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

Report Period : October 1-31, 2024
Report Date: November 5, 2024
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Using results from Baker Hughes and Nanometrics

Seismic Monitoring Update

Please take note of upcoming modifications regarding the seismic monitoring and data processing at Sulphur Mines salt dome: the borehole and surface seismic arrays data will be combined for microseismic event processing.

The following actions are underway:

- Nanometrics will continue acquisition using the surface seismic array.
- Baker Hughes will have real-time access to the surface array waveform data for integration into the borehole waveform data for processing the microseismic location and magnitude estimates.
- Baker Hughes will provide event locations and magnitudes for all seismic events at Sulphur Mines Salt Dome using the combined borehole arrays and surface array waveform data.
- Event locations using the surface array only will no longer be provided.
- The seismic monitoring changes are anticipated to start in late November or early December 2024.

Alert Level Status: Normal (Green)

1. **Summary Borehole Array Summary October 2024**

- 132 events were detected in October on the borehole seismic arrays located in PPG Well No. 006-X and PPG Well No. 020; 35 located microseismic events and 97 seismic detections.
    - 15 events are located in the proposed seismic monitoring AOI, 9 in the cap rock, 1 in the salt, one near Cavern PPG 06 and 4 events in proximity to Cavern PPG 016.
    - Largest event in October was a magnitude -0.8 event on October 21 at 10:58, located outside the AOI on the northern flank of the dome at 5850 ft depth.

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. Both of the borehole arrays were fully functional in October 2024.

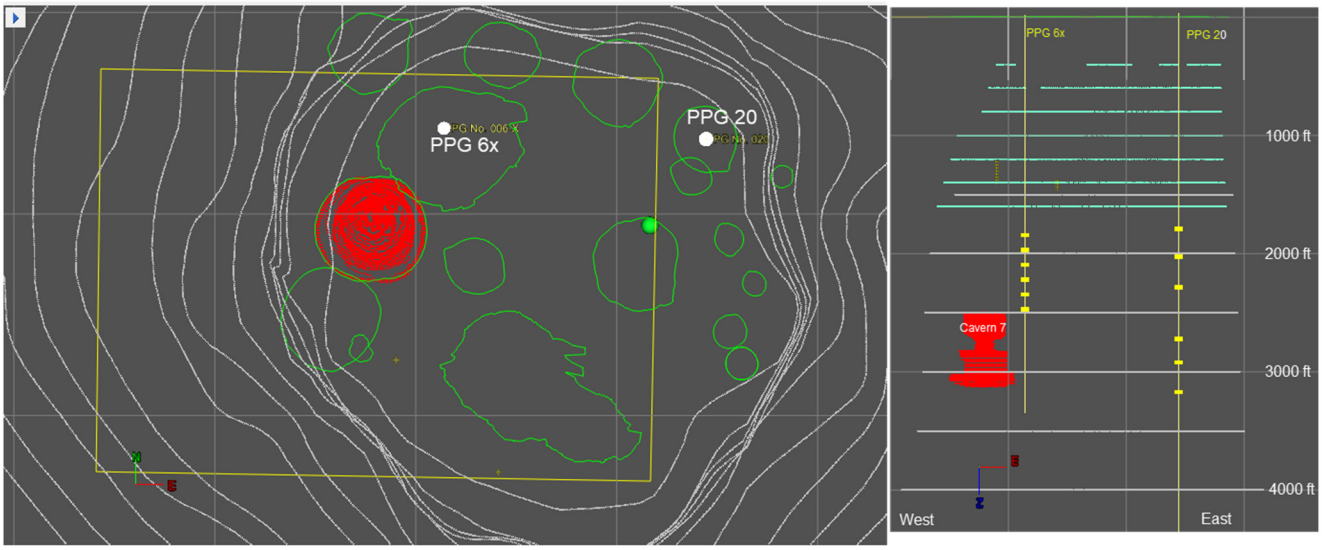

Figure 1. Map (left) and West-East cross section (looking from south) of the Sulphur Mines Salt Dome. The salt boundary is indicated by gray contour lines in map and side view. The borehole microseismic arrays are labeled and the various cavern are outlined in green in map view. In cross section the 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.

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

132 seismic events were detected in October 2024 on the borehole seismic arrays. 35 events had waveform with adequate signal to noise levels to compute a location and magnitude. The October 2024 microseismic event catalog is listed in the Appendix in Table 4. The remaining event-detected waveforms are too poor quality to determine an event location and magnitude. Each detection is classified as shallow or deep depending on the energy arriving along the array. Seismic energy arriving from below the array is classified as a "deep" detection and energy arriving from above the array as "shallow" detection. The October 2024 temporal distribution of located and detected microseismic events is shown in Figure 2. Caverns with proximal seismic activity in October are PPG 16 with four events, three event in proximity of Sulphur Storage 04, and one event near the roof of PPG 06.

