



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

Report Period : November 1-30, 2024

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Using results from Baker Hughes and Nanometrics



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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.
- Estimated date change for processing modifications- The seismic monitoring changes are anticipated to start late December 2024 or early January 2025.

Alert Level Status: Normal (Green)

1. Summary Borehole Array Summary November 2024

- 122 events were detected in November on the borehole seismic arrays located in PPG Well No. 006-X and PPG Well No. 020; 40 located microseismic events and 82 seismic detections.
 - The largest events in November were two magnitude -0.8 events: one near Cavern 7 at 3050 feet on Nov. 14 at 12:24:41 AM; and one near Cavern 6 on November 17 at 12:02:42 AM, at 3323 ft.

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 sensor coordinates are listed in the Appendix, Table 2. Both of the borehole arrays were fully functional in November 2024, however, from Nov. 25-30, the vertical component of level 3 in the PPG 20 array background noise increased, apparently due to electrical interferences. The noise lowered after Nov. 30, 2024.

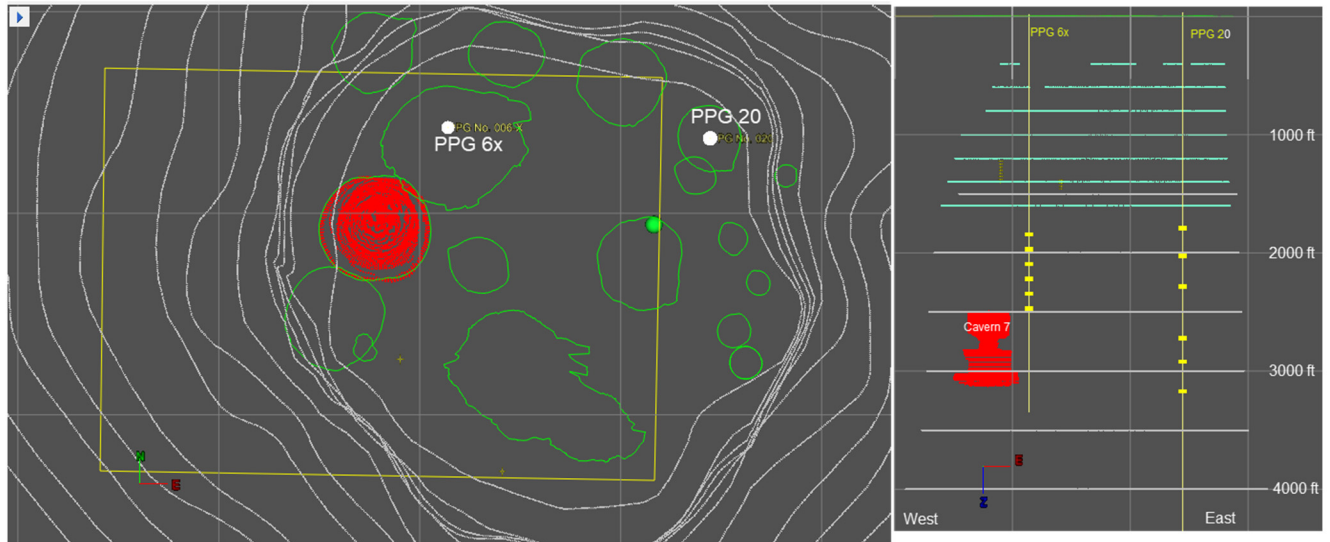


Figure 1. Map (left) and West-East cross section (looking from south) of the Sulphur Mines Salt Dome. The salt boundary is indicated by gray contour lines in map and side view. The borehole microseismic arrays are labeled and the various cavern are outlined in green in map view. In cross section the 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. November 2024 Microseismic Activity (using the borehole seismic arrays).

122 seismic events were detected in November 2024 on the borehole seismic arrays. 40 events had waveforms with adequate signal to noise levels to compute an event location and magnitude. The November 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 November 2024 temporal distribution of located and detected microseismic events is shown in Figure 2. The salt caverns with proximal seismic activity in November are:

- PPG 07 six events, including one of the largest events recorded in November, magnitude -0.8
- LGS 02 five events
- PPG 06 four events, including one of the largest events recorded in November, magnitude -0.8
- Caverns PPG 02, PPG 22 and PPG 16 each had one event.

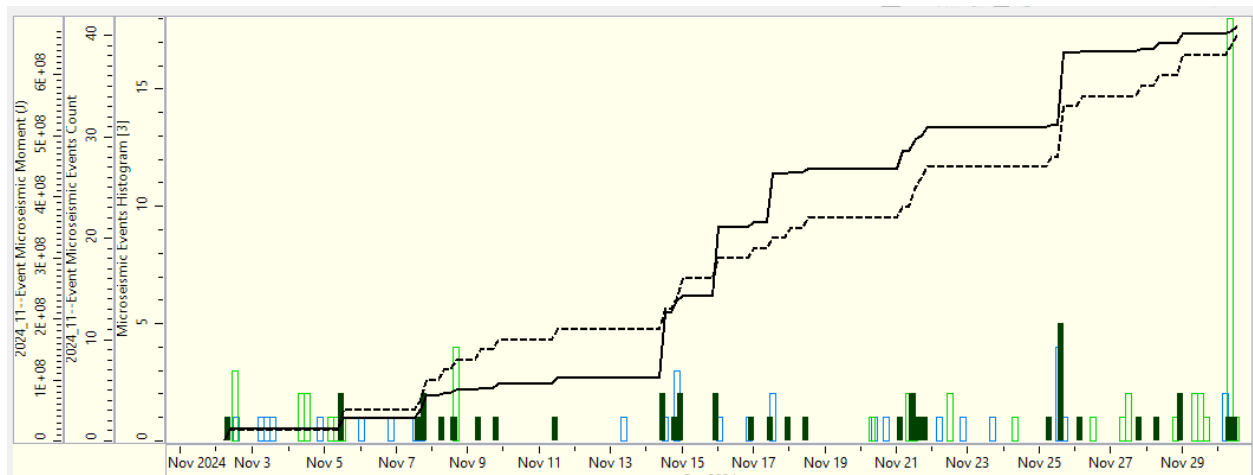


Figure 2. Temporal distribution of microseismic detections and locations in November 2024 recorded at Sulphur Mines salt dome with the borehole arrays. The histograms indicate the number of events in a four-hour time window. The event detections are unfilled boxes, where blue indicates a deep detection (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.

