



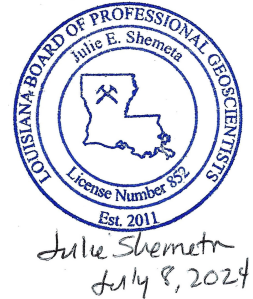
Microseismic Monitoring Report Sulphur Mines Salt Dome Borehole and Surface Seismic Arrays

Report Period : June 1-30, 2024

Report Date: July 8, 2024

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Using results from Baker Hughes and Nanometrics



June 2024 is the proposed start of a new combined monthly report for the borehole arrays and broadband surface seismic array. The bi-weekly surface seismic reports will cease and the reporting frequency will depend on the Microseismic Alert Level, proposed in May 2024 (Appendix Table 1). We propose to stop the event location notifications on the surface seismic array and use the reporting structure for the proposed alert levels.

Alert Level Status: Normal (Green)

1. Summary Borehole Array Summary June 2024

- 69 events were recorded in June on the borehole seismic arrays located in PPG Well No. 006-X and PPG Well No. 020: 25 located microseismic events and 44 seismic detections.
 - 18 events are located in the proposed seismic monitoring AOI, 3 in the cap rock and the remaining in the salt dome flanks.
 - Largest event was a magnitude 0.03 (surface magnitude), -0.3 (borehole magnitude) which occurred on June 14, 2024 05:25:21 CDT and was located in the AOI near Cavern 6 at a depth of 3133 (± 415 ft).
- The borehole array was operational during the month of June 2024. There were two outages for the PPG No. 6X, the bottom three sensors were offline from June 24 19:00 to June 25 16:00 and June 29 04:00 to 07:00 due to a software issue in the digitizers. New software was uploaded to the digitizer and is expected to resolve the issue.

a. Borehole Seismic Arrays

Baker Hughes "Microseismic Services" group operates and processes data for the borehole seismic arrays located in PPG Well No. 006-X and PPG Well No. 020. The seismic array locations are shown in Figure 1 and the coordinates are listed in the Appendix, Table 2.

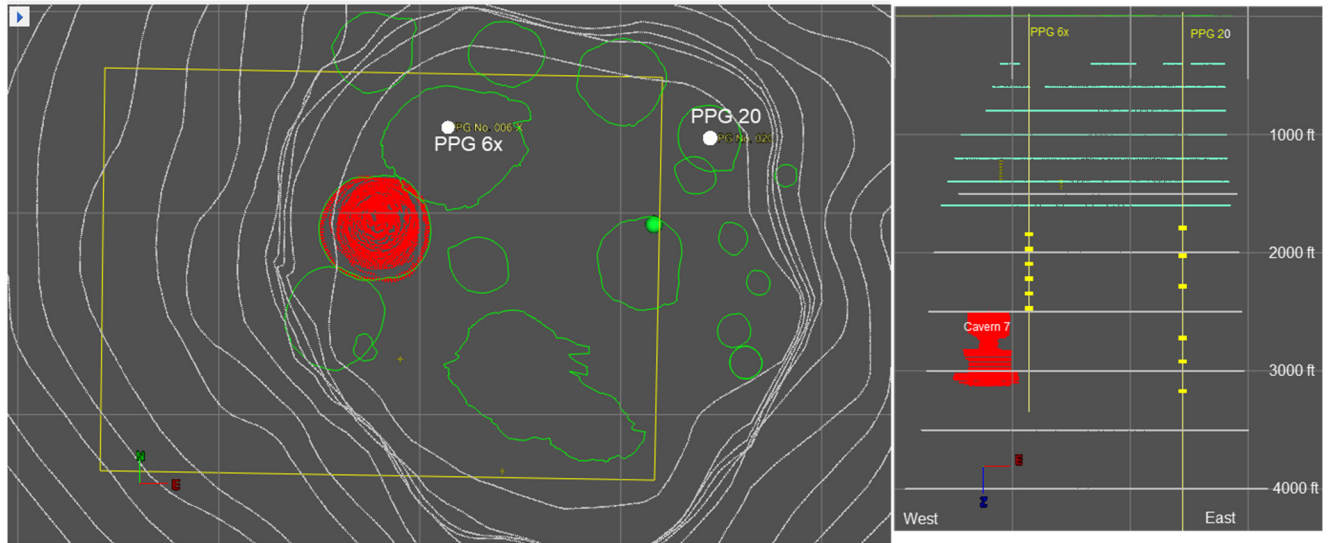


Figure 1. Map (left) and West-East cross section (looking from south) of the Sulphur Mines Salt Dome. The salt boundary is indicated by gray contour lines in map and side view. The borehole microseismic arrays are labeled and the various cavern are outlined in green in map view. In cross section the wellbores with the borehole array sensors are marked by yellow vertical line and yellow markers show the geophone positions in depth for PPG No. 006X and PPG No. 020. Cavern 7 is shown by a red sonar survey in both figures. The proposed AOI is indicated in map view by the yellow square. The grid is 1000 feet in both figures.

b. June 2024 Microseismic Activity (using the borehole seismic arrays).

69 total seismic events were detected in June 2024 on the borehole seismic arrays. 25 events had waveform with good signal to noise and a location and magnitude was estimated. The June event catalog is listed in the Appendix in Table 4. The remaining detections are too poor quality to determine an event location or magnitude. The locatable events occurred sporadically over the month with one event every few days until June 20, 25 and 28th, which had two events per day and June 26 with 4 events.

