Chevron Argentina
El Trapial Pad C – 2021h, 2022h, 2023h & 2024h
Final Results

November 12th, 2020

Project Location
Neuquén Basin, Argentina

Prepared for

November 2020

by

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Outline

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- Project and Completions Summary

Event Locations

- Event Locations and Source Mechanism Overview

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- Stress Analysis and Stimulation Potential

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- Wellbore Spacing, Stage Length, & Vertical Height

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- Source Mechanisms
- Data Quality & Noise Analysis
- Earthquakes
- b Value Analysis

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- Stage-by-Stage Results – All Events
- Stage-by-Stage Results – Reservoir Events

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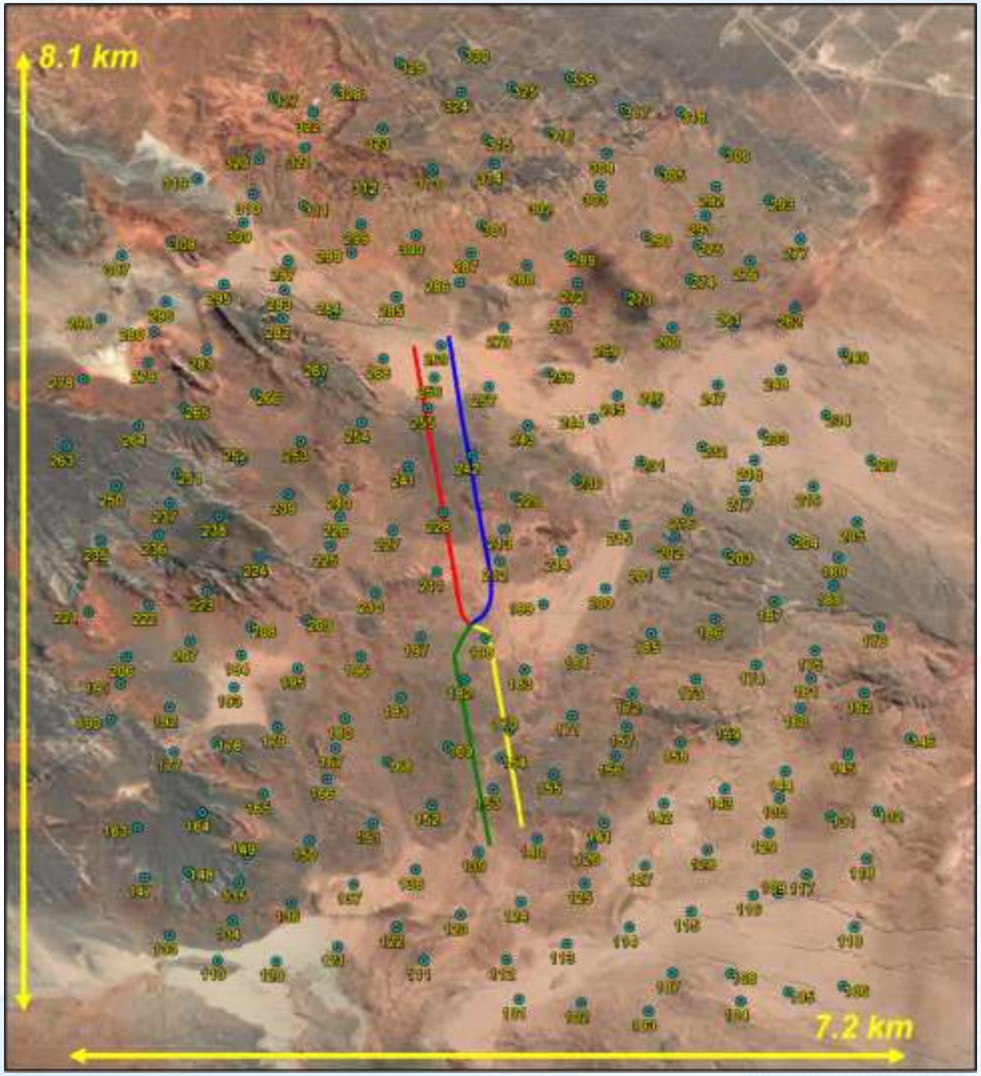
Objectives

1. Fault Interaction
2. Determine Fracture Geometry
3. Determine Orientation of SHmax
4. Evaluate Treatment Efficiency



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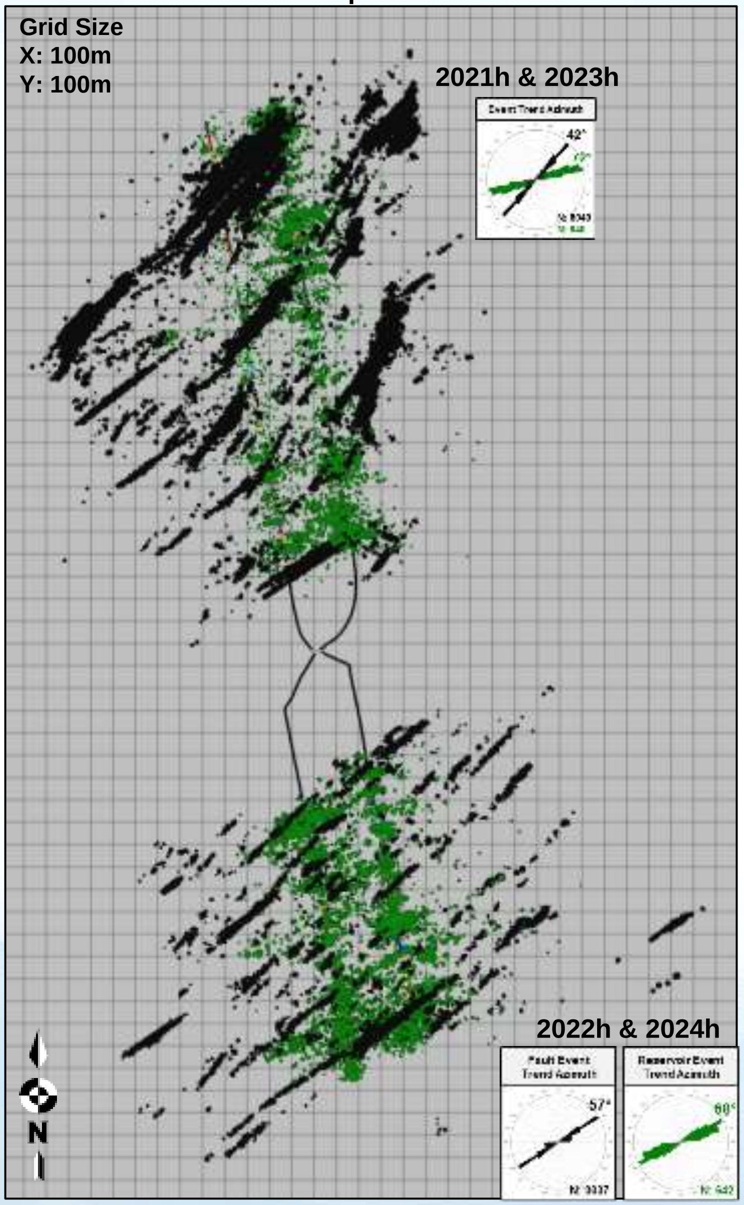
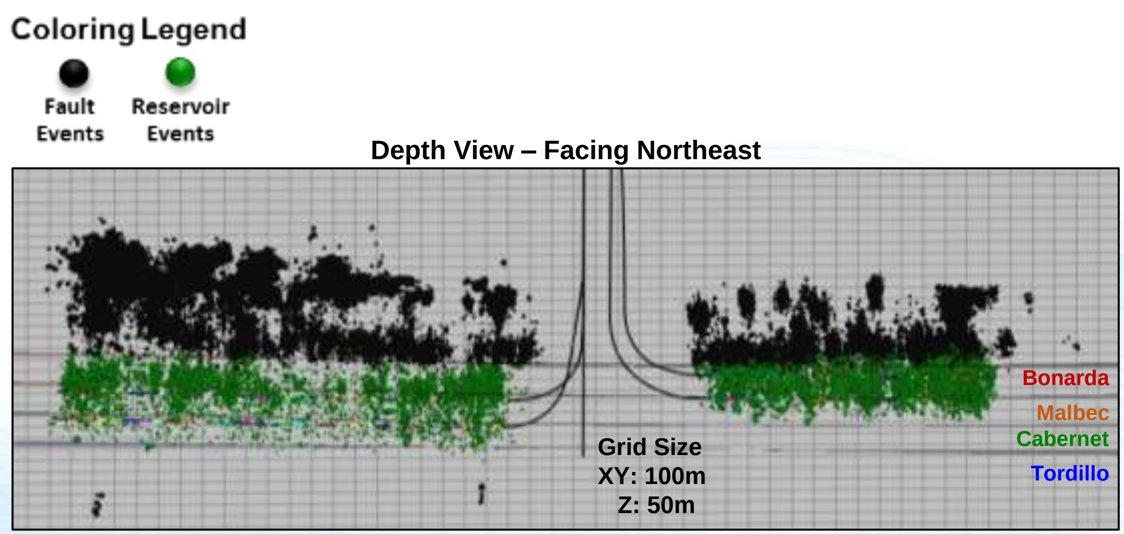
Objective #1 – Fault Interaction

Map View



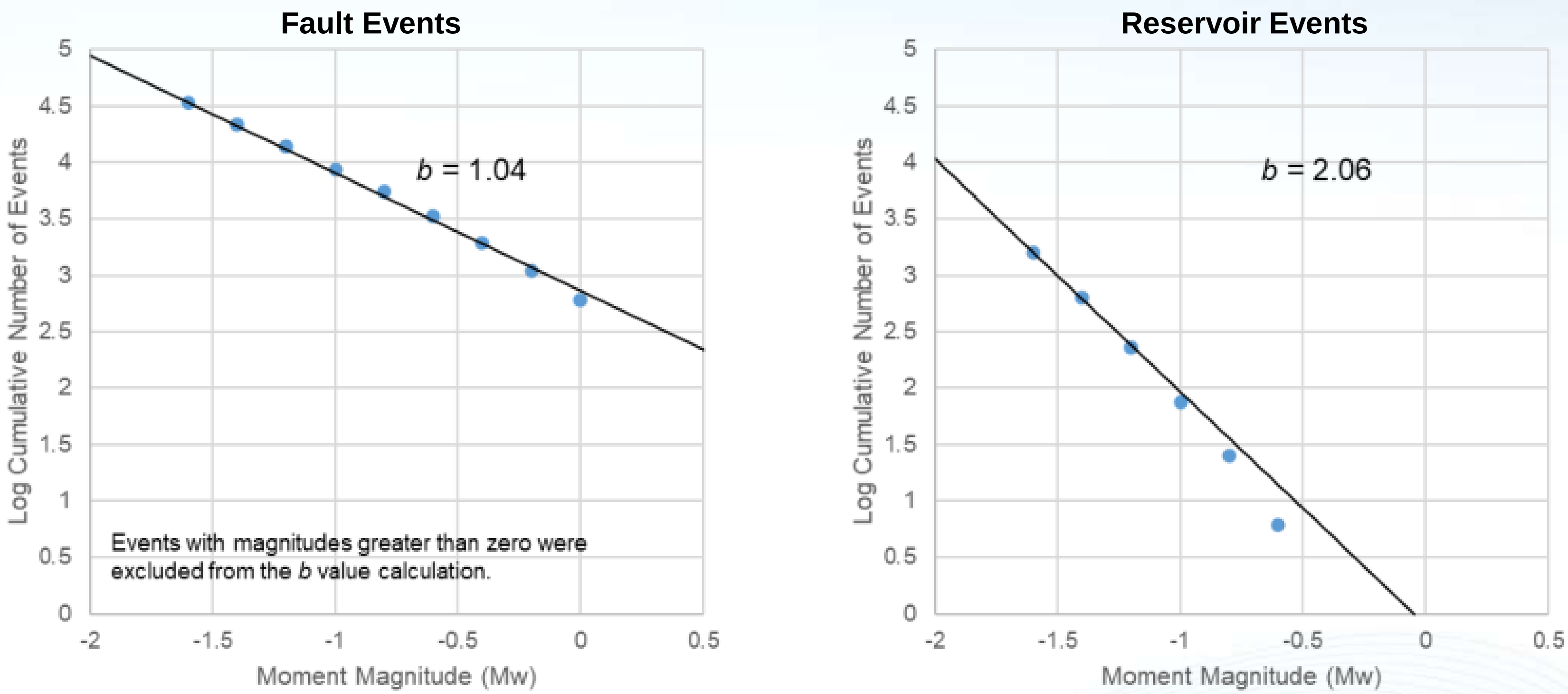
- Shallow fault activity was observed throughout the duration of recording.
- There was one reported earthquake with a local magnitude (ML) of 3.3 that was recorded by the array.

Depth View – Facing Northeast



Events are sized by magnitude and colored by event type.

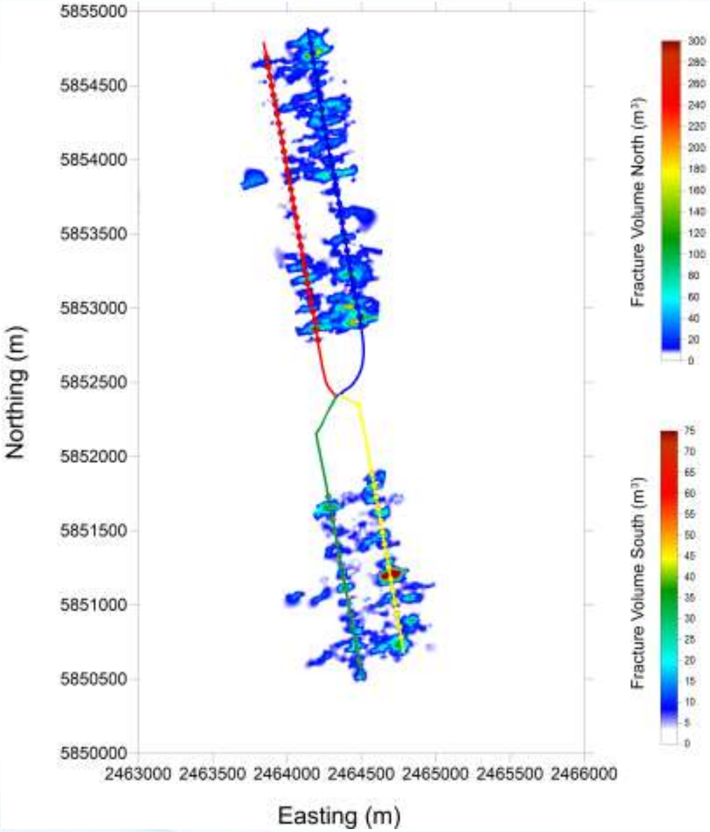
Objective #1 – Fault Interaction – *b* Value



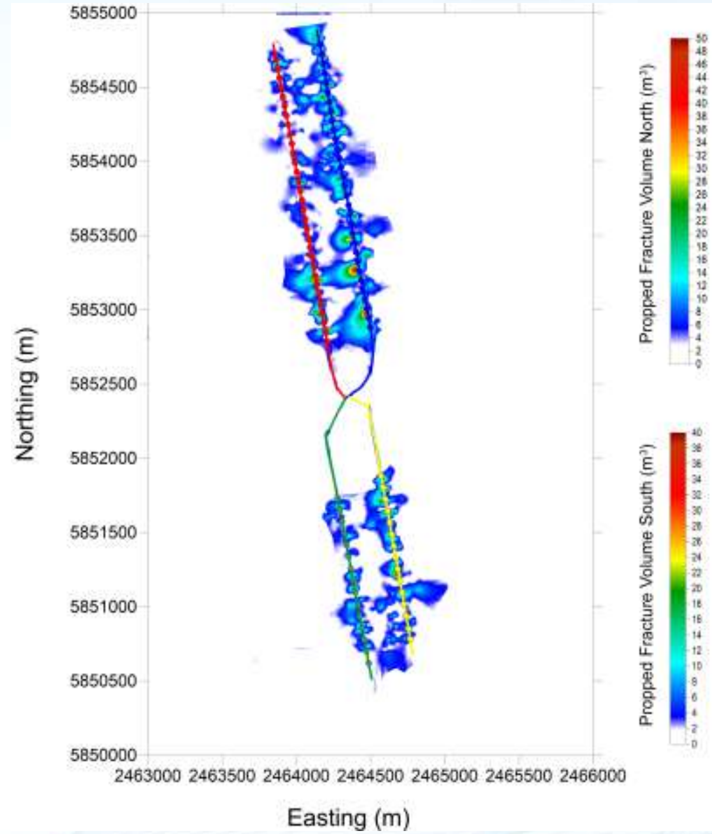
- A b-value of ~1 suggests that the events are related to the stimulation of pre-existing faults or features and is typical of a strike-slip stress regime.
- A b-value of ~2 suggests that the events are related to hydraulic fracturing.

Objective #2 – Fracture Geometry (Sliced Below Bonarda Top)

Fracture Volume



Propped Fracture Volume



- Fracture geometry calculated as P90 (inner-90th percentile length, height and longitudinal width)
- Measurements based on stage by stage fracture geometry for fractures located below Bonarda top

Reservoir

P90 Metric (m)	2021	2022	2023	2024
Propped Half-Length	105	87	67	82
Half-Length	297	283	162	226
Propped Height	246	110	118	145
Height	354	132	192	166
Propped Half-Width	50	65	28	44
Half-Width	91	170	69	95

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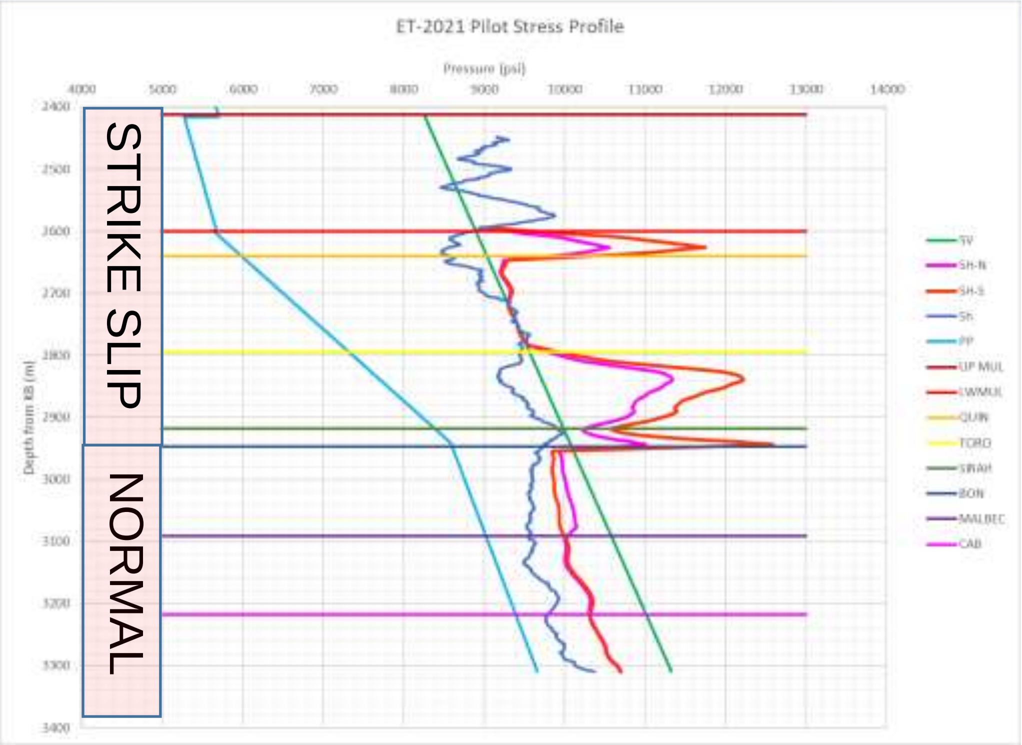
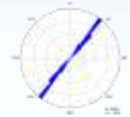
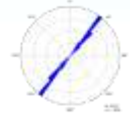
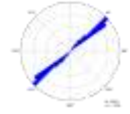
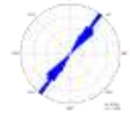
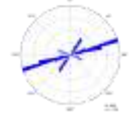
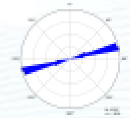
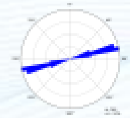
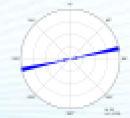
Objective #3 – Determine Orientation of SH_{max}



Formation	Fracture Strike	Pad	Sh_{max}	Φ
UP MULICHINCO		North	81°	0.25
		South	-	-
LW MULICHINCO		North	81°	0.21
		South	82°	0.14
QUINTUCO		North	66°	0.67
		South	66°	0.77
TORRONTES		North	60°	0.24
		South	62°	0.39
SIRAH		North	57°	0.25
		South	59°	0.11
BONARDA		North	84°	0.61
		South	81°	0.49
MALBEC		North	80°	0.40
		South	81°	0.43
CABERNET		North	81°	0.44
		South	-	-

Stress ratio, Φ

$$\Phi = \frac{\sigma_2 - \sigma_3}{\sigma_1 - \sigma_3}$$

Assuming strike-slip stress regime

$$SH_{max} = \sigma_1 = \frac{\sigma_2 - \sigma_3}{\Phi} + \sigma_3$$

Assuming normal stress regime

$$SH_{max} = \sigma_2 = \Phi(\sigma_1 - \sigma_3) + \sigma_3$$

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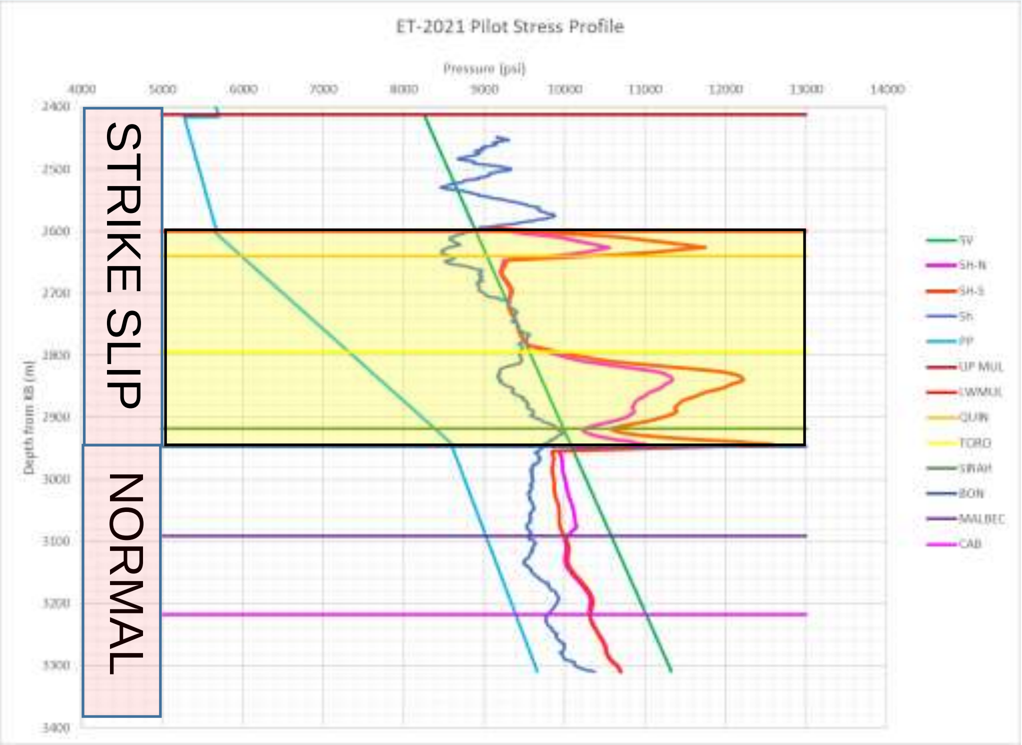
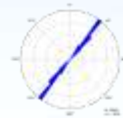
Objective #4 – Evaluate Treatment Efficiency



Formation	Fracture Strike	Pad	Sh_{max}	Φ
UP MULICHINCO		North	81°	0.25
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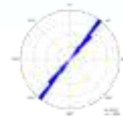
LW MULICHINCO		North	81°	0.21
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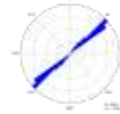
QUINTUCO		North	66°	0.67
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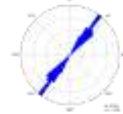
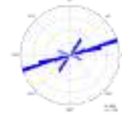
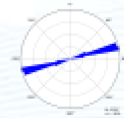
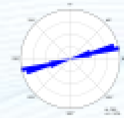
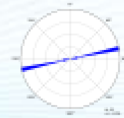
TORRONTES		North	60°	0.24
		South	62°	0.39
SIRAH		North	57°	0.25
		South	59°	0.11
BONARDA		North	84°	0.61
		South	81°	0.49
MALBEC		North	80°	0.40
		South	81°	0.43
CABERNET		North	81°	0.44
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Stress ratio, Φ

$$\Phi = \frac{\sigma_2 - \sigma_3}{\sigma_1 - \sigma_3}$$

Assuming strike-slip stress regime

$$SH_{max} = \sigma_1 = \frac{\sigma_2 - \sigma_3}{\Phi} + \sigma_3$$

Assuming normal stress regime

$$SH_{max} = \sigma_2 = \Phi(\sigma_1 - \sigma_3) + \sigma_3$$

- Fractures growing above Bonarda into high pore-pressure gradient rock reactivates shallow faults that continue to slip when pumping ceases

Project Background

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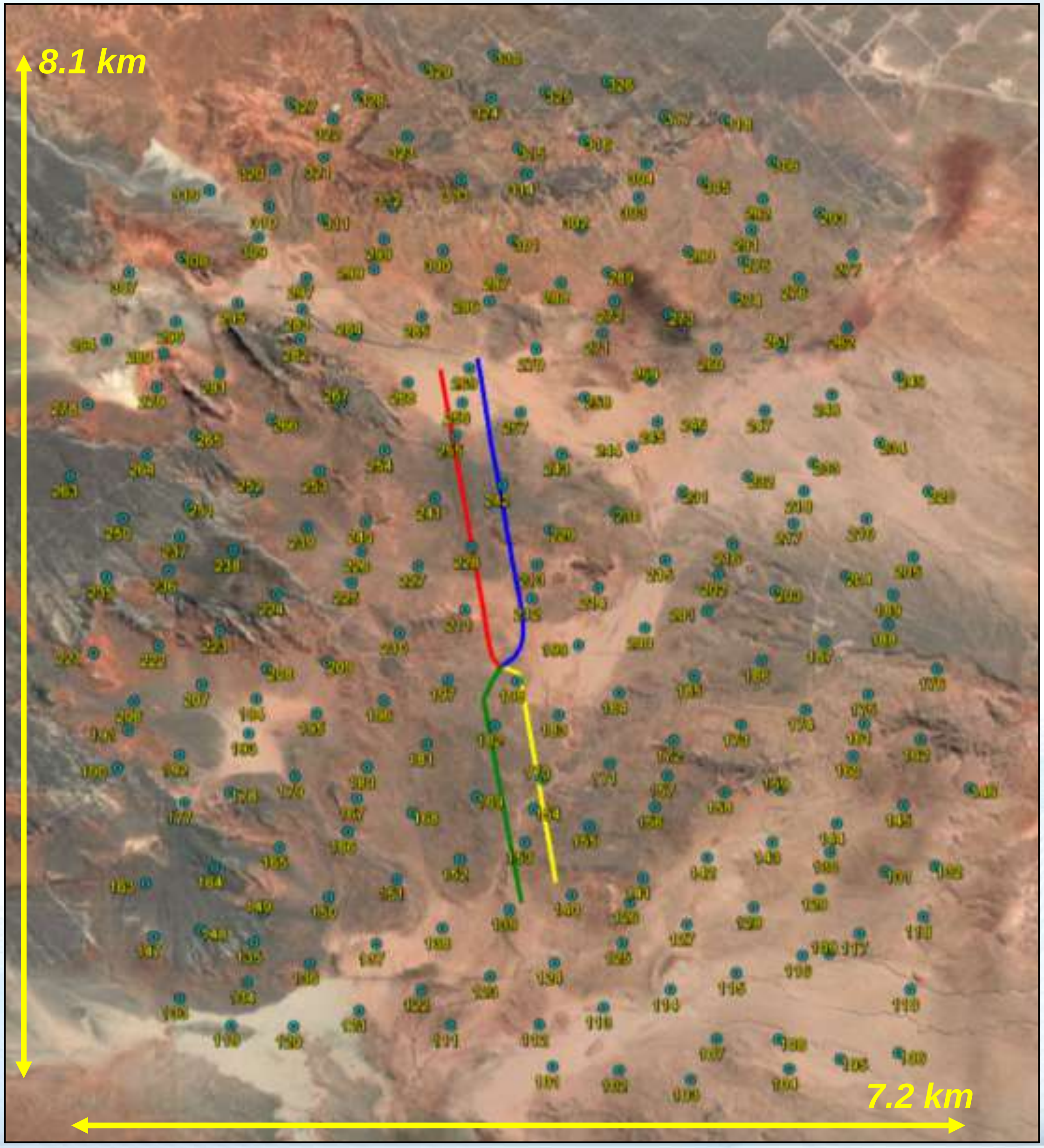
Acquisition Summary

- There are 230 stations in the array represented by blue circles.
- The array consists of 2 multi-level sondes per station buried at 30 and 15 meters for a total of 460 channels and covers ~58 km^2.
- Wellbore Legend:

red line	ET-2021h
blue line	ET-2023h
green line	ET-2022h
yellow line	ET-2024h

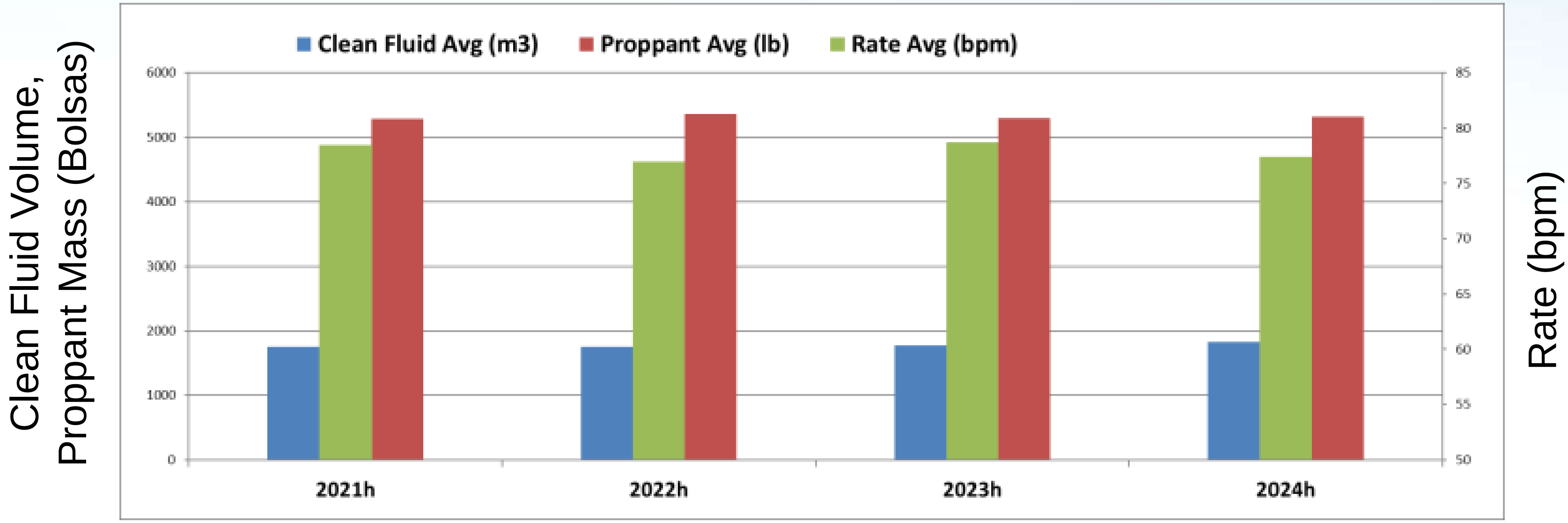
- Treatment dates:

  6/08/2020 – 7/14/2020
- 254 pump hours recorded (4 wells, 92 perf/plug stages)
- Target Formations: Vaca Muerta (Bonarda, Malbec & Cabernet)
- Average Target Depths:
  3,001m TVD – 2022h
  3,065m TVD – 2023h
  3,095m TVD – 2024h
  3,193m TVD – 2021h
- Data was acquired with the Sercel Unite recording system at a 2ms sample rate.



MicroSeismic

Treatment Summary



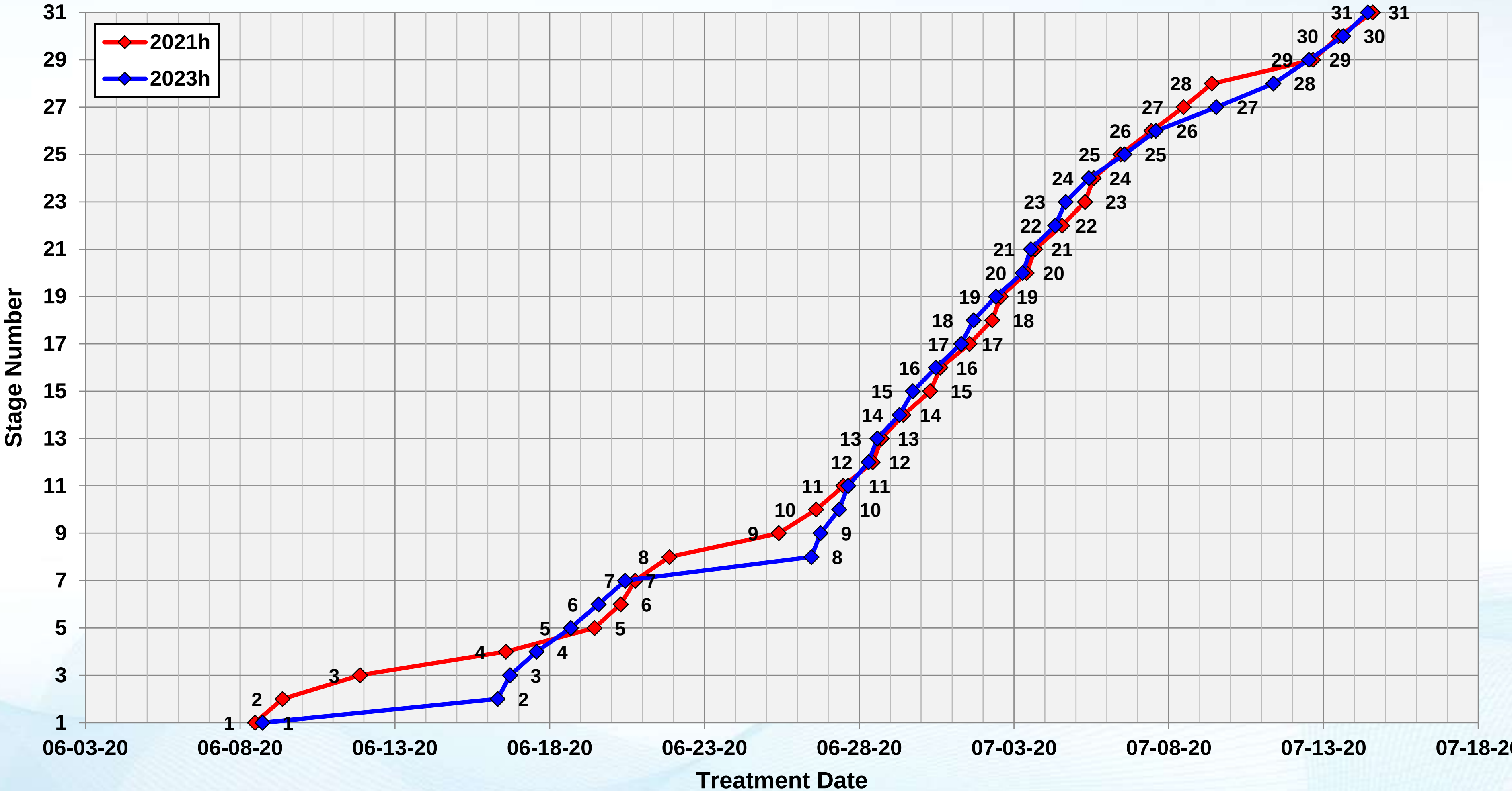
North

Well	Stages	Stage Length (m)	Clusters	Fluid Volume per Stage (m^3)	Proppant per Stage (lbs)	Slurry Rate (bpm)	Average Pressure (psi)	Fluid/m of completed lateral (m^3/m)	Proppant/m of completed lateral (lbs/m)
2021h	31	65	10	1,747	529,500	78.5	9,839	26.9	8,146
2023h	31	65	10	1,773	529,632	78.7	9,628	27.3	8,148

South

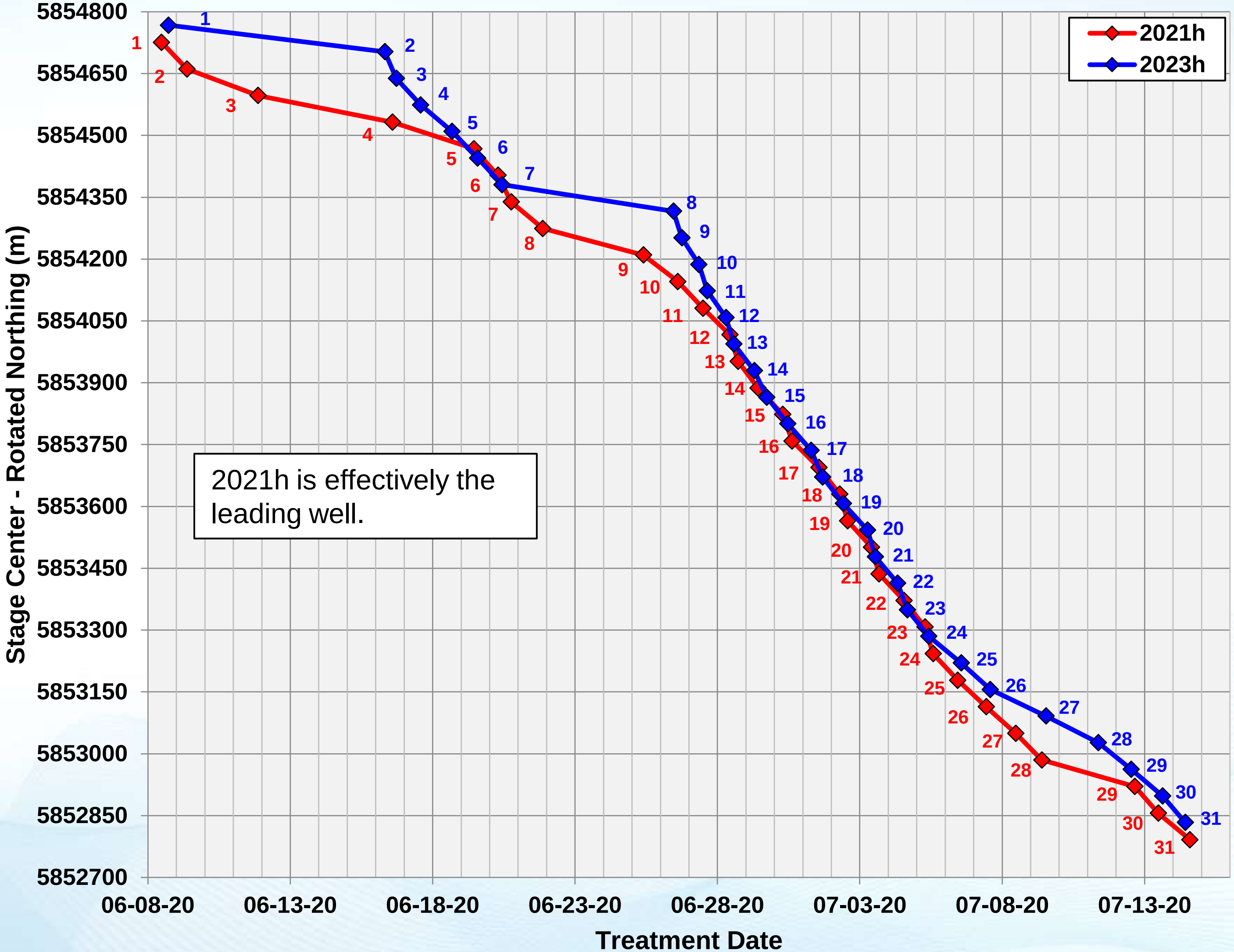
Well	Stages	Stage Length (m)	Clusters	Fluid Volume per Stage (m^3)	Proppant per Stage (lbs)	Slurry Rate (bpm)	Average Pressure (psi)	Fluid/m of completed lateral (m^3/m)	Proppant/m of completed lateral (lbs/m)
2022h	15	80	10	1,746	536,273	76.9	8,252	21.8	6,703
2024h	15	80	10	1,831	532,167	77.4	9,337	22.8	6,652

Treatment Order – 2021h & 2023h

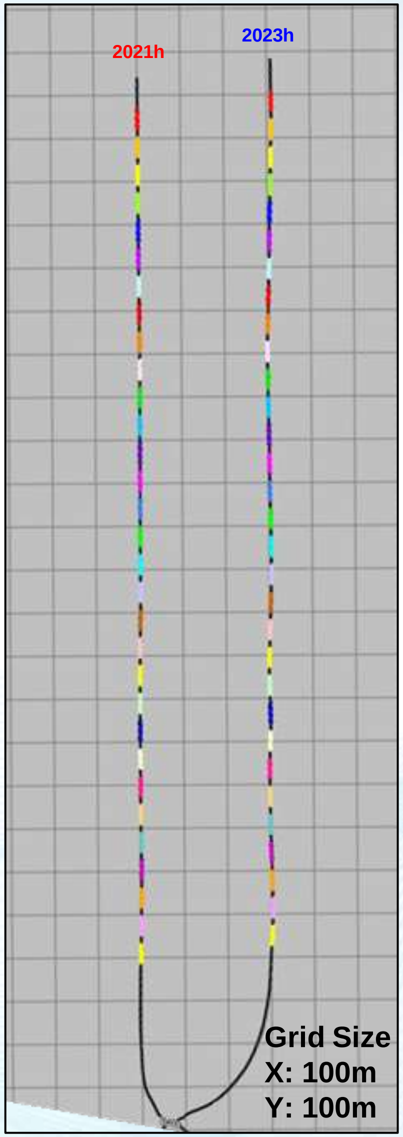


MicroSeismic

Treatment Order – 2021h & 2023h



Map View –
Rotated Wellbores

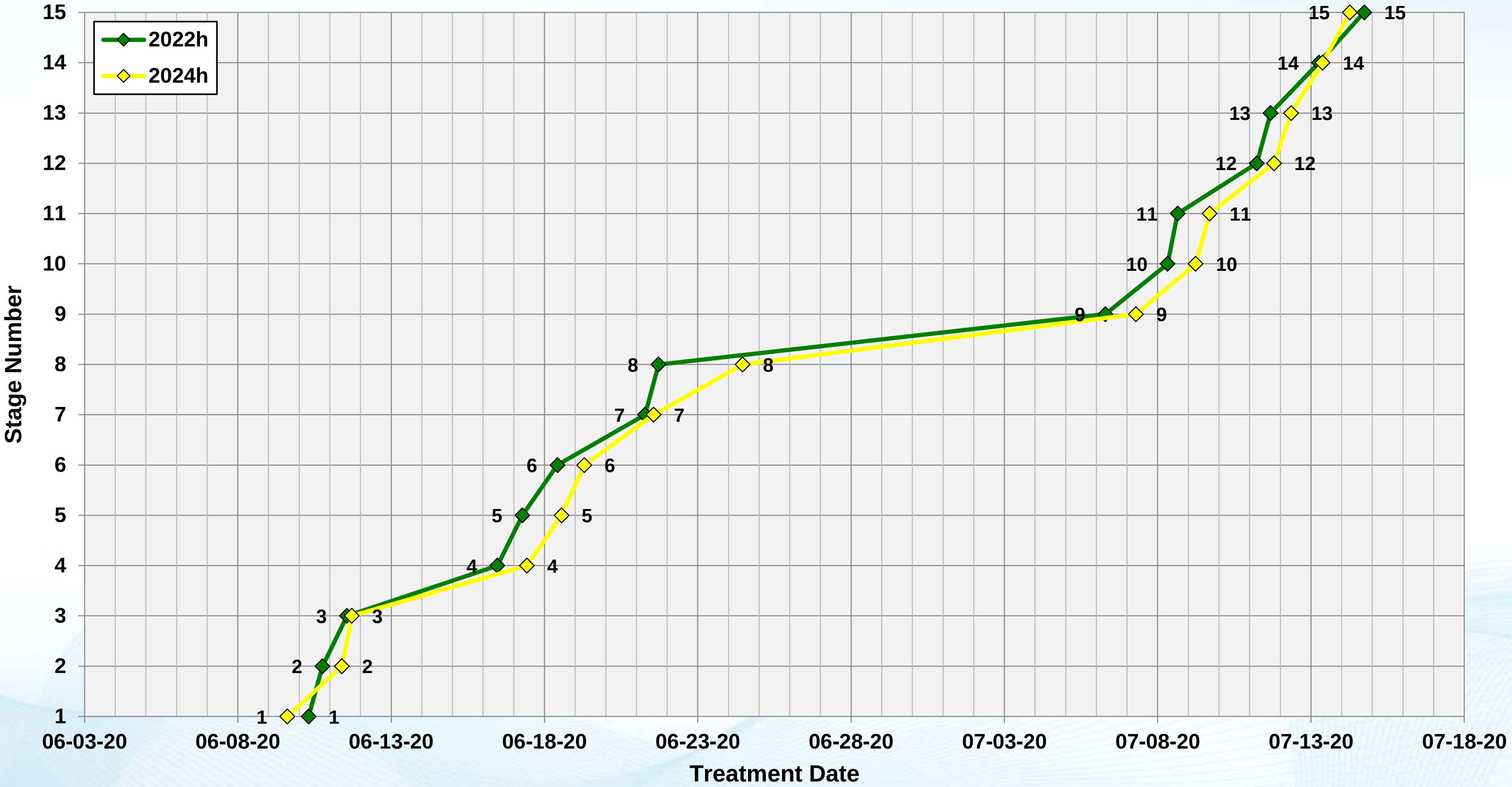


Stage Coloring Legend

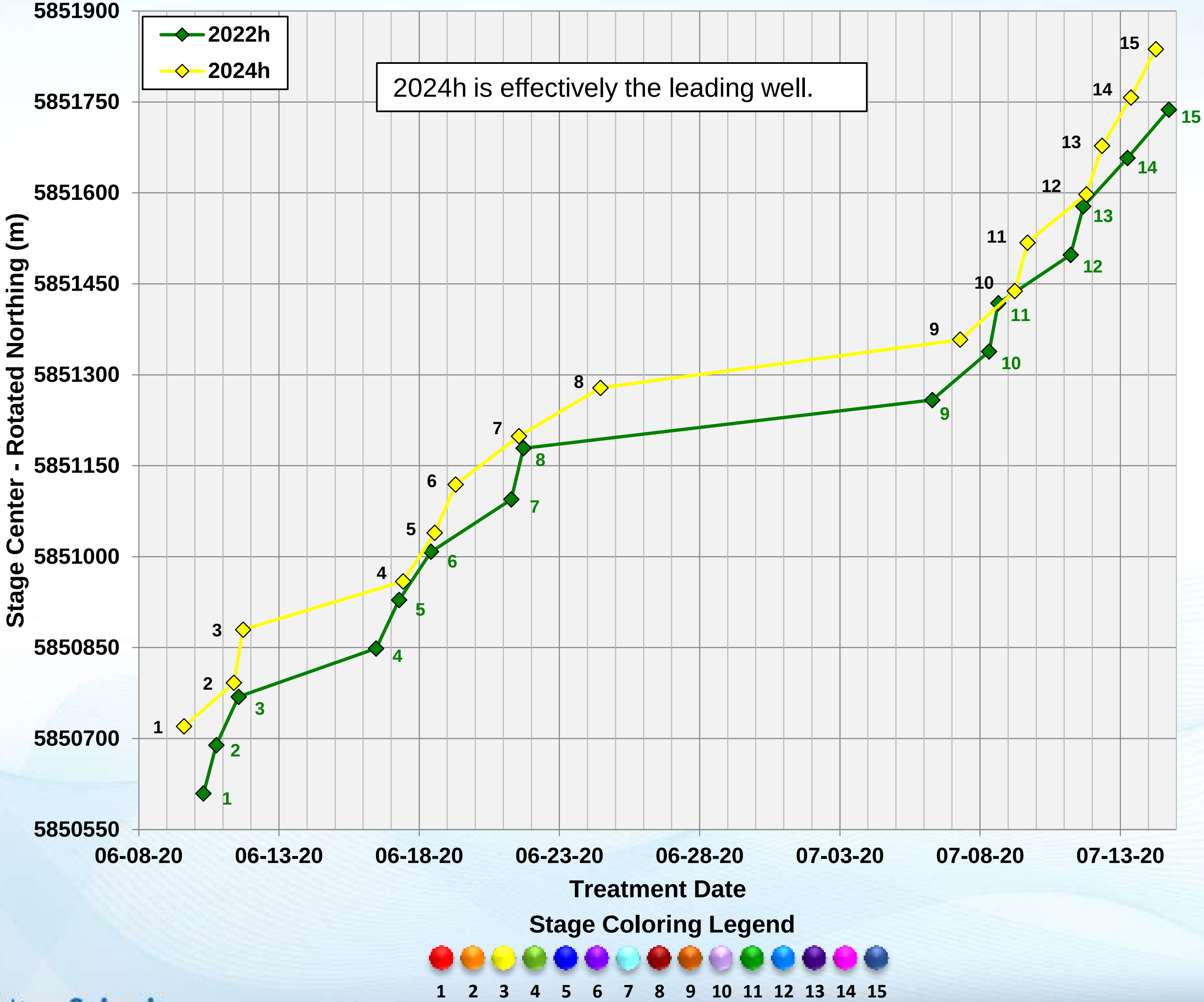
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

MicroSeismic

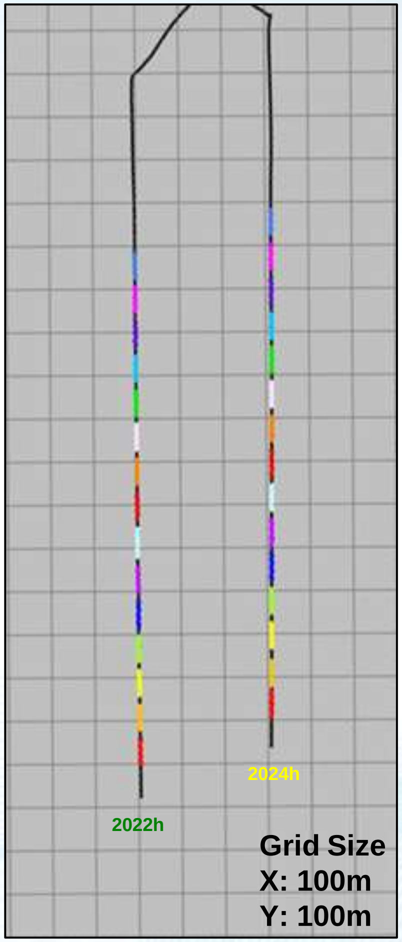
Treatment Order – 2022h & 2024h



Treatment Order – 2022h & 2024h



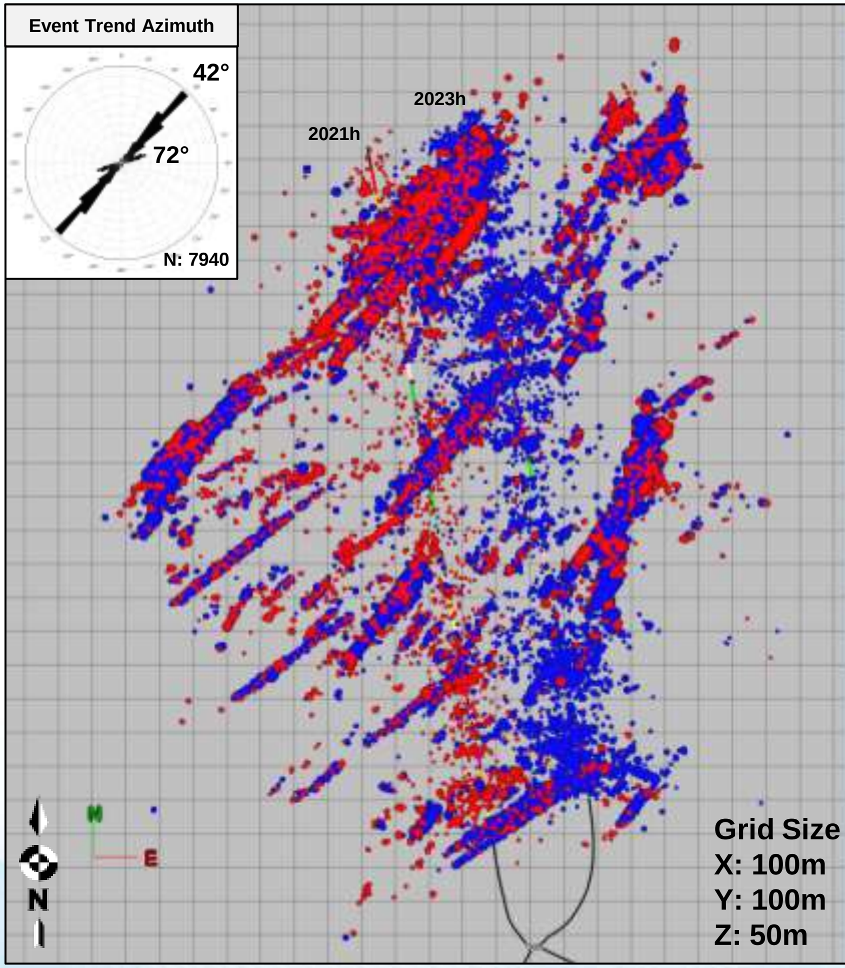
Map View –
Rotated Wellbores



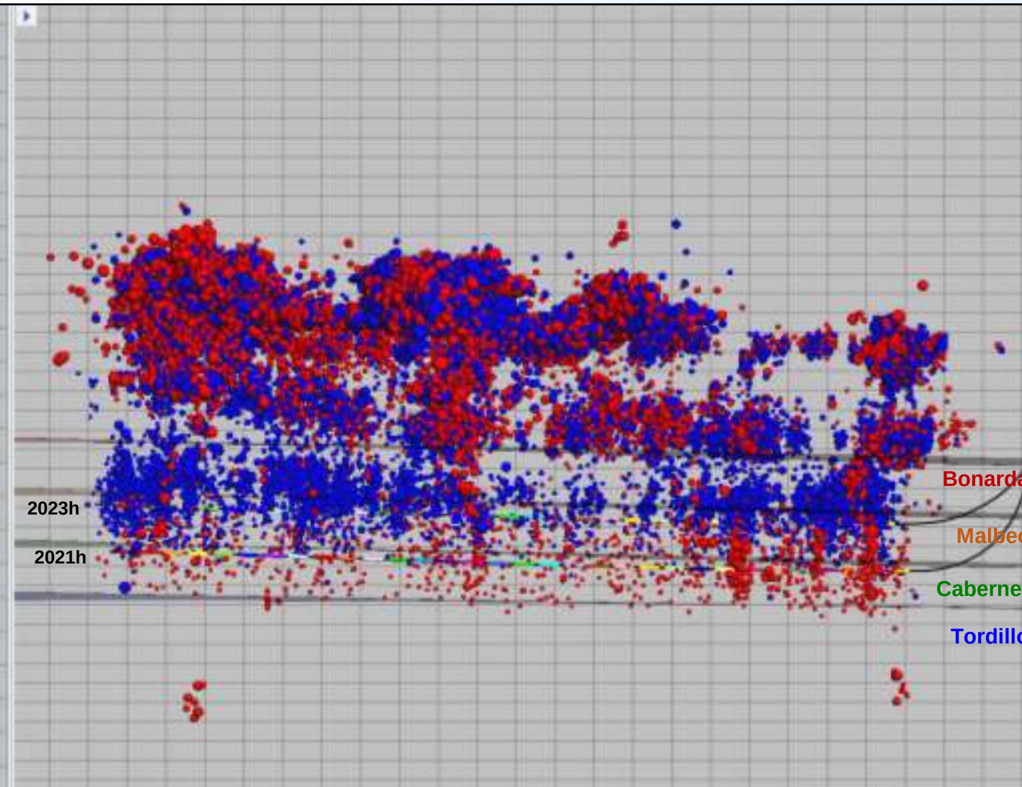
Microseismic Event Locations

2021h & 2023h – Event Locations

Map View



Depth View – Facing Northeast



- A significant amount of microseismicity was observed above the Bonarda formation.
- This shallow activity forms long linear trends with azimuths that range from ~15° to 55°.