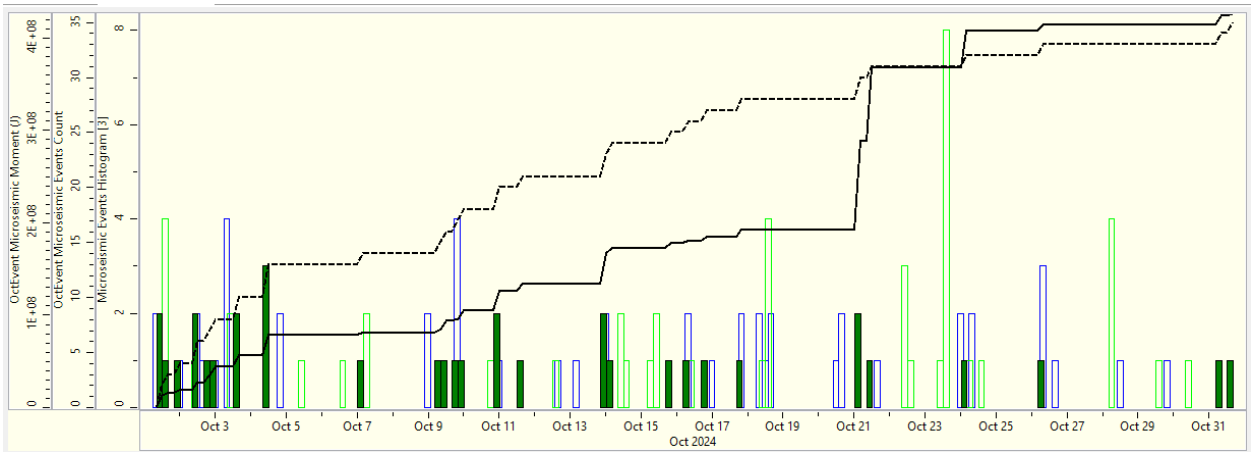

Figure 2. Temporal distribution of microseismic detections and locations in October 2024 recorded at Sulphur Mines salt dome with the borehole arrays. The histograms indicate the number of events in a four-hour time window. The event detections are unfilled boxes, where blue indicates a deep detection (seismic energy is emulating from below the seismic array) and green indicated is a shallow event detection (seismic energy is coming from above the seismic array). The located events time distribution is indicated by filled dark green boxes. Black line shows the cumulative seismic moment and the black dotted line is cumulative number of the located seismic events.

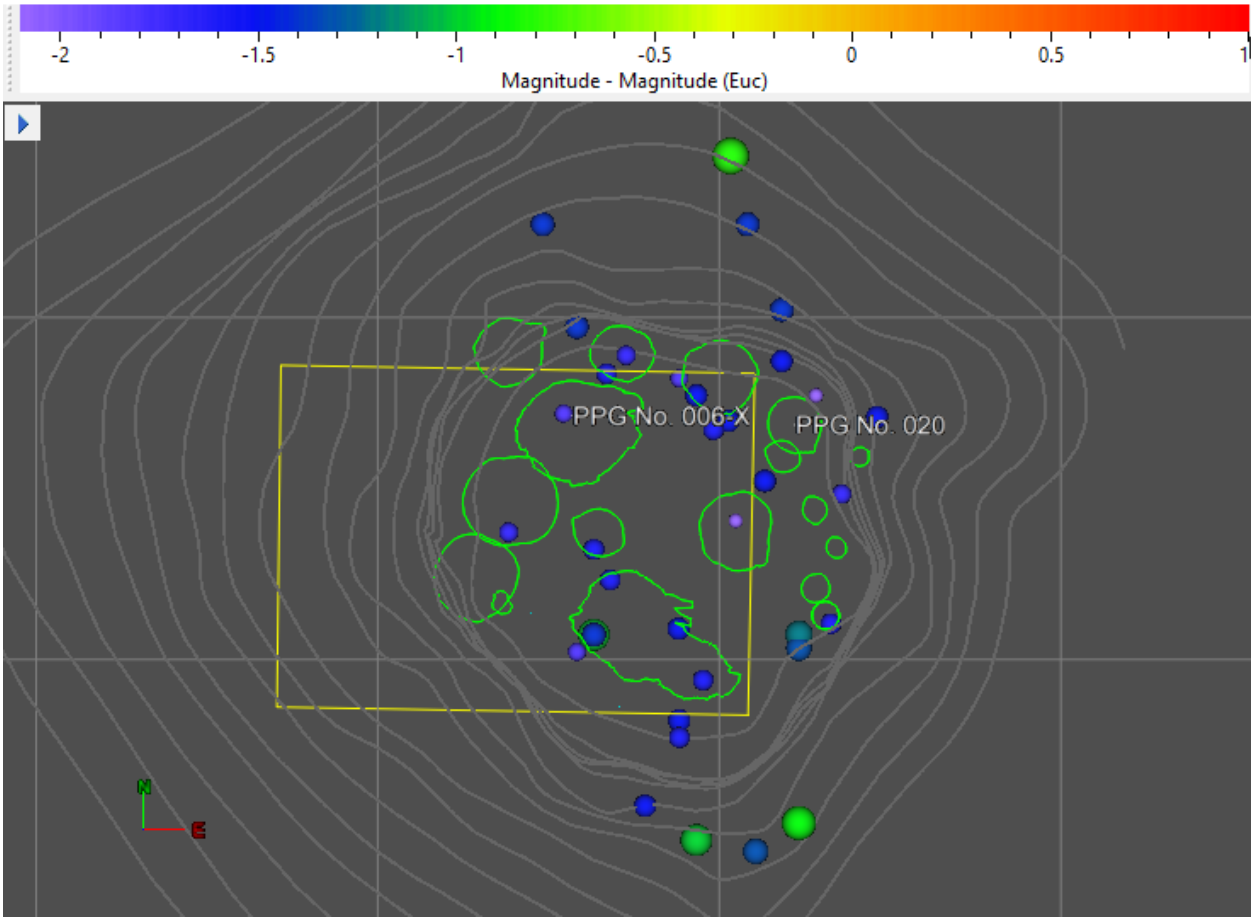

Figure 3. Map of the October 2024 borehole microseismic events colored and sized by magnitude. The locations and magnitudes were computed using data from the borehole seismic arrays in PPG No. 006X and PPG No. 020 (labeled). Grid is 2000 ft. The yellow box is the proposed AOI, gray lines are the salt contours.