The event locations are located near Cavern 2, Cavern 16 and Cavern 6 and on the south flank of Sulphur Mines dome. One event was reported near Cavern 7, a magnitude -2.2 on June 22 at 6:45:48 AM. Three events occurred in one minute near Cavern 2 on June 26 at 7:27 AM.

The June microseismic magnitudes range from -2.2 to -0.3 with a median magnitude of -1.4 (Figure 5). The largest event was recorded on June 14 at 5:25 AM, the event is located near Cavern 6 (Figures 2 and 3). The magnitude estimates for this event is -0.3 (using the borehole arrays) and 0.03 (using the surface array).

The depth distribution in June is from about 1000 to 6000 ft subsea, with a median depth of 2885 ft (Figure 5).

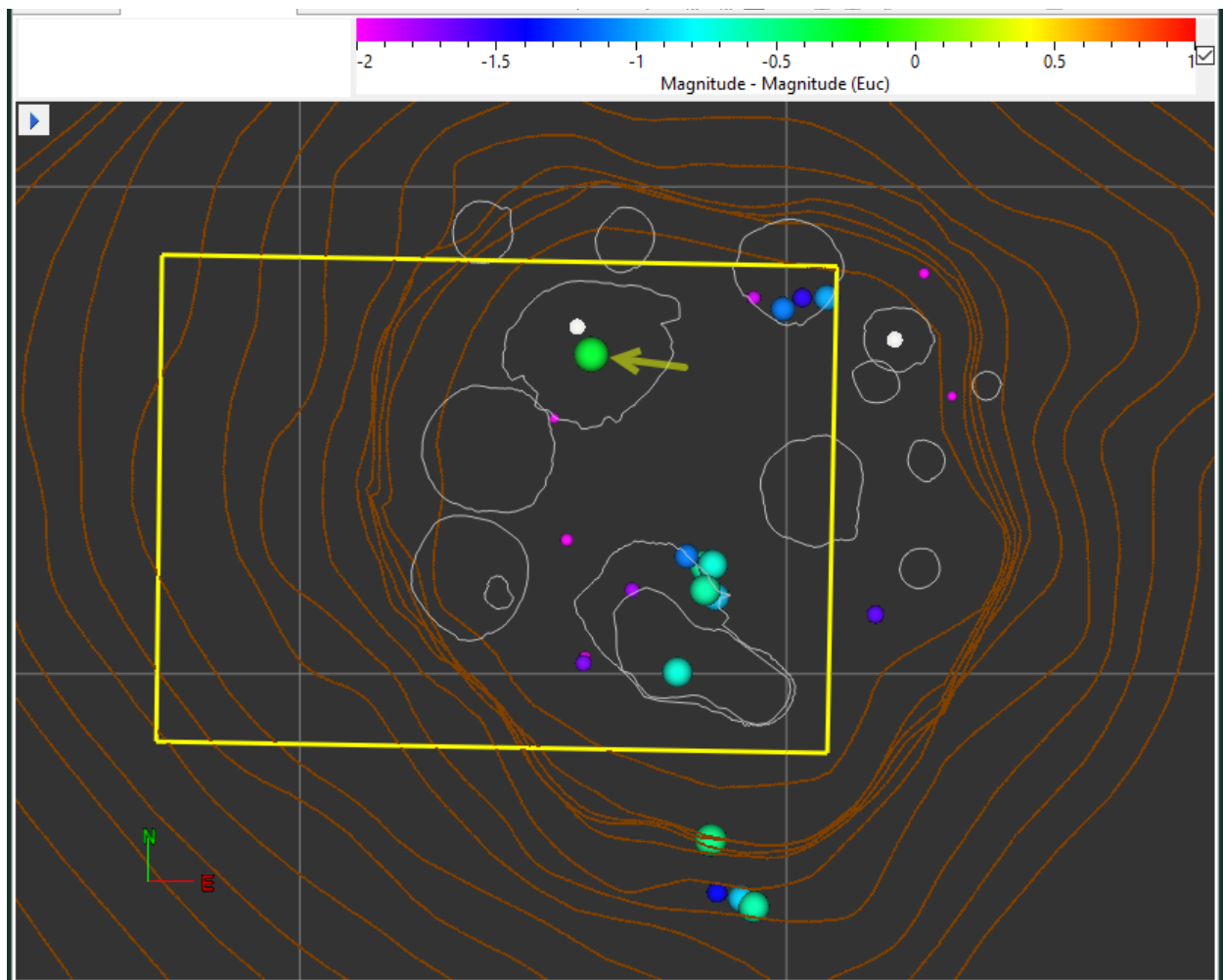


Figure 2. Map of microseismic events colored and sized by the borehole magnitude located in June 2024. The locations and magnitudes were computed using data from the borehole seismic arrays in PPG No. 006X and PPG No. 020. The largest magnitude event (magnitudes -0.3 borehole, 0.03 surface) occurred on June 14, 2024 and is marked by arrow. Grid is 2000 ft.