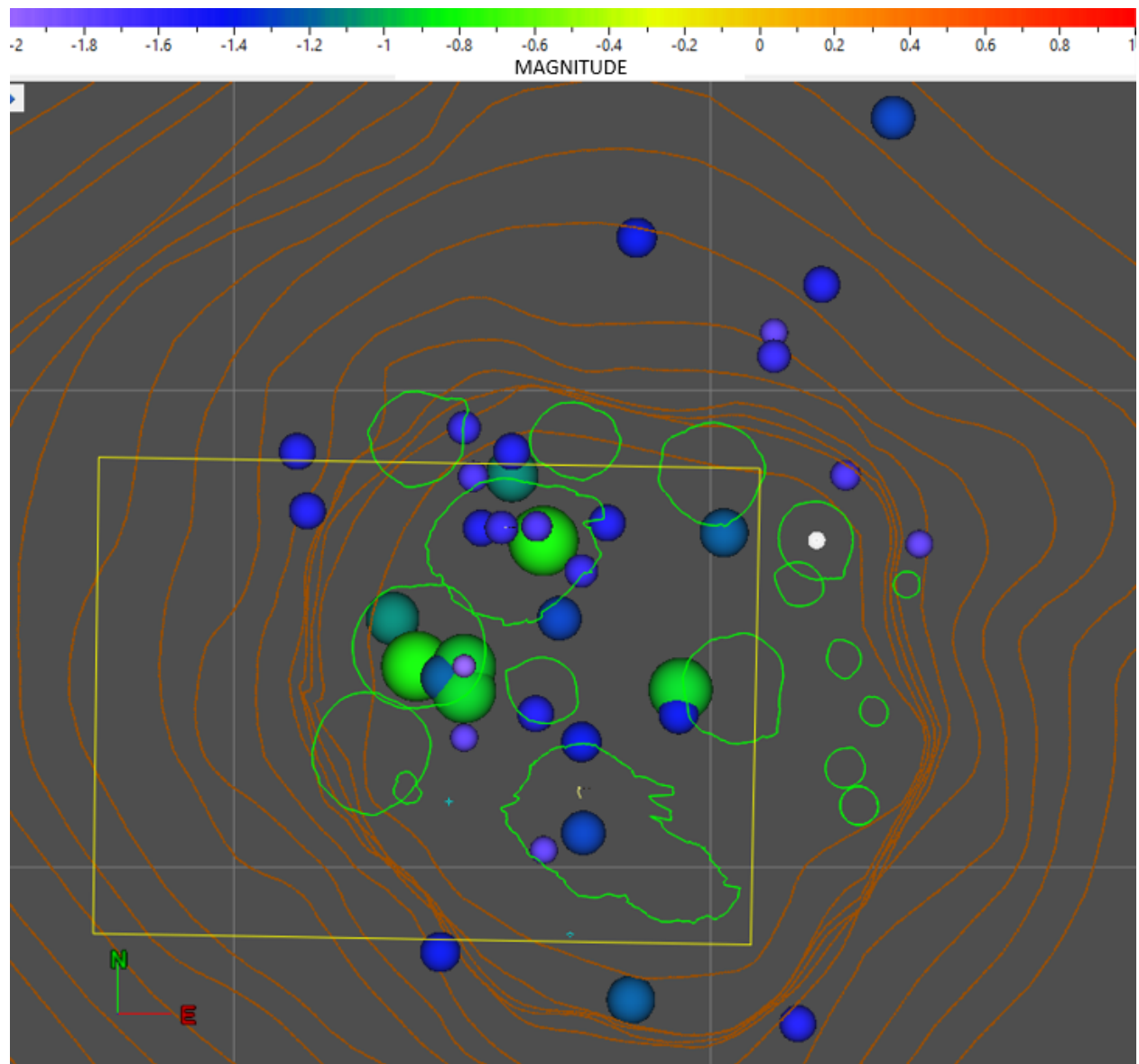


Figure 3. Map of the November 2024 borehole microseismic events colored and sized by magnitude. The locations and magnitudes were computed using data from the borehole seismic arrays in PPG No. 006X and PPG No. 020 (labeled). Grid is 2000 ft. The yellow box is the proposed AOI, the orange lines are the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

