

MICROSEISMIC MONITORING

MONTHLY REPORT: January 2025

Sulphur Mines Salt Dome – Louisiana (US)



2634299-SUL-MR-250101

Client / Site	Sulphur Mines	
Recipient	Joshua Bradley (Westlake)	
Reference	2634299-SUL-MR-250101	
Period	from	2025/01/01
	to	2025/01/31

Revision history

Version	Date	Issued by	Verified by	Approved by	Description
1.0	2025/02/12	E BARBIERI	J. BARNAVOL	N.T. CAO	Monthly report

Acronyms

Acronym	Signification
N/A	Not Applicable
PGV	Peak Ground Velocity
AOI	Area of Interest

Table of contents

Summary.....	4
Introduction.....	5
I. Alert Level Status.....	5
II. Seismic Network.....	5
Microseismic activity using the borehole array	6
I. Distribution of the microseismic events.....	6
II. Event Location.....	8
All event locations (inside and outside AOI).....	8
Event Locations in AOI.....	10
III. Magnitude and depth distribution.....	12
Microseismic history from the beginning of the acquisition.....	14
I. History of the detections.....	14
II. History of the magnitudes.....	15
III. History of the event locations.....	16
History in Cap-Rock and on the Flank.....	16
History around the caverns.....	17
Microseismic activity using the surface broadband network.....	19
I. Surface Broadband Seismic Network Summary.....	19
II. Broadband Trillium Compact Seismic network.....	19
Appendix 1 – Alert level criteria.....	21
Appendix 2 – Network Coordinates.....	22
Appendix 3 – Catalog of located events using borehole array.....	23
Appendix 4 – Catalog of located events using surface network	24

Summary

Network & IT status	System Uptime	<ul style="list-style-type: none"> 100 % – Borehole arrays 100% – Surface Network
	Digitizers connectivity	Continuous, with no acquisition stops
	Sensors / Noise level	Borehole arrays: <ul style="list-style-type: none"> PPG-6 (6 levels) → 10 to 60 nm/s (RMS) PPG-2 (6 levels) → 9 to 60 nm/s (RMS) Surface receivers: <ul style="list-style-type: none"> 6 sensors (3-axis) → RMS: N/A
Seismic activity	BOREHOLE ARRAYS	
	Detections	100
	(of which) Located	43
	Max magnitude	-0.4
	Max PGV	0.4120 mm/s
	Min depth	1150 (ft)
	Max depth	5550 (ft)
	SURFACE ARRAY	
	Detections	8
	(of which) Located	5
	Max magnitude	-0.4
	Max PGV	N/A
	Number of alerts in the month	0 – No alert triggered in January

PGV = Peak Ground Velocity – Maximum vibration measured on the sensors (mm/s)

Introduction

I. Alert Level Status

During January 2025, the alert level status was: Low (Green). Alert level criteria are listed in Appendix 1.

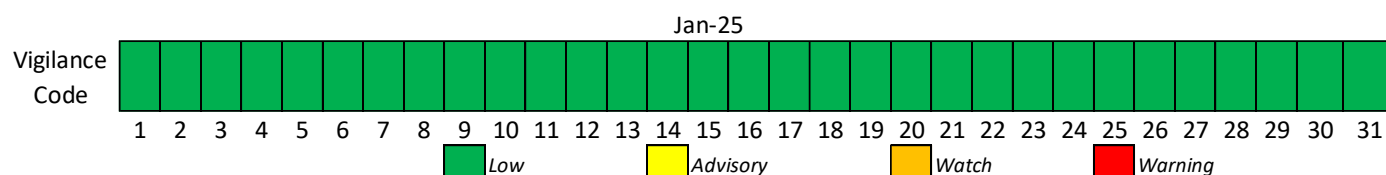


Figure 1: Alert status level during January 2025.

II. Seismic Network

Microseismic monitoring in Sulphur Mines Salt Dome is executed by:

- Two borehole 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 2 and the coordinates are listed in the *Appendix 2*. The borehole arrays were fully functional in January 2025.
- A surface network, composed by 6 Broadband Trillium:**
 - Nanometrics operates the surface broadband array. The broadband station locations are shown in Figure 2 and listed in *Appendix 2*

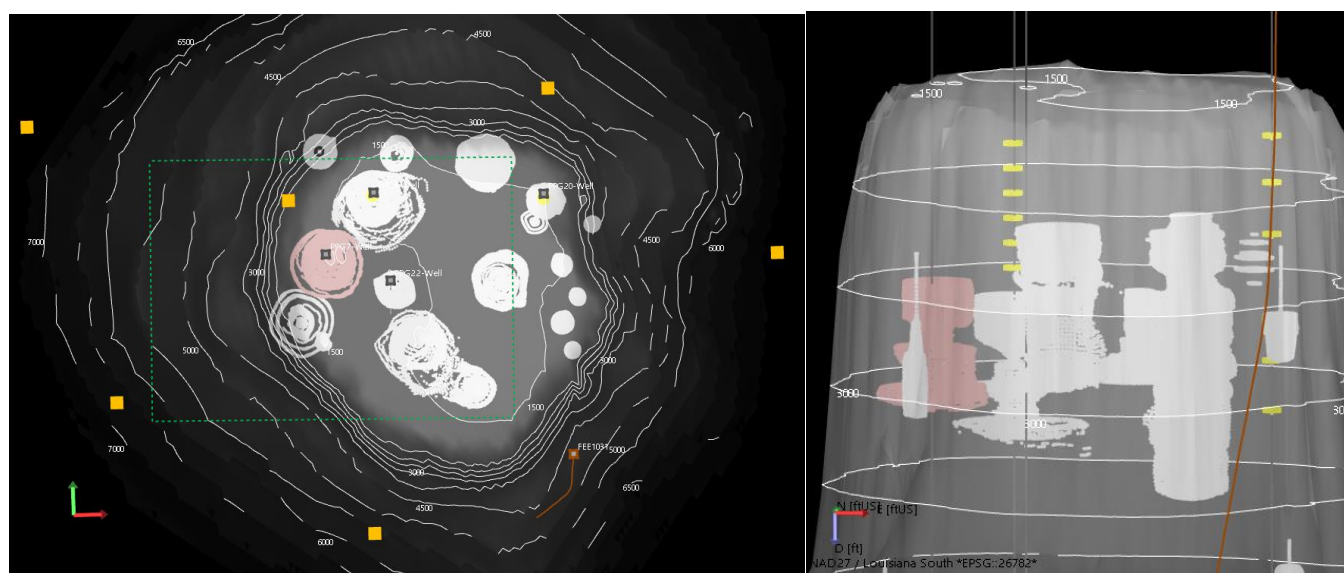


Figure 2: Map (left) and West-East cross section (looking from the South) of the Sulphur Mines Salt Dome. The salt boundary is indicated by gray contour lines in map and side view. The wellbores with the borehole array sensors are marked by yellow dots for PPG No. 006X and PPG No. 020. Cavern 7 is represented with a red sonar survey in both figures. The proposed AOI is indicated on the map view by the green square. The surface network is indicated by the orange squares.

Microseismic activity using the borehole array

- In January 2025, 100 seismic events have been detected by the borehole arrays. **43** events had waveform with sufficient signal to noise ratio to compute their location and magnitude.
- Amongst the 43 located events, **34 are in the AOI** (Area of Interest) area.
 - 11 in the AOI cap-Rock,
 - 1 in the AOI flank,
 - 22 are close to the caverns in the AOI –the cavern with the largest number of associated events was PPG 07 (12 events).
- The other events (9) are outside the AOI and located:
 - 6 on the flank of the salt dome,
 - 1 on cavern PPG-20,
 - 2 on the Cap Rock.
- Maximum Magnitude during this period was: -0.4 on the 01/26/2025 at 16:04:27 (CST) for an event associated with cavern PPG-07 in the AOI.

The catalog of the located events is presented in *Appendix 3*.

I. Distribution of the microseismic events

The histogram below shows the number of the locatable and non-locatable events during January 2025.

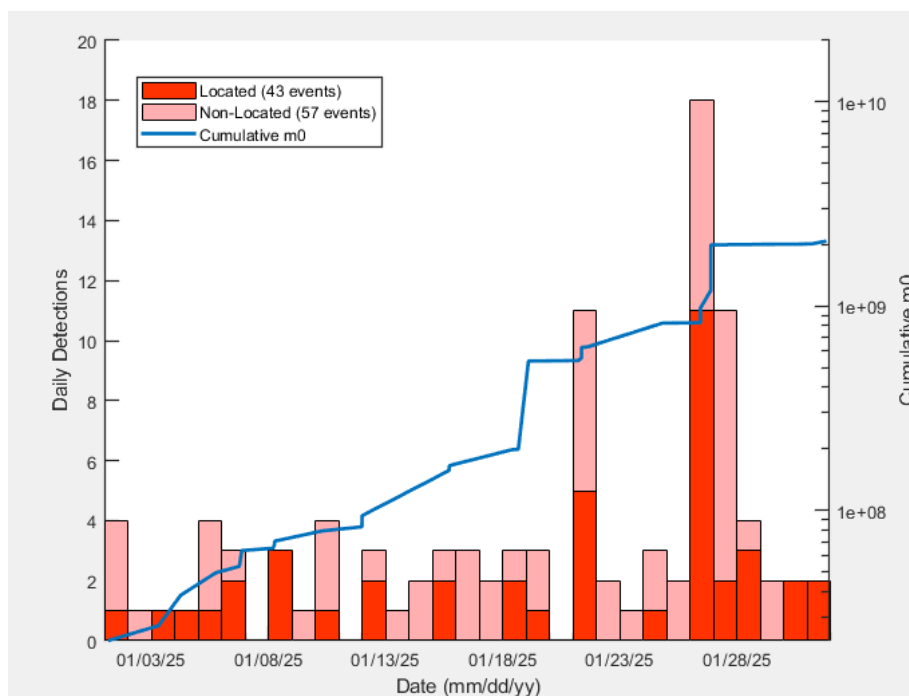


Figure 3: Daily distribution of all the events during January 2025. Dark color represents the located events while light ones show the not located events. Blue line represents the cumulative seismic moment M_0 for the located events.