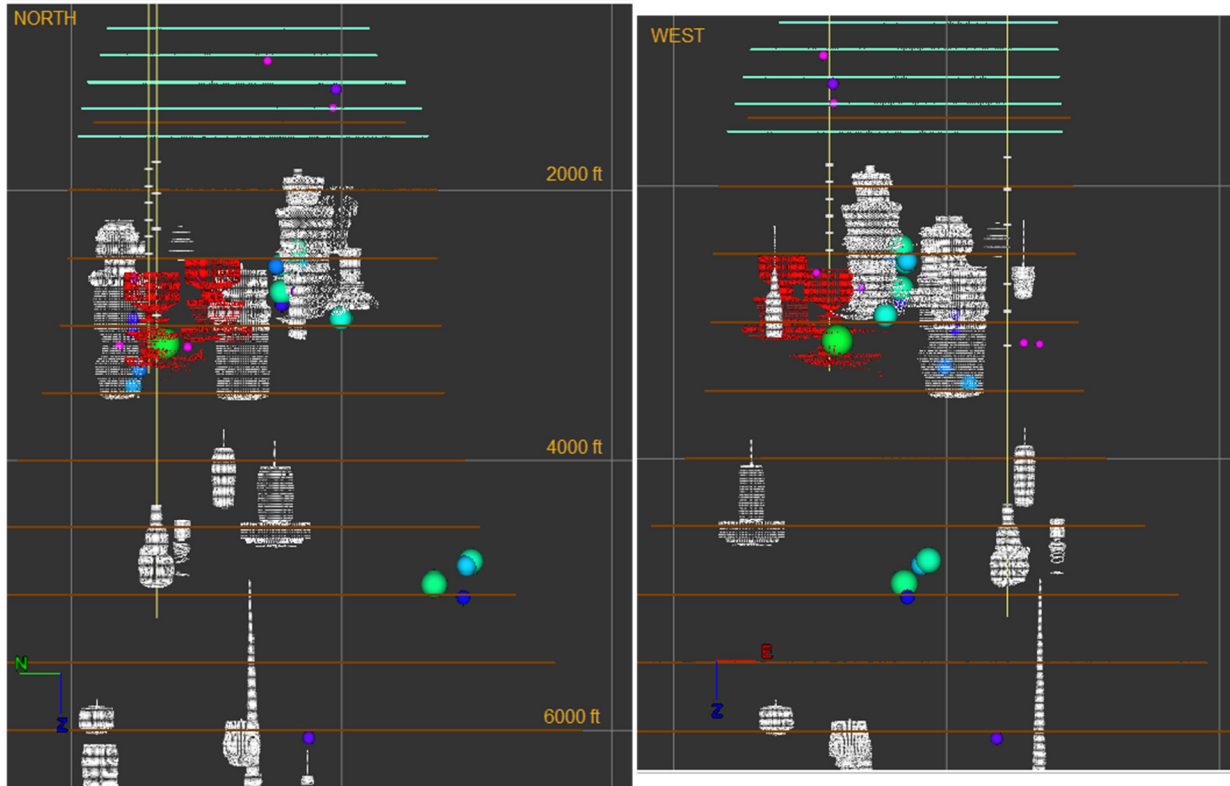


Figure 3. Cross sections N-S (left), looking from east, and E-W (right), looking from south. The events are sized and colored by magnitude (see color scale on map view). The borehole arrays are indicated by yellow wellbores and markers in side view. The salt (orange) and caprock (light green) boundaries are indicated by dots. The caverns as mapped by sonar are shown within the salt. Caverns 6 and 7 are colored red. Grid is 2000 ft.

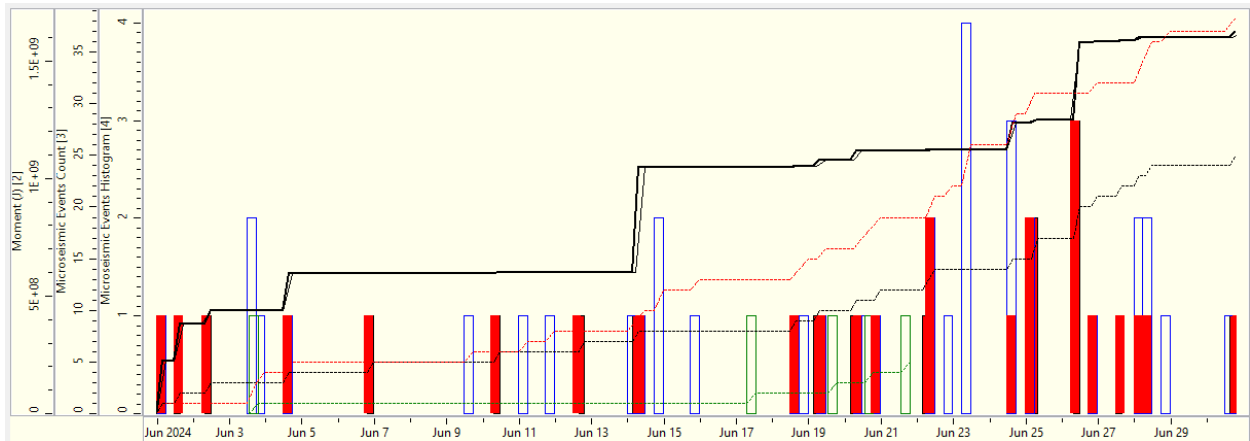


Figure 4. Time line of deep (blue) and shallow (green) detections and events (red) reported for the borehole arrays in June 2024. Histograms are the number of events per four hours. Black line is the cumulative seismic moment and the dotted lines are cumulative number of detections per event type.