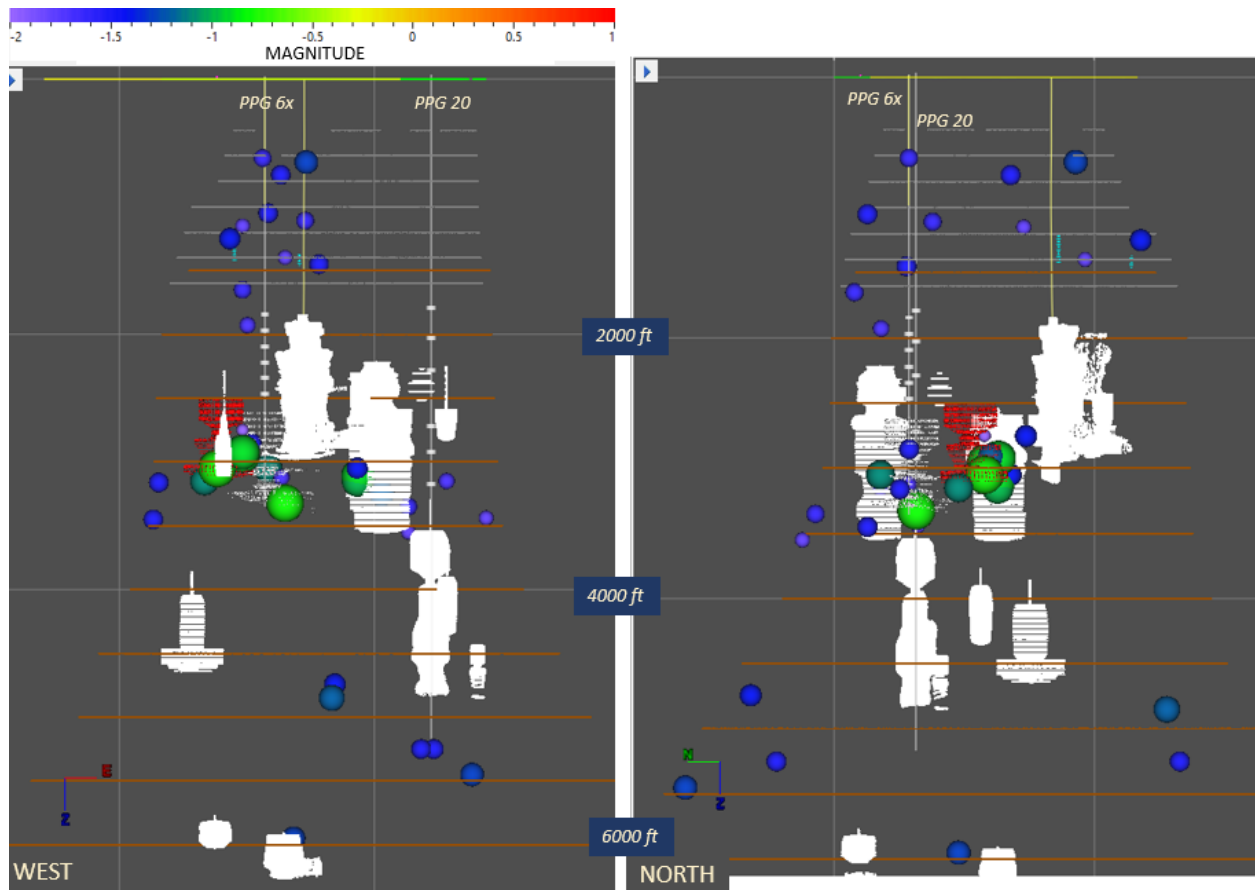


Figure 4. The November 2024 microseismic locations shown in depth view. The cross sections W-E (left), looking from south; and N-S (right), looking from west. The microseismic events are sized and colored by magnitude. The salt (dark orange) and caprock (gray) boundaries are indicated by dots. The various 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 November microseismic magnitudes range from -2.0 to -0.8 with a median magnitude of -1.5 (Figure 5). The largest events in November were two magnitude -0.8 events, one occurred near Cavern at on November 14 at 12:24:41 CST at 3050 feet depth and the second event was on November 17 at 12:02:42 CST, located near Cavern 6 at 3323 ft depth.

The depth distribution in November is from 619 to 5950 ft subsea, with a median depth of 3080 ft subsea (Figure 5).

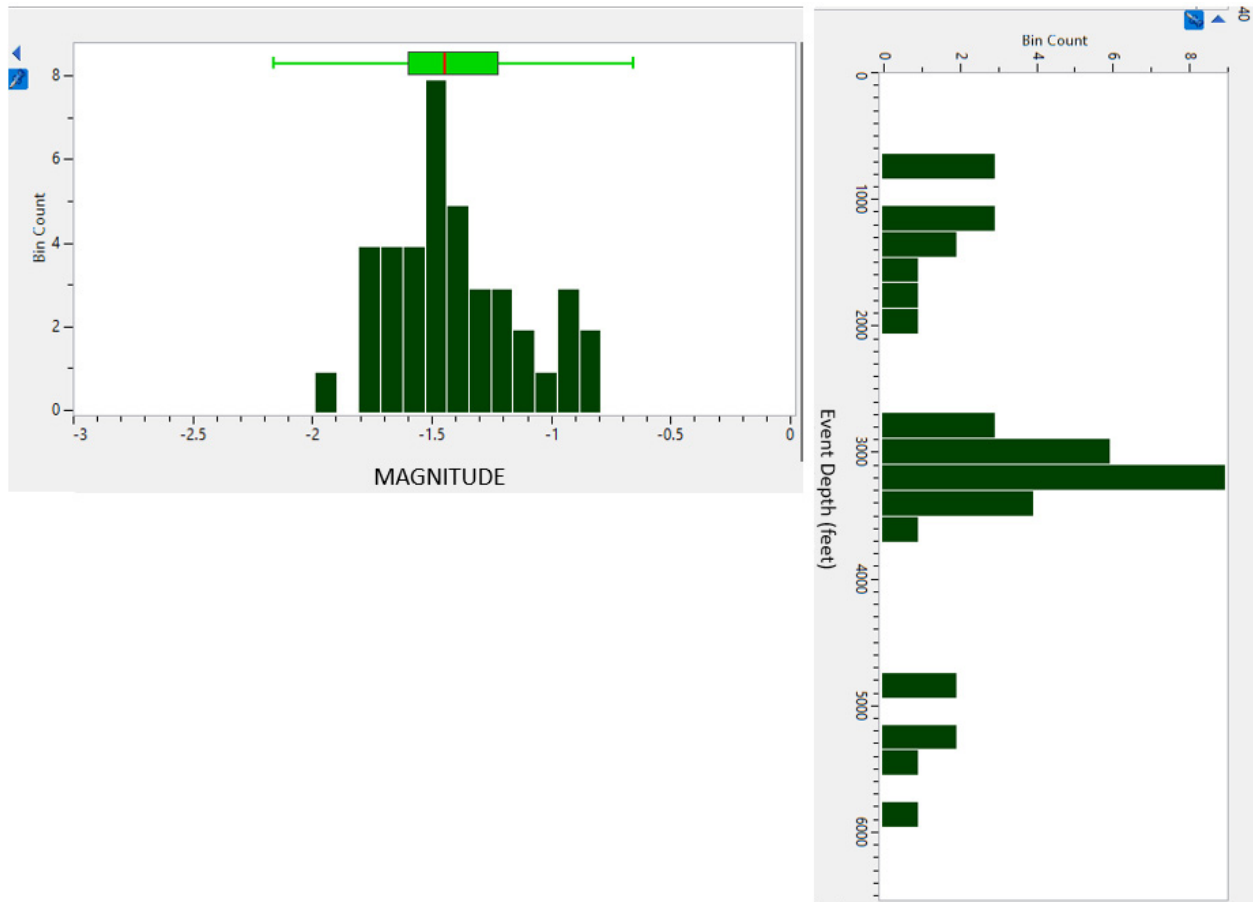


Figure 5. The magnitude distribution (left) and depth distribution (right) for microseismic activity in November 2024.

c. AOI Microseismic activity using borehole seismic arrays.

