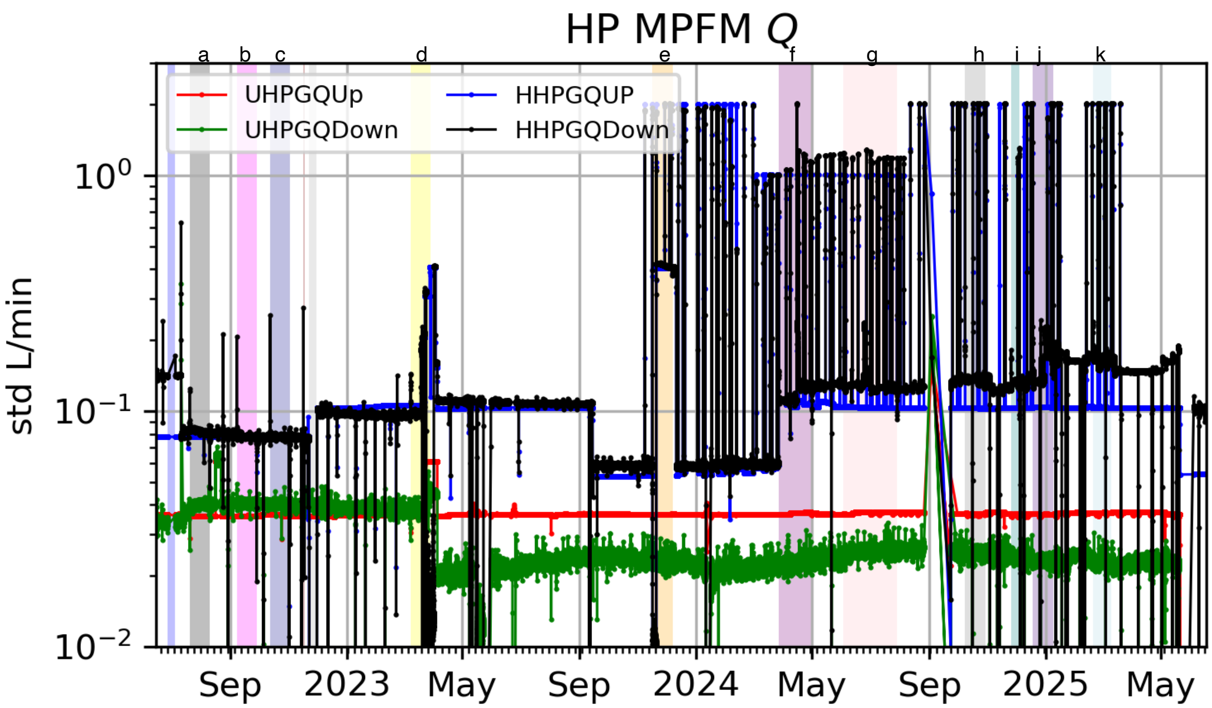

Figure 1. Gas stream mass flowrates (GQ) up- and down-stream of HP packer for heated (H) and unheated (U) arrays.

In Figure 1, the mass flowrates of gas upstream and downstream of the packers are close to the same (i.e., red vs. green for unheated; and black vs. blue for heated) during most of the data record. Since the BATS 2d test, the downstream flowrate in the unheated array (green) is slightly lower than the upstream flowrate in the unheated array, which is not as expected (the unheated array should not be impacted by the heater test in the adjacent array), but this difference is small and is accentuated because of the logarithmic y-axis scale.

In preparation for the BATS 2e heating test, the gas flowrate was increased to 400 std mL/min, considering that the last heater test, under similar conditions (BATS 2d) produced large amounts of water, which led to condensation in the circulation tubing. The flowrate was then reduced back down to "background" of 75 std mL/min after BATS 2e. At the beginning of BATS 2f, the gas flowrate was increased to 100 std mL/min and has remained there.

From late 2023 (near BATS 2e) to March 2025, the short jumps in heated array gas flowrates to 1 to 2 std L/min are times when the active sampling was being conducted in the underground using the cold trap (most of the sampling periods are 1 hour long).

Table 1. BATS 2 events associated with colored bars in timeseries figures.

Event	Color	Begin	End
Higher gas flowrate to initially dry out HP boreholes	Pink	25 Apr 2022 12:30	16 May 2022 09:00
WIPP power maintenance	Blue	27 Jun 2022 08:30	05 Jul 2022 10:15
BATS 2a heater test (90 °C setpoint – 3 weeks)	Black	20 Jul 2022 08:29	10 Aug 2022 07:38
BATS 2b heater test (115 °C setpoint – 3 weeks)	Magenta	07 Sep 2022 14:52	28 Sep 2022 08:02
BATS 2c heater test (130 °C setpoint – 3 weeks)	Dark Blue	12 Oct 2022 10:01	02 Nov 2022 11:43
HP Packer out of borehole	Gray	22 Nov 2022 09:45	30 Nov 2022 08:05
BATS 2d heater test (140 °C setpoint – 3 weeks)	Yellow	08 Mar 2023 09:20	29 Mar 2023 09:36
BATS 2e heater test (140 °C setpoint – 3 weeks)	Orange	16 Nov 2023 09:42	07 Dec 2023 11:37
BATS 2f heater test (140 °C setpoint – 5 weeks)	Purple	27 Mar 2024 08:34	01 May 2024 09:33
BATS 2g heater test (140 °C setpoint – 8 weeks)	Peach	03 Jun 2024 08:34	29 Jul 2024 09:34
BATS 2h heater test (140 °C SP – 2 outages)	Dark Gray	08 Oct 2024 10:10	29 Oct 2024 08:00
BATS 2i heater test (140 °C SP – ramped cooldown)	Teal	25 Nov 2024 08:37	04 Dec 2024 09:17
BATS 2j heater test (140 °C SP - aborted)	Indigo	18 Dec 2024 09:07	08 Jan 2025 12:37
BATS 2k heater test (140 °C SP –ramped cooldown)	Light Blue	19 Feb 2025 07:53	10 Mar 2025 9:24

Figure 2 shows the time series of air pressure in the tubing between the packer and the switching solenoids for the heated and unheated arrays measured at the MPFM and averaged every 10 minutes on the Campbell dataloggers. The cold-trap sampling periods are also clearly visible in the pressure data. The combination of higher gas flowrate and different plumbing for the cold trap result in a higher gas pressure in the system. Earlier samples from the cold trap (before March 2024) were conducted at gas flowrates of 2 std L/min, which resulted in the highest observed gas pressures.

Figure 3 shows the time series of air temperature in the tubing upstream and downstream of the HP borehole packer (upstream of the now-fixed switching solenoids), measured at the MPFM and averaged every 10 minutes on the Campbell dataloggers. Gas stream temperatures show effect of changes in ambient drift temperature, with few significant additional fluctuations visible.

In January 2024, there was a drop in circulation gas temperature (the minimum temperature is 22 to 23 °C), at a time when the flowrate dropped below 0.01 std mL/min in both arrays.

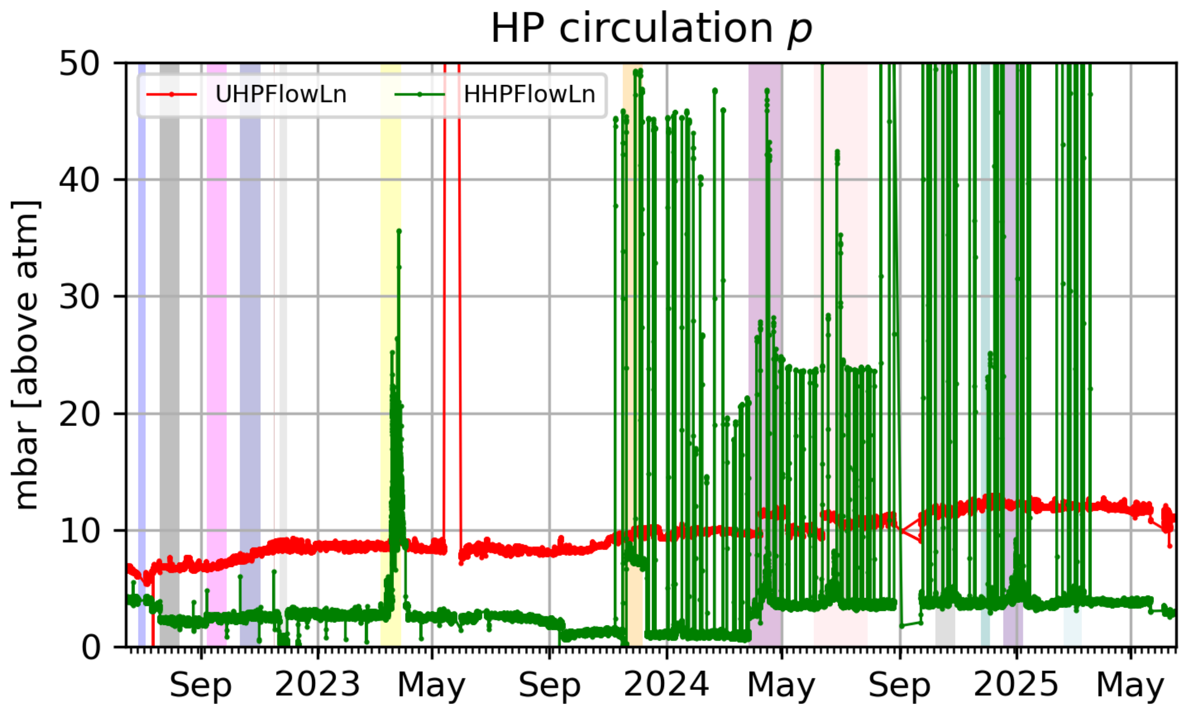

Figure 2. Gas stream pressure downstream of HP packers; “FlowLn” in legend indicates flowline.

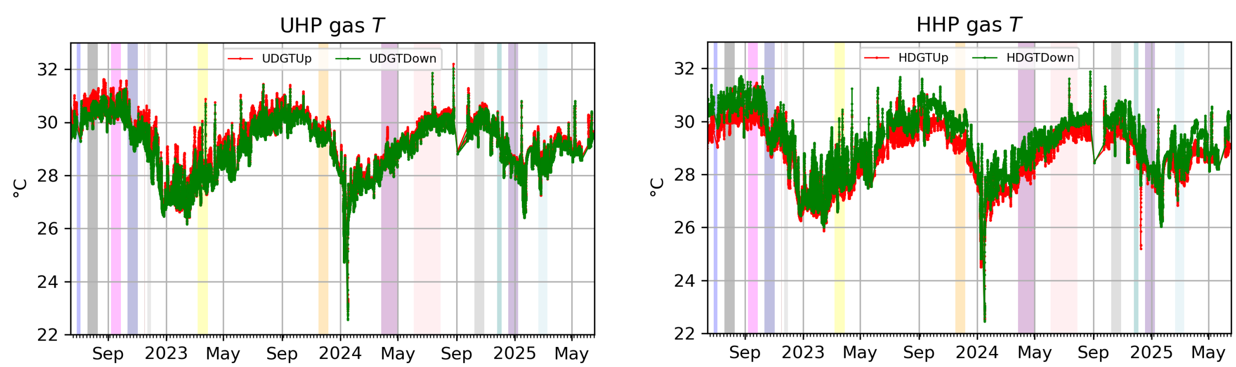

Figure 3. Gas temperature up- (red) and down-stream (green) of HP packers (unheated array left, heated array right).

1.1.2 HP: WATER CONTENT TIME SERIES

Water production from the HP gas stream is estimated using data from multiple observations made in the HP gas stream. Descriptions and assumptions for water production and the system are as follows:

- The gas flowing into the packer-isolated interval is assumed dry (UHP N_2; less than 10^{-5} volume fraction water).
- The gas mass flowrate leaving the HP packers is measured by MPFM. The water concentration in this gas stream is measured using two different instruments:
    - two LI-COR 850 instruments (both heated and unheated) recording water concentration data at 10-minute averages (Figure 4 and Figure 5).
    - both branches of the gas system have Campbell EE181-L TRH probes measuring in-line air temperature and RH at 10-minute average (Figure 6) before and after desiccant canisters on each branch.
- Desiccant canisters are weighed once or twice weekly (Figure 7) to measure the total mass of water leaving the borehole system.

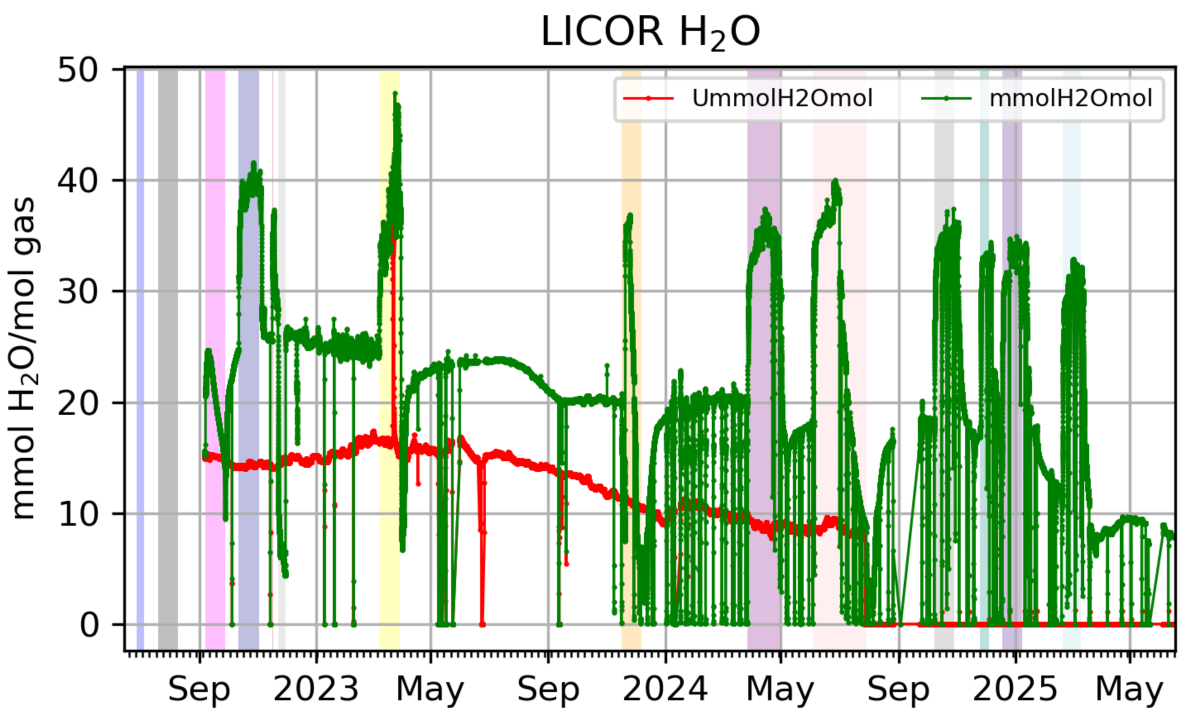

Figure 4. LI-COR water concentrations. Red is unheated array; green is heated array. No initial capital letter is heated array, leading “U” is unheated.

The water concentrations reported by the LI-COR (Figure 4) show higher water concentration during the BATS 2 heater tests, and lower concentrations between tests. In heater tests BATS 2c, d, and f, the higher water concentration lasted for the entire heating period (3 weeks for BATS 2c and d, and 5 weeks for BATS 2f). In other heater tests (b and e) water concentration dropped after a 2-3 weeks of heating. In the longest and most recent heater test (BATS 2g), the water concentration dropped to levels below the typical background observed between tests.

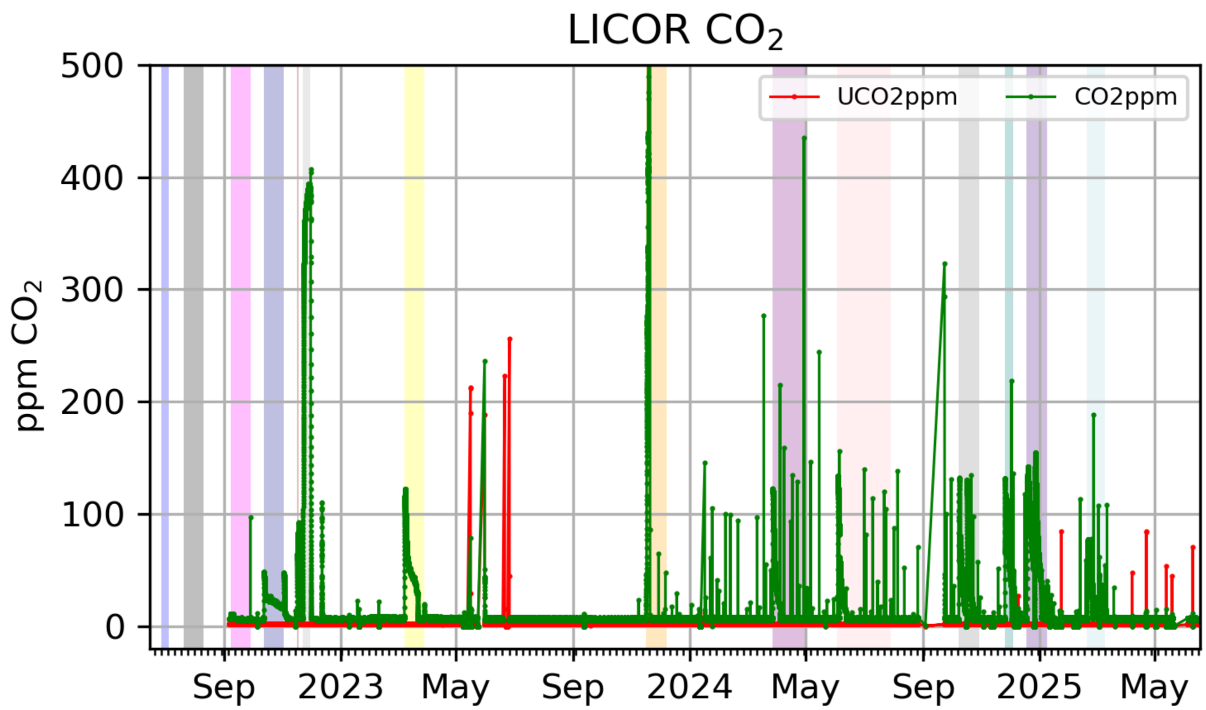

Figure 5. LI-COR CO_2 concentrations. Red is unheated array green is heated array. No initial capital letter is heated array, leading "U" is unheated.

The LI-COR also measures CO_2 concentrations (Figure 5), which were at approximately atmospheric levels while the heated HP packer was out of the borehole (400 ppm), as expected. At the beginning of multiple heating tests, the CO_2 concentrations spike, then rapidly decay. At the beginning of BATS 2e there was a very high peak (green values extend beyond the graph to approximately 2500 ppm), which is believed to be erroneous or possibly due to some other effect on the sensor (e.g., water condensation). These spikes and decays likely are caused by CO_2 desorbing from the borehole wall or exsolving from brine at elevated temperatures.

During cold trap sampling events, the CO_2 level rose for one 10-minute measurement, which is likely due to atmospheric gas (~400 ppm CO_2) in the cold trap being flushed through the system when the cold trap sampling is started.

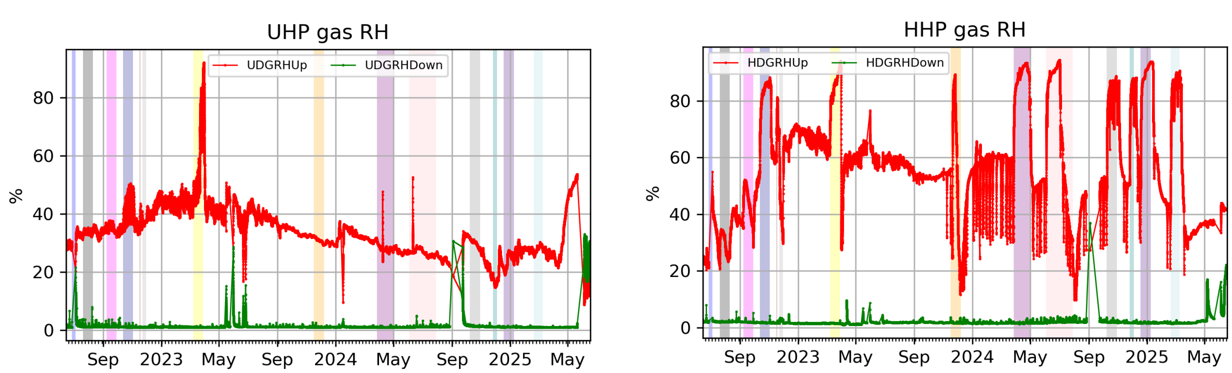

Figure 6. RH up- (red) and down-stream (green) of the unheated array (left) and heated array (right) desiccant.

Relative humidity (RH) time series are measured both upstream and downstream of the Drierite desiccant canisters (Figure 6). These RH sensors are downstream of the second set of solenoid valves, which are now no longer switching in the updated plumbing system (see Section 3.1.1). The upstream RH in the unheated array was elevated at the end of BATS 2d (and to a lesser degree during BATS 2c). The downstream RH is mostly ≤ 1% (green curves).

The desiccant water production data are presented graphically in Figure 7. The unheated array produced similar water concentration in air from the heated array. From October 2023 through May 2025, the two arrays produced approximately the same concentration of water vapor. The heated array produced a higher concentration of water in produced air during unheated periods from October 2022 to October 2023 (see aqua-colored horizontal bar) and during the last heater test (March 2025). Near the end of the elevated water production period in the heated array (August and September 2023), the water production rate dropped even lower, before recovering to approximately the same rate observed in the unheated array (see purple colored bar).

At early times the newly drilled BATS 2 heated array was producing more brine because the boreholes were fresh (boreholes are drilled with air, but the fresh salt produces more brine initially). After BATS 2b (and even more between BATS 2c and 2d) brine production likely increased due to induced damage from heating and cooling cycles.

The unheated array showed a spike in water production during BATS 2d (see yellow vertical bar in Figure 12), which is like the data seen in the RH sensors and LI-COR during this period. This supports the hypothesis that some of the large amount of water produced during this test went into the unheated array tubing. Water concentration in the unheated array rose to levels in the heated array (~0.025 g H_2O/L air) near the end of the BATS 2d heating period. This is believed to be an artifact or leakage between the two branches through the switching solenoids.