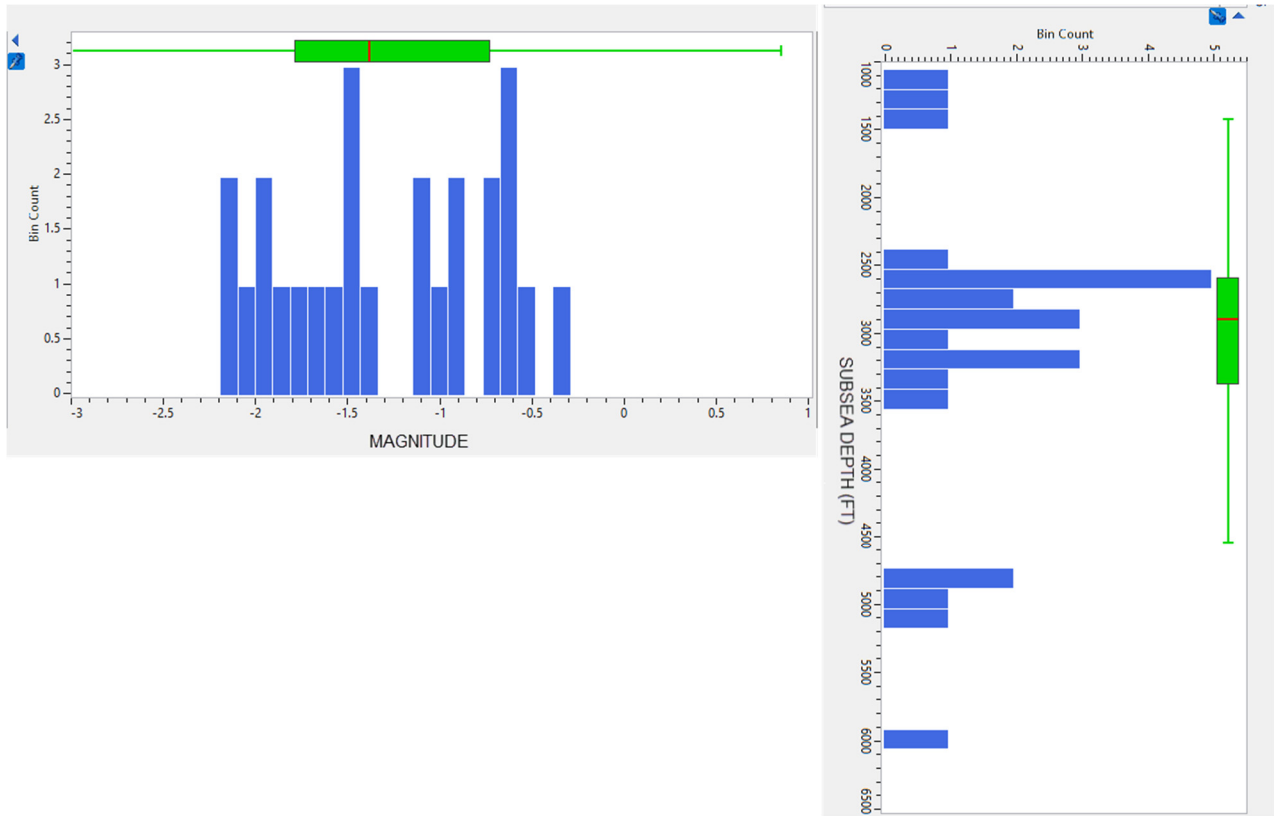


Figure 5. The microseismic magnitude distribution (left) and depth distribution (right) for activity in June 2024.

c. AOI Microseismic activity using borehole seismic arrays.

18 events were located in the proposed AOI in June 2024 using the borehole arrays. There was a magnitude -2.2 event on June 22 at 6:45:48 AM located on the NE side of Cavern 7 (Figures 6 and 7). Microseismic events were located near caverns PPG No. 016 (5 events), Caverns 6 (1 event), PPG No. 02 (8 events), three events in the cap rock on the SSE part of the dome (Figures 6 and 7).