28 events are located in the proposed AOI in November 2024 (Figures 6 and 7). Seven of the AOI events are located in cap rock and three events are located on the dome flank. The remaining AOI events were in proximity to salt caverns and were listed previously.

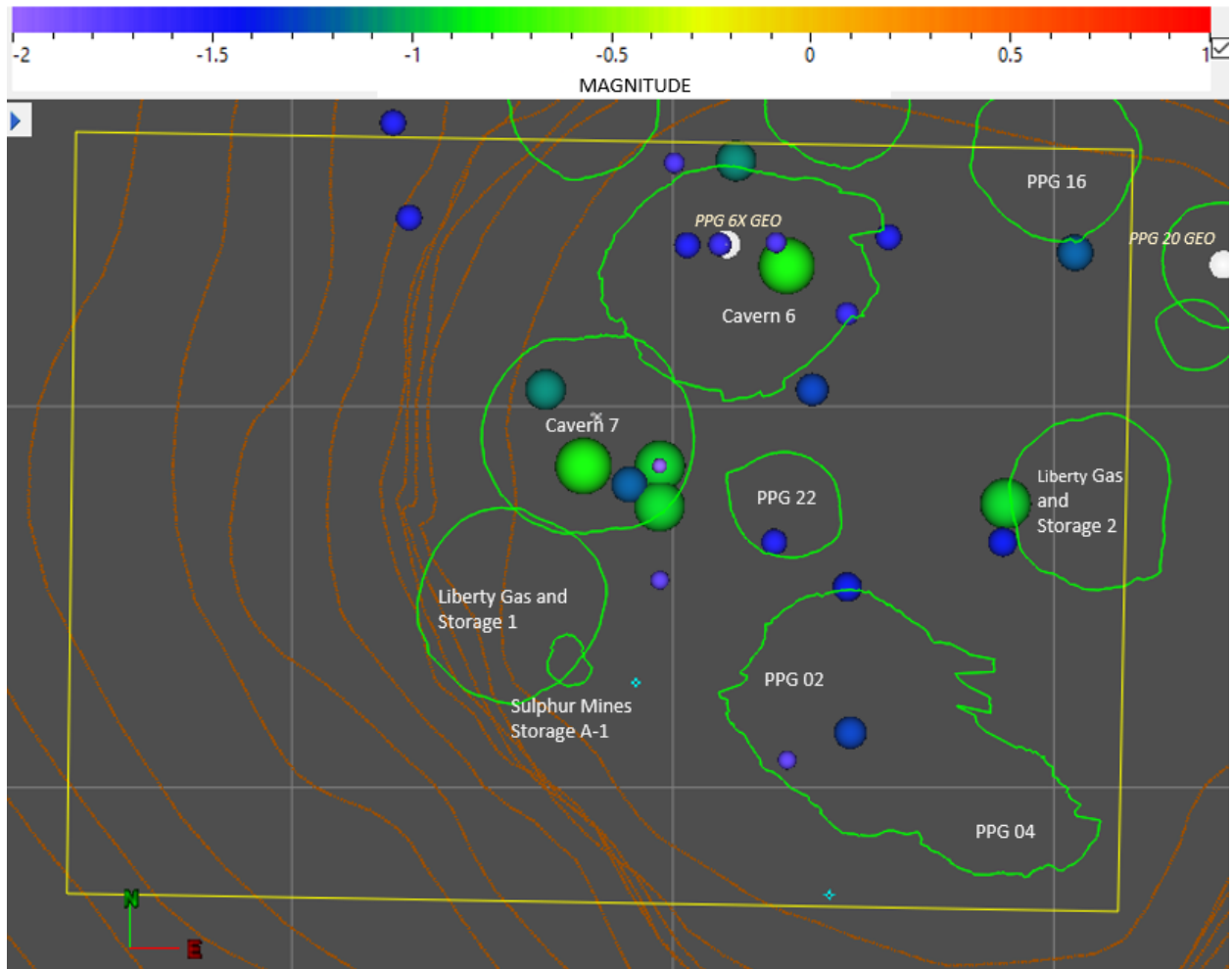


Figure 6. Map view of microseismic activity in November 2024 shown by colored dots in the proposed AOI (yellow box). The events are sized and colored by magnitude. The salt contours are shown by orange lines, cavern outlines by green lines. Grid is 1000 feet. The geophone wells are labeled.