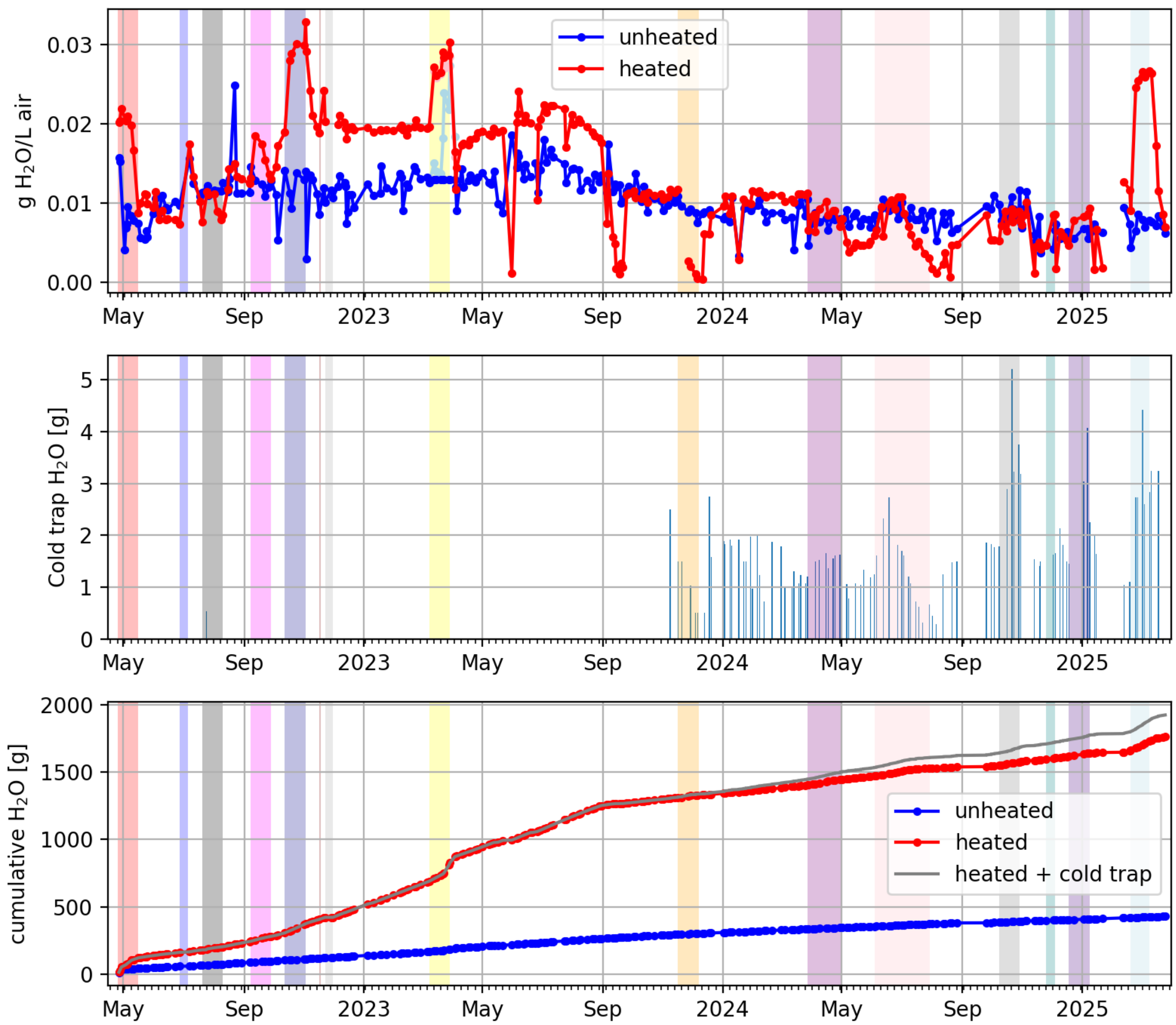

Figure 7. Desiccant water production as instantaneous concentration (top), cold trap sampling events (middle), and desiccant water production as cumulative mass (bottom) data.

1.1.3 HP: GAS COMPOSITION TIME SERIES

The SRS QMS-200 gas analyzer monitors the gas stream for compositional changes with time. The gas analyzer is operating in "P vs. T" mode, which monitors the signal at ten specific values of mass divided by charge (i.e., m/z), using the Faraday cup sensor. Figure 8 shows the relative reported ion current for three key gases, normalized by the ion current reported for N_2 (to adjust for differences in pressure of the input gas stream). Assuming N_2 concentration is near 1, the normalized ion current then is essentially the volume fraction of each gas in the overall stream. Argon is added to the system behind the heated D borehole packer, while CO_2 and H_2O are not added to the system.

In August 2023, the SRS QMS-200 gas analyzer failed, and it was swapped out with a different version of the same piece of equipment, while the original unit was sent back to the manufacturer for repairs.

Figure 8 shows the normalized signal associated with CO_2 (m/z=44), Ar (m/z=40), and H_2O (m/z=18). For each of the BATS 2 heating tests shown in Figure 8 (BATS 2e, f, and g) there is a clear peak of argon after heating has ended, when argon gas pressurized behind the HD has flowed to the HHP borehole, once the permeability changes due to contraction associated with cooling.

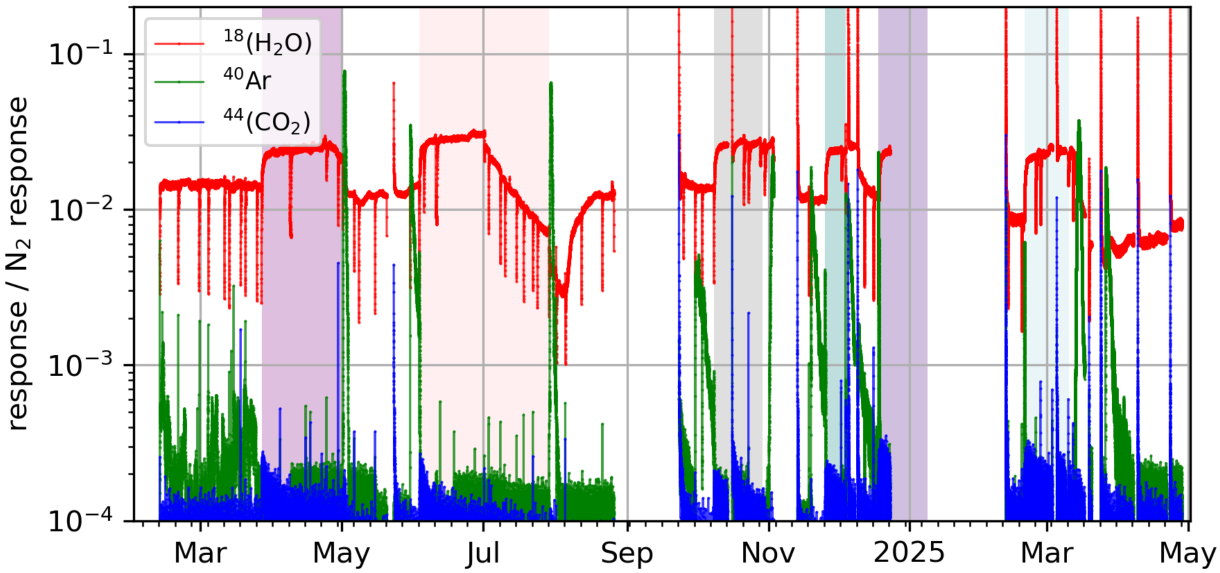

Figure 8. SRS gas analyzer data since February 2024. Heated array data shown.

The very high CO_2 levels observed in the LICOR instrument at the beginning of BATS 2e (Figure 5) do not similarly show up in the observations made with the SRS gas analyzer, supporting the statement that these LICOR measurements are likely erroneous. The rise and slow decay of CO2 in heating tests BATS 2f and g are also visible in the SRS gas analyzer data.

Short drops in water concentration shown in Figure 8 are associated with cold trap sampling times. Some of these times (but not all) also have increases in Ar and CO_2 signals, assumed to be due to the small amount of atmospheric air inside the cold trap when it is first connected at each sampling.

Figure 9 shows a more detailed plot (x-axis minor tick marks are every 12 hours) of the gas analyzer results around the four BATS 2 heater tests that have occurred since the last FY24 report in August 2024. BATS 2h and BATS 2k both successfully ramped down the heater power at the end of heating (1 degree C per hour), which delayed the breakthrough of argon from the heated D borehole. The temperature in the heated F2 borehole (TC2) is plotted to illustrated both the slower cool-down in these tests, and show when heating was interrupted (Table A-2).

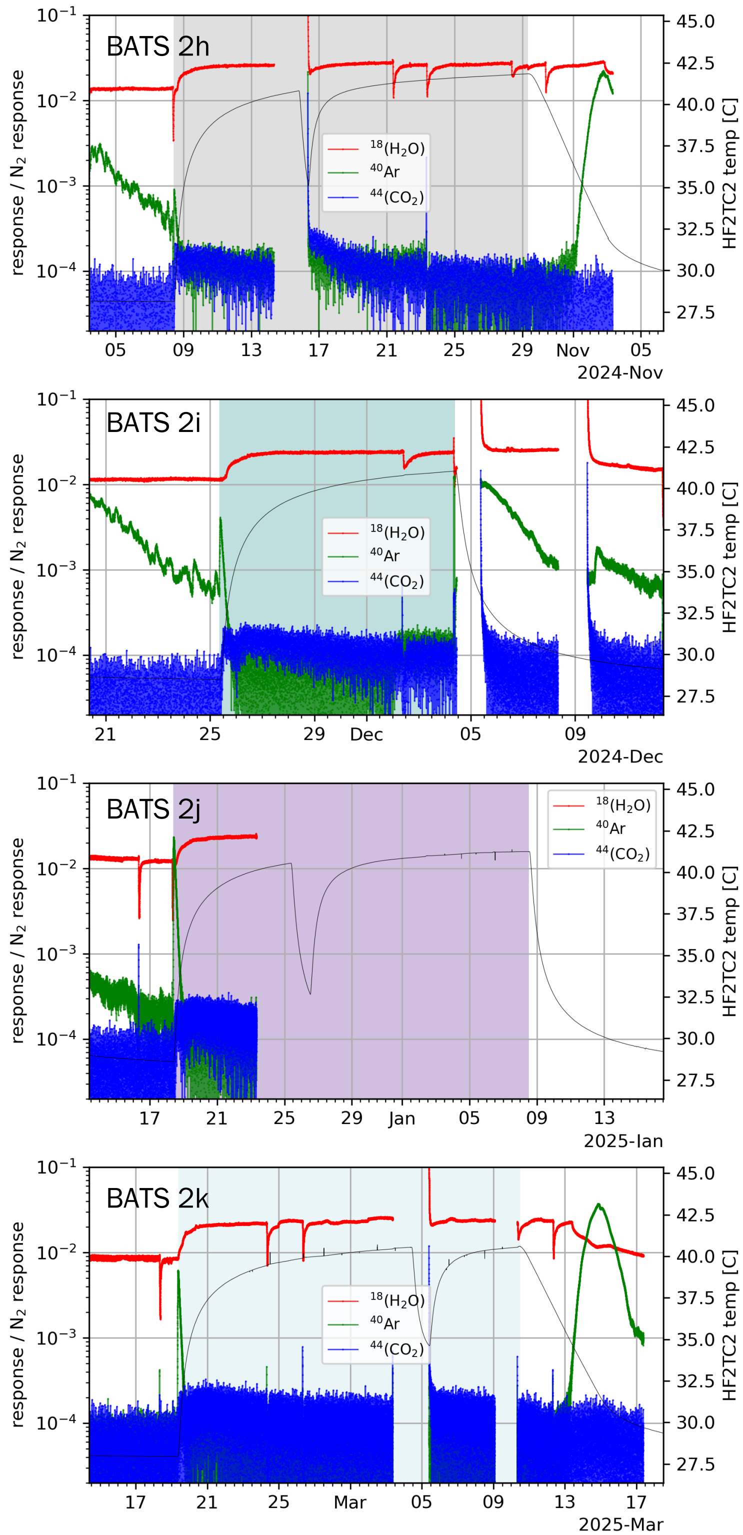

Figure 9. SRS QMS-200 data for heater tests BATS 2h through BATS 2k. Thin black line is temperature at HF2TC2. Breaks in data are associated with power interruptions.

1.1.4 HP: HEATER POWER AND TEMPERATURE TIME SERIES

The heater controller reports applied current and voltage, apparent heater resistance, and power to the heater (Figure 10). These data are critical to characterizing the applied thermal boundary condition in numerical modeling. The controller also reports the temperature at thermocouples inside the borehole used to control and provide a high temperature safety limit for the heater. In the upper-left subplot of Figure 10, 4TC_C_SP_Max (green) gives the temperature observed on the setpoint thermocouple, while 4TC_C_SP (red) gives the setpoint; they only differ when the borehole is hotter than the heater (i.e., between heating events). Only the heated array HP borehole is collecting this time series.

The power measured by the heater controller can be confirmed by using either $P = VI$ (power from potential and current) or $P = I^2R$ (power from current squared and resistance). Both checks give similar values to those reported directly by the controller, providing some confidence in the internal consistency of the measurements. The heater element resistance increases slightly (33.5 to 34.75 ohm) during the first four heater test episodes but then holds constant, which is a sign the heating element is still behaving nominally. Most of the heater controller parameters (aside from thermocouples) are only reported or only make sense when the heater is on (i.e., the setpoint is greater than the ambient temperature).

The most recent heater tests (BATS 2e through k) had the same temperature setpoint (140 ºC), but the limit thermocouples reported decreasing. This disparity between the temperature at the controller and limit thermocouples may be due to their arrangement and position in the borehole, and how well they contact the borehole wall. See Figure 11 for plot showing a detail associated with most recent tests, where ramping down of heater power in BATS 2 h and k are visible.

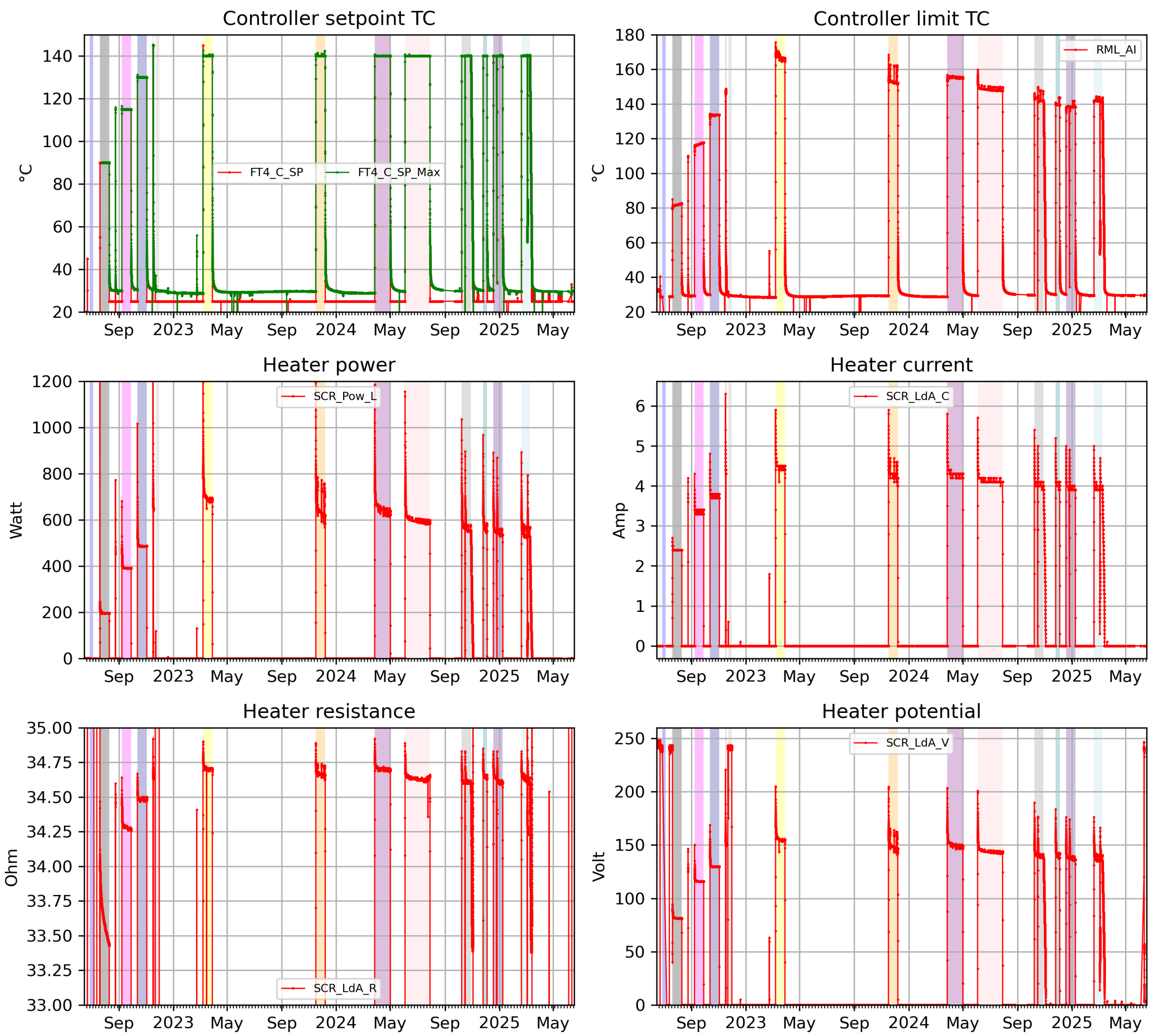

Figure 10.All BATS 2 power controller data.

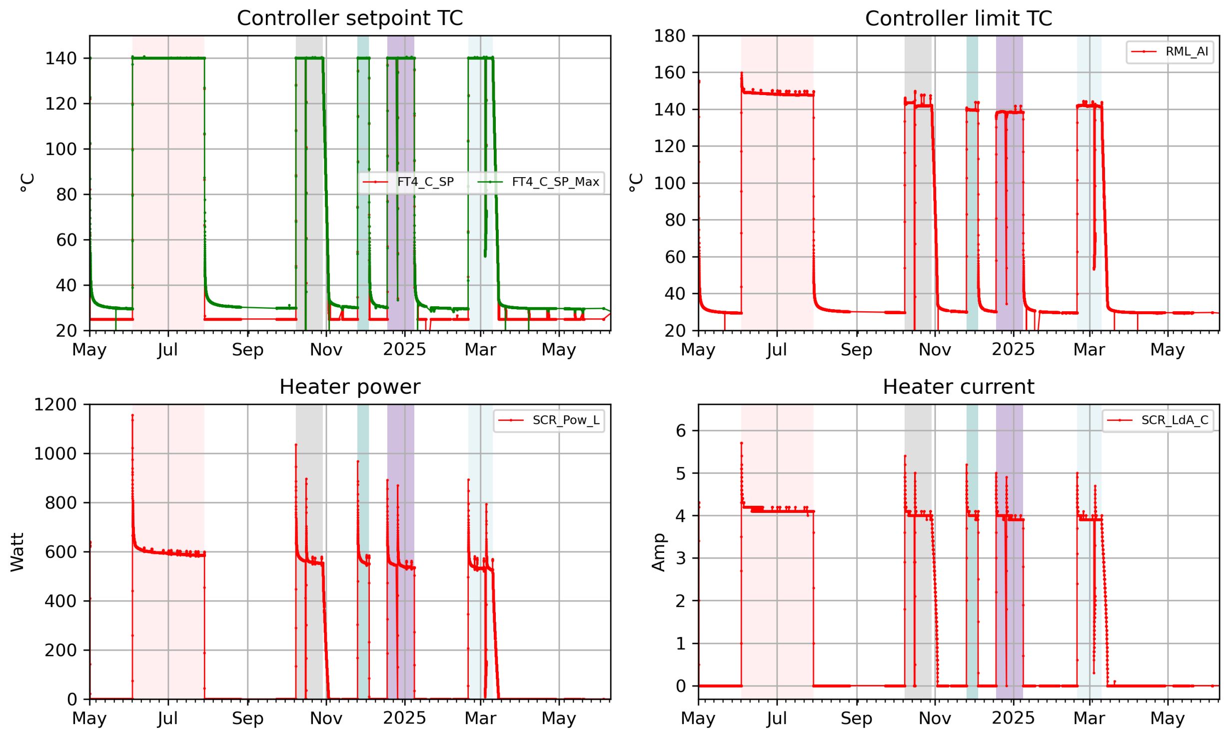

Figure 11. BATS 2 power controller data since May 2024.

1.2 D: CONTINUOUS GAS PRESSURE TESTING

The interval behind the inflatable IPI packer in the D borehole was pressurized to approximately 20 psi [1.4 bar] above atmospheric pressure and closed in (i.e., disconnected from the inflation tank). The packer inflation pressure (roughly 80 psi [5.5 bar] above atmospheric) and the pressure of gas in the interval behind the packer are both monitored. Figure 12 shows the gas pressure behind the packer in the D borehole through time.

The slow decrease in pressure behind the D borehole between heating events (Figure 12) can be used to constrain the interval relative gas permeability, which appears to sometimes increase (i.e., steeper declines) and sometimes decrease. Interpretation of these data is more complex than interpreting single-phase pressure decline since this is movement of gas through a variably brine-saturated fracture system. Gas pressure decline is sensitive to the gas relative permeability of the interval. The relative permeability might change due to fractures mechanically opening and closing (i.e., changes in absolute permeability due to thermal expansion and contraction) or due to changes in brine content in fractures (i.e., changes in relative permeability due to migration of liquid).

The rise in pressure during the BATS 2 heater tests is expected due to essentially heating a closed container of gas (i.e., permeability is low enough to prevent significant gas leakage).