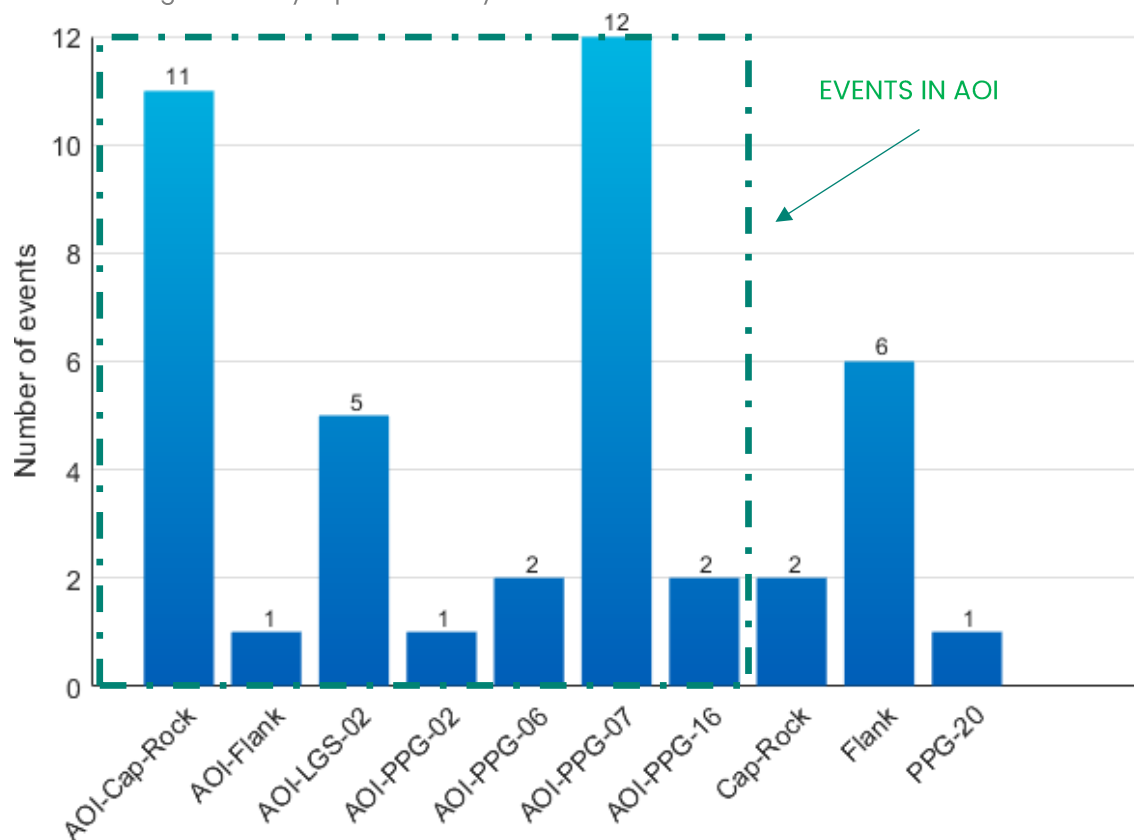


Figure 4: Event distribution by associated cavern.
The green rectangle indicates the events in the AOI.

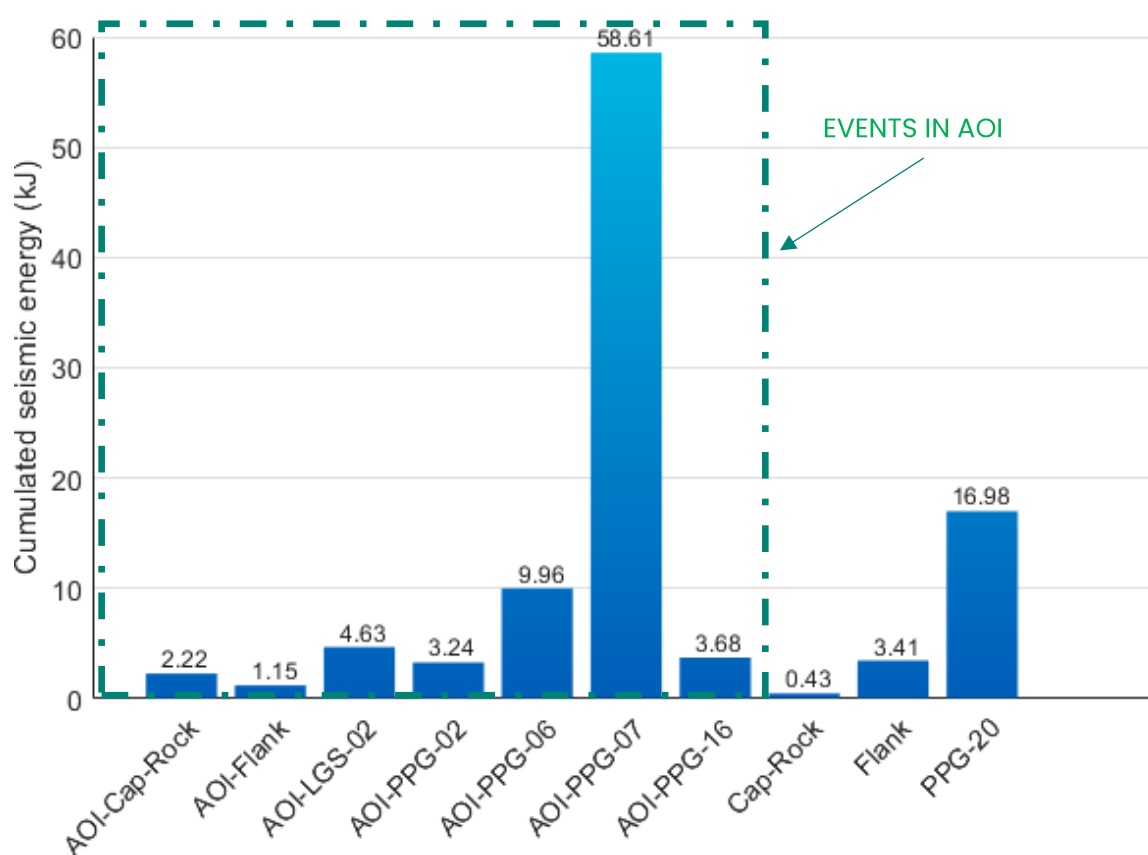


Figure 5: Event energy distribution by cavern.
The green rectangle indicates the events in the AOI.

II. Event Location

All event locations (inside and outside AOI)

The figures below show the event locations for all the events located using the borehole arrays.