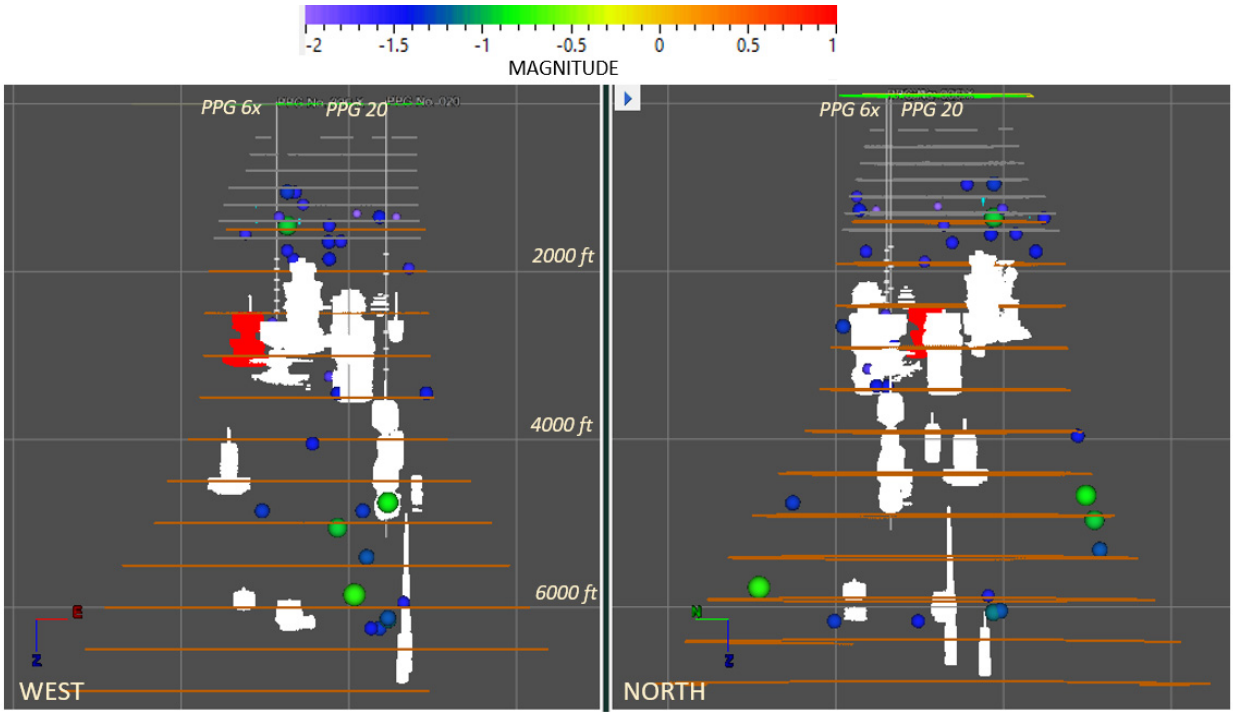

Figure 4. The October 2024 microseismic locations shown in depth view. The cross sections W-E (left), looking from south; and N-S (right), looking from west. The microseismic events are sized and colored by magnitude. The salt (dark orange) and caprock (gray) boundaries are indicated by dots. The various salt caverns as mapped by sonar are shown within the salt. Geophone locations are indicated by hash marks, PPG 20 and PPG 6x well labeled. Grid is 2000 ft.

The October microseismic magnitudes range from -2.1 to -0.8 with a median magnitude of -1.5 (Figure 5). The largest event in October was a magnitude -0.8 event on October 21, 2024 at 10:58:35 CDT, on the northern flank of the dome, outside the AOI, at 5850 ft depth.

The depth distribution in October is from 1050 to 6250 ft subsea, with a median depth of 2750 ft subsea (Figure 5).

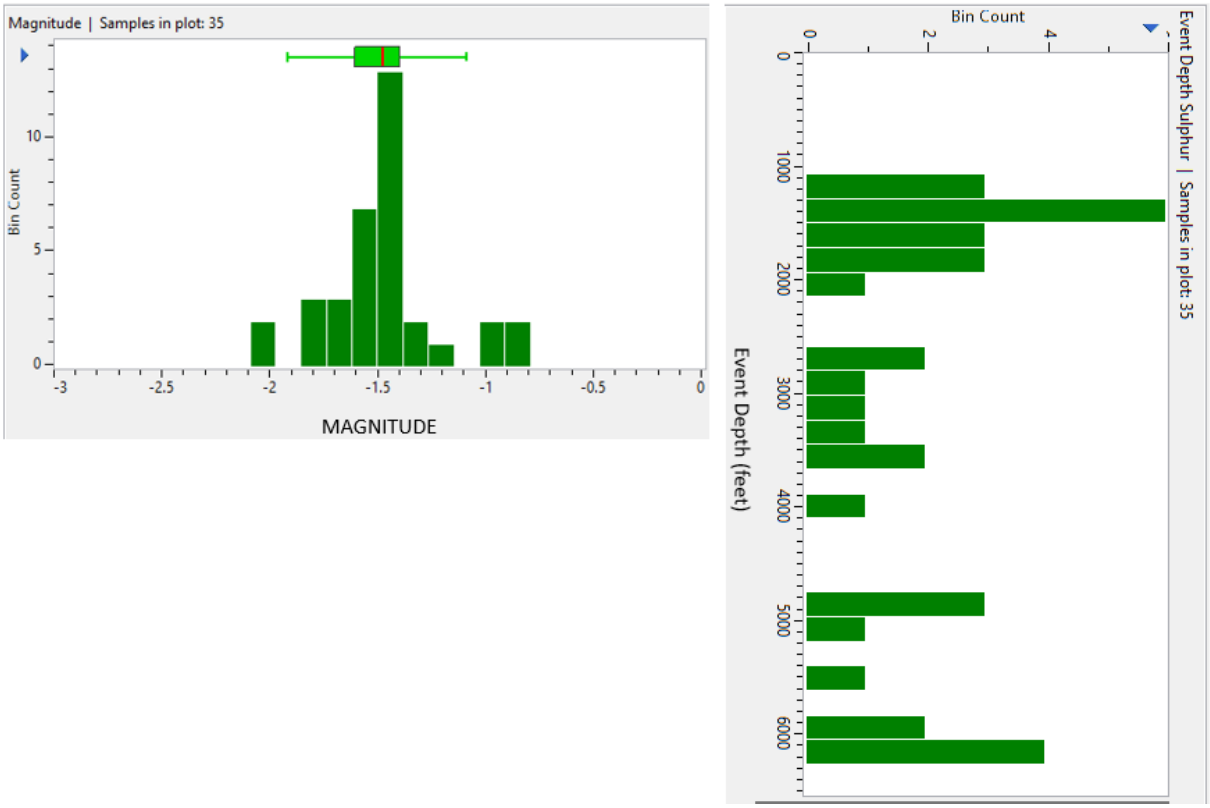

Figure 5. The magnitude distribution (left) and depth distribution (right) for microseismic activity in October 2024.

c. **AOI Microseismic activity using borehole seismic arrays.**

15 events are located in the proposed AOI in October 2024 using the borehole seismic arrays (Figures 6 and 7). Nine of the AOI events are located in cap rock and one event is located on the dome flank. The remaining AOI events were in proximity to salt caverns: one event near the roof of PPG 06 and four near PPG 16.