Events are sized by magnitude and colored by well.

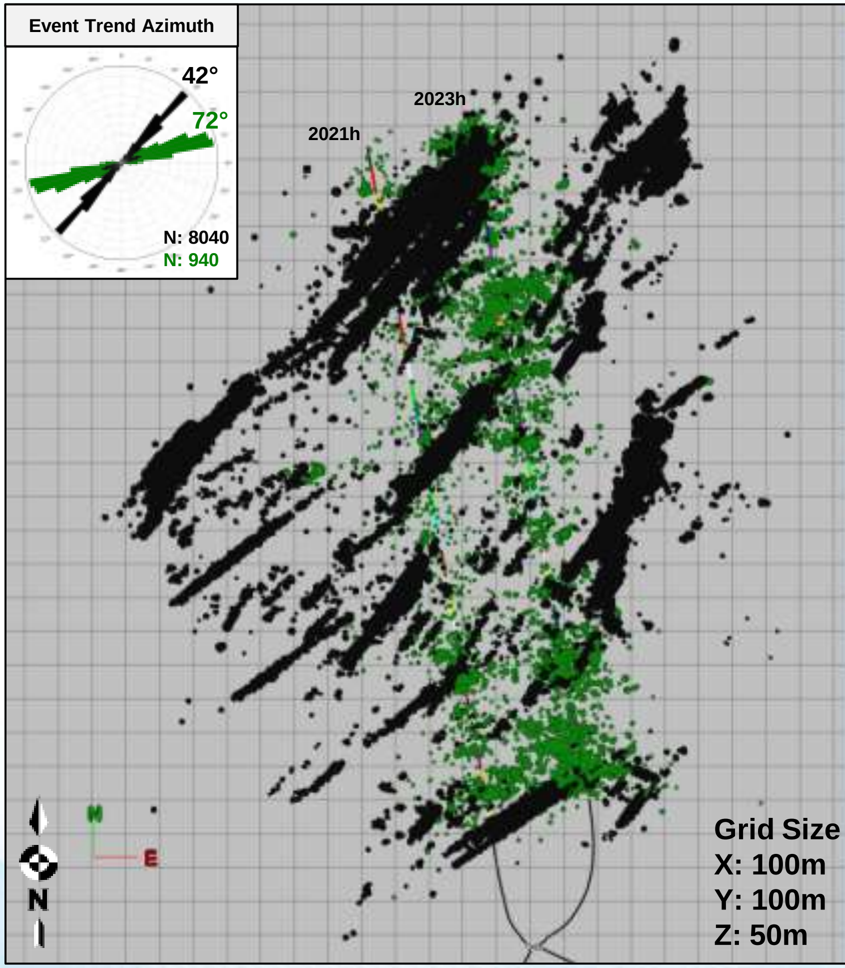
Well Coloring Legend

2021h 2023h

MicroSeismic

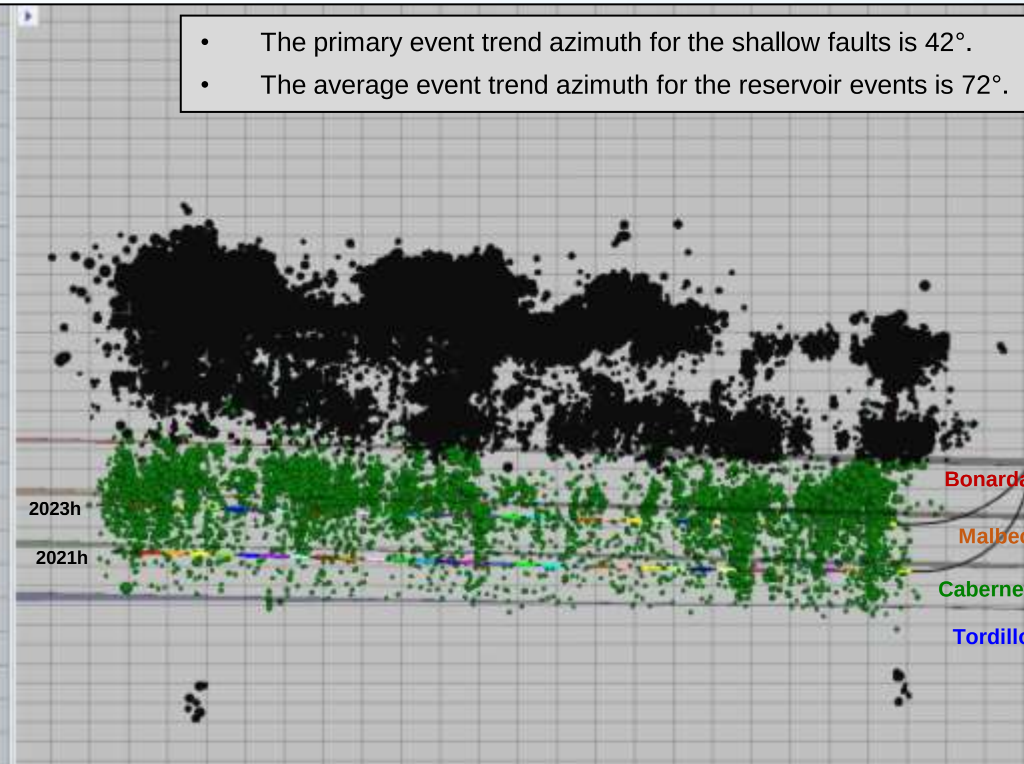
2021h & 2023h – Event Locations

Map View



Events are sized by magnitude and colored by event type.

Depth View – Facing Northeast



- The primary event trend azimuth for the shallow faults is 42°.
- The average event trend azimuth for the reservoir events is 72°.

Fault event classification:

1. All strike-slip and oblique strike-slip events above the Bonarda horizon and 100m or more below the Tordillo horizon.
2. All dip-slip and oblique dip-slip events 200m or more above the Bonarda horizon.
3. Strike-slip and oblique strike-slip events below the Bonarda horizon if:
   - Strike azimuth is greater than 110°
   - Strike azimuth is less than 60° and event depth is from 0m to 30m below the Bonarda horizon
   - 2023h events with strike azimuths less than 50° and event depths between 0m to 52m below the Bonarda horizon
   - For 2023h, a few strike-slip and oblique strike-slip events with strike azimuths between 60° and 80° and depths between 0m and 52m below the Bonarda horizon were classified as fault events due to their proximity to other fault events and far distance from the 2023h wellbore.

Coloring Legend

Fault Events | Reservoir Events

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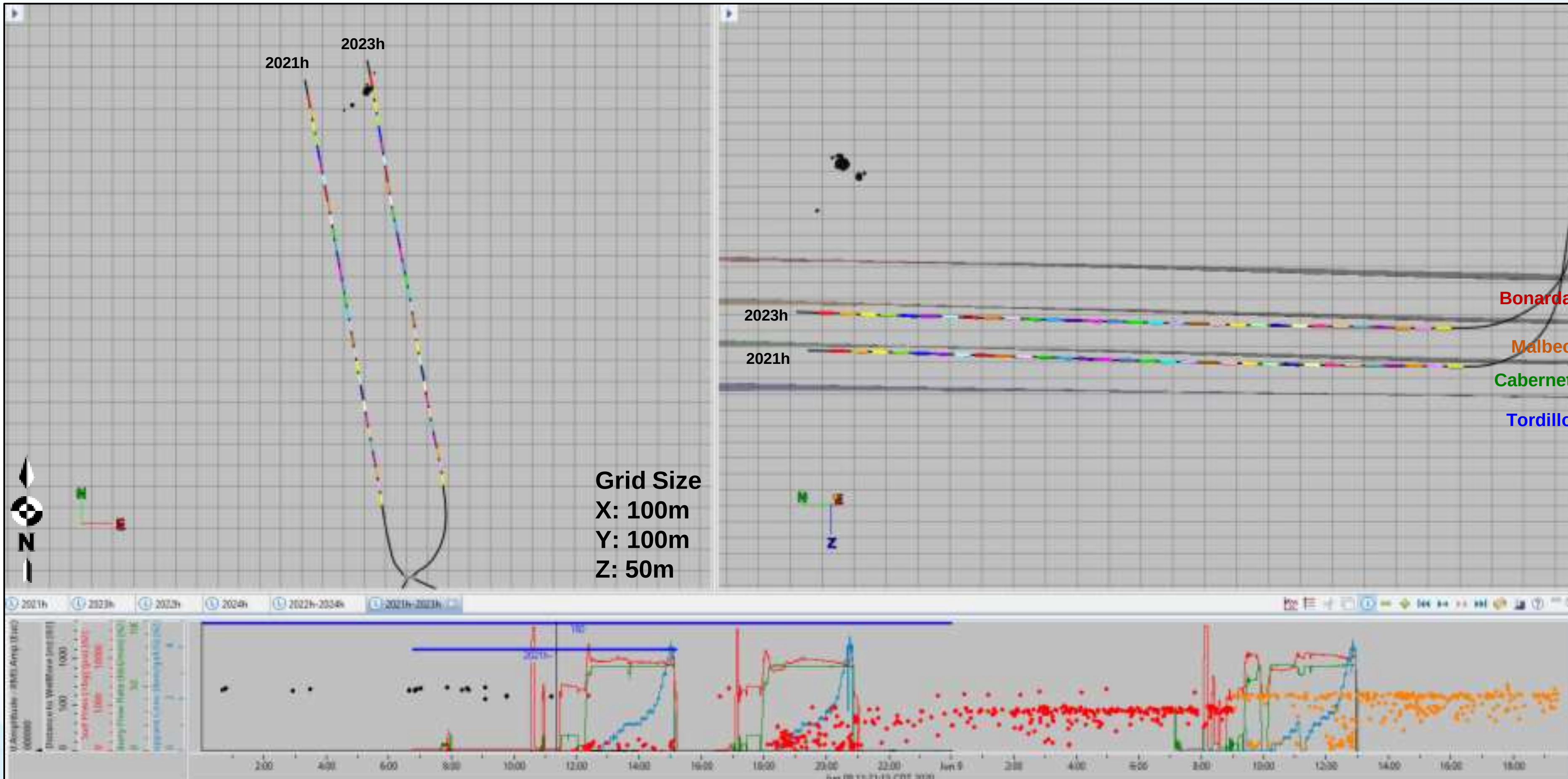
2021h & 2023h – Activity Before Pumping of First Stage

Map View | **Depth View – Facing Northeast**



Treatment Plot Legend: ● Event Distance to Wellbore — Bottomhole Proppant Concentration — Slurry Flow Rate — Treating Pressure

Events are sized by magnitude and colored by event type.

Coloring Legend

Fault Events | Reservoir Events

- Displaying events observed from the start of recording until the start of the first stage (2021h stage 1). The first event was observed ~41 minutes after recording begins.
- Some activity is observed along the shallow fault above stage 1 of the 2023h well.

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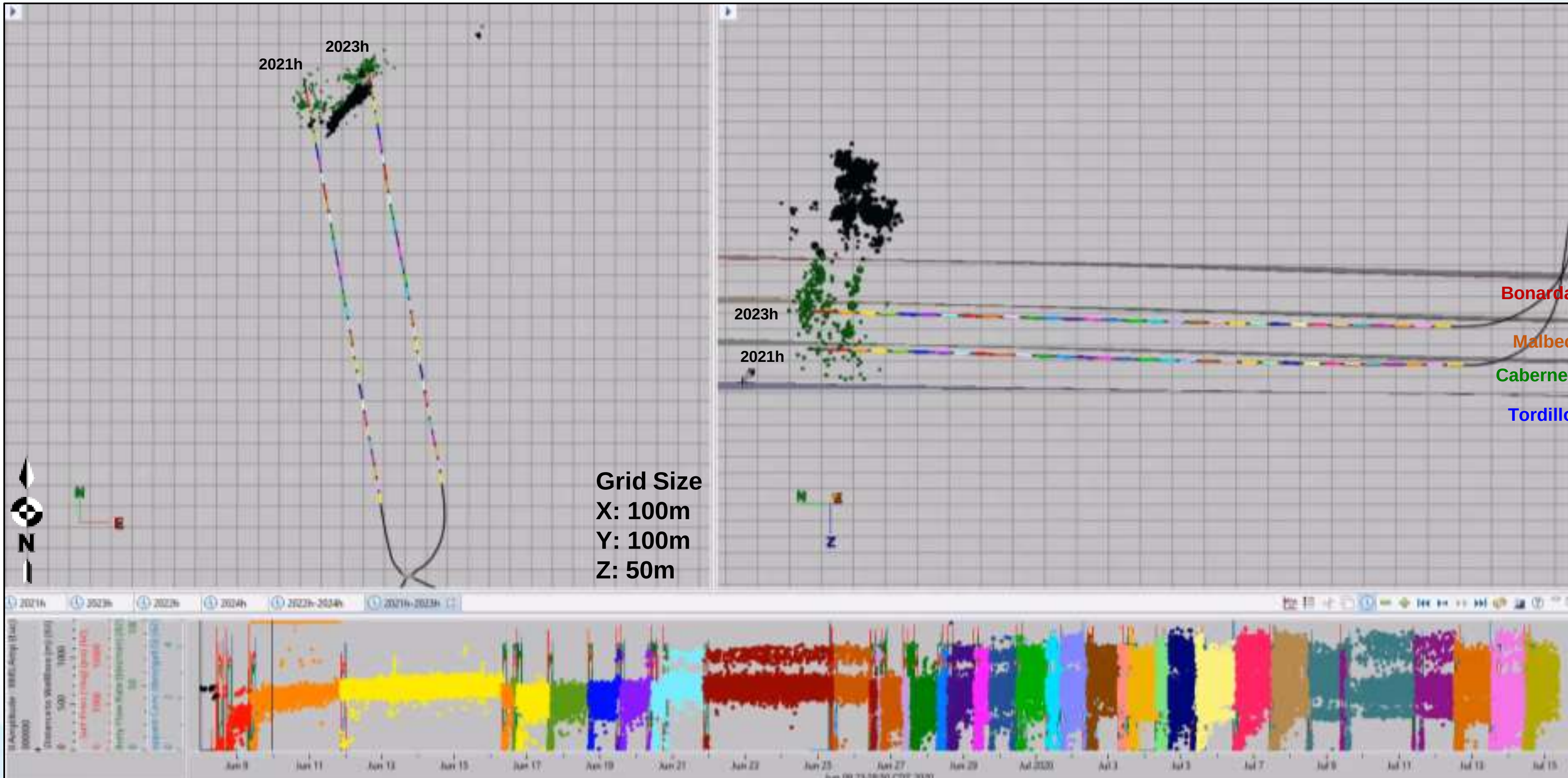
2021h & 2023h – Movie – Two Day Sliding Time Window

Map View | **Depth View – Facing Northeast**



Treatment Plot Legend: ● Event Distance to Wellbore — Bottomhole Proppant Concentration — Slurry Flow Rate — Treating Pressure

Events are sized by magnitude and colored by event type.

Coloring Legend

Fault Events **Reservoir Events**

- The fault activity moves heel-ward as the frac progresses and propagate vertically over time.
- Once activated, the activity continues to be observed above the toe and middle section of the wellbores for the remainder of the recording period.

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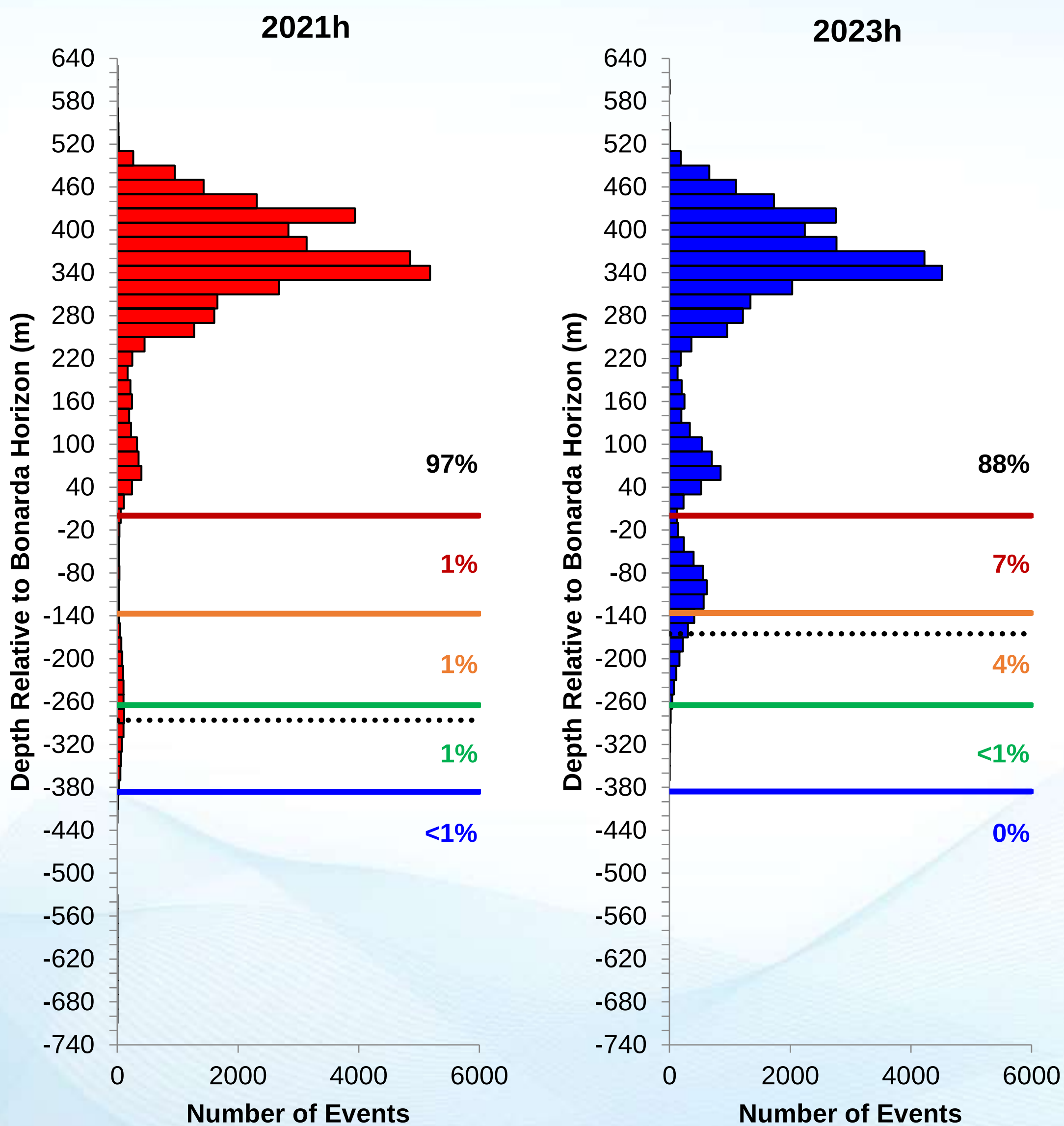
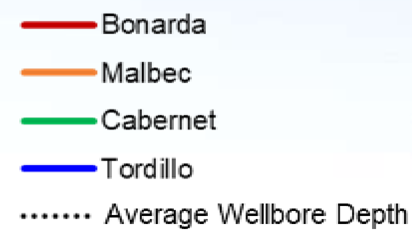
Relative Depth Distribution – All Events





- The majority of the microseismicity observed during the 2021h and 2023h treatments occurred 250m to 500m above the top of the Bonarda horizon.

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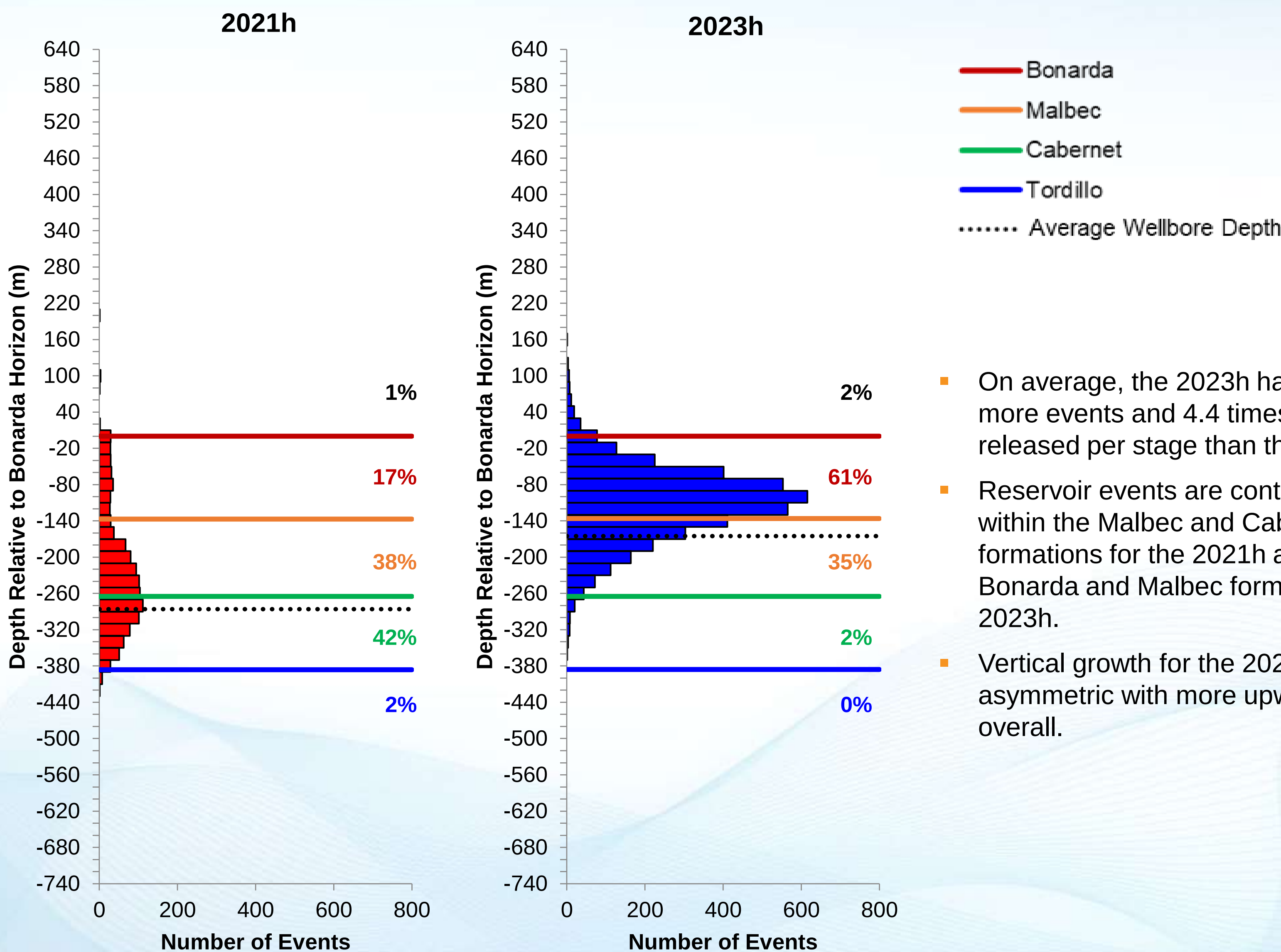
Relative Depth Distribution – Reservoir Events



- On average, the 2023h had 3.4 times more events and 4.4 times more energy released per stage than the 2021h.
- Reservoir events are contained primarily within the Malbec and Cabernet formations for the 2021h and within the Bonarda and Malbec formations for the 2023h.
- Vertical growth for the 2021h & 2023h was asymmetric with more upward growth overall.

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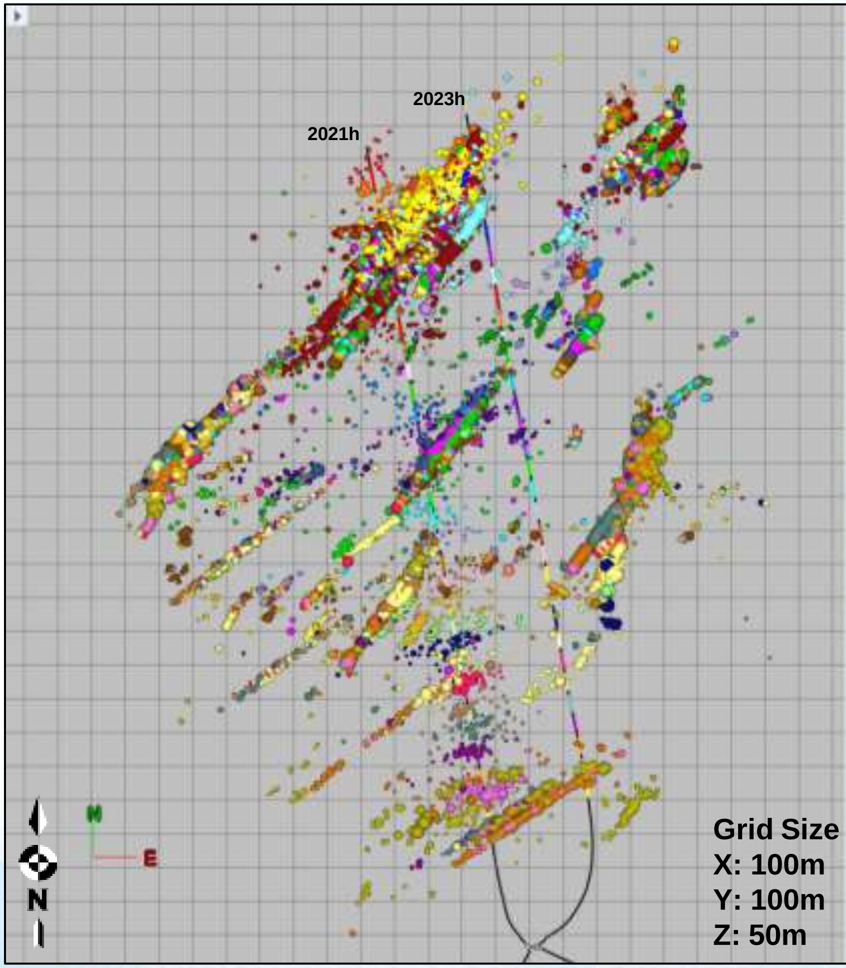
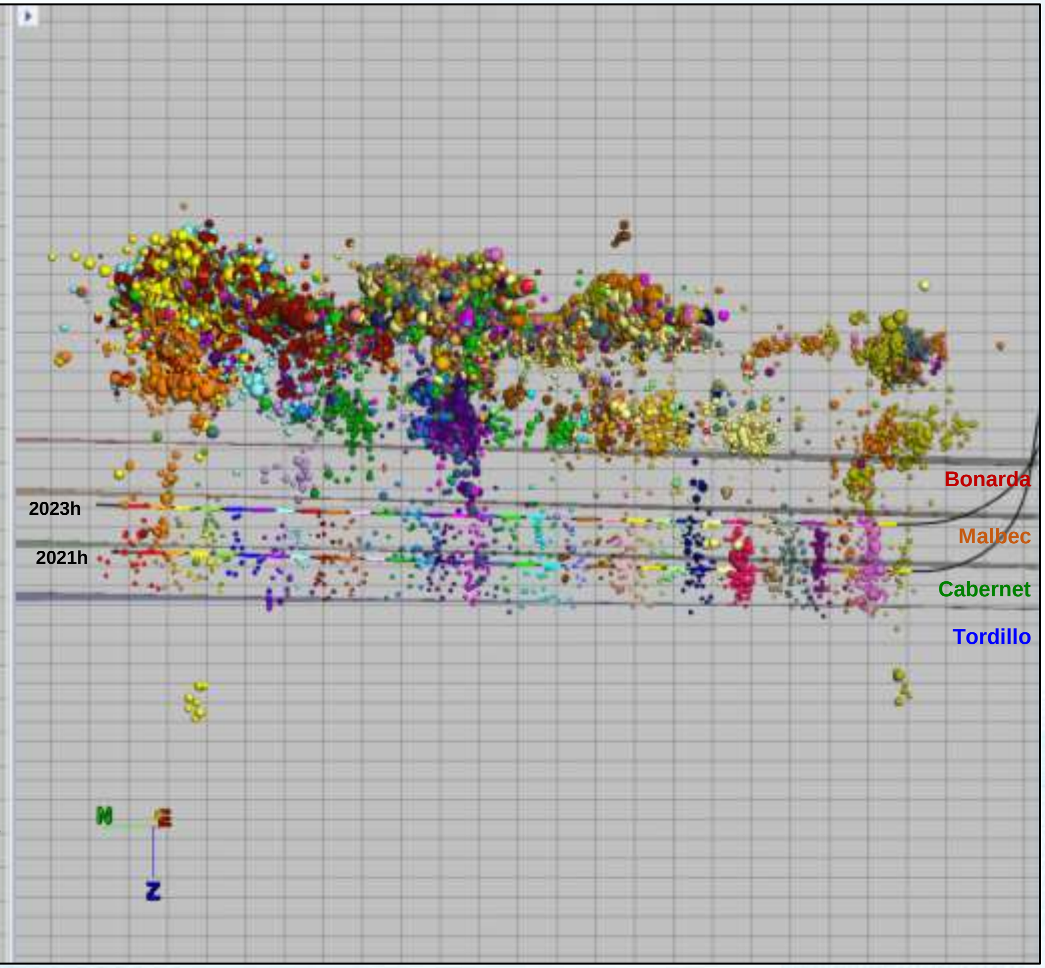
2021h – Event Locations

Map View



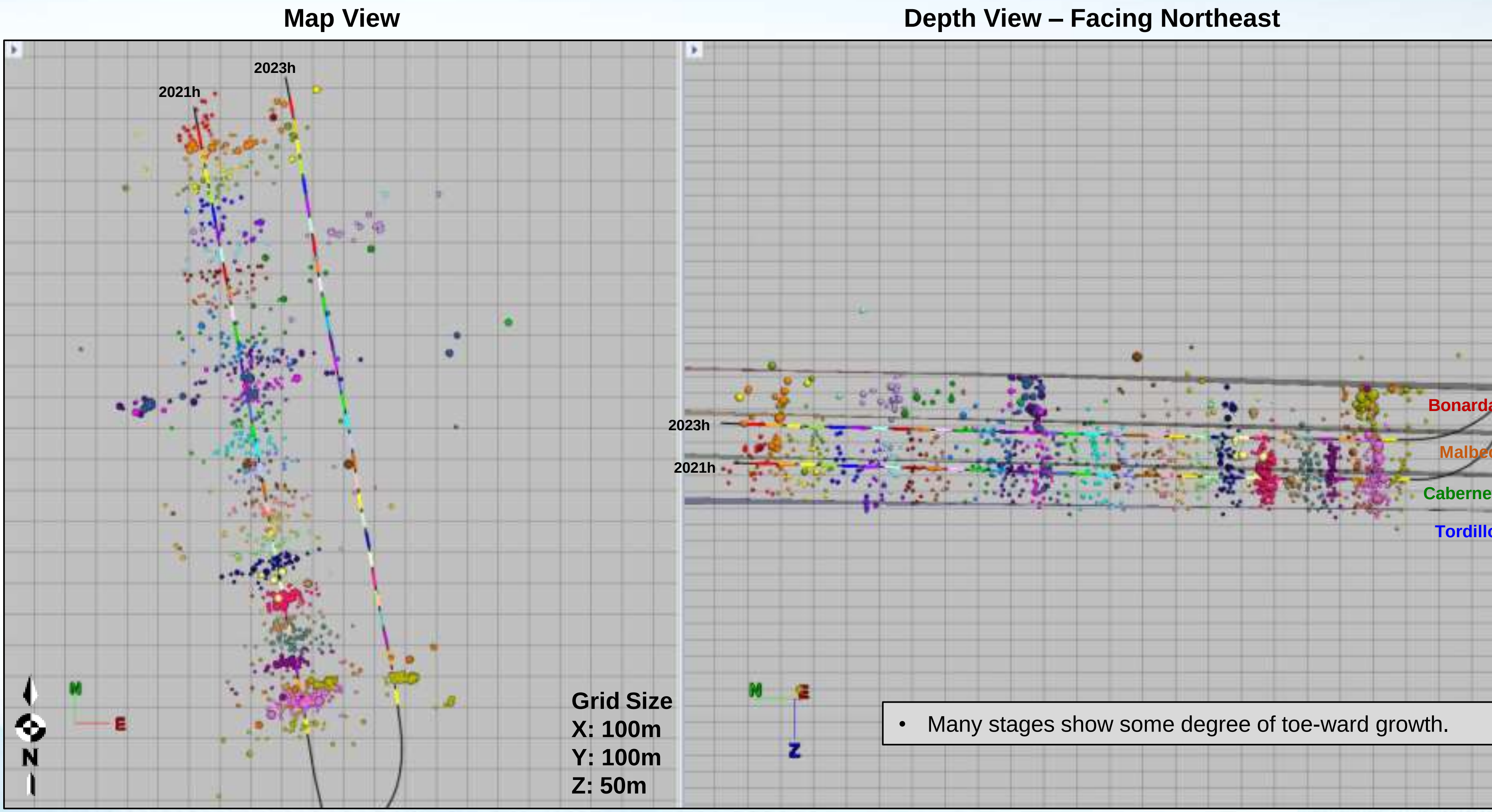
Depth View – Facing Northeast



Events are sized by magnitude and colored by stage.

Stage Coloring Legend

2021h – All Reservoir Events



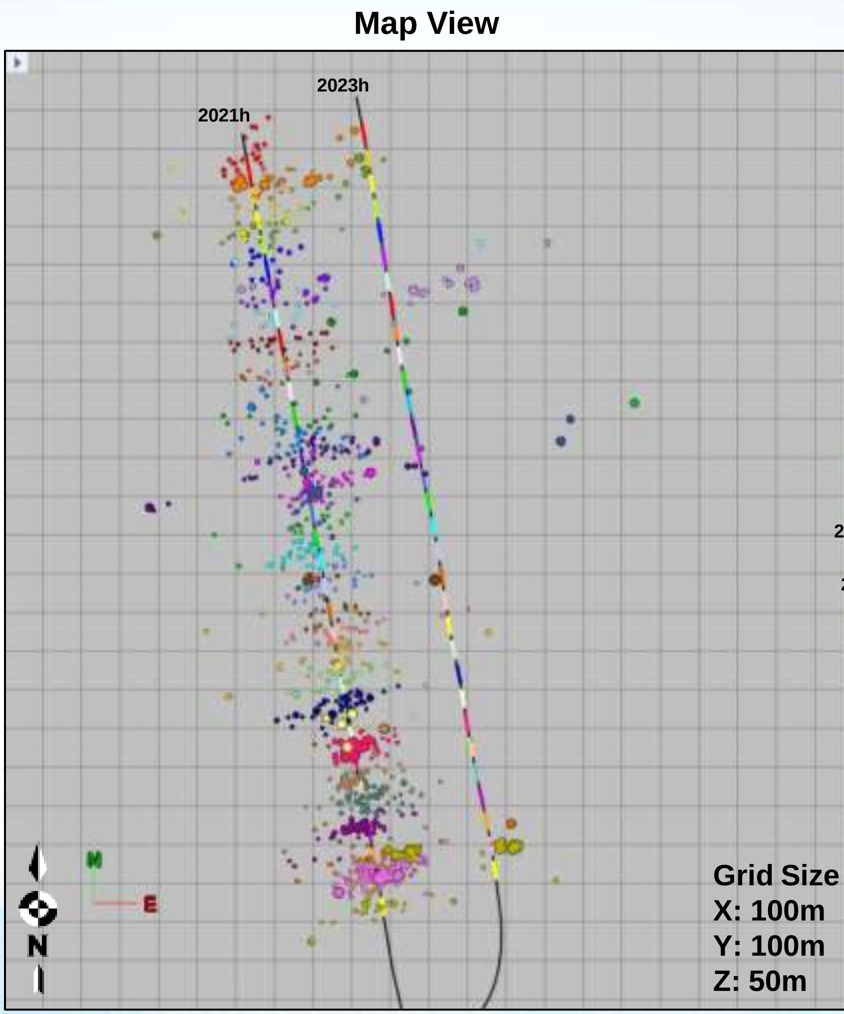
- Many stages show some degree of toe-ward growth.

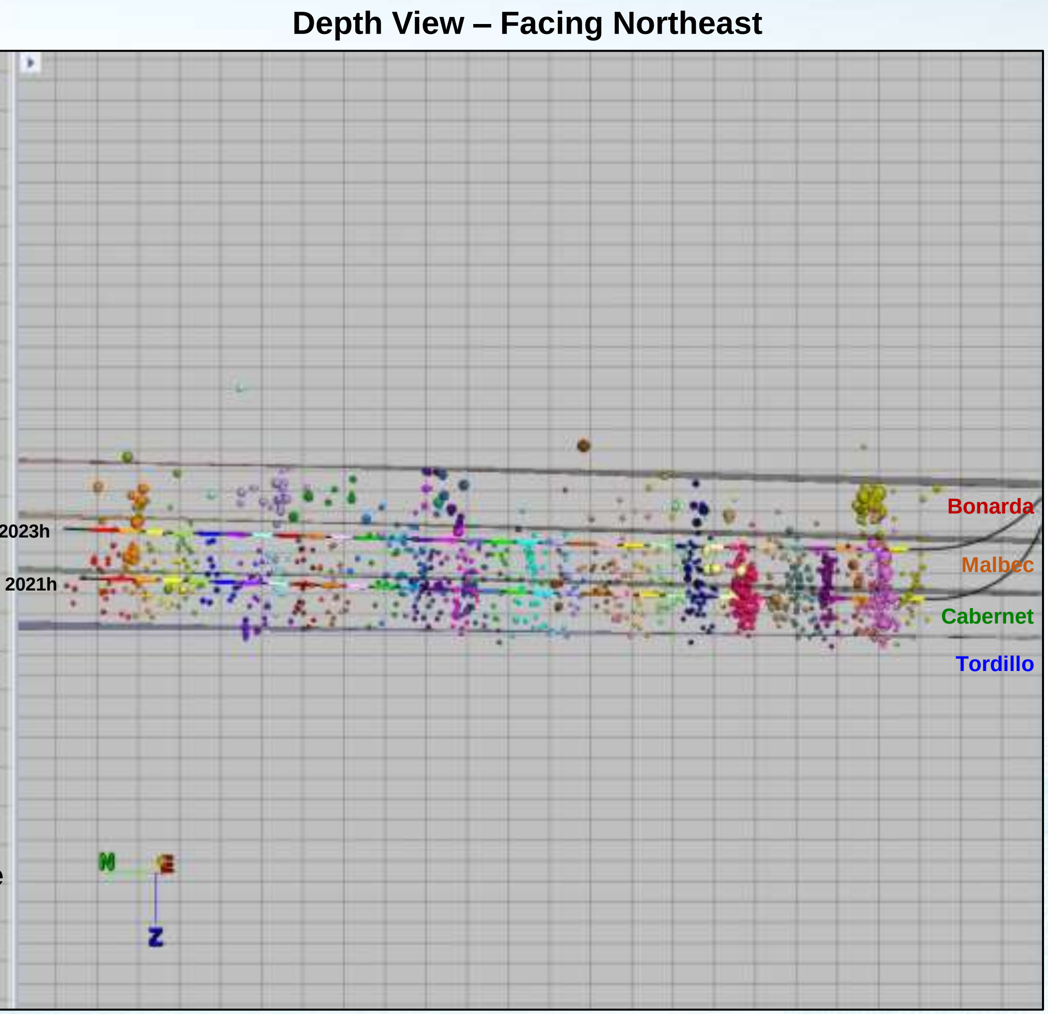
Events are sized by magnitude and colored by stage.

Stage Coloring Legend

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

2021h – Reservoir Events During Frac Times





Events are sized by magnitude and colored by stage.

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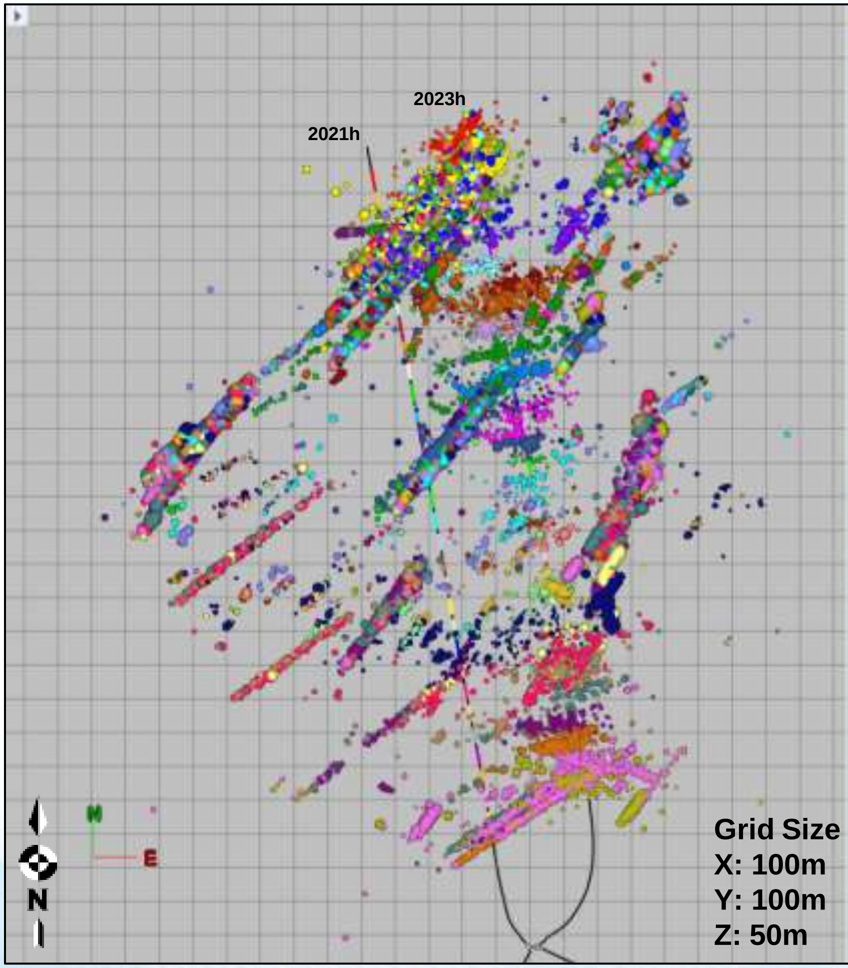
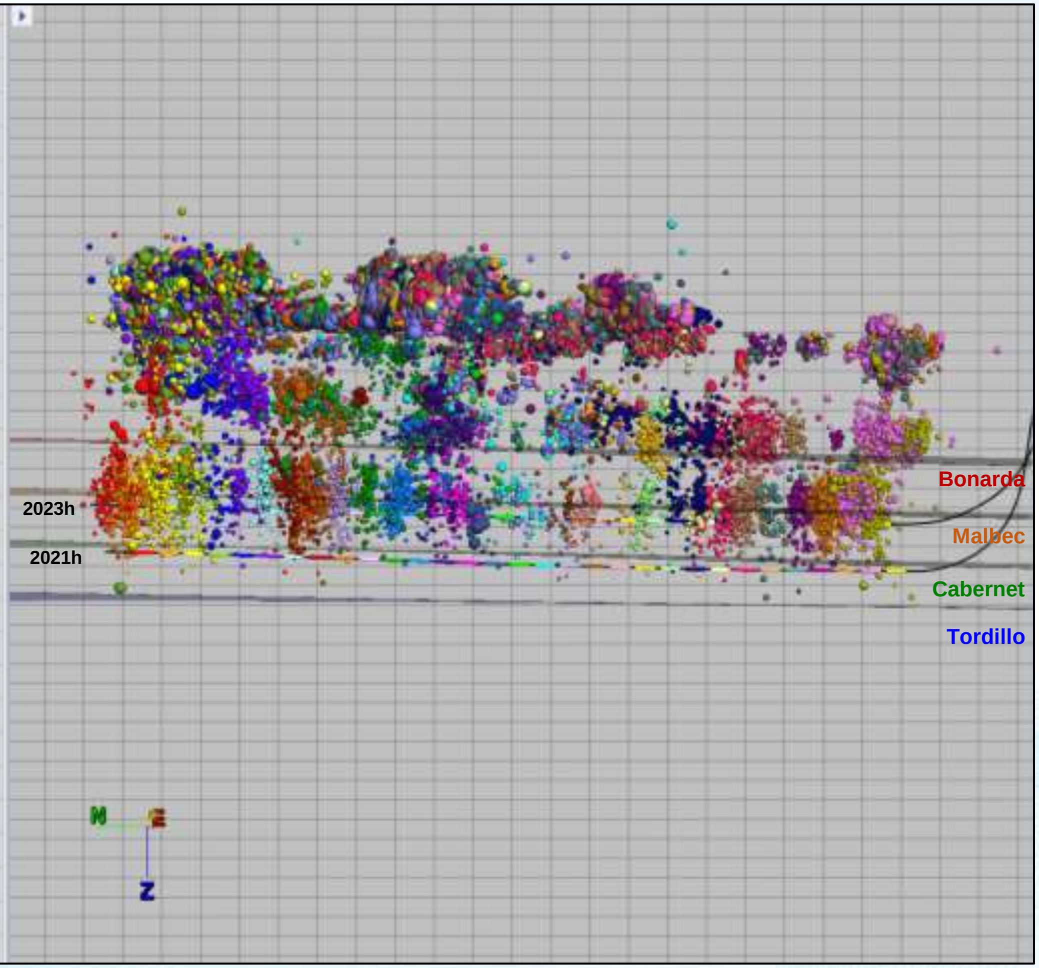
2023h – Event Locations

Map View



Depth View – Facing Northeast



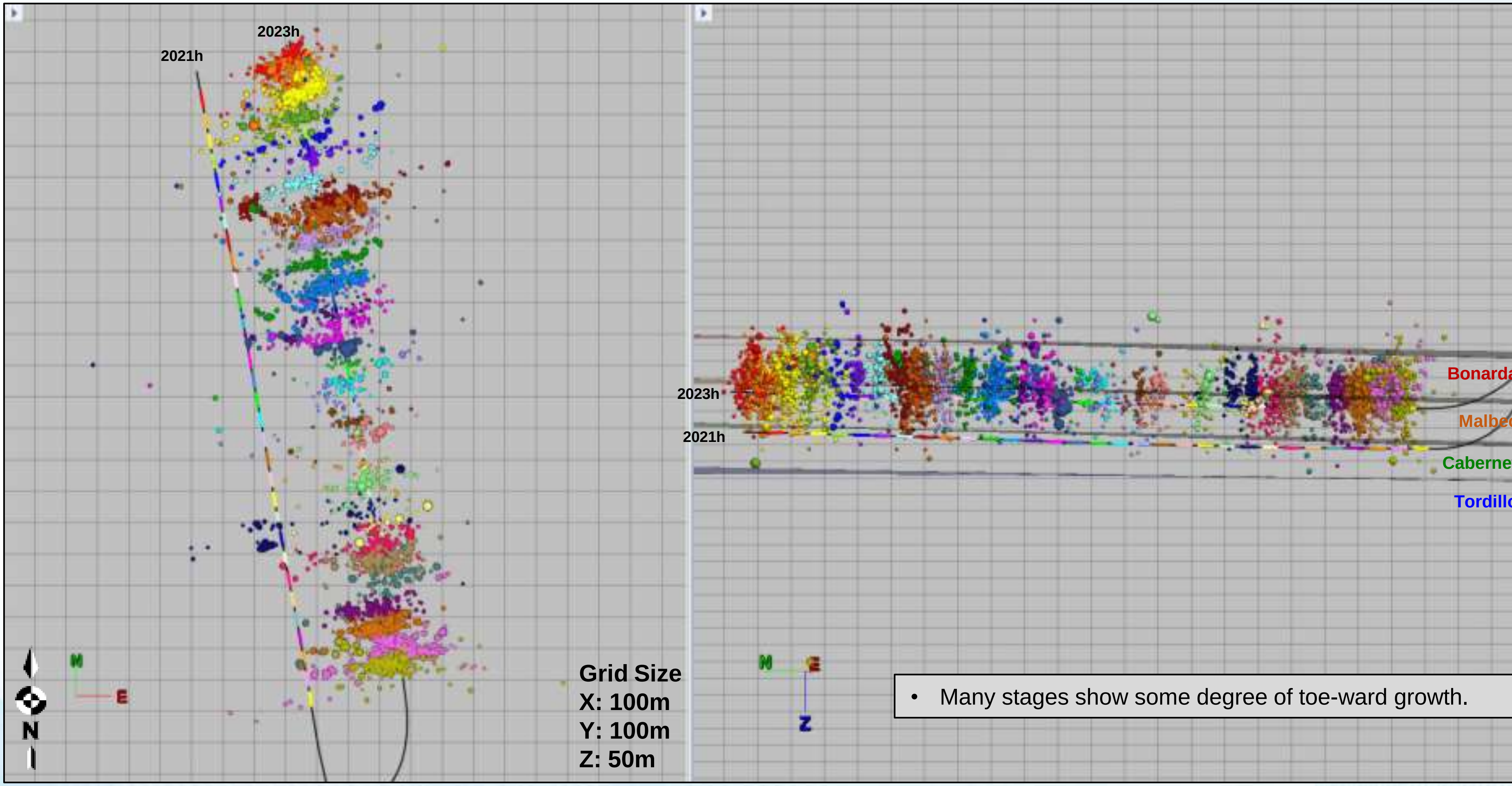
Events are sized by magnitude and colored by stage.