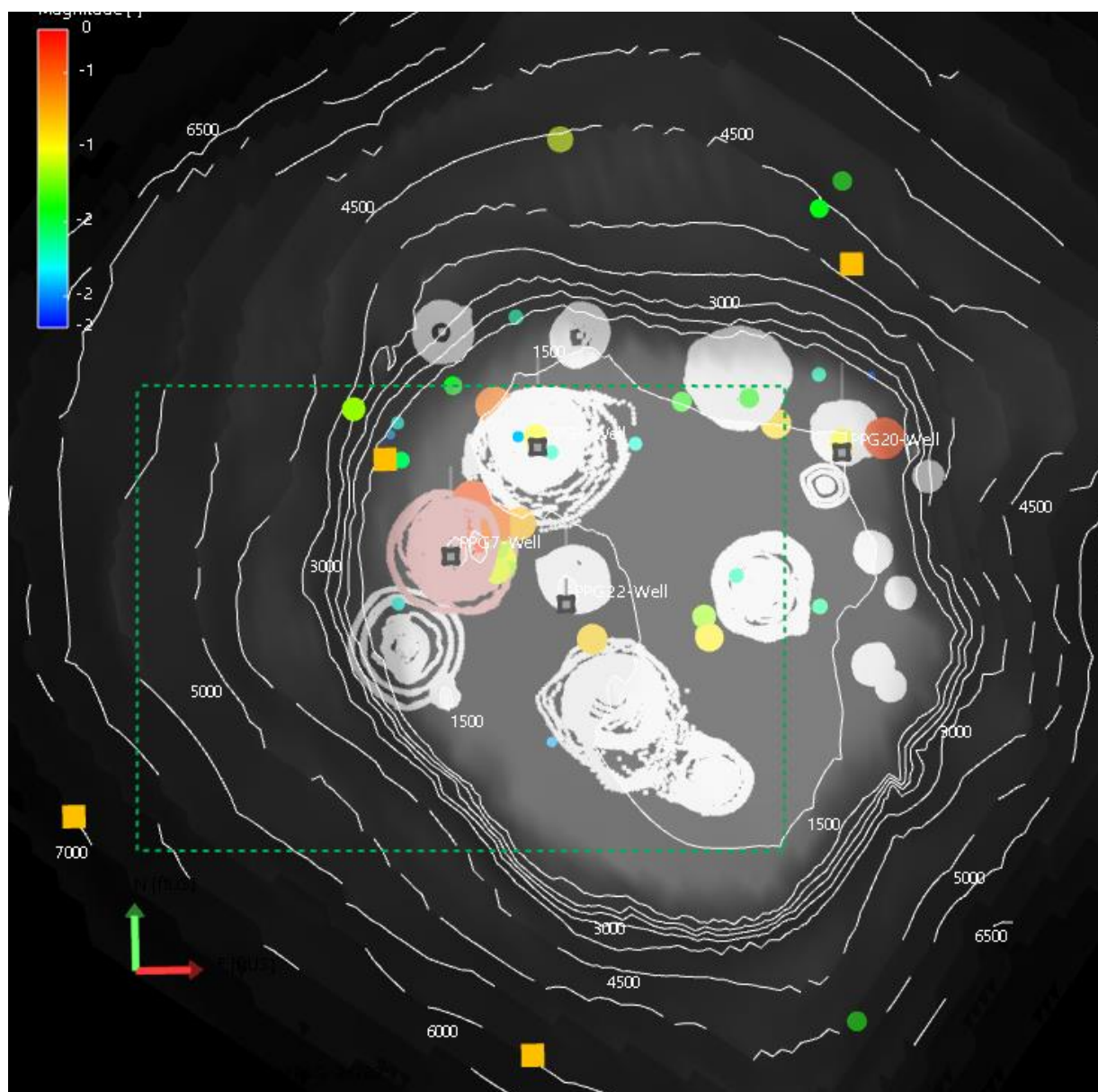


Figure 6: Map of the located events in January 2025. The events are colored, from blue to red, and sized by magnitude; the green rectangle represents the AOI.

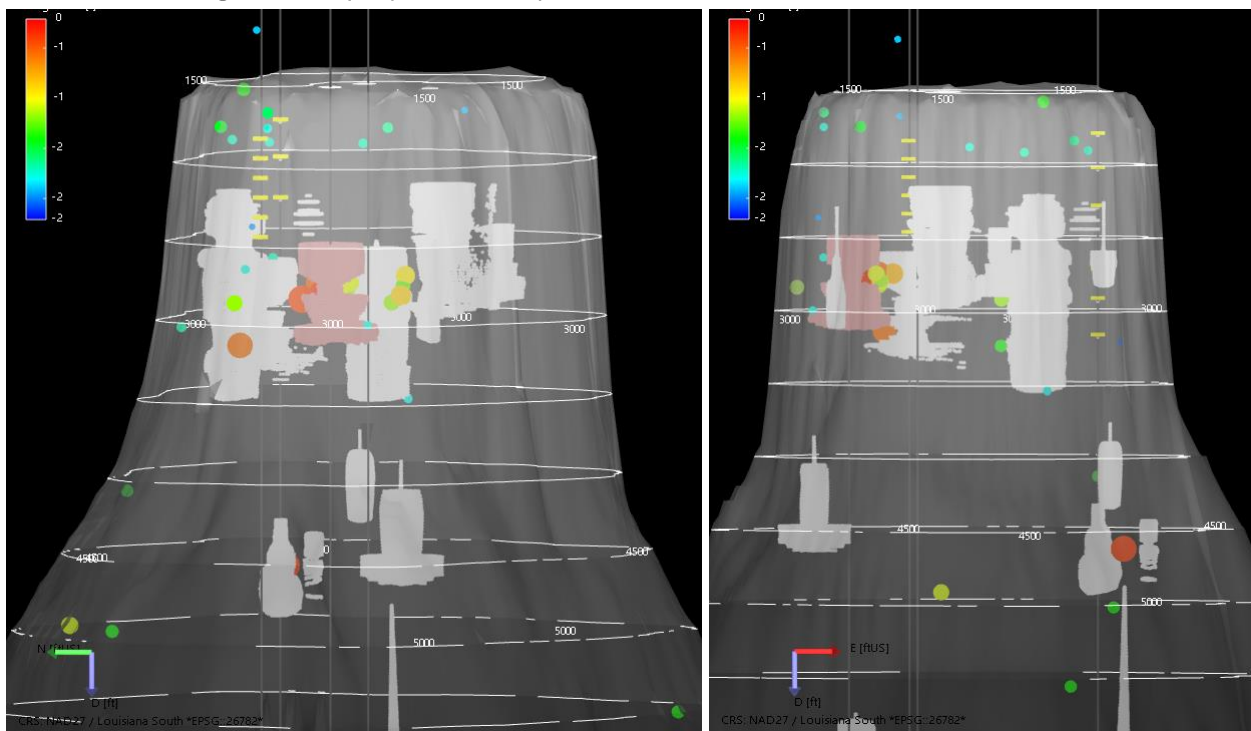


Figure 7: Cross sections W-E (right) looking from the South, and N-S (left), looking from the West.
The events are colored, from blue to red, and sized by magnitude.

Event Locations in AOI

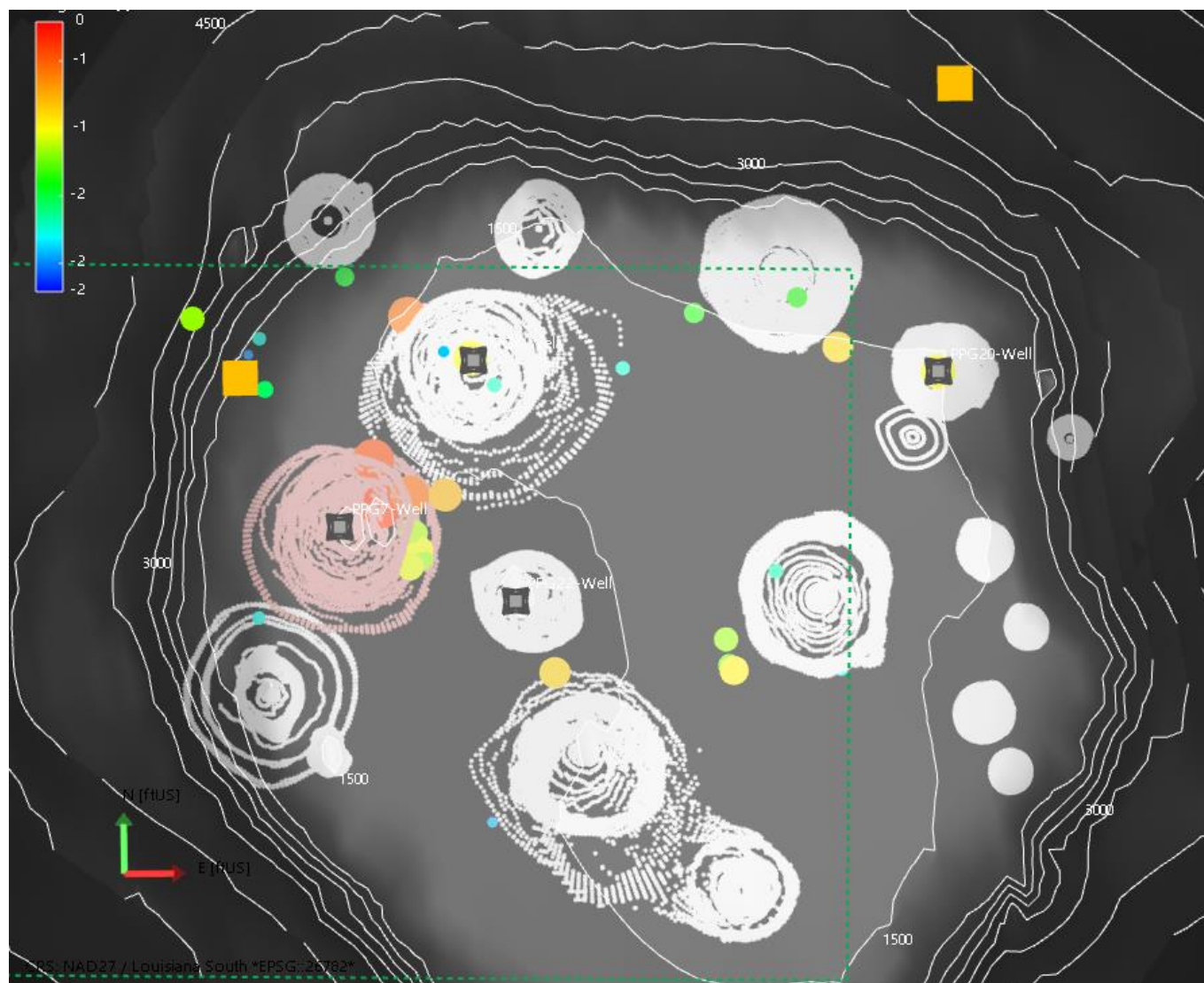


Figure 8: Map of the located events inside the AOI in January 2025. The events are colored, from blue to red, and sized by magnitude; the green rectangle represents the AOI, the orange squares represent the surface stations.