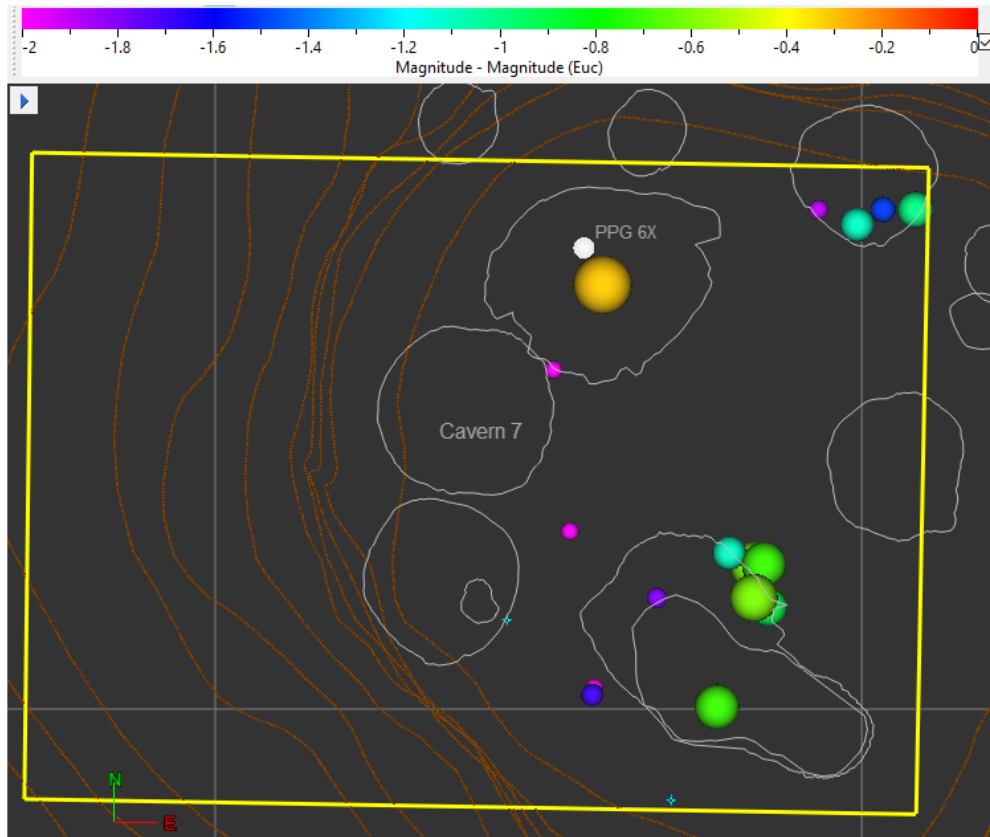


Figure 6. Map view of microseismic activity in June 2024 shown by colored dots in the proposed AOI (the AOI boundary is indicated by the yellow box). The events are sized and colored by magnitude. The salt contours are shown by orange lines, cavern outlines by white lines. Grid is 2000 feet. The PPG No. 006X well with borehole sensors located within the AOI is labeled.

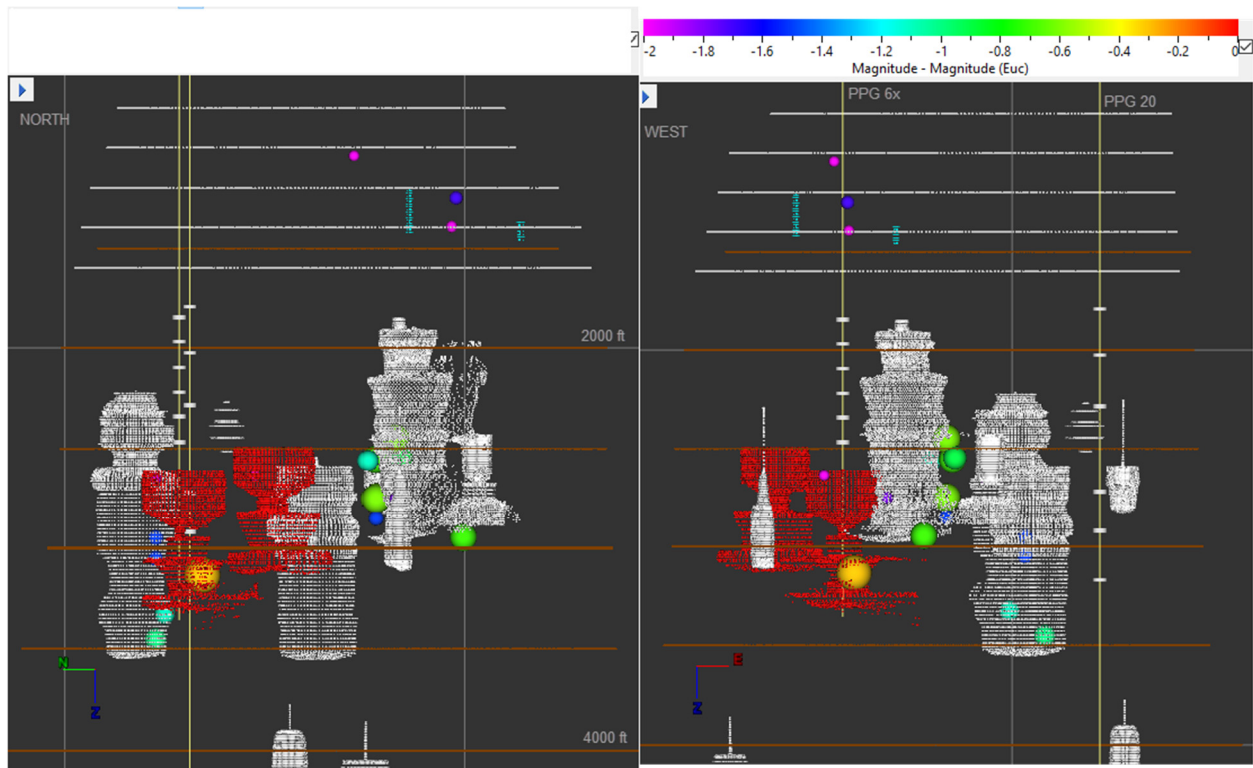


Figure 7. North-South (left) and West – East (right) vertical cross sections with microseismic events located in the proposed AOI with cavern sonars. Microseismic events are shown by colored dots, sized and colored by magnitude. Grid is 2000 feet. Salt (orange) and cap rock (gray) contours and legacy cap rock SWD perforations (cyan) are shown. Caverns 6 and 7 are shown in red, other caverns in white. Geophones are shown by the gray hash marks.

2. Surface Broadband Seismic Array Summary

- Four event locations reported using the surface broadband array in June 2024, all four events were co-recorded on the borehole arrays. (Table 5).
- The co-recorded borehole event locations were used to calibrate the surface array 3D velocity structure and re-calculate surface array event locations.
 - The surface array's 3D P- and S-wave velocity model was updated using the borehole locations for calibration and the updated model will be used for all future processing.
- The surface array was operational the entire month of June.
- Stations SUL03, SUL04, SUL05 and SUL06 are the quietest surface stations, SUL02 and SUL07 continue to be about 5-10 dB noisier than the other stations.

a) Broadband Trillium Compact Seismic Array

Nanometrics (<https://nanometrics.ca/home>) operates and processes data for the broadband array. The broadband station locations are shown in Figure 8 and listed in Table 3.