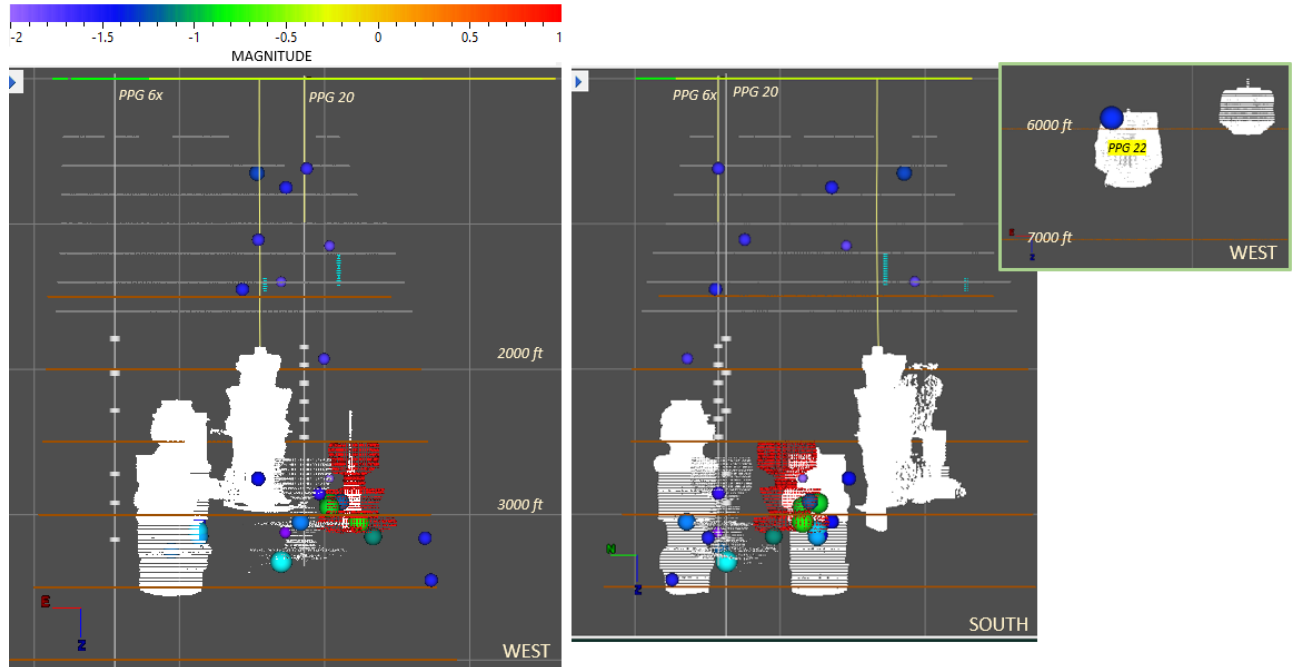


Figure 7. Vertical cross sections with the November 2024 microseismic events located in the proposed AOI with cavern sonars. Left cross section is oriented west–east (looking from NORTH) and center figure is north-south (looking from west) and right figure is a zoom in near PPG 22, looking from north. Microseismic events are shown by colored dots, sized and colored by magnitude. Grid is 1000 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.

Cavern 6 and 7 microearthquake activity in November 2024. Figure 8 is an oblique depth view of the microseismic activity located near Caverns 6 and 7 in November. The activity near Cavern 7 is located on the ESE side of Cavern 7 between ~2000 and 3000 ft depth (Figures 6, 7 and 8). The Cavern 7 activity occurred on Nov. 9 (one event), Nov. 14 (three events) and Nov. 15 (two events). The activity on PPG 6 followed the Cavern 7 events, three events occurred on Nov. 17 and one of Nov. 21. The largest events located in November were two -0.8 events each located near Caverns 6 and 7, as mentioned above. Refer to the event catalog in the Appendix Table 4 for details on time, depth and magnitude.

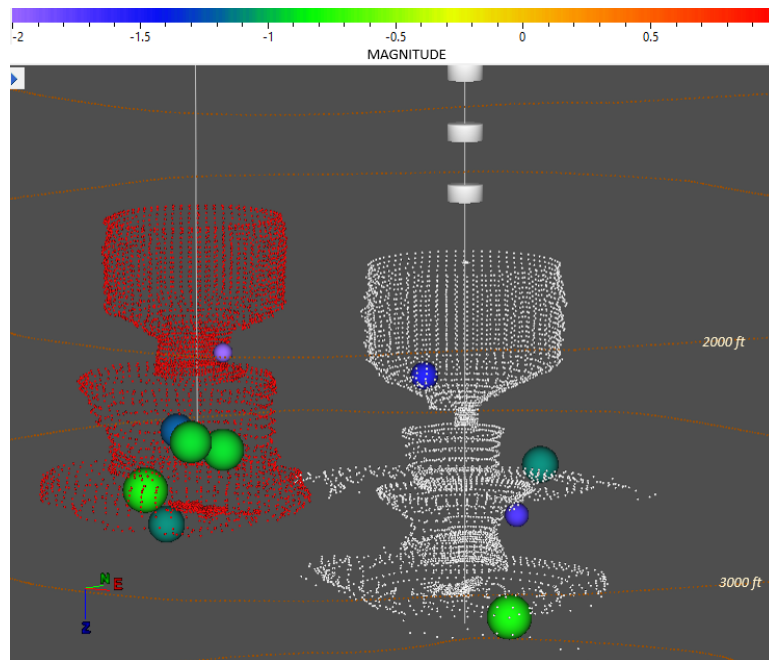


Figure 8. Oblique view looking from the south of microseismicity (colored spheres) located near Caverns 6 (white dots) and Cavern 7 (red dots). The orange dots indicate the salt dome boundary. The events are sized and colored by magnitude. The lower three geophones in Cavern 6 are marked by gray cylinders.

a. 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 9 and 10. 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 November activity near Cavern 7 is the first microseismic events into occur near the cavern except for a few scattered events over the past six months.