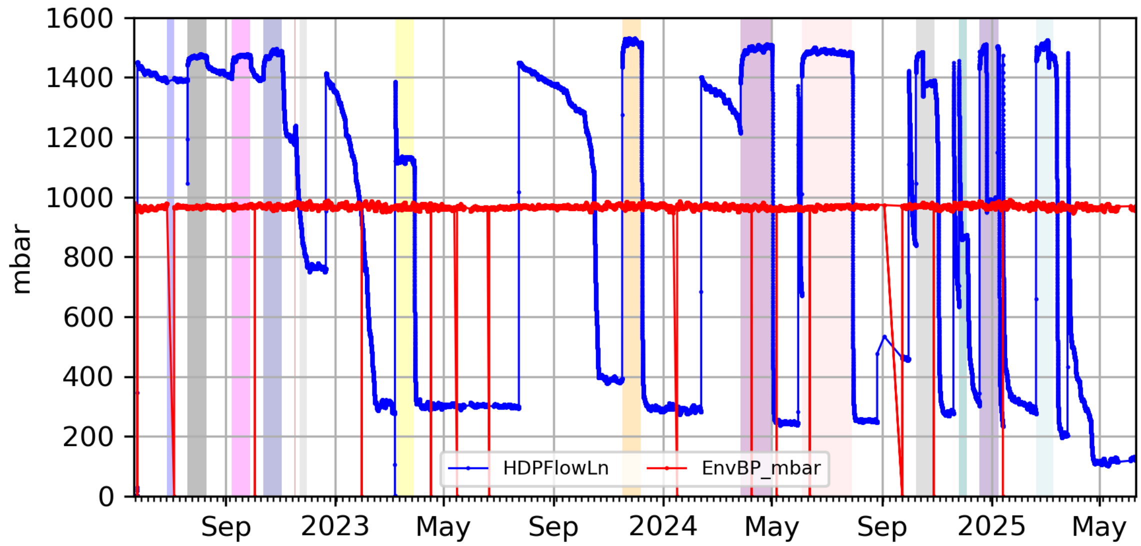

Figure 12. Interval gas pressure (above atmospheric) for heated D borehole and barometric pressure on same scale.

Adding the atmospheric pressure measured in the drift (red line in Figure 12) to the gauge gas pressure measurement behind the packer in the heated D borehole (blue line in Figure 12) produces the absolute pressure (Figure 13), where most of the high-frequency daily fluctuations are now canceled out. Fluctuations of the same magnitude and opposite direction occur in the atmospheric pressure data and the heated D borehole pressure data.

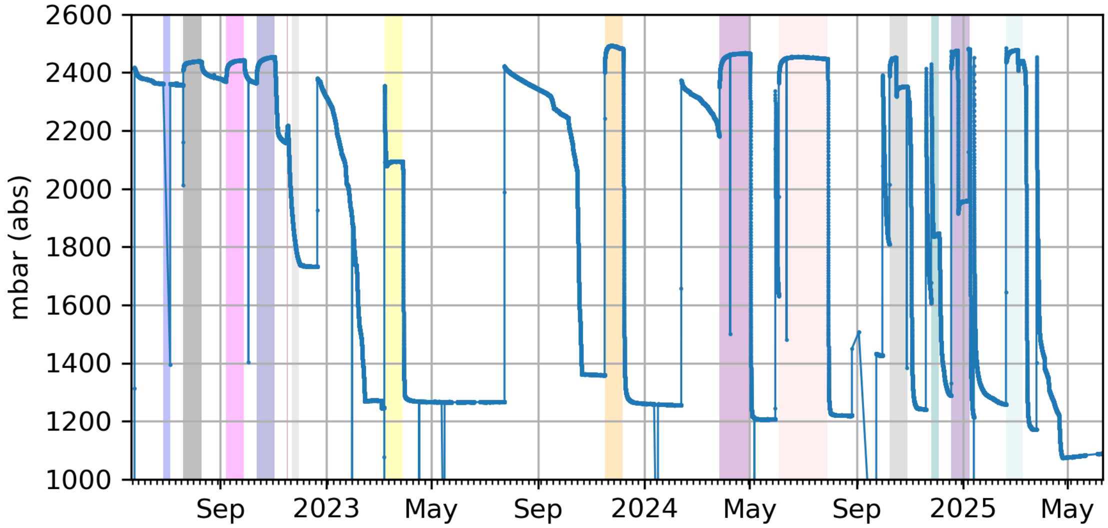

Figure 13. Interval gas pressure (absolute) for heated D borehole.

Figure 14 shows the D borehole gas pressure response for the most recent heating events. The data are plotted along with the temperature in a nearby borehole, to illustrate the effects of heating and different cooling rates more clearly.

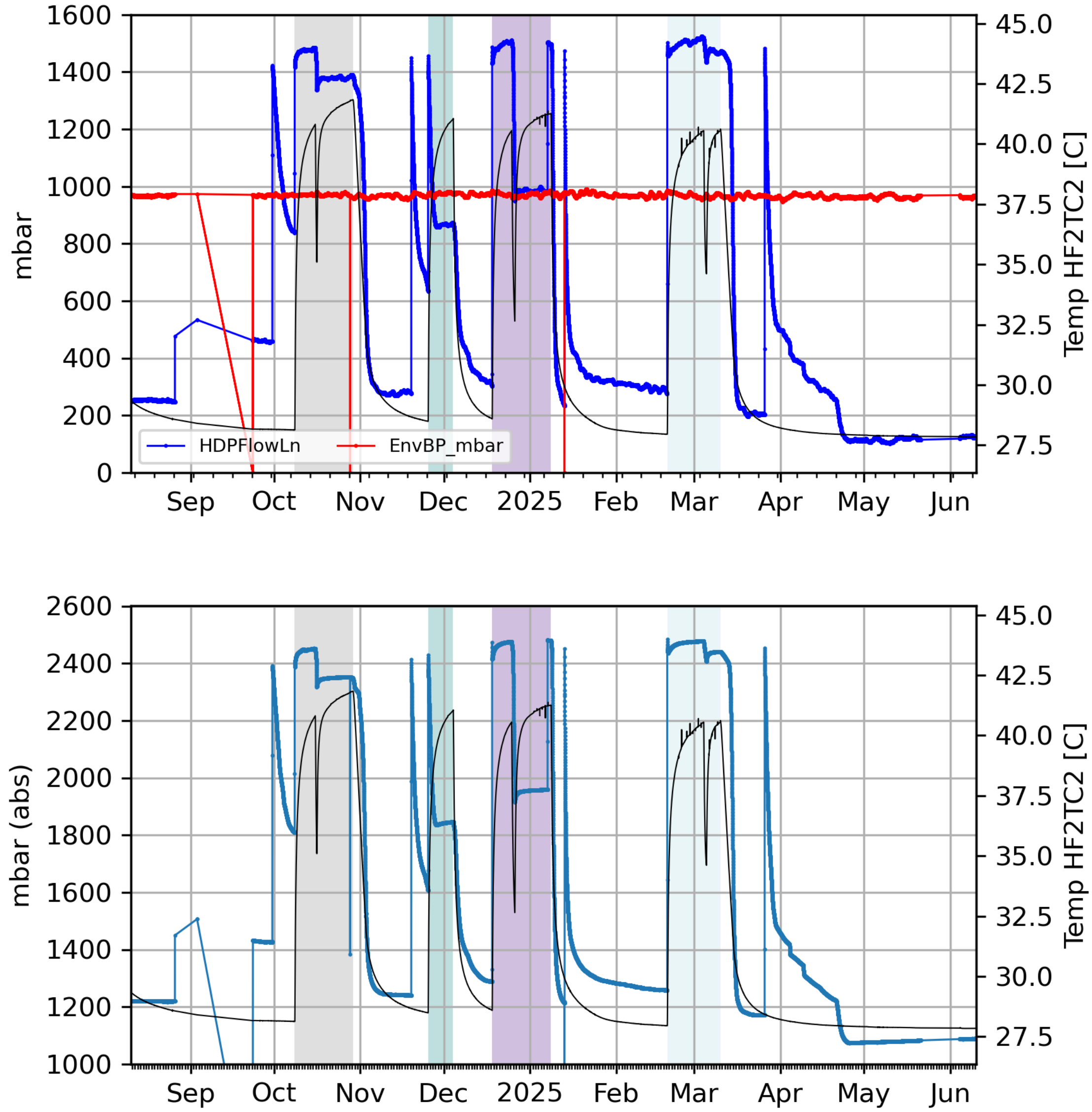

Figure 14. Interval gas pressure (gauge, top; absolute, bottom) for heated D borehole. Temperature in nearby borehole shown in thin black line.

1.3 AE: DATA FROM BATS 2 HEATED AE BOREHOLES

Acoustic emission (AE) data presented here was recorded in the heated BATS 2 array from October 31, 2023, until March 30, 2025. Data recording spans 7 thermal cycles and 101 days of power outages or other gaps in recorded data. Of the 16 channels originally installed in March 2022, 13 channels remain functional. Daily recordings have been compiled and filtered to remove noise from electrical interference associated with the ERT system and mining activity. Data has been filtered to ensure that at least 50% of the total energy of every AE hit recorded must be withing the 10 – 250 KHz frequency band. Data not meeting this requirement is discarded from filtered datasets. Data is further filtered with an elevated threshold of 45 dB, up from 31 dB at the time of recording. Over 350,000 AE hits remain after filtering. Cumulative hits can be seen in Figure 15, and daily AE counts can be seen in Figure 16. AE accumulates throughout the year, with rapid increases in activity associated with the onset and cessation of heating. There is a small increase at the onset of heating, and a much larger increase at the beginning of cooling, or when the active heating stops (Figure 15).

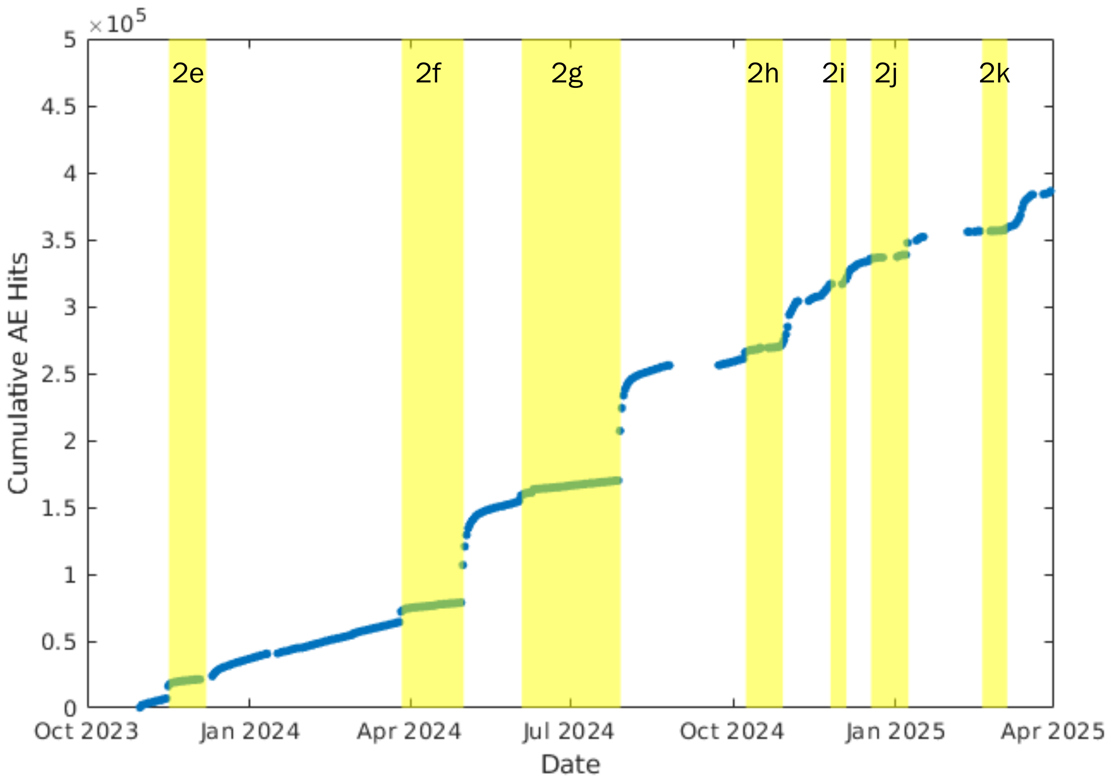

Figure 15. Cumulative AE hits over time for BATS 2 heater tests. Heated periods are marked in yellow and labelled.

Daily rates increase at the onset of heating and further increase at the onset of cooling (Figure 16). Rates briefly spike at the onset of heating, before decreasing to levels below background levels. At the end of heating, AE rates spike again but remain elevated over time after decay. Both heating and cooling decays can be fit by a power law relationship:

$$\text{Daily AE rate} = A * (\text{Days since change})^{b}$$

The power law relationship was fit as a function of days since previous change, or the days held at a given heater output. Values for parameter of the power law fit are in Figure 17, Figure 18, and Table 2. Data was fit to the first seven days of data after a thermal change, depending on data availability with power outages. Onset of cooling and onset of heating are treated separately. The data is usually well described by the power law fits (R^2>0.95), but cooling data from heater events 2h, 2i, and 2k do not follow power law distributions. Additionally, heating data is missing from heater events 2i and 2k. Figure 17 shows a positive relationship with *A* values and days since previous change. *A* values slightly increase for heating data and dramatically increase for cooling data. *b* values show an inverse relationship with days since previous change (Figure 18). Heating values decrease gradually, and cooling values have significant decrease with days since previous change. The power law parameters can be fit with log relationships to days since previous change. Heating data is well fit by the relationship, but R^2 values are low for cooling data, reflecting scatter in the cooling data. The relationship indicates that for longer duration hold times, it would be expected to have stronger surges in AE rate at the onset but faster decays. Cooling data has predicted stronger surges and slower decays than heating, but cooling would be expected to decay faster when heating intervals exceed two months.

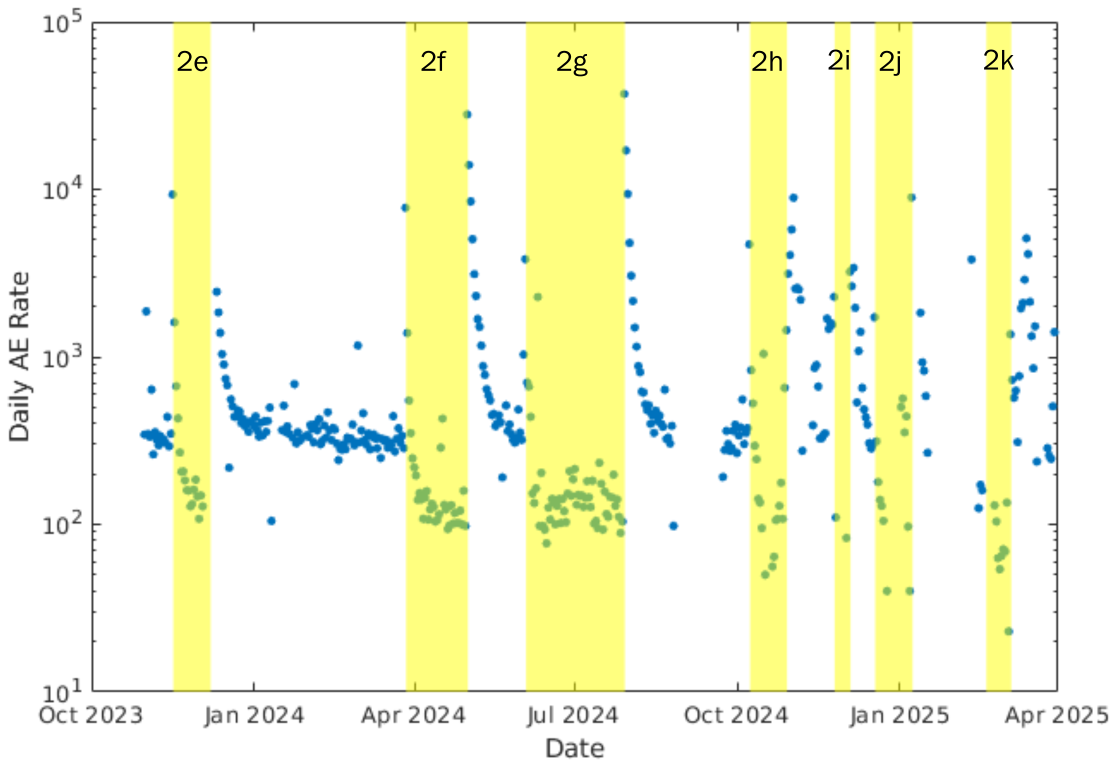

Figure 16. Daily AE hit rate for BATS 2 heater tests. Heated periods are marked in yellow and labelled.

Table 2. Power law fits for AE rate decay.

BATS 2 heating event	Date	A	b	R^2	Days from Previous Change
2e	11/16/2023	7436.2	-2	0.994	240
	12/7/2023	37050	-1.69	0.997	21
2f	3/27/2024	5943.9	-1.911	0.992	111
	5/1/2024	34090	-1.464	0.974	35
2g	6/3/2024	3336.2	-1.686	0.979	33
	7/29/2024	46345	-1.678	0.974	56
2h	10/8/2024	3847.9	-1.793	0.988	71
	10/29/2024	7607.1	-0.859	0.08	21
2i	11/25/2024	--	--	--	27
	12/4/2024	3969	-0.682	0.526	9
2j	12/18/2024	1250	-1.512	0.969	14
	1/8/2025	9579.2	-1.161	0.991	21
2k	2/19/2025	--	--	--	42
	3/5/2025	1166.6	-0.516	0.708	14

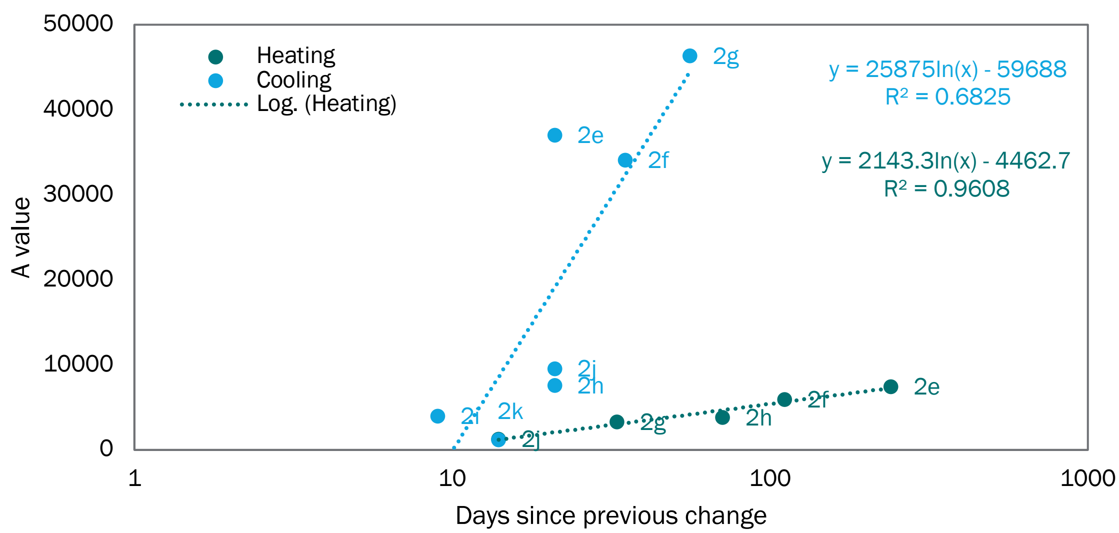

Figure 17. Calculated A values for heating and cooling events for AE rate decay.

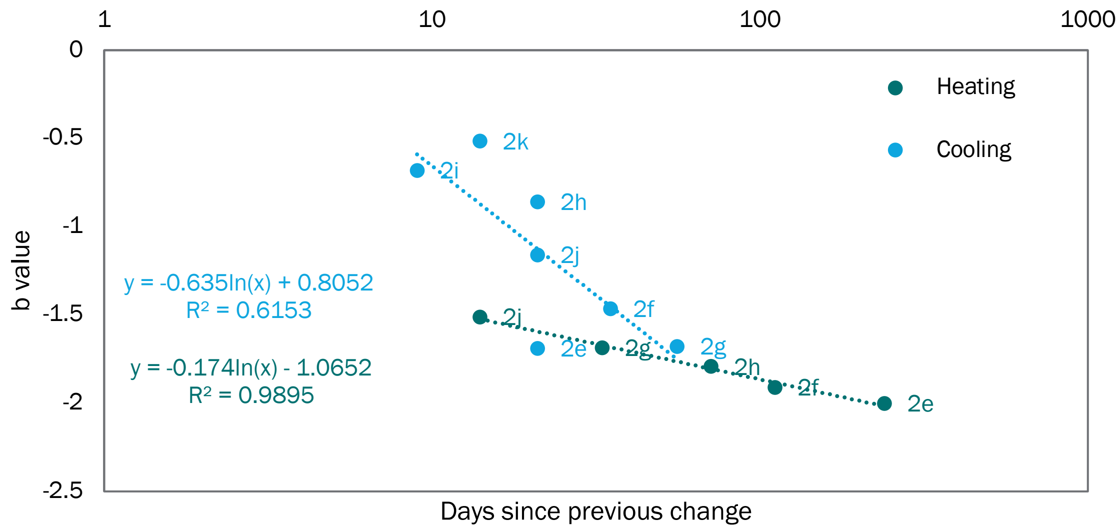

Figure 18. Calculated b values for heating and cooling events for AE rate decay.