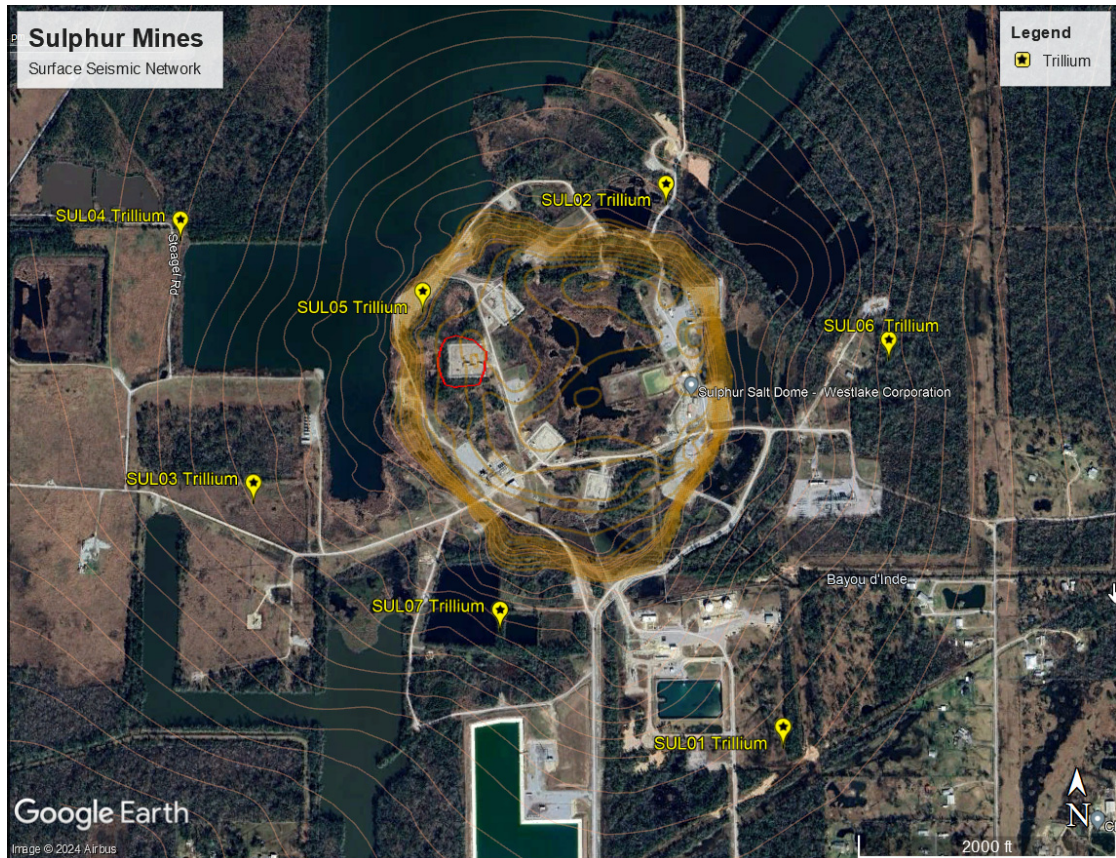


Figure 8. Google Earth map image showing the location of the six broadband seismic (Trillium Compact Sensors, yellow symbols and labels) stations near and at the Sulphur Mines Salt Dome. The contours are the salt and cap rock elevations, the red circle is the general outline of Cavern 7.

b). Surface Seismic Array Comments

Event Locations. Compared to the borehole array where the seismic waves are travelling mostly through salt, the surface velocity model is more complex as the seismic waves travel through salt, cap rock and sediment. The signal to noise ratio for the P- and S-wave arrivals is lower due to the higher noise levels on the surface array and the longer ray path distance from the event to the seismic station, the energy is weaker at the surface due to signal attenuation. This makes accurate P- and S-wave arrivals more difficult to pick on the surface array. Both the picking accuracy and complex velocity model is reflected in the accuracy of surface array event locations. For reporting information about the seismic events, the borehole event location will be considered more reliable than the surface array and is considered the preferred event location. Where applicable, both surface and borehole event magnitudes be reported for co-recorded events. Under the Microseismic Alert System, the larger magnitude estimate will be considered in assigning the Alert Level status.