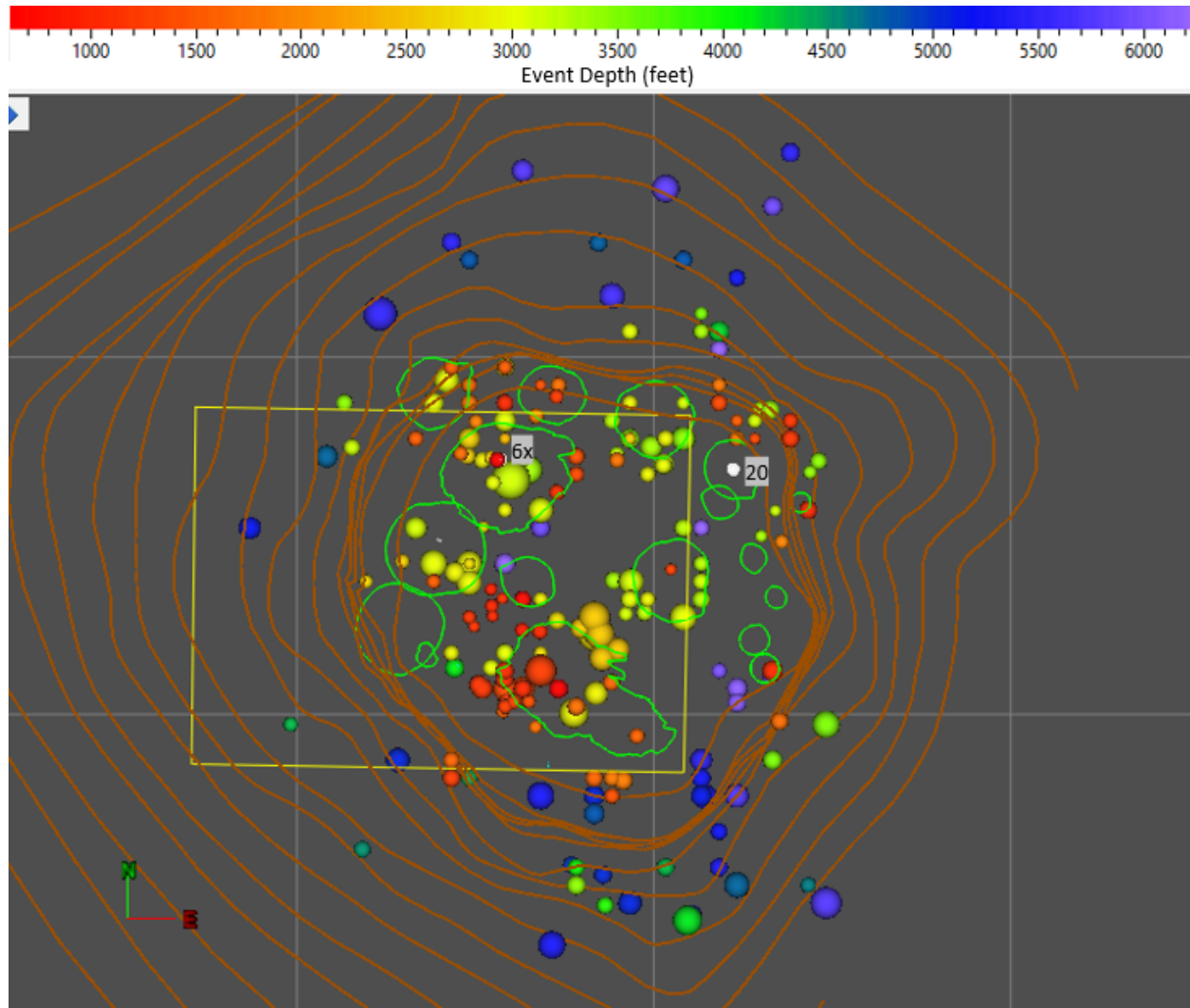


Figure 9. . Map view of the cumulative microseismicity recorded from April 22 to November 30, 2024 using borehole seismic arrays (PPG 6-X and PPG 20 (labeled on map as 6x and 20)) Events are sized by magnitude and colored by depth. Grid is 2000 ft. The salt dome contours are shown by orange lines. The proposed AOI is indicated by yellow box. The green lines are cavern outlines projected to the surface.