The average signal level (ASL) is a measure of the continuously varying amplitude that has been averaged over a 500 msec time window. ASL increases with changes in heater output Figure 19. At the onset of heating, there is a short-lived increase in ASL. At the onset of cooling, the is a more pronounced increase in ASL. Like daily AE rates, ASL reach levels below background levels during heating (Figure 17, Figure 19)

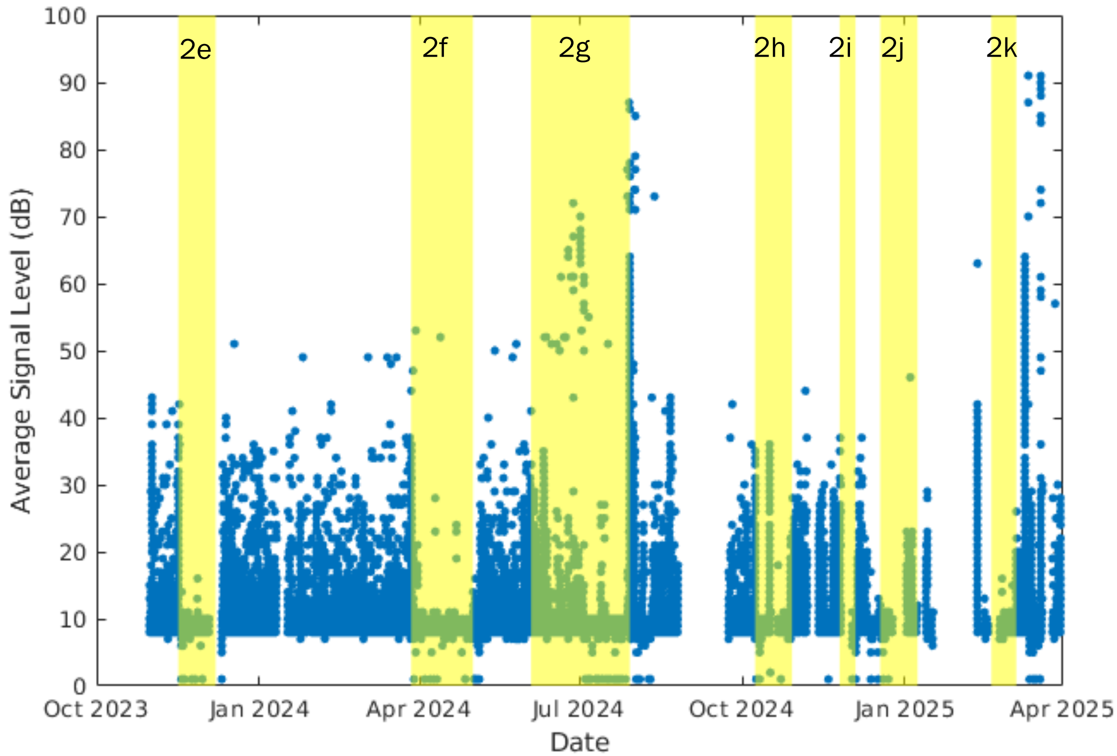

Figure 19. Average signal level (dB) for BATS 2 heater tests. Heater periods are marked in yellow and labelled.

The frequency centroid is derived from fast Fourier transforms on recorded waveforms and represents the average frequency based on the energy of frequency bands. At the onset of heating, the frequency centroid briefly increases its range before reducing for the duration of heating (Figure 20). Both high and low ends of the frequency spectrum decrease. At the onset of cooling, the range of the frequency centroid increases. Both high and low ends of the frequency spectrum increase, with sharp increases in the high frequency content. Frequency content decays to background level but stays broader than heating cycles.

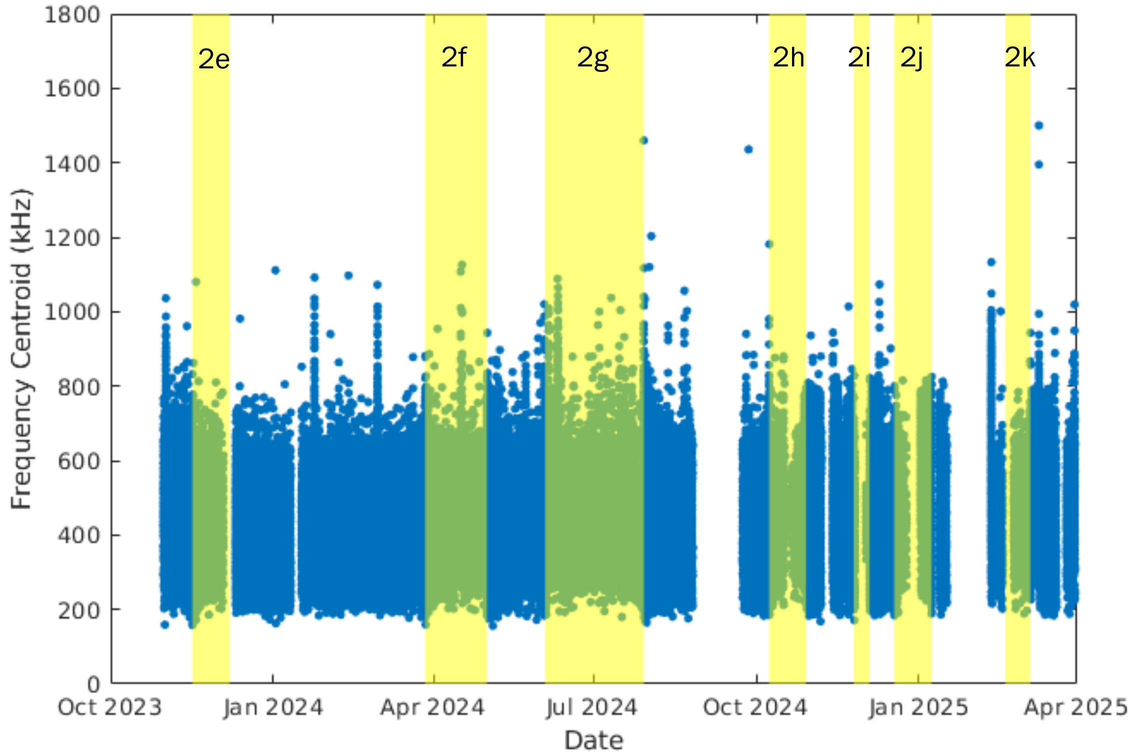

Figure 20. AE frequency centroid for BATS 2 heater tests. Heated periods are marked in yellow and labelled.

AE source mechanisms can be difficult to determine using traditional seismic methods. Large volumes of data, short travel distances, and single component sensors make it difficult to invert for focal mechanisms. To estimate source mechanisms, the ratio of AE hit energy to length is taken as a proxy of tensile versus shear sources (Aggelis, 2011; Shiotani, 2006, Shiotani et al., 2001). Shear sources are assumed to release lower amounts of energy over longer durations, while tensile sources are assumed to release higher amounts of energy over shorter durations. The ratio of energy release to release rate is plotted as counts per duration to rise per amplitude for each AE hit. Counts are defined as the number of threshold crossings per in the recorded waveform associated with an AE hit, duration is defined as the length of the AE hit, rise is defined as the time to peak amplitude from the first threshold crossing, and amplitude is the maximum value of the AE hit. Tensile sources with higher energy and shorter durations should plot along the rise per amplitude axis, and shear sources with lower energy and longer durations should plot along the counts per duration axis. The majority of AE hits plot along the rise per amplitude axis indicating that the source mechanism would likely be tensile (Figure 21). Tensile cracks are opening mode cracks, and the associated increase in porosity would be associated with increases in permeability in the borehole region.

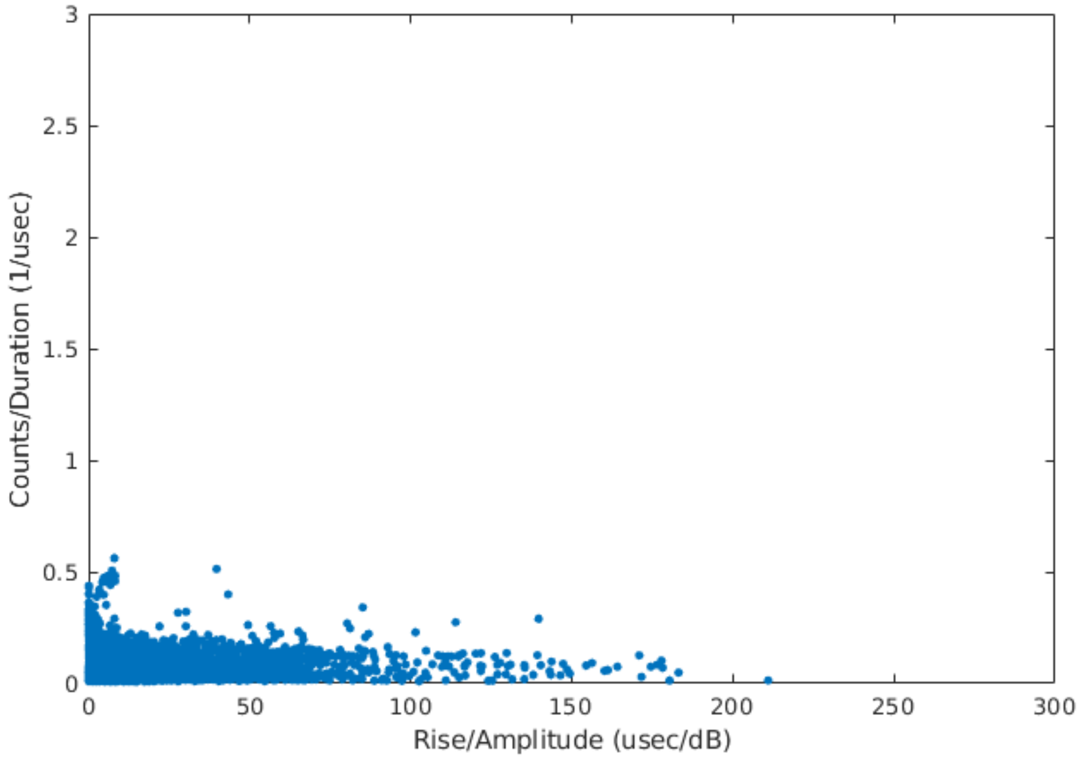

Figure 21. Ratio of Counts per duration to rise per amplitude for AE hits for BATS 2 heater tests.

The data presented here shows clear impacts of heater cycles on emitted acoustic emissions. The onset of the heating results in increases in AE activity, average signal levels, and frequency centroid range. Values for each parameter decay to levels below background levels with continued heating, showing the borehole is quieter during heating than ambient conditions (Figure 15, Figure 16, Figure 19, and Figure 20). At the onset of cooling when the heater is powered down, AE activity surges with marked increased in AE rate, average signal levels, and frequency centroid range (Figure 15, Figure 16, Figure 19, and Figure 20). The increases in these values are significantly greater than the observed increases with heating (Figure 17, Figure 18, and Table 2). AE activity remains elevated until it decays to background levels. Proxies for source mechanism indicate that damage is likely caused by tensile source mechanisms (Figure 21). This type of damage would be associated with increases in permeability in the borehole region. AE activity shows that most of the damage occurs during cooling, and the quiet, stable periods during heating are incurring less damage that would alter hydraulic behavior. It is possible that the quiet periods during heating are due to the activation of thermally sensitive plastic deformation mechanisms that do not emit AE. While this type of deformation mechanism would have an impact on borehole closure, plastic deformation is isochoric and would not increase permeability.

1.4 T: TEMPERATURE TIME SERIES

Thirty-six sealed Type-K thermocouples are grouted into the two T boreholes, and more thermocouples are co-located with other observations in other boreholes (e.g., AE, F, and SL).

Resistance temperature detectors (RTDs) are used in place of thermocouples in the ERT boreholes (E1 through E4).

The unheated array (Figure 22) now shows regional fluctuations of temperature in the salt, as ERT survey are no longer being conducted in the unheated array. Most of the thermocouples in the ERT boreholes in the unheated array have failed since they were installed in 2019. The BATS 2 heated array is further away from the BATS 1 unheated array than the BATS 1 heated array was, so the effects of the BATS 2 heating events are not observed in the unheated array, as they were in BATS 1. The unheated T1 borehole shows that the variation of ambient temperature with depth varies with seasons (an unexplained downward shift appears to impact the deepest two thermocouples in the UT2 borehole, compared to the shallower thermocouples). In the summer, the drift air is warmer than the salt and in the winter the salt is warmer than the drift air. A maximum of 1 °C difference is observed between TC1 and TC16 in the summer, and approximately 0.75 °C difference is observed between these thermocouples in the winter. The annual variation in the shallowest thermocouple is approximately 2 °C, and the annual variation in the deepest thermocouple is only 0.7 °C.

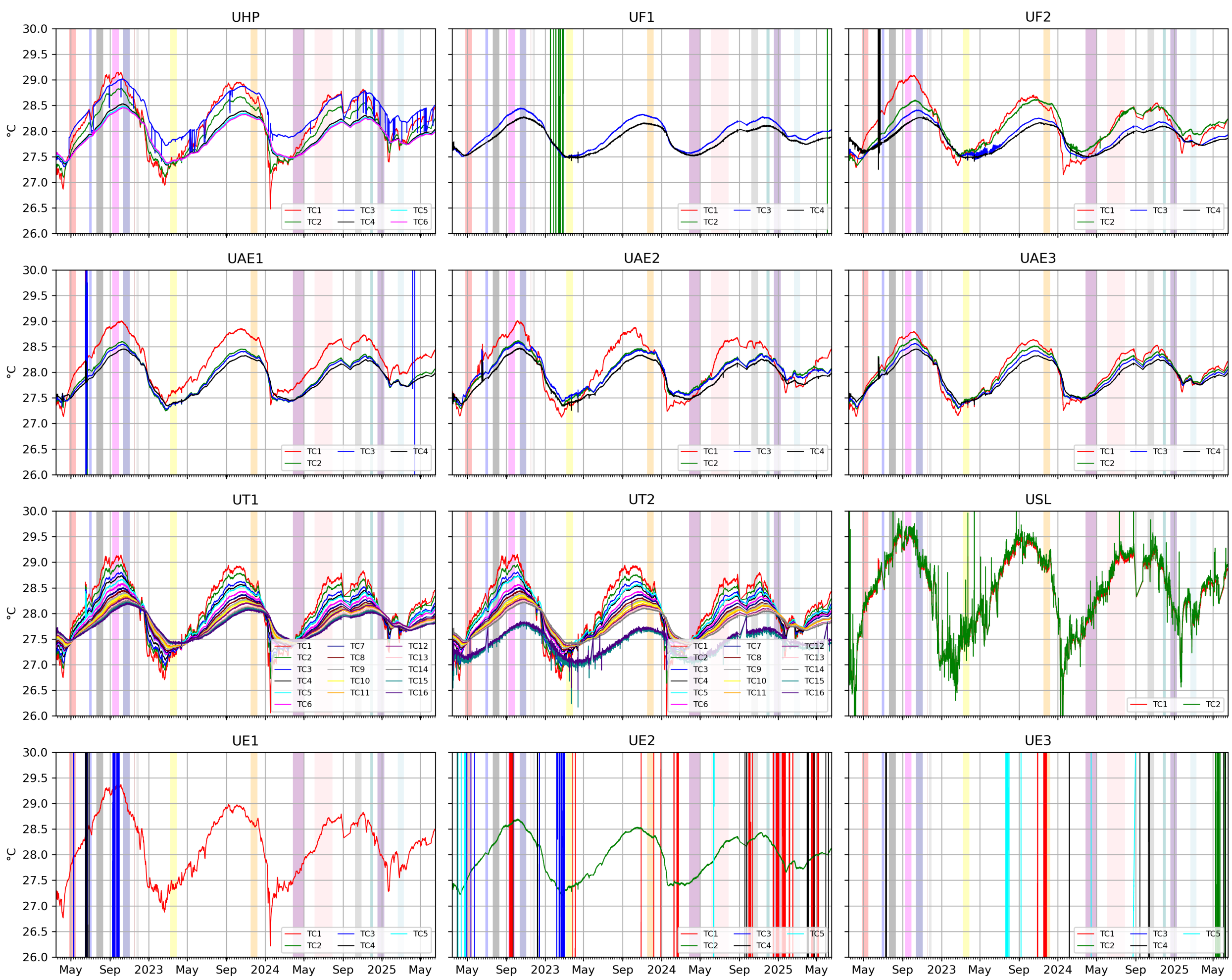

Figure 22. Thermocouple data from unheated array.

An average “deep” salt temperature of 27.77 °C [81.99 °F] is inferred from the average UT1TC16 temperature between 1 June 2022 and 1 June 2024 (two years). This is consistent with what has been observed previously at WIPP, but it is clearer in the unheated array data now than when it was subject to more man-made impacts.

Figure 23 shows temperature data observed in the BATS 2 heated array. Each subplot in the plot is a different borehole; curves within each subplot show data from different thermocouples. In each borehole thermocouple “TC1” is closest to the drift, “TC2” is deeper in the borehole, etc. Thermocouple and RTD data collected during ERT surveys are not deleted from the BATS 2 dataset (some noise is still observed in the data during ERT surveys each night), as was done in BATS 1.

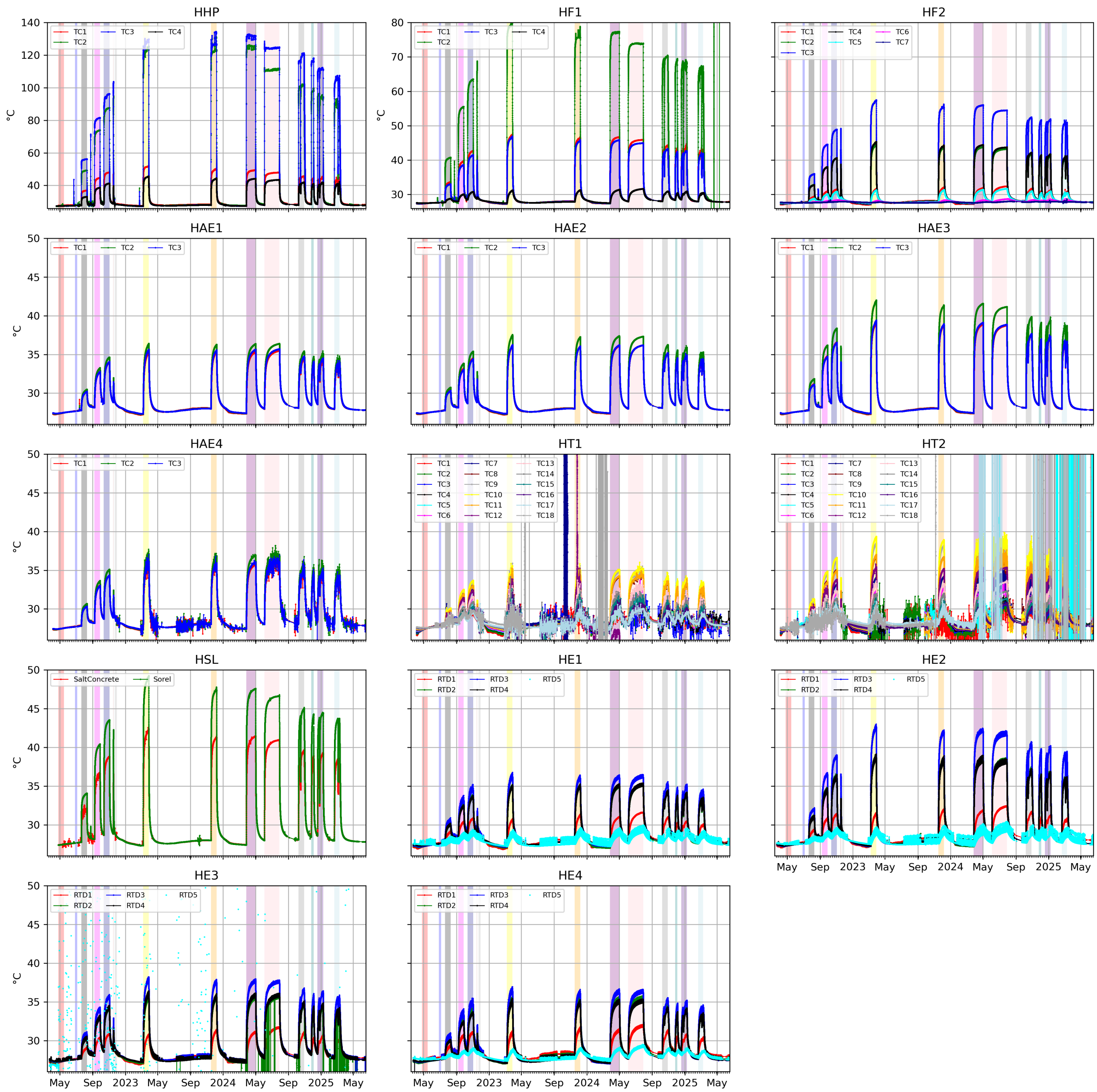

Figure 23.Temperature data from heated array. Each subplot shows the thermocouples or RTDs from a single borehole.

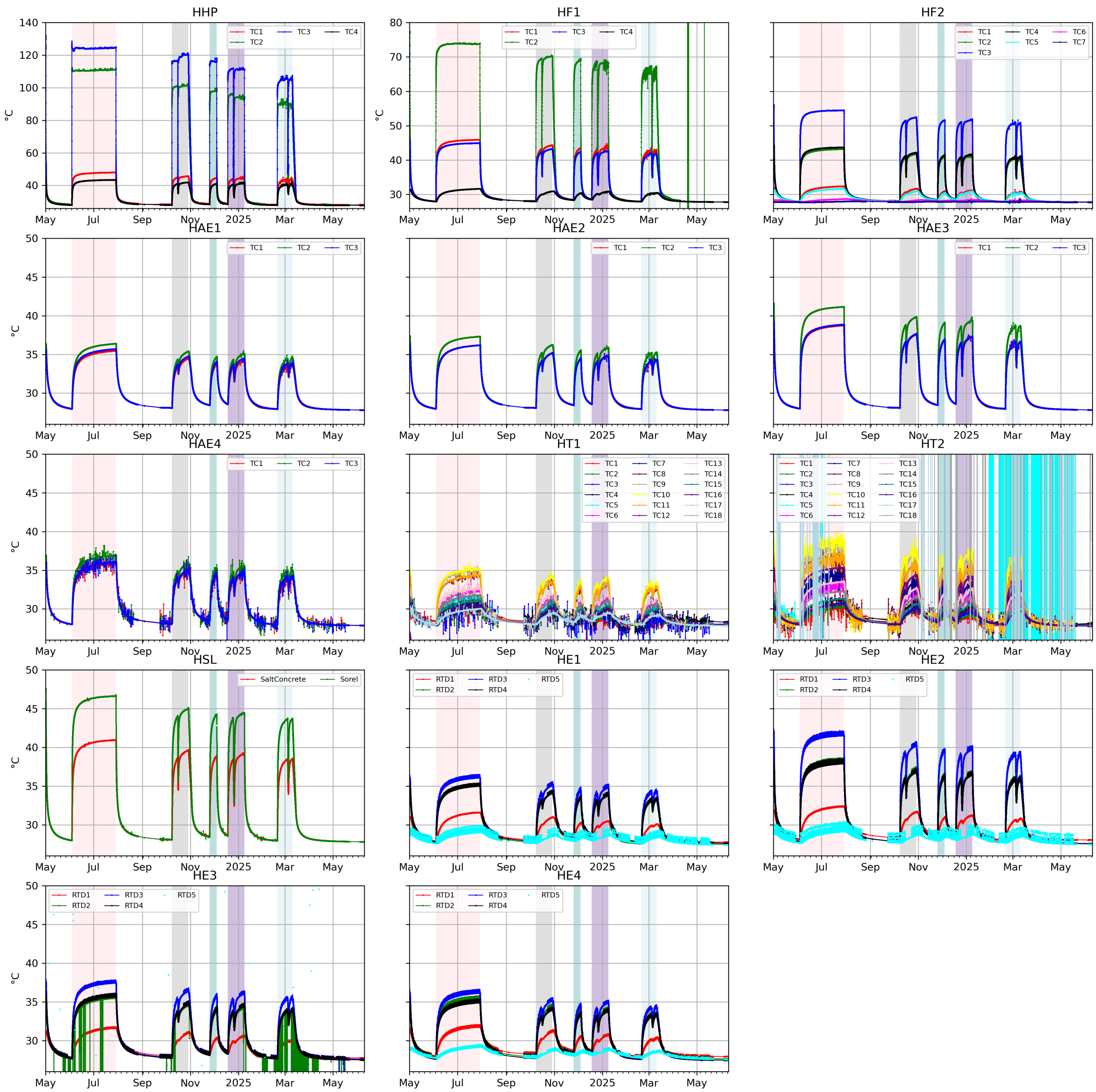

Figure 24. **Recent temperature data from heated array since May 2024. Each subplot shows the thermocouples or RTDs from a single borehole.**

Figure 24 shows the most recent 5 heating tests in more detail; the slower ramp down of BATS 2h and 2k are visible in the closer thermocouples.