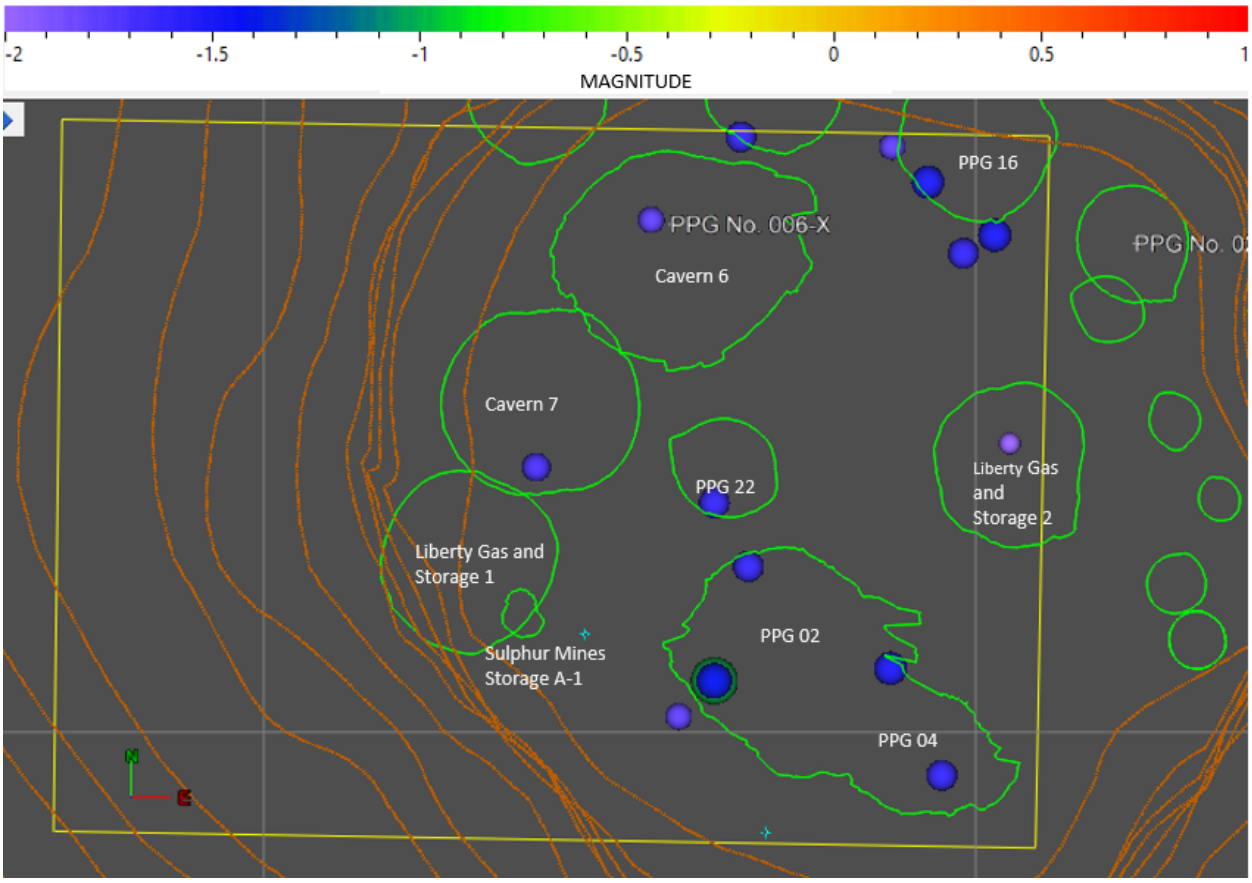

Figure 6. Map view of microseismic activity in October 2024 shown by colored dots in the proposed AOI (yellow box). The events are sized and colored by magnitude. The salt contours are shown by orange lines, cavern outlines by green lines. Grid is 2000 feet. The PPG 6x and PPG 020 borehole array locations are labeled.