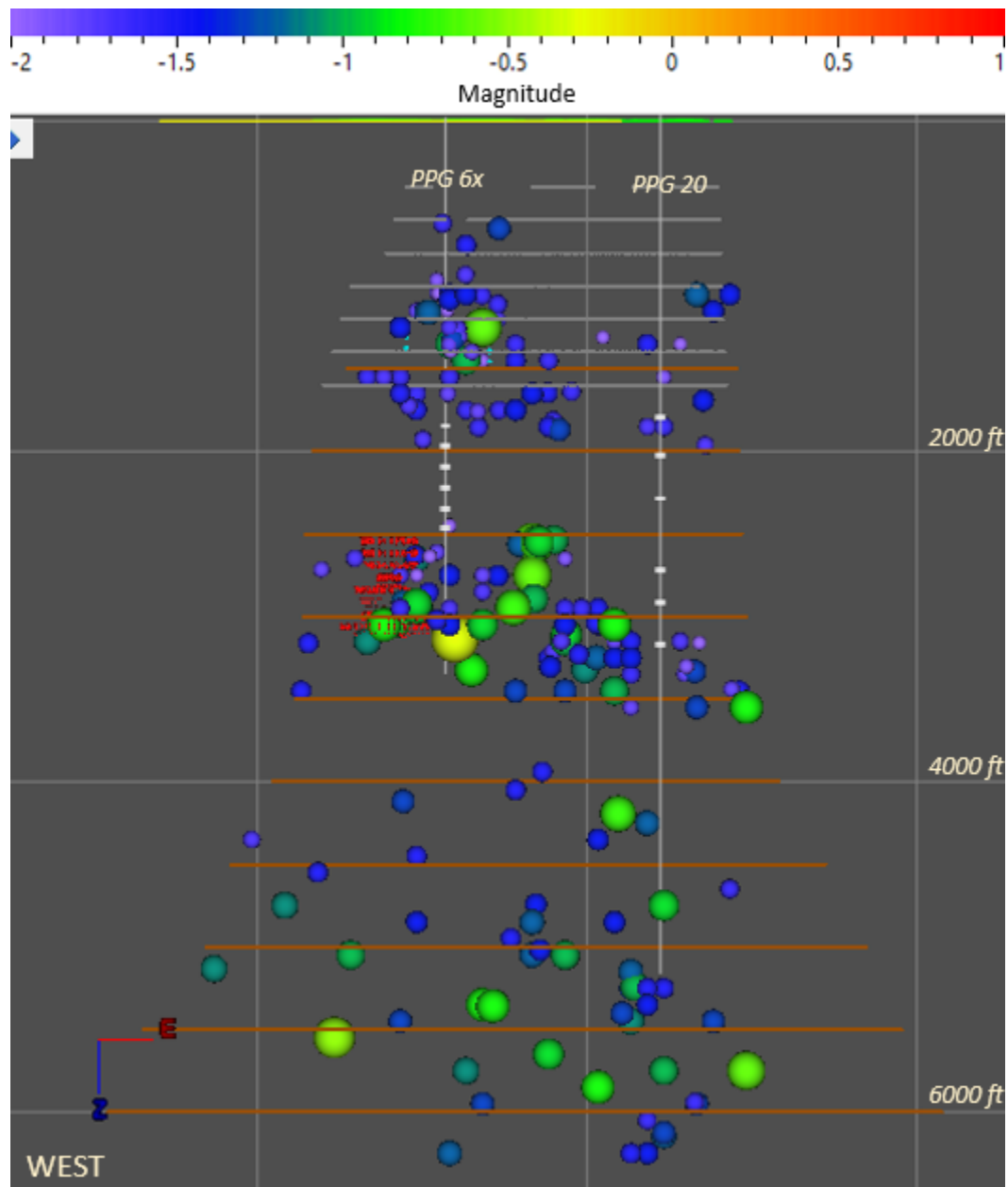


Figure 10. West-East side view of the cumulative microseismicity recorded from April 22 to November 30, 2024 using borehole seismic arrays (labeled PPG 6x and PPG 20). The microseismic events are sized by magnitude and colored by magnitude. The Salt boundary is shown by dark orange dotted lines, cap 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 November 30, 2024 is magnitude -1.5 (Figure 10 inset).

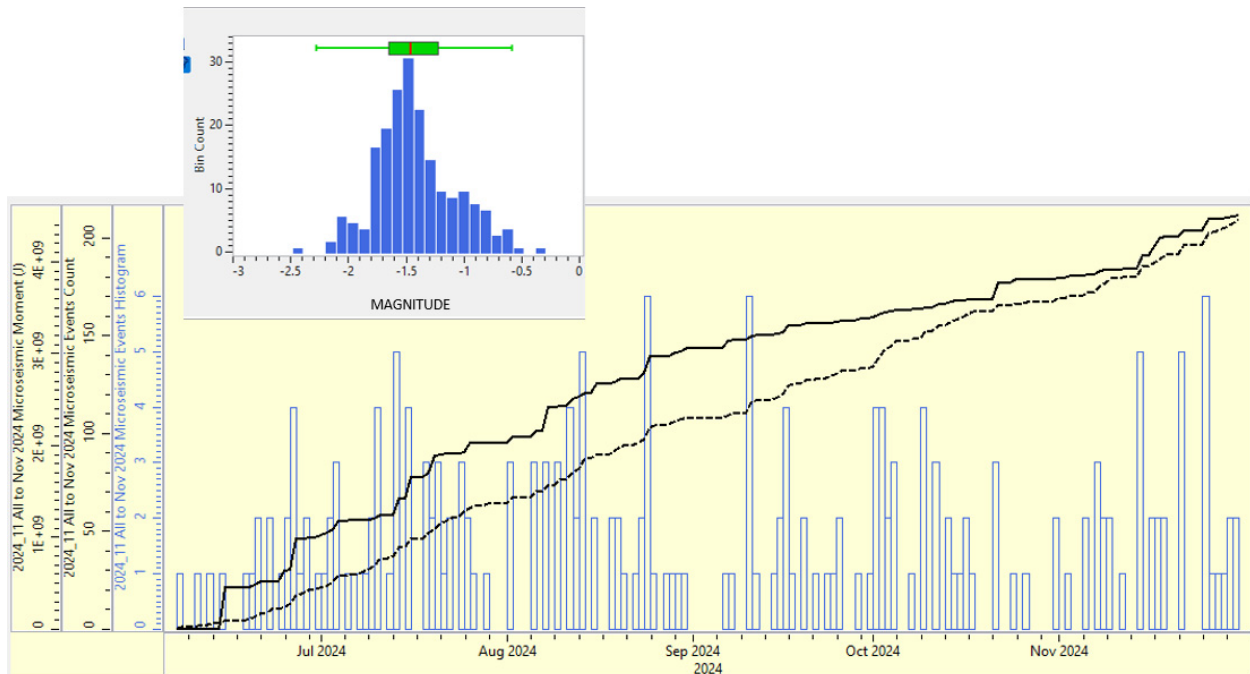


Figure 11. Time line of all microseismicity located at Sulphur Mines using the borehole arrays from April 22 to the end of November 2024. The histogram is the number of events per day, the black solid line is the cumulative seismic moment and the black dotted line the cumulative number of events. The upper left histogram shows the magnitude distribution for the 203 events located at Sulphur Mines from April 22 to November 31, 2024, (excluding the perforation shots).

November 2024 marked the largest number of events located in the AOI since recording started in mid-April (Figure 12). The energy (seismic moment) is the 2nd highest since June (Figure 12).