1.5 E: ELECTRICAL RESISTIVITY TOMOGRAPHY (ERT) DATA

Rutqvist et al. (2024) and Chen et al. (2024) provide a detailed summary of data collection, inversion, and analysis of BATS 2 ERT data. Recently, Wang et al. (2023) published an analysis of the ERT data collected as part of BATS 1. Between BATS 1 and BATS 2, improvements were made to the model used to invert the data, and there are more electrodes distributed across four boreholes in BATS 2 as compared to three boreholes in BATS 1.

ERT surveys were nominally conducted nightly, but they were not conducted during power outages or periods when there were equipment issues (see surveys on days with asterisks in Figure 25). The top subplot shows average resistance and temperature, while the middle plot shows lower resistance measurements, and the bottom subplot shows the higher resistance measurements. The low- and high-resistance measurements react differently to the beginning and ending of heating (red stripes).

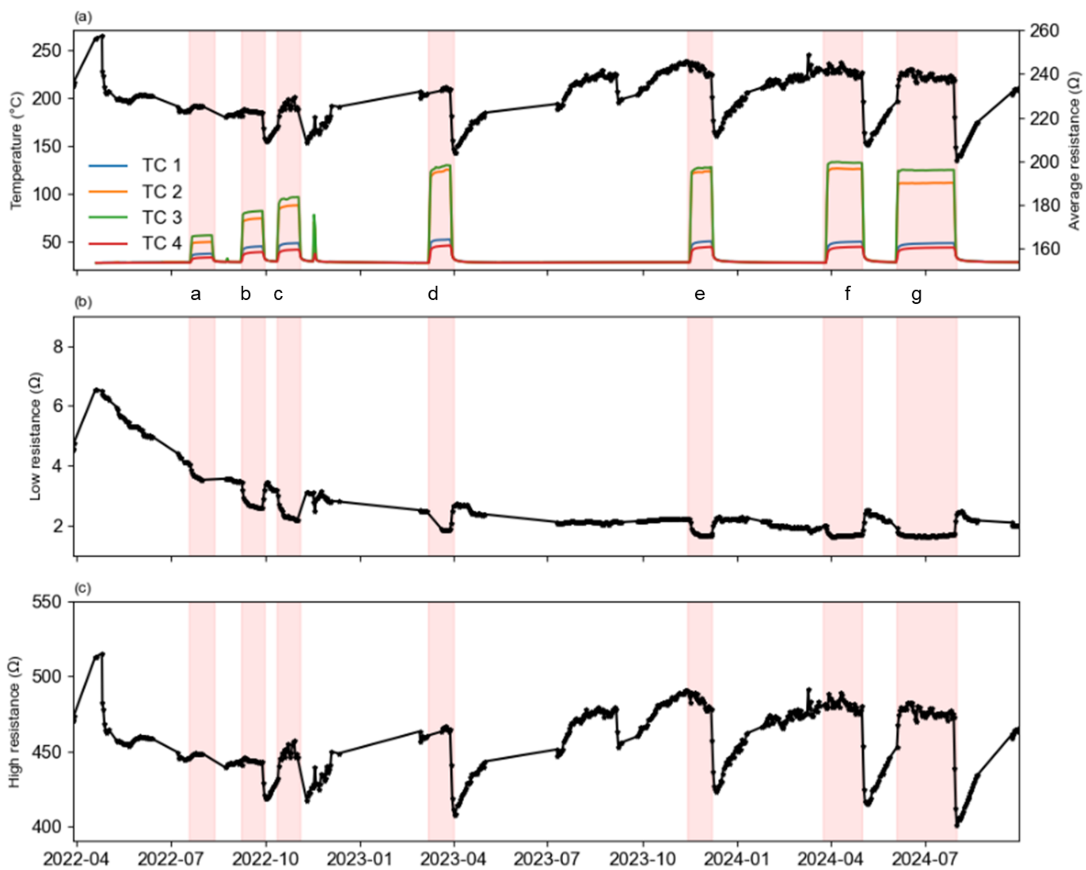

Figure 25. Time-series of temperature and average resistance during BATS 2: (a) daily average temperature data from four thermocouples in HHP and average resistance data from ERT, with asterisks indicating the days when ERT data measurements were taken, (b) the trend of low resistance data (<100 Ω) and (c) the trend of high resistance data (≥100 Ω). Red shading represents heating periods (Chen et al., 2024).

Figure 26 shows the inverted resistivity distribution in a box around the BATS 2 heated array. Like in the averaged raw observations (Figure 25), there are several types of responses to the start and end of heating events (i.e., the red stripe in subplot c).

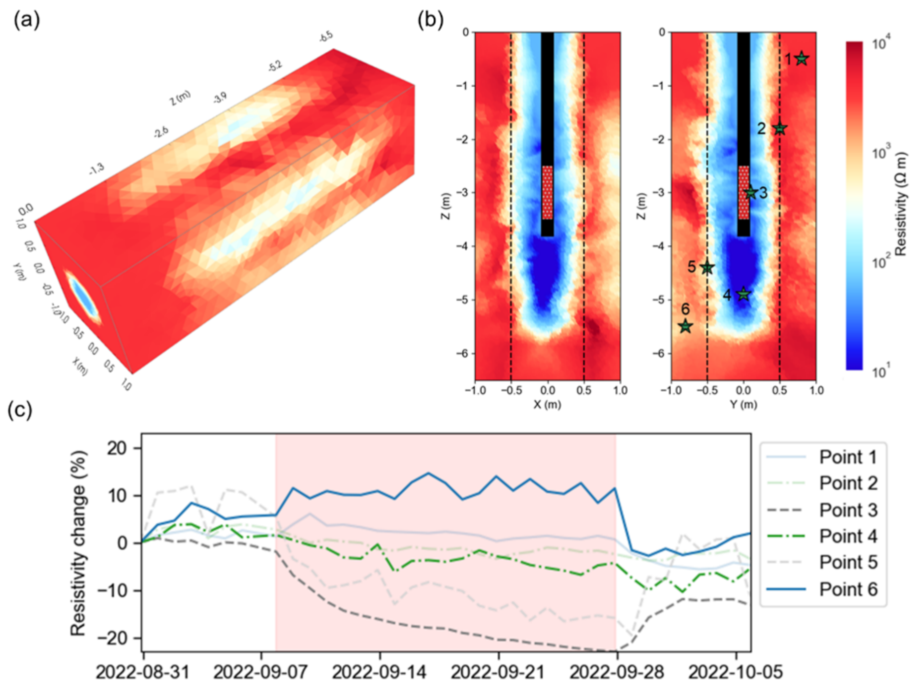

Figure 26 The inverted resistivity distribution from the selected baseline (2022/08/30) in BATS 2b: (a) a three-dimensional perspective, (b) cross-sections along HP borehole with the extent of HHP heater indicated with a red box, and (c) the time evolution of resistivity at the six points shown in (b) during second heating phase (Chen et al., 2024).

Using time-series clustering analysis, several classes of responses were characterized (Figure 27). These response correlate physically with the anticipated distribution of the damaged zone and the distribution of brine in salt surrounding the heated borehole.

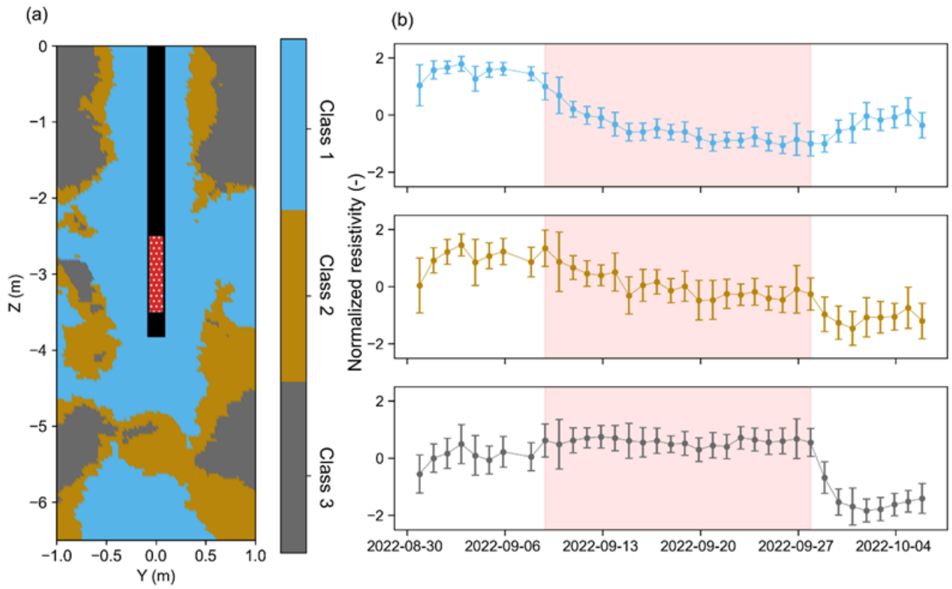

Figure 27. The time-series clustering results: (a) the spatial distribution of classes with HHP borehole and heated interval indicated, and (b) the normalized resistivity changes in each cluster with its uncertainty (one standard deviation). Red shading is BATS 2b heating test (Chen et al., 2024).

Figure 28a shows the resistance responses during heating cycles showed unexpected binary trends, with distinct behaviors observed between low-resistance (<100 Ω) and high-resistance (≥100 Ω) regions during the heating and cooling phases. Through time-series clustering analysis, we identified three primary zones with characteristic resistivity responses (Figure 28B=b): EDZ (Excavation Damaged Zone), EdZ (Excavation disturbed zone), and the far-field (intact) zone. The EDZ, characterized by significant resistivity decreases during heating and increases after heating, reflects enhanced brine mobility and porosity changes in the most damaged region surrounding the excavated heater borehole. The EdZ displayed intermediate behavior with consistent resistivity decreases during and after heating, indicating gradual salt crystal deformation and sustained brine redistribution. The far-field zone exhibited increasing resistivity during heating and decreasing after heating, consistent with thermal expansion effects on intact salt and limited brine mobility and variation. These distinct responses reflect the underlying mechanical and hydrological properties specific to each zone, with the EDZ showing the most dynamic brine movement, the EdZ exhibiting transitional characteristics, and the far-field maintaining properties typical of intact rock salt. The spatial evolution of zones from H2 to H7, as shown in Figure 28b, demonstrates a clear trend toward increased homogenization. Specifically, analyzing the resistivity behavior throughout successive heating events reveals that regions near the heat source progressively exhibit characteristics more like the far-field zone. This trend suggests a healing process, where localized permeability variations diminish over time, reducing the heterogeneity between initially distinct zones. The observed transition provides strong evidence that rock salt undergoes self-sealing under thermal loading, reinforcing its long-term suitability as a repository material.

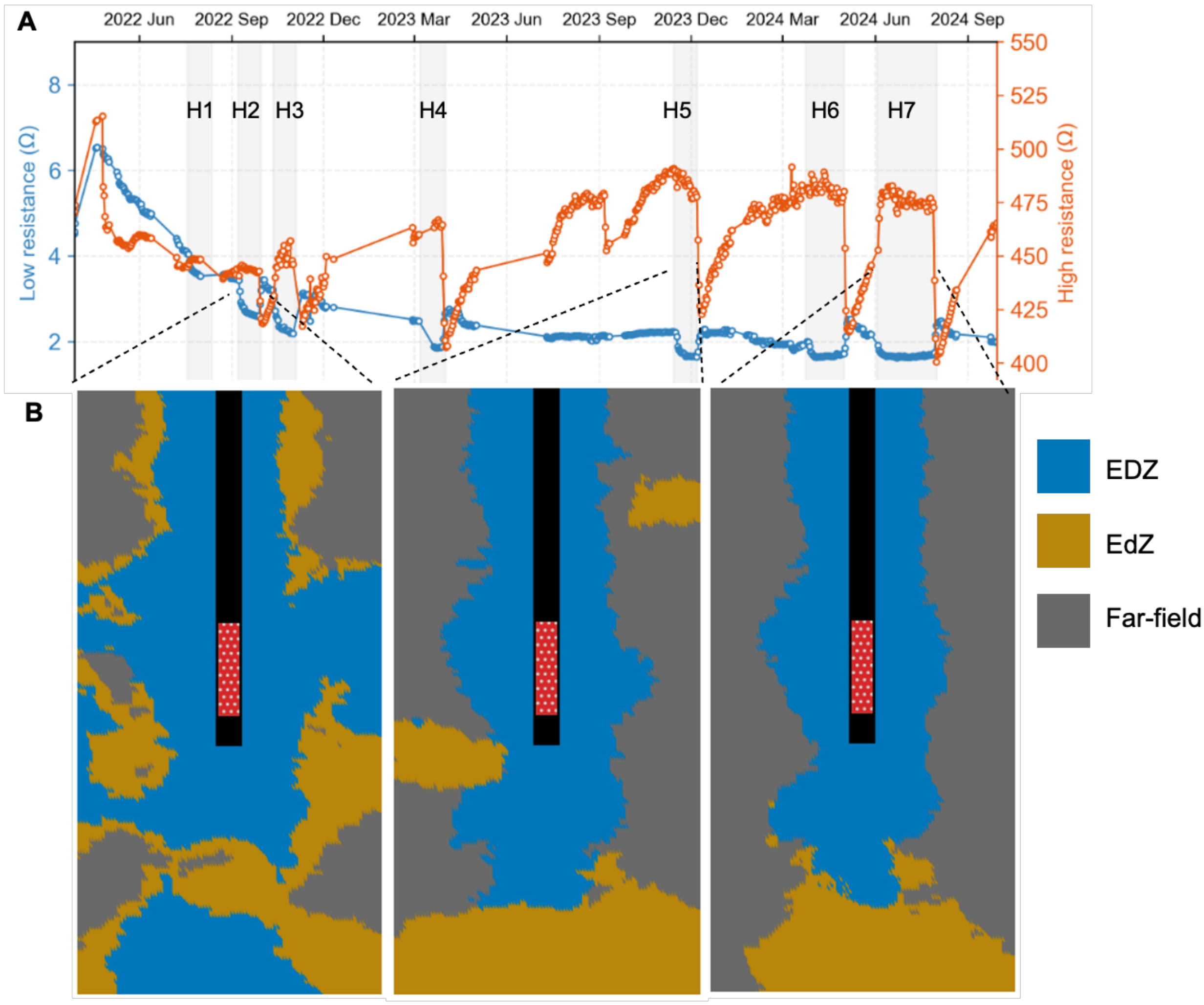

Figure 28. Temporal and spatial evolution of electrical resistivity in rock salt during heating experiments. (a) Time series of measured low resistance (blue) and high resistance (orange) data from June 2022 to September 2024, showing contrasting behaviors during heating and cooling cycles. (b) Cross-sectional views of the three primary zones identified through time-series clustering analysis at different time points, showing the spatial distribution of the excavation damaged zone (EDZ, blue), disturbed zone (EdZ, orange), and far-field zone (grey). The heater location is indicated by the black vertical line with red dots. The distinct zones demonstrate the heterogeneous response of the rock salt formation to thermal loading, with EDZ showing the most dynamic behavior near the heater, EdZ exhibiting transitional characteristics, and the far-field maintaining properties typical of intact rock salt.

1.6 F: FIBER OPTIC DATA

Monitoring of the thermo-mechanical dynamics with near-continuous recording of fiber optic datasets was continued during 2025. The example datasets linking DFOS (Distributed Fiber Optic Sensing) data with salt deformation during heating events and due to long term slow creeping of salt and closure of the draft are shown in Figure 29. Two distinct zones of elevated strain are observed: one near 5 meters, corresponding to thermal expansion from heater activation, and another near 2 meters, indicating gradual drift closure over time. The results demonstrate the ability of DFOS to resolve both localized thermal effects and broader mechanical deformation in rock salt.

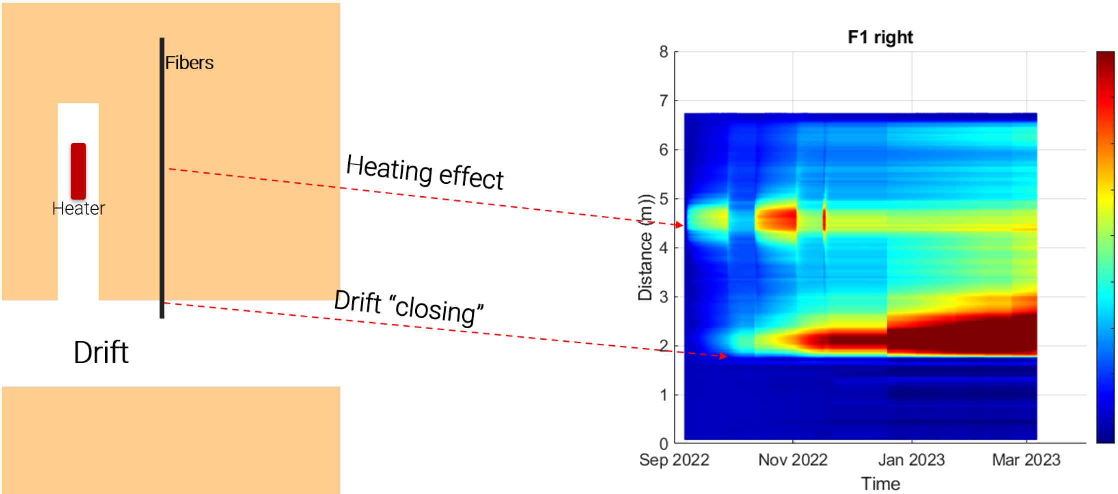

Figure 29. Time-lapse distributed fiber-optic strain measurement example along borehole F1 ("F1 right"). The colormap shows strain magnitude (in microstrain) as a function of distance along the borehole and time. Elevated strain near 5 m corresponds to thermal expansion from heater activation, while the increasing strain near 2 m reflects progressive drift closure.

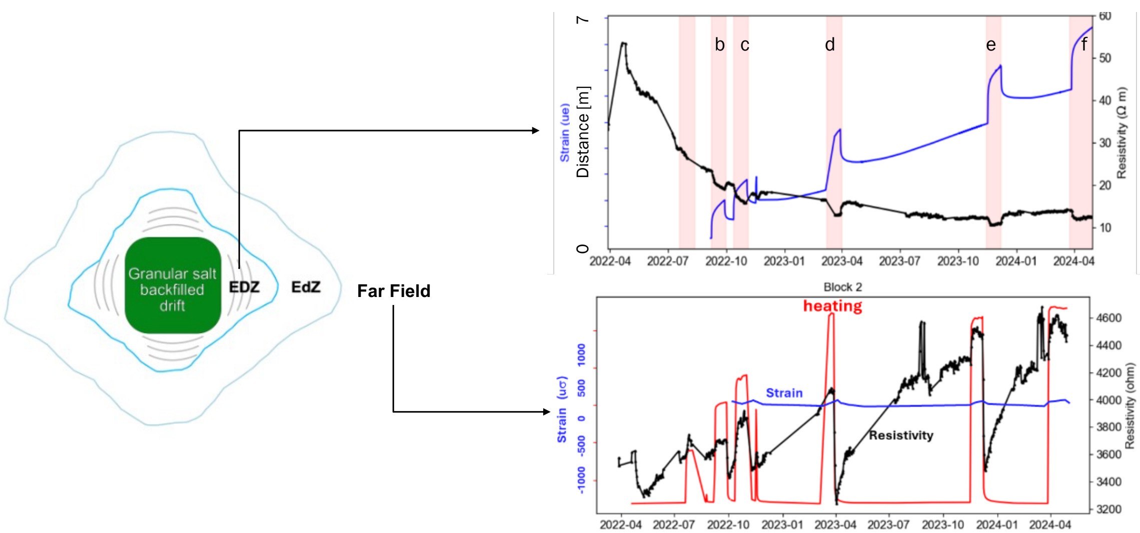

Figure 30. Coupled strain and resistivity responses in rock salt during BATS 2 heating experiments, illustrating differences between the EDZ and far-field regions. The schematic (left) shows sensor placement across zones. The top-right plot shows long-term strain decrease and resistivity increase in the EDZ, reflecting creep closure and brine depletion. The bottom-right plot (Block 2) highlights sharp increases in strain and resistivity during heating events, indicative of thermal expansion and localized drying. Far-field regions exhibit muted responses, emphasizing the spatial variability in deformation and fluid behavior captured by integrated DFOS and ERT monitoring.

Figure 30 illustrates the coupled evolution of strain and resistivity in rock salt during BATS 2 heating experiments, with distinct responses observed between the EDZ and the far field. In the EDZ, strain decreases over time due to creep closure, while resistivity increases, reflecting compaction and reduced brine content. In contrast, the far field exhibits smaller strain changes and relatively stable resistivity, indicating limited mechanical and hydrological disturbance. Heating events cause sharp, transient increases in both strain and resistivity in the EDZ, consistent with thermal expansion and localized drying, while the far field shows more muted responses. These contrasts highlight spatial variability in salt deformation and fluid redistribution, underscoring the importance of integrated DFOS and ERT monitoring for characterizing repository-scale processes.