Stage Coloring Legend

MicroSeismic

2023h – All Reservoir Events

Map View | **Depth View – Facing Northeast**

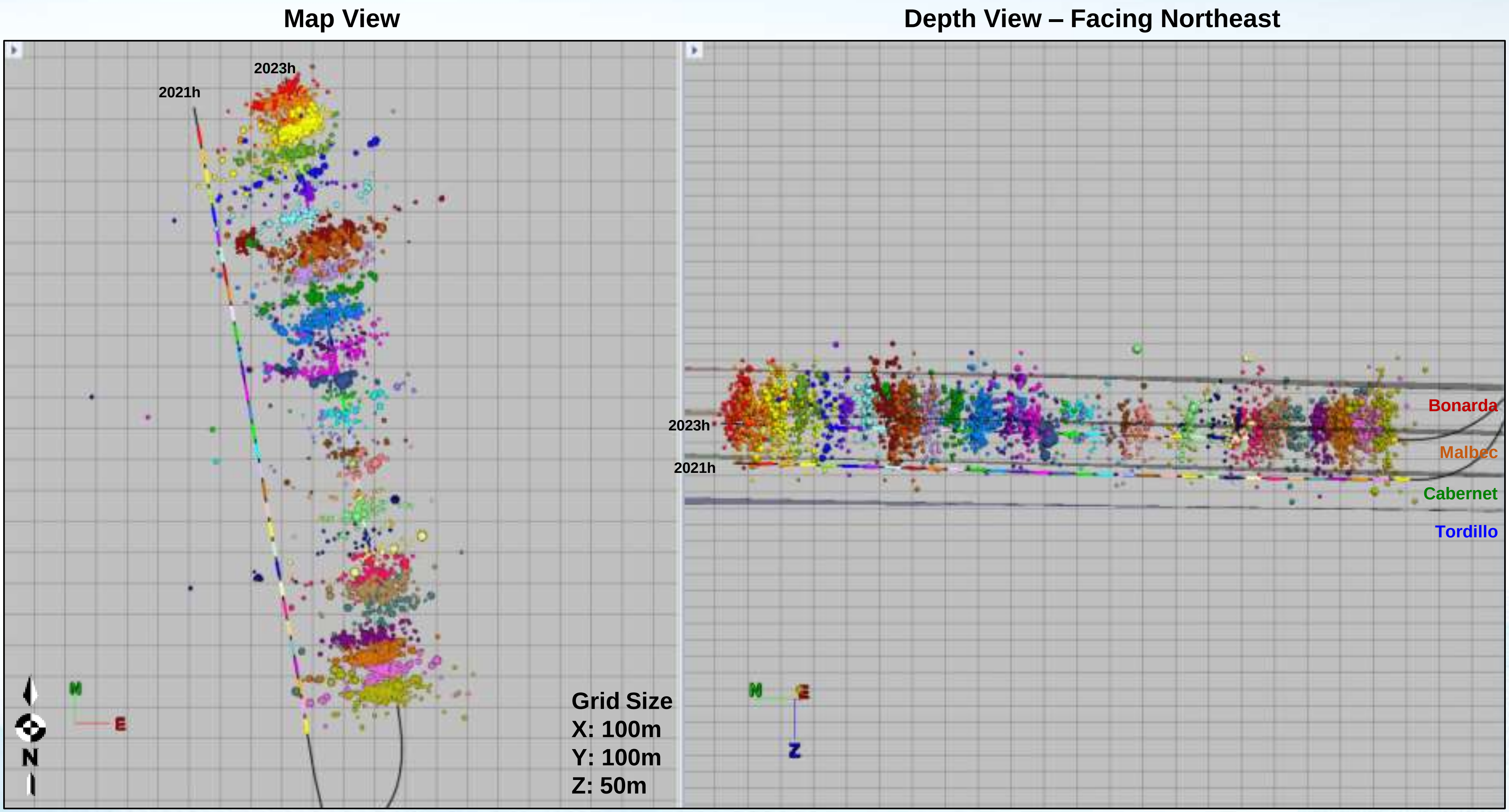


Events are sized by magnitude and colored by stage.

Stage Coloring Legend

MicroSeismic

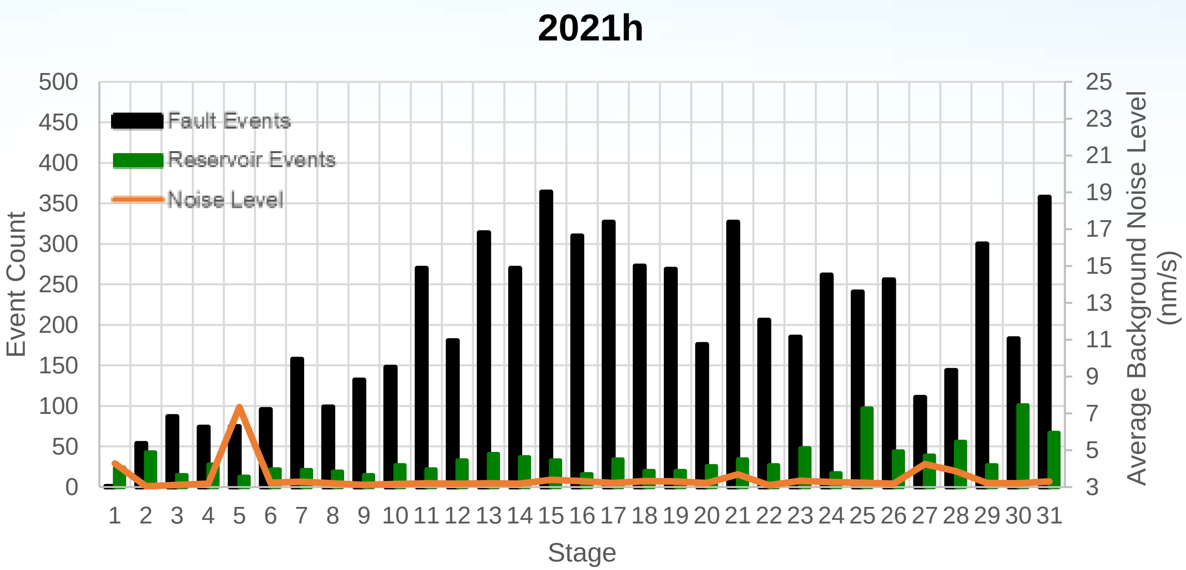
2023h – Reservoir Events During Frac Times

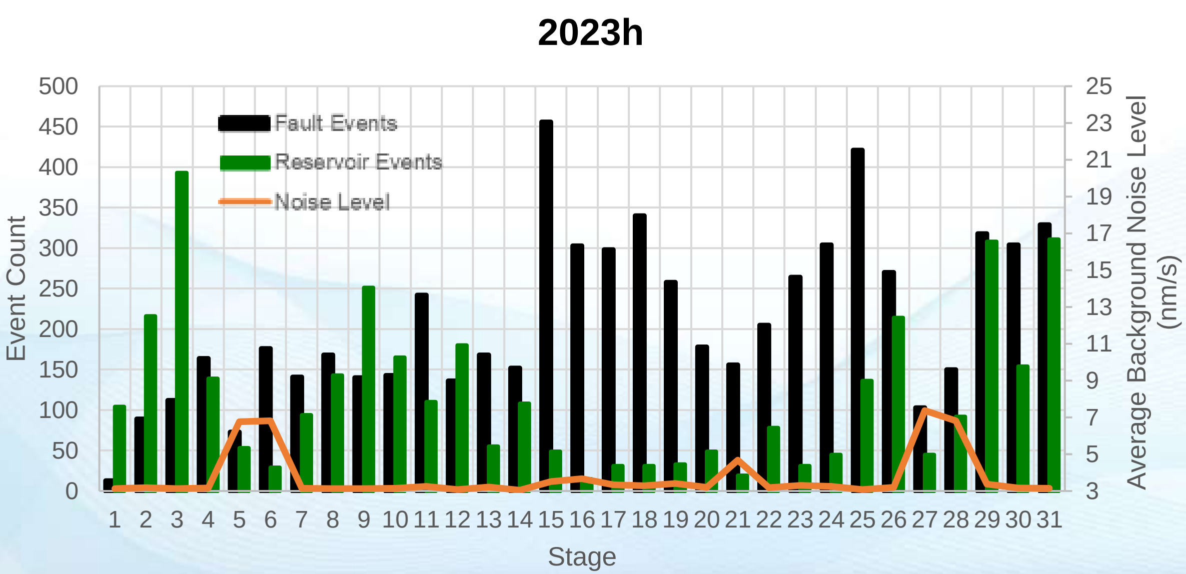


Events are sized by magnitude and colored by stage.

MicroSeismic

Event Count Versus Noise Level



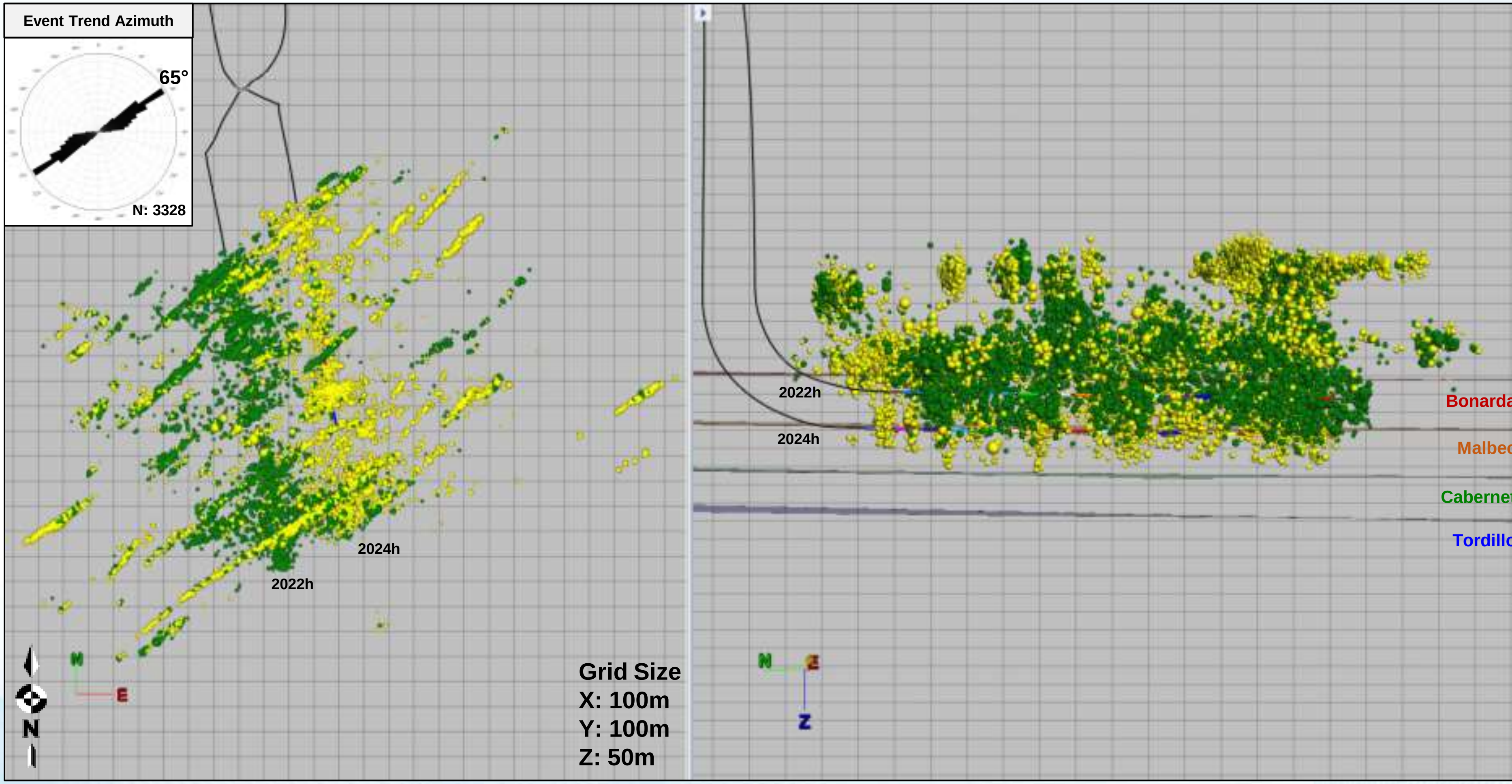


- Fault and Reservoir event counts were calculated during frac times only.
- The plotted average background noise levels are for both geophone levels combined.
- The overall low reservoir event counts for the 2021h are not due to high noise levels.
- The lower reservoir event counts for stages 15-19 of the 2023h could be due to higher fault event counts.

MicroSeismic

2022h & 2024h – Event Locations

Map View | Depth View – Facing Northeast



Events are sized by magnitude and colored by well.

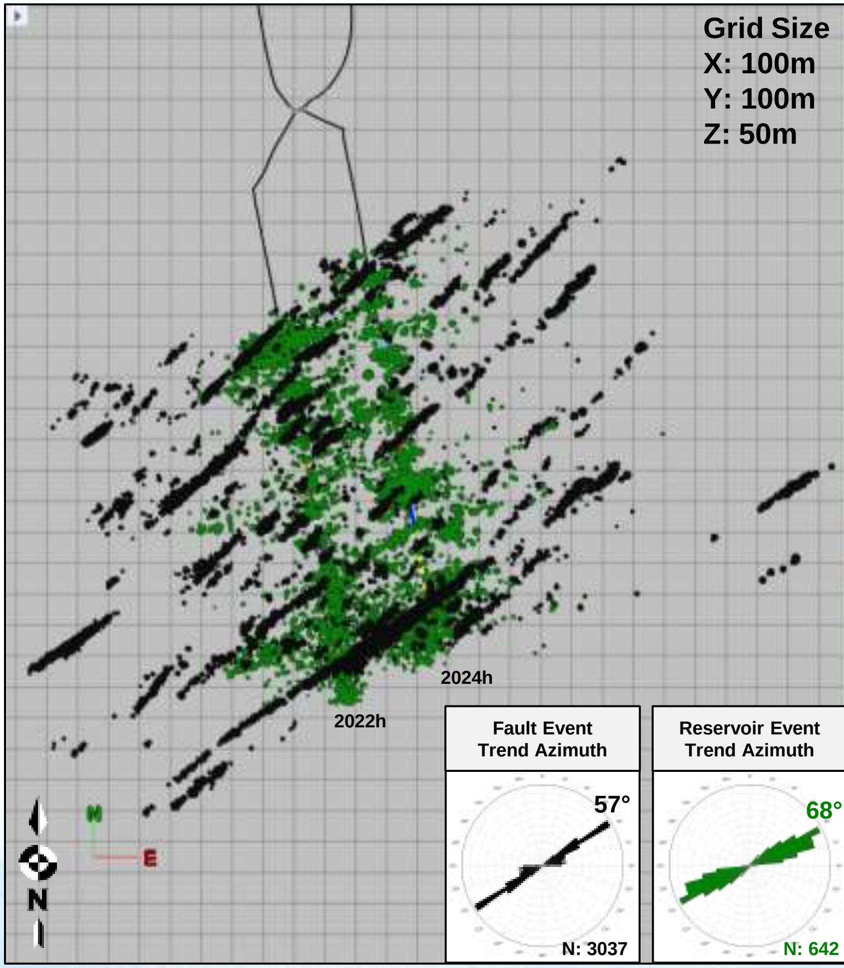
Well Coloring Legend

2022h 2024h

MicroSeismic

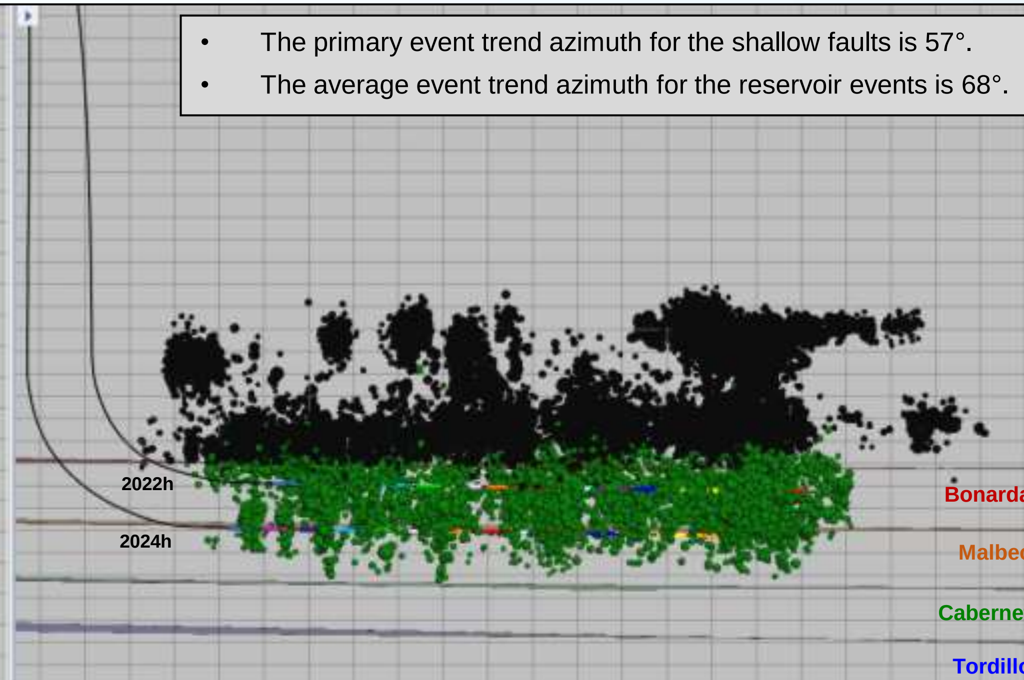
2022h & 2024h – Event Locations

Map View



Events are sized by magnitude and colored by event type.

Depth View – Facing Northeast



Fault event classification:

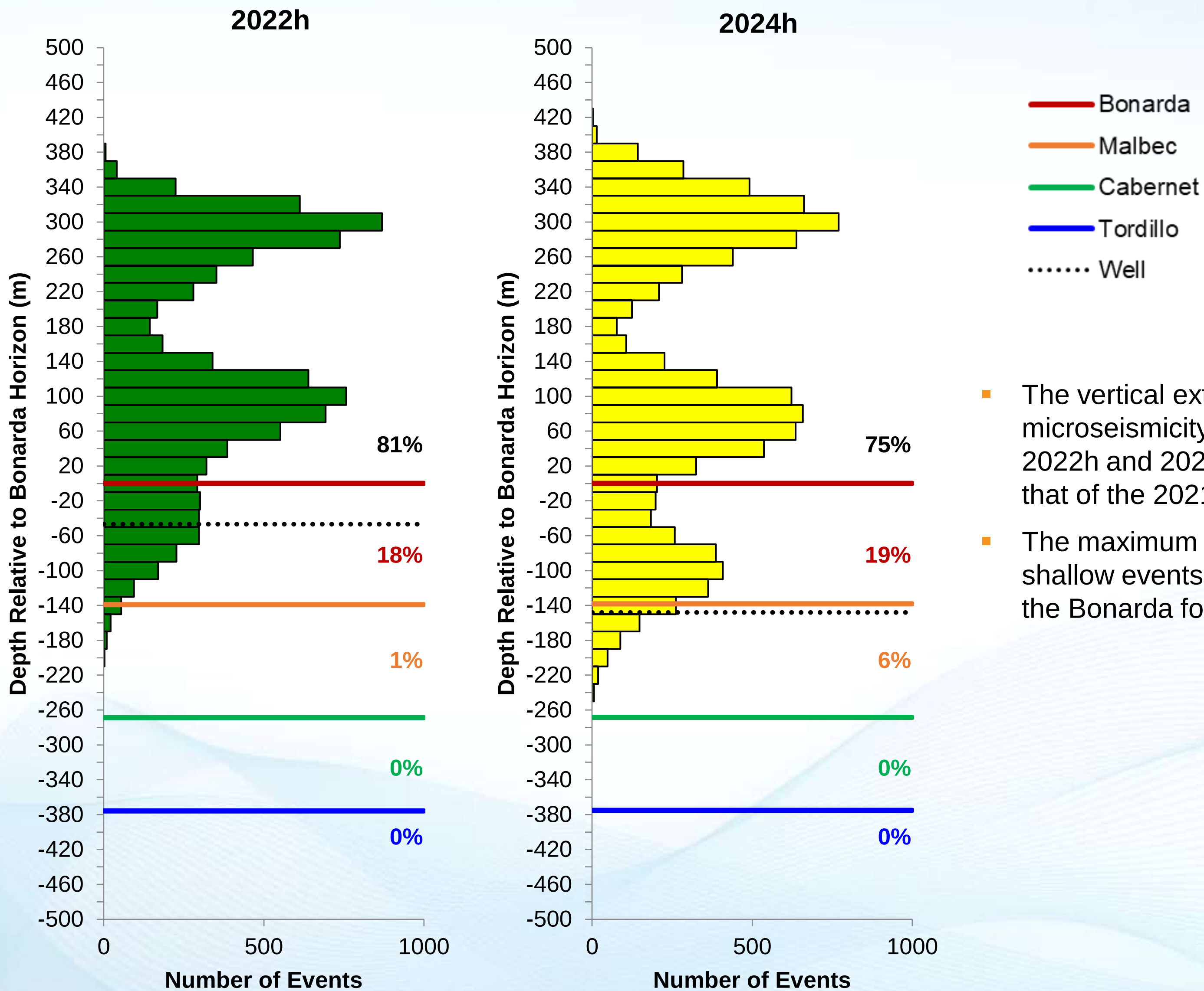
1. All strike-slip and oblique strike-slip events 51m or more above the Bonarda horizon.
2. Strike-slip and oblique strike-slip events with depths between 0m to 51m above the Bonarda horizon if:
   - Strike azimuths less than 68° or greater than 105°; or
   - Strike azimuth between 68° and 105° with easting greater than 2465010 and northing less than 5850840m; or
   - Strike azimuth between 68° and 105° with easting greater than 2465100; or
   - Strike azimuth between 68° and 105° with easting greater than 2464925 and northing greater than 5851705m
3. Strike-slip and oblique strike-slip events with depths between 0m to 47m below the Bonarda horizon if:
   - Event easting is less than 2463960m
   - Event easting is greater than 2465090m
   - Event easting is greater than 2464930m with a northing less than 5850760m
   - 2022h events with northings greater than 5851900m
   - 2024h events with event eastings greater than 2464930m with northings greater than 5851700m and depths between 0m and 40m below the Bonarda horizon

Coloring Legend

Fault Events   Reservoir Events

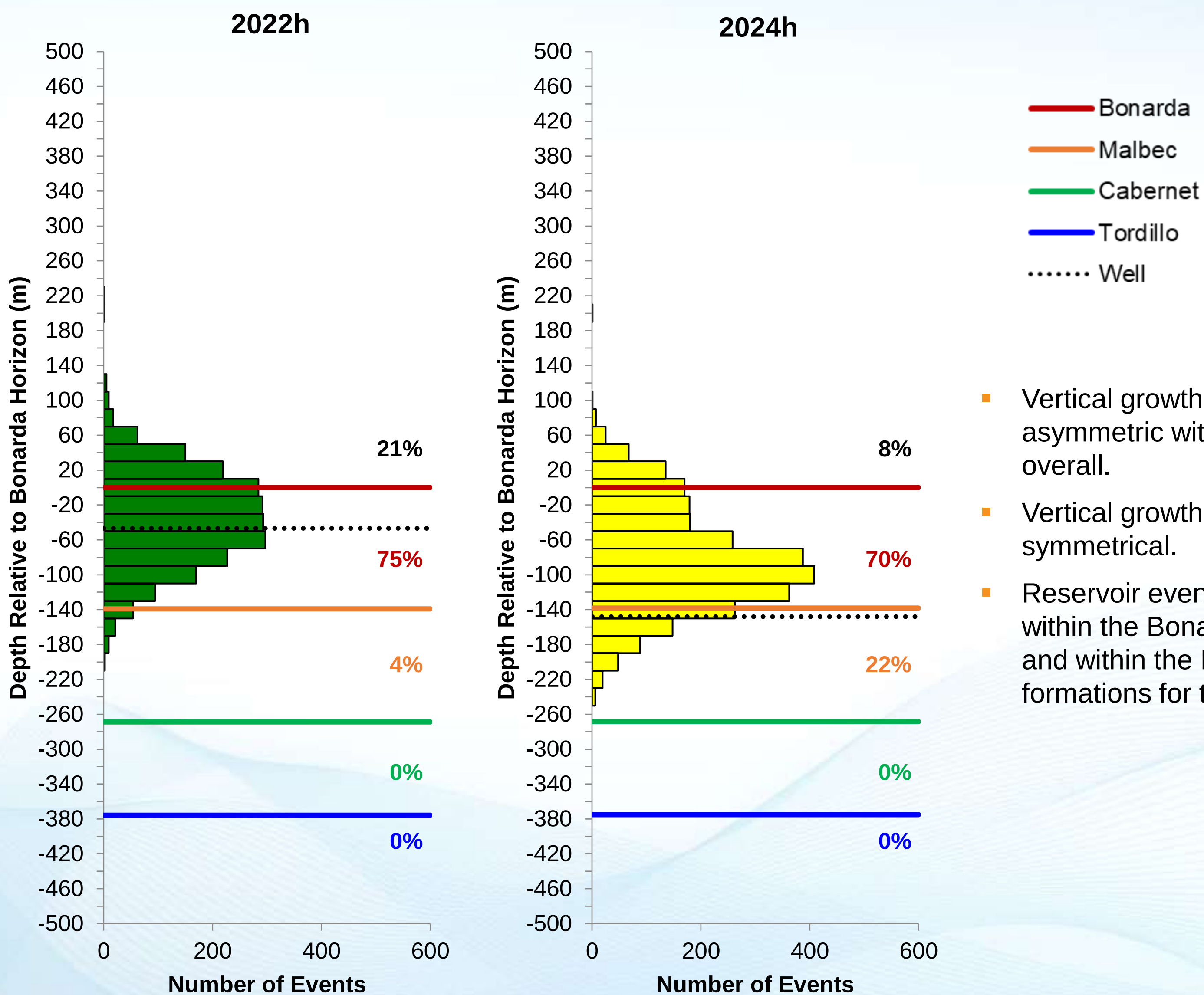
MicroSeismic

Relative Depth Distribution – All Events



- The vertical extent and amount of shallow microseismicity observed during the 2022h and 2024h treatments is less than that of the 2021h and 2023h.
- The maximum vertical extent of the shallow events is ~390 m above the top of the Bonarda formation.

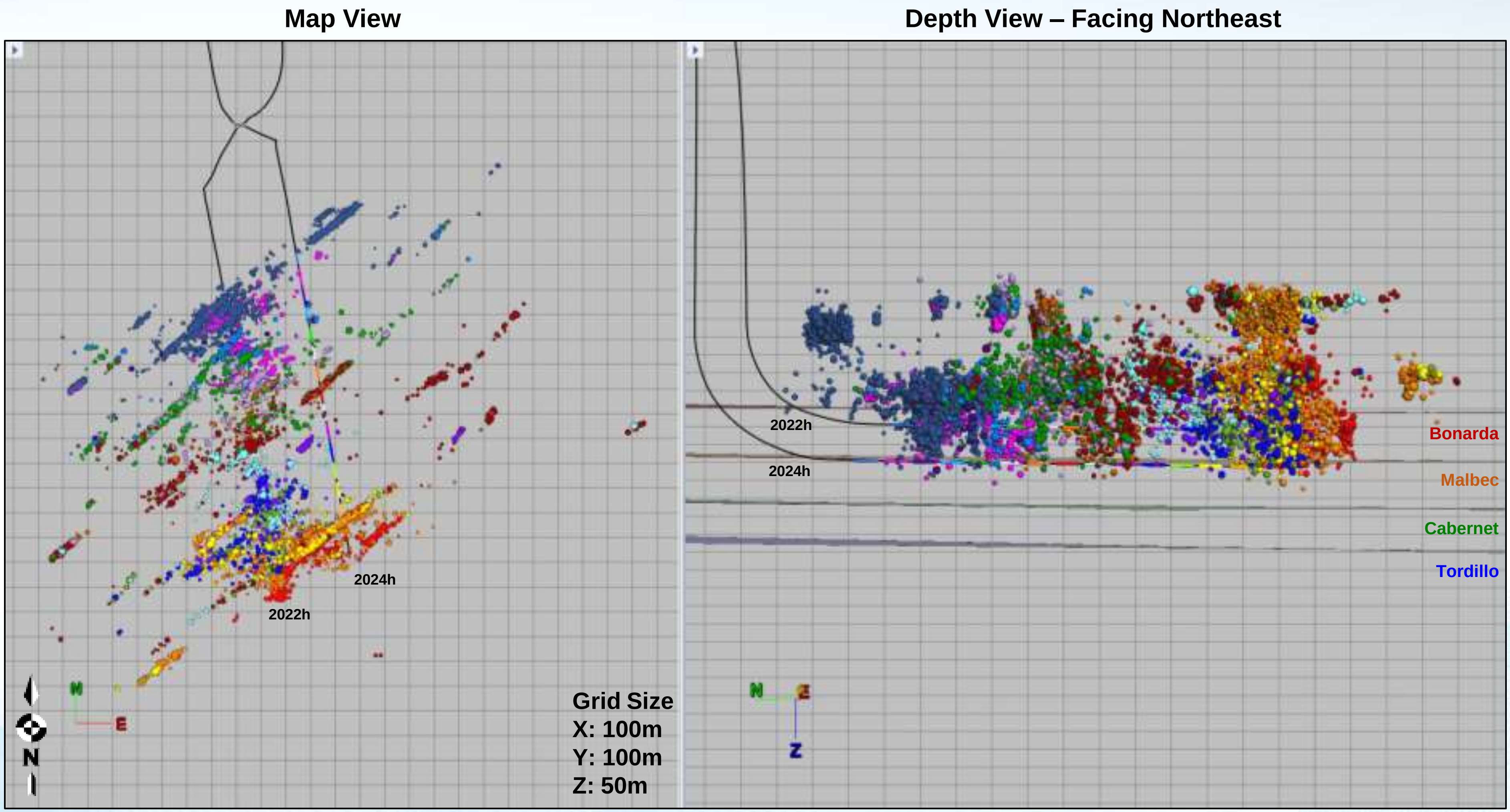
Relative Depth Distribution – Reservoir Events



- Vertical growth for the 2024h was asymmetric with more upward growth overall.
- Vertical growth for the 2022h is symmetrical.
- Reservoir events are contained primarily within the Bonarda formation for the 2022h and within the Bonarda and Malbec formations for the 2024h.

MicroSeismic

2022h – Event Locations

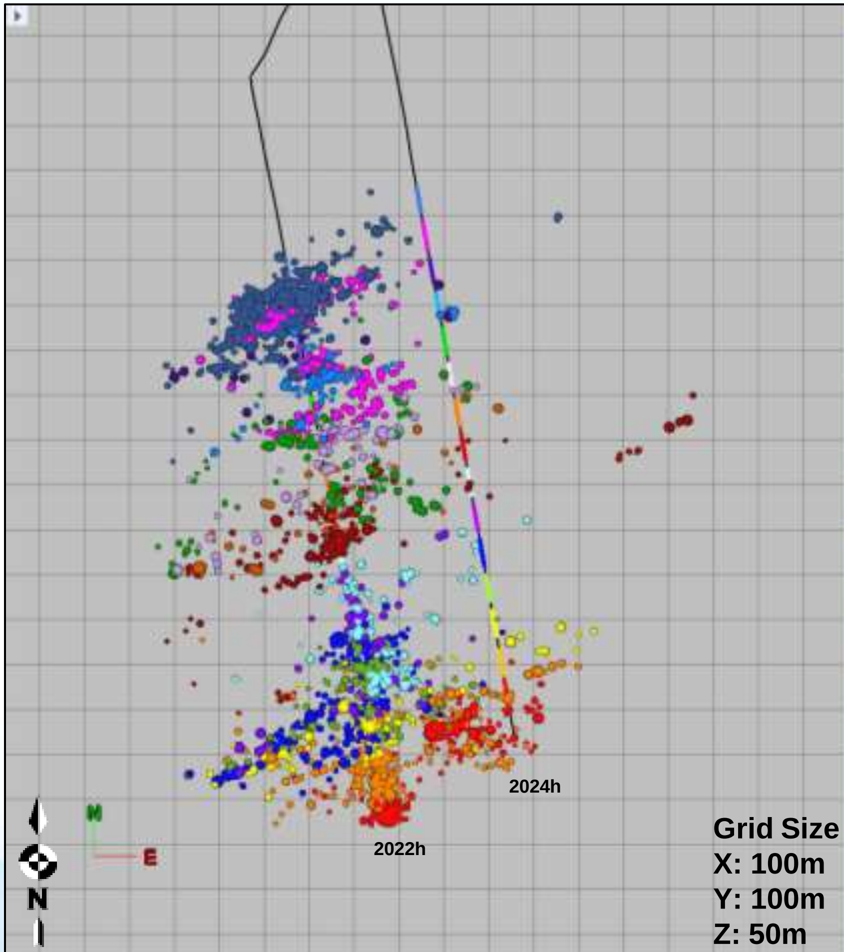


Events are sized by magnitude and colored by stage.

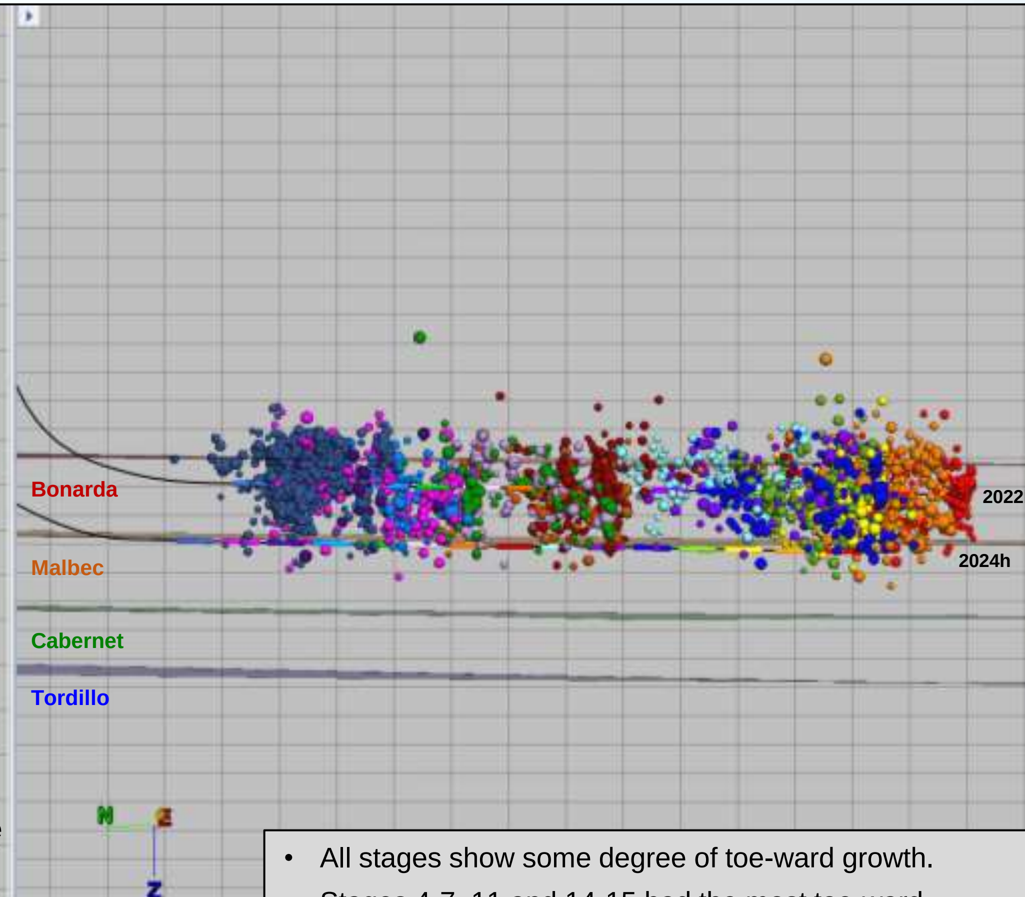
MicroSeismic

2022h – All Reservoir Events

Map View



Depth View – Facing Northeast



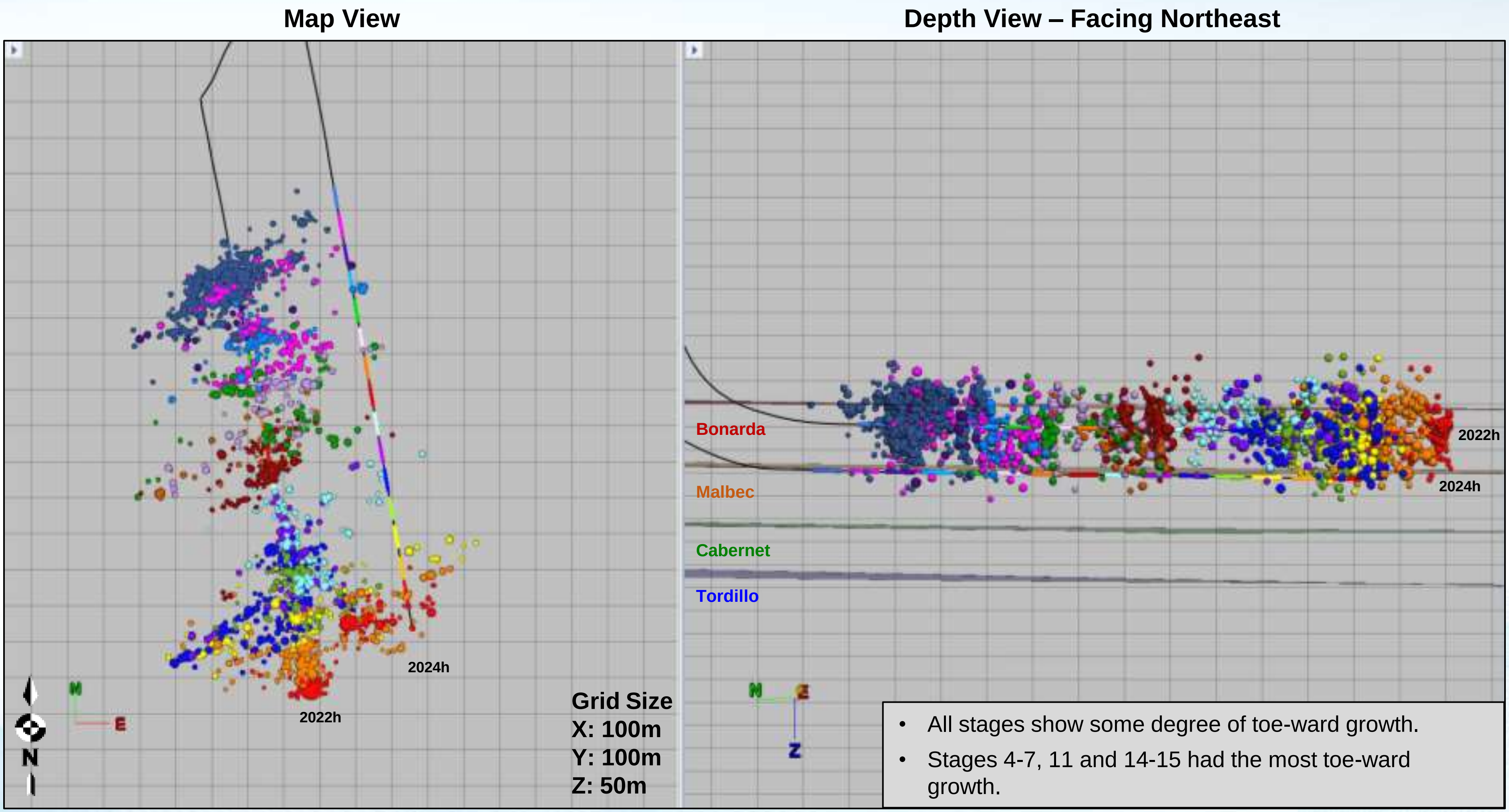
- All stages show some degree of toe-ward growth.
- Stages 4-7, 11 and 14-15 had the most toe-ward growth.

Events are sized by magnitude and colored by stage.

Stage Coloring Legend

MicroSeismic

2022h – Reservoir Events During Frac



- All stages show some degree of toe-ward growth.
- Stages 4-7, 11 and 14-15 had the most toe-ward growth.

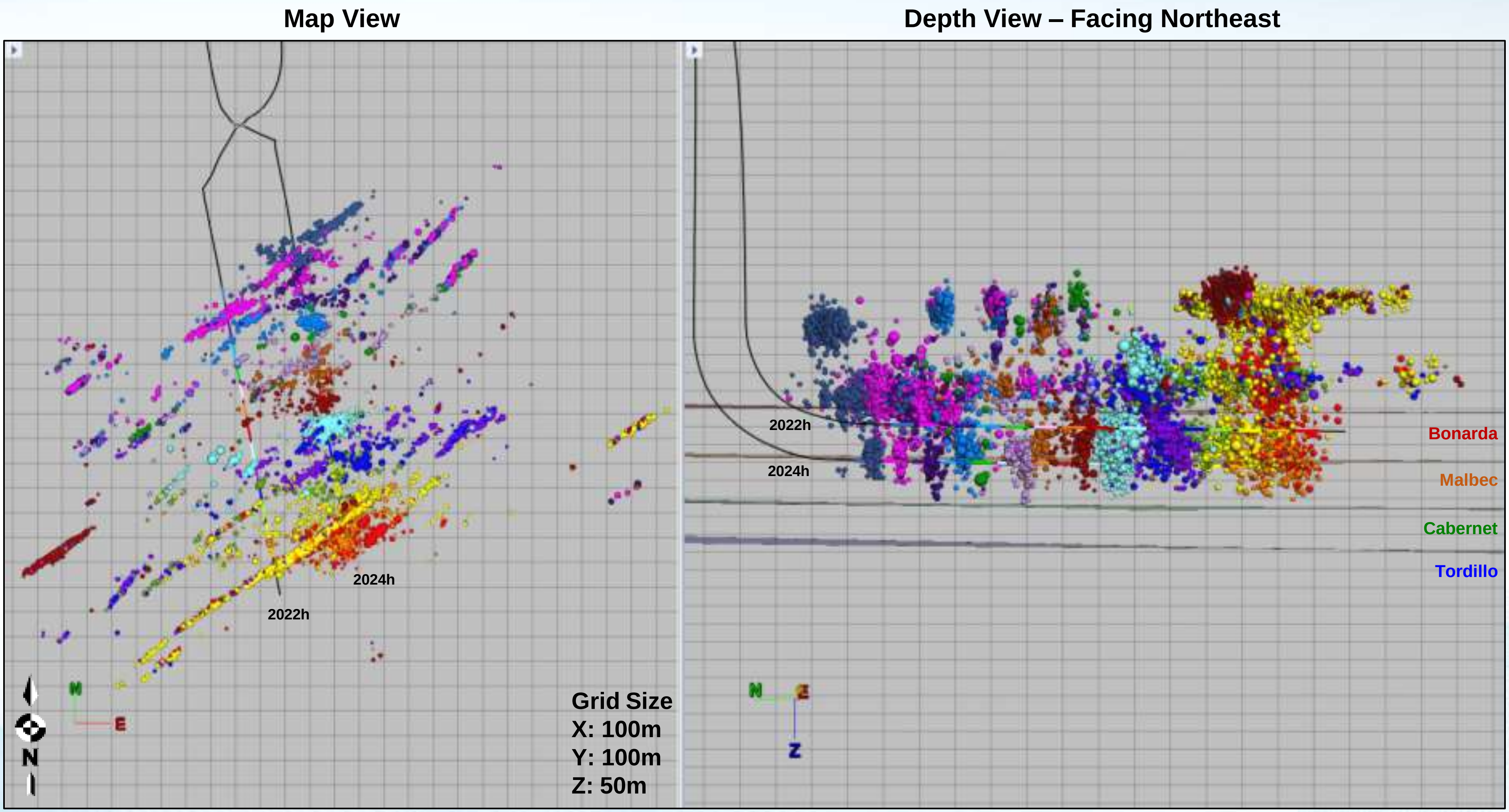
Events are sized by magnitude and colored by stage.

Stage Coloring Legend

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

MicroSeismic

2024h – Event Locations



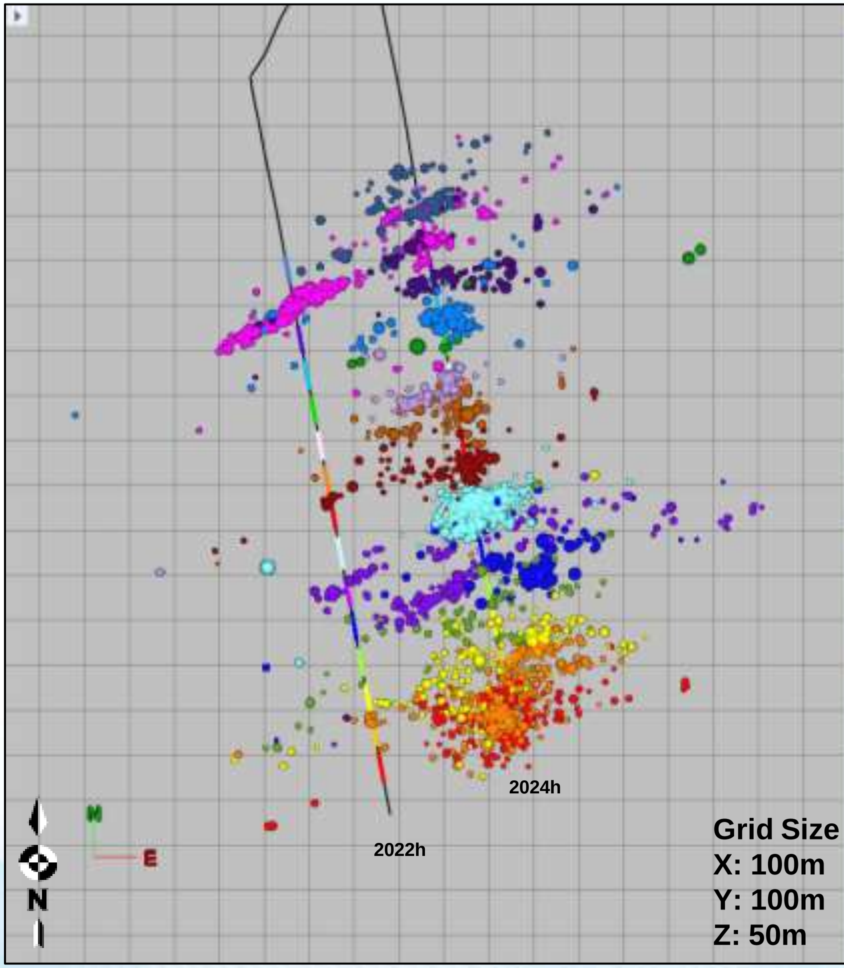
Events are sized by magnitude and colored by stage.