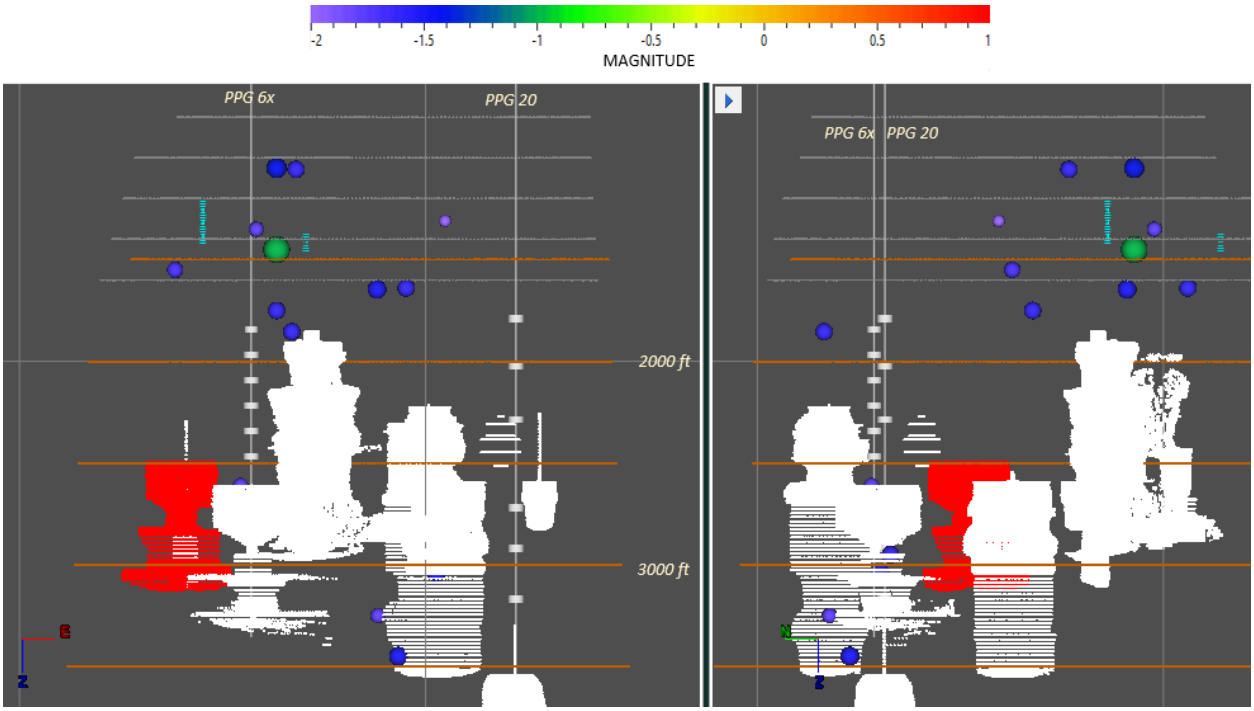

Figure 7. West–east (left, looking from south) and north-south (right, looking from west) vertical cross sections with the October 2024 microseismic events located in the proposed AOI with cavern sonars. Microseismic events are shown by colored dots, sized and colored by magnitude. Grid is 2000 feet. Salt boundary is shown in (orange), cap rock in gray. Cavern sonars are indicated by white dots, cavern 7 sonar is shown in red. The borehole geophone locations are indicated by hash marks, PPG 20 and PPG 6x wells are labeled.

d. Cumulative Seismicity since start of the borehole arrays

The cumulative seismicity located since the start of the borehole arrays in salt and cap rock is shown in Figures 8 and 9. In general, the cumulative seismicity is scattered throughout the Sulphur Mines dome and flanks. Events in the cap rock are generally scatter over the salt dome with some clustering to the SSW. The events >4700 feet depth is mostly off the northern and southern flanks of the dome, with some clustering in the southern flank. The seismic activity below the cap rock and above 4700 ft appears to be associated with various caverns in the dome. There is continues to be very little seismicity observed near Cavern 7.

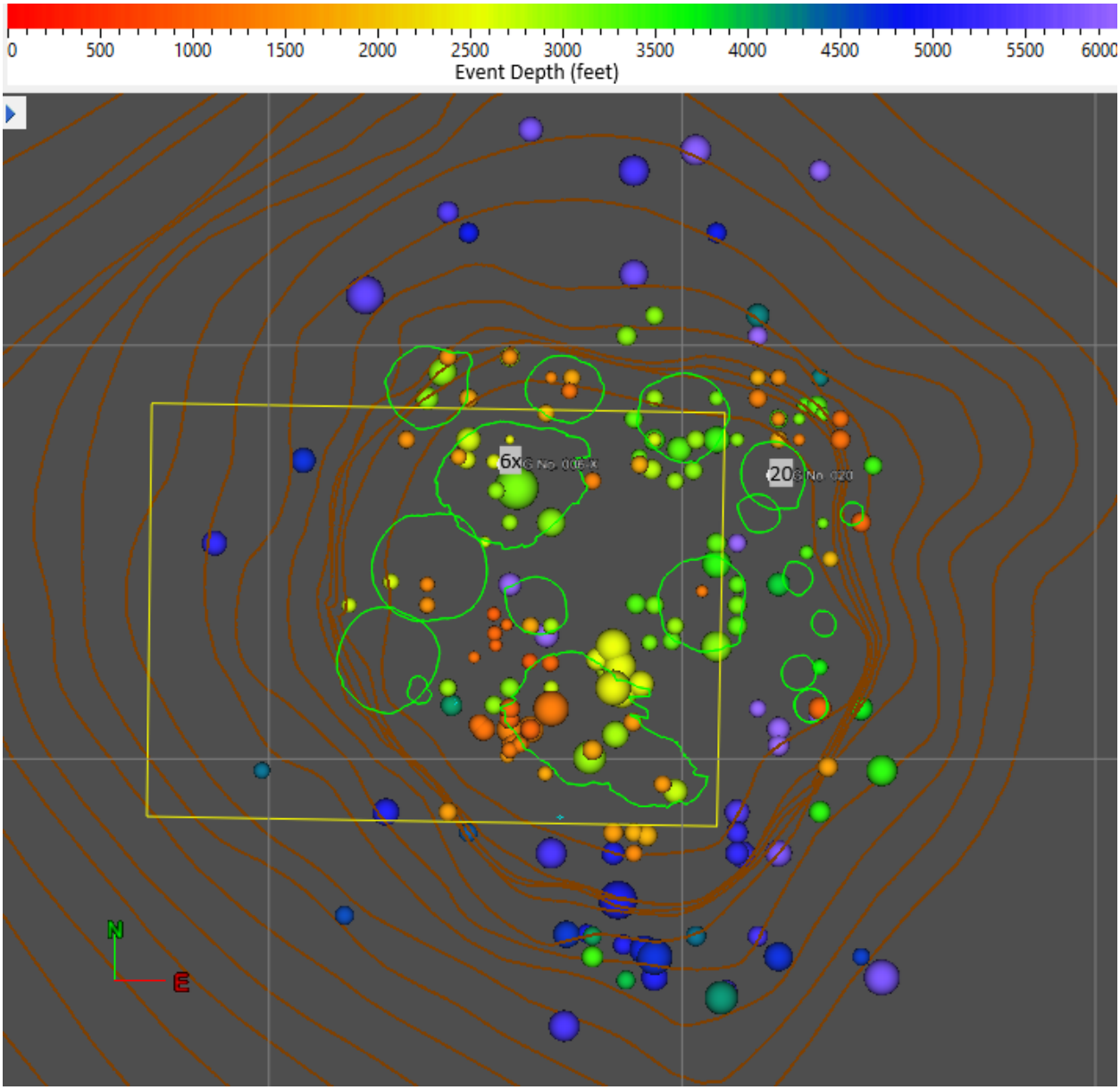

Figure 8. . Map view of the cumulative microseismicity recorded from April 22 to October 31, 2024 using borehole seismic arrays (PPG 6-X and PPG 20 (labeled on map as 6x and 20)) Events are sized by magnitude and colored by depth. Grid is 2000 ft. The salt dome contours are shown by orange lines.