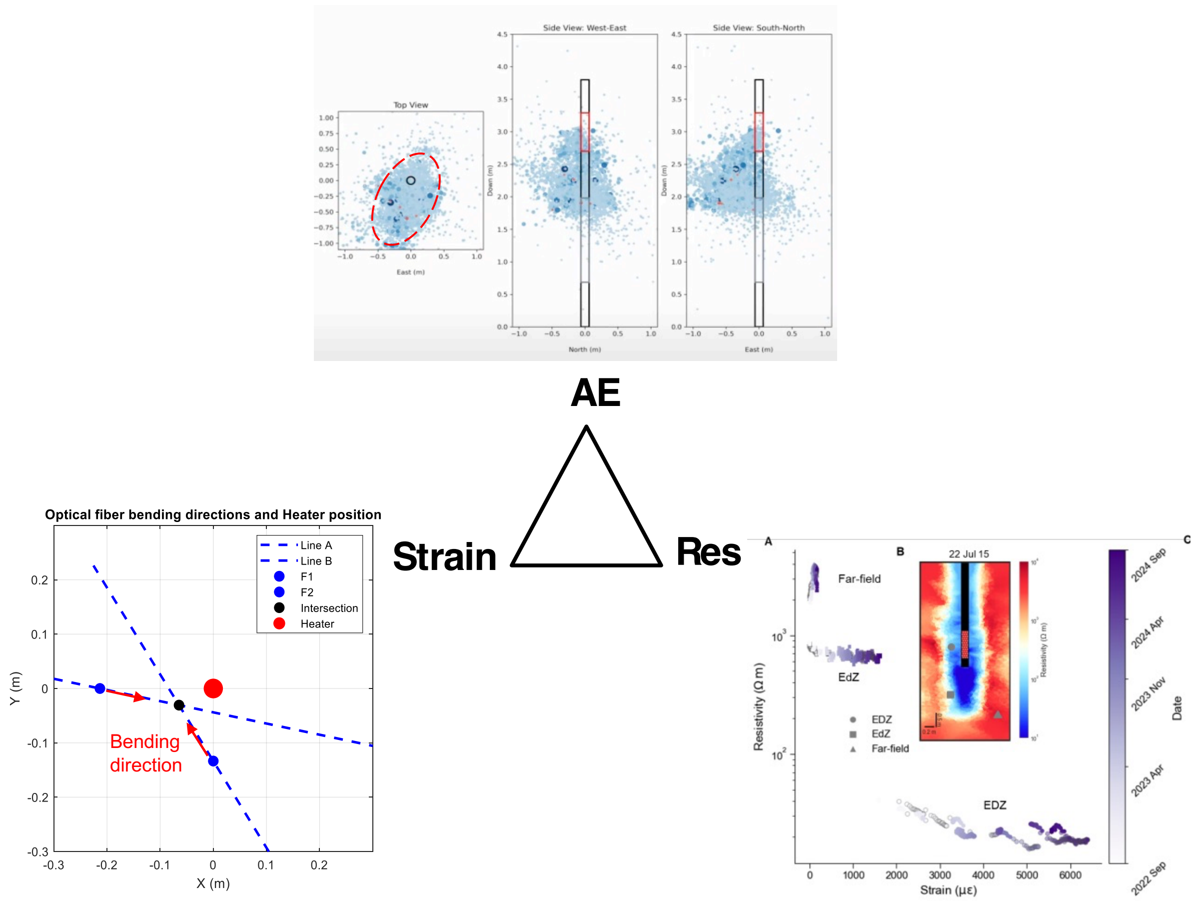

Figure 31. Joint interpretation of acoustic emission (AE), fiber-optic strain, and electrical resistivity data reveals a localized zone of enhanced activity in the lower-left quadrant from the heater. This region exhibits concentrated microseismicity, elevated strain, and reduced resistivity, indicating focused thermal deformation, brine migration, and evolving permeability in the salt.

This figure presents a joint interpretation of acoustic emission (AE), resistivity, and fiber-optic strain measurements to characterize salt deformation and fluid dynamics around the heater borehole in the BATS 2 test. All three datasets consistently identify the **lower-left quadrant from the heater** as a more **active zone**, exhibiting greater deformation and possibly more fluid movement. The AE event locations (top) cluster asymmetrically in this region, indicating enhanced microcracking or fracturing. Fiber-optic strain data (bottom left) show directional bending and strain accumulation toward the same quadrant, consistent with localized mechanical response to thermal loading. The resistivity vs. strain plot (bottom right) shows a strong correlation between increasing strain and decreasing resistivity in the EDZ, suggesting enhanced brine mobility and evolving porosity. The resistivity map inset further confirms this low-resistivity, high-activity zone. Together, the three independent measurements converge to reveal a spatially localized zone of intense thermally driven salt deformation, brine redistribution, and permeability change—key processes relevant to long-term repository performance.

1.7 SM: AIR TEMPERATURE AND RH TIME SERIES

Figure 32 shows the temperature and RH associated with the behind-the packer interval in the SM and SL boreholes. The right subplot shows the air temperature behind the packer rising during the heating portion of the test (red and green curves), while the left subplot shows the RH rising during heating in the heated SL borehole (with the nature of rise being more muted in the heated SM borehole). RH near 75% is indicative of equilibrium between moist air and halite at ambient temperature. These observed RH values indicate there is not a significant amount of dry air getting around the packer.

The rise in RH behind the packer during heating is likely due to liquid brine being present in the seal borehole (SL), but not the sample borehole (SM; because of repeated removal of any standing brine for geochemical sampling). The upward spikes (~1%) in all the RH data (heated and unheated arrays) are in response to power outages. The RH sensor requires a warm-up time each time after the power is disconnected. The early (2022 and 2023) downward spikes (1 to 2%) in the RH data in the SM borehole are associated with sampling attempts. A vacuum pump is connected to the 6.4 mm [0.25 in] tubing to extract any brine standing at the back of the borehole. When air and water are removed from the borehole for sampling, less humid drift air must flow in to replace it.

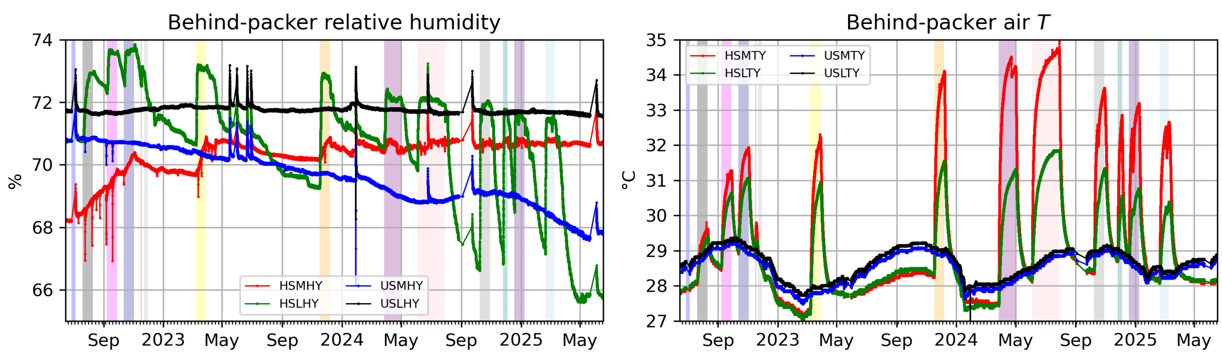

Figure 32.Relative humidity (left) and air temperature (right) for SM and SL boreholes.

1.8 SL: SEAL BOREHOLE DATA

The new BATS 2 seals were emplaced as part of the BATS 2 construction, while the unheated seals from BATS 1 are still in place.

1.8.1 SL: AIR TEMPERATURE AND RH TIME SERIES

Figure 32 shows the air temperature and relative humidity data associated with the SL boreholes. Unlike the SM boreholes, the relative humidity behind the packer rises in the SL borehole in response to heating. This is likely due to standing brine in the borehole being removed regularly from the SM borehole by vacuum pump, while any brine that accumulates in the SL borehole would remain and would tend to saturate parts the emplaced seals with time.

1.8.2 SL: STRAIN AND TEMPERATURE TIME SERIES

The lab-constructed seals were instrumented with embedded strain gauges to observe strain in the salt once the borehole has closed in and made contact on the laboratory-fabricated cement plugs. The vibrating-wire GEOKON strain gauges installed in seals as part of BATS 1 in the unheated seal have failed and are no longer reporting valid values. The VPG strain gauges in the unheated seal are still working (blue line in top subplot of Figure 33), and the data show a clear change in slope in December 2022. This is interpreted to mean that the borehole has crept shut against the unheated seal; now the sample is showing a higher steady state strain rate (~570 microstrains per year now, compared to ~140 microstrains per year before) under the now-increased stress (assumed near lithostatic) in the seal. This elevated strain rate would be associated with a steady-state creep rate of the seal material under constant load. This unheated array strain gauge was installed as part of BATS 1 in 2019 and is embedded in the salt concrete portion (see detailed description in Kuhlman et al., 2020) of the unheated SL composite seal. It has taken roughly three years for the borehole to close in on the unheated SL borehole salt concrete seal.

Similar VPG strain gauges in the sorel and salt concrete seals in the heated SL boreholes (red [sorel] and green [salt concrete] lines in Figure 33) show clear straining in response to heating events. The sorel seal experiences higher temperatures than the salt concrete seal, due to each seal's thermocouple's relative distance to the heater. In May 2023, after BATS 2d, the VPG gauge in the heated sorel cement seal saw a similar increase in strain rate. It has taken roughly one year for the borehole to close in on the BATS 2 heated sorel seal, but the nature of the response is clearly different in the heated seal, compared to the unheated seal.

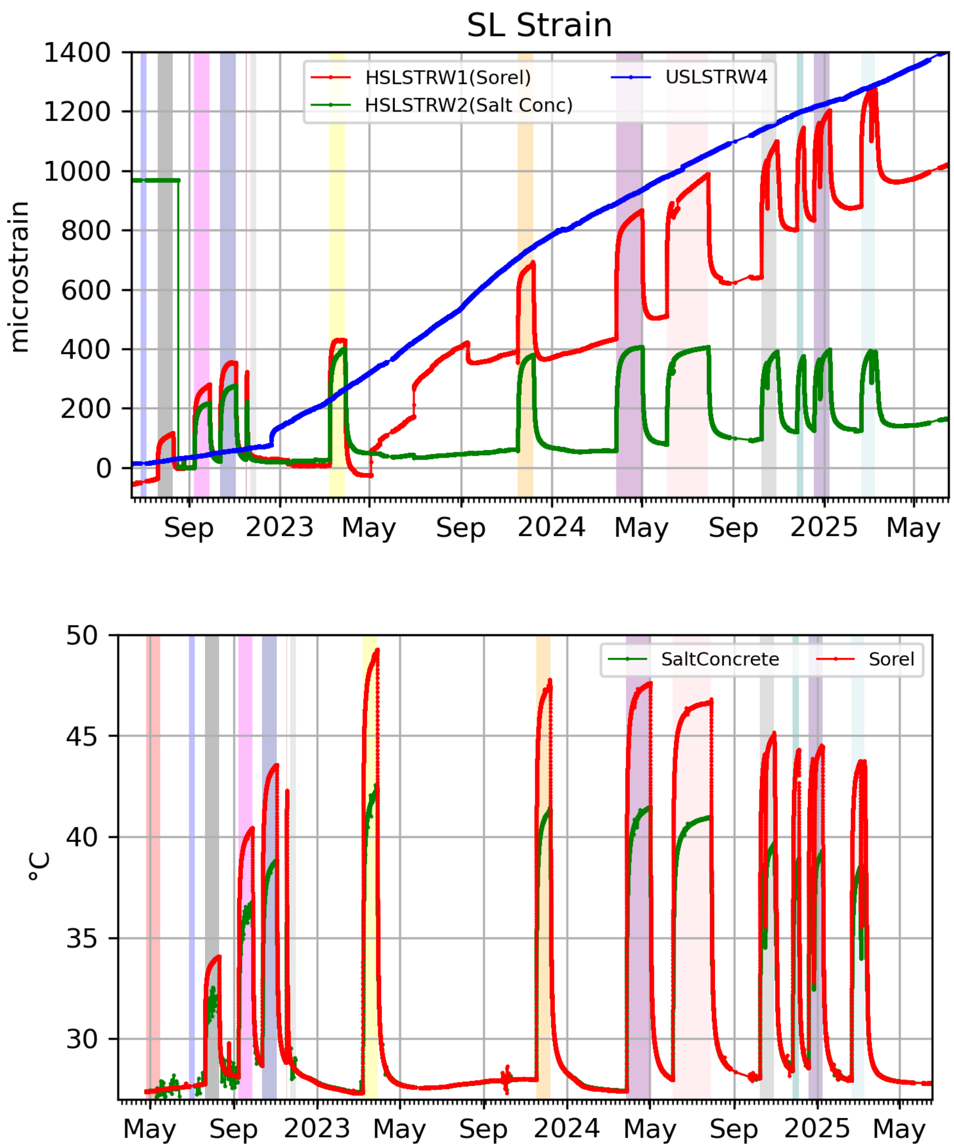

Figure 33.Strain (top) and temperature (bottom) inside cement plugs in SL borehole.

1.9 IN-DRIFT TIME SERIES

Weather station measurements were made in the N-940 drift. Figure 34 shows 10-minute average air temperature, RH, barometric pressure, and air speed near the datalogger enclosures. Drift air temperature increased during the observation period, associated with summer weather. The RH generally rises from spring into summer, associated with changing seasons on the surface, since air from the surface is ventilated through the mine. Large changes in ventilation air speeds are likely due to changes in routing of ventilation in the WIPP underground, which are due to ventilation needs and proximity of other activities in WIPP (e.g., mining or rock bolting). Lower ventilation air speeds occur at night when fewer personnel are underground at WIPP. Barometric pressure fluctuations generally stay between 960 and 970 mbar, with higher-amplitude fluctuations in winter and spring.

The air temperature in the drift fluctuated approximately 3.5 °C through a 12-month period, but there are spikes of higher temperatures observed when the mine ventilation is low, possibly due to heat generated by the instrumentation and computers in the N-940 drift at BATS.

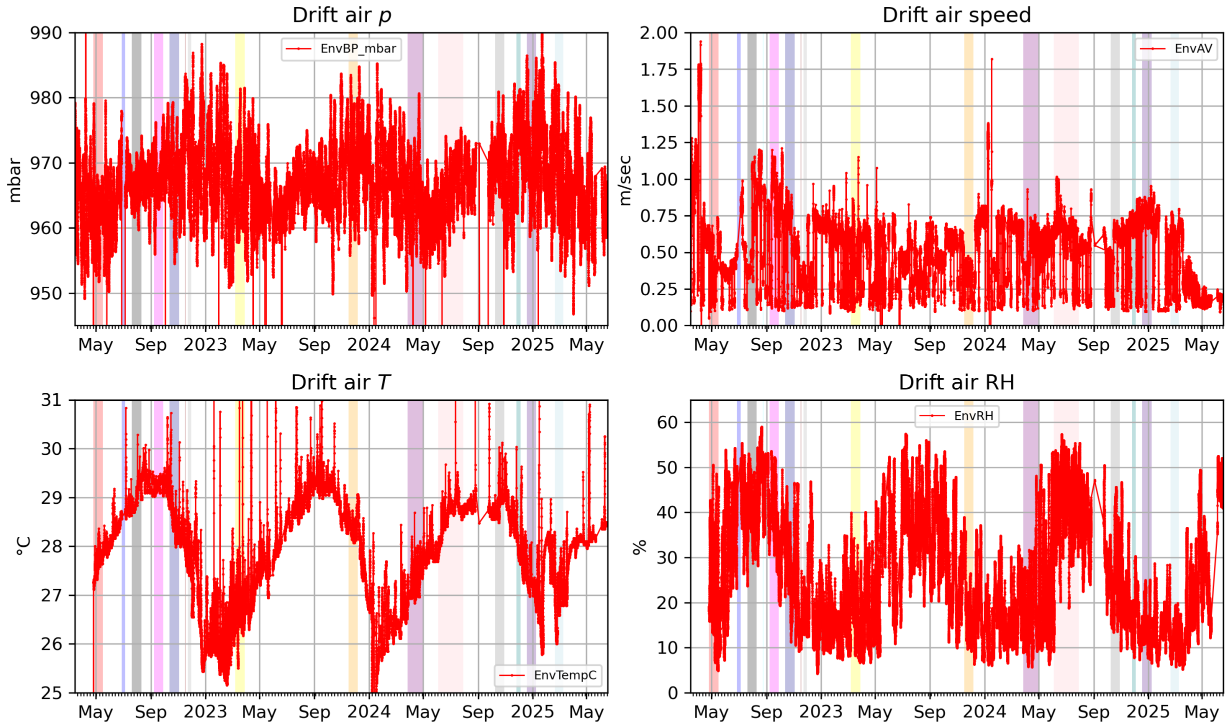

Figure 34. In-drift barometric pressure (top left), air speed (top right), air temperature (bottom left), and RH (bottom right) during BATS 2.

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APPENDIX A – TABULAR DATA

Table A-1. TCO BATS 2 major events (SN is serial number).

Date	Activity Category	Description
27-Oct-2021	BATS 2 Drilling & Coring	Drilling started for BATS 2 heated array.
1-Nov-2021	BATS 2 Brine Sampling	Brine samples collected from BATS 2 AE1 and E4 boreholes.
2-Feb-2022	BATS 2 Brine Sampling	Brine samples collected from BATS 2 AE1, AE3, E2, E3, E4, F1, and T1 boreholes.
18-Feb-2022	BATS 2 Drilling & Coring	Drilling completed for BATS 2 heated array.
24-Feb-2022	BATS 2 Brine Sampling	Brine samples collected from BATS 2 AE4, D, F2, SM, E2, and E3 boreholes.
28-Feb-2022	BATS 2 Drilling & Coring	All BATS 2 boreholes blown out with air and cleaned.
1-Mar-2022	BATS 2 Video Logging	Video logging of BATS 2 E1, E2, E3, E4, F1, F2, T1, and T2 boreholes.
3-Mar-2022	BATS 2 Permeability Testing	Permeability testing of BATS 2 SL borehole.
3-Mar-2022	BATS 2 Instrumentation Installation	Installation of the D inflatable packer in the BATS 2 D borehole.
7-Mar-2022	BATS 2 Permeability Testing	Permeability testing of BATS 2 HP borehole.
7-Mar-2022	BATS 2 Instrumentation Installation	Data collection started for datalogger SN 7071 file named BATS2_Array_Unheated_Gas_SN7071.
7-Mar-2022	BATS 2 Instrumentation Installation	Data collection started for datalogger SN 7072 file named BATS2_Array_Unheated_Temperature_SN7072.
8-Mar-2022	BATS 2 Brine Sampling	Brine samples collected from BATS 2 AE2, AE3, AE4, D, E1, E2, E3, E4, F1, F2, HP, SL, SM, T1, AND T2 boreholes.
14-Mar-2022	BATS 2 Video Logging	Video logging of BATS 2 AE1, AE2, AE3, AE4, D, HP, SL, and SM boreholes.
15-Mar-2022	BATS 2 Grouting Instrument Arrays	Instrument arrays grouted in BATS 2 T1, T2, and E1 boreholes.
21-Mar-2022	BATS 2 Grouting Instrument Arrays	Instrument arrays grouted in BATS 2 E2, E3, and E4 boreholes.
22-Mar-2022	BATS 2 Brine Sampling	Brine samples collected from BATS 2 AE2, AE3, AE4, D, F1, F2, HP, SL, AND SM boreholes.
23-Mar-2022	BATS 2 Instrumentation Installation	Data collection started for datalogger SN 29189 file named BATS2_ERT_RTDs_SN29189.
28-Mar-2022	BATS 2 Grouting Instrument Arrays	Instrument arrays grouted in BATS 2 F1 and F2 boreholes.
5-Apr-2022	BATS 2 Instrumentation Installation	Installation of the SL cement plug in the BATS 2 SL borehole.
5-Apr-2022	BATS 2 Instrumentation Installation	Data collection started for datalogger SN 19480 file named BATS2_Heated_Temperature_SN19480.
13-Apr-2022	BATS 2 Instrumentation Installation	Installation of the SM mechanical packer in the BATS 2 SM borehole.