Stage Coloring Legend

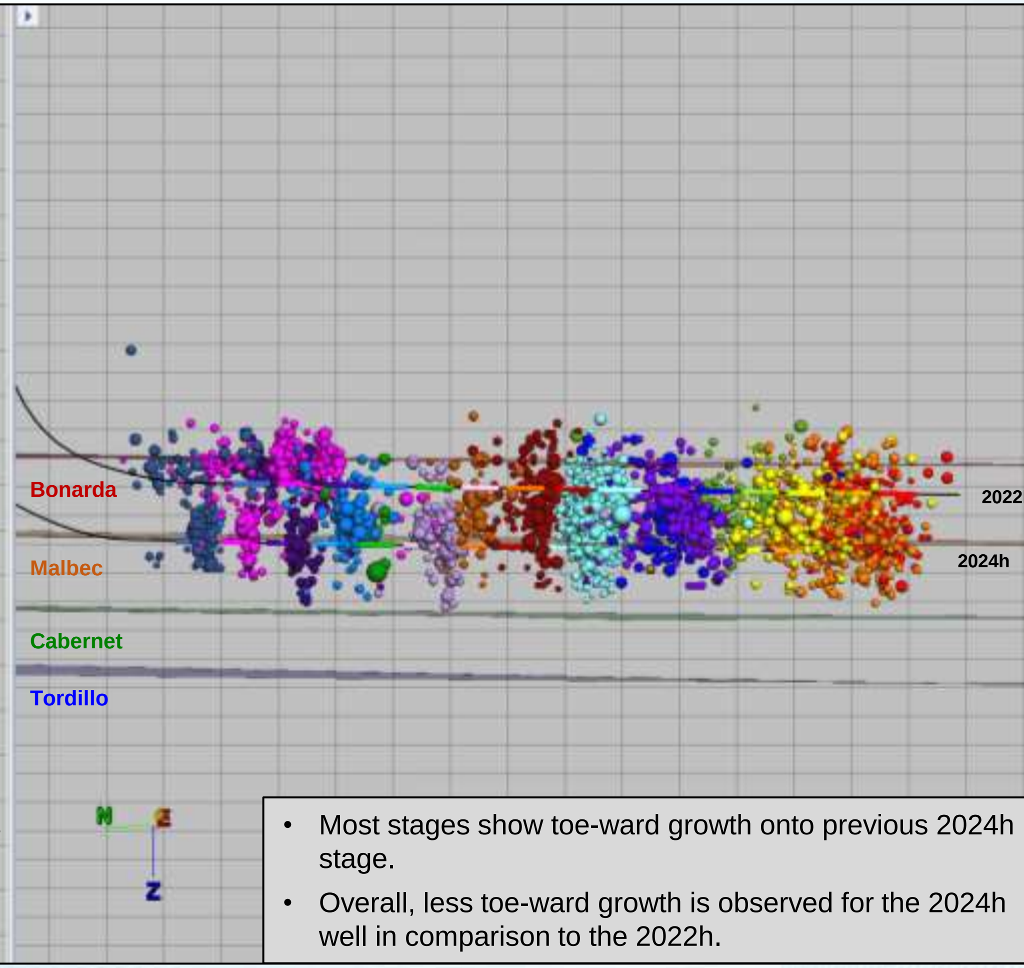
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

2024h – All Reservoir Events

Map View



Depth View – Facing Northeast



- Most stages show toe-ward growth onto previous 2024h stage.
- Overall, less toe-ward growth is observed for the 2024h well in comparison to the 2022h.

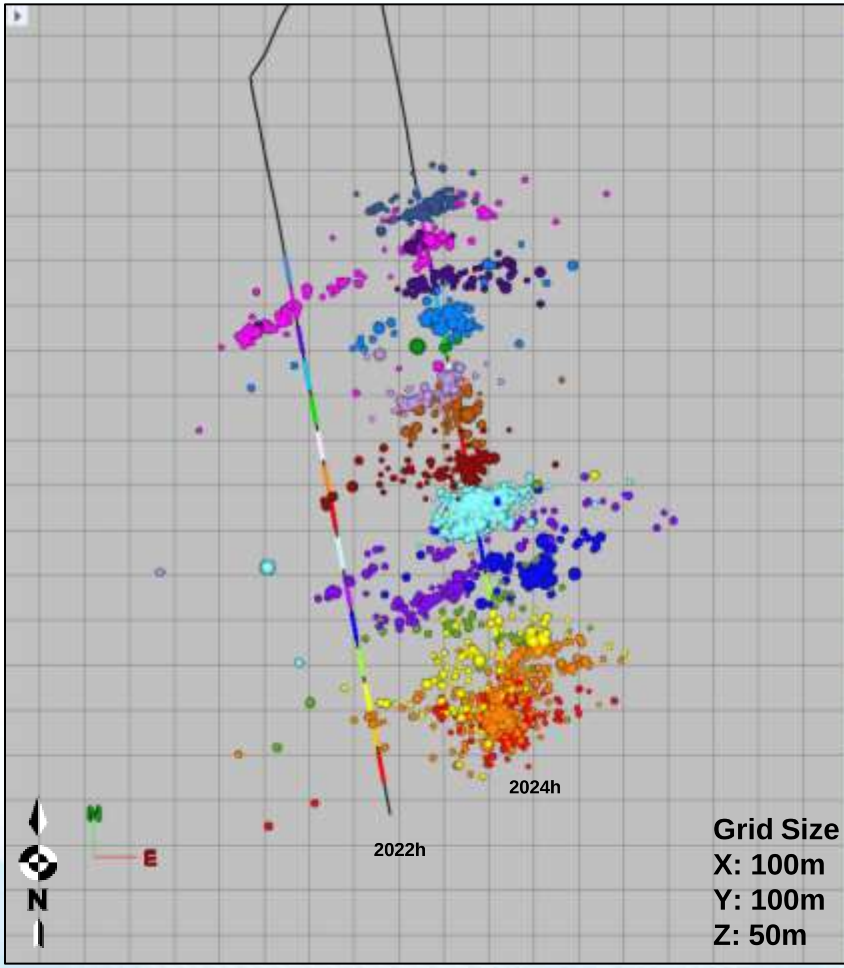
Events are sized by magnitude and colored by stage.

Stage Coloring Legend

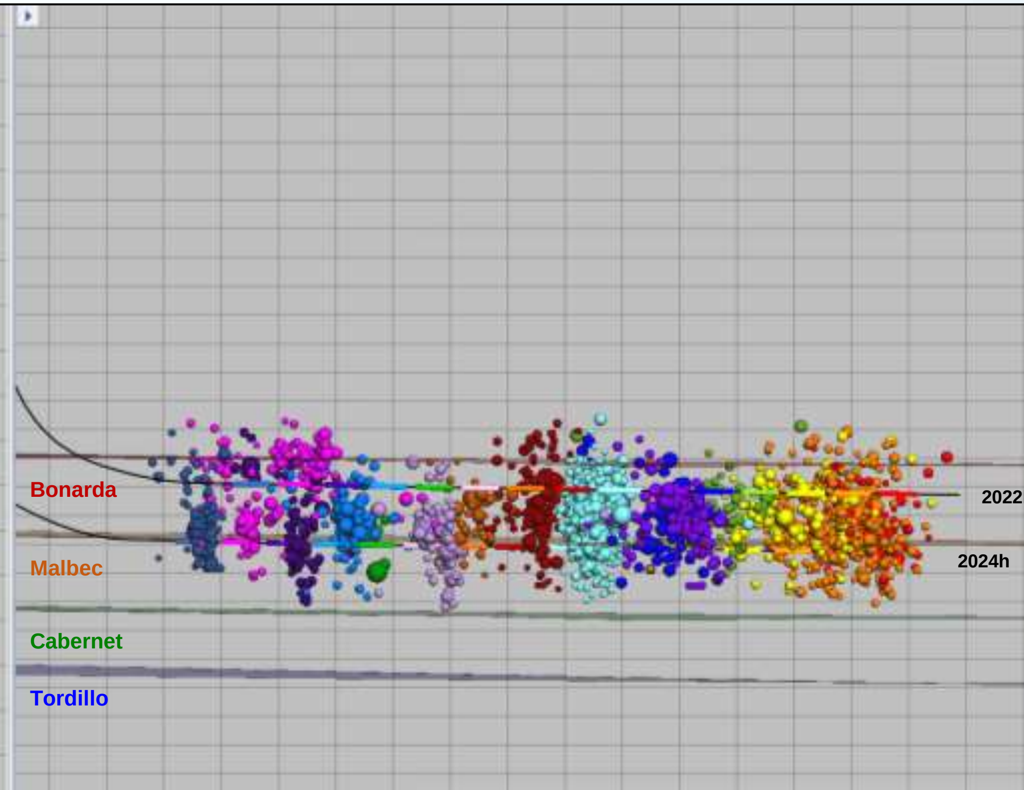
MicroSeismic

2024h – Reservoir Events During Frac

Map View



Depth View – Facing Northeast



- Most stages show toe-ward growth onto previous 2024h stage.
- Overall, less toe-ward growth is observed for the 2024h well in comparison to the 2022h.

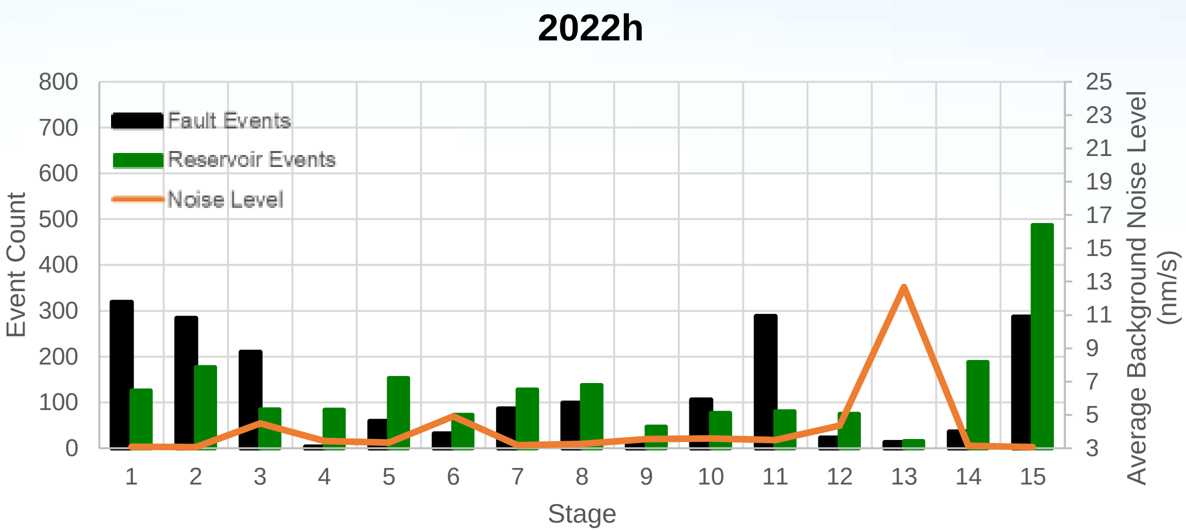
Events are sized by magnitude and colored by stage.

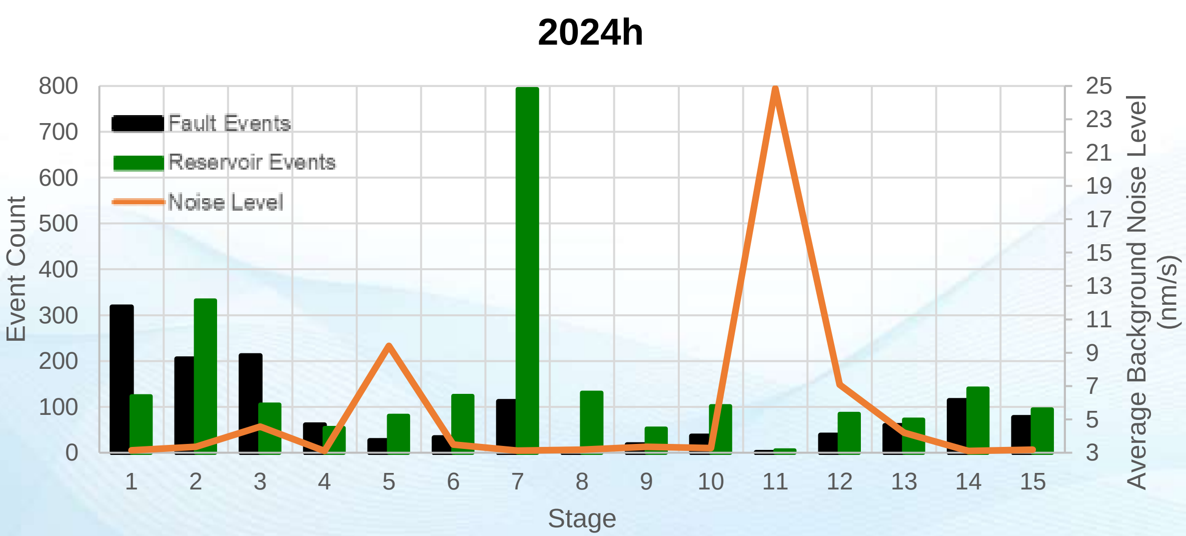
Stage Coloring Legend

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

MicroSeismic

Event Count Versus Noise Level





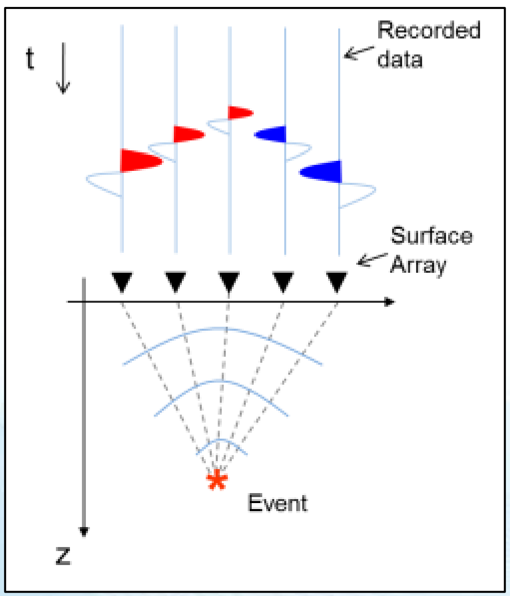
- Fault and Reservoir event counts were calculated during frac times only.
- The plotted average background noise levels are for both geophone levels combined.
- The low event counts for stage 13 of the 2022h and stage 11 of the 2024h are due to high background noise levels.

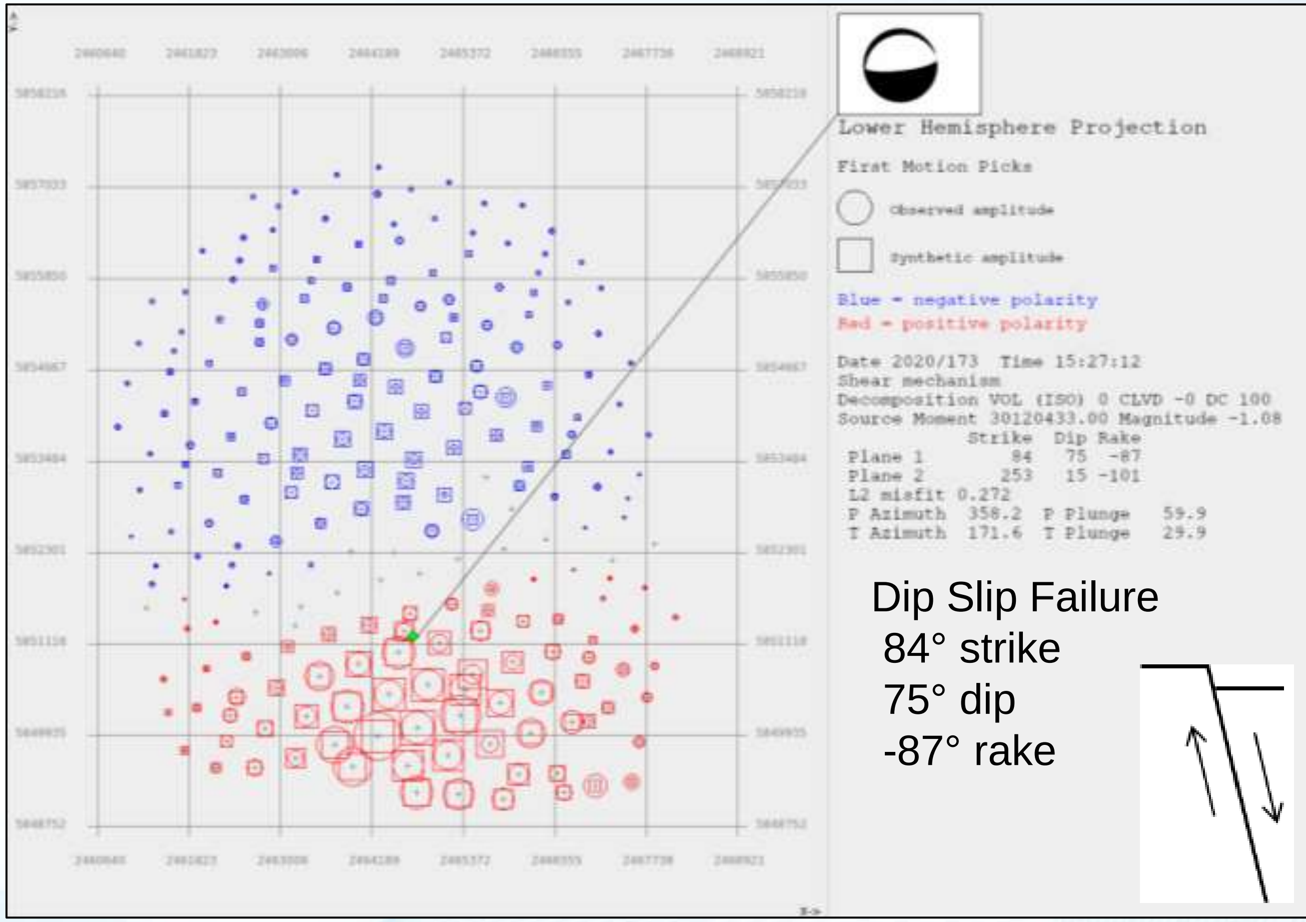
Source Mechanisms

MicroSeismic

Source Mechanism – 2024h Stage 7 Event

- Radiated energy contains information on fracture area, orientation and how the rock broke.
- Discrete fracture plane solutions are derived from this.

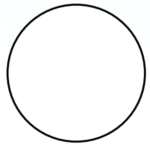




Source Mechanism Groups – Reservoir

- Focal mechanism solutions from P wave picking and used for imaging event locations.
- Strike/Dip/Rake of preferred nodal plane indicated below focal mechanism.

Isotropic/Mechanical



75° Dip-Slip

	Strike	Dip	Rake
Plane 1	75	81	78
Plane 2	309	15	143

257° Dip-Slip

	Strike	Dip	Rake
Plane 1	257	85	76
Plane 2	150	15	162

258° Dip-Slip

	Strike	Dip	Rake
Plane 1	258	67	76
Plane 2	111	27	120

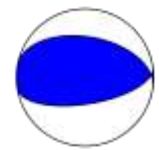
81° Dip-Slip

	Strike	Dip	Rake
Plane 1	81	89	84
Plane 2	339	6	168

84° Dip-Slip

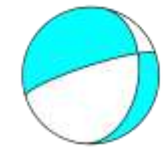
	Strike	Dip	Rake
Plane 1	84	75	-87
Plane 2	253	15	-101

81° Dip-Slip (Low Dip Angle)



	Strike	Dip	Rake
Plane 1	81	55	79
Plane 2	279	36	105

252° Oblique Dip-Slip



	Strike	Dip	Rake
Plane 1	252	77	-66
Plane 2	9	27	-150

249° Oblique Strike-Slip

	Strike	Dip	Rake
Plane 1	249	87	-159
Plane 2	158	69	-3

78° Oblique Strike-Slip

	Strike	Dip	Rake
Plane 1	78	81	-18
Plane 2	171	72	-171

252° Strike-Slip

	Strike	Dip	Rake
Plane 1	252	87	-3
Plane 2	342	87	-177

78° Strike-Slip

	Strike	Dip	Rake
Plane 1	168	87	-171
Plane 2	78	81	-3

Source Mechanism Groups – Fault

- Focal mechanism solutions from P wave picking and used for imaging event locations.
- Strike/Dip/Rake of preferred nodal plane indicated below focal mechanism.

12° Strike-Slip

	Strike	Dip	Rake
Plane 1	102	90	6
Plane 2	12	84	180

24° Strike-Slip

	Strike	Dip	Rake
Plane 1	114	90	3
Plane 2	24	87	180

39° Strike-Slip

	Strike	Dip	Rake
Plane 1	39	90	-180
Plane 2	309	90	0

45° Strike-Slip

	Strike	Dip	Rake
Plane 1	315	87	-6
Plane 2	45	84	-177

51° Strike-Slip

	Strike	Dip	Rake
Plane 1	141	90	3
Plane 2	51	87	180

234° Strike-Slip

	Strike	Dip	Rake
Plane 1	234	87	174
Plane 2	324	84	3

269° Strike-Slip

	Strike	Dip	Rake
Plane 1	269	89	-1
Plane 2	359	89	-179

183° Oblique Dip-Slip (Low Dip Angle)

	Strike	Dip	Rake
Plane 1	317	79	79
Plane 2	183	15	135

102° Oblique-Slip (Low Dip Angle)

	Strike	Dip	Rake
Plane 1	328	77	103
Plane 2	102	18	45

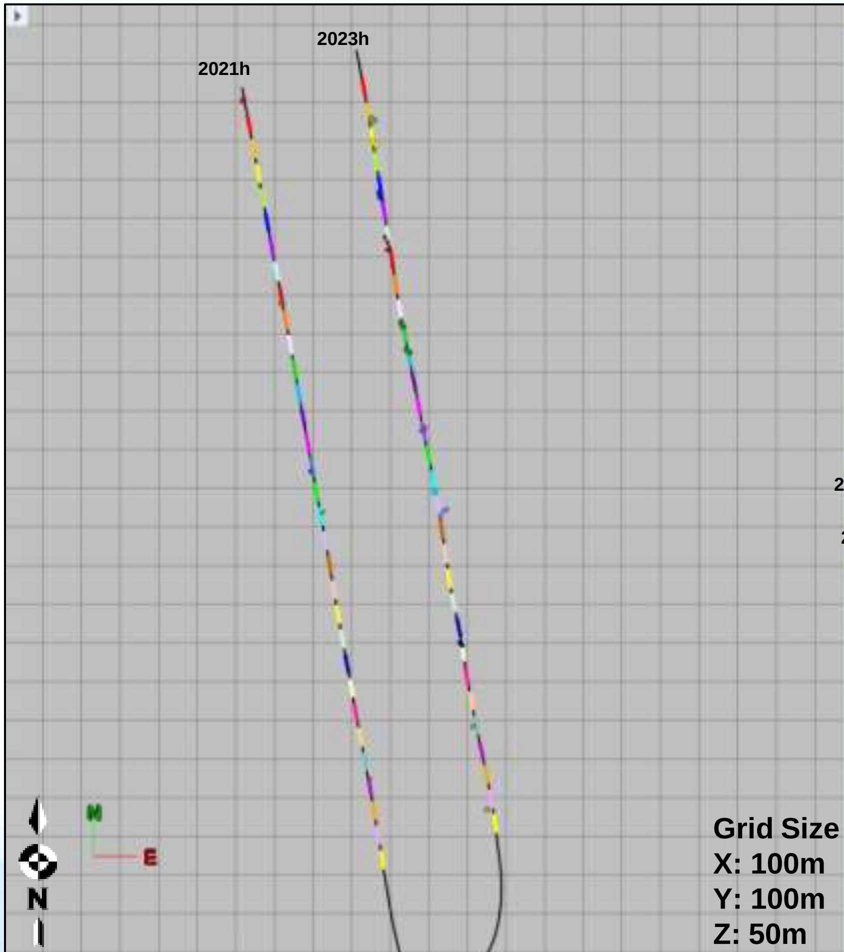
168° Oblique Dip-Slip (Low Dip Angle)

	Strike	Dip	Rake
Plane 1	302	79	79
Plane 2	168	15	135

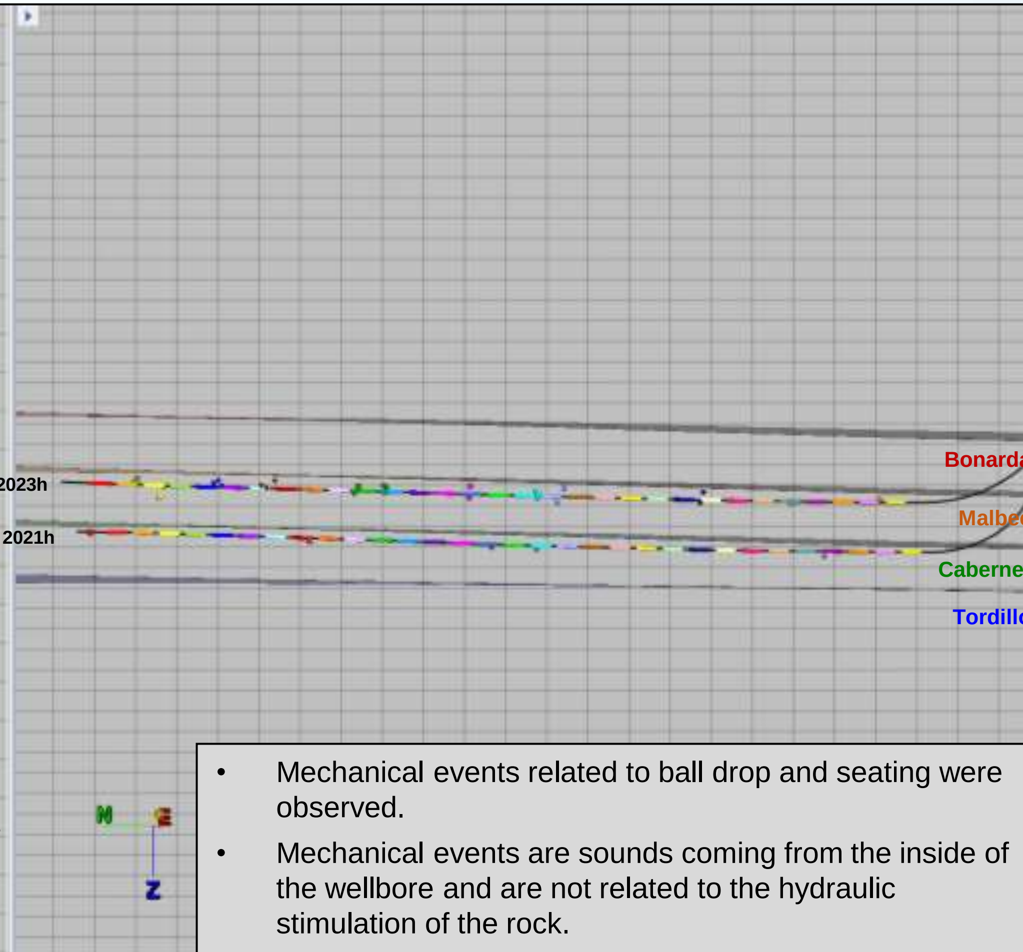
MicroSeismic

2021h & 2023h – Mechanical Events

Map View



Depth View – Facing Northeast



- Mechanical events related to ball drop and seating were observed.
- Mechanical events are sounds coming from the inside of the wellbore and are not related to the hydraulic stimulation of the rock.

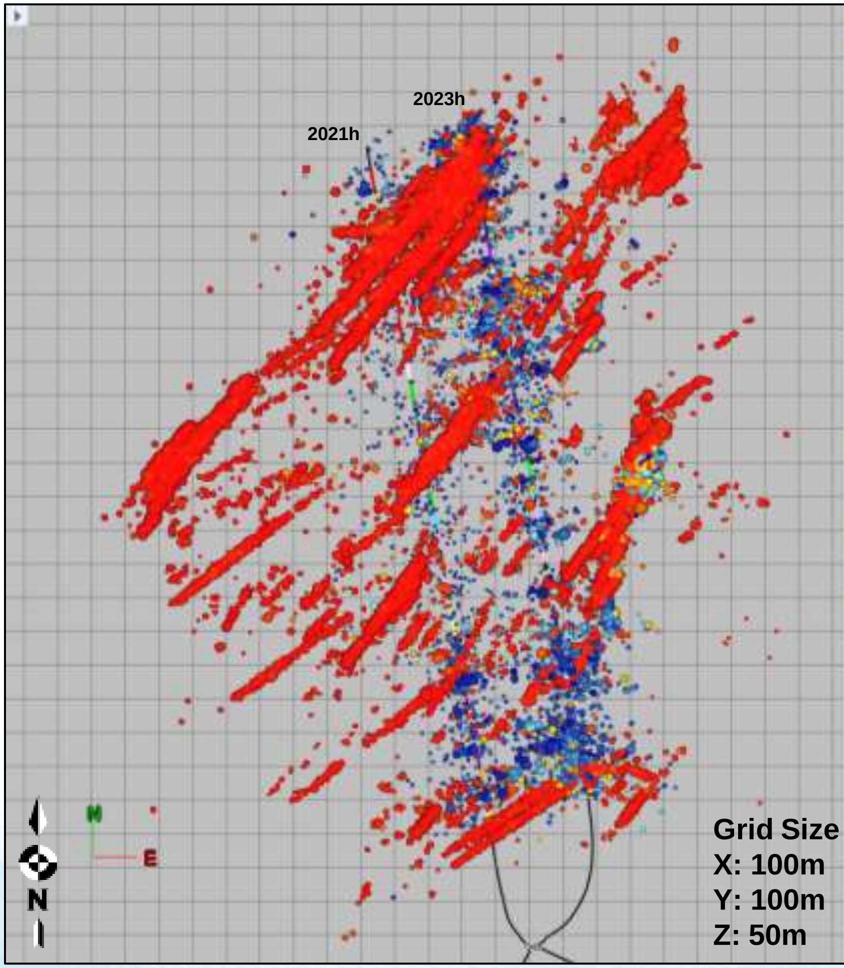
Events are sized by magnitude and colored by stage.

Stage Coloring Legend

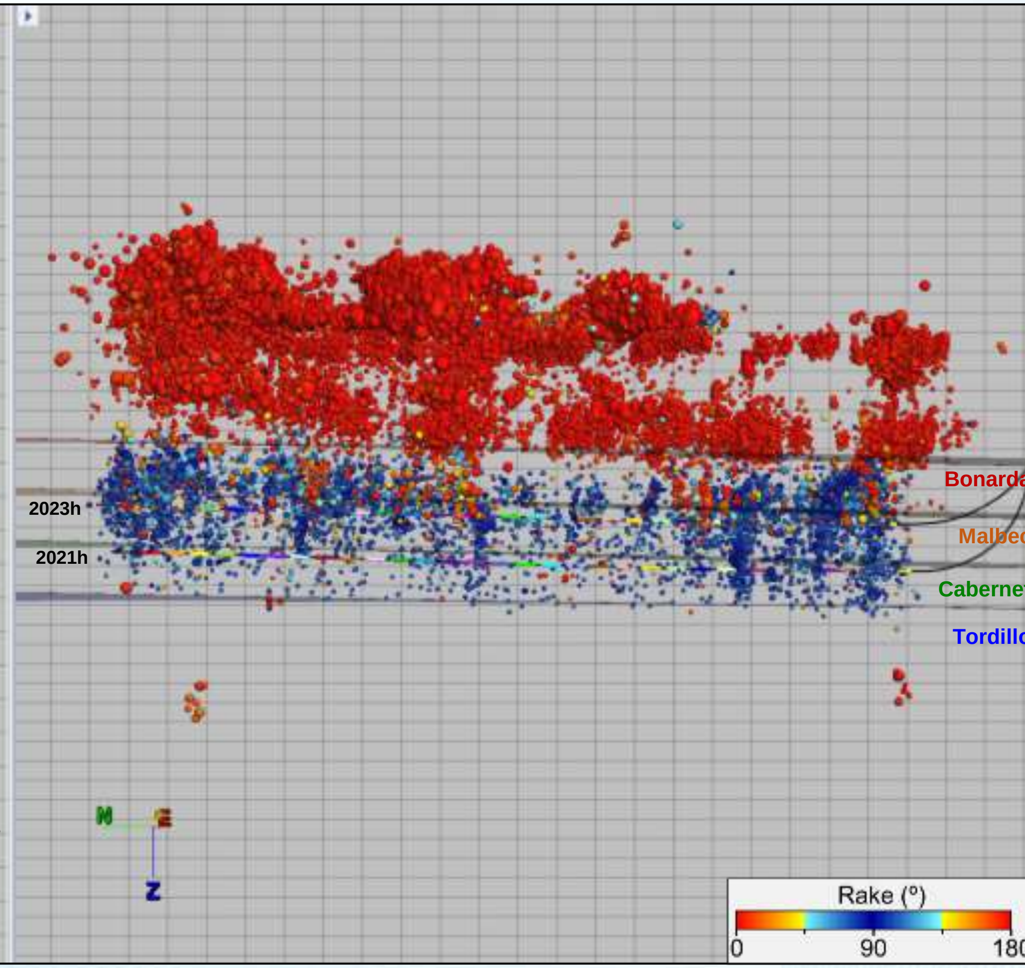
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

2021h & 2023h – All Events Colored by Rake

Map View

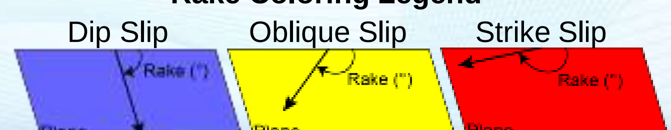


Depth View – Facing Northeast



Events are sized by magnitude and colored by rake.

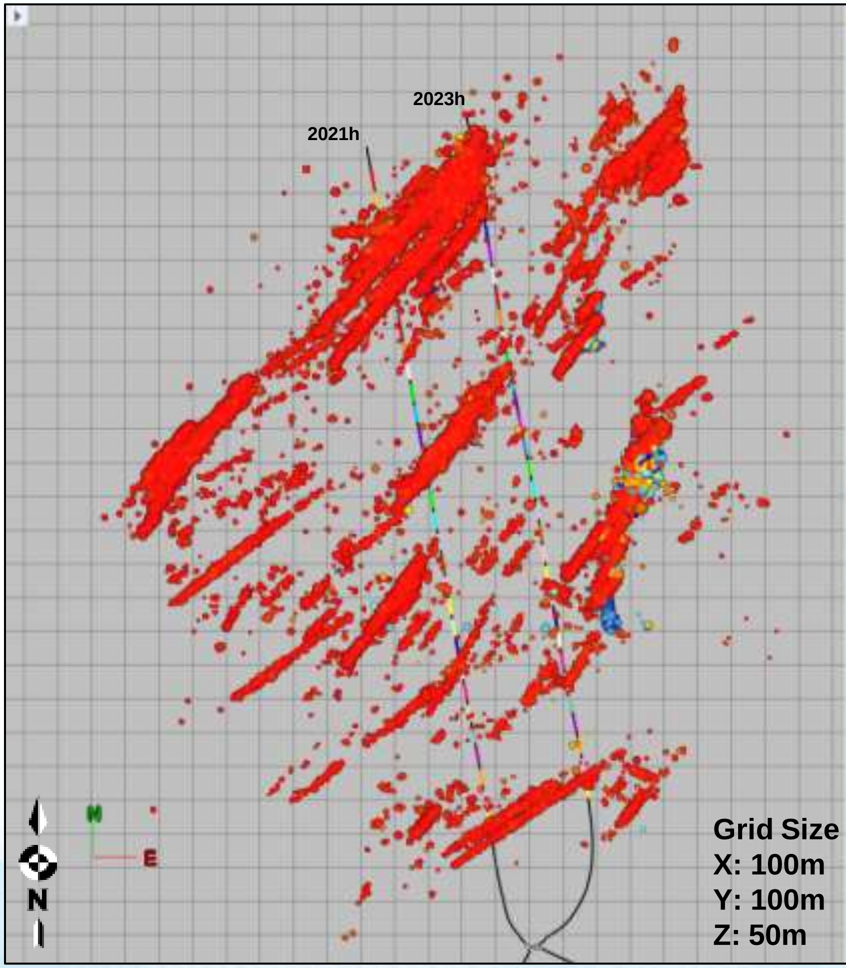
Rake Coloring Legend



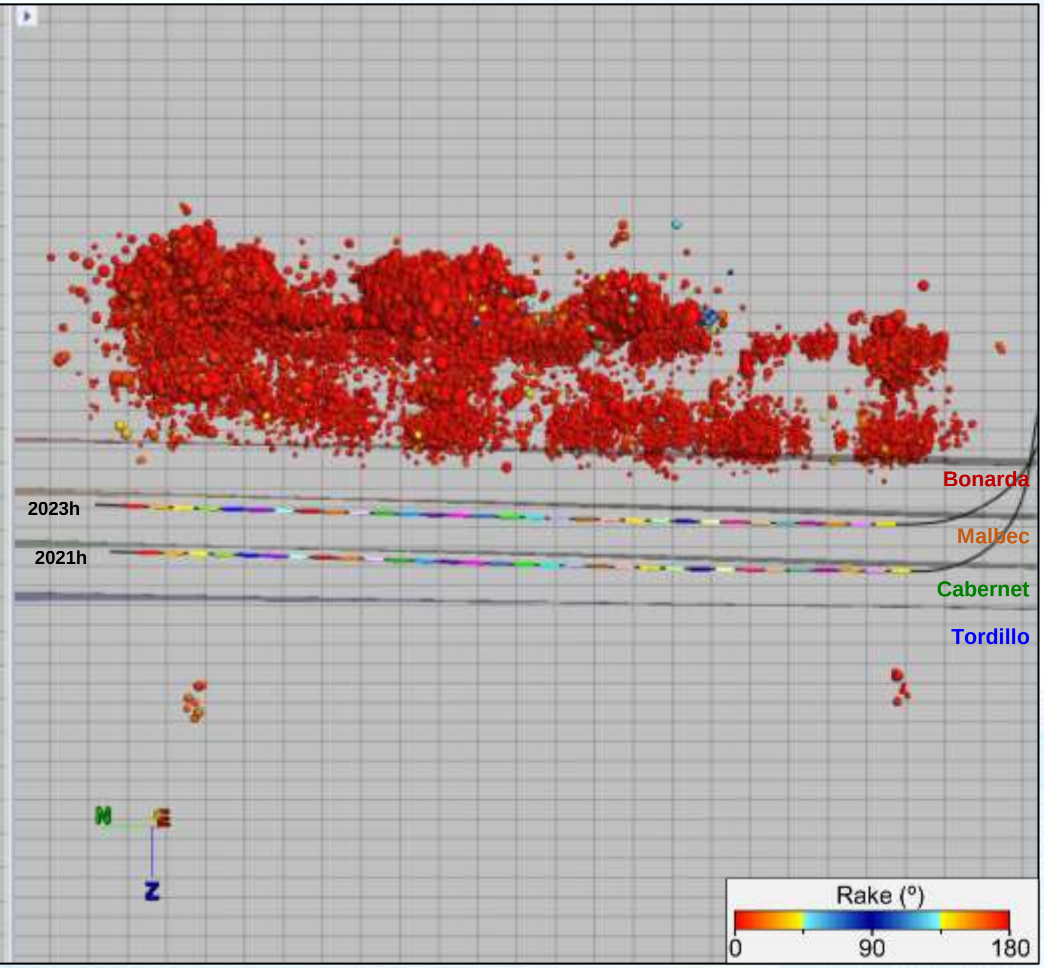
MicroSeismic

2021h & 2023h – Fault Events Colored by Rake

Map View

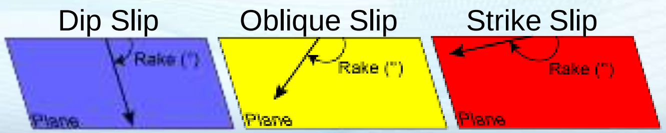


Depth View – Facing Northeast



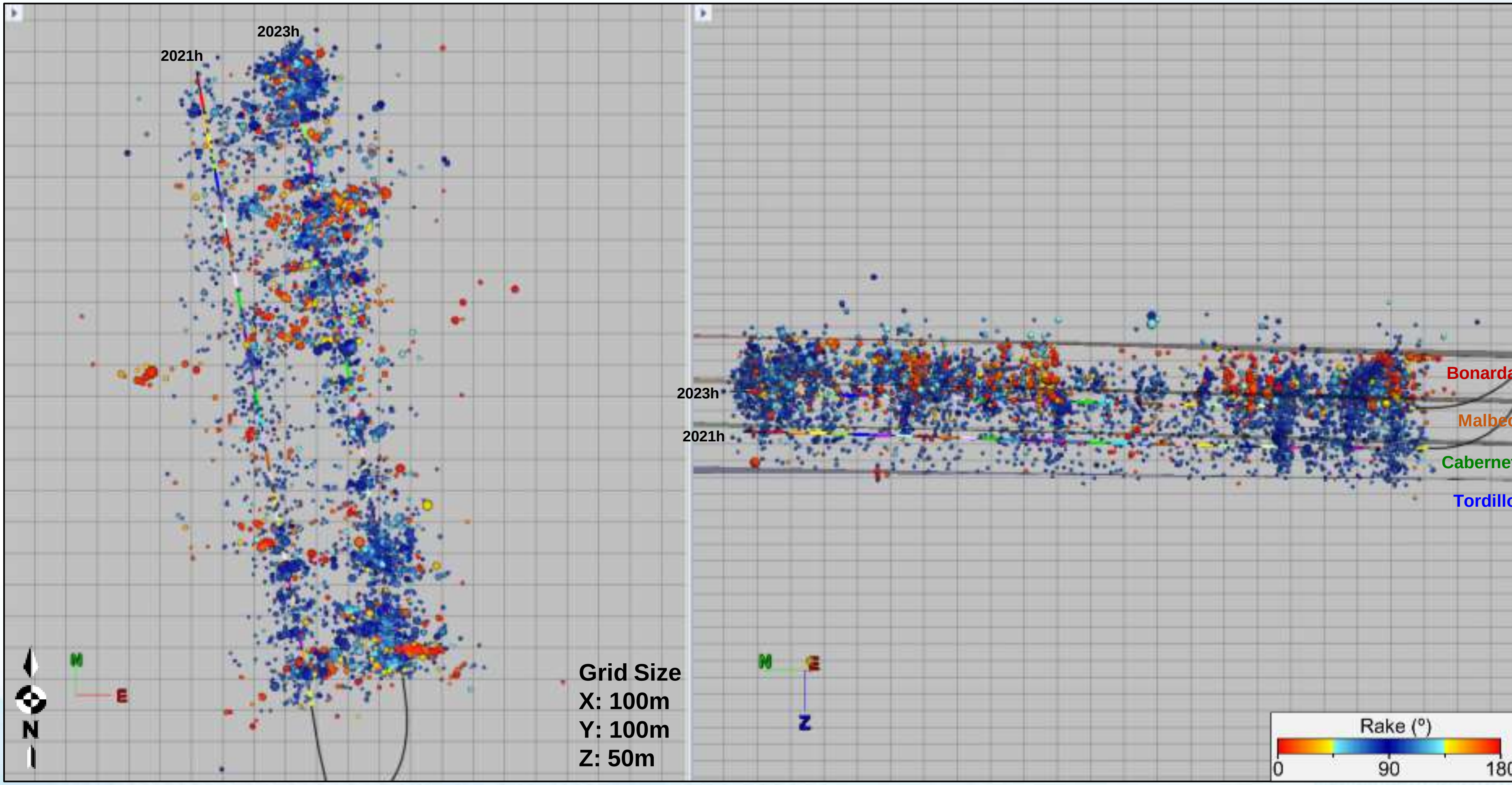
Events are sized by magnitude and colored by rake.

Rake Coloring Legend



2021h & 2023h – Reservoir Events Colored by Rake

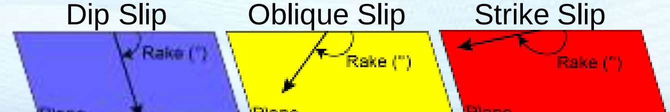
Map View | **Depth View – Facing Northeast**



Events are sized by magnitude and colored by rake.

Rake Coloring Legend

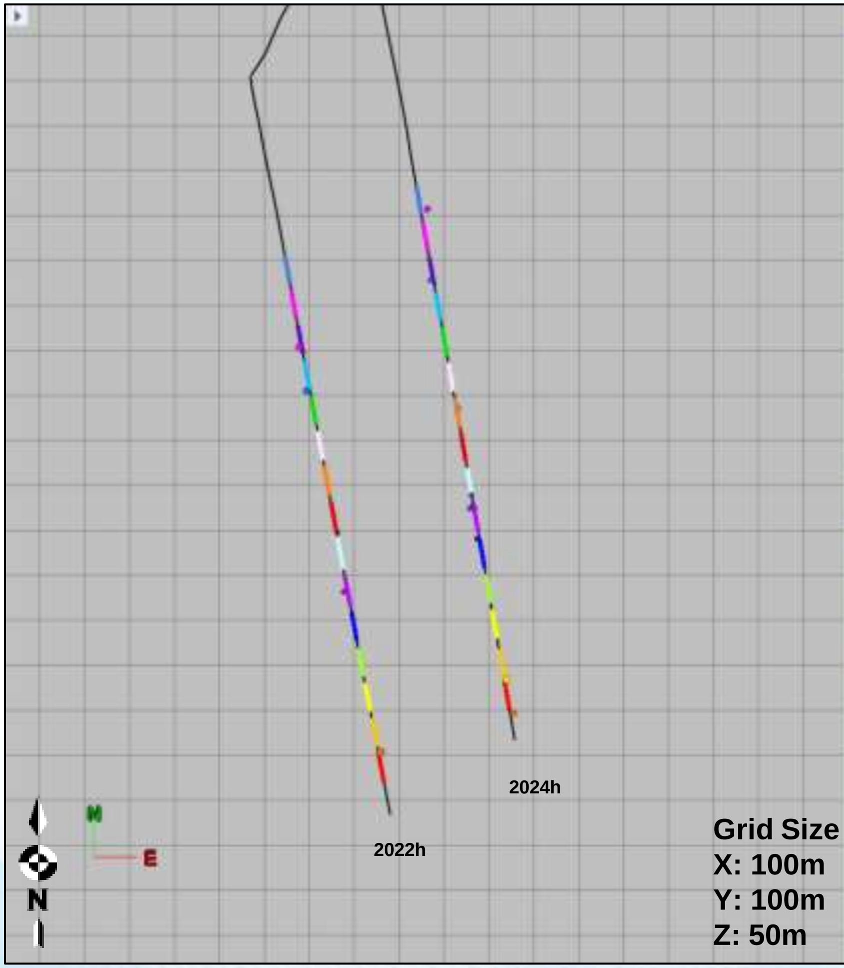
Dip Slip | Oblique Slip | Strike Slip



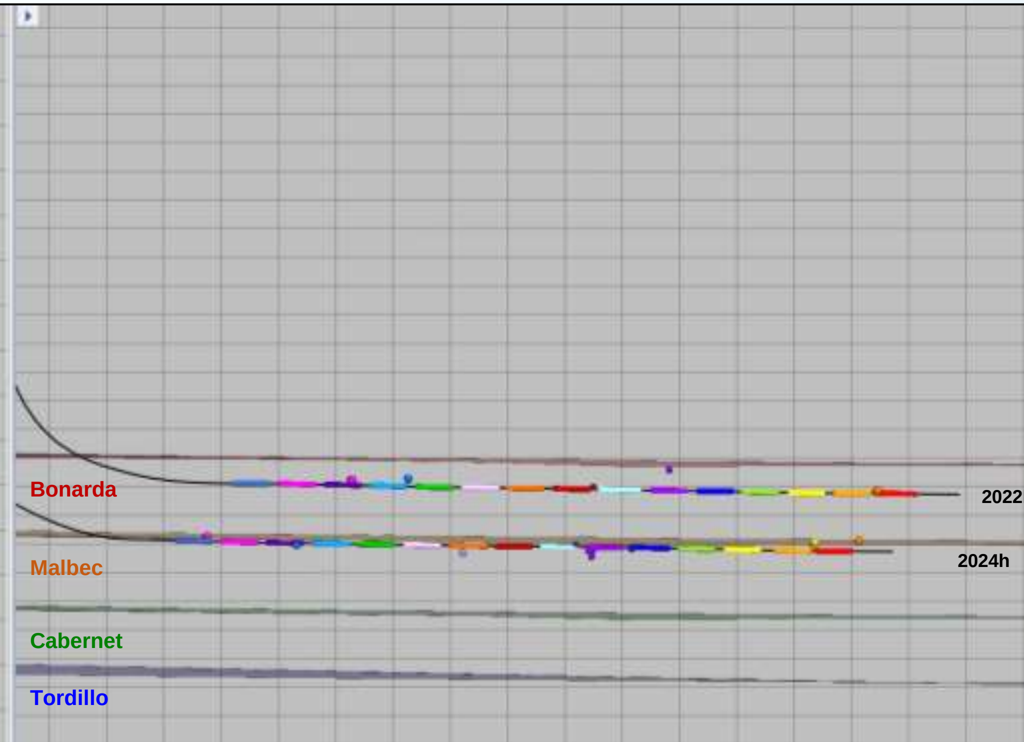
MicroSeismic

2022h & 2024h – Mechanical Events

Map View



Depth View – Facing Northeast



- Mechanical events related to ball drop and seating were observed.
- Mechanical events are sounds coming from the inside of the wellbore and are not related to the hydraulic stimulation of the rock.

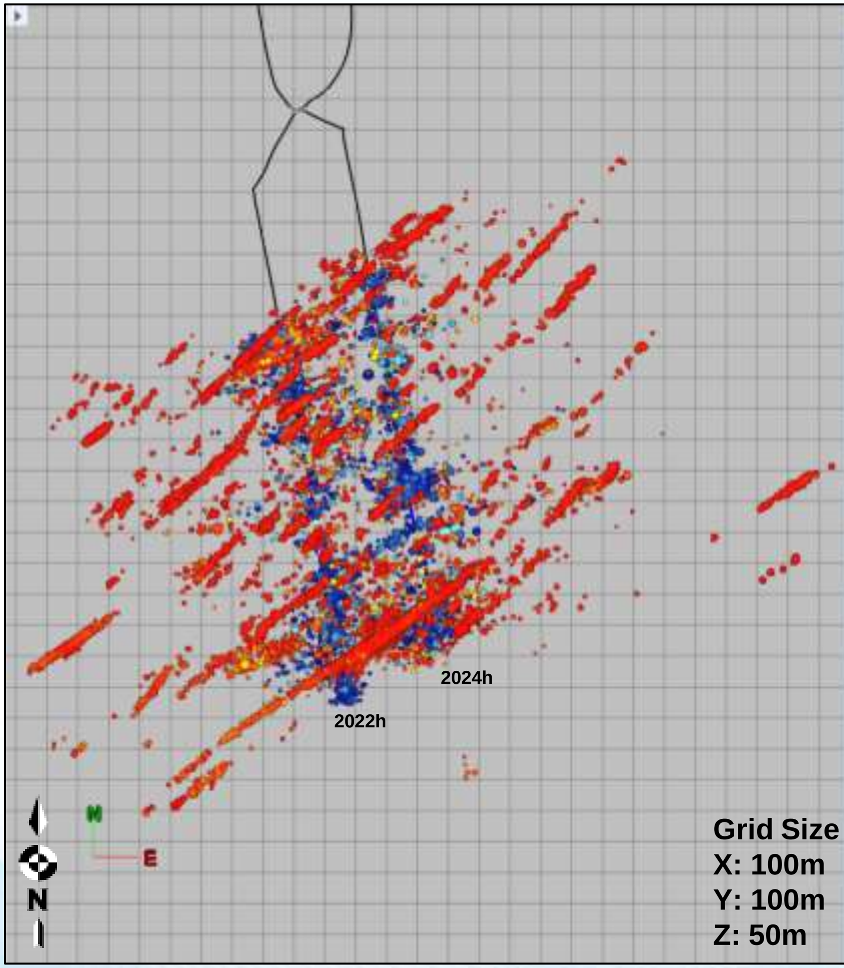
Events are sized by magnitude and colored by stage.