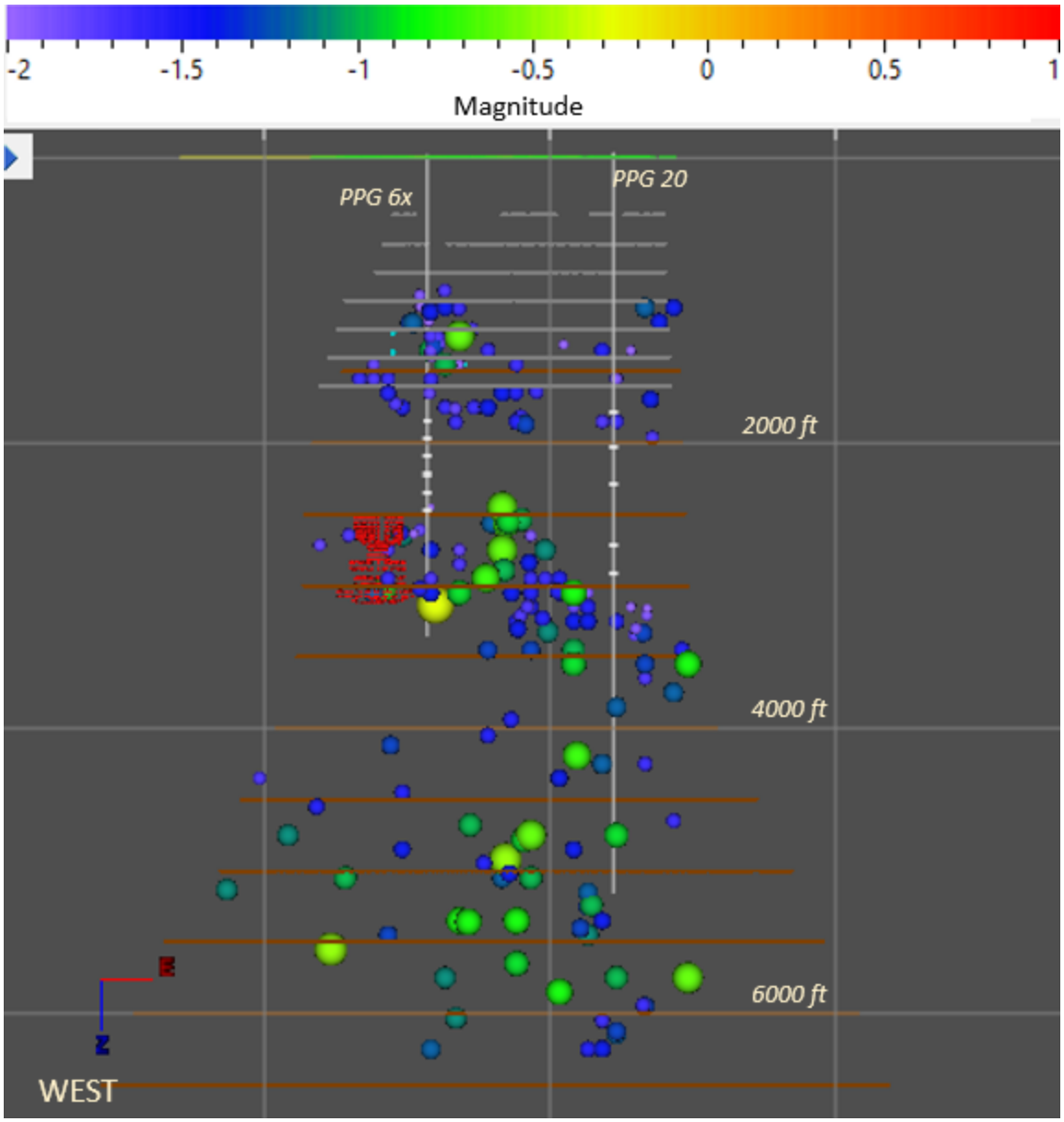

Figure 9. West-East side view of the cumulative microseismicity recorded from April 22 to October 31, 2024 using borehole seismic arrays (labeled PPG 6x and PPG 20). The microseismic events are sized by magnitude and colored by magnitude. The Salt boundary is shown by dark orange dotted lines, cap rock by gray dotted lines. Cavern 7 sonar is shown in red. Grid is 2000 ft.

Figure 10 shows the timeline of the 193 (excluding perforation shots) events located since the start of the borehole monitoring on April 22, 2024. The median magnitude for all the activity from April 22 to October 30, 2024 is magnitude -1.5 (Figure 10 inset).