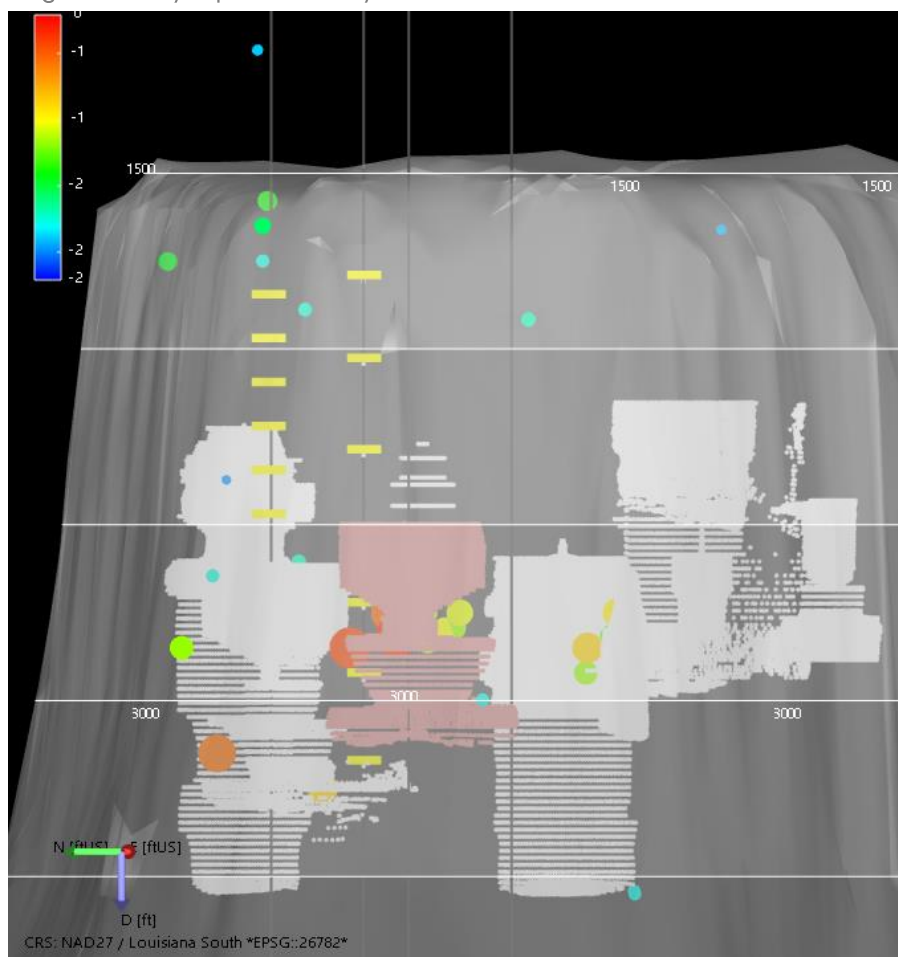


Figure 9: Cross sections N-S (looking from West) of the located events.
The events are colored, from blue to red, and sized by magnitude.

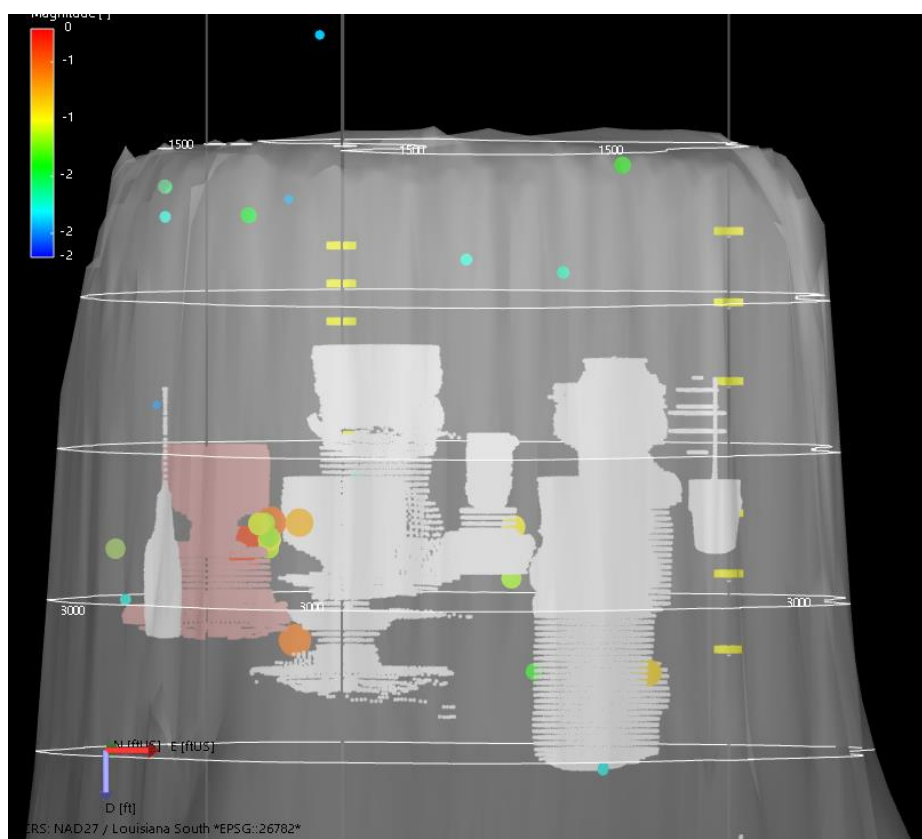


Figure 10: Cross sections W-E (looking from south) of the located events.
The events are colored, from blue to red, and sized by magnitude.

III. Magnitude and depth distribution

The figure below shows the distribution of the magnitudes in January 2025.

In January, magnitudes are between -2.2 and -0.4, median value is -1.35.

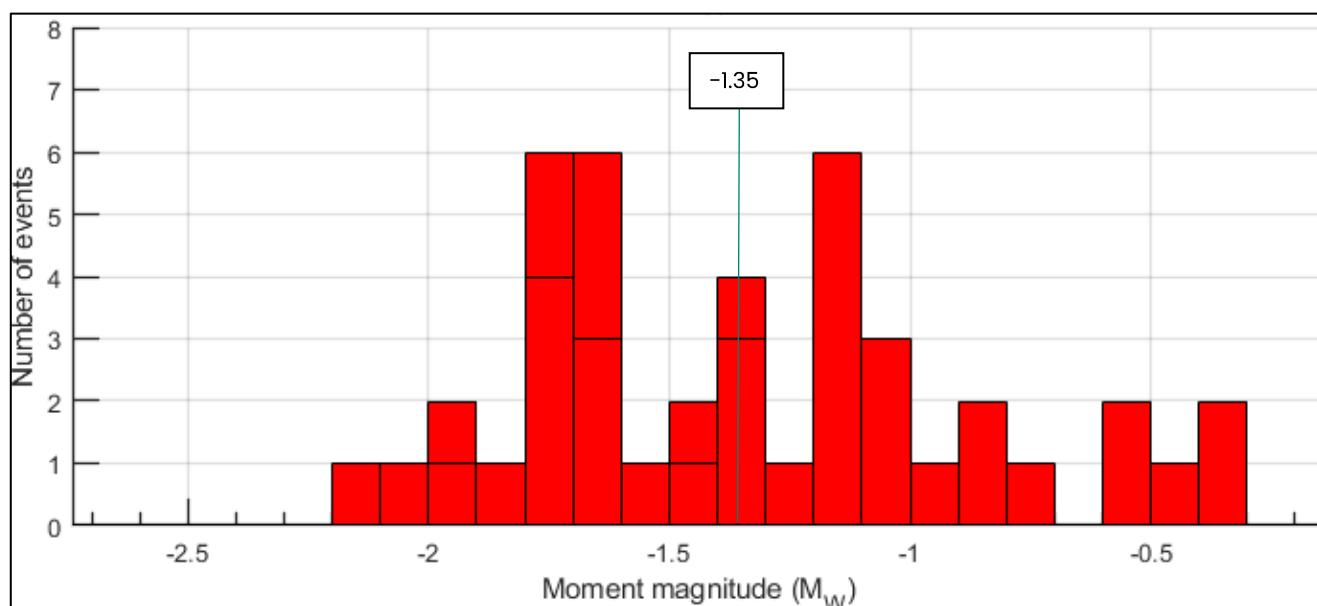


Figure 11: Distribution of magnitudes (M_w) for located events in January 2025.

The figure below shows the depth distribution in January 2025.

Events are located between 1,150 ft and 5,550 ft. It is possible to distinguish 3 main groups:

- The first one between 1,579 ft and 1,916 ft (above the caverns depth),
- A second one between 2,600 ft and 3,500 ft (at depth of the caverns),
- A third composed of 5 events below 4,000 ft.