Stage Coloring Legend

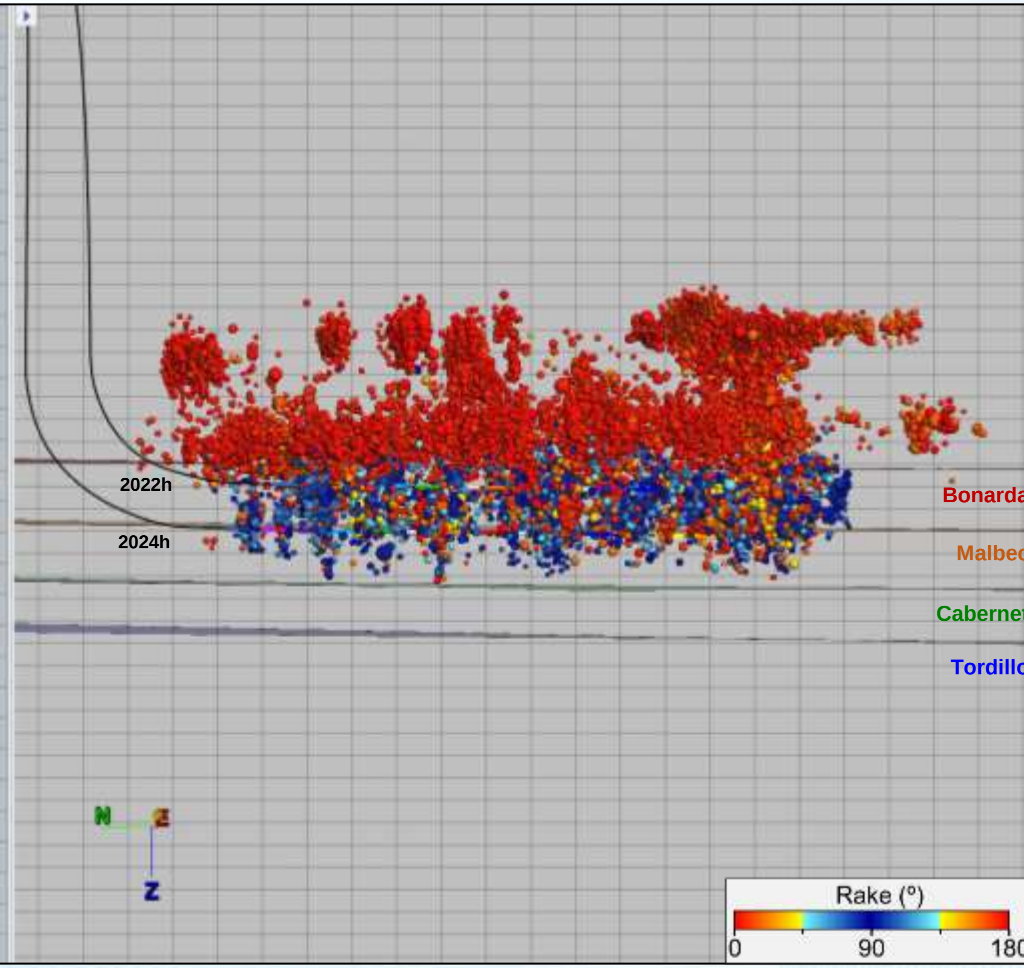
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

2022h & 2024h – All Events Colored by Rake

Map View

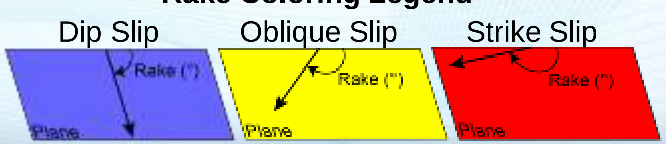


Depth View – Facing Northeast



Events are sized by magnitude and colored by rake.

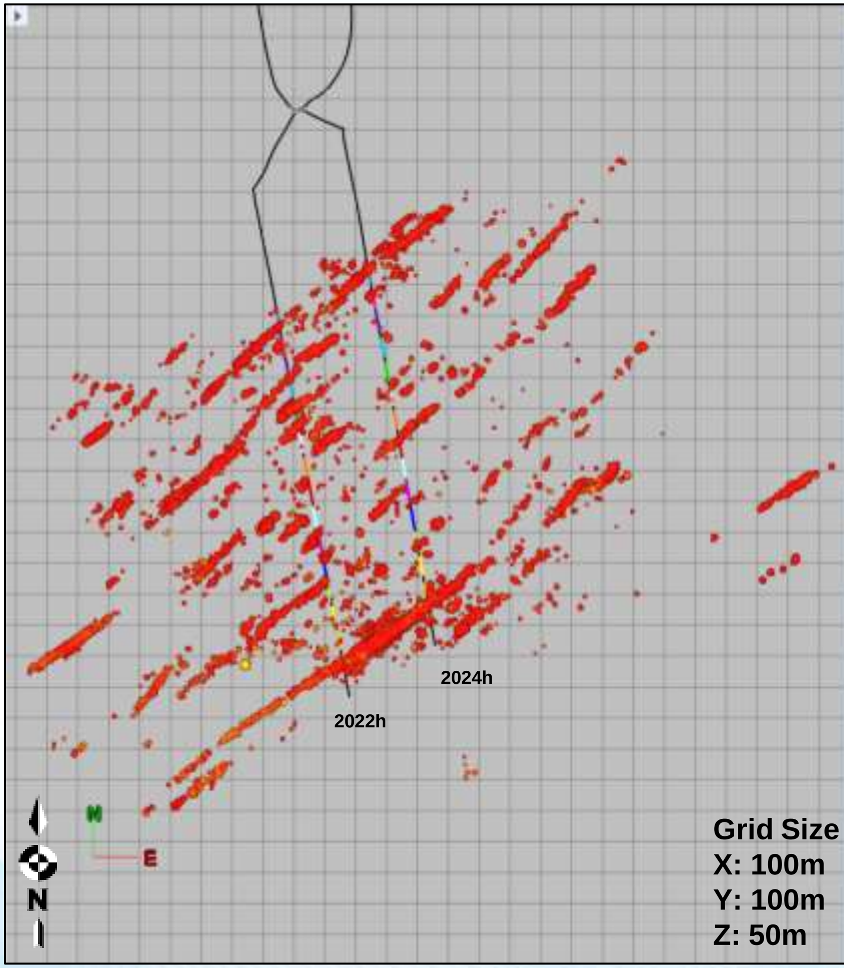
Rake Coloring Legend



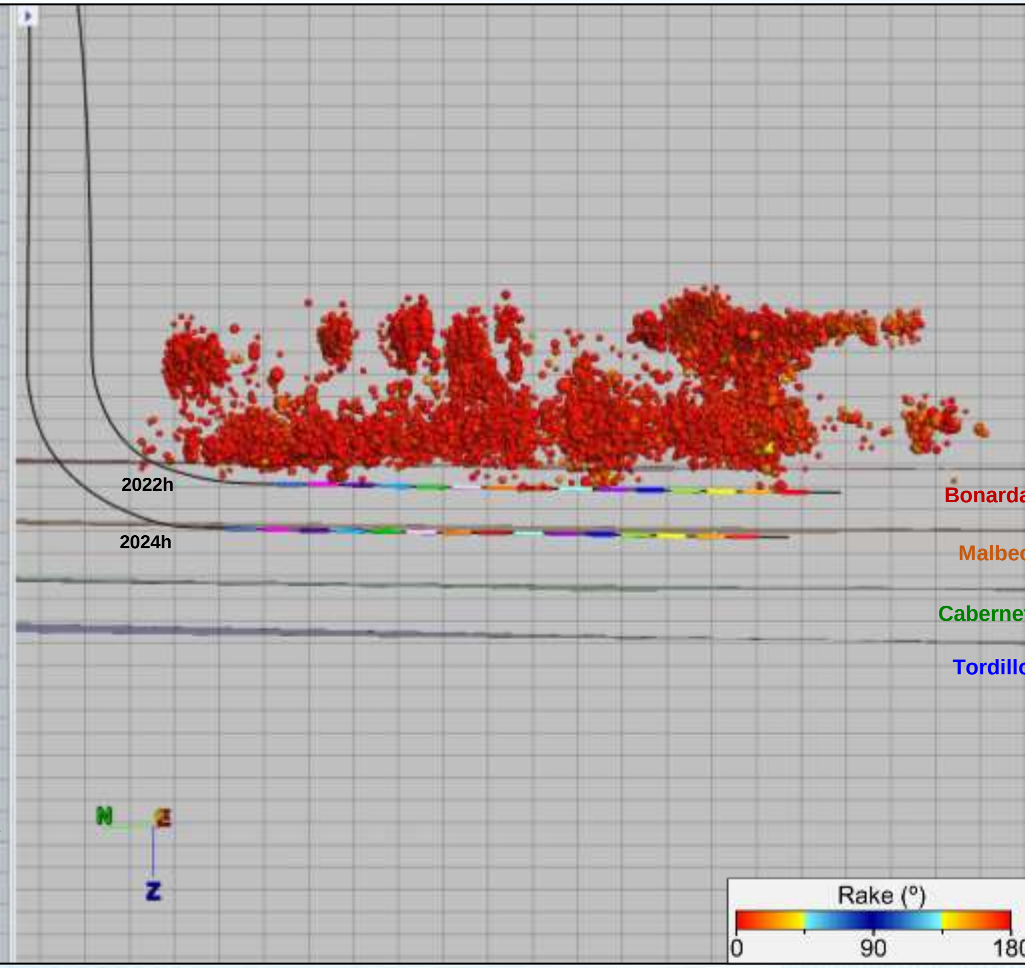
MicroSeismic

2022h & 2024h – Fault Events Colored by Rake

Map View

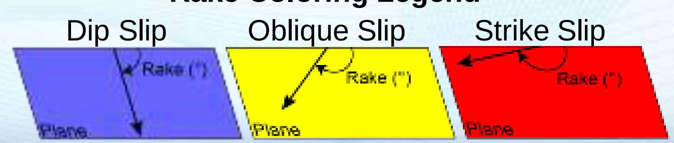


Depth View – Facing Northeast



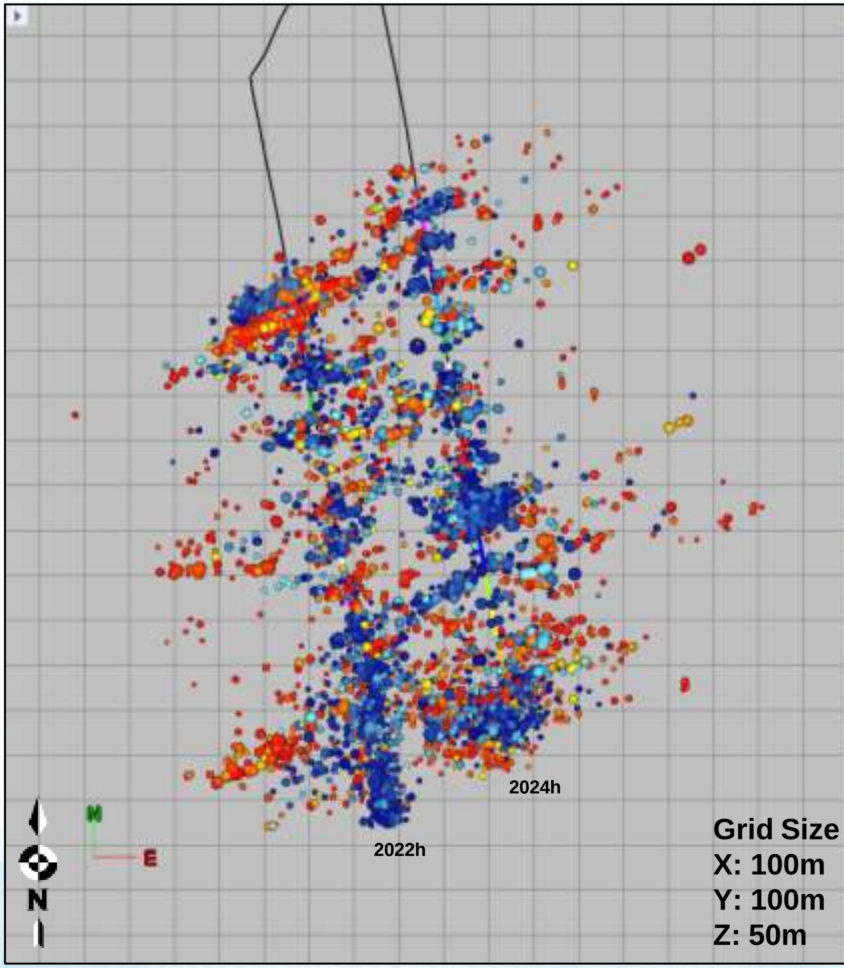
Events are sized by magnitude and colored by rake.

Rake Coloring Legend

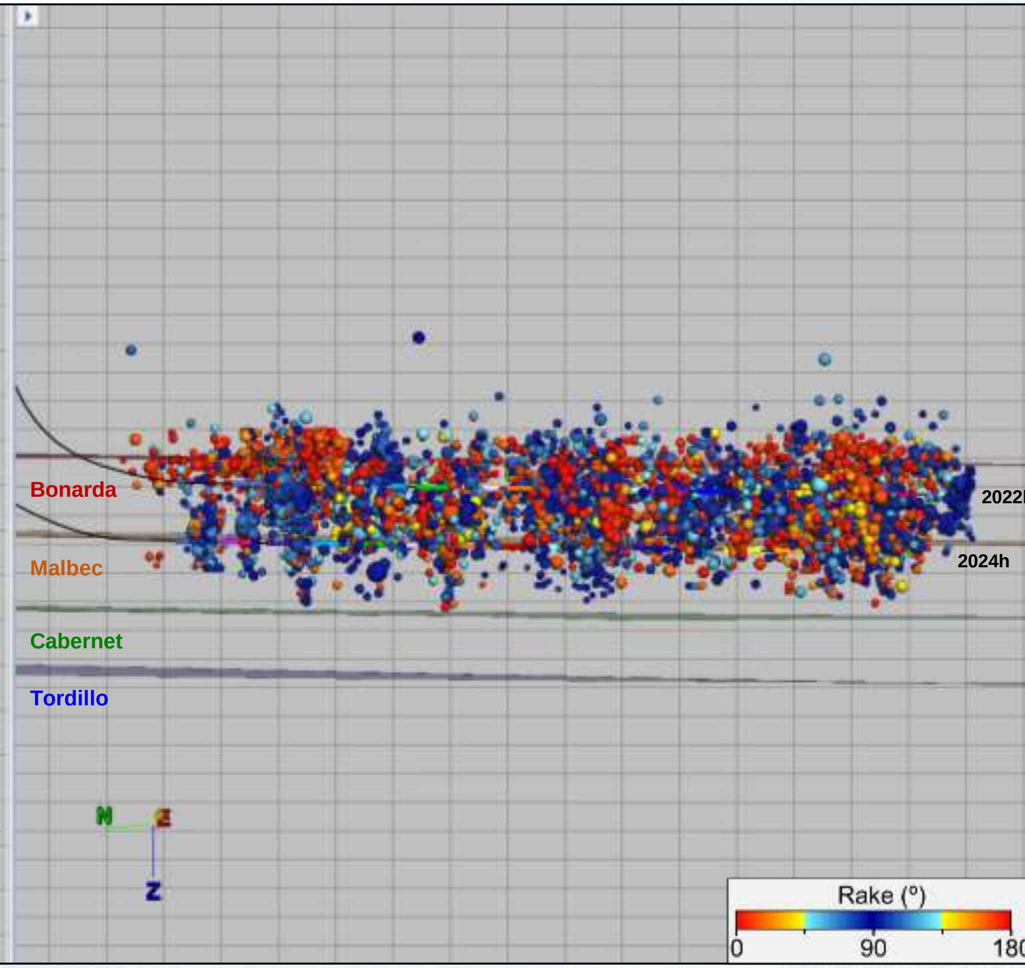


2022h & 2024h – Reservoir Events Colored by Rake

Map View



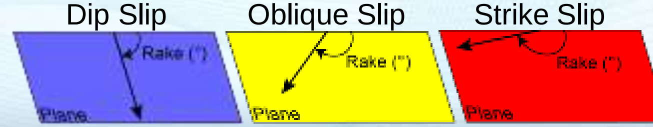
Depth View – Facing Northeast



Events are sized by magnitude and colored by rake.

Rake Coloring Legend

Dip Slip | Oblique Slip | Strike Slip



MicroSeismic

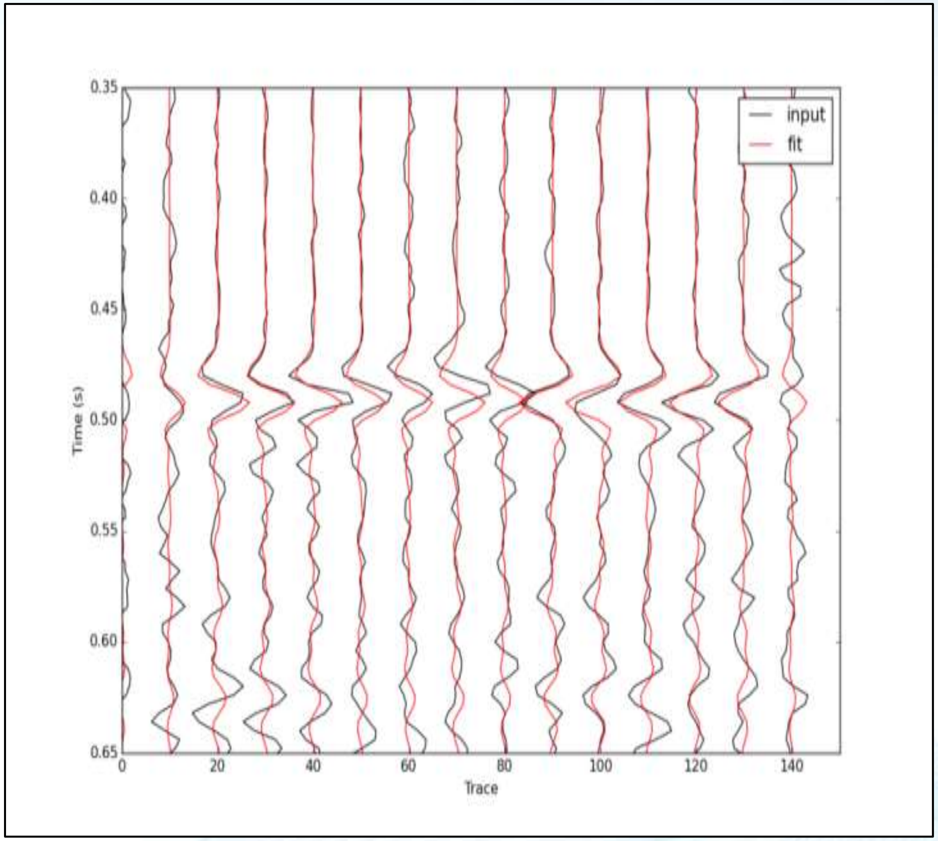
Automatic Moment Tensor Inversion Results (AMTI)

MicroSeismic

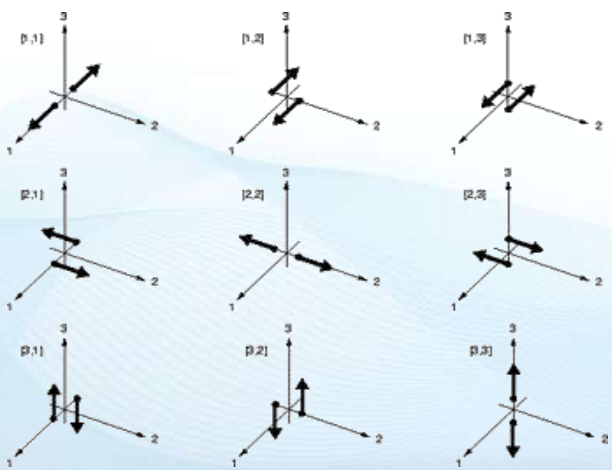
AMTI Explanation

With the estimate of the source time function, the estimated moment tensor can be found by minimizing the squared difference between the recorded data trace at each receiver and the modeled data trace (Sipkin, 1982; Song and Toksoz, 2011):

$$\hat{m} = \arg\min \sum_i \left(d_i(t) - G'_{ij} m_j * \hat{s}(t) \right)^2$$



Force couples

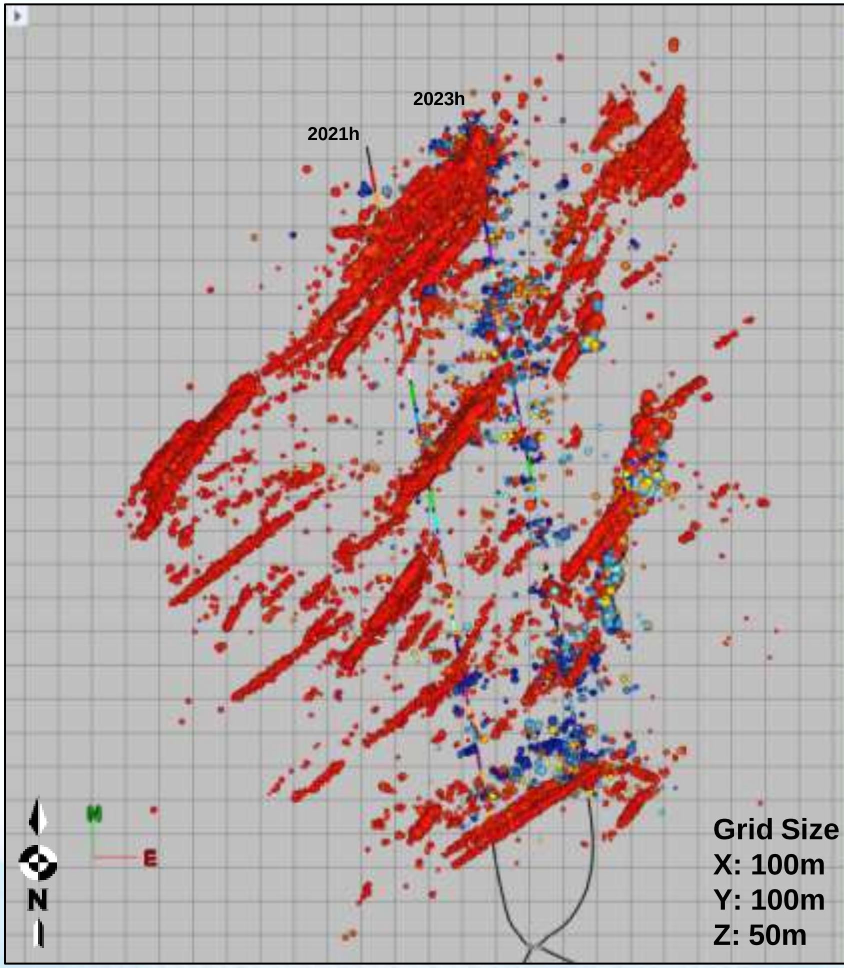


Moment Tensor

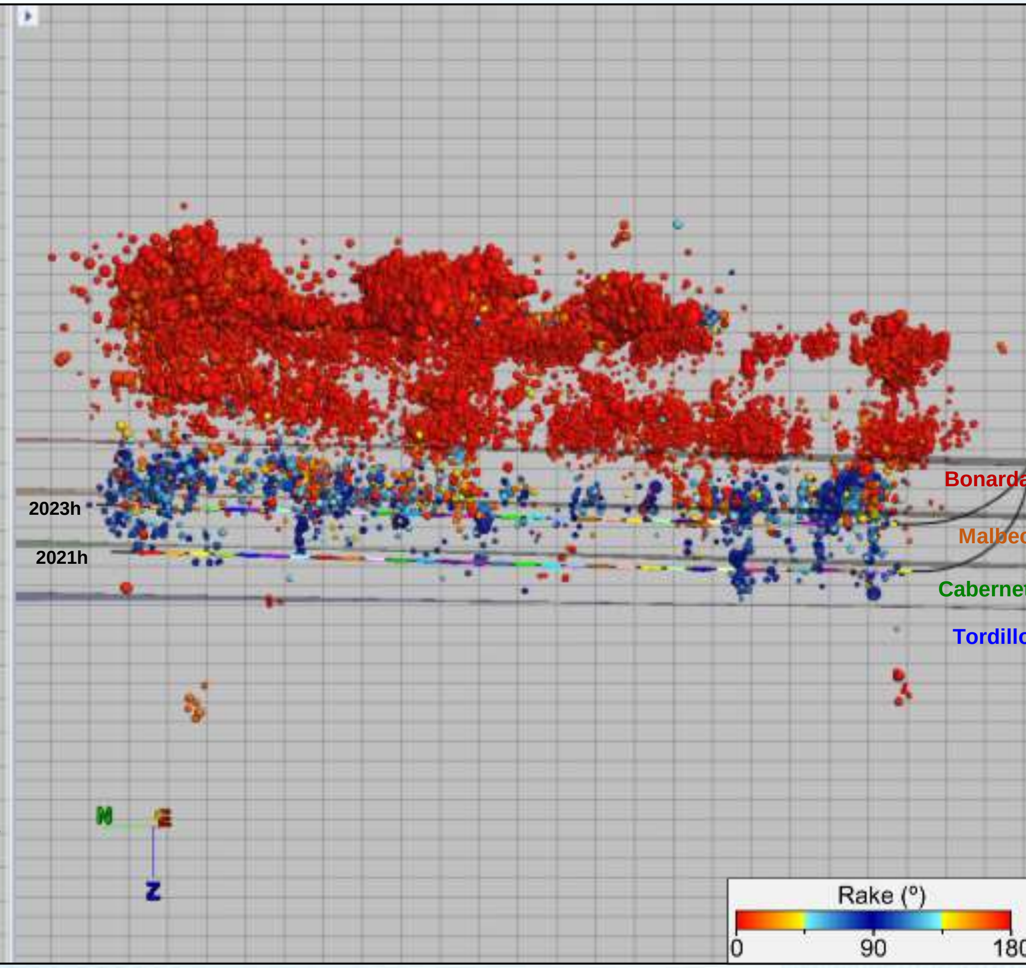
$$\mathbf{M} = M_0 \begin{bmatrix} M_{11} & M_{12} & M_{13} \\ M_{21} & M_{22} & M_{23} \\ M_{31} & M_{32} & M_{33} \end{bmatrix}$$

2021h & 2023h – Events with Unique Moment Tensor Solutions

Map View

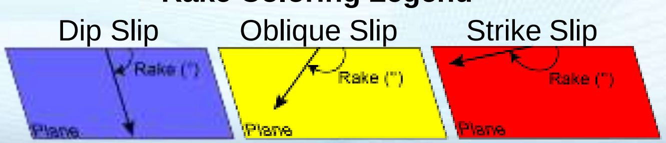


Depth View – Facing Northeast



Events are sized by magnitude and colored by rake.

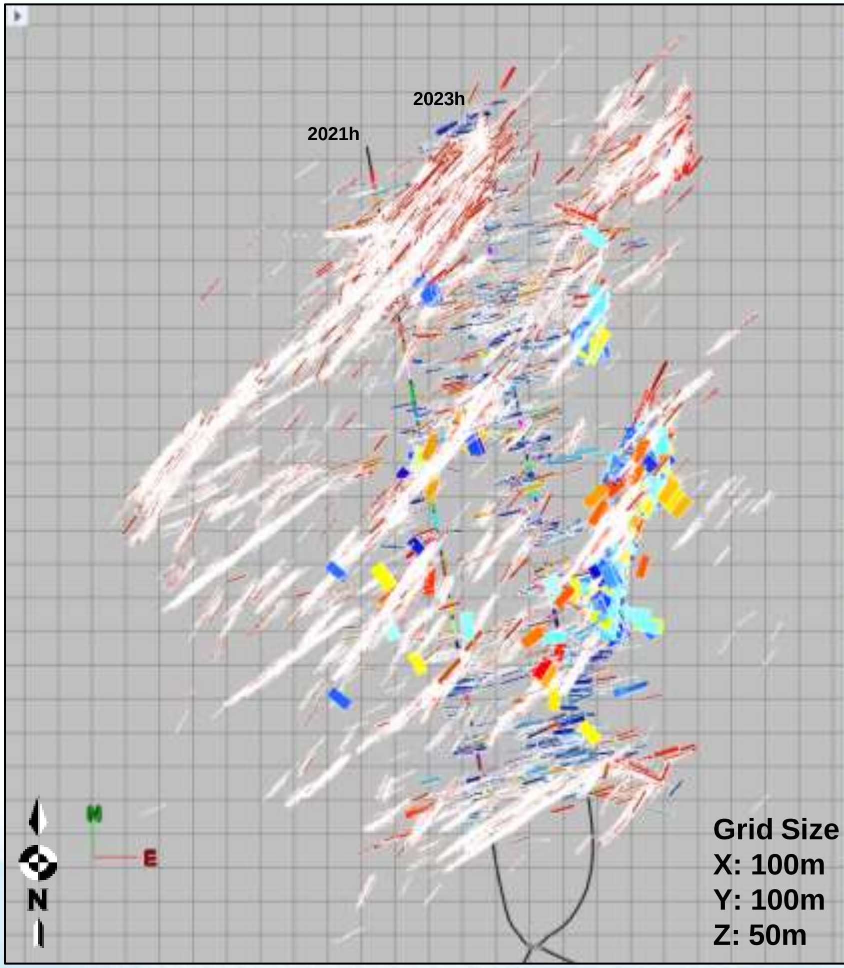
Rake Coloring Legend



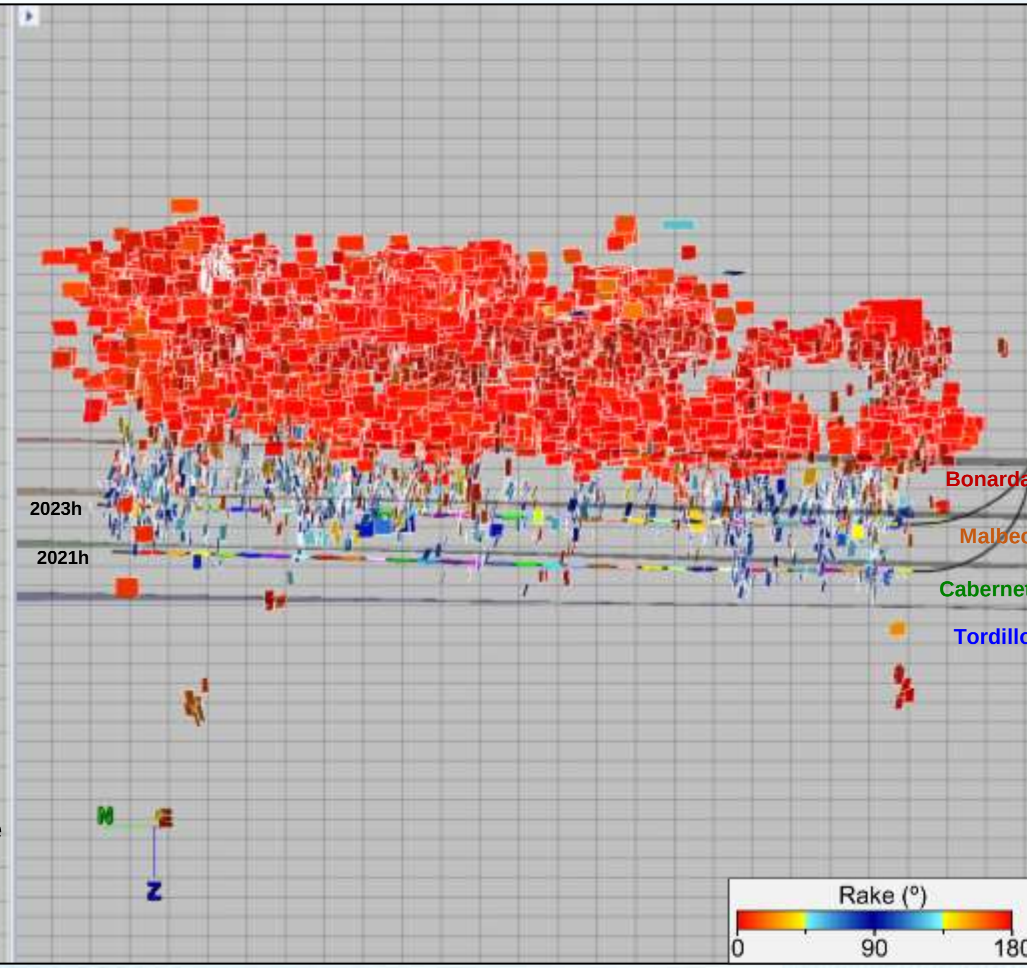
MicroSeismic

2021h & 2023h – Events with Unique Moment Tensor Solutions

Map View

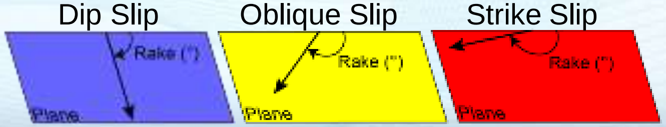


Depth View – Facing Northeast



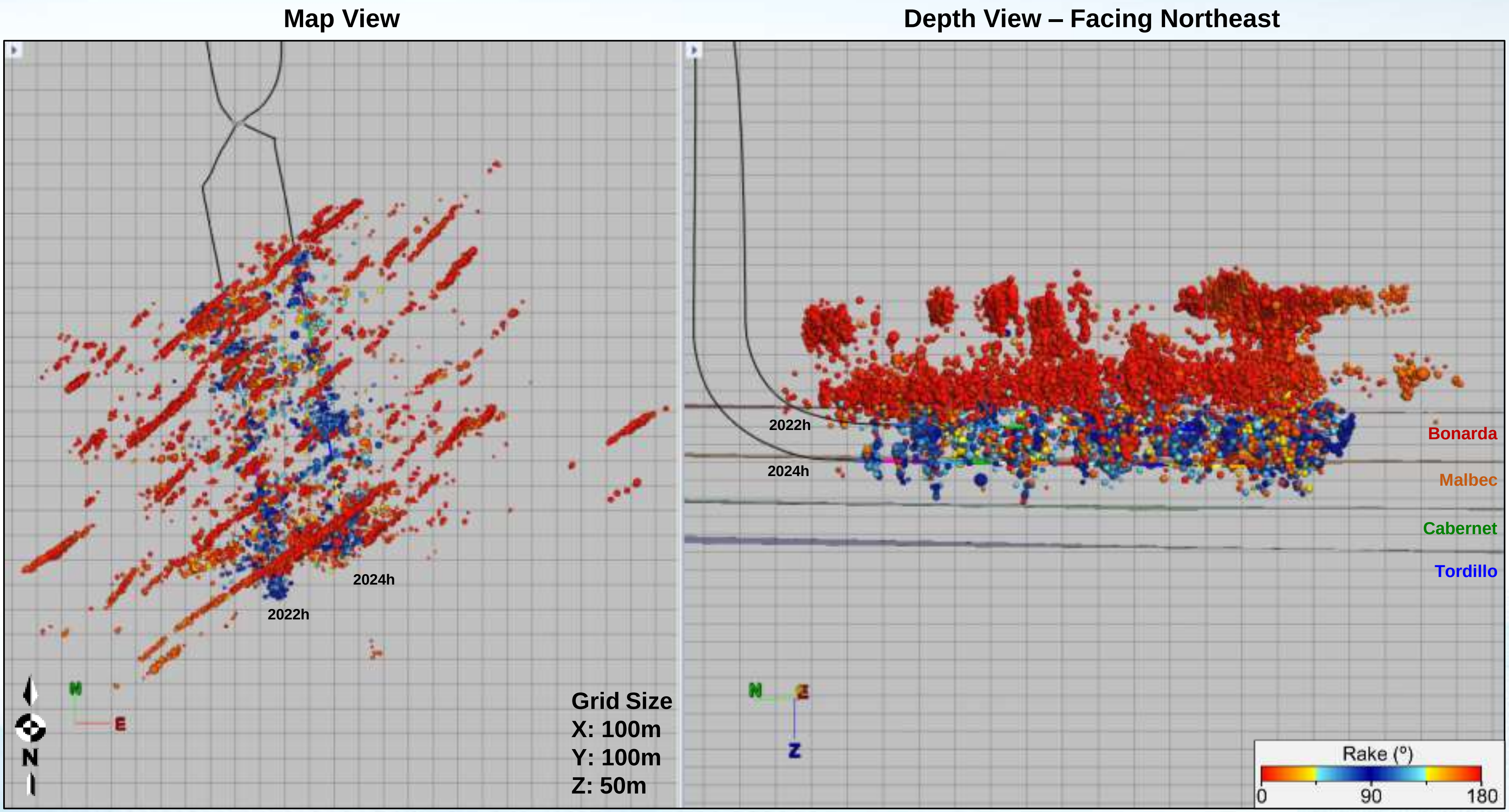
Events are styled as fracture planes, colored by rake, and sized by magnitude.

Rake Coloring Legend

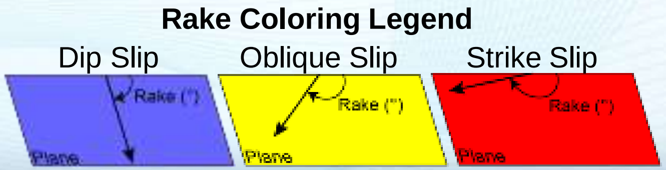


MicroSeismic

2022h & 2024h – Events with Unique Moment Tensor Solutions



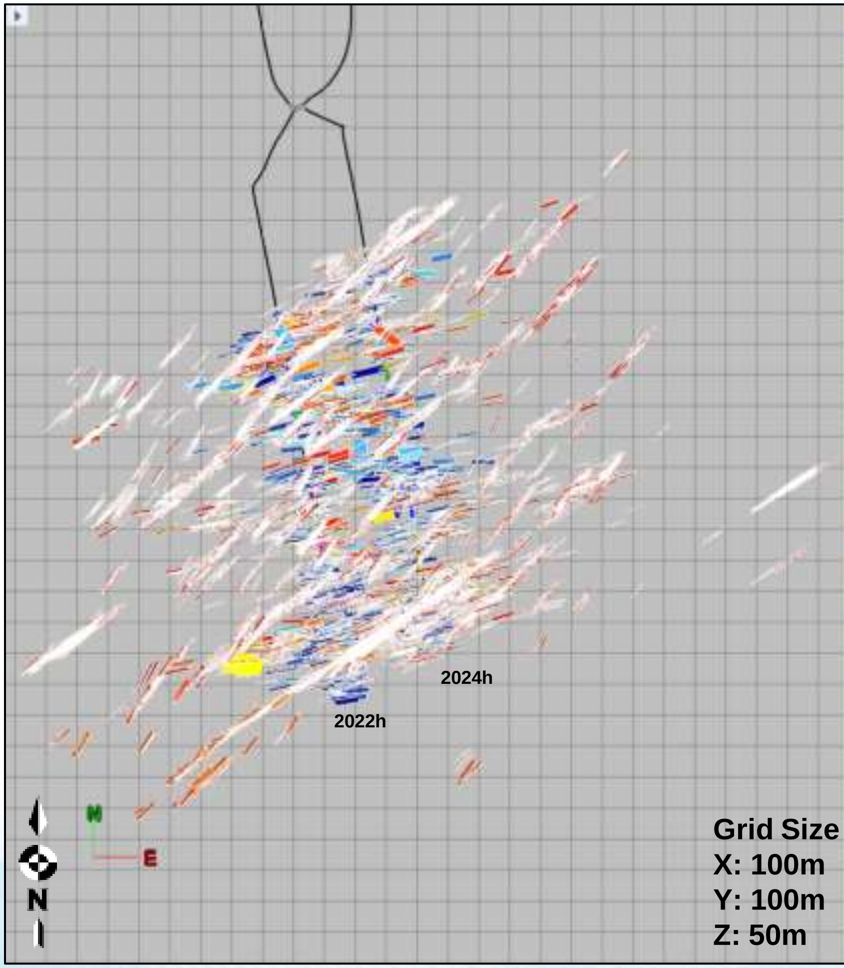
Events are sized by magnitude and colored by rake.



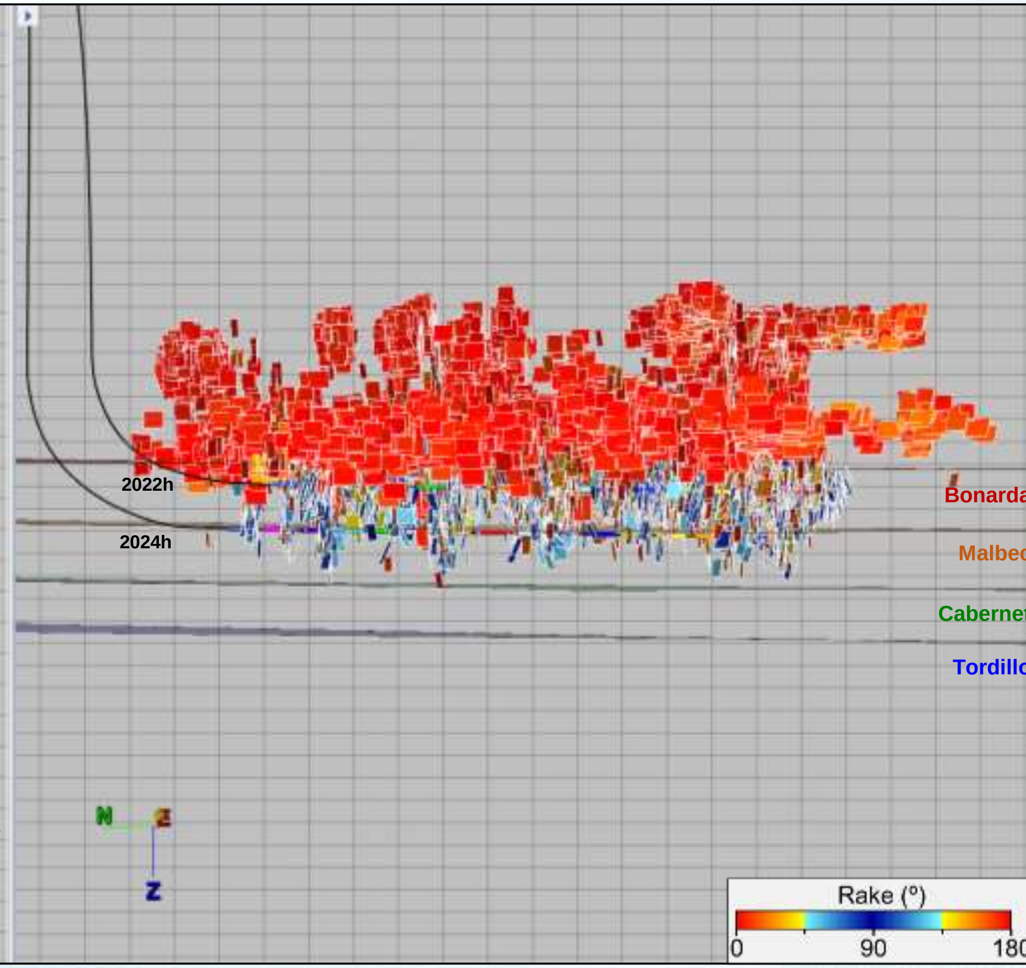
MicroSeismic

2022h & 2024h – Events with Unique Moment Tensor Solutions

Map View



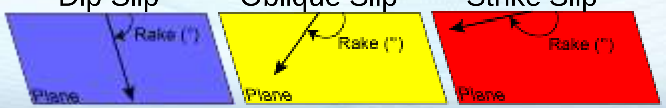
Depth View – Facing Northeast



Events are styled as fracture planes, colored by rake, and sized by magnitude.

Rake Coloring Legend

Dip Slip | Oblique Slip | Strike Slip



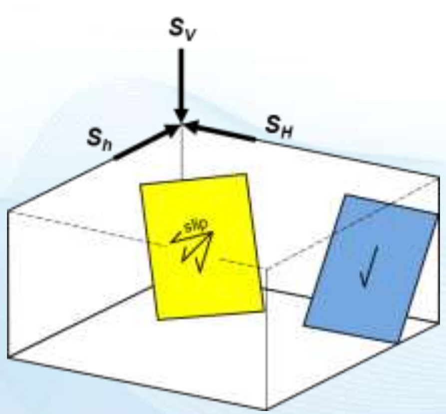
MicroSeismic

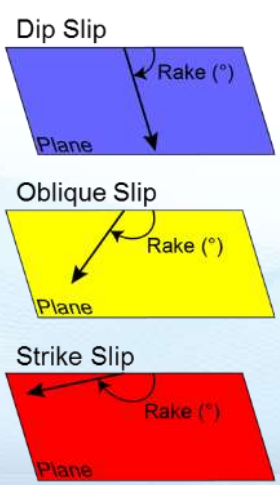
Geomechanical Completions Evaluation

MicroSeismic

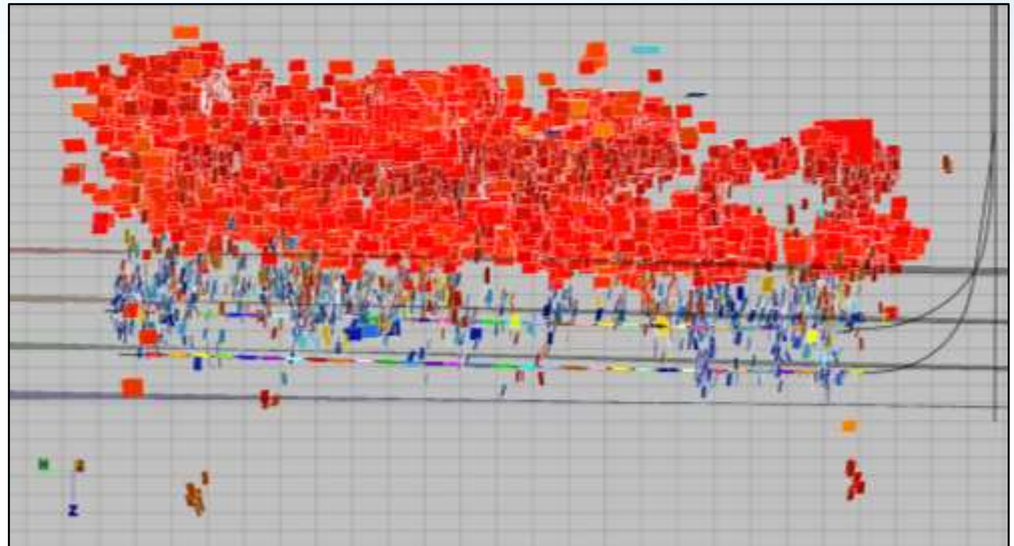
Geomechanical Completions Evaluation

- Evaluated complexities associated with treatment and/or geology.
- Performed a stress field inversion (*SHmax* orientation and magnitude) and estimated stimulation potential of fractures.
- A discrete focal mechanism is computed for each event of sufficient SNR (>4).
- 79,973 events are used in geomechanics analyses.