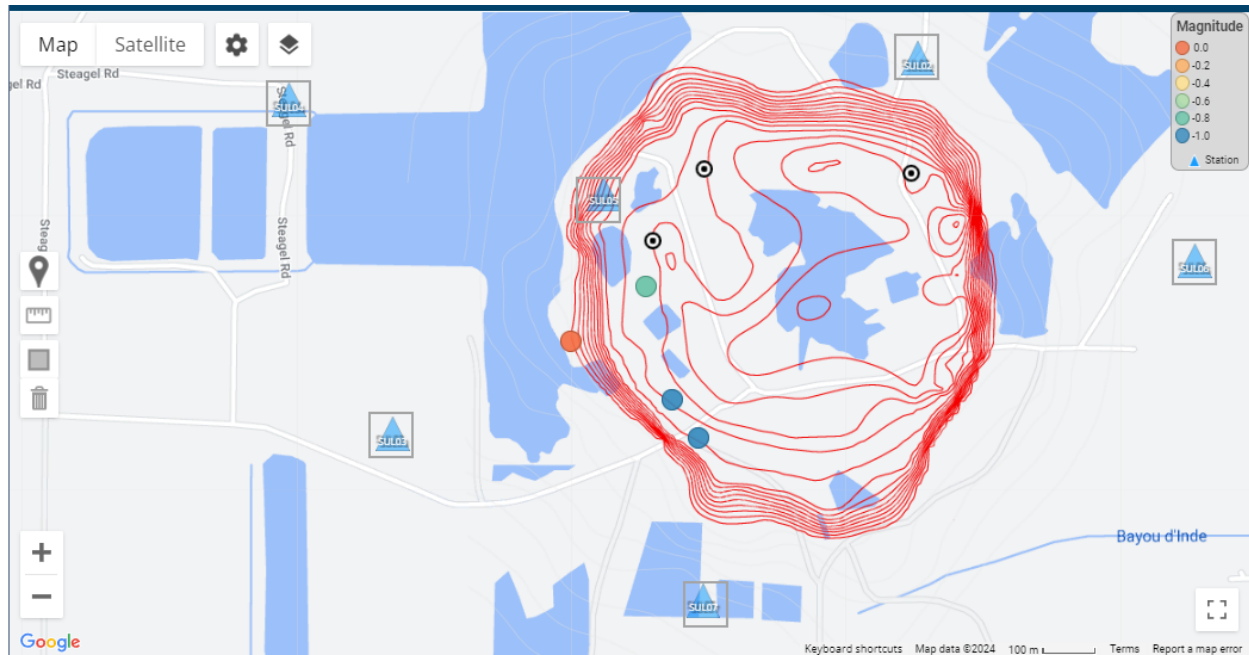


Figure 9. Map showing event locations (colored dots) using the surface array in June 2024. The salt contours are shown in red. Seismic stations are shown by blue triangles with boxes.

Magnitudes. The event magnitudes from either seismic array are computed by measuring the low-frequency content of the seismic waveform. The larger the microseismic event, the lower the frequency. For magnitude estimates >0 , the surface array has an advantage over the borehole arrays, as the surface sensors are 20 second (0.05 Hz) broadband seismometers. The seismometers allow for accurate recording of lower frequency, thus larger events. The borehole arrays have 15 Hz borehole geophones, the sensors are designed to record frequencies mostly higher than 10 Hz. The surface array “low-frequency” advantage is evident in the June 14 event; the surface array computed a slightly larger magnitude (0.03) than the borehole array (-0.3). The broadband instruments are able to capture more of the lower-frequency signal and better estimate event magnitudes for events magnitude approximately magnitude >0 . The combination of results using both seismic arrays plays to the strengths of each system.

Appendix

Table 1. Proposed Microseismic Alert Level Criteria and Response for Sulphur Mines Dome.

Alert Status	Criteria	Response
Low (GREEN)	No events with magnitude ≥ 0.5 in AOI and/or Less than 30 MEQ per day in AOI with magnitudes ≥ -1	Once per week data processing, with previous monthly microseismic activity summary in the AOI is provided by the 15th of the following month to LDNR IMD.
Advisory (YELLOW)	Event with magnitude ≥ 0.5 and < 1.0 in AOI and/or Count of MEQ per day ≥ 30 and < 40 in AOI with magnitudes ≥ -1	Daily data processing M-F. Weekly reporting is provided LDNR IMD with activity summary from the previous week. Status remains active until seismic levels within the AOI reach "low"(green) level for 1 day.
Watch (ORANGE)	Event with magnitude ≥ 1 and < 1.5 in AOI and/or Count of MEQ ≥ 40 and < 50 with magnitudes ≥ -1 in AOI	Seven days per week data processing, 2x week reporting with activity for the previous days is provided via email and text message notifications to IMD. Status remains active until seismic levels within the AOI reach Advisory or Low criteria for 2 consecutive days.
Warning (RED)	Event with magnitude ≥ 1.5 in the AOI and/or Count of MEQ ≥ 50 with magnitudes ≥ -1 in the AOI	Seven days per week data processing, daily reporting with online meetings with stake holders as needed. The warning status level remains active until seismicity levels within the AOI reach a lower status level for 2 consecutive days.

Table 2. Borehole Sensor Locations

Wellbore	Sensor #	TVD SS	Northing ft	Easting ft
PPG 6x	Sonde 1	1844	1343141	583425
PPG 6x	Sonde 2	1969	1343141	583425
PPG 6x	Sonde 3	2094	1343141	583425
PPG 6x	Sonde 4	2219	1343141	583425
PPG 6x	Sonde 5	2344	1343141	583425
PPG 6x	Sonde 6	2469	1343141	583425
PPG 20	Sonde 1	1790	1344445	583372
PPG 20	Sonde 2	2025	1344445	583372
PPG 20	Sonde 3	2285	1344445	583372
PPG 20	Sonde 4	2720	1344445	583372
PPG 20	Sonde 5	2920	1344445	583372
PPG 20	Sonde 6	3170	1344445	583372

Table 3. Seismic Station locations and operational dates at Sulphur Mines Dome (to July 1, 2024). Temporary Station locations and start and end dates provided by Westlake. Trillium station locations provided by Nanometrics.