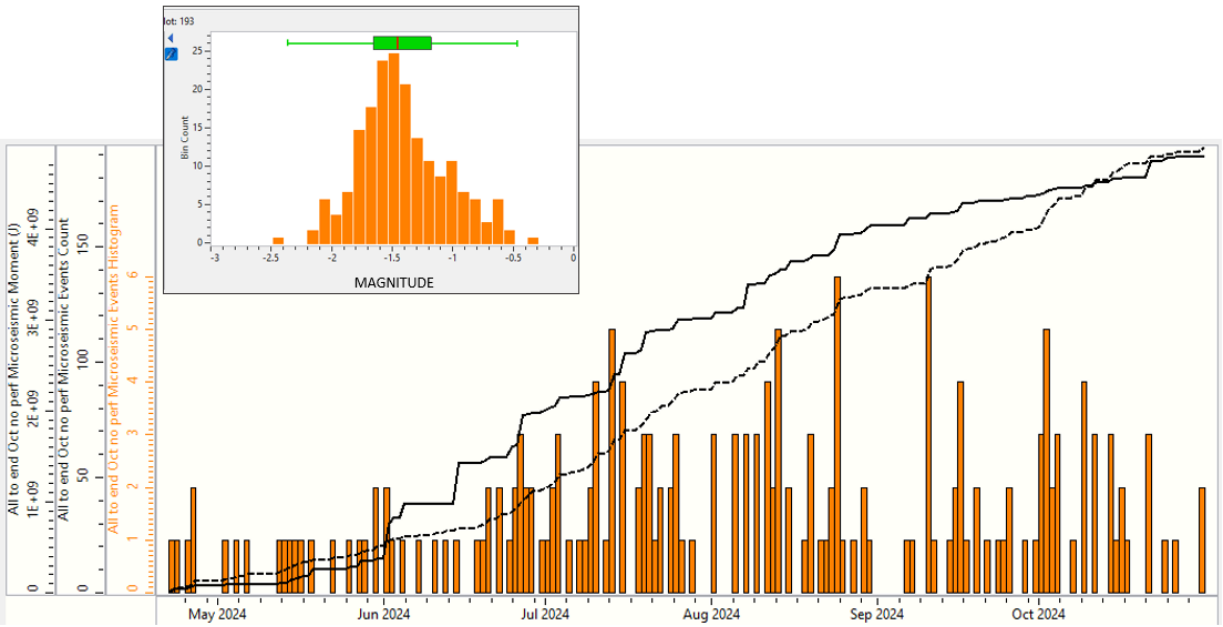

Figure 10. Time line of all microseismicity located at Sulphur Mines using the borehole arrays from April 22 to the end of October 2024. The histogram is the number of events per day, the black solid line is the cumulative seismic moment and the black dotted line the cumulative number of events. The upper left histogram shows the magnitude distribution for the 193 events located at Sulphur Mines from April 22 to October 31, 2024, (excluding the perforation shots).

There is an increase in both in number of events and the seismic moment (a proxy for energy) starting in late June over the entire dome.

The number of events in the AOI peaks in August, however the microseismicity energy decreases in July and continues to decrease through October (Figure 11).

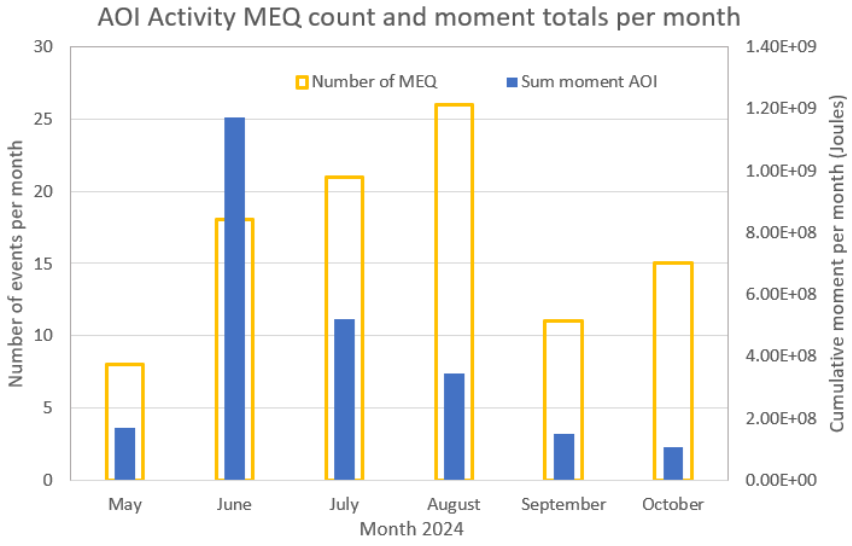

Figure 11. Graph of AOI microseismic activity by month. Yellow boxes indicate the count of MEQ per month (left axis) located in the AOI, the blue filled boxes (right axis) shows the cumulative seismic moment by month.

2. Surface Broadband Seismic Array Summary

- There are no seismic events reported in October 2024 on the surface array.
- Station SUL07 was repaired during a maintenance visit on October 1 and 2. As of October 3, all the surface seismic stations are operational through the end of October.
- The background noise on stations SUL04, SUL05 and SUL06 in October continue to be the quietest surface stations, SUL02 and SUL07 continue to be about 5-10 dB nosier. Station SUL03 background noise increased during the day mid-October, likely due to berm and other construction activity in the area. The berm construction will affect the background noise level surface array as it moves across the dome in the vicinity of the various seismic 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 show in Figure 12 and listed in Table 3.