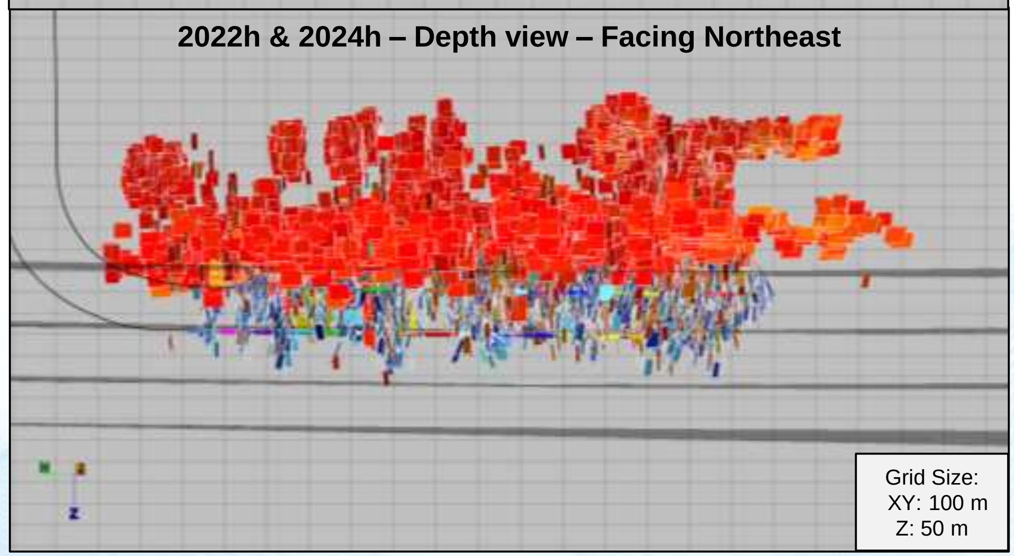




2021h & 2023h – Depth view – Facing Northeast



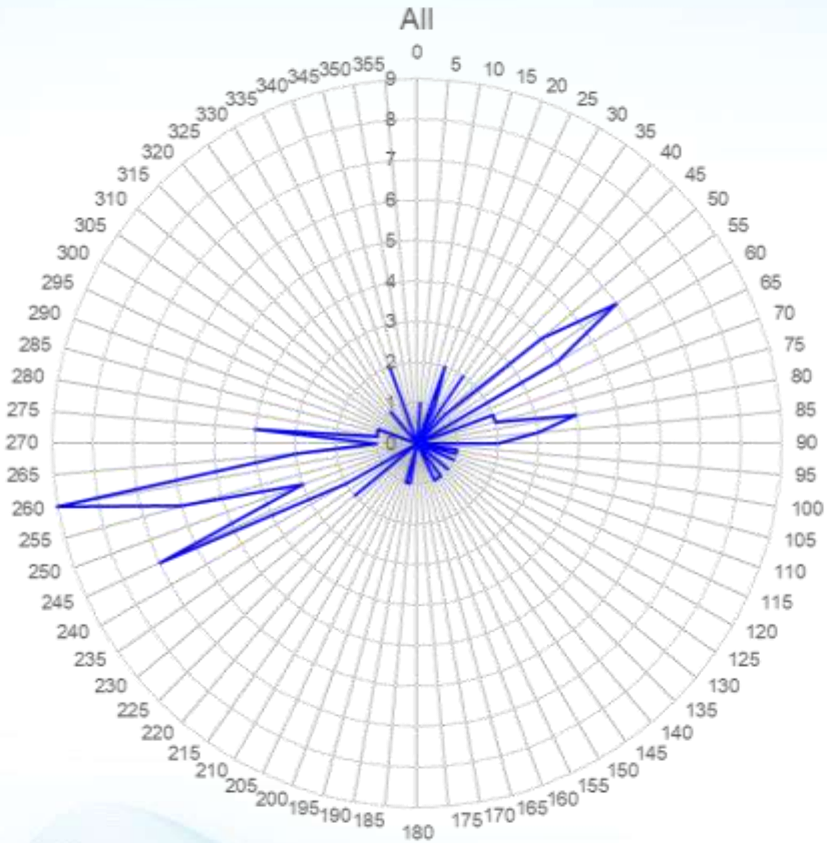
2022h & 2024h – Depth view – Facing Northeast

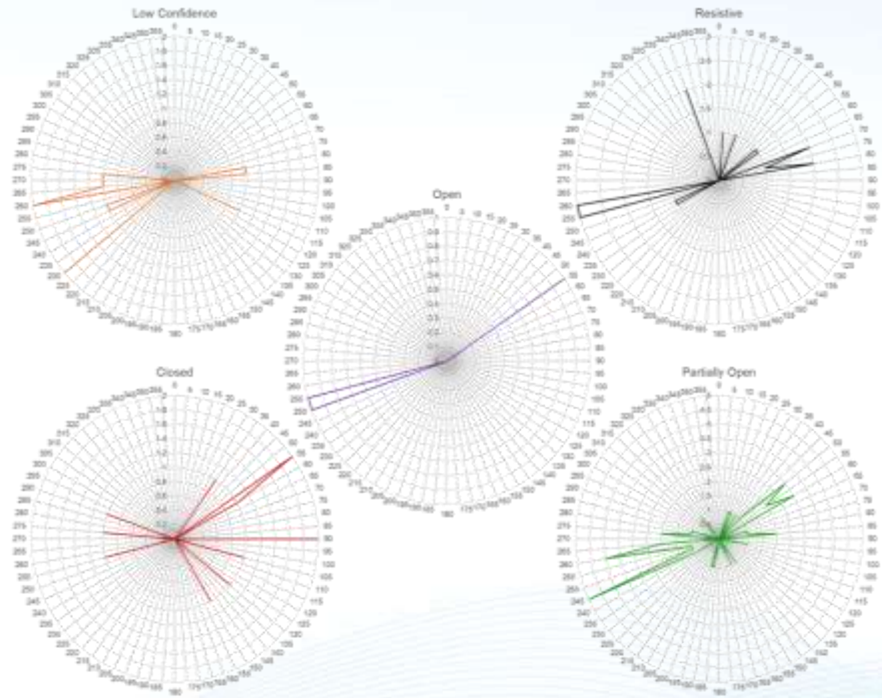


DFNs are sized by magnitude and colored by rake.

MicroSeismic

Natural Fractures – Strike Azimuth

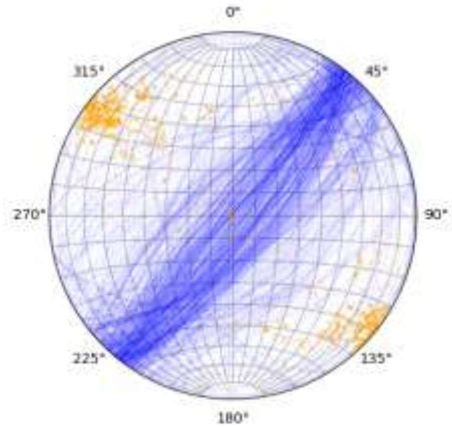




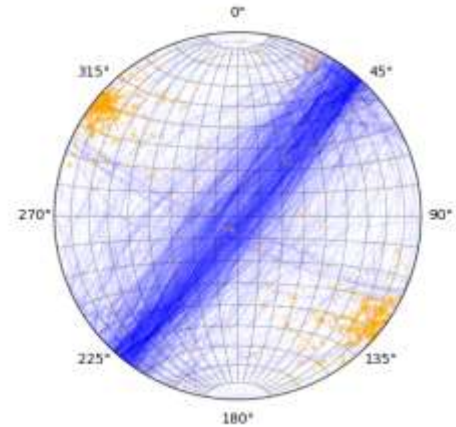
- Natural fracture orientations have a wide range of distributions
- Primary sets – 80° and 50-65°

Fracture Propagation Analysis – Above Bonarda Top

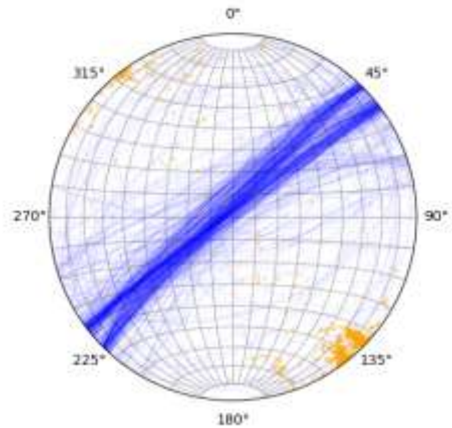
2021h



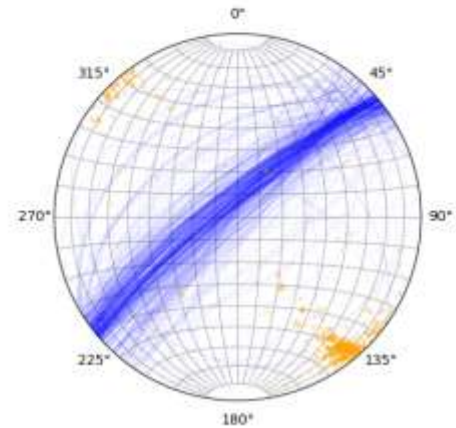
2023h



2022h



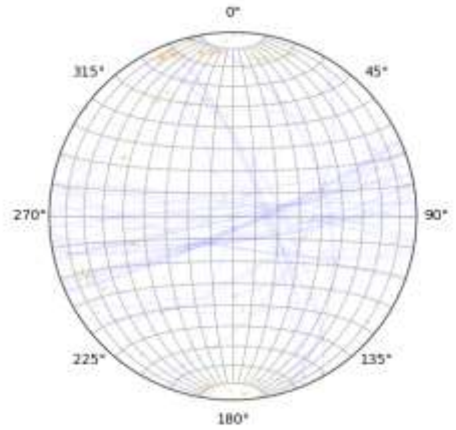
2024h



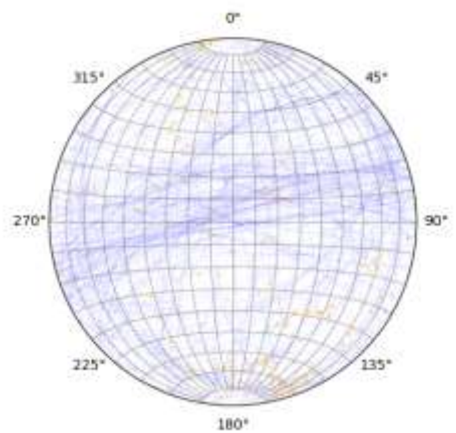
- Patented time space pattern recognition algorithm with outlier detection and noise removal
- Assesses the direction and organization of time sequential events

Fracture Propagation Analysis – Below Bonarda Top

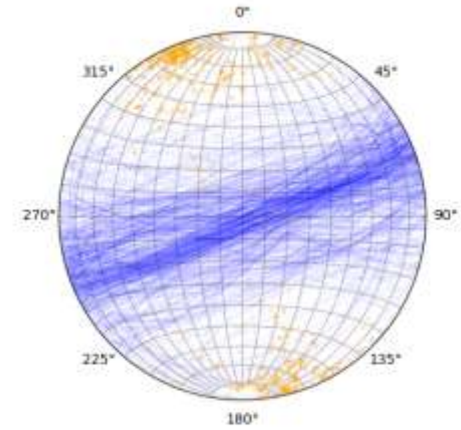
2021h



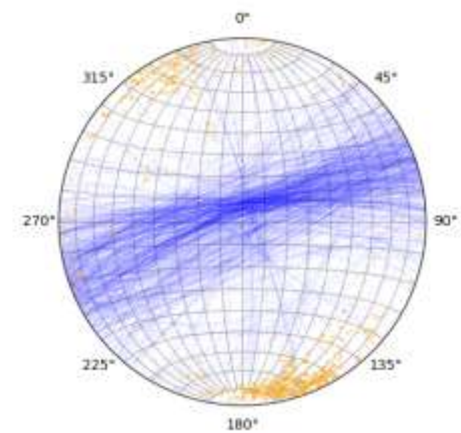
2022h



2023h



2024h

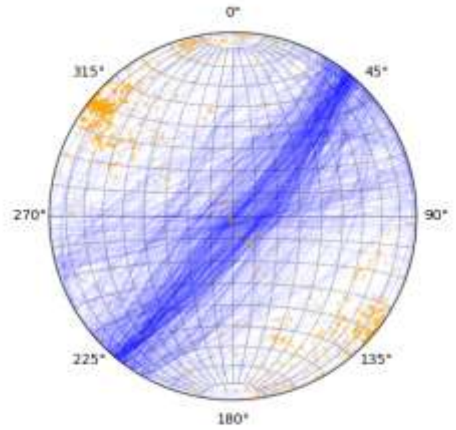


- Patented time space pattern recognition algorithm with outlier detection and noise removal
- Assesses the direction and organization of time sequential events

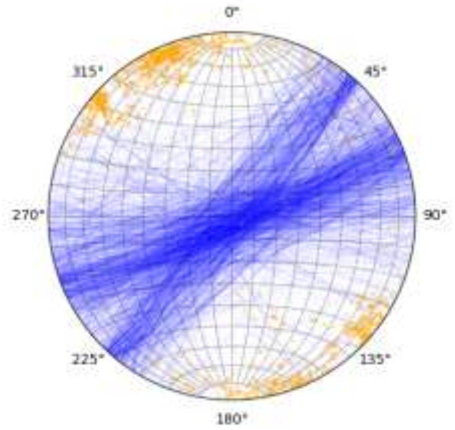
MicroSeismic

AMTI Summary – All Formations

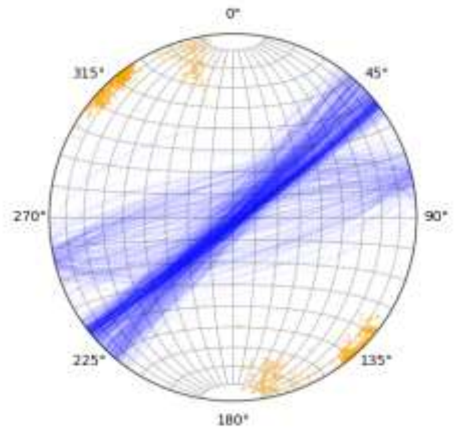
2021h



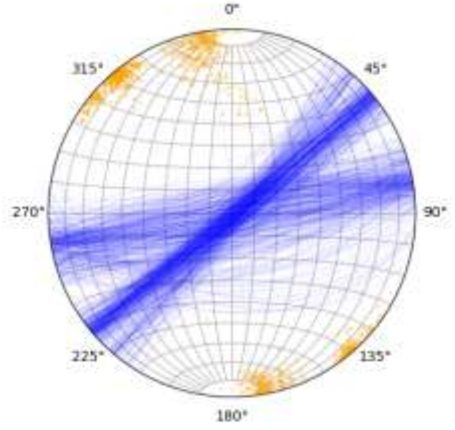
2023h



2022h



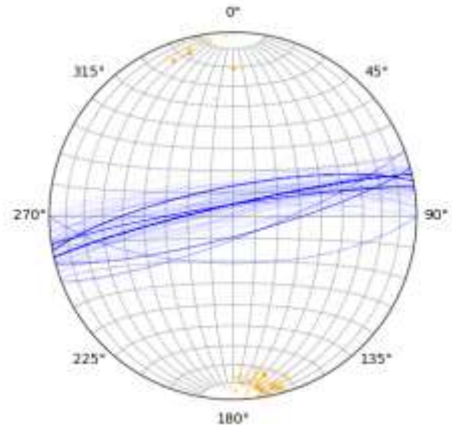
2024h



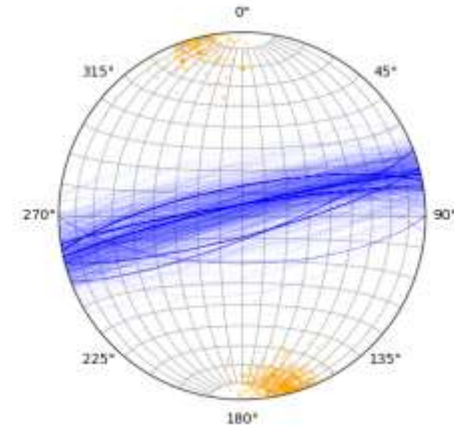
- Stereonet plot of the AutoMTI solutions
- Dominant focal mechanisms share orientations with the Fracture Propagation Analysis

AMTI Summary – Below Bonarda Top

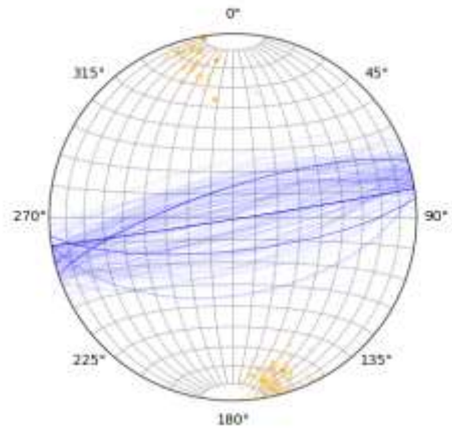
2021h



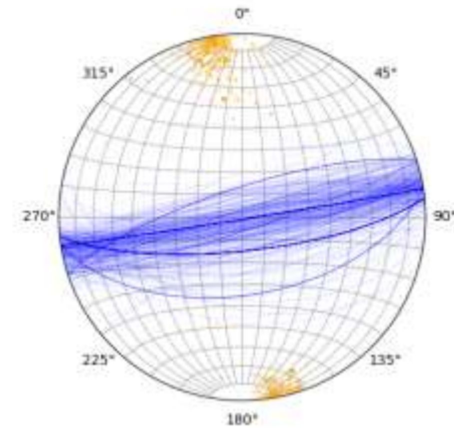
2023h



2022h



2024h

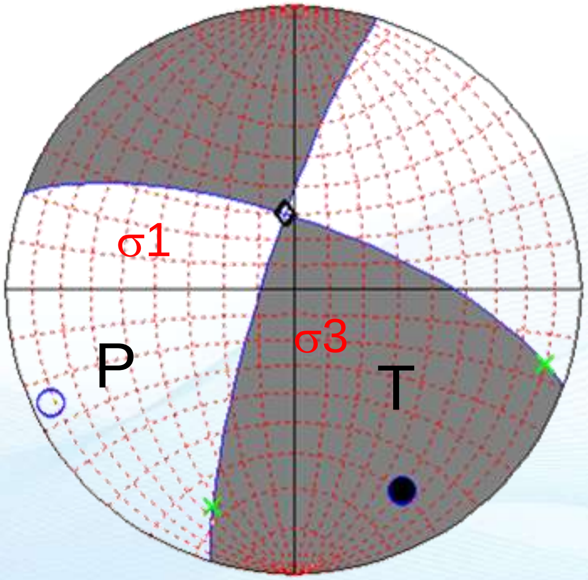


- Stereonet plot of the AutoMTI strike solutions

MicroSeismic

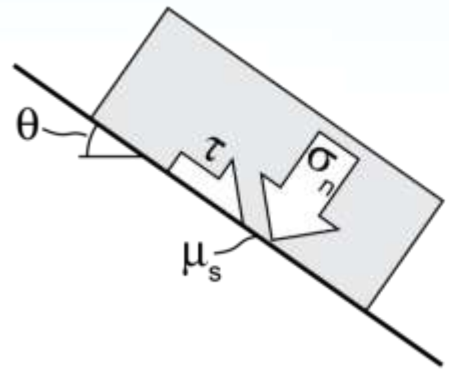
Focal Mechanism Solution

- The P- and T-axes inferred from a single fault plane solution may vary significantly from the principal stress directions, the only restriction that can be placed on the maximum principal stress is that it must be in the dilatational quadrant of the focal mechanism (McKenzie, 1969)
- The goal of a stress inversion is to find the stress state which minimizes the average difference between the observed slip vectors and the theoretical orientations of maximum shear stress on the faults (“misfit angle”)



Fracture Stress States

- Increasing fluid pressure drives Mohr circle to the left
- Fractures occur when driving forces exceed frictional forces or when the Mohr circle intersects the Frictional Sliding Envelope

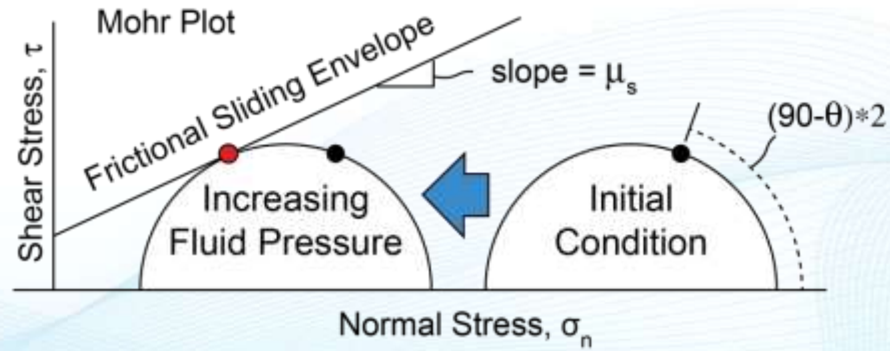


Mohr-Coulomb Criterion:

$$\tau = \mu_s \sigma_n + C_o$$

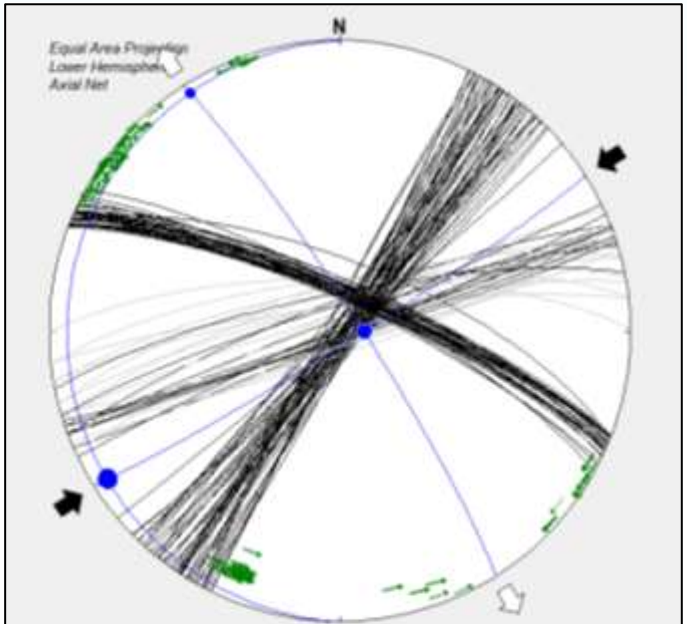
Failure occurs when:

$$\tau - \mu_s \sigma_n - C_o \geq 0$$



Wallace-Bott Hypothesis

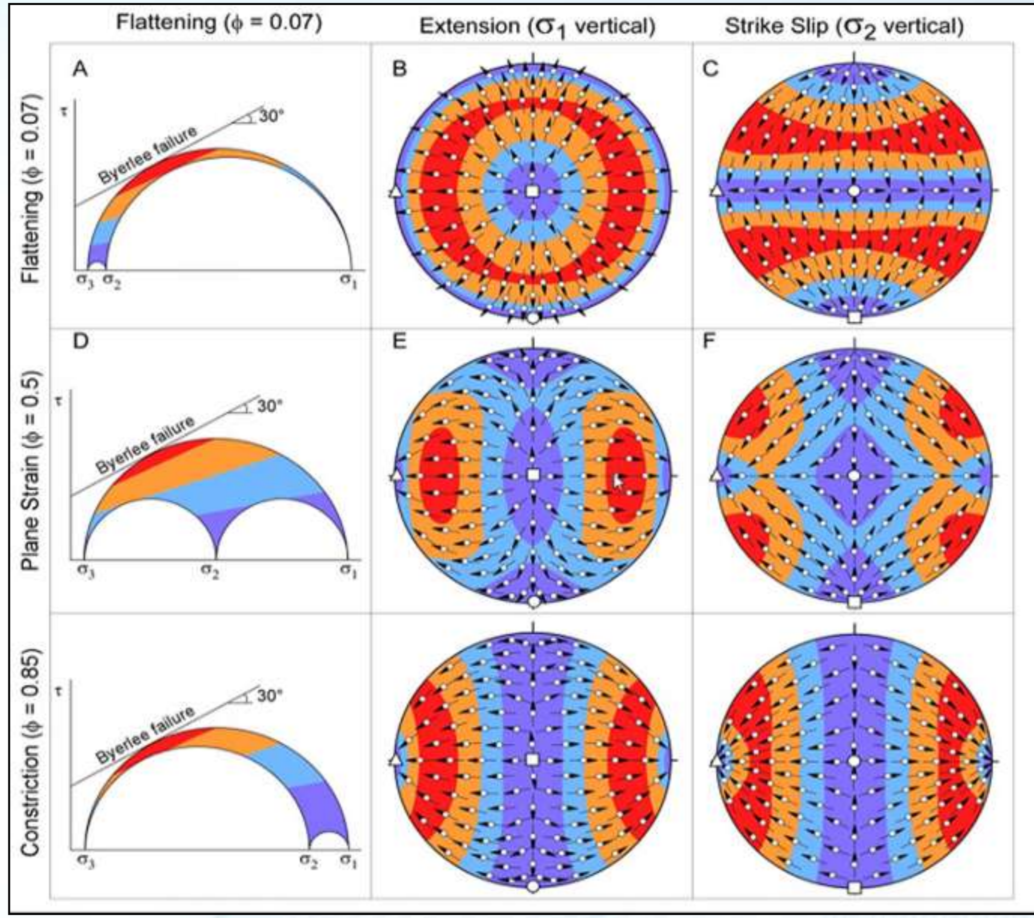
Example data – Sirah Fm, North Wells



Data points shown have lowest misfit angle to modeled stress state

▪ S_h ● S_V ● S_H

$$\phi = \frac{(\sigma 2 - \sigma 3)}{(\sigma 1 - \sigma 3)}$$

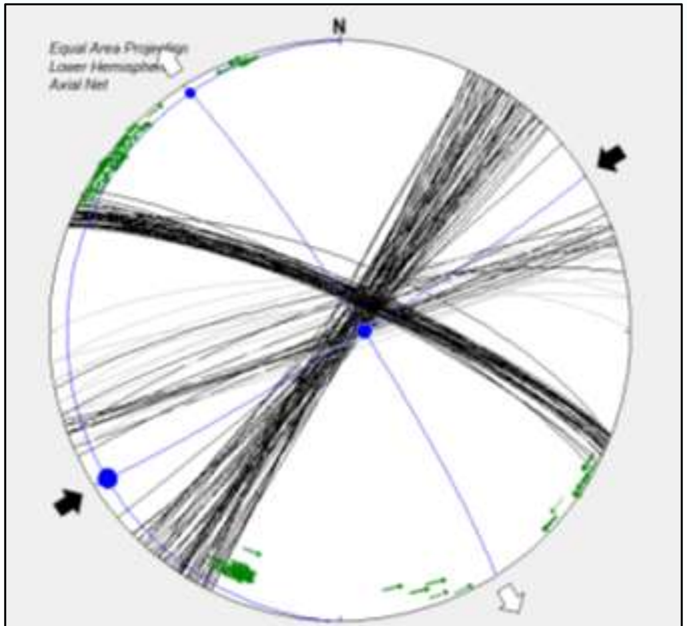


Based on Bott, 1959 and many others

- Inversion assumptions
  - Slip occurs parallel to maximum shear stress
  - Stress is uniform in region of study
  - Slip occurs on pre-existing faults or fracture planes

Sirah Formation – North Wells

Example data – Sirah Fm, North Wells

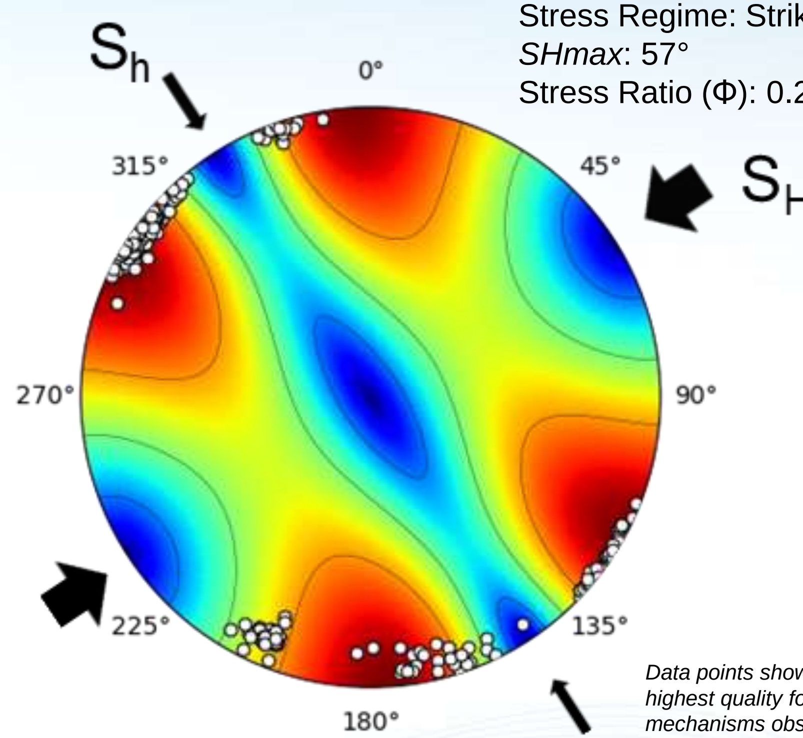


Data points shown have lowest misfit angle to modeled stress state

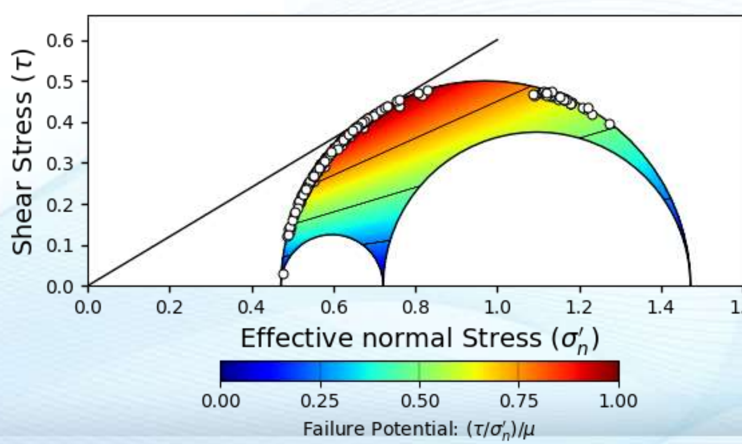
▪ S_h ● S_V ● S_H

- Slip linear vectors (green)
  - Located at poles to fracture plane strike and dip
  - Individual vector oriented in direction of fracture plane slip (rake)
  - Population of vectors point to modelled minimum horizontal stress location on stereonet (S_h)

Stress Regime: Strike Slip
SHmax: 57°
Stress Ratio (Φ): 0.25



Data points shown are highest quality focal mechanisms observed on North wells in Sirah Fm.

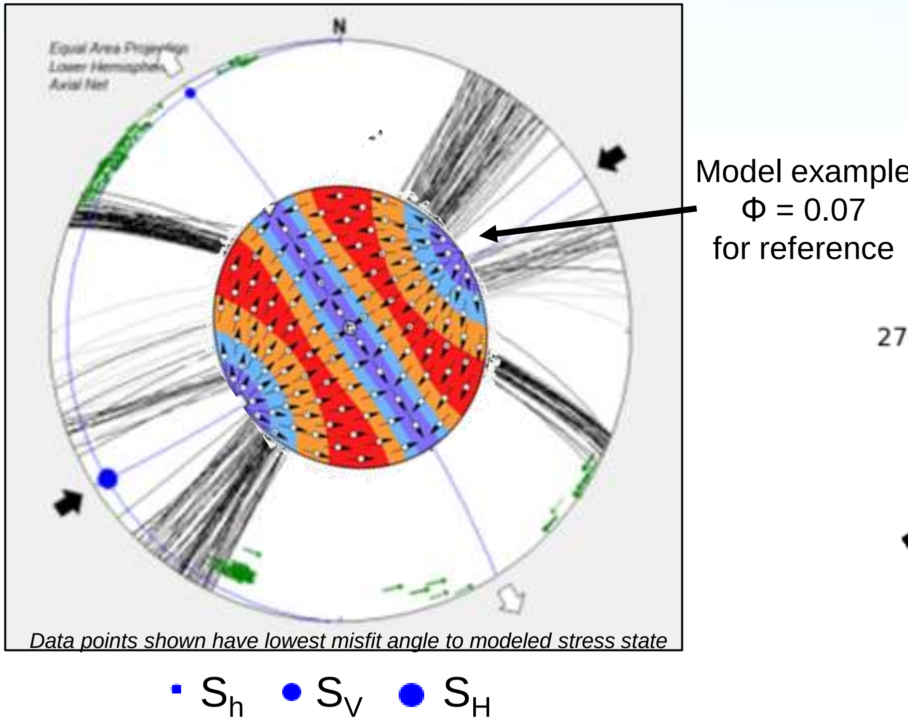


$$\phi = \frac{(\sigma 2 - \sigma 3)}{(\sigma 1 - \sigma 3)}$$

MicroSeismic

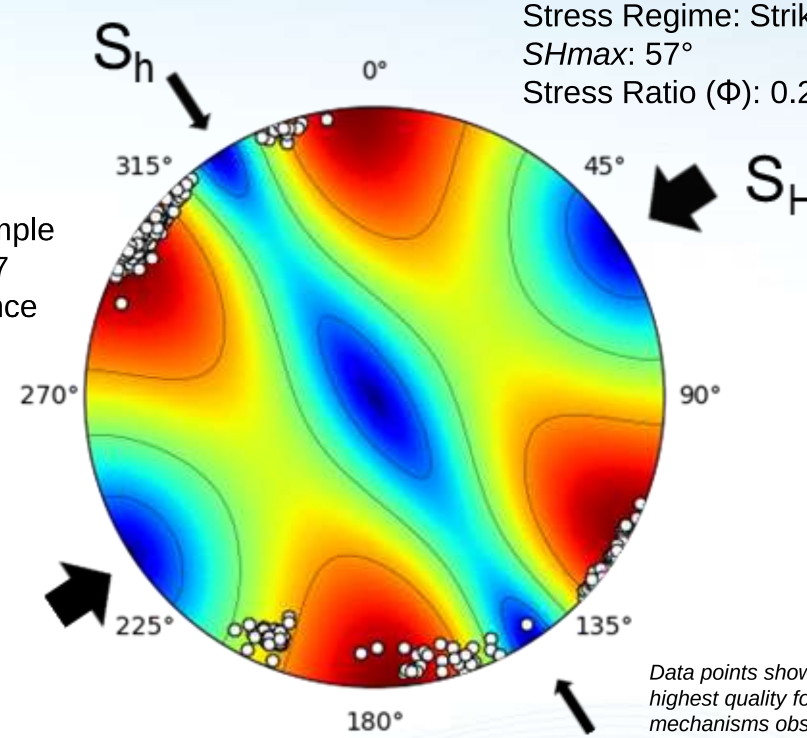
Sirah Formation – North Wells

Example data – Sirah Fm, North Wells



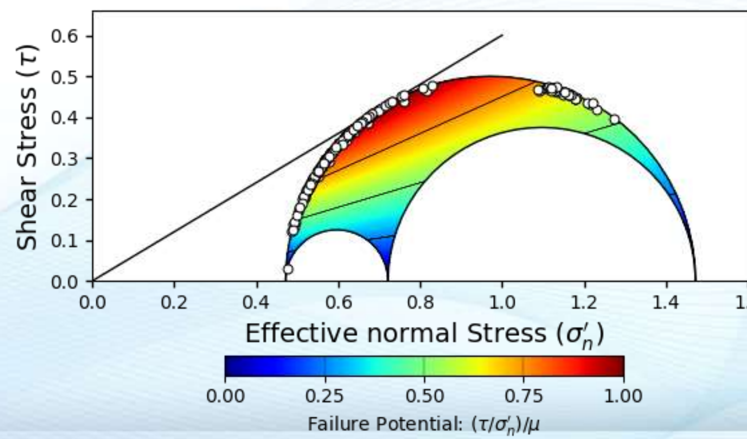
Data points shown have lowest misfit angle to modeled stress state

Stress Regime: Strike Slip
SHmax: 57°
Stress Ratio (Φ): 0.25



Data points shown are highest quality focal mechanisms observed on North wells in Sirah Fm.

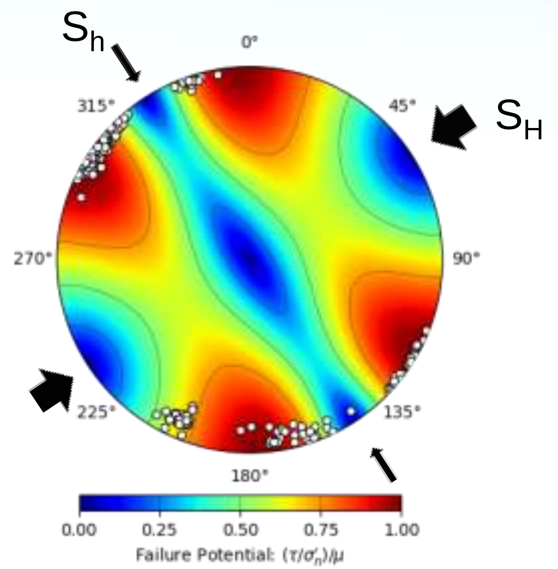
- Stress Inversion Model
  - Principle stress orientation
    - Strikes-slip stress regime defined by predominance of strike slip mechanisms on steeply dipping planes
    - S_h-min point located along slip reversal plane
  - Stress ratio (Φ)
    - Observed slip vectors match model slip to determine Φ

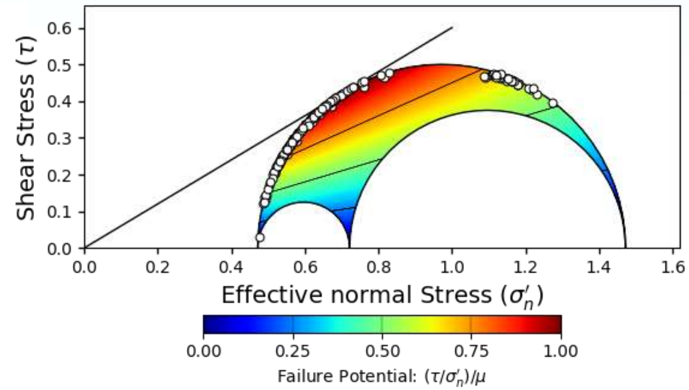


$$\phi = \frac{(\sigma 2 - \sigma 3)}{(\sigma 1 - \sigma 3)}$$

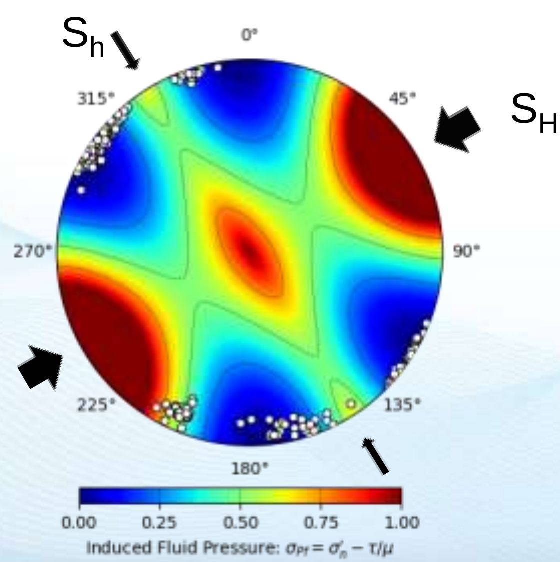
MicroSeismic

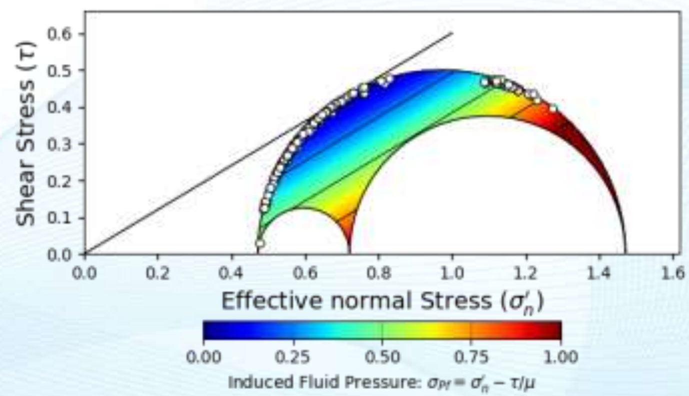
Sirah – North Pad





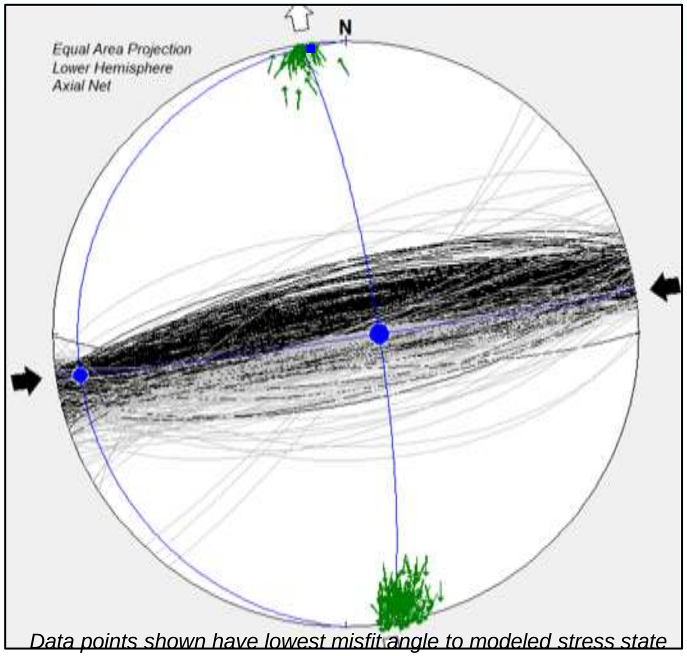
Stress Regime: Strike Slip
SHmax: 57°
Stress Ratio (Φ): 0.25



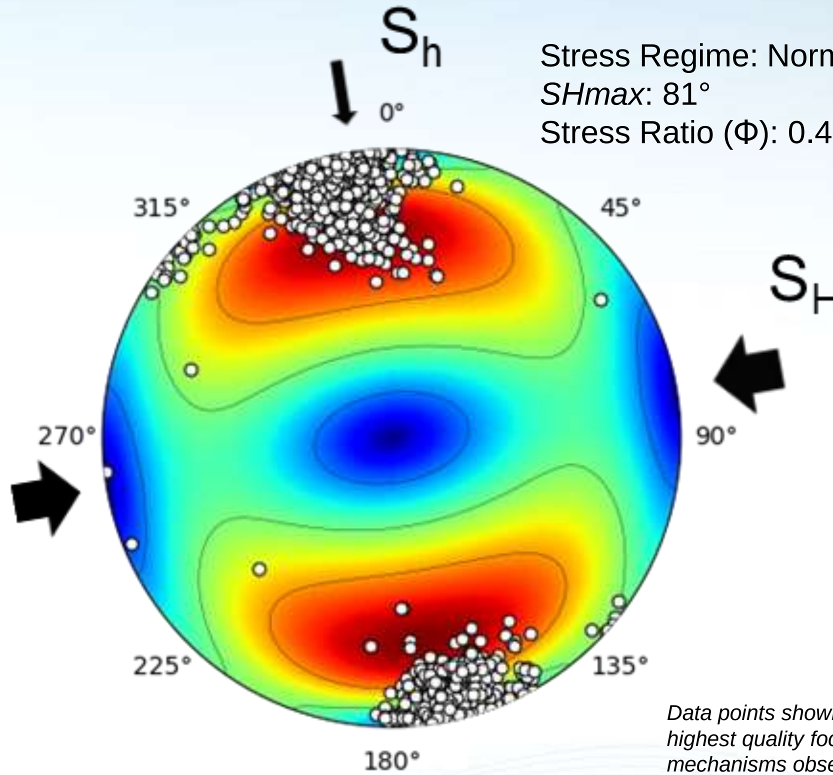


Bonarda Formation – South Wells

Example data – Bonarda Fm, South Wells



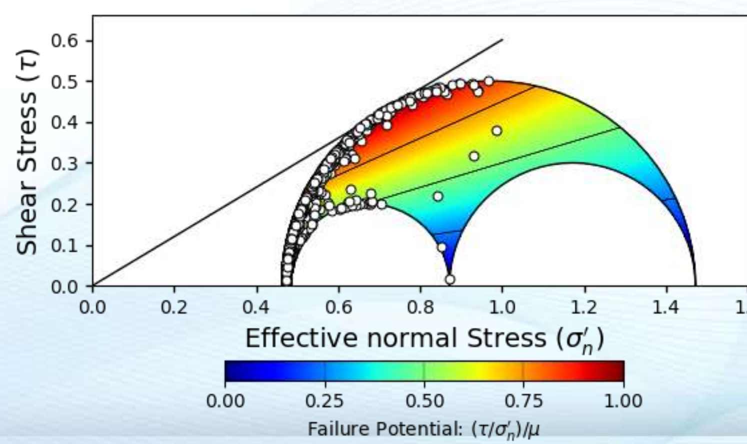
S_h • S_V • S_H



Stress Regime: Normal
SHmax: 81°
Stress Ratio (Φ): 0.49

Data points shown are highest quality focal mechanisms observed on South wells in Bonarda Fm.

- Stress Inversion Model
  - Principle stress orientation
    - Normal stress regime defined by predominance of normal dip-slip mechanisms on steeply dipping planes
    - S_h-min point located along slip reversal plane
  - Stress ratio (Φ)
    - Observed slip vectors match model slip to determine Φ

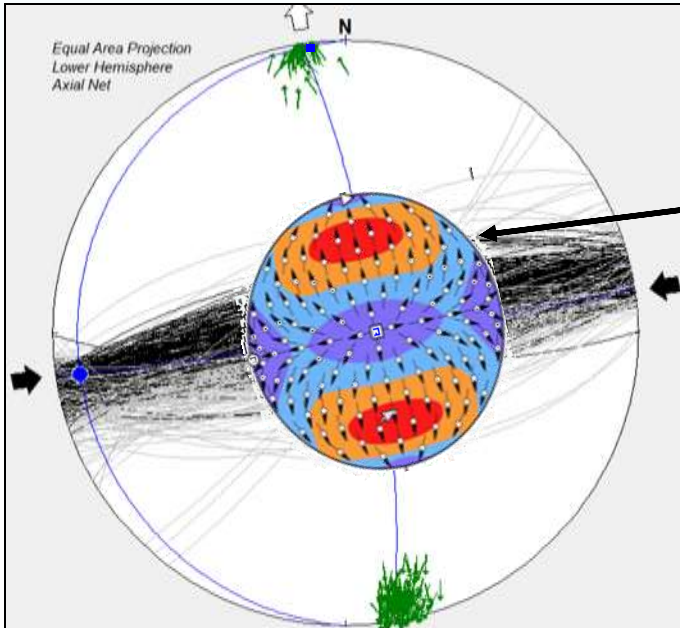


$$\phi = \frac{(\sigma 2 - \sigma 3)}{(\sigma 1 - \sigma 3)}$$

MicroSeismic

Bonarda Formation – South Wells

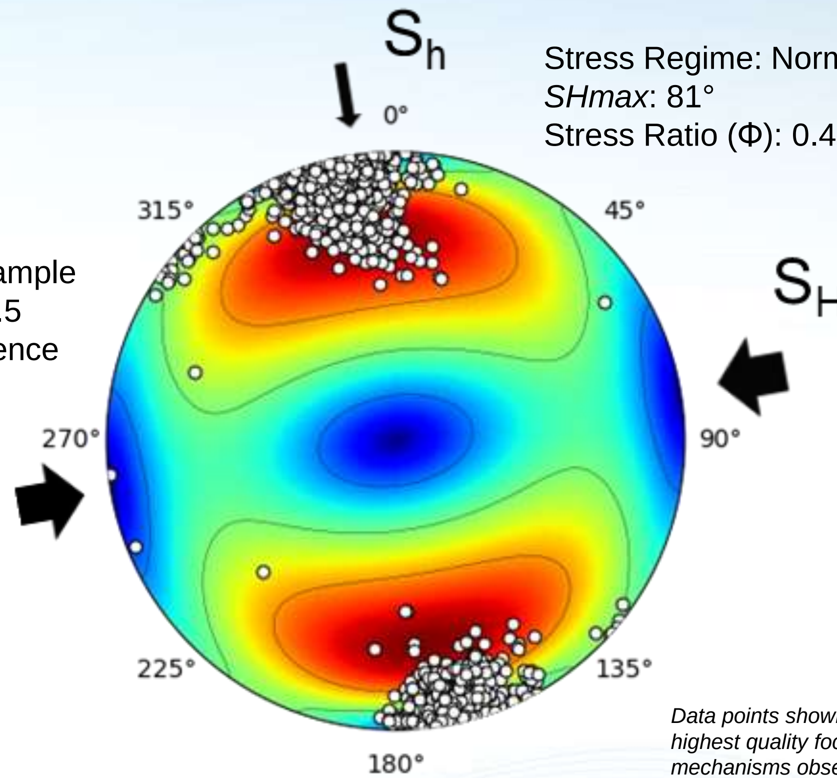
Example data – Bonarda Fm, South Wells



Data points shown have lowest misfit angle to modeled stress state

▪ S_h ● S_V ● S_H

Model example
$\Phi = 0.5$
for reference



Stress Regime: Normal
SHmax: 81°
Stress Ratio (Φ): 0.49

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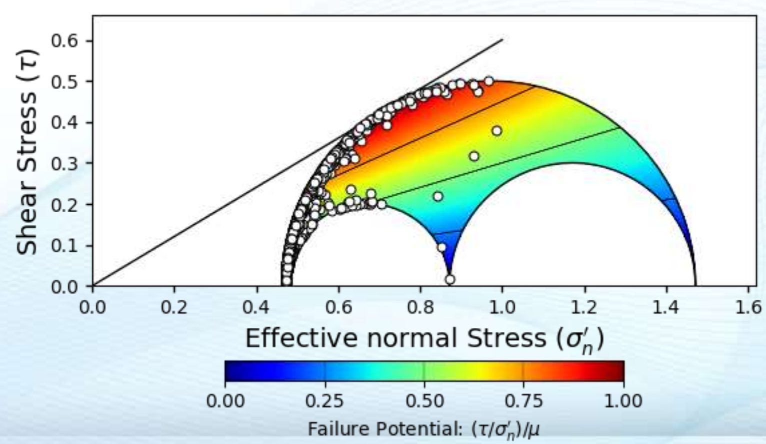
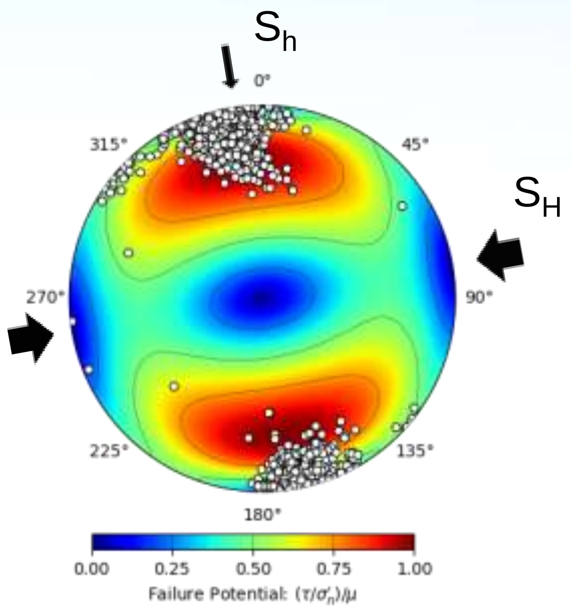
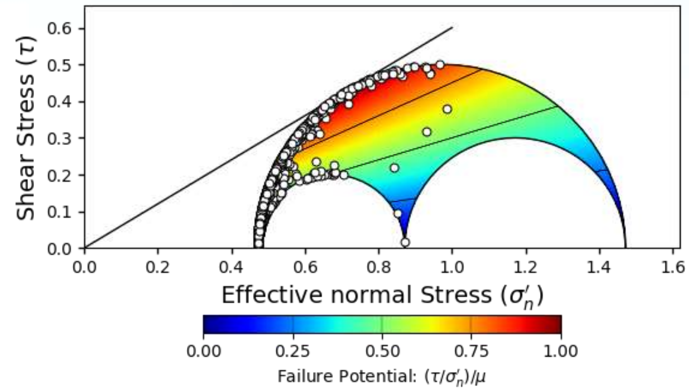


$$\phi = \frac{(\sigma 2 - \sigma 3)}{(\sigma 1 - \sigma 3)}$$

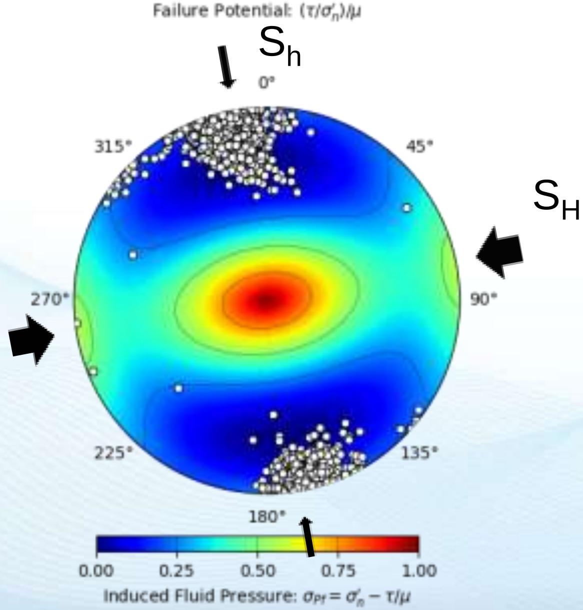
MicroSeismic

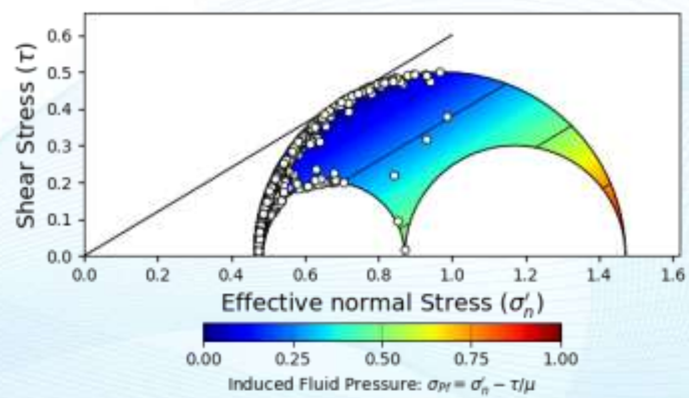
Bonarda – South Pad



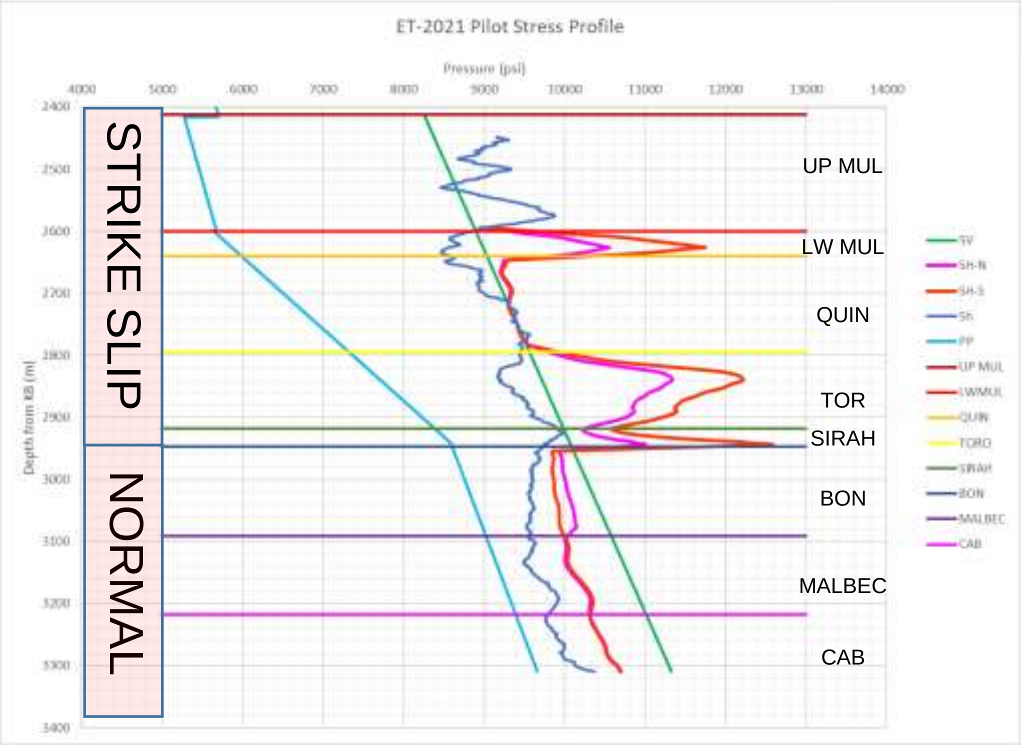


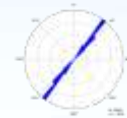
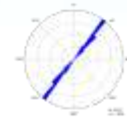
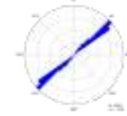
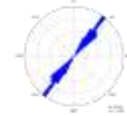
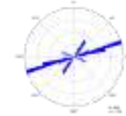
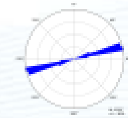
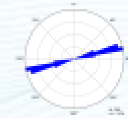
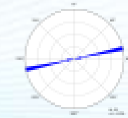
Stress Regime: Normal
SHmax: 81°
Stress Ratio (Φ): 0.49