Date	Activity Category	Description
14-Apr-2022	BATS 2 Instrumentation Installation	Installation of the HP packer assembly in the BATS 2 HP borehole.
25-Apr-2022	BATS 2 Instrumentation Installation	The Picarro and Gas Analyzer were started for gas flow measurements and data collection.
25-Apr-2022	BATS 2 Instrumentation Installation	Circulation plumbing completed and circulation flow started to heated and unheated arrays.
25-Apr-2022	BATS 2 Instrumentation Installation	Data collection started for datalogger SN 7069 file named BATS2_Array_D_Borehole_Inflation_SN7069.
25-Apr-2022	BATS 2 Instrumentation Installation	Data collection started for datalogger SN 16312 file named BATS2_Heated_Gas_SN16312.
25-Apr-2022	BATS 2 Instrumentation Installation	Data collection started for datalogger SN 7075 file named BATS2_LVDT_SG_TRH_SN7075.
25-Apr-2022	BATS 2 Instrumentation Installation	Data collection started for datalogger SN 29190 file named BATS2_Power_Controller_SN29190.
3-May-2022	BATS 2 Brine Sampling	Brine sample collected from SM borehole.
9-May-2022	BATS 2 Power Outage	Planned power outage, power restored 5/10/2022.
25-May-2022	BATS 2 Permeability Testing	Permeability testing of BATS 2 D borehole - nitrogen gas.
31-May-2022	BATS 2 Brine Sampling	Brine sample collected from SM borehole.
9-Jun-2022	BATS 2 Power Outage	Planned power outage, power restored 6/13/2022.
13-Jun-2022	BATS 2 Brine Sampling	Brine sample collected from SM borehole.
22-Jun-2022	BATS 2 Instrumentation Installation	Power controller testing and troubleshooting. Power controller issues resolved, and the power controller is ready to use for heating.
27-Jun-2022	BATS 2 Power Outage	Planned power outage, power restored 7/5/2022.
11-Jul-2022	BATS 2 Brine Sampling	Brine sample collected from SM borehole.
11-Jul-2022	BATS 2 Instrumentation Installation	Power controller settings re-configured.
18-Jul-2022	BATS 2 Permeability Testing	Permeability testing of BATS 2 D borehole - nitrogen gas. Test ended and nitrogen vented from the borehole.
18-Jul-2022	BATS 2 Permeability Testing	Permeability testing of BATS 2 D borehole - argon gas. The argon gas will also act as a tracer for the gas analyzer.
20-Jul-2022	BATS 2a Heating Event	The BATS 2 HP borehole heater was set to a 90 °C set point for 3 weeks of scheduled heating.
25-Jul-2022	BATS 2 Brine Sampling	Brine sample collected from SM borehole.
25-Jul-2022	BATS 2 Instrumentation Installation	Datalogger SN 29190 (power controller) was re-configured to capture additional power controller data.
29-Aug-2022	BATS 2 Power Outage	Planned Power Outage, power restored 9/6/2023
6-Sep-2022	BATS 2 Brine Sampling	Brine sample collected from SM borehole. 9 ml sample clear to cloudy in color
7-Sep-2022	BATS 2b Heating Event	The BATS 2 HP borehole heater was set to a 115 °C set point for 3 weeks of scheduled heating.
19-Sep-2022	BATS 2 Brine Sampling	Brine sample collected from SM borehole. 18 ml sample light brown in color
3-Oct-2022	BATS 2 Picarro Issues	Instrument not working as expected, no measurements were being made by the Picarro from 10/3/22 to 11/2/22

Date	Activity Category	Description
5-Oct-2022	BATS 2 Power Outage	Unexpected Power Outage from 10:24 to 11:20
12-Oct-2022	BATS 2 Brine Sampling	Brine sample collected from SM borehole. 19 ml sample light brown in color
12-Oct-2022	BATS 2c Heating Event	The BATS 2 HP borehole heater was set to a 130 °C set point for 3 weeks of scheduled heating.
24-Oct-2022	BATS 2 Brine Sampling	Brine sample collection attempted from SM borehole.
3-Nov-2022	BATS 2 Picarro Issues	Replacement Picarro installed.
7-Nov-2022	BATS 2 Brine Sampling	Brine sample collected from SM borehole. 14 ml sample
7-Nov-2022	BATS 2 ERT Issues	ERT file sizes started decreasing in size. Periodically the ERT is not finishing data runs. Issues persist through 12/5/22
14-Nov-2022	BATS 2 Brine Sampling	Brine sample collection attempted from SM borehole.
14-Nov-2022	BATS 2 Power Outage	Unexpected Power Outage from 07:43 to 09:08
16-Nov-2022	BATS 2d Heating Event	The BATS 2 HP borehole heater was set to a 140 °C set point, but test aborted after ~1.5 days
21-Nov-2022	BATS 2 gas analyzer issues	Gas analyzer is no longer recording data in P vs T mode
22-Nov-2022	BATS 2 Brine Sampling	Brine sample collection attempted from SM borehole.
22-Nov-2022	BATS 2 HP packer	packer removed from HP borehole to check heater, blister in packer rubber prevents re-insertion of packer.
30-Nov-2022	BATS 2 HP packer	packer blister bled using syringe, packer re-inserted into heated HP borehole and re-inflated
5-Dec-2022	BATS 2 ERT Issues	The ERT problem is related to the internal battery. The battery is low. The ERT was turned off to try to re-charge the battery.
7-Dec-2022	BATS 2 ERT Issues	The ERT was re-started. The small file size issue continued and the internal battery was low. Issue persisted through 12/14/22
7-Dec-2022	BATS 2 Gas Analyzer Issues	Gas analyzer is returning errors about RGA head
14-Dec-2022	BATS 2 ERT Issues	The ERT was removed from service and a replacement ERT will be installed in February.
14-Dec-2022	BATS 2 Gas Analyzer Issues	Gas analyzer is removed from service
19-Dec-2022	BATS 2 Brine Sampling	Brine sample collected from SM borehole. 34 ml sample
21-Dec-2022	BATS 2 HD Perm Test	Filled interval behind HD packer with argon to ~20 psi
9-Jan-2023	BATS 2 Power Outage	Unexpected Power Outage from 19:20 to 20:06
10-Jan-2023	BATS 2 Brine Sampling	Brine sample collected from SM borehole. 6 ml sample light brown in color
18-Jan-2023	BATS 2 Gas Analyzer Issues	Repaired gas analyzer is re-connected and started in P vs T mode
20-Jan-2023	BATS 2 Power Outage	Unexpected Power Outage from 00:49 to 08:55
30-Jan-2023	BATS 2 Brine Sampling	Brine sample collected from SM borehole. 4 ml sample clear to colorless
21-Feb-2023	BATS 2 Brine Sampling	Brine sample collection attempted from SM borehole.
27-Feb-2023	BATS 2 ERT Issues	The replacement ERT was installed and ERT data collection resumed.
8-Mar-2023	BATS 2d Heating Event	The BATS 2 HP borehole heater was set to a 140 °C set point for 3 weeks of scheduled heating.
13-Mar-2023	BATS 2 Brine Sampling	Brine sample collected from SM borehole. 18 ml sample light brown in color

Date	Activity Category	Description
16-Mar-2023	BATS 2 Power Outage	Unexpected Power Outage, power restored 3/20/23
20-Mar-2023	BATS 2 Brine Sampling	Brine sample collected from SM borehole. 7 ml sample clear to colorless
28-Mar-2023	BATS 2 Brine Sampling	Brine sample collected from SM borehole. 3 ml sample clear to colorless
1-Apr-2023	BATS 2 Picarro Issues	Instrument has intermittent errors and is repeatedly not operating as expected. Errors continue through 7/2/23
3-Apr-2023	BATS 2 Brine Sampling	Brine sample collection attempted from SM borehole.
10-Apr-2023	BATS 2 Brine Sampling	Brine sample collection attempted from SM borehole.
10-Apr-2023	BATS 2 Power Outage	Unexpected Power Outage, power restored 4/17/23
17-Apr-2023	BATS 2 Brine Sampling	Brine sample collection attempted from SM borehole.
24-Apr-2023	BATS 2 Brine Sampling	Brine sample collection attempted from SM borehole.
1-May-2023	BATS 2 Brine Sampling	Brine sample collection attempted from SM borehole.
1-May-2023	BATS 2 Power Outage	Unexpected Power Outage, power restored 5/8/23
8-May-2023	BATS 2 Power Outage	Planned Power Outage, power restored 11:05
8-May-2023	BATS 2 Power Outage	Unexpected Power Outage, power restored 5/9/23
10-May-2023	BATS 2 ERT Issues	The ERT stopped working due to low internal battery voltage. The ERT was re-started.
12-May-2023	BATS 2 Power Outage	Unexpected Power Outage, power restored 5/16/23
16-May-2023	BATS 2 Power Outage	Multiple unexpected Power Outages during the day
17-May-2023	BATS 2 ERT Issues	The ERT stopped working due to low internal battery voltage. The ERT was turned off. A replacement ERT is installed in July.
23-May-2023	BATS 2 Power Outage	Unexpected Power Outage, power restored 5/24/23
12-Jun-2023	WIPP Shaft Activities	Approximately at 8:30, there was a 2 to 4 second noise in the N940 drift that sounded like a potential back fall. The UFE was contacted and the noise was from the blast at the exhaust shaft excavation.
19-Jun-2023	BATS 2 Power Outage	Planned Power Outage, power restored 6/21/23
21-Jun-2023	BATS 2 Brine Sampling	Brine sample collected from SM borehole. 7 ml sample light brown in color
22-Jun-2023	BATS 2 Power Outage	Unexpected Power Outage from 23:20 to 23:30
2-Jul-2023	BATS 2 Picarro Issues	Picarro is no longer working. All troubleshooting and attempted fixes did not resolve instrument issues. Picarro removed from service.
10-Jul-2023	BATS 2 ERT Issues	The replacement ERT was installed and ERT data collection resumed.
24-Jul-2023	BATS 2 HD Perm Test	Filled interval behind HD packer with argon to ~21 psi
24-Jul-2023	BATS 2 Power Outage	Planned Power Outage at 08:45
25-Jul-2023	BATS 2 Brine Sampling	Brine sample collected from SM borehole. 17 ml sample light brown in color
7-Aug-2023	BATS 2 Brine Sampling	Brine sample collection attempted from SM borehole.
7-Aug-2023	BATS 2 Power Outage	Planned Power Outage at 08:45
7-Aug-2023	BATS 2 Picarro Issues	The Picarro was removed from the underground.
21-Aug-2023	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 5 mL of brine was collected, and it was lt. brown in color.

Date	Activity Category	Description
21-Aug-2023	BATS 2 Gas Analyzer Issues	The gas analyzer was re-started. The turbo pump did not sound normal when the GA was re-starting. Normal sound is a loud and winding pitch. Like a jet engine getting louder as the rpm's increase. There was little to no sound for the turbo pump.
23-Aug-2023	WIPP Shaft Activities	At 11:09, blasting from shaft 5 was heard and felt in the north end of the WIPP underground. This time can be used by the AE PI to evaluate the AE data for a better understanding of how shaft 5 blasting affects AE data.
29-Aug-2023	BATS 2 Gas Analyzer Issues	From 12:00 to 12:20 the gas analyzer was disconnected and removed from the gas circulation plumbing. After the GA was removed the circulation inlet and outlet for the gas analyzer were plugged to close the circulation plumbing circuit.
5-Sep-2023	BATS 2 Plumbing	Datalogger sn 16312 for the heated gas array was re-configured to remove the solenoid switching. The solenoids will no longer switch, and the heated array gas stream is permanently flowing to the GA system.
5-Sep-2023	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 8 mL of brine was collected, and it was lt. brown in color.
5-Sep-2023	BATS 2 Brine Sampling	Brine sampling of the unheated SM borehole. 0 mL of brine was collected.
11-Sep-2023	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected.
11-Sep-2023	BATS 2 AE Issues	The heated AE was off, and data were not being collected. Data collection stopped on 9/7/2023 at 17:35. The external hard drive disk was full.
13-Sep-2023	BATS 2 Power Outage	Started to investigate reported power outage that was reported yesterday afternoon. All instruments using computers/laptops were down. The GA laptop was OFF. All other computers were running, but the cold and hot AE programs were not. The ERT program showed "failed run" and was in idle mode. The FO program was in a "1 second pause" mode and was not recording data. U/G Electrical Maintenance indicated that they would need to reconfigure our electrical feed due to an MSHA citation concerning a ground control problem near the PPC that was providing power.
18-Sep-2023	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 7 mL of brine was collected. The brine was lt. brown in color.
18-Sep-2023	BATS 2 Power Outage	Data review of CSI sn16312 1-minute data shows that there was an unexpected power outage on 9/15/2023 from 08:58 to 09:06.
25-Sep-2023	BATS 2 Brine Sampling	Brine sampling the heated SM borehole. 9 mL of brine, clear to colorless in color, was collected.
25-Sep-2023	BATS 2 ERT Issues	The ERT was on, and the next data collection was scheduled for 9/25/2023 at 17:00, however there were no data files written since the ERT was re-started on 9/21/2023.
2-Oct-2023	BATS 2 Brine Sampling	Brine sampling the heated SM borehole. 4 mL of brine, clear to colorless in color, was collected.
10-Oct-2023	BATS 2 Brine Sampling	Brine sampling the heated SM borehole. 3 mL of brine, clear to colorless in color, was collected.
16-Oct-2023	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole was stopped after 10 minutes of sampling. 8 mL of brine was collected, and the brine was clear to colorless in color.
23-Oct-2023	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole ended. Sampling time was 10 minutes. Two drops of brine were collected (<1 mL, maybe 0.1 mL). No sample was collected due to an insufficient amount.
30-Oct-2023	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole was stopped. 0 mL of brine was collected - no sample.
1-Nov-2023	BATS 2 Cold Trap	The cold trap items were added, and the heated circulation gas flow was returned to normal.

Date	Activity Category	Description
6-Nov-2023	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole was stopped. 0 mL of brine was collected - no sample.
6-Nov-2023	BATS 2 AE Issues	The unheated AE screen showed that the instrument was on and working. However, there were no new data files since 10/30/2023. The unheated AE was re-started, and data collection resumed.
8-Nov-2023	BATS 2 Cold Trap	Approximately 2 to 3 mL of liquid was collected from the heated HP borehole by the cold trap.
13-Nov-2023	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole was stopped after 10 minutes. 5 mL of brine was collected. Brine was relatively clear.
16-Nov-2023	BATS 2 Plumbing	A new gas cylinder was added to the heated circulation flow line. Two full gas cylinders are in place for the heated circulation flow line.
16-Nov-2023	BATS 2 Cold Trap	The cold trap gas flow was stopped. Approximately 1.5 mL of brine was collected. The valves were returned to the normal position.
16-Nov-2023	BATS 2 Permeability	Argon gas flow to the heated HD borehole. The borehole pressure was 20.81 psi. Approximately 6.98 L of argon was used to recharge the borehole.
16-Nov-2023	BATS 2 Heater Test	The heated HP borehole power controller (heater controller) setpoint was changed from 25 ºC to 140 ºC. The PV temperature at startup was 30 ºC. The power output started to increase.
20-Nov-2023	BATS 2 Plumbing	Check of the heated circulation flow rate at the flow controller showed that the flow was 0 mL/min. The two UHP cylinders were checked, and the valves were open and both cylinders had gas. Further checks showed that the valve by the pressure transducer was closed. The wrong valve was closed after the permeability test on 11/16/2023. Data review shows that gas flowed to the heated circulation flow line for ~20 minutes at 400 mL/min before the valve was accidentally closed. The valves were labeled to avoid making this mistake in the future. The valve that was supposed to be closed was on the heated D argon flow line. Since the gas cylinder valve to the heated D flow line was closed, the permeability test was not negatively impacted.
20-Nov-2023	BATS 2 Cold Trap	Approximately 1.5 to 2.0 g of brine water were collected in the cold trap.
20-Nov-2023	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected.
27-Nov-2023	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 5 mL of brine was collected. The color was clear to colorless.
29-Nov-2023	BATS 2 Cold Trap	The heated circulation flow rate was changed from 2 L/min to 400 mL/min. The heated circulation valves were turned to direct flow to the main heated circulation flow line. Approximately 1.03 g of water was collected in the cold trap.
4-Dec-2023	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. Approx. 1mL of brine was collected. The color was clear.
4-Dec-2023	BATS 2 Cold Trap	Approximately 0.5 g of water was collected in the cold trap.
6-Dec-2023	BATS 2 Cold Trap	Approximately 0.5 g of water was collected in the cold trap.
13-Dec-2023	BATS 2 Brine Sampling	Brine sampling for the heated SM borehole. 0 mL of brine was collected - no sample.
13-Dec-2023	BATS 2 Cold Trap	Approximately 0.5 g of water was collected in the cold trap.
18-Dec-2023	BATS 2 Brine Sampling	Brine sampling for the heated SM borehole. 0 mL of brine was collected - no sample.
18-Dec-2023	BATS 2 Cold Trap	2.75 g of water was collected in the cold trap.
20-Dec-2023	BATS 2 Cold Trap	1.59 g of water was collected in the cold trap.

Date	Activity Category	Description
2-Jan-2024	BATS 2 Brine Sampling	Brine sampling for the heated SM borehole. 0 mL of brine was collected - no sample.
2-Jan-2024	BATS 2 Cold Trap	1.89 g of water was collected in the cold trap.
3-Jan-2024	BATS 2 Cold Trap	1.83 g of water was collected in the cold trap.
8-Jan-2024	BATS 2 Brine Sampling	Brine sampling for the heated SM borehole. 0 mL of brine was collected - no sample.
8-Jan-2024	BATS 2 Cold Trap	1.92 g of water was collected in the cold trap.
10-Jan-2024	BATS 2 Cold Trap	1.80 g of water was collected in the cold trap.
17-Jan-2024	BATS 2 Cold Trap	1.92 g of water was collected in the cold trap.
22-Jan-2024	BATS 2 Cold Trap	Approximately 1.5 g of water was collected in the cold trap.
22-Jan-2024	BATS 2 Brine Sampling	Brine sampling for the heated SM borehole. 0 mL of brine was collected - no sample.
24-Jan-2024	BATS 2 Power Outage	Unplanned power outage on reconfigured power feed. Gas Analyzer turbopump was very audible compared to a controlled power down. Notified underground electrician.
24-Jan-2024	BATS 2 Cold Trap	Approximately 1.5 g of water was collected in the cold trap.
29-Jan-2024	BATS 2 Brine Sampling	The heated SM borehole packer can't be removed from the borehole. The sampling tubing can't be tested. The sampling tubing is possibly clogged and not working.
29-Jan-2024	BATS 2 Brine Sampling	Brine sampling for the heated SM borehole. 0 mL of brine was collected - no sample.
29-Jan-2024	BATS 2 Cold Trap	1.98 g of water was collected in the cold trap.
31-Jan-2024	BATS 2 Cold Trap	0.97 g of water was collected in the cold trap.
5-Feb-2024	BATS 2 Brine Sampling	Brine sampling for the heated SM borehole. 0 mL of brine was collected - no sample.
5-Feb-2024	BATS 2 Cold Trap	2.00 g of water was collected in the cold trap.
7-Feb-2024	BATS 2 Cold Trap	1.24 g of water was collected in the cold trap.
12-Feb-2024	BATS 2 Cold Trap	Check of the cold trap showed that the inflow was 2.0940 L/min and the outflow was 0.4740 L/min. The large difference is most likely due to the missing O-rings in the ultra torr fittings.
12-Feb-2024	BATS 2 Brine Sampling	Brine sampling for the heated SM borehole. 0 mL of brine was collected - no sample.
12-Feb-2024	BATS 2 Cold Trap	0.72 g of water was collected in the cold trap.
12-Feb-2024	BATS 2 Permeability	The flow valve to the heated D borehole was closed. Prior to closing the valve, the flow was 0.0002 L/min (set point was 2 L/min) and the pressure was 20.32 psi.
14-Feb-2024	BATS 2 Brine Sampling	3/8-inch tubing was passed thru the heated SM borehole packer pass thru to check for clearance. The tubing did pass thru and reached the end of the borehole. Some obstructions were felt in the borehole, possibly precipitated brine nodules. When the tubing was removed it was wet and there was brown clay on the tubing.
14-Feb-2024	BATS 2 Brine Sampling	Brine sampling for the heated SM borehole. 0 mL of brine was collected - no sample.
20-Feb-2024	BATS 2 Cold Trap	Replacement O-rings were inserted into the cold trap ultra torr fittings.

Date	Activity Category	Description
20-Feb-2024	BATS 2 Brine Sampling	Brine sampling for the heated SM borehole. 0 mL of brine was collected - no sample.
20-Feb-2024	BATS 2 Cold Trap	1.88 g of water was collected in the cold trap.
29-Feb-2024	BATS 2 Brine Sampling	Brine sampling for the heated SM borehole. 0 mL of brine was collected - no sample.
29-Feb-2024	BATS 2 Cold Trap	1.79 g of water was collected in the cold trap.
4-Mar-2024	BATS 2 Brine Sampling	Brine sampling for the heated SM borehole. 0 mL of brine was collected - no sample.
4-Mar-2024	BATS 2 Cold Trap	0.98 g of water was collected in the cold trap.
11-Mar-2024	BATS 2 Brine Sampling	Brine sampling for the heated SM borehole. 0 mL of brine was collected - no sample.
11-Mar-2024	BATS 2 Cold Trap	1.01 g of water was collected in the cold trap.
18-Mar-2024	BATS 2 Brine Sampling	Brine sampling for the heated SM borehole. 0 mL of brine was collected - no sample.
18-Mar-2024	BATS 2 Cold Trap	1.08 g of water was collected in the cold trap.
20-Mar-2024	BATS 2 Cold Trap	1.23 g of water was collected in the cold trap.
25-Mar-2024	BATS 2 Brine Sampling	Brine sampling for the heated SM borehole. 0 mL of brine was collected - no sample.
25-Mar-2024	BATS 2 Cold Trap	1.07 g of water was collected in the cold trap.
27-Mar-2024	BATS 2 Permeability	Argon flow to the heated D borehole was stopped. The heated D borehole pressure was 20.02 psi.
27-Mar-2024	BATS 2 Heater Test	The heated HP borehole power controller set point was changed from 25 °C to 140 °C.
1-Apr-2024	BATS 2 Packer	Based on the amount of gas flowed to the heated HP packer, the packer may have a leak.
3-Apr-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected.
4-Apr-2024	BATS 2 Cold Trap	1.49 g of water was collected in the cold trap.
8-Apr-2024	BATS 2 data issues	The heated circulation (outflow side) flow controller was not reading properly. The reading was well above the high-end range of 2 L/min. Most likely, the additional water in the system, higher temperatures from the heating cycle, and the change for when the cold trap is in use are causing the flow controller to read erratically.
8-Apr-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected.
8-Apr-2024	BATS 2 Cold Trap	1.52 g of water was collected in the cold trap.
15-Apr-2024	BATS 2 Cold Trap	1.65 g of water was collected in the cold trap.
17-Apr-2024	BATS 2 Cold Trap	1.37 g of water was collected in the cold trap.
22-Apr-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected.
22-Apr-2024	BATS 2 Cold Trap	1.56 g of water was collected in the cold trap.
29-Apr-2024	BATS 2 Cold Trap	1.56 g of water was collected in the cold trap.
29-Apr-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected.
29-Apr-2024	BATS 2 Cold Trap	1.63 g of water was collected in the cold trap.