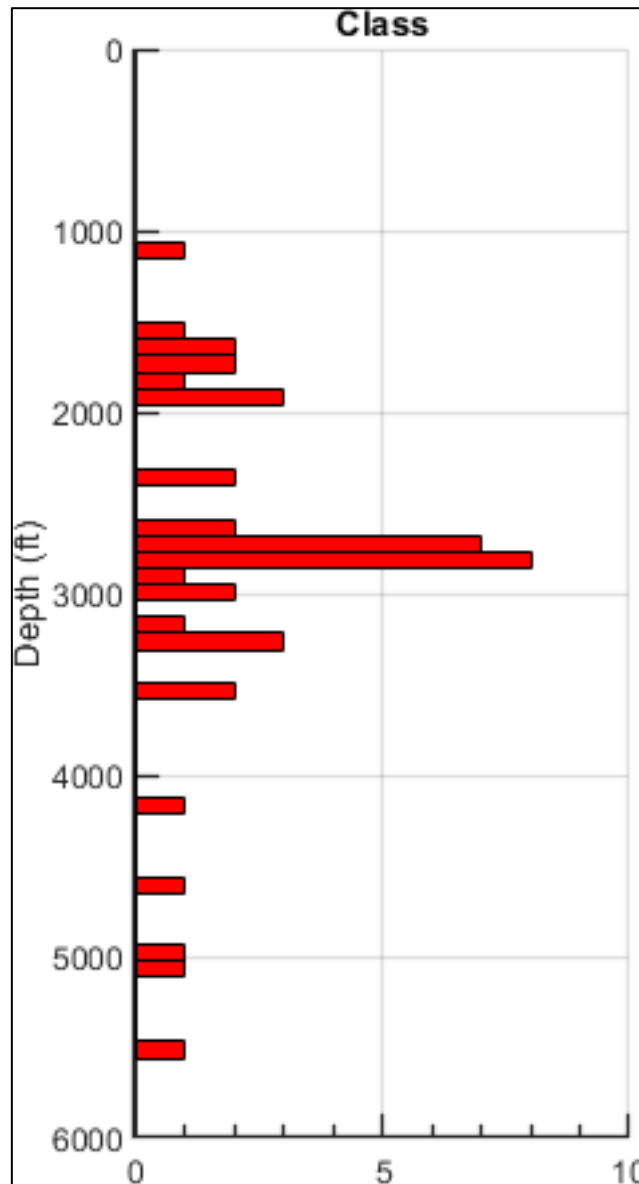


Figure 12: Distribution of the depths for located events.

Microseismic history from the beginning of the acquisition

I. History of the detections

In January 2025, the total number of detections (located and not-located events) decrease slightly with respect to the previous month (100 detected events in January 2025 compared with 93 detected events in December 2024).

The number of located events is slightly more in January 2025 (43 located events) with respect to December 2024 (38 located events).

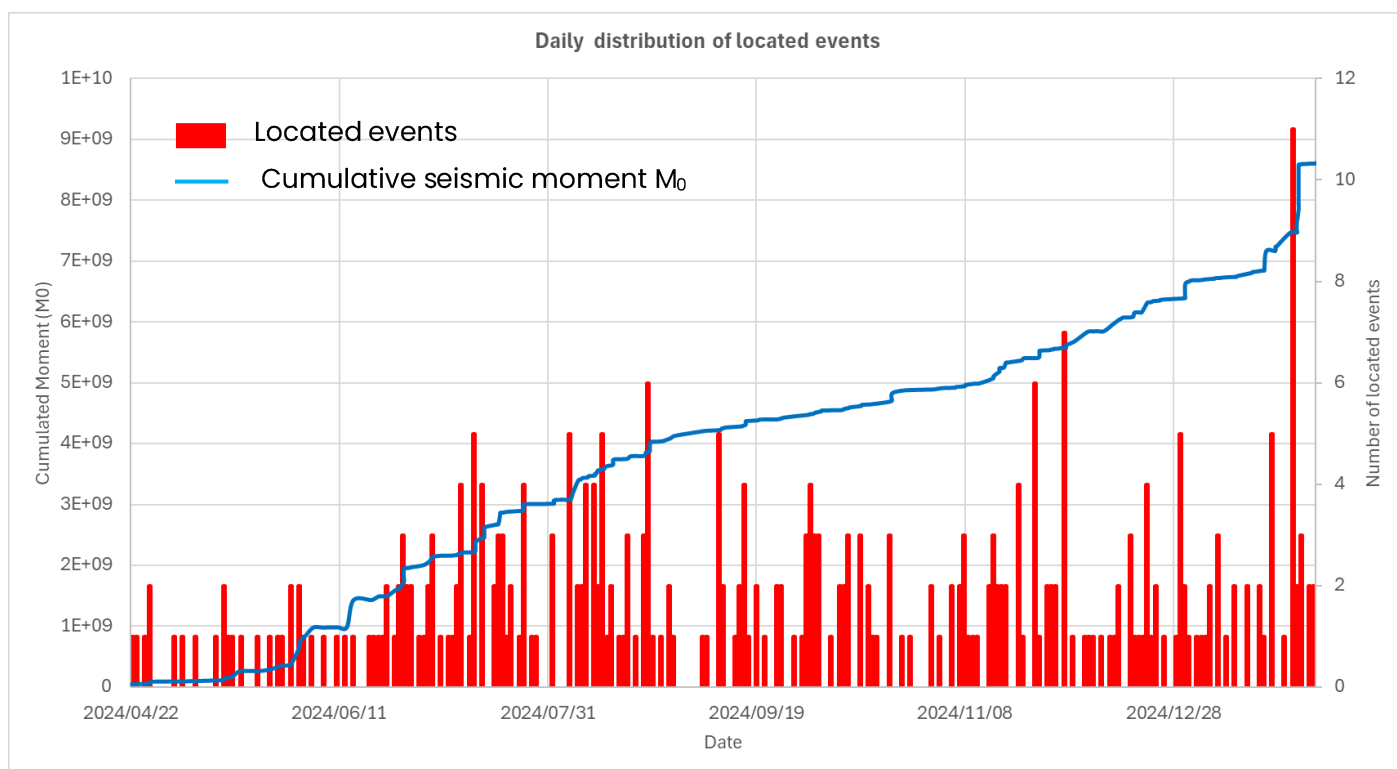


Figure 13: Distribution of the located events since the beginning of the acquisition. The blue line represents the cumulative seismic moment M_0 .

II. History of the magnitudes

Figure 14 shows the magnitude distribution since the beginning of the acquisition. Dark color bars present the current monthly period and light green color bars present the distribution since the beginning of the acquisition.

Since the beginning of the acquisition events magnitude were between -2.5 and -0.4 (for 363 located events). The median value of the magnitude since the beginning of the acquisition is -1.45.

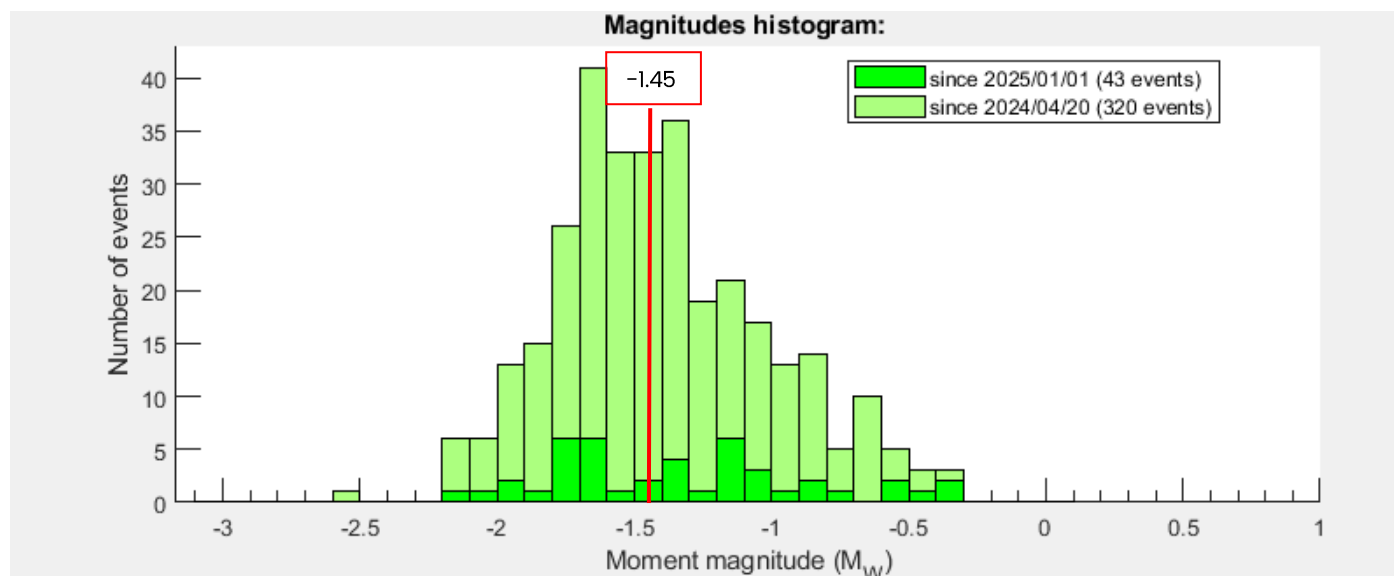


Figure 14: Magnitude (M_w) distribution for deep located events. Dark color bars present the current monthly period and light green color bars present the distribution since the beginning of the acquisition.