Stress Inversion Results



Formation	Fracture Strike	Pad	SH_{max}	Φ
UP MULICHINCO		North	81°	0.25
		South	-	-
LW MULICHINCO		North	81°	0.21
		South	82°	0.14
QUINTUCO		North	66°	0.67
		South	66°	0.77
TORRONTES		North	60°	0.24
		South	62°	0.39
SIRAH		North	57°	0.25
		South	59°	0.11
BONARDA		North	84°	0.61
		South	81°	0.49
MALBEC		North	80°	0.40
		South	81°	0.43
CABERNET		North	81°	0.44
		South	-	-

Stress ratio, Φ

$$\Phi = \frac{\sigma_2 - \sigma_3}{\sigma_1 - \sigma_3}$$

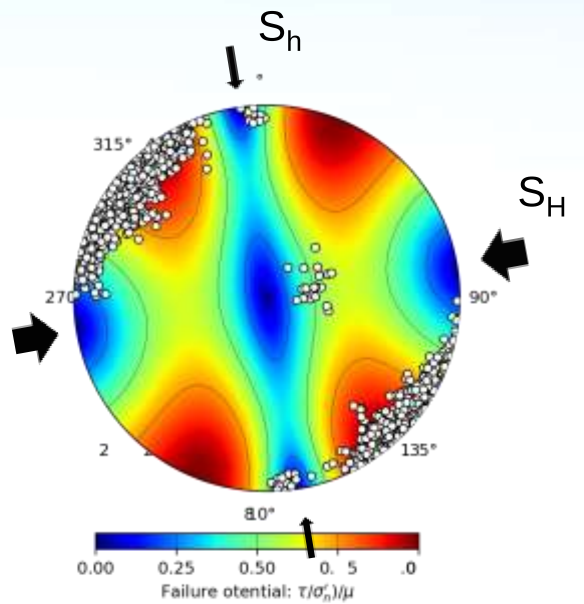
Assuming strike-slip stress regime

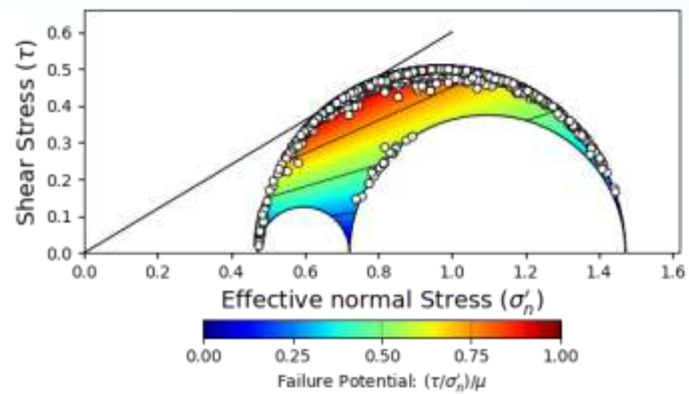
$$SH_{max} = \sigma_1 = \frac{\sigma_2 - \sigma_3}{\Phi} + \sigma_3$$

Assuming normal stress regime

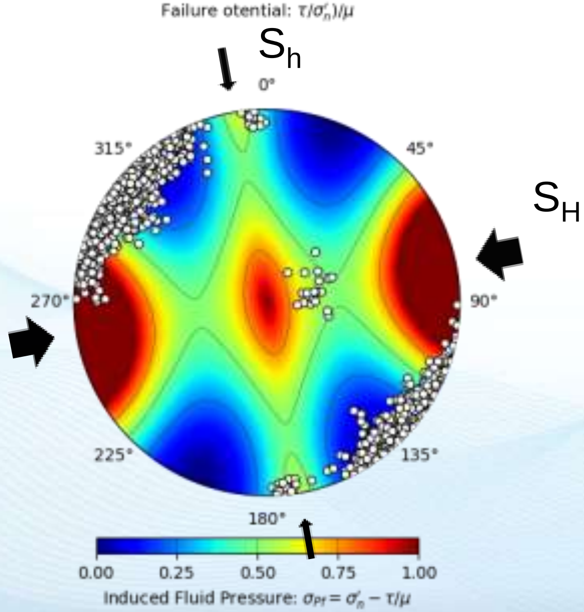
$$SH_{max} = \sigma_2 = \Phi(\sigma_1 - \sigma_3) + \sigma_3$$

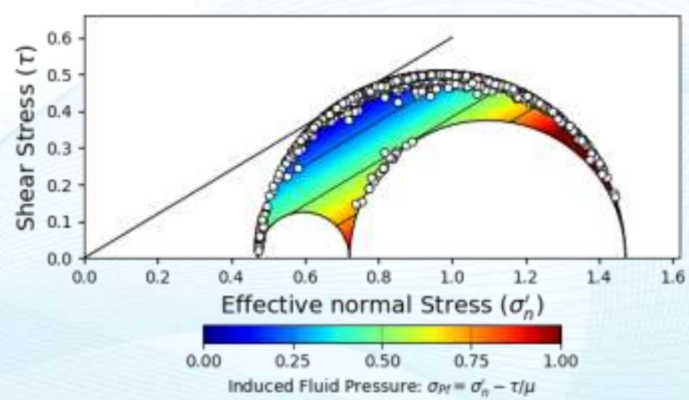
Upper Mulichinco – North Pad



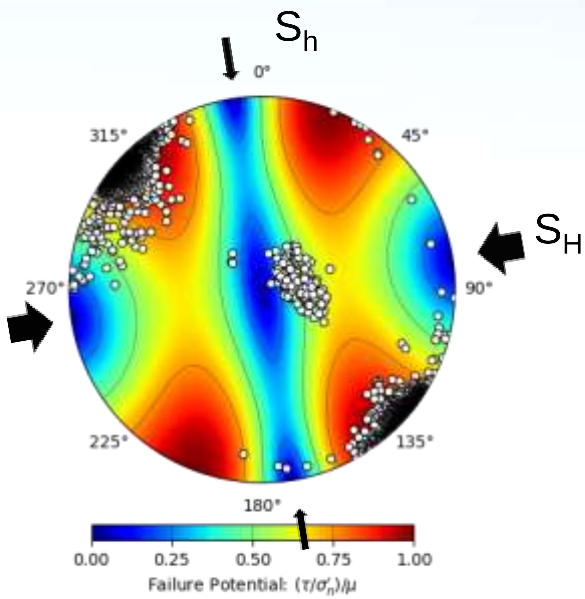


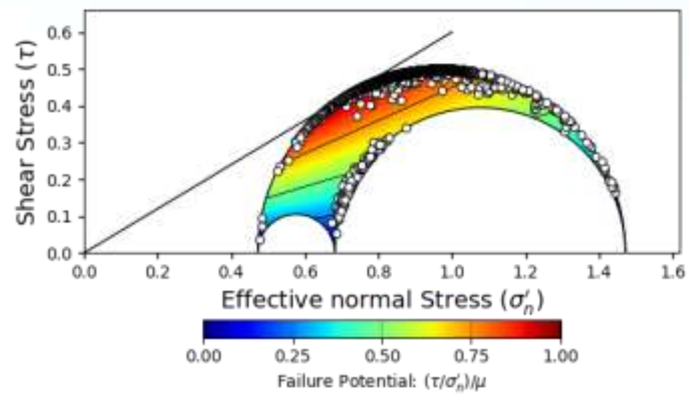
Stress Regime: Strike Slip
SHmax: 81°
Stress Ratio (Φ): 0.25

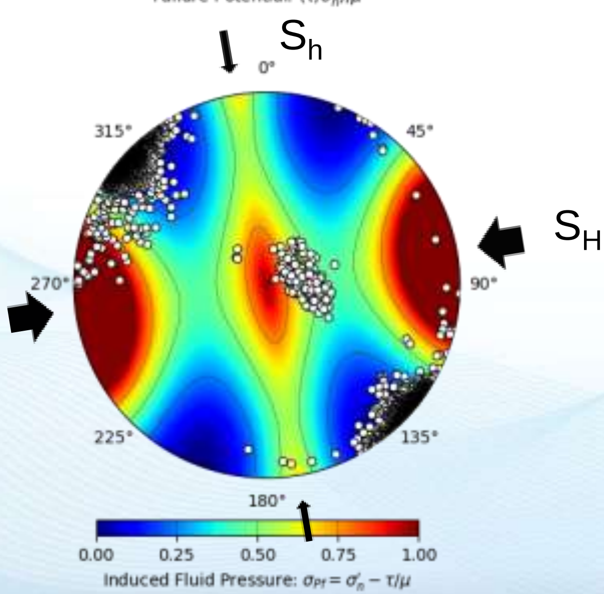




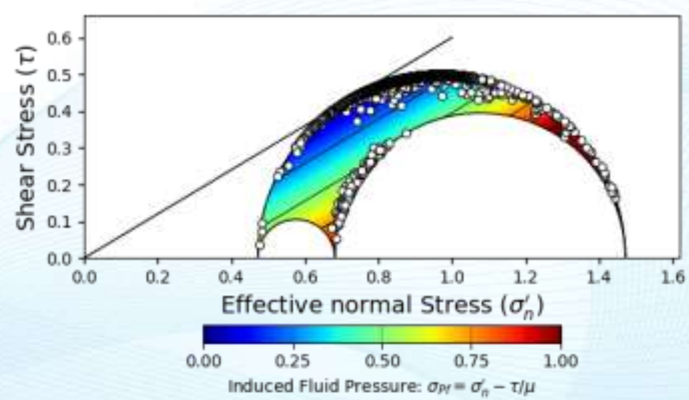
Lower Mulichinco – North Pad





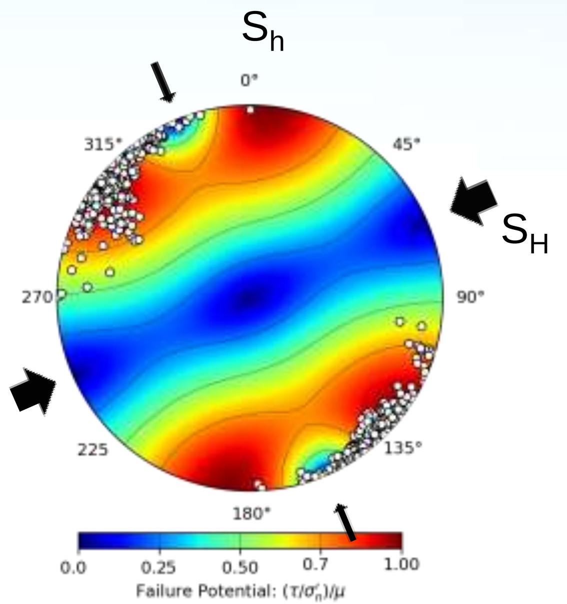


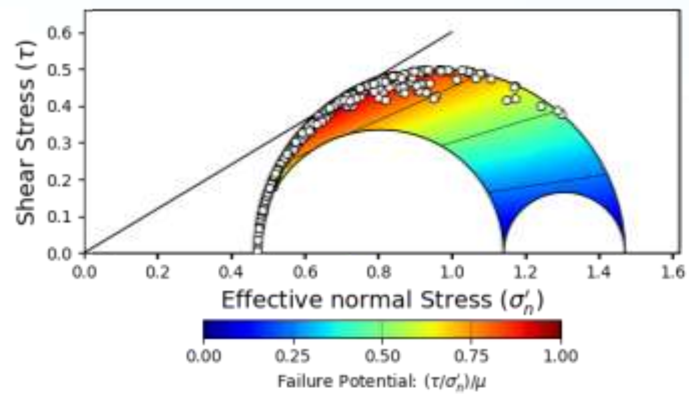
Stress Regime: Strike Slip
SHmax: 81°
Stress Ratio (Φ): 0.21

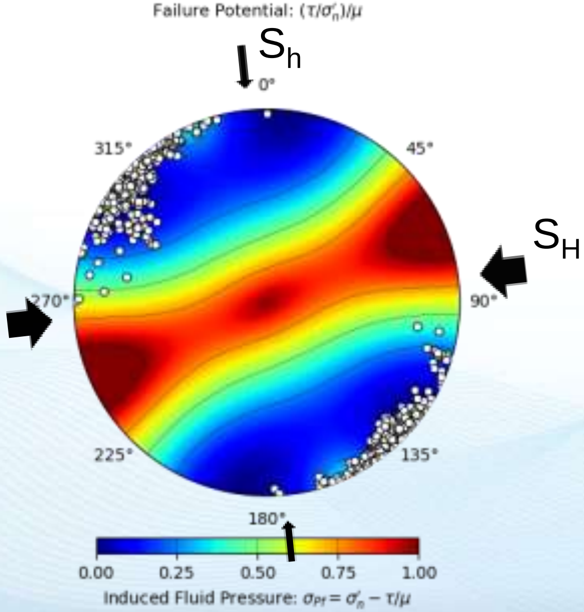


MicroSeismic

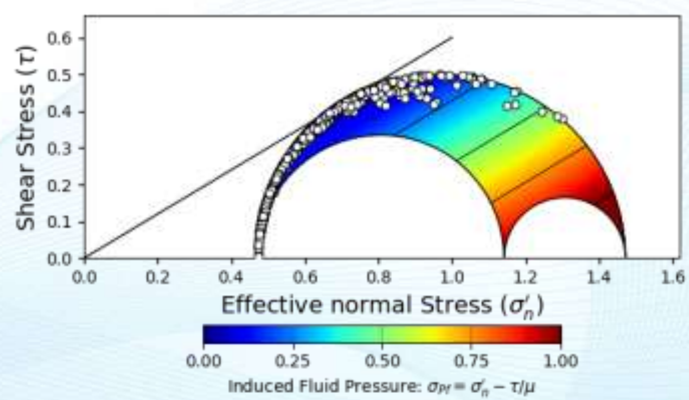
Quintuco – North Pad





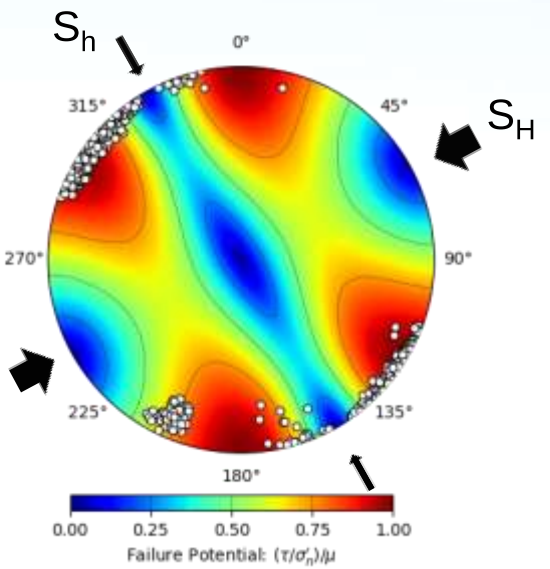


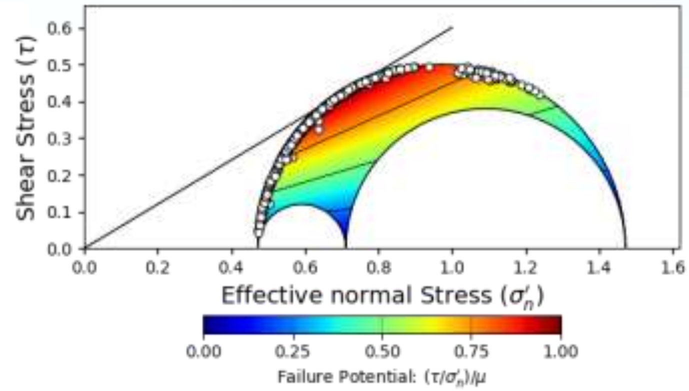
Stress Regime: Strike Slip
SHmax: 66°
Stress Ratio (Φ): 0.67



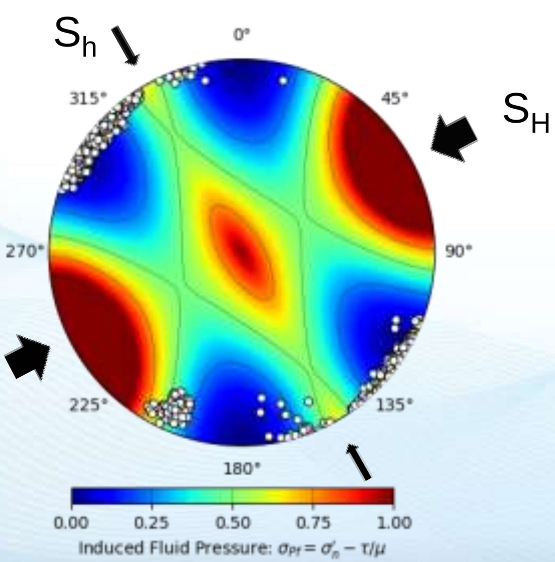
MicroSeismic

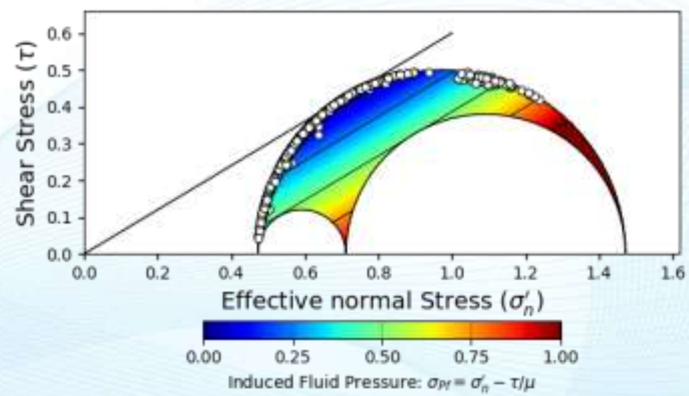
Torrontes – North Pad





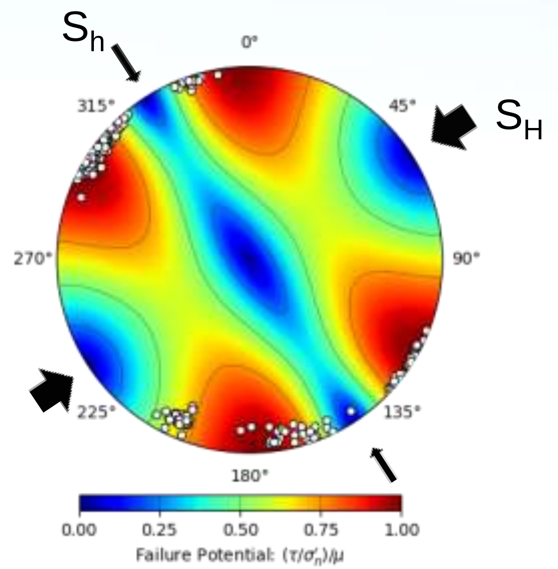
Stress Regime: Strike Slip
SHmax: 60°
Stress Ratio (Φ): 0.24

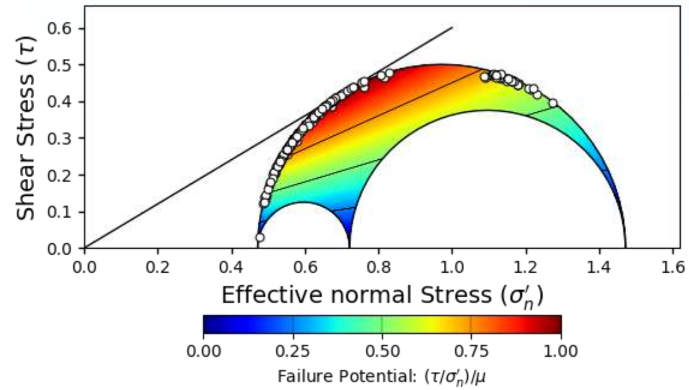




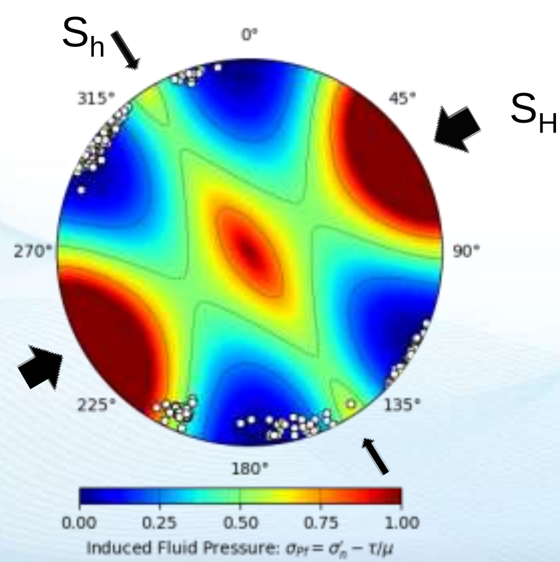
MicroSeismic

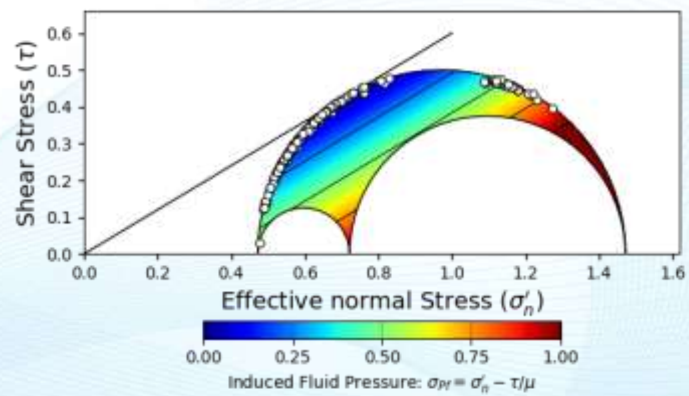
Sirah – North Pad



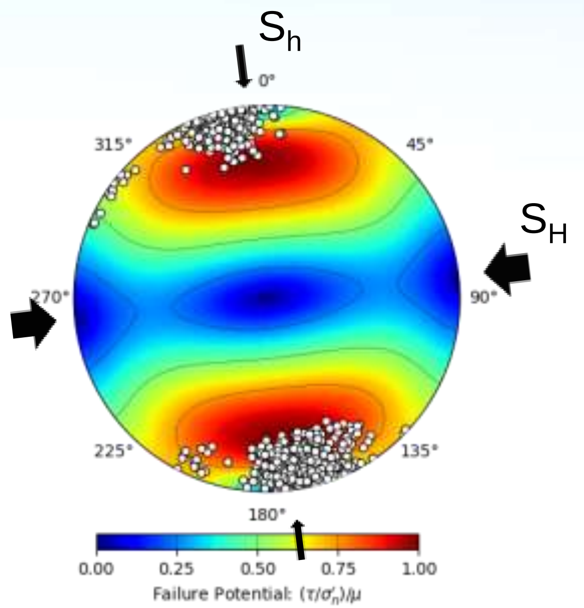


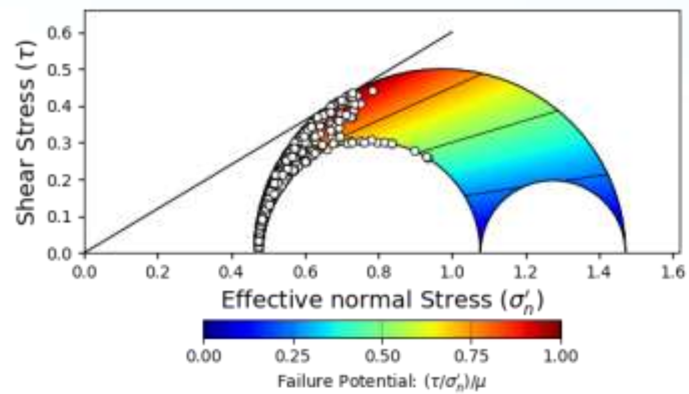
Stress Regime: Strike Slip
SHmax: 57°
Stress Ratio (Φ): 0.25



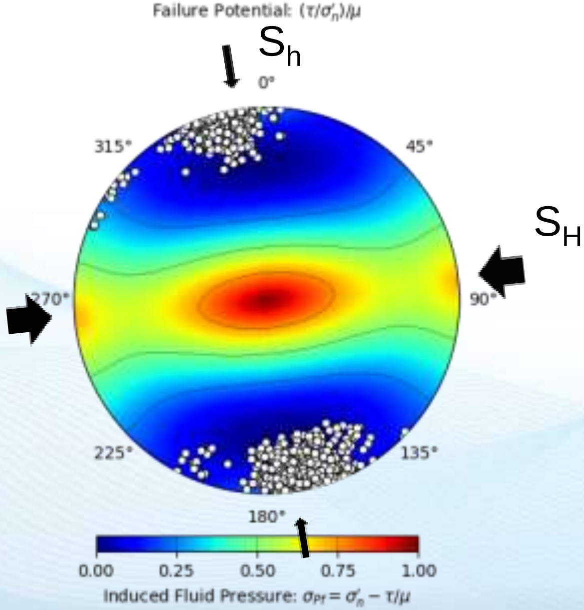


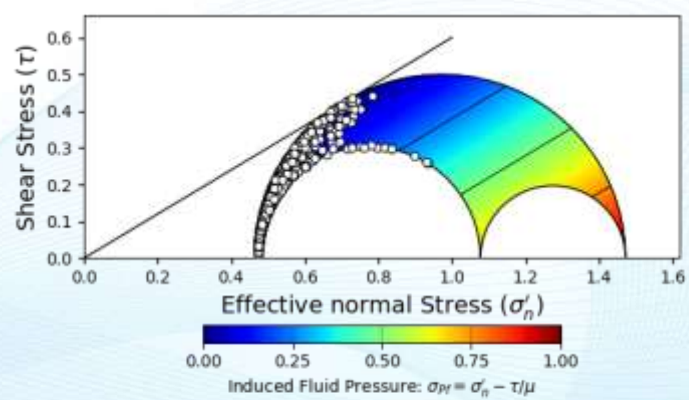
Bonarda – North Pad





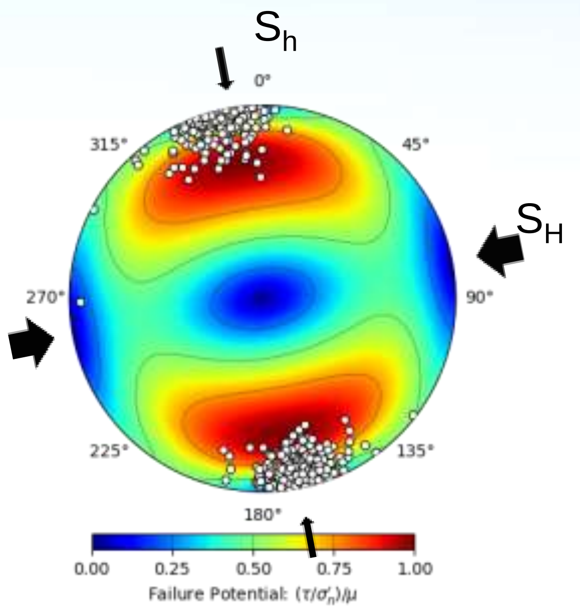
Stress Regime: Normal
SHmax: 84°
Stress Ratio (Φ): 0.61

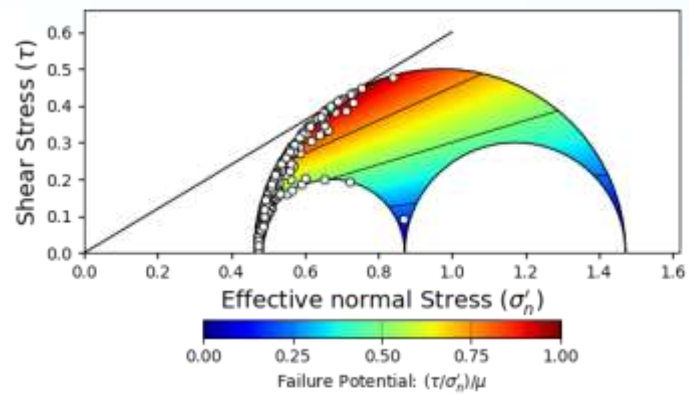




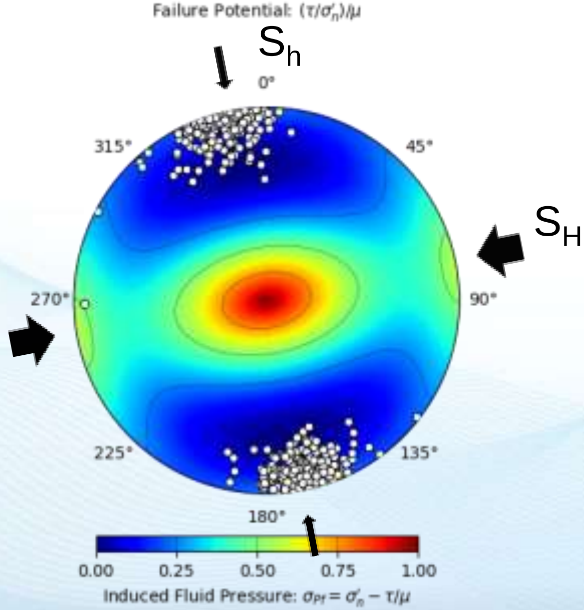
MicroSeismic

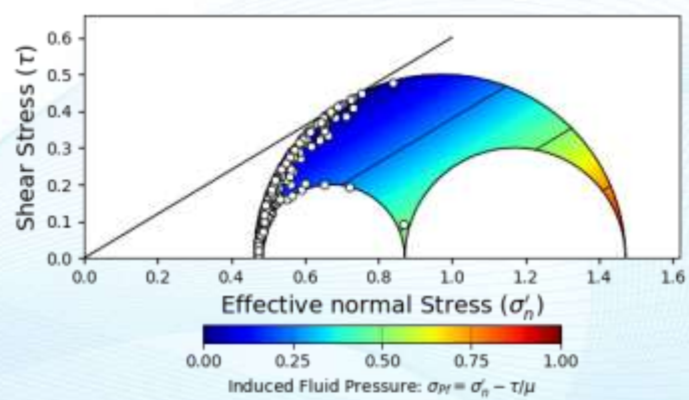
Malbec – North Pad





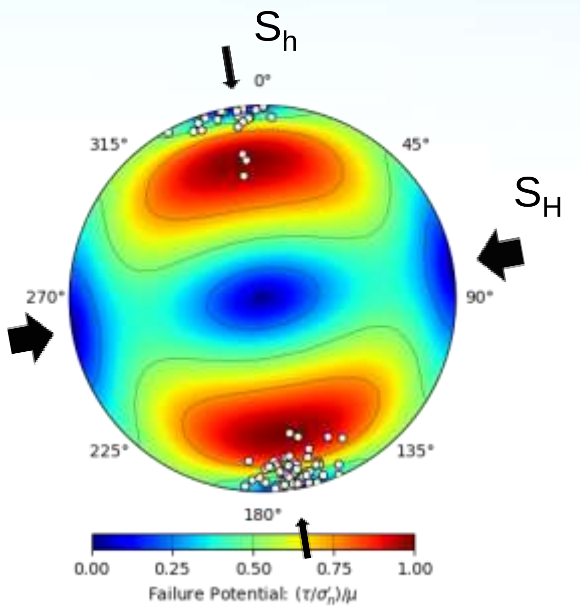
Stress Regime: Normal
SHmax: 80°
Stress Ratio (Φ): 0.40

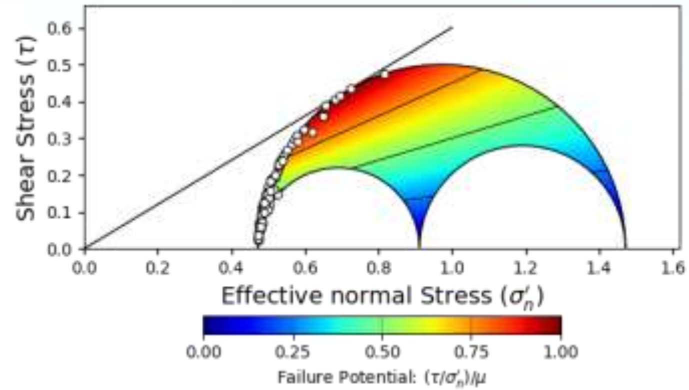




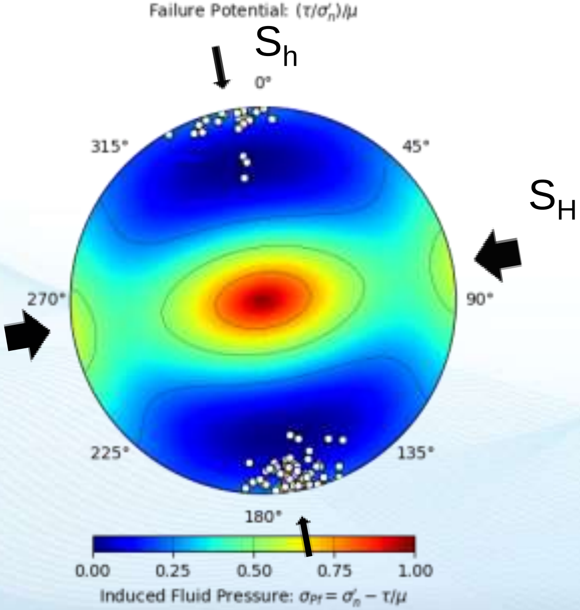
MicroSeismic

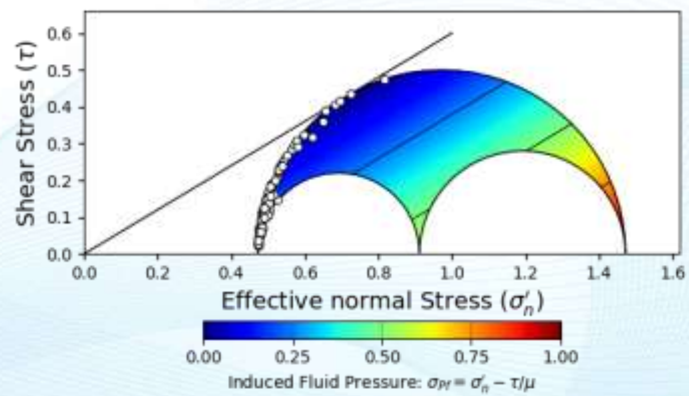
Cabernet – North Pad





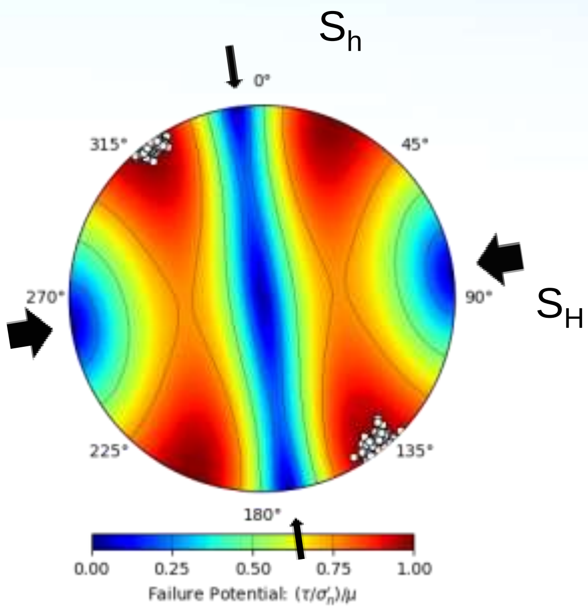
Stress Regime: Normal
SHmax: 81°
Stress Ratio (Φ): 0.44

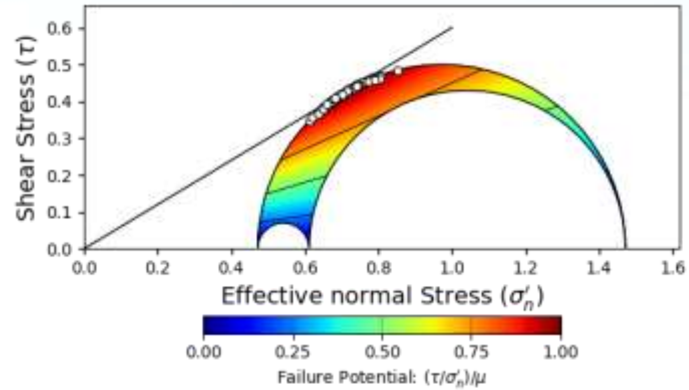




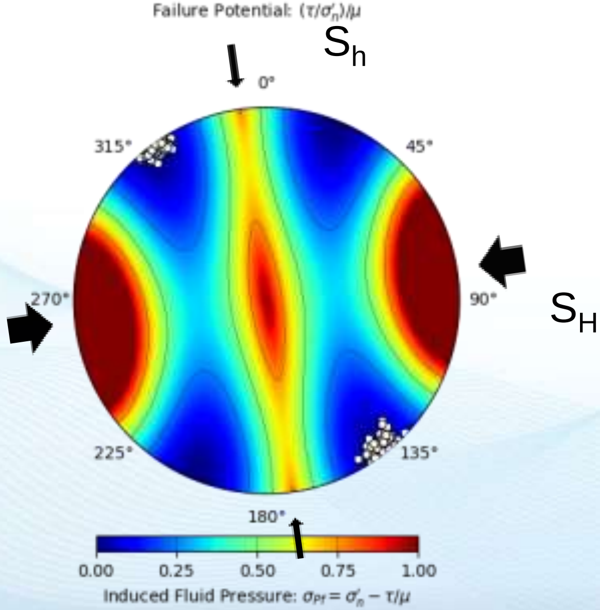
MicroSeismic

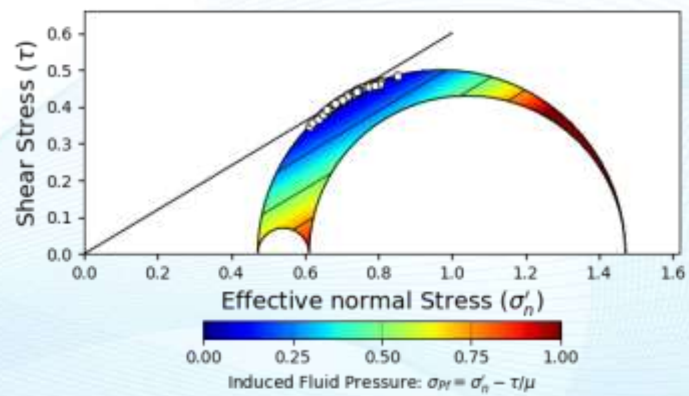
Lower Mulichinco – South Pad





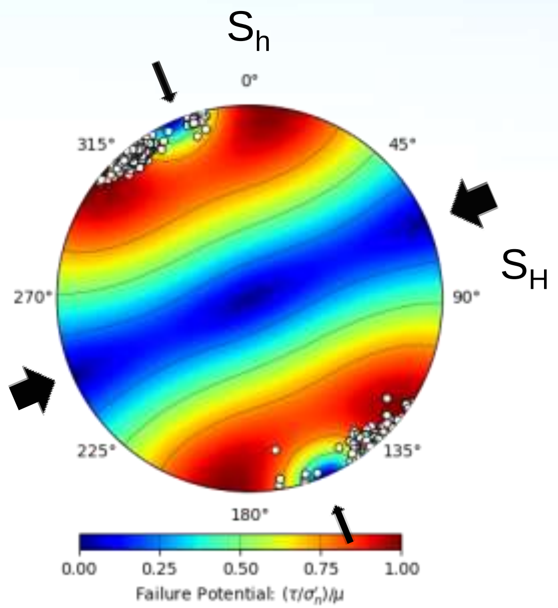
Stress Regime: Strike Slip
SHmax: 82°
Stress Ratio (Φ): 0.14

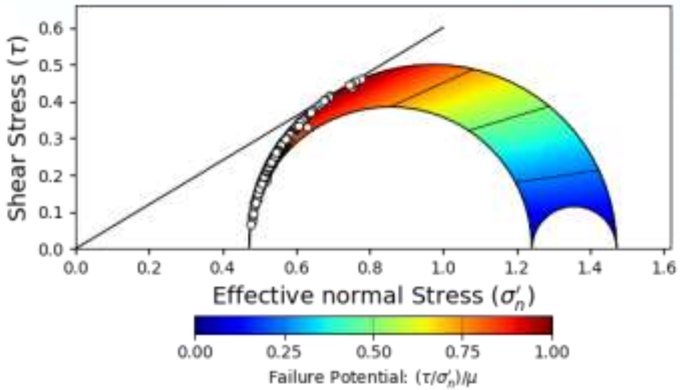




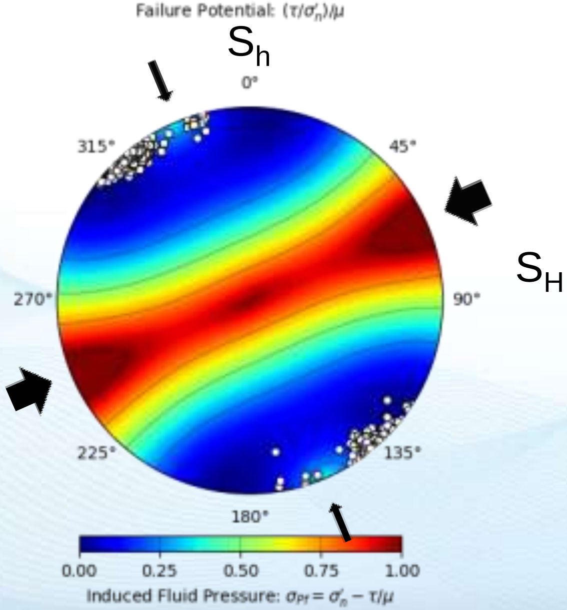
MicroSeismic

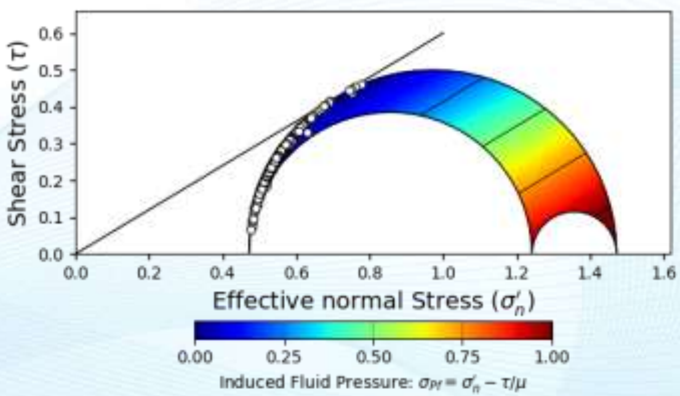
Quintuco – South Pad



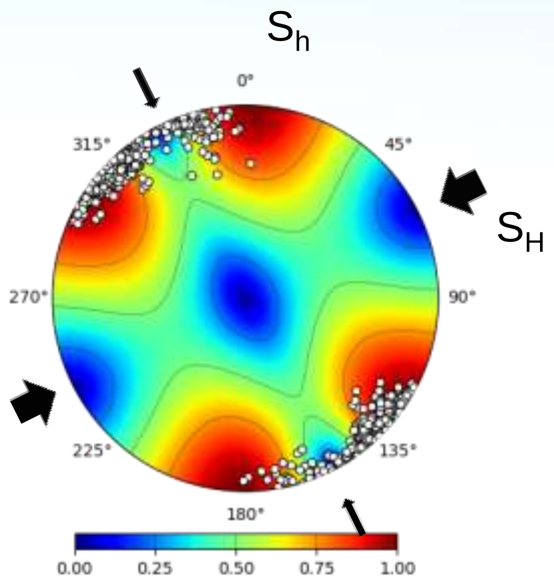


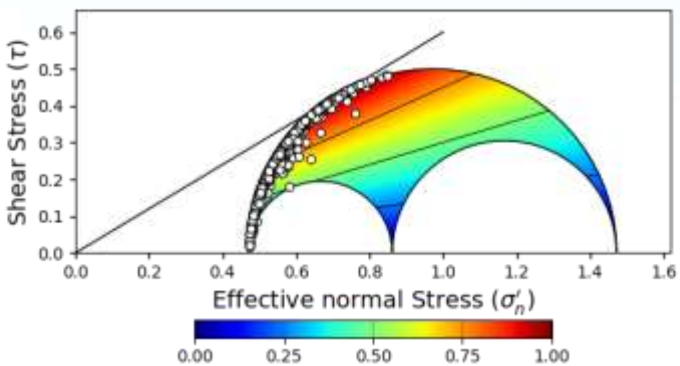
Stress Regime: Strike Slip
SHmax: 66°
Stress Ratio (Φ): 0.77

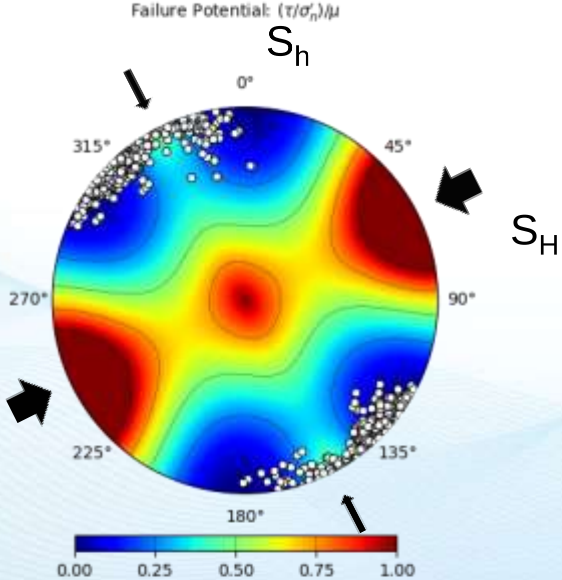




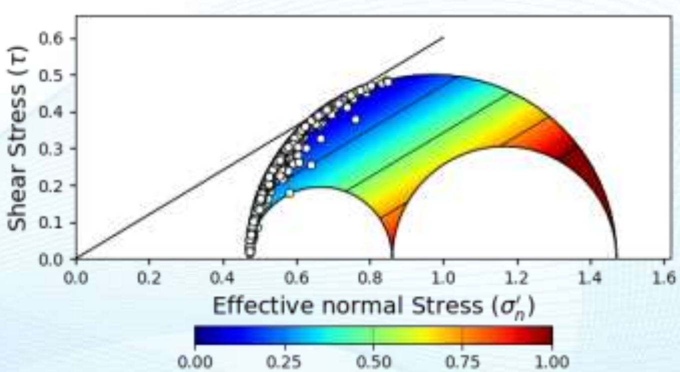
Torrontes – South Pad



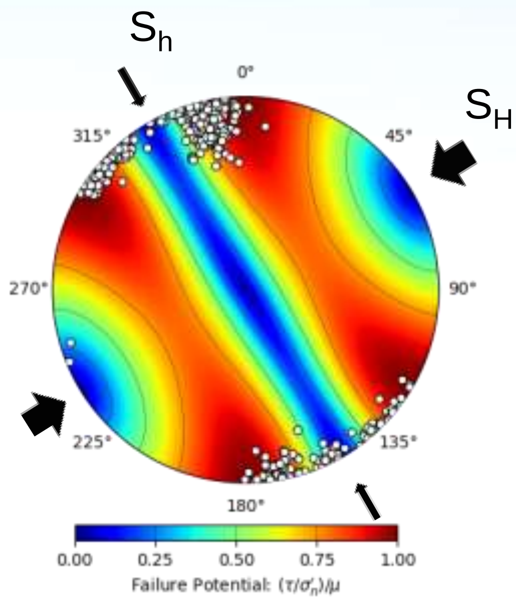


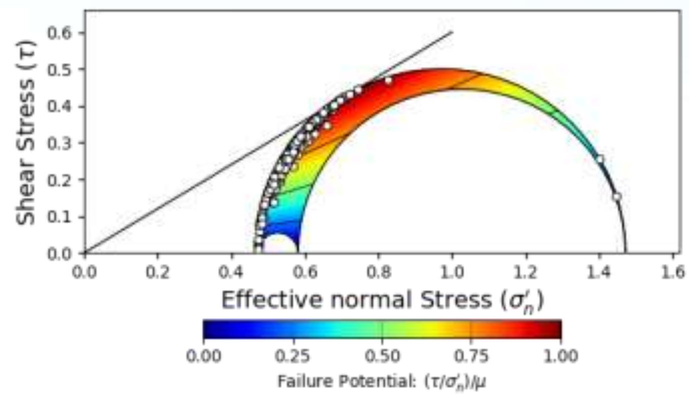


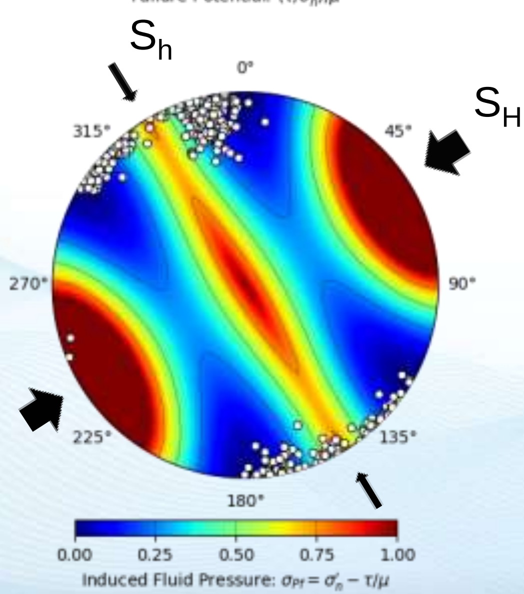
Stress Regime: Strike Slip
SHmax: 62°
Stress Ratio (Φ): 0.39