Date	Activity Category	Description
29-Apr-2024	BATS 2 Battery Backup	Data review shows that the unheated array gas datalogger (sn7071) 12Vdc/100 Ah AGM battery was not being charged. There could be an issue with the fuses or NOCO Genius GEN5X2 smart charger. The LED lights on the smart charger have been showing green since installation and that indicates the battery is 100% Charged.
1-May-2024	BATS 2 Battery Backup	Data logger sn7071 shows the battery voltage at 12.7VDC this morning for the unheated array gas. Battery does not appear to be fully charged even though the NOCO charger indicator lights indicate full charge. NOCO charger power cycled and appeared to start charging. 7071 data downloaded for examination in the office.
1-May-2024	BATS 2 Battery Backup	1.41 g of water was collected in the cold trap.
1-May-2024	BATS 2 Heater Test	HP borehole power controller setpoint was changed from 140 to 25 °C to terminate heating. The control thermocouple started dropping slowly indicating that the heating cycle was ending.
1-May-2024	BATS 2 Battery Backup	Examination of the downloaded data from sn7071 shows that the NOCO Genius GEN5X2 smart charger was providing charge to the battery but then appears to have stopped charging the battery late yesterday or early this morning around midnight. We should plan on replacing the charger as soon as possible as it appears to be defective.
6-May-2024	BATS 2 Cold Trap	1.06 g of water was collected in the cold trap.
8-May-2024	BATS 2 Cold Trap	0.78 g of water was collected in the cold trap.
15-May-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected.
15-May-2024	BATS 2 Cold Trap	1.07 g of water was collected in the cold trap.
20-May-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected.
20-May-2024	BATS 2 Cold Trap	1.05 g of water was collected in the cold trap.
23-May-2024	BATS 2 Power Outage	Instrumentation status suggests that there was an unexpected power outage.
23-May-2024	BATS 2 Cold Trap	1.34 g of water was collected in the cold trap.
30-May-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected.
30-May-2024	BATS 2 Cold Trap	1.19 g of water was collected in the cold trap.
30-May-2024	BATS 2 Permeability	Pressurized HD borehole with Argon to 20psi. Mass flow controller (MFC) was set to 1 L/min and valves were opened. MFC and data logger were observed as borehole was pressurized.
3-Jun-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected.
3-Jun-2024	BATS 2 Permeability	The heated D borehole pressure was 20.8 psi. The flow controller was reading ~0 L/min.
3-Jun-2024	BATS 2 Heater Test	The heated HP borehole power controller setpoint was changed from 25 °C to 140 °C.
5-Jun-2024	BATS 2 Cold Trap	1.62 g of water was collected in the cold trap.
10-Jun-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 8 mL of brine was collected, and it was lt. brown in color.
12-Jun-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. <1 mL of brine was collected, and it was lt. brown in color.
12-Jun-2024	BATS 2 Battery Backup	The new charge controller for the unheated array gas datalogger was installed and the datalogger was connected to the AGM battery for power.
12-Jun-2024	BATS 2 Cold Trap	2.32 g of water was collected in the cold trap.

Date	Activity Category	Description
18-Jun-2024	BATS 2 Cold Trap	2.73 g of water was collected in the cold trap.
18-Jun-2024	BATS 2 Brine Sampling	Borehole video logging of the heated SM borehole showed standing brine in the back of the borehole and video also showed that the sampling tubing was in the back of the borehole in contact with the brine.
24-Jun-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. ~2 to 3 drops of brine was collected. There was not enough brine for a sample.
27-Jun-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 1 mL of brine was collected. The brine was clear to colorless. Note - the camera was in the borehole during sample collection.
27-Jun-2024	BATS 2 Cold Trap	1.82 g of water was collected in the cold trap.
1-Jul-2024	BATS 2 Battery Backup	The fuse in the NOCO charger to the AGM battery was removed and then re-inserted into the fuse holder. The charging cycle for the NOCO charger started.
1-Jul-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 3 mL of brine was collected. The brine was light brown in color.
1-Jul-2024	BATS 2 Cold Trap	1.70 g of water was collected in the cold trap.
3-Jul-2024	BATS 2 Cold Trap	1.61 g of water was collected in the cold trap.
8-Jul-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected -no sample.
8-Jul-2024	BATS 2 Cold Trap	1.21 g of water was collected in the cold trap. The temperature of the cold trap was -37.0 ºC since there was no more dry ice.
10-Jul-2024	BATS 2 Cold Trap	1.08 g of water was collected in the cold trap.
15-Jul-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected -no sample.
15-Jul-2024	BATS 2 Cold Trap	0.72 g of water was collected in the cold trap.
18-Jul-2024	BATS 2 Cold Trap	0.62 grams of water was collected in the cold trap.
22-Jul-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected -no sample.
22-Jul-2024	BATS 2 Cold Trap	0.32 grams of water was collected in the cold trap.
24-Jul-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected -no sample.
24-Jul-2024	BATS 2 Cold Trap	0.54 grams of water was collected in the cold trap.
29-Jul-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected -no sample.
29-Jul-2024	BATS 2 Cold Trap	0.67 grams of water was collected in the cold trap.
29-Jul-2024	BATS 2 Heating	9:33 AM Stopped the heating cycle as scheduled after the 8 week run time by setting the heater set point to 25C.
1-Aug-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected -no sample.
1-Aug-2024	BATS 2 Cold Trap	0.45 grams of water was collected in the cold trap.
5-Aug-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected -no sample.
5-Aug-2024	BATS 2 Cold Trap	0.29 grams of water was collected in the cold trap.

Date	Activity Category	Description
12-Aug-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected -no sample.
12-Aug-2024	BATS 2 Cold Trap	1.25 grams of water was collected in the cold trap.
19-Aug-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected -no sample.
21-Aug-2024	BATS 2 Cold Trap	1.48 grams of water was collected in the cold trap.
26-Aug-2024	BATS 2 Brine Sampling	Brine sampling of the heated SM borehole. 0 mL of brine was collected -no sample.
26-Aug-2024	BATS 2 Cold Trap	1.50 grams of water was collected in the cold trap.
26-Aug-2024	BATS 2 Permeability	Argon gas flow to the heated D borehole was stopped. The pressure was 20.57 psi. ~ 7.31 liters of argon were used to re-charge the heated D borehole.
26-Aug-2024	BATS 2 Power Outage	The planned power outage started. All dataloggers remained on and were powered by the dc batteries.
23-Sep-2024	BATS 2 Brine Sampling	Brine sampling the heated SM borehole. No sample collected.
25-Sep-2024	BATS 2 Cold Trap	1.86 grams of water was collected in the cold trap.
30-Sep-2024	BATS 2 Brine Sampling	Brine sampling the heated SM borehole. 9 mL of brine was collected. The brine was lt. brown in color.
30-Sep-2024	BATS 2 Cold Trap	1.83 grams of water was collected in the cold trap.
30-Sep-2024	BATS 2 Permeability	Argon gas flow to the heated D borehole was stopped. After gas flow was ended the pressure in the D borehole was 20.61 psi. Approximately 6.3 liters of gas were used to re-charge the D borehole to ~20 psi.
3-Oct-2024	BATS 2 Cold Trap	1.78 grams of water was collected in the cold trap.
8-Oct-2024	BATS 2 Brine Sampling	Stopped brine sampling the heated SM borehole. 7 mL of brine was collected. The brine was lt. brown in color.
8-Oct-2024	BATS 2 Cold Trap	1.79 grams of water was collected in the cold trap.
8-Oct-2024	BATS 2 Permeability	Argon gas flow to the heated D borehole was stopped. The psi in the borehole was 20.60 psi. Approximately 3.89 liters of argon were used to re-charge the permeability test.
8-Oct-2024	BATS 2 Heating	The heated HP borehole power controller setpoint was changed from 25 deg C to 140 deg C.
14-Oct-2024	BATS 2 Brine Sampling	Stopped brine sampling the heated SM borehole. 24 mL of brine was collected. The brine was lt. brown in color.
16-Oct-2024	BATS 2 Power Outage	Power restored following an unexpected power outage. Data review shows that the unexpected power outage started on 10/15/2024 at ~19:10.
16-Oct-2024	BATS 2 Cold Trap	2.90 grams of water was collected in the cold trap.
21-Oct-2024	BATS 2 Brine Sampling	Stopped brine sampling the heated SM borehole. ~1 mL of brine was collected. The brine was clear to colorless in color.
21-Oct-2024	BATS 2 Cold Trap	5.21 grams of water was collected in the cold trap.
23-Oct-2024	BATS 2 Cold Trap	3.23 grams of water was collected in the cold trap.
28-Oct-2024	BATS 2 Brine Sampling	Stopped brine sampling the heated SM borehole. ~2 mL of brine was collected. The brine was light brown to clear.

Date	Activity Category	Description
28-Oct-2024	BATS 2 Cold Trap	3.76 grams of water was collected in the cold trap. Some of the water was spilled when transferring to the collection vials. As a result, only 1 sample vial contains a sample.
29-Oct-2024	BATS 2 Heating	The heated HP power controller setpoint was changed to 25 deg C.
30-Oct-2024	BATS 2 Cold Trap	3.19 grams of water was collected in the cold trap.
4-Nov-2024	BATS 2 Power Outage	Instruments suggest that there was an unexpected power outage.
4-Nov-2024	BATS 2 Brine Sampling	Stopped brine sampling the heated SM borehole. ~4 mL of brine was collected. The brine was light brown to clear.
13-Nov-2024	BATS 2 Cold Trap	1.54 grams of water was collected in the cold trap.
13-Nov-2024	BATS 2 Power Outage	Power was restored to the BATS experiment.
13-Nov-2024	BATS 2 Brine Sampling	Stopped brine sampling the heated SM borehole. 0 mL collected - no sample.
18-Nov-2024	BATS 2 Brine Sampling	Stopped brine sampling the heated SM borehole. 0 mL of brine was collected - no sample.
18-Nov-2024	BATS 2 Cold Trap	1.41 grams of water was collected in the cold trap.
19-Nov-2024	BATS 2 Permeability	Stopped argon gas flow to the heated D borehole permeability test. The borehole pressure was 21.09 psi and ~7.73 liters of argon were used to recharge the permeability test.
19-Nov-2024	BATS 2 Cold Trap	1.50 grams of water was collected in the cold trap.
25-Nov-2024	BATS 2 Permeability	Heated D borehole top-off complete. Argon pressure 21.19 psig for permeation test.
25-Nov-2024	BATS 2 Heating	Started new heating cycle. Setpoint set to 140C. Starting heating as expected.
25-Nov-2024	BATS 2 Brine Sampling	Stopped brine sampling the heated SM borehole. 0 mL of brine was collected - no sample.
2-Dec-2024	BATS 2 data issues	I noticed before starting the cold trap that the H1 cylinder was completely empty. I had hoped to change it out last week on Wednesday as it was getting low but was unable due to no underground access. The H2 cylinder provided a continued flow of nitrogen, but at a lower pressure of ~16 psi. The pressure was adjusted up to 20 psi.
4-Dec-2024	BATS 2 calibration	Set Gas Analyzer to sample drift air per PI.
5-Dec-2024	BATS 2 Brine Sampling	Stopped brine sampling the heated SM borehole. 0 mL of brine was collected - no sample.
9-Dec-2024	BATS 2 Power Outage	No power for the experiment. An unexpected power outage started on 12/8/2024 and the entire underground lost power.
9-Dec-2024	BATS 2 Power Outage	Power was restored to the BATS experiment.
9-Dec-2024	BATS 2 Brine Sampling	Stopped brine sampling the heated SM borehole. 0 mL of brine was collected - no sample.
12-Dec-2024	BATS 2 Cold Trap	1.82 grams of water was collected in cold trap.
16-Dec-2024	BATS 2 Brine Sampling	Stopped brine sampling the heated SM borehole. 0 mL of brine was collected - no sample.
16-Dec-2024	BATS 2 Cold Trap	1.49 grams of waer rine was collected in cold trap.
18-Dec-2024	BATS 2 Cold Trap	1.45 grams of water was collected in cold trap.

Date	Activity Category	Description
18-Dec-2024	BATS 2 Permeability	Argon gas flow to the heated D borehole was stopped and the pressure was 21.82 psi. ~7.83 liters of argon were used to pressurize the borehole to 21.87 psi.
18-Dec-2024	BATS 2 Heating	The heated HP borehole flow controller setpoint was changed from 25 deg C to 140 deg C.
23-Dec-2024	BATS 2 Brine Sampling	Stopped brine sampling the heated SM borehole. 0 mL of brine was collected - no sample.
2-Jan-2025	BATS 2 Power Outage	The GA, FO, ERT, and AE systems were not collecting data. This suggests that there was an unexpected power outage.
2-Jan-2025	BATS 2 Brine Sampling	Stopped brine sampling for the heated SM borehole. 0 mL collected - no sample.
2-Jan-2025	BATS 2 Cold Trap	3.04 grams of water was collected in cold trap.
6-Jan-2025	BATS 2 Brine Sampling	Stopped brine sampling for the heated SM borehole. 0 mL collected - no sample.
6-Jan-2025	BATS 2 Cold Trap	4.07 grams of water was collected in cold trap.
7-Jan-2025	BATS 2 Permeability	Argon gas flow to the heated D borehole was ended. ~3.29 liters of argon were used to charge the borehole to 21.80 psi.
8-Jan-2025	BATS 2 Heating	The heated HP power controller setpoint was changed from 140 deg C to 25 deg C.
8-Jan-2025	BATS 2 Cold Trap	2.25 grams of water was collected in cold trap.
13-Jan-2025	BATS 2 Brine Sampling	Stopped brine sampling for the heated SM borehole. 0 mL collected - no sample.
13-Jan-2025	BATS 2 Cold Trap	2.00 grams of water was collected in cold trap.
13-Jan-2025	BATS 2 Permeability	Argon gas flow to the heated D borehole was stopped. The pressure in the borehole was 21.84 psi.
15-Jan-2025	BATS 2 Cold Trap	1.64 grams of water was collected in cold trap.
21-Jan-2025	BATS 2 Power Outage	Power was restored to the BATS experiment.
21-Jan-2025	BATS 2 Brine Sampling	Stopped brine sampling for the heated SM borehole. 0 mL collected - no sample.
11-Feb-2025		Stopped brine sampling for the heated SM borehole. 0 mL collected - no sample.
11-Feb-2025	BATS 2 data issues	Due to the extremely low drierite wt. for the heated circulation gas flow, a flow meter was used to check gas flow in various locations for the heated circulation flow plumbing.
11-Feb-2025	BATS 2 data issues	The troubleshooting of the heated circulation gas flow plumbing and system suggested that the GA system was causing the issue. When troubleshooting started, the 100 mL/min gas flow was measuring 23 mL/min at the drierite. When the GA system exhaust was removed from the plumbing the gas flow to the drierite showed 98 to 99 mL/min for the 100 mL/min setpoint. The GA system should still be reading the heated circulation gas flow since the inlet to the GA was plumbed to the gas flow. Only the exhaust of the GA was disconnected from the plumbing system.
12-Feb-2025	BATS 2 Cold Trap	1.04 grams of water was collected in cold trap.
18-Feb-2025	BATS 2 Brine Sampling	Stopped brine sampling for the heated SM borehole. 0 mL collected - no sample.
18-Feb-2025	BATS 2 Cold Trap	1.10 grams of water was collected in cold trap.
19-Feb-2025	BATS 2 Permeability	Argon gas flow to the heated D borehole was stopped. The borehole pressure was 21.79 psi.
19-Feb-2025	BATS 2 Heating	The heated HP borehole power controller setpoint was changed from 25 deg C to 140 deg C.

Date	Activity Category	Description
24-Feb-2025	BATS 2 Brine Sampling	Stopped brine sampling for the heated SM borehole. 0 mL collected - no sample.
24-Feb-2025	BATS 2 Cold Trap	2.73 grams of water was collected in cold trap.
26-Feb-2025	BATS 2 Cold Trap	2.74 grams of water was collected in cold trap.
3-Mar-2025	BATS 2 Cold Trap	4.42 grams of water was collected in cold trap.
5-Mar-2025	BATS 2 Power Outage	There was an unexpected power outage on 3/4/2025.
5-Mar-2025	BATS 2 Cold Trap	2.60 grams of water was collected in cold trap.
10-Mar-2025	BATS 2 Brine Sampling	Stopped brine sampling for the heated SM borehole. 0 mL collected - no sample.
10-Mar-2025	BATS 2 Cold Trap	2.83 grams of water was collected in cold trap.
10-Mar-2025	BATS 2 Heating	The heated HP borehole power controller setpoint was changed from 140 deg C to 25 deg C.
12-Mar-2025	BATS 2 Cold Trap	3.24 grams of water was collected in cold trap ~93 deg C for collection.
17-Mar-2025	BATS 2 Brine Sampling	Stopped brine sampling for the heated SM borehole. 0 mL collected - no sample.
19-Mar-2025	BATS 2 Cold Trap	0.75 grams of water was collected in cold trap.
24-Mar-2025	BATS 2 Power Outage	Instrument status shows that there was a power outage.
26-Mar-2025	BATS 2 Permeability	Argon gas flow to the heated D borehole was stopped. The Starting pressure for the permeability test was `21.51 psi.
31-Mar-2025	BATS 2 Brine Sampling	Stopped brine sampling for the heated SM borehole. 0 mL collected - no sample.
7-Apr-2025	BATS 2 Brine Sampling	Stopped brine sampling for the heated SM borehole. 0 mL collected - no sample.
7-Apr-2025	BATS 2 Power Outage	An unexpected power outage occurred, the entire UG was without power.
14-Apr-2025	BATS 2 Brine Sampling	Stopped brine sampling for the heated SM borehole. 0 mL collected - no sample.
23-Apr-2025	BATS 2 Power Outage	There was an unexpected power outage starting on 4/21/2025.
28-Apr-2025	BATS 2 Brine Sampling	Stopped brine sampling for the heated SM borehole. 0 mL collected - no sample.
5-May-2025	BATS 2 Power Outage	Instrument status shows that there was a power outage.
5-May-2025	BATS 2 Brine Sampling	Stopped brine sampling for the heated SM borehole. 0 mL collected - no sample.
14-May-2025	BATS 2 Brine Sampling	Stopped brine sampling for the heated SM borehole. 0 mL collected - no sample.
19-May-2025	BATS 2 Power Outage	Discovered a lengthy (~2 to 3 day) unplanned power outage had occurred as the battery voltages for the data loggers was getting low. Electrical maintenance was notified and restored power later in the morning. We were advised that a planned power outage would occur as early as this afternoon and power would be out for ~2 days or so.
19-May-2025	BATS 2 Power Outage	Power was restored to the BATS experiment.
19-May-2025	BATS 2 Brine Sampling	Stopped brine sampling for the heated SM borehole. 0 mL collected - no sample.
21-May-2025	BATS 2 Gas Flowrate	The unheated gas circulation gas flow was stopped and will remain off for the time being. The heated circulation gas flow was changed from 100 mL/min to 50 mL/min.
21-May-2025	BATS 2 Power Outage	All dataloggers were downloaded and then turned off. There was no AC power due to power outages at WIPP and the dataloggers were turned off to preserve the backup DC batteries.
4-Jun-2025	BATS 2 Power Outage	Power was found to be restored to the BATS experiment after a very lengthy planned outage.

Date	Activity Category	Description
4-Jun-2025	BATS 2 Brine Sampling	Stopped brine sampling for the heated SM borehole. 0 mL collected - no sample.
9-Jun-2025	BATS 2 Brine Sampling	Stopped brine sampling for the heated SM borehole. 0 mL collected - no sample.
9-Jun-2025	BATS 2 Heater failure	The maintenance engineer (ME) arrived and checked the breaker and the receptacle and found no issues. The cord was plugged back in and still showed no power with the breaker turned ON. The cord plug seems to be the issue. I told the ME that we would take the plug apart and check connections on Wednesday.
11-Jun-2025	BATS 2 Heater failure	The power cord receptacle for the heated HP heating element was measured and the resistance was 2.68 M ohm. This suggests that the heating element is shorted out and basically an open circuit.

Table A-2. Power Outages Impacting BATS 2

Type	Date	Time	Comments
Planned	06/09/22		06/09/2022 @ 9:30, the Gas analyzer and AEs were shutdown for planned power outage on 06/11/2022
Planned	06/27/22	8:13	All dataloggers were shutdown for planned power outage
Planned	08/29/22	7:38	AE, gas analyzer, fiber optic, and Picarro were shutdown for planned power outage
Unexpected	10/12/22	10:24	
Unexpected	11/14/22	7:43	
Unexpected	01/10/23	19:20	
Unexpected	01/20/23	0:49	
Unexpected	03/16/23	10:54	
Unexpected	04/17/23	14:38	
Unexpected	05/08/23	21:40	
Unexpected	05/12/23	3:40	
Unexpected	05/16/23	3:40	power restored at 3:50.
Unexpected	05/16/23	14:40	
Unexpected	05/16/23	15:53	
Unexpected	05/24/23	15:09	Power to instruments was left off for planned power outage on 05/27/2023 to 05/29/2023.
Planned	06/19/23		pinched cable repair.
Unexpected	06/22/23	23:30	
Planned	07/24/23	8:46	transfer switch change, momentary - less than 1-second.
Planned	08/07/23	8:45	transfer switch change, momentary - less than 1-second.
Unexpected	09/11/23	20:08	
Unexpected	09/12/23	1:53	
Unexpected	09/15/23	8:58	
Planned	09/11/23		MSHA issue, bolting - planned (sort of) for gas analyzer, AE's, ERT, and fiber optic. Dataloggers were left running.
Planned	01/04/24	8:15	transfer switch change, momentary - less than 1-second.
Unexpected	01/11/24	6:26	
Planned	01/24/24	11:15	transfer switch change, momentary - less than 1-second.
Unexpected	01/24/24	11:36	outage after transfer switch change.
Unexpected	05/21/24	12:53	outage due to transfer switch change.
Unexpected	10/15/24	19:10	
Planned	11/10/24		11/10 through 11/13
Planned	12/04/24		12/04 through 12/05
Unexpected	12/25/24	11:50	12/25 through 12/26 Unexpected power outage.
Planned	01/10/25	23:30	
Planned	01/11/25	9:00	
Unexpected	01/17/25	10:20	
Unexpected	01/23/25	7:10	
Unexpected	02/05/25	8:00	

Type	Date	Time	Comments
Unexpected	02/10/25	18:30	
Unexpected	03/04/25	10:00	
Unexpected	03/24/25	9:20	
Planned	03/19/25	7:38	
Unexpected	04/21/25	18:10	WIPP supporting Cementation
Unexpected	04/22/25	8:40	WIPP supporting Cementation
Unexpected	04/22/25	14:40	WIPP supporting Cementation
Unexpected	05/01/25	20:50	
Unexpected	05/13/25	3:30	
Unexpected	05/17/25	9:20	