III. History of the event locations

History in Cap-Rock and on the Flank

The figure below shows the history of the events located in Cap-Rock and on the Flank of the salt dome.

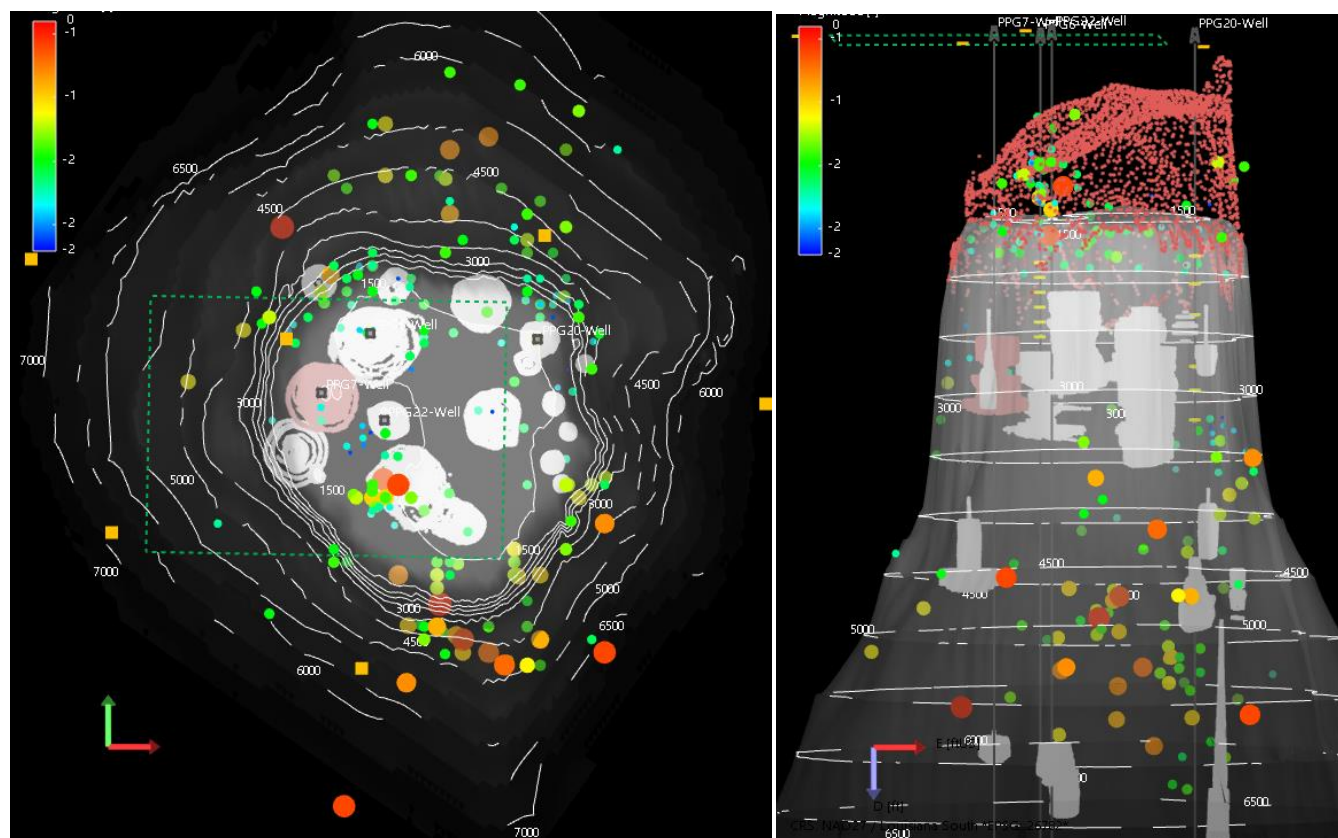


Figure 15: Map view (left) and W-E side view (right) of the cumulative seismicity recorded since the beginning of the acquisition with borehole seismic arrays in the Cap Rock (red formation) and on the Flank. Green rectangle represents the AOI area. The events are colored, from blue to red, and sized by magnitude.

History around the caverns

The figure below shows the history of the events associated with the caverns since the beginning of the acquisition.

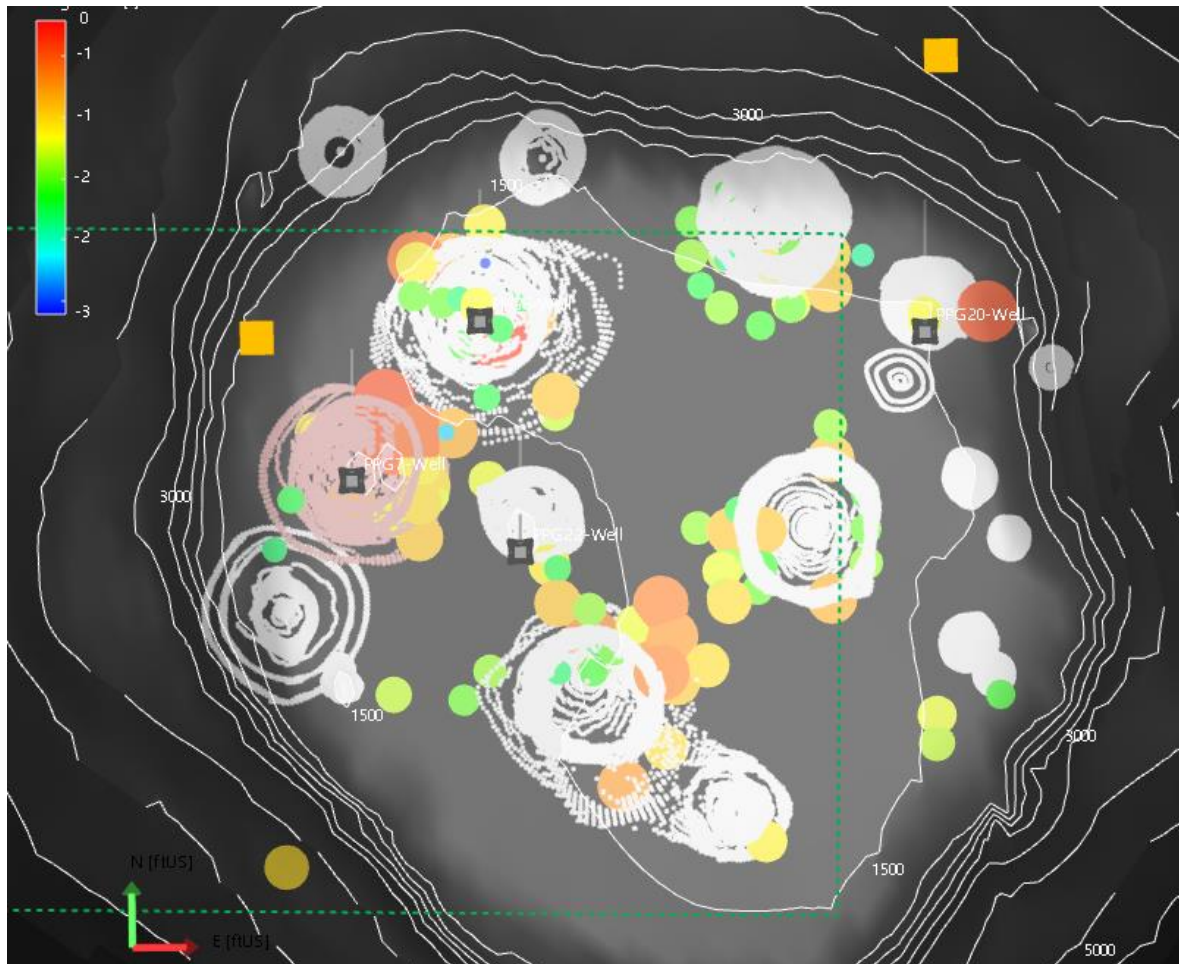


Figure 16: Map view of the events located close to the caverns since the beginning of the acquisition.
The events are colored, from blue to red, and sized by magnitude.