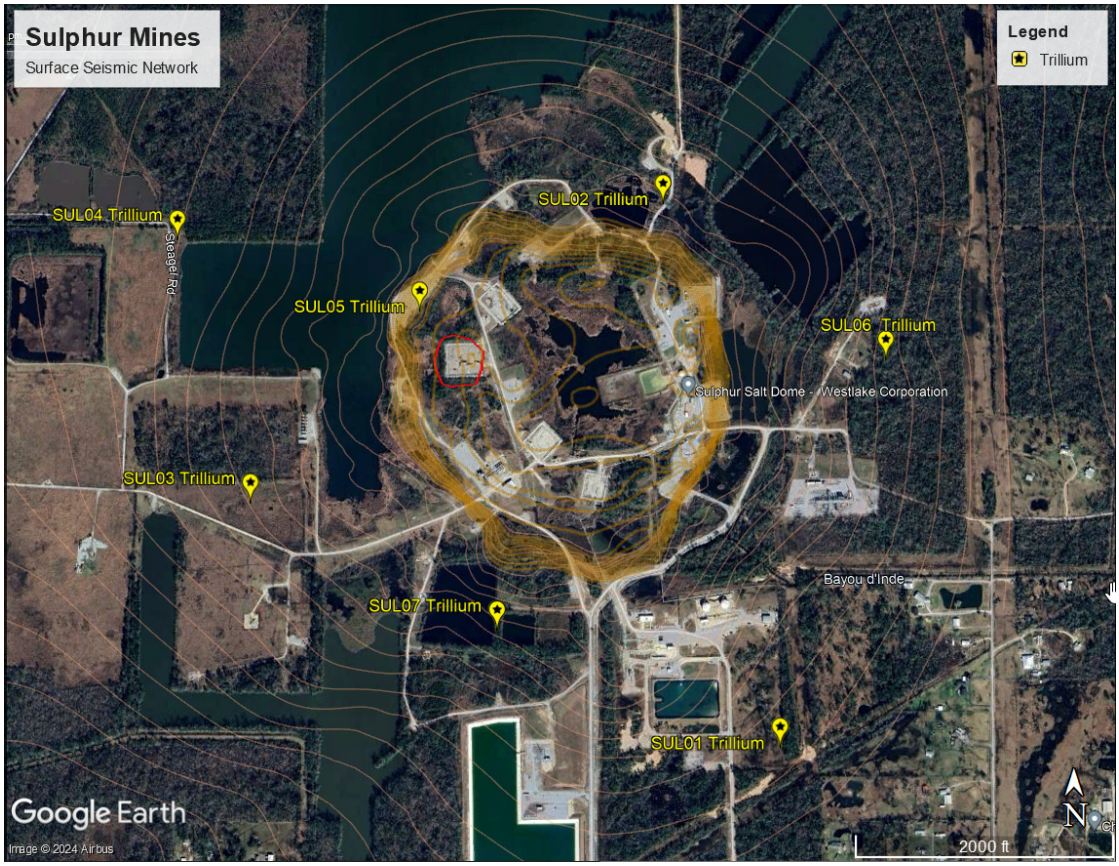

Figure 12. Google Earth map image showing the location of the six broadband seismic (Trillium Compact Sensors, yellow symbols and labels) stations near and at the Sulphur Mines Salt Dome. The contours are the salt and cap rock elevations, the red circle is the general outline of Cavern 7.

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 LNDR 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 October 1, 2024). Temporary Station locations and start and end dates provided by Westlake. Trillium station locations provided by Nanometrics and Westlake (Trillium SUL 02-07).

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	
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	5/12/2023
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
	LAT NAD 83	**LON NAD 83**		
SUL02 trillium	30.2570	-93.4098	9/13/2023	
SUL03 trillium	30.2505	-93.4203	9/12/2023	
SUL04 trillium	30.2563	-93.4224	9/12/2023	
SUL05 trillium	30.2547	-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. October 2024 Microseismic Event Catalog.

UTC time is used for monthly catalog time window.

Note: Cap rock and salt classification based on waveforms and Baker Hughes interpretation of event location.

Central date and time	Easting (ft)	Northing (ft)	Depth (ft)	Mag. (Mw)	Location uncertainties			Area/Cavern
					ΔEasting (ft)	ΔNorthing (ft)	ΔDepth (ft)	
10/01/2024 08:28:51	1344054	583395	3039	-1.5	241	727	351	AOI_PPG_16
10/01/2024 08:29:00	1343966	583344	2950	-1.6	280	1123	661	AOI_PPG_16
10/01/2024 13:33:30	1343455	583779	1201	-1.7	350	1104	607	Cap_Rock
10/01/2024 22:44:10	1342766	582744	1550	-1.7	494	1010	713	AOI_Cap_Rock
10/02/2024 10:15:15	1343089	583438	2610	-1.8	330	760	455	AOI_PPG_06
10/02/2024 10:43:24	1343362	582465	1056	-1.6	377	1504	847	AOI_Cap_Rock
10/02/2024 16:52:41	1343566	581144	4050	-1.5	773	2908	1415	Flank
10/02/2024 22:13:24	1342966	584544	4850	-1.4	743	2578	1202	Flank
10/03/2024 16:16:37	1343766	581644	1850	-1.5	417	1817	854	Cap_Rock
10/03/2024 16:17:21	1343905	581879	1639	-1.6	371	1703	1187	AOI_Cap_Rock
10/04/2024 08:52:12	1343761	582179	1646	-1.5	339	1473	1450	AOI_Cap_Rock
10/04/2024 09:20:55	1343766	581544	1450	-1.6	408	2188	1517	Cap_Rock
10/04/2024 09:51:51	1343166	583944	2750	-1.4	326	1061	527	Flank
10/07/2024 04:09:36	1343766	583644	3250	-1.8	394	1002	550	AOI_PPG_16
10/09/2024 06:33:36	1344717	582967	1962	-1.7	287	750	334	Flank
10/09/2024 11:43:03	1344366	584044	6250	-1.4	970	3139	1531	Salt
10/09/2024 19:21:39	1344096	582811	1309	-2.1	303	1030	492	AOI_Cap_Rock
10/09/2024 21:07:46	1344166	584544	4850	-1.4	696	2417	1051	Flank
10/10/2024 23:24:56	1344213	580878	5402	-1.3	963	3601	2171	Flank
10/10/2024 23:42:36	1344366	583744	1350	-1.5	280	948	575	Cap_Rock
10/11/2024 15:05:55	1344266	583044	6250	-1.5	979	2965	1362	Salt
10/13/2024 22:54:21	1344467	582147	6145	-1.2	994	3218	1554	Sul_Stor_04
10/13/2024 22:54:41	1344466	582066	6125	-1.3	995	3228	1560	Sul_Stor_04
10/14/2024 04:01:30	1343266	582644	1750	-1.6	316	1168	681	AOI_Cap_Rock
10/15/2024 20:27:44	1344653	582209	5941	-1.6	998	3052	1626	Sul_Stor_04
10/16/2024 07:41:10	1343166	582044	1350	-1.8	460	1788	1246	AOI_Cap_Rock
10/16/2024 19:24:41	1343341	583671	1854	-1.6	235	678	484	AOI_Flank
10/17/2024 20:27:58	1343866	583544	3450	-1.5	352	1395	681	AOI_PPG_16
10/21/2024 03:09:25	1343866	580944	5050	-1	1003	3352	1846	Flank
10/21/2024 03:09:30	1344466	581044	4750	-0.9	1182	2988	2325	Flank
10/21/2024 10:58:35	1344066	584944	5850	-0.8	1030	3267	1735	Flank
10/24/2024 01:39:39	1343266	582144	1450	-1	434	1629	726	AOI_Cap_Rock
10/26/2024 06:29:52	1344924	583418	3449	-1.5	407	1280	1176	Flank
10/31/2024 08:00:24	1343266	582144	1050	-1.4	438	1692	689	AOI_Cap_Rock
10/31/2024 14:02:07	1344566	583544	1350	-2.1	297	866	419	Cap_Rock