Station	LAT WGS84	LON WGS84	Date start	Date end
Temp_1a	30.2575	-93.4123	1/30/2023	2/9/2023
Temp_1b	30.2534	-93.4135	2/9/2023	4/3/2023
Temp_2a	30.2570	-93.4097	1/30/2023	2/9/2023
Temp_2b	30.2555	-93.4132	2/9/2023	2/27/2023
Temp_2c	30.2547	-93.4138	2/27/2023	4/5/2023
Temp_3a	30.2533	-93.4091	1/30/2023	2/9/2023
Temp_3b	30.2563	-93.4146	2/9/2023	4/5/2023
Temp_4a	30.2486	-93.4123	1/30/2023	2/27/2023
Temp_4b	30.2507	-93.4121	2/27/2023	3/8/2023
Temp_4c	30.2506	-93.4100	3/8/2023	3/15/2023
Temp_4d	30.2503	-93.4119	3/15/2023	est 4/3/2023
Temp_5a	30.2502	-93.4156	1/30/2023	2/27/2023
Temp_5b	30.2507	-93.4153	2/27/2023	3/15/2023
Temp_5c	30.2504	-93.4140	3/15/2023	est 4/3/2023
Temp_6a	30.2532	-93.4166	1/30/2023	3/15/2023
Temp_6b	30.2529	-93.4161	3/15/2023	4/4/2023
Temp_7a	30.2547	-93.4161	1/30/2023	4/3/2023
Semi Perm S01	30.2453	-93.4073	4/4/2023	5/12/2023
Semi Perm S02	30.2571	-93.4098	4/6/2023	
Semi Perm S03	30.2536	-93.4091	4/6/2023	
Semi Perm S04	30.2470	-93.4213	4/5/2023	
Semi Perm S04_1	30.2506	-93.4204	5/12/2023	
Semi Perm S05	30.2564	-93.4224	4/5/2023	
Semi Perm S06	30.2532	-93.4167	4/5/2023	
Semi Perm S07	30.2547	-93.4162	4/5/2023	
SUL01 trillium	30.2452	-93.4071	9/20/2023	3/12/2024
SUL02 trillium	30.2570	-93.4099	9/13/2023	
SUL03 trillium	30.2504	-93.4203	9/12/2023	
SUL04 trillium	30.2562	-93.4223	9/12/2023	
SUL05 trillium	30.2546	-93.4161	9/13/2023	
SUL06 trillium	30.2535	-93.4043	3/12/2024	
SUL07 trillium	30.2477	-93.4141	3/12/2024	

Table 4. June 2024 Microseismic Event Catalog.
UTC time is used for monthly catalog time window.

Date Time CDT (UTC date range used for reporting)	Easting (ft)	Northing (ft)	Depth (ft)	Borehole		Uncertainties			Description
				Array Magnitude (Mw)	Surface Array Magnitude (Mw)	ΔEasting (ft)	ΔNorthing (ft)	ΔDepth (ft)	
05/31/2024 23:24:04	1343689	581318	4919	-0.5		1238	3011	1591	Flank
06/01/2024 12:51:32	1343866	581044	4750	-0.6		900	3226	1567	Flank
06/02/2024 10:31:20	1343815	581078	4782	-0.9		997	3130	1619	Flank
06/04/2024 14:35:53	1343666	582344	2450	-0.6		302	1402	875	AOI_PPG_02
06/06/2024 23:08:32	1344566	583644	3150	-2.1		352	620	477	Flank
06/10/2024 10:11:22	1343166	582044	1250	-1.7		490	1804	873	AOI_Cap_Rock
06/12/2024 15:46:42	1344681	583140	3159	-2.2		354	601	463	Flank
06/14/2024 05:25:22	1343198	583312	3133	-0.3	0.03	327	997	415	AOI_PPG_06
06/18/2024 12:20:57	1343097	582550	1042	-2.0		456	1477	621	AOI_Cap_Rock
06/19/2024 05:57:36	1343590	582483	2562	-1.1		412	1356	791	AOI_PPG_02
06/20/2024 06:58:52	1344166	583544	3450	-1.0		387	890	530	AOI_PPG_16
06/20/2024 22:14:31	1343172	582066	1393	-2.0		498	1743	823	AOI_Cap_Rock
06/22/2024 06:45:48	1343046	583049	2636	-2.2		418	776	423	AOI_PPG_07
06/22/2024 09:39:46	1343366	582344	2750	-1.8		583	1519	848	AOI_PPG_02
06/24/2024 14:14:24	1343552	582007	2946	-0.7	-0.96	442	1873	893	AOI_PPG_02
06/25/2024 04:33:13	1344066	583544	2950	-1.5		403	712	588	AOI_PPG_16
06/25/2024 04:33:35	1344066	583544	3050	-1.5		432	756	638	AOI_PPG_16
06/26/2024 07:27:22	1343697	582448	2555	-0.7	-0.82	300	1392	680	AOI_PPG_02
06/26/2024 07:27:29	1343710	582316	2547	-0.9		294	1535	748	AOI_PPG_02
06/26/2024 07:27:44	1343666	582444	2750	-0.6	-0.68	349	1378	564	AOI_PPG_02
06/26/2024 22:33:39	1343666	582444	2850	-1.5		322	1450	766	AOI_PPG_02
06/27/2024 13:51:37	1344366	582244	6050	-1.6		971	3141	1577	Flank
06/28/2024 01:09:32	1343715	581102	5019	-1.4		1079	3241	1748	Flank
06/28/2024 08:05:52	1343866	583544	2650	-1.9		269	797	700	AOI_PPG_16
06/30/2024 18:33:02	1343986	583498	3323	-1.1		460	938	613	AOI_PPG_16

Table 5. June 2024 Microseismic Event Broadband Surface Seismic Array Catalog

Date/Time CDT	Easting ft	Northing ft	Depth ft	Magnitude Mw	Depth error (ft)	Horizontal error (ft)
06/14/2024 05:25:21	1342222	582526	2986	0.03	886	738
06/24/2024 14:14:24	1342850	582156	1444	-0.96	558	304
06/26/2024 07:27:22	1343012	581908	2001	-0.82	919	728
06/26/2024 07:27:44	1342694	582863	3346	-0.68	1083	1409