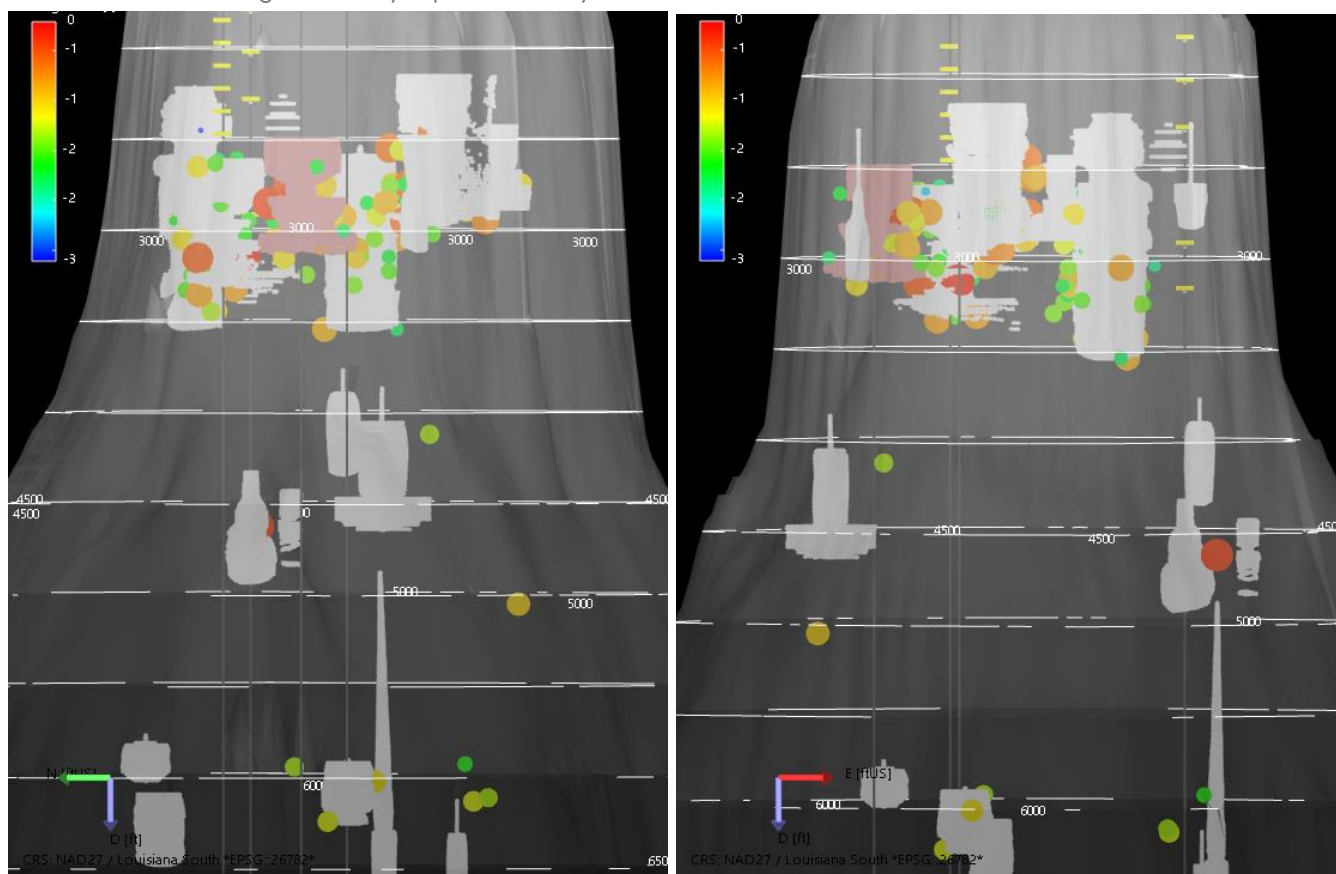


Figure 17: Cross sections W-E (right), looking from the South; and N-S (left), looking from the West of the events located close to the caverns since the beginning of the acquisition. The events are colored, from blue to red, and sized by magnitude.

Microseismic activity using the surface broadband network

I. Surface Broadband Seismic Network Summary

- Five microseismic events were recorded with the surface network in January 2025. Four of them were co-recorded by the borehole seismic array.
- All six of the surface seismic stations were operational in January.

II. Broadband Trillium Compact Seismic network

Nanometrics (<https://nanometrics.ca/home>) operated and performed the seismic processing for the surface broadband stations in January 2025. The surface seismic station locations are shown in Figure 13 and listed in Appendix 2. All the surface seismic stations were operational in January 2025.

The background noise on stations SUL03, SUL05, SUL06, and SUL07 is generally the lowest on the array in January. Station SUL02 located on the NE salt dome exhibits ~5 dB higher noise overall compared to the other stations. Station SUL04 shows noise levels up to 25 dB higher than the other stations. In general, the surface seismic stations typically show higher noise during the day.

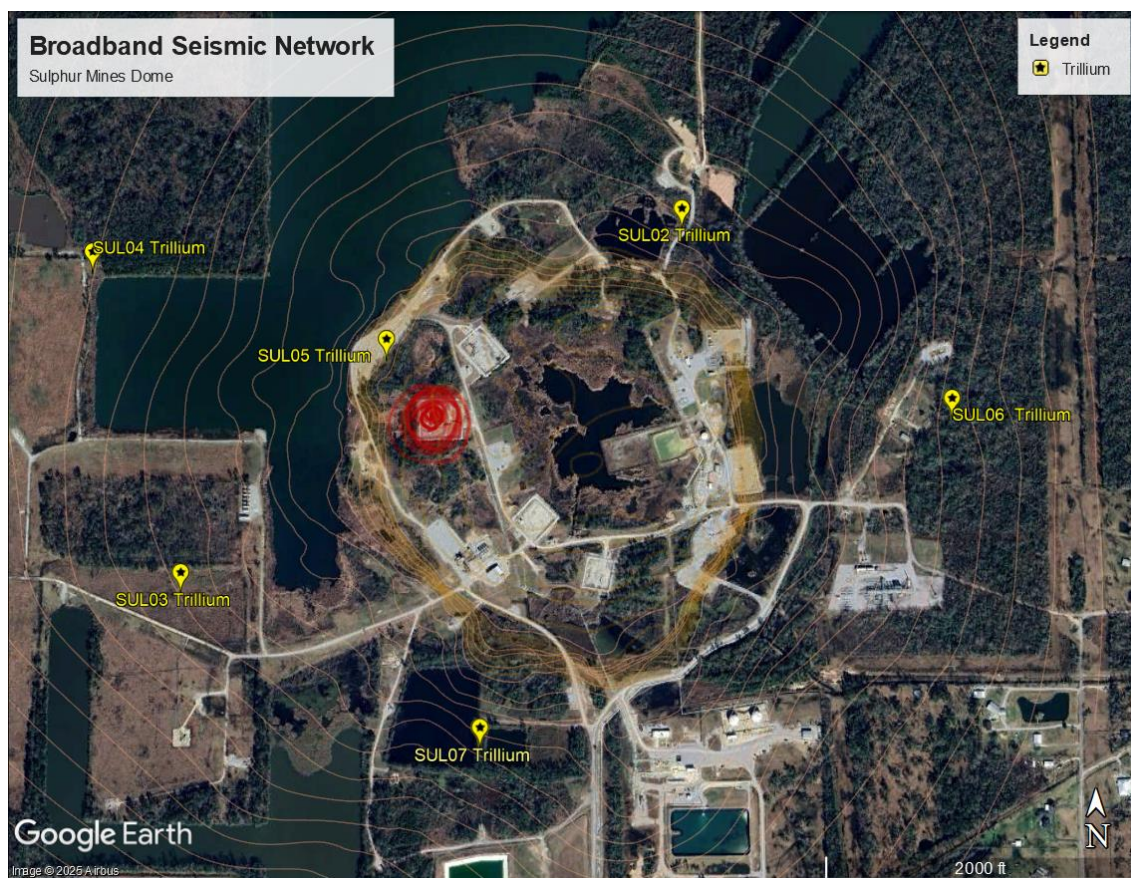


Figure 13. Map view showing the location of the six broadband seismic stations (Trillium Compact Sensors, yellow symbols and labels) near and at the Sulphur Mines Salt Dome. The contours are the salt and cap rock elevations, the red circle is the general outline of Cavern 7.

Four of the five events recorded with the surface network were co-recorded on the borehole arrays. The locations from the surface network (Figure 14) and the borehole arrays differ in X-Y position from ~130 feet to over 1,600 feet, the depths from 500 to 1,000 feet. Magnitudes show good agreement, with a variation up to ± 0.4 . The surface network and borehole array integration are expected to be finalized in February. This will eliminate the dual locations and magnitude calculations. The surface event catalog is listed in *Appendix 4*.