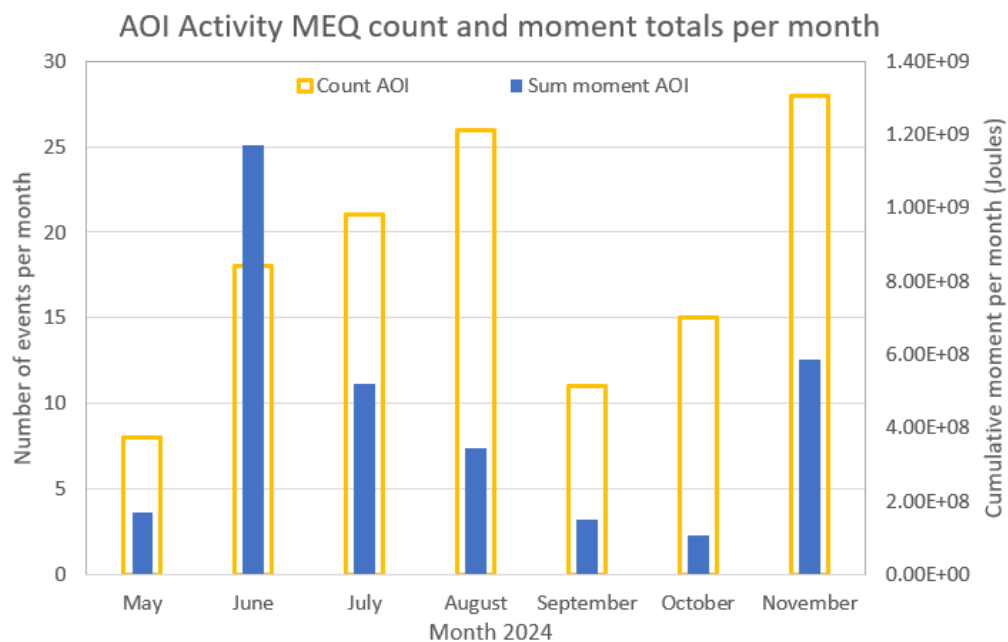


Figure 12. Graph of AOI microseismic activity by month. Yellow boxes indicate the count of MEQ per month (left axis) located in the AOI, the blue filled boxes (right axis) shows the cumulative seismic moment by month.

2. Surface Broadband Seismic Array Summary

- There are no seismic events reported in November 2024 on the surface array.
- All the surface seismic stations are operational in November.
- The background noise on stations SUL03, SUL05, SUL06, and SUL07 is the lowest on the array in November, while SUL02 and SUL04 are about 5-10 dB noisier. The seismic station background noise is highly variable, 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 shown in Figure 13 and listed in Table 3.



Figure 13. 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 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 November 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	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
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. November 2024 Microseismic Event Catalog.*UTC time is used for monthly catalog time window.**Note: Cap rock, salt and cavern 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
					Δ Easting (ft)	Δ Northing (ft)	Δ Depth (ft)	
11/02/2024 05:05:18	1343666	581444	4850	-1.2	855	2959	1430	AOI_Cap_Rock
11/05/2024 09:26:39	1343566	583444	1450	-1.5	292	833	450	AOI_Cap_Rock
11/05/2024 11:24:35	1343690	584641	4742	-1.4	640	2320	837	Flank
11/07/2024 13:40:07	1343366	583044	5950	-1.3	872	3185	1453	Flank
11/07/2024 17:44:33	1343004	583639	1928	-1.7	325	527	437	AOI_Cap_Rock
11/07/2024 19:05:46	1344056	583403	3248	-1.2	308	704	320	AOI_Cap_Rock
11/08/2024 08:32:24	1342966	582544	1150	-1.8	538	1488	913	AOI_Cap_Rock
11/08/2024 15:43:26	1344366	581344	5250	-1.5	882	3268	1978	AOI_Cap_Rock
11/09/2024 05:53:43	1342966	582844	2750	-2.0	365	1162	686	Flank
11/09/2024 18:36:26	1344466	584444	5250	-1.5	790	2676	1355	Flank
11/11/2024 09:58:23	1343458	582526	2753	-1.4	348	1362	741	Cap_Rock
11/14/2024 12:24:42	1342766	582844	3050	-0.8	465	1337	656	AOI_Cap_Rock
11/14/2024 12:24:57	1342666	583044	3150	-1.1	477	1405	695	AOI_Flank
11/14/2024 19:21:55	1342886	582795	2912	-1.2	412	1232	613	AOI_Flank
11/14/2024 21:36:45	1344266	584144	3350	-1.6	620	1349	838	Flank
11/14/2024 21:37:02	1344266	584244	3550	-1.8	651	1504	892	Flank
11/15/2024 23:37:28	1342965	582738	2923	-0.9	497	1232	602	AOI_Flank
11/15/2024 23:37:40	1342966	582844	2950	-0.9	400	1093	484	Cap_Rock
11/17/2024 00:37:40	1343038	583423	2854	-1.5	379	1014	492	AOI_LGS02
11/17/2024 12:02:43	1343299	583369	3323	-0.8	325	1114	437	AOI_LGS02
11/17/2024 22:21:05	1343271	583430	3122	-1.7	316	1029	443	AOI_LGS02
11/18/2024 09:43:33	1342966	583844	1650	-1.6	400	833	527	Flank
11/21/2024 02:00:55	1343166	583644	3050	-1.1	319	1051	448	AOI_LGS02
11/21/2024 10:08:30	1343166	583744	1050	-1.5	352	1172	571	AOI_LGS02
11/21/2024 12:02:27	1343466	582144	650	-1.3	456	2122	1011	AOI_PPG_02
11/21/2024 14:56:01	1343457	583243	1109	-1.6	290	1061	579	Cap_Rock
11/21/2024 20:24:55	1344766	585144	5450	-1.3	1044	3178	1630	AOI_PPG_022
11/25/2024 05:50:35	1344876	583356	3439	-1.8	373	720	559	AOI_PPG_06
11/25/2024 13:55:14	1343874	582745	3111	-0.9	302	1113	440	Flank
11/25/2024 13:55:18	1343865	582720	3144	-1.4	337	1141	497	Flank
11/25/2024 13:55:18	1343866	582644	3050	-1.4	346	1180	531	AOI_PPG_06
11/25/2024 13:55:24	1343866	582744	3150	-1.0	336	1136	509	AOI_PPG_06
11/25/2024 13:55:33	1343866	582744	3150	-1.7	343	1121	528	AOI_PPG_06
11/26/2024 03:46:41	1343300	582072	1398	-1.8	446	1637	722	AOI_PPG_07
11/27/2024 18:23:42	1344566	583644	3150	-1.7	364	613	468	AOI_PPG_07
11/28/2024 07:31:10	1342866	581644	1250	-1.4	623	2661	1279	AOI_PPG_07
11/28/2024 22:28:47	1342266	583744	3450	-1.5	481	1585	1022	AOI_PPG_07
11/28/2024 22:29:07	1342308	583495	3161	-1.5	386	1235	815	AOI_PPG_07
11/30/2024 08:32:59	1343123	583425	619	-1.6	491	1852	608	AOI_PPG_07
11/30/2024 10:58:45	1343266	582644	750	-1.5	428	1559	604	AOI_PPG_16