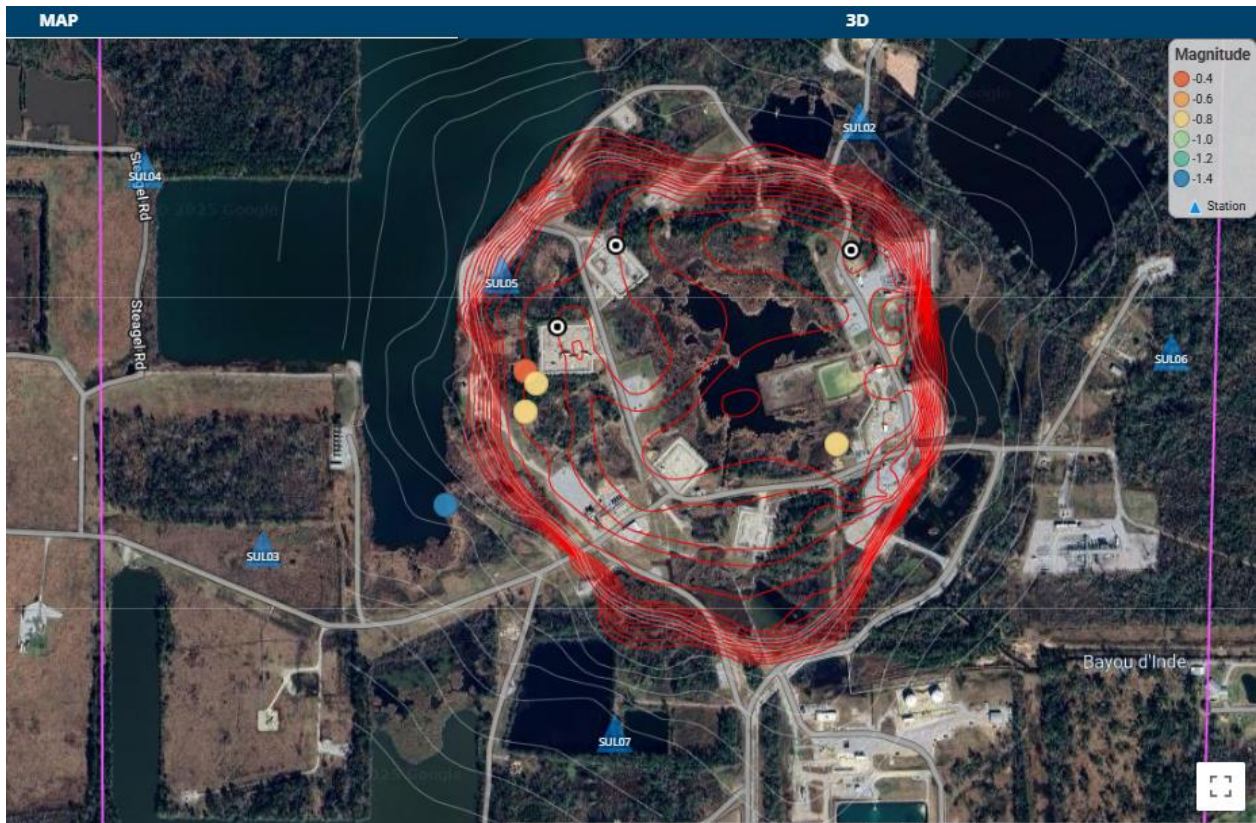


Figure 14. Satellite view, from the Nanometrics Athena website, of the microseismic events located using the surface seismic array in January 2025. The colored dots indicate the event locations colored by magnitude, from blue to red.

Appendix 1 – Alert level criteria

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

Alert Status	Criteria	Response
Low (GREEN)	No event 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.

Appendix 2 – Network Coordinates

Borehole arrays coordinates:

Wellbore	Sensor #	TVD SS ft	Easting ft	Northing ft
PPG 6x	Sensor 1	1844	1,343,141	583,425
PPG 6x	Sensor 2	1969	1,343,141	583,425
PPG 6x	Sensor 3	2094	1,343,141	583,425
PPG 6x	Sensor 4	2219	1,343,141	583,425
PPG 6x	Sensor 5	2344	1,343,141	583,425
PPG 6x	Sensor 6	2469	1,343,141	583,425
PPG 20	Sensor 1	1790	1,344,445	583,372
PPG 20	Sensor 2	2025	1,344,445	583,372
PPG 20	Sensor 3	2285	1,344,445	583,372
PPG 20	Sensor 4	2720	1,344,445	583,372
PPG 20	Sensor 5	2920	1,344,445	583,372
PPG 20	Sensor 6	3170	1,344,445	583,372

Surface network coordinates:

Station	LAT NAD 83	LON NAD 83	Date start	Date end
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	

Trillium station locations provided by Nanometrics and Westlake (Trillium SUL 02-07).

Appendix 3 – Catalog of located events using borehole array

Remark: UTC time is used for monthly catalog time window.

#	Event origin time CST (UTC – 6)	Easting (ft)	Northing (ft)	Depth (ft)	Mw	ΔEasting (ft)	ΔNorthing (ft)	ΔDepth (ft)	Detected by
1	31/12/2024 21:43:43	1342366	583544	2850	-1.2	352	1113	775	AOI-Flank
2	01/03/2025 01:36:37	1343065	583922	3040	-1.7	403	1256	614	Flank
3	01/04/2025 00:09:50	1344466	580844	5550	-1.4	1353	3514	2714	Flank
4	01/05/2025 12:24:00	1344054	583584	1579	-1.4	217	775	506	AOI-Cap-Rock
5	01/06/2025 12:31:12	1344353	583674	1914	-1.7	263	651	373	Cap-Rock
6	01/06/2025 14:56:29	1344466	584444	5050	-1.4	772	2472	1171	Flank
7	01/07/2025 23:02:41	1343187	582128	1661	-1.9	449	1652	923	AOI-Cap-Rock
8	01/08/2025 00:31:25	1344166	582544	3550	-1.8	625	1421	842	AOI-LGS-02
9	01/08/2025 00:35:38	1344167	582546	3542	-1.8	620	1409	839	AOI-LGS-02
10	01/10/2025 01:36:48	1342792	583656	1751	-1.4	375	683	631	AOI-Cap-Rock
11	01/11/2025 18:13:03	1343206	583349	2605	-1.7	303	771	432	AOI-PPG-06
12	01/11/2025 18:23:41	1343766	583544	3250	-1.4	331	911	448	AOI-PPG-16
13	01/15/2025 11:32:55	1344166	583444	3250	-0.9	308	949	435	AOI-PPG-16
14	01/15/2025 11:55:48	1344366	584344	4150	-1.4	783	1857	1351	Flank
15	01/18/2025 04:10:12	1343266	584644	4950	-1.1	716	2539	966	Flank
16	01/18/2025 10:39:06	1344575	583644	3225	-2.1	369	622	523	Flank
17	01/18/2025 21:02:29	1344625	583349	4636	-0.4	644	1555	712	PPG-20
18	01/21/2025 00:19:15	1342542	582706	2998	-1.8	582	1314	795	AOI-PPG-07
19	01/21/2025 03:27:35	1343853	582559	2816	-1.3	304	1308	762	AOI-LGS-02
20	01/21/2025 03:27:42	1343845	582631	2921	-1.2	351	1369	820	AOI-LGS-02
21	01/21/2025 03:27:50	1343866	582544	2750	-0.9	302	1313	774	AOI-LG2-02
22	01/21/2025 09:09:14	1343066	583444	1150	-1.9	384	917	399	AOI-Cap-Rock
23	01/24/2025 14:27:30	1342966	583544	3150	-0.5	366	1133	541	AOI-PPG-06
24	01/26/2025 05:22:50	1342966	582844	2750	-1.7	399	1053	519	AOI-PPG-07
25	01/26/2025 05:22:55	1342966	582844	2750	-1.1	380	1061	512	AOI-PPG-07
26	01/26/2025 05:23:04	1342966	582844	2750	-1.0	378	1052	508	AOI-PPG-07
27	01/26/2025 05:23:13	1342981	582938	2831	-1.1	376	1052	495	AOI-PPG-07
28	01/26/2025 05:23:21	1342996	582866	2793	-1.2	378	1077	514	AOI-PPG-07
29	01/26/2025 05:23:32	1342992	582891	2802	-1.0	376	1069	506	AOI-PPG-07
30	01/26/2025 16:04:22	1342966	583044	2750	-0.5	343	919	470	AOI-PPG-07
31	01/26/2025 16:04:24	1343066	583044	2750	-0.8	369	943	512	AOI-PPG-07
32	01/26/2025 16:04:30	1342889	583013	2819	-0.4	403	1045	506	AOI-PPG-07
33	01/26/2025 16:04:36	1342866	583144	2850	-0.4	400	1012	495	AOI-PPG-07
34	01/26/2025 16:04:54	1342966	582944	2750	-1.1	399	998	493	AOI-PPG-07
35	01/27/2025 09:36:44	1342566	583344	1750	-1.8	440	755	569	AOI-Cap-Rock
36	01/27/2025 09:36:49	1342566	583344	1650	-1.6	490	792	457	AOI-Cap-Rock
37	01/28/2025 10:48:10	1342521	583441	2372	-2.2	350	670	457	AOI-Cap-Rock
38	01/28/2025 10:48:16	1342521	583441	2372	-2.0	350	670	457	AOI-Cap-Rock
39	01/28/2025 10:48:21	1342552	583486	2645	-1.8	334	889	659	AOI-Cap-Rock

#	Event origin time CST (UTC - 6)	Easting (ft)	Northing (ft)	Depth (ft)	Mw	ΔEasting (ft)	ΔNorthing (ft)	ΔDepth (ft)	Detected by
40	01/30/2025 13:22:58	1344340	582684	1835	-1.6	306	1112	720	Cap-Rock
41	01/30/2025 15:19:18	1343565	583392	1888	-1.7	192	674	430	AOI-Cap-Rock
42	01/31/2025 00:16:15	1343986	582820	1916	-1.7	215	950	441	AOI-Cap-Rock
43	01/31/2025 14:42:16	1343366	582544	2850	-0.9	387	1489	959	AOI-PPG-02

Appendix 4 – Catalog of located events using surface network

SP LA SOUTH NAD27					Location Uncertaines	
Local date and time CST (UTC -6 hours)	Easting (ft)	Northing (ft)	Depth (ft)	Mag (Mw)	ΔHorizontal (ft)	ΔDepth (ft)
1/11/2025 18:23:41	1342111	582183	3904	-1.3	1152	1050
1/18/2025 21:02:29	1344287	582480	2723	-0.7	956	1312
1/26/2025 16:04:21	1342559	582914	1575	-0.4	364	951
1/26/2025 16:04:29	1342619	582848	1673	-0.6	417	984
1/26/2025 16:04:46	1342556	582685	1280	-0.8	626	1903