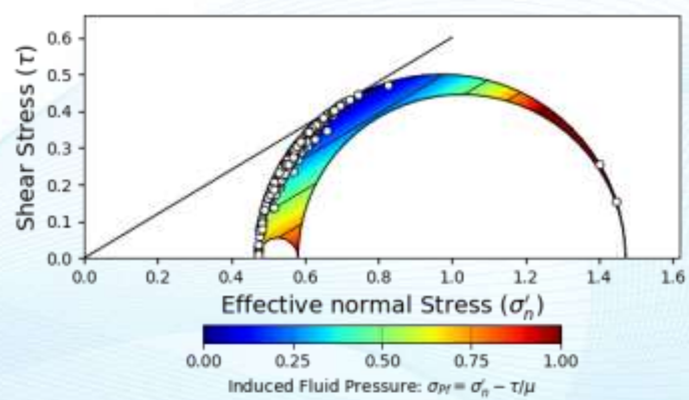
Sirah – South Pad



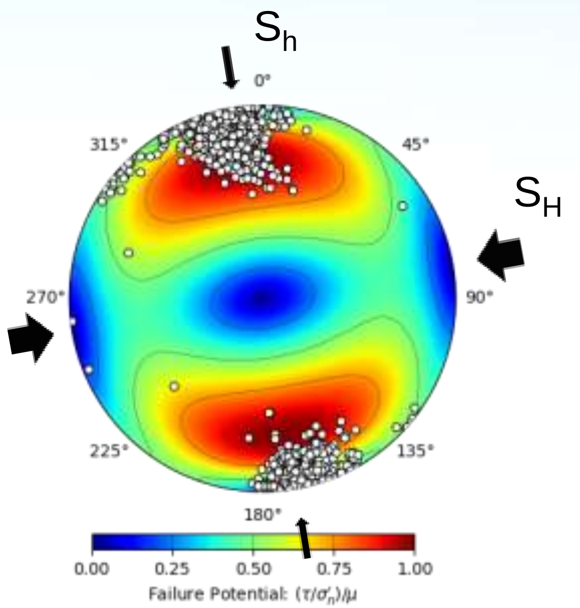


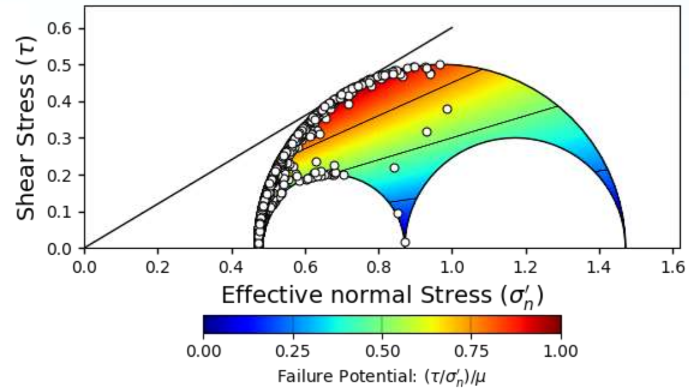


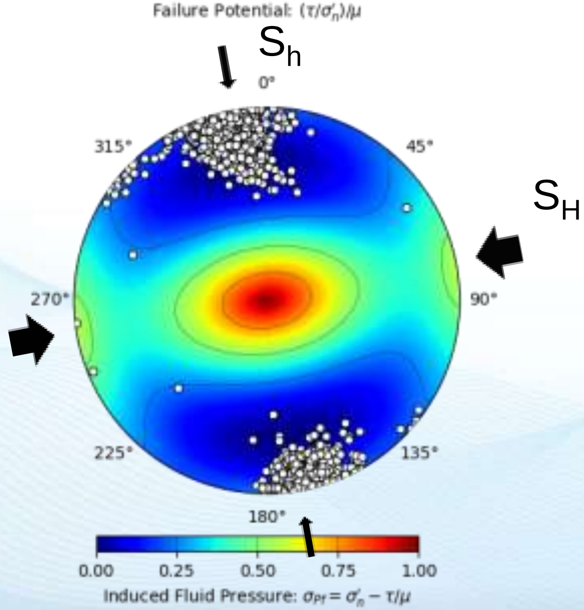
Stress Regime: Strike Slip
SHmax: 59°
Stress Ratio (Φ): 0.11



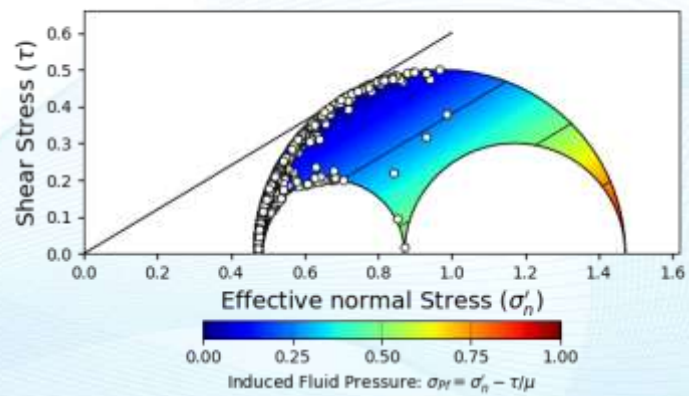
Bonarda – South Pad



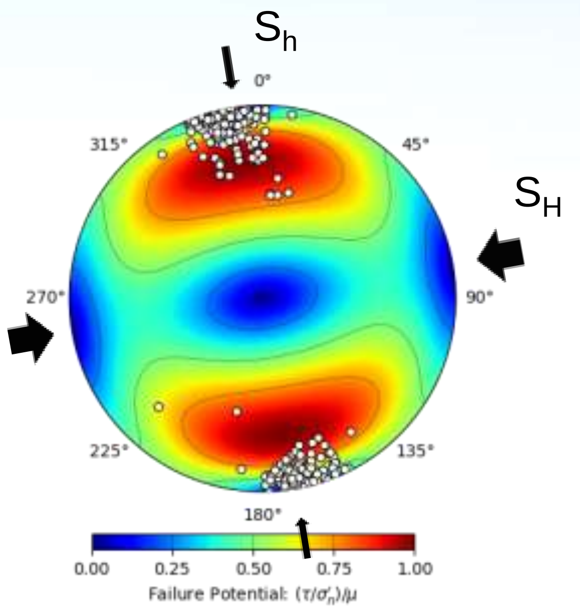


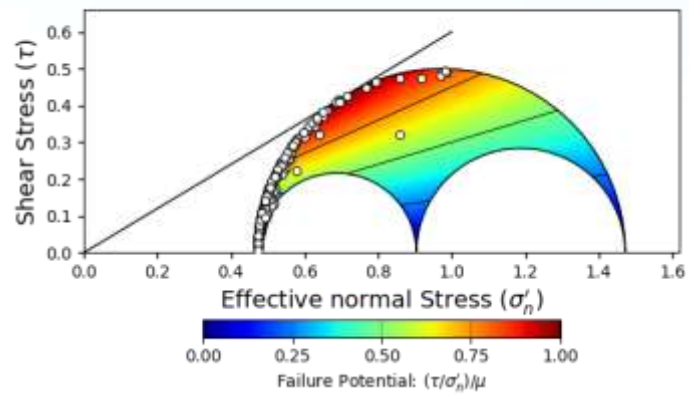


Stress Regime: Normal
SHmax: 81°
Stress Ratio (Φ): 0.49

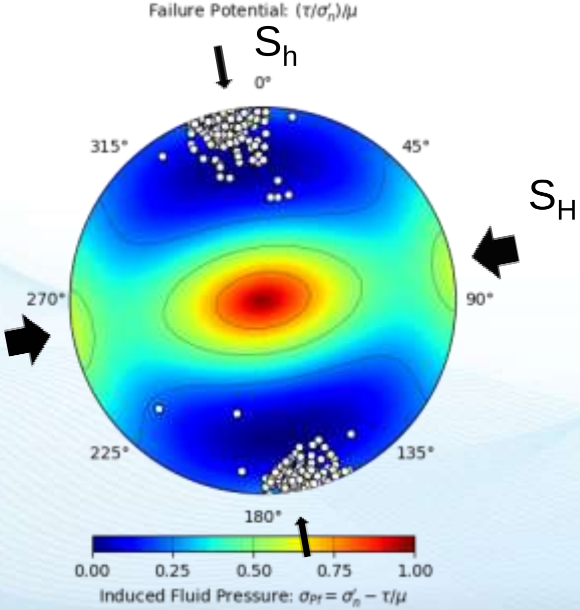


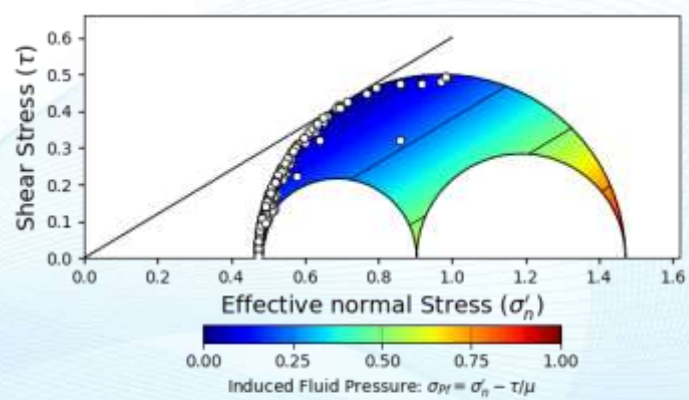
Malbec – South Pad





Stress Regime: Normal
SHmax: 81°
Stress Ratio (Φ): 0.43





MicroSeismic

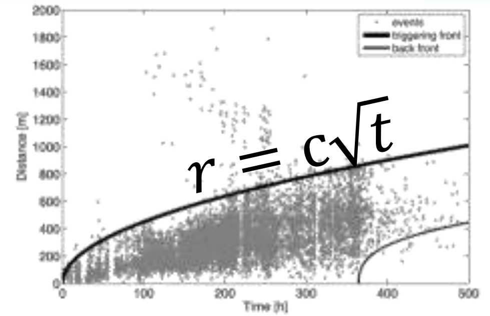
Observations

- Natural fracture orientations are consistent with observed fracture trends and focal mechanisms and play a key role in observed fracture geometry
- Shallow vertical faulting continues during treatment duration once fractures extend above Bonarda top
- *SHmax* oriented ~80° in reservoir below Sirah
- Wellbore orientation optimally oriented with respect to *SHmax*

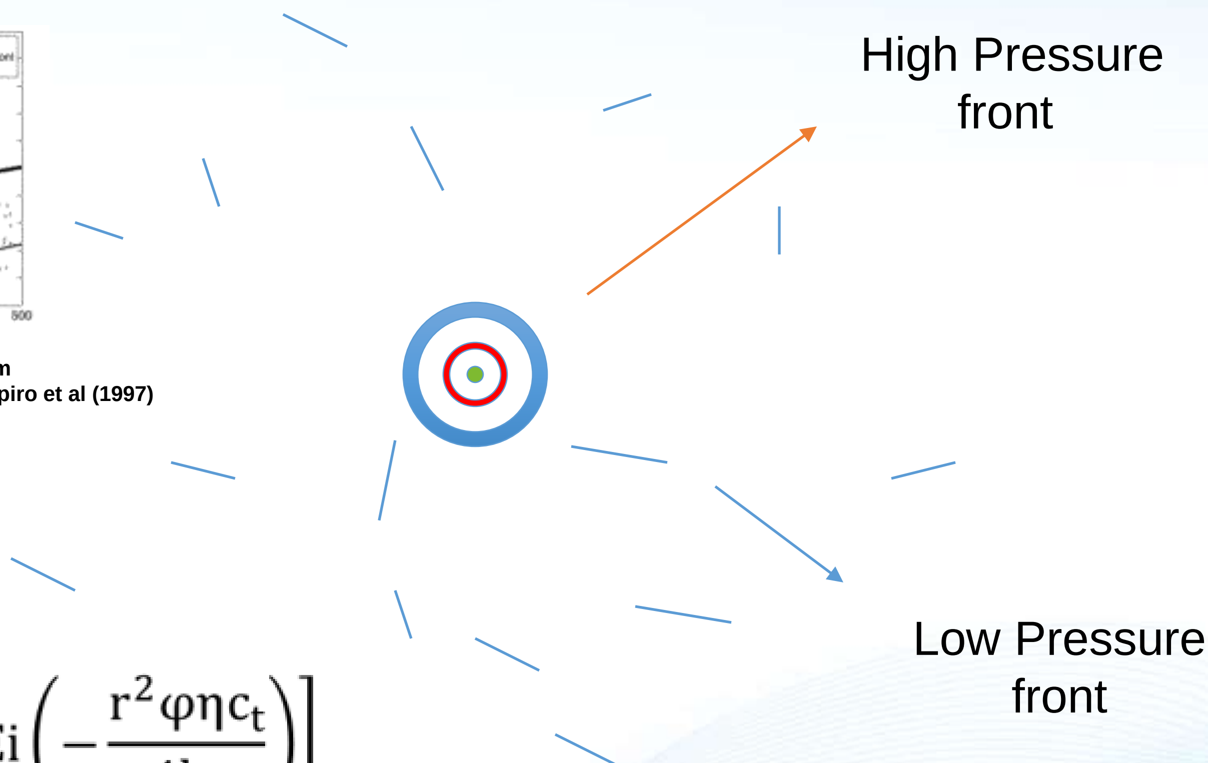
Descriptive Completions Evaluation

MicroSeismic

Pressure Diffusion



From
Shapiro et al (1997)



$$\Delta P = \frac{-q\eta}{2\pi kh}\left[-\frac{1}{2}\,\mathrm{Ei}\left(-\frac{r^2\varphi\eta c_t}{4kt}\right)\right]$$

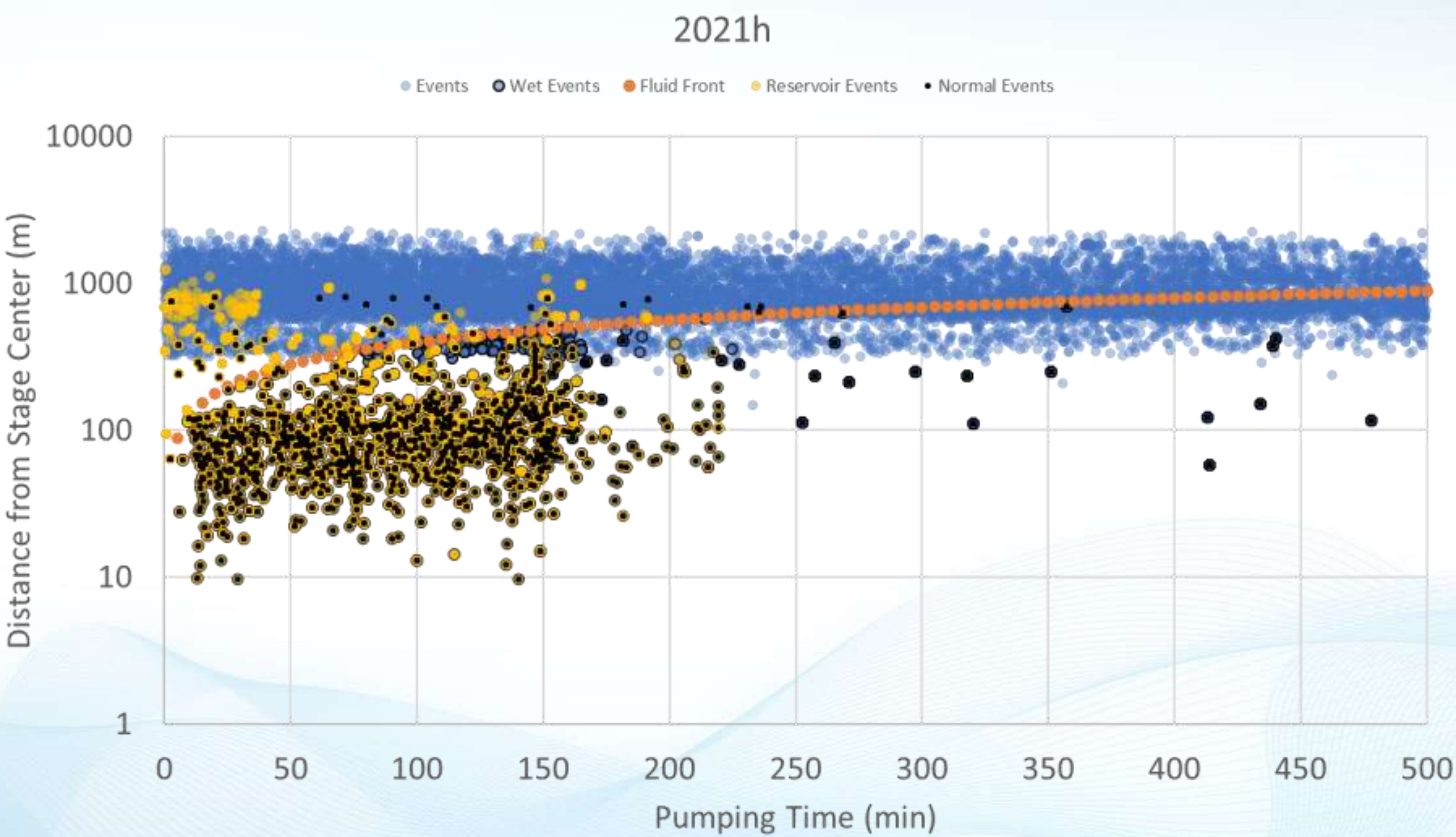
- Events behind fluid-diffusion front used to calibrate fracture model
- Events ahead of fluid front can occur when pore-pressure is transmitted through natural fracture network or from rock stress to accommodate increased fracture volume in reservoir

Fluid Propagation Analysis – Fracture Model Calibration

- Fluid-induced events to calibrate fracture model
  - Events occurring while pumping and behind fluid-diffusion front during pumping
  - Events occurring after shutdown and focal mechanism associated with normal stress regime virgin stress state
- Events ahead of fluid front can occur when pore-pressure is transmitted through fracture network or from rock stress to accommodate increased fracture volume in reservoir

MicroSeismic

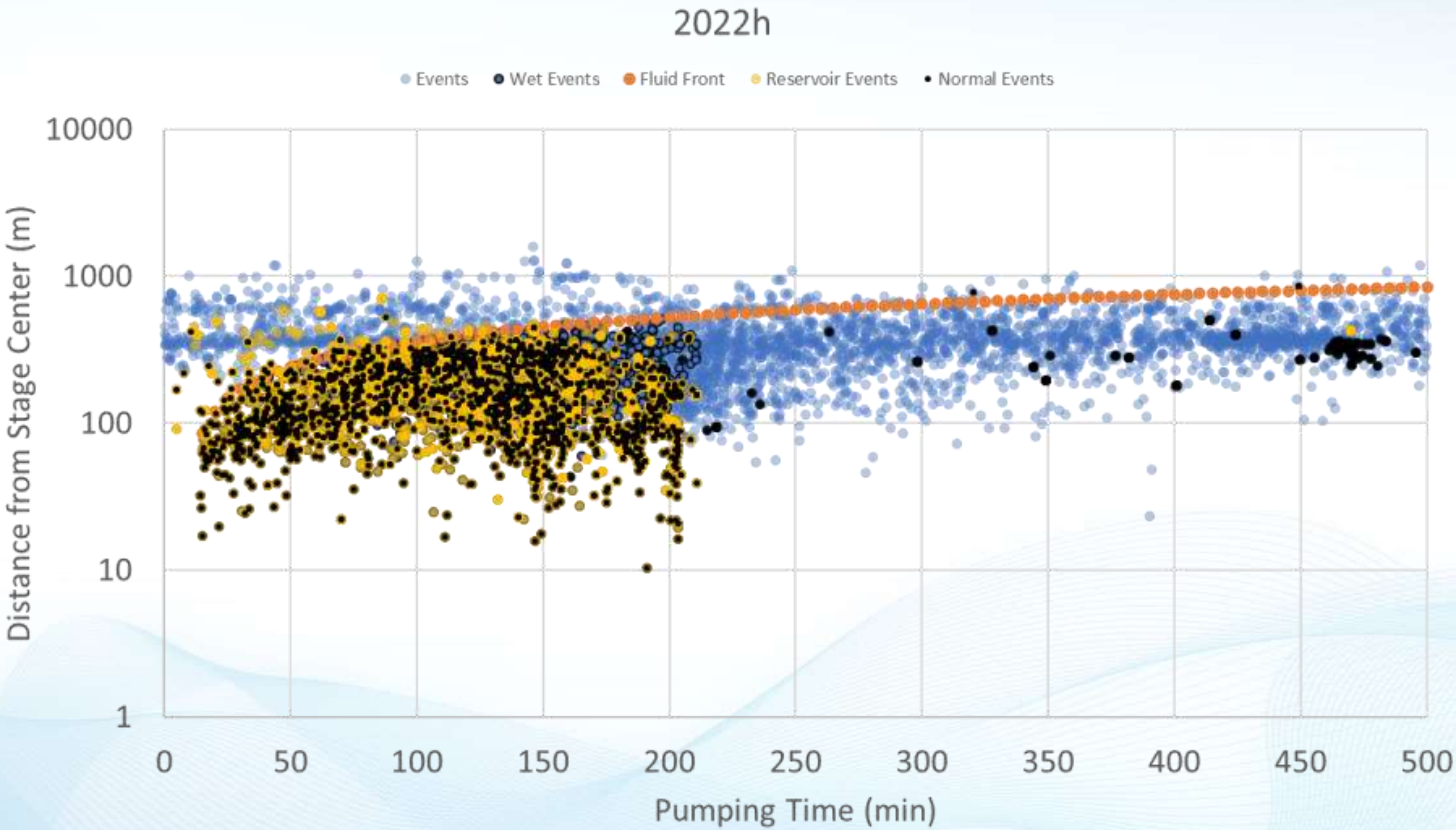
2021h – Fluid Propagation Analysis



**Normal events include normal and oblique dip-slip mechanism events*

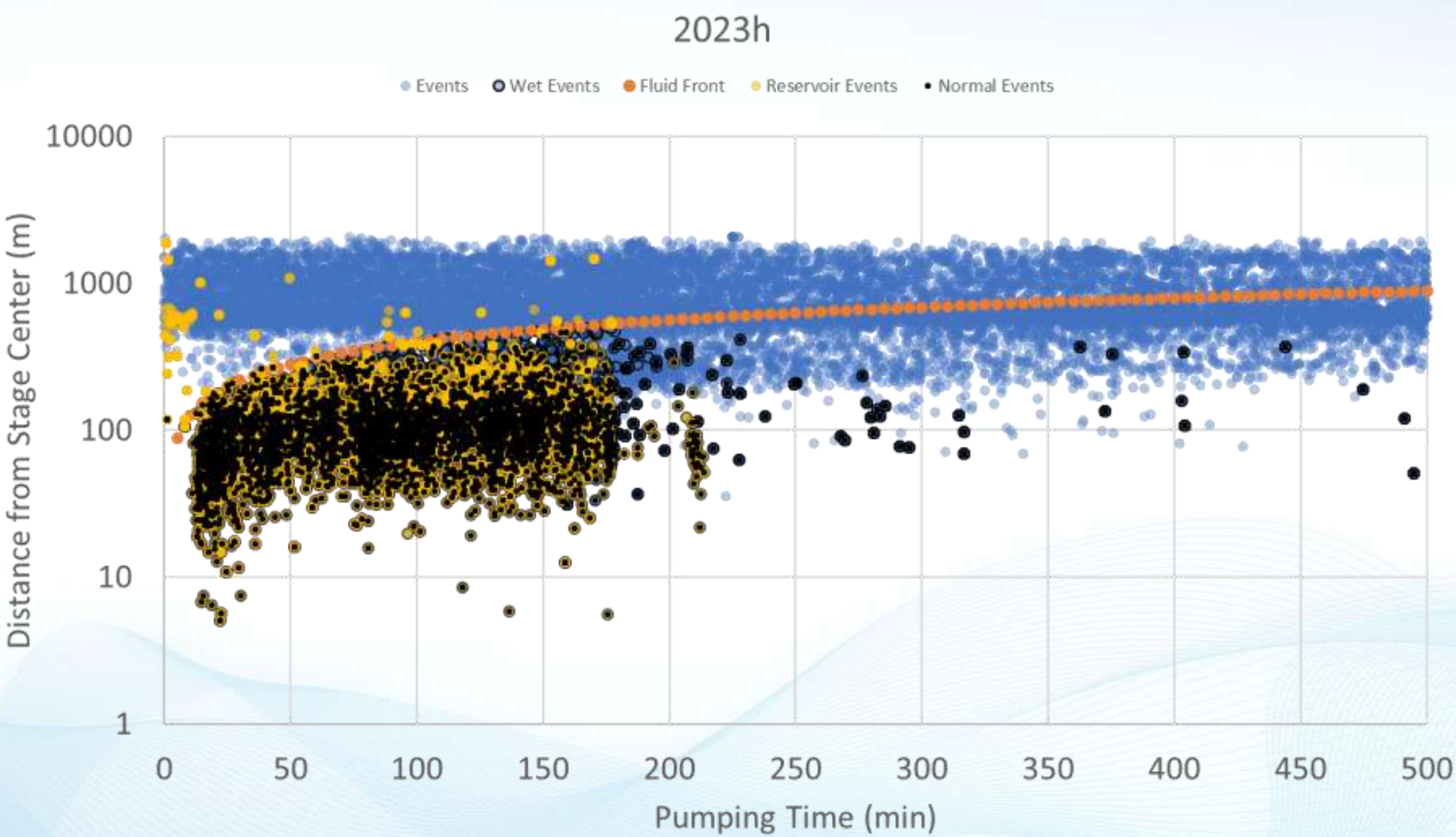
MicroSeismic

2022h – Fluid Propagation Analysis



*Normal events include normal and oblique dip-slip mechanism events

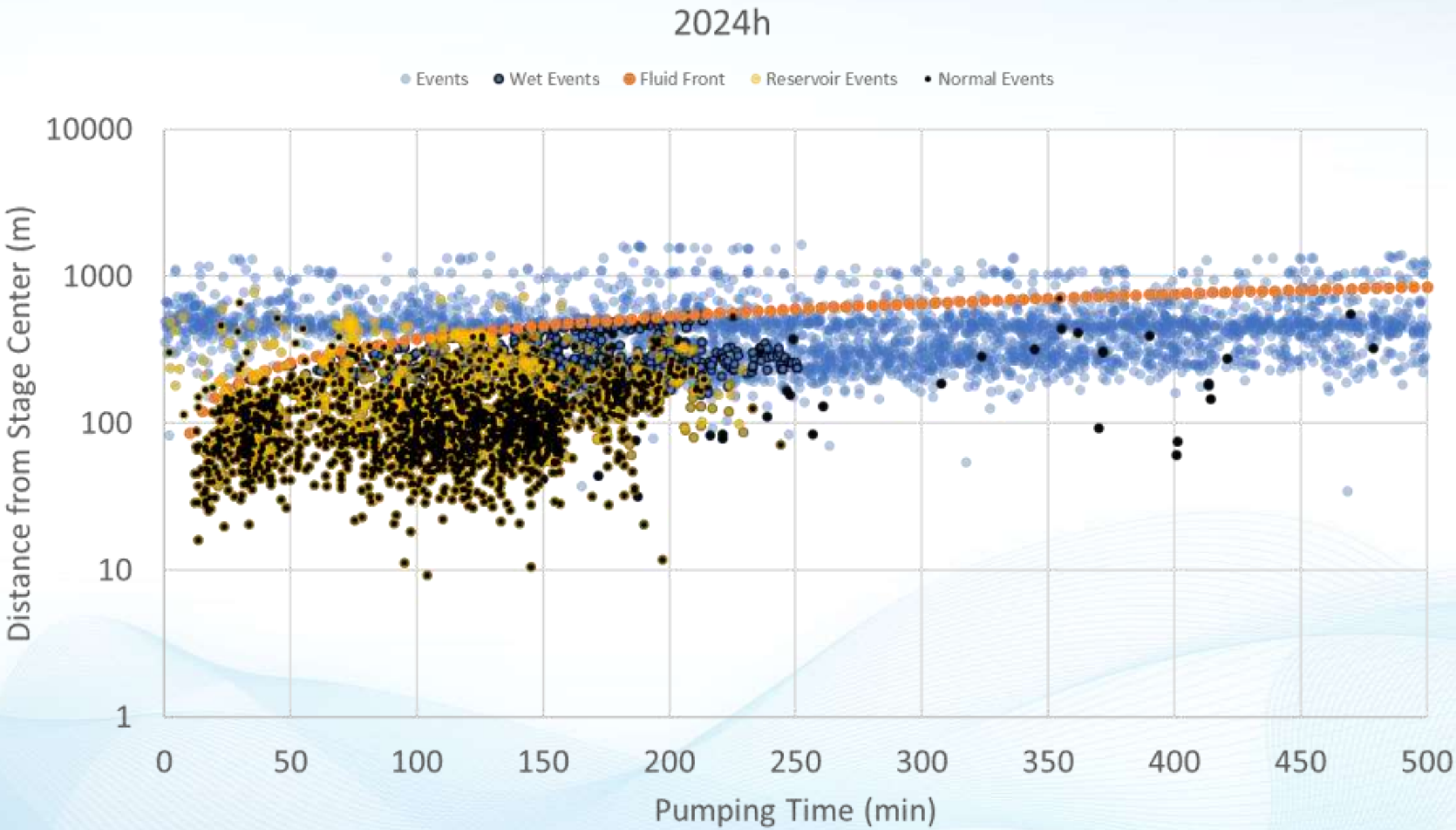
2023h – Fluid Propagation Analysis



*Normal events include normal and oblique dip-slip mechanism events

MicroSeismic

2024h – Fluid Propagation Analysis



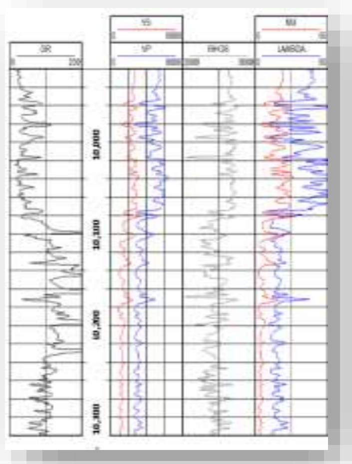
Normal events include normal and oblique dip-slip mechanism events

Fracture Modeling Workflow

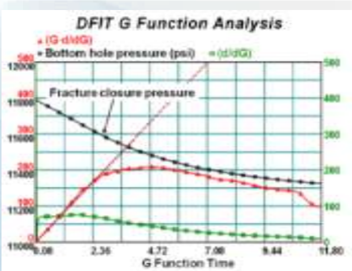
$$M_0 = A\mu\delta$$

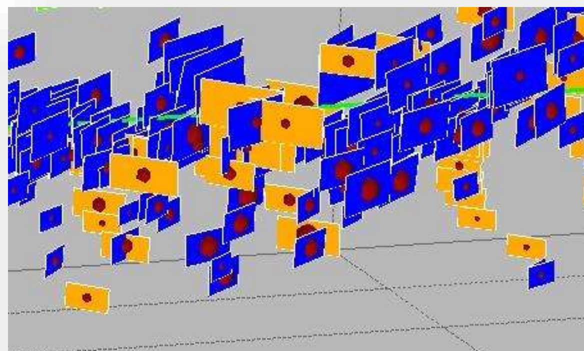
$$\Delta V_f = A * \Delta u = (\Delta V_{inj})\eta k$$

$Rock\ Rigidity, \mu$



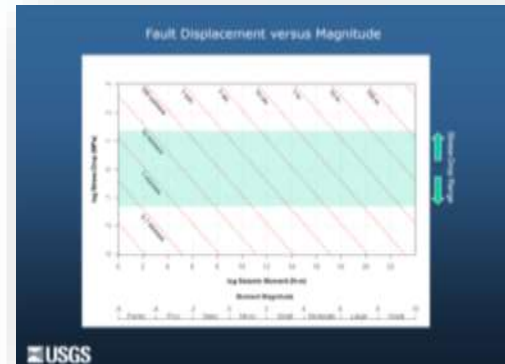
$Fluid\ Efficiency, \eta$





Events Colored Red and Sized by M_0
Fractures Oriented by Focal Mechanism with Area, A

$Displacement, \delta$



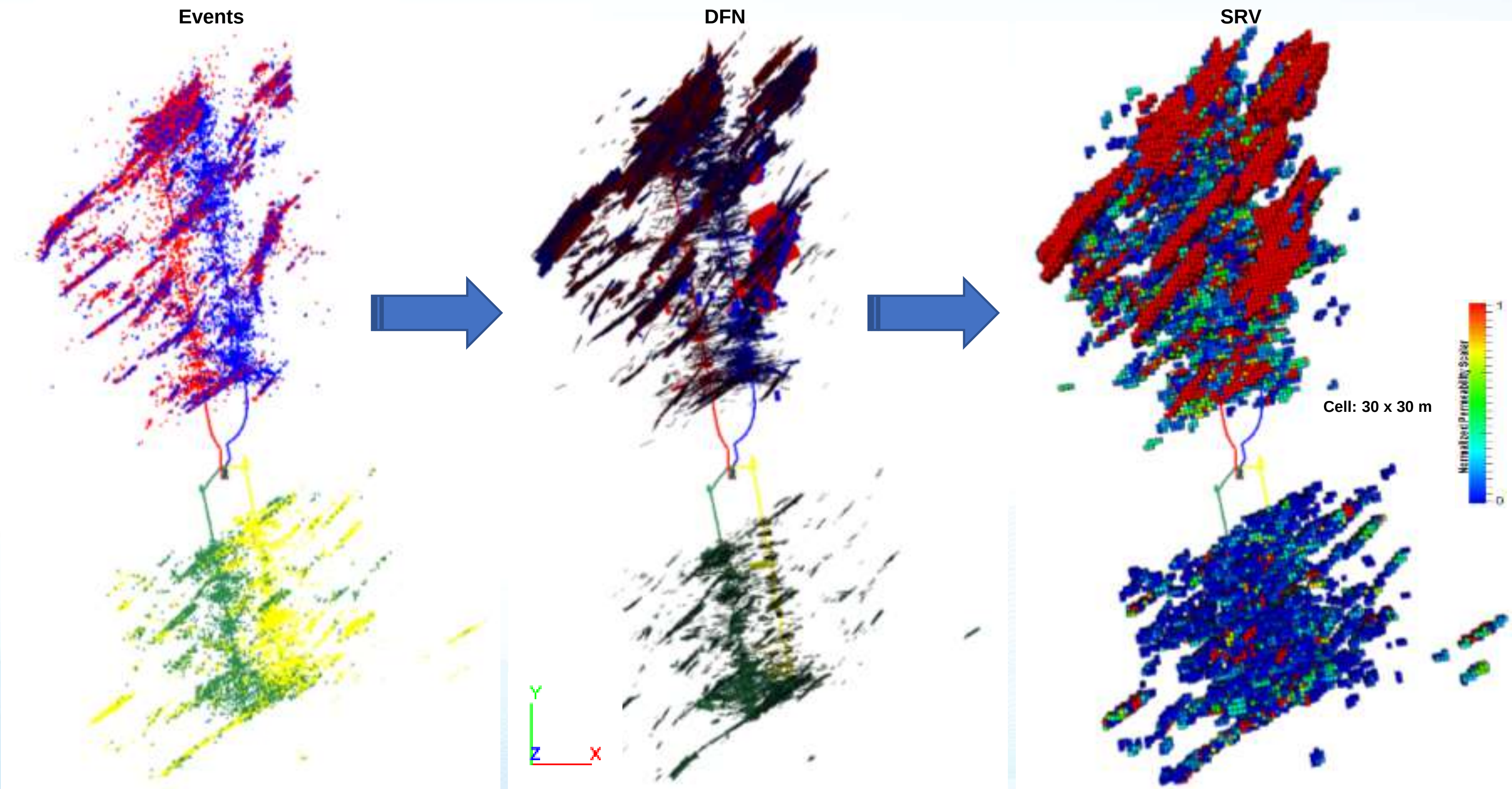
$Injected\ Volume, \Delta V_{inj}$

Clean Volume + Proppant Volume
Propped Volume assumes 100 lbs = 1ft^3

Discrete Fracture Network Modeling

2021h
2022h
2023h
2024h

One fracture is modeled per microseismic event. Individual fracture orientation is determined by focal mechanism. Fracture geometry is determined from moment magnitude, rock rigidity, and injected fluid volume.



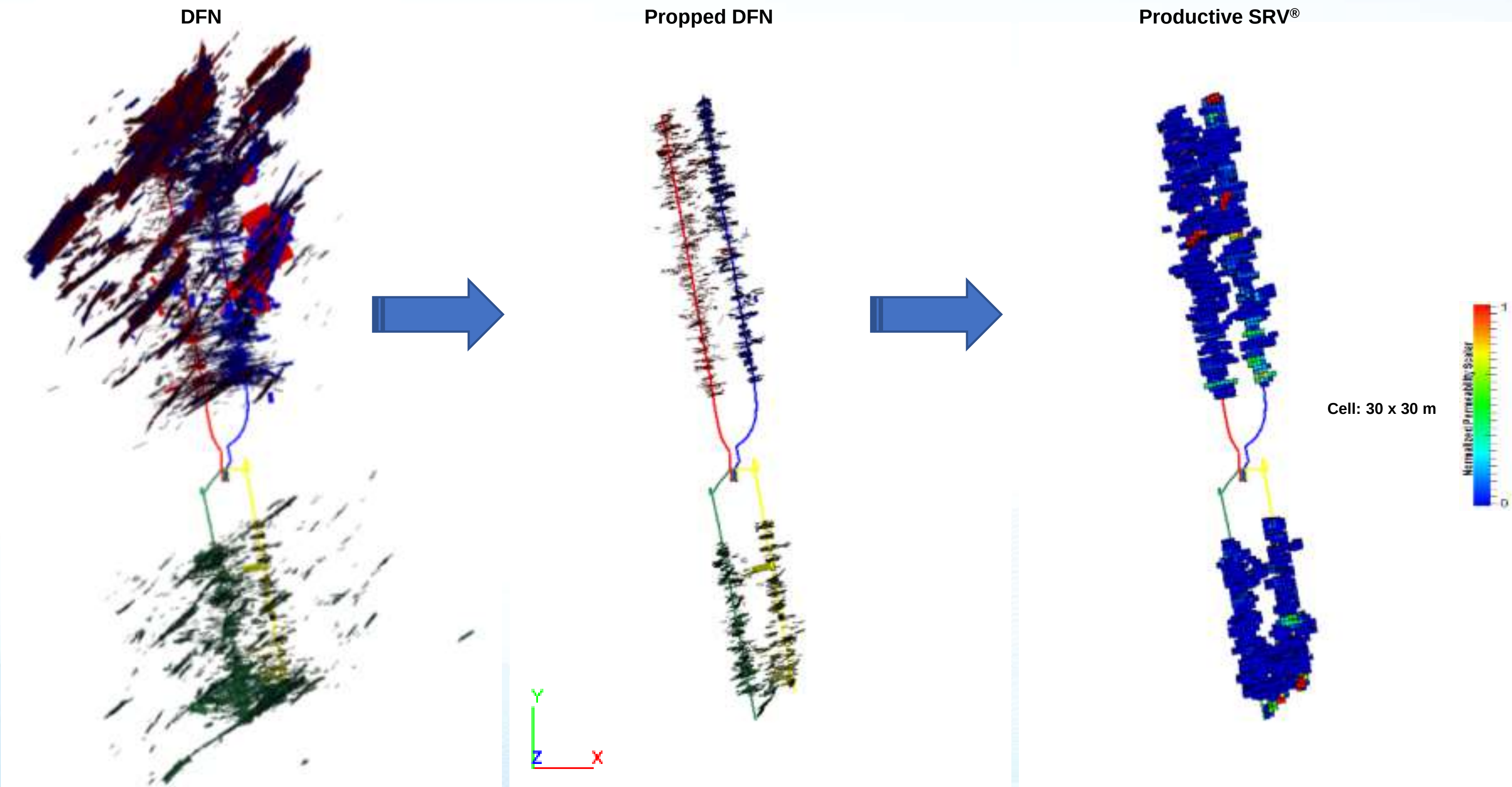
A network of 30 m cells is placed over the DFN.
Cells containing fractures form the Total SRV.

MicroSeismic

Where is the Proppant ?

2021h
2022h
2023h
2024h

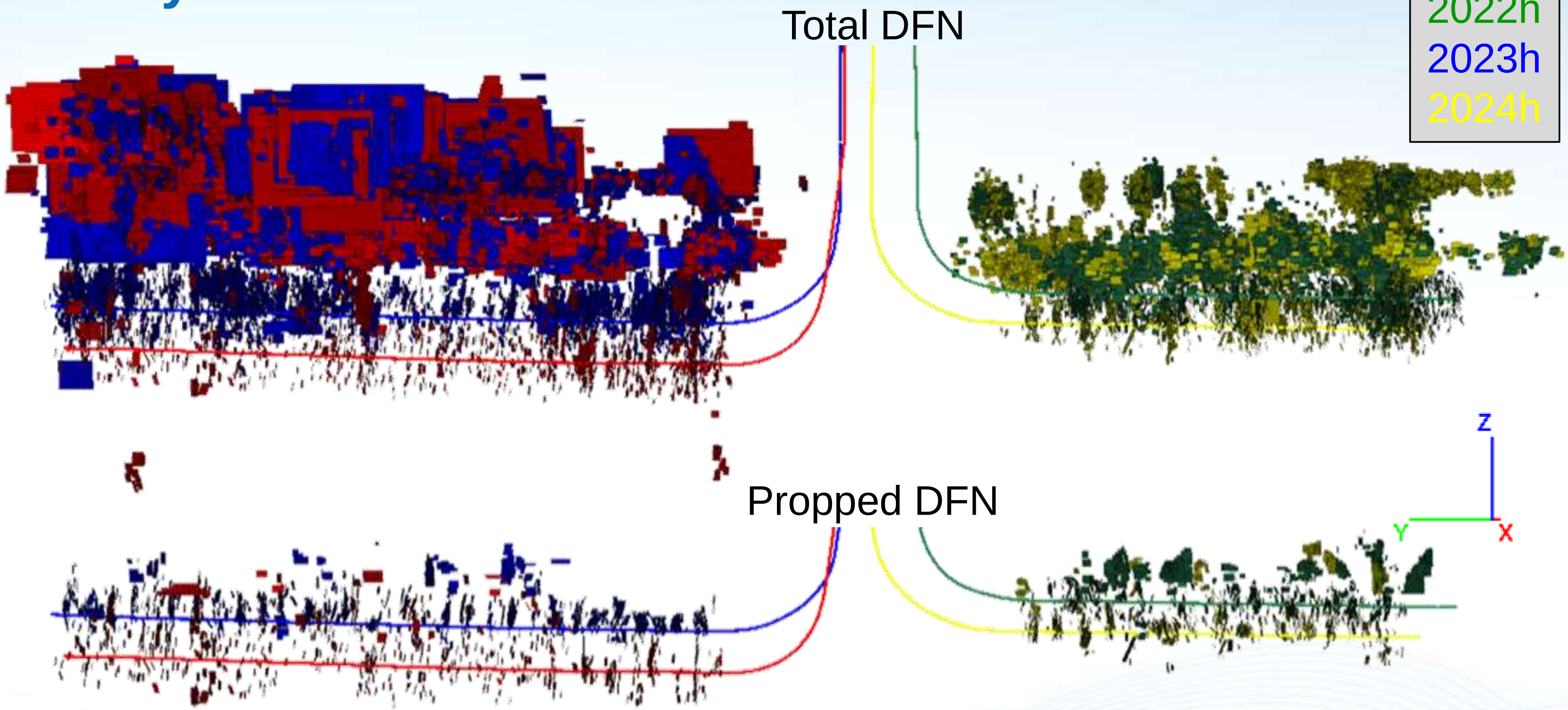
Modeled fractures are filled with proppant from the stage centers out on a stage-by-stage basis.



A network of 30 m cells is placed over the Propped DFN. Cells containing proppant filled fractures form the Productive-SRV®.

MicroSeismic

DFN by Formation



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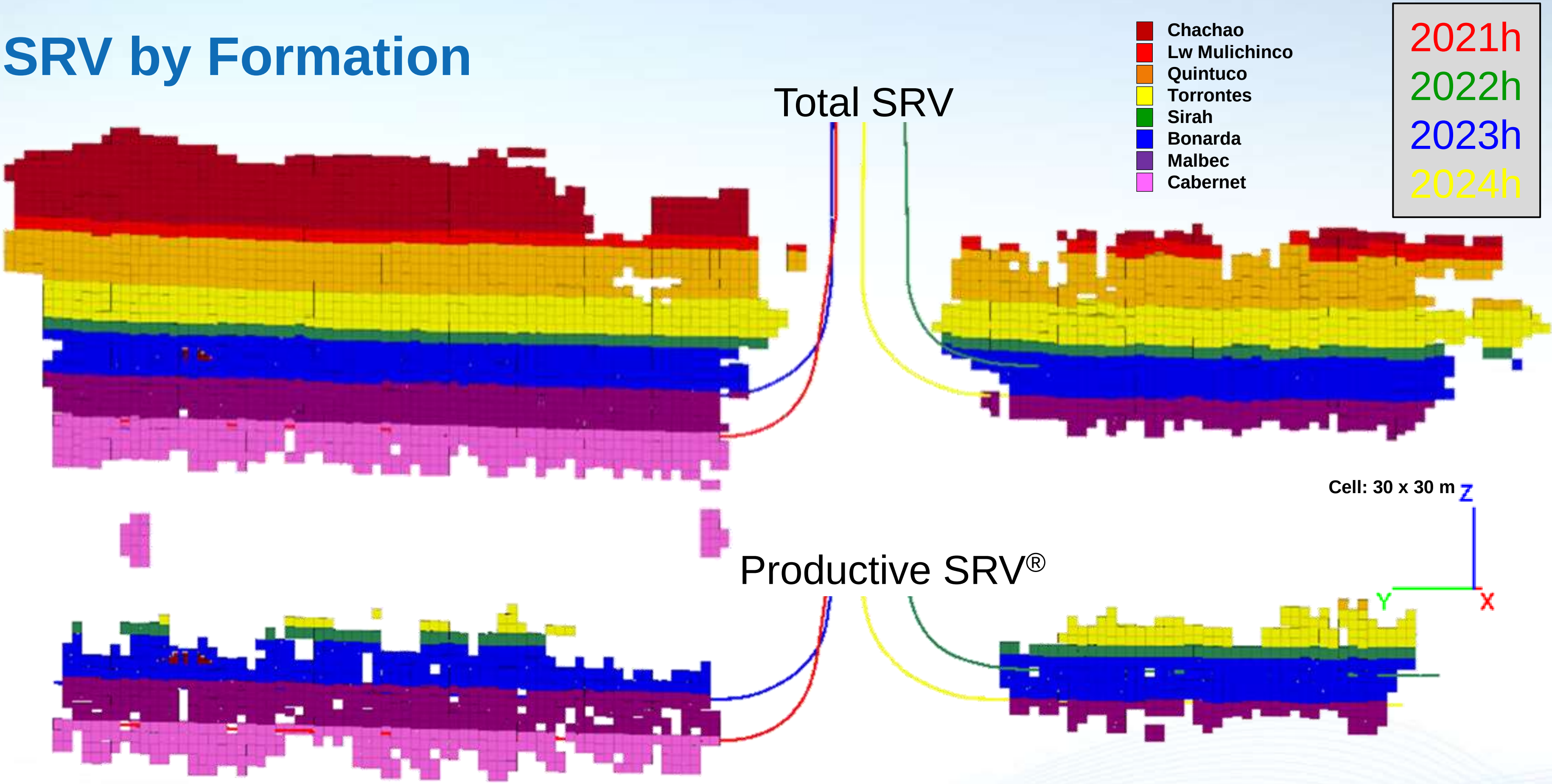
SRV by Formation



Total SRV (m^3):	1.14×10^9	100%	Productive SRV (m^3):	1.59×10^8	14%
Chachao	1.50×10^8	13%	Chachao	-	0%
Lw Mulichinco	5.73×10^7	5%	Lw Mulichinco	-	0%
Quintuco	2.20×10^8	19%	Quintuco	1.76×10^5	<1%
Torrontes	2.23×10^8	20%	Torrontes	8.61×10^6	4%
Sirah	7.26×10^7	6%	Sirah	8.90×10^6	12%
Bonarda	2.27×10^8	20%	Bonarda	6.46×10^7	29%
Malbec	1.29×10^8	11%	Malbec	4.97×10^7	38%
Cabernet	5.75×10^7	5%	Cabernet	2.73×10^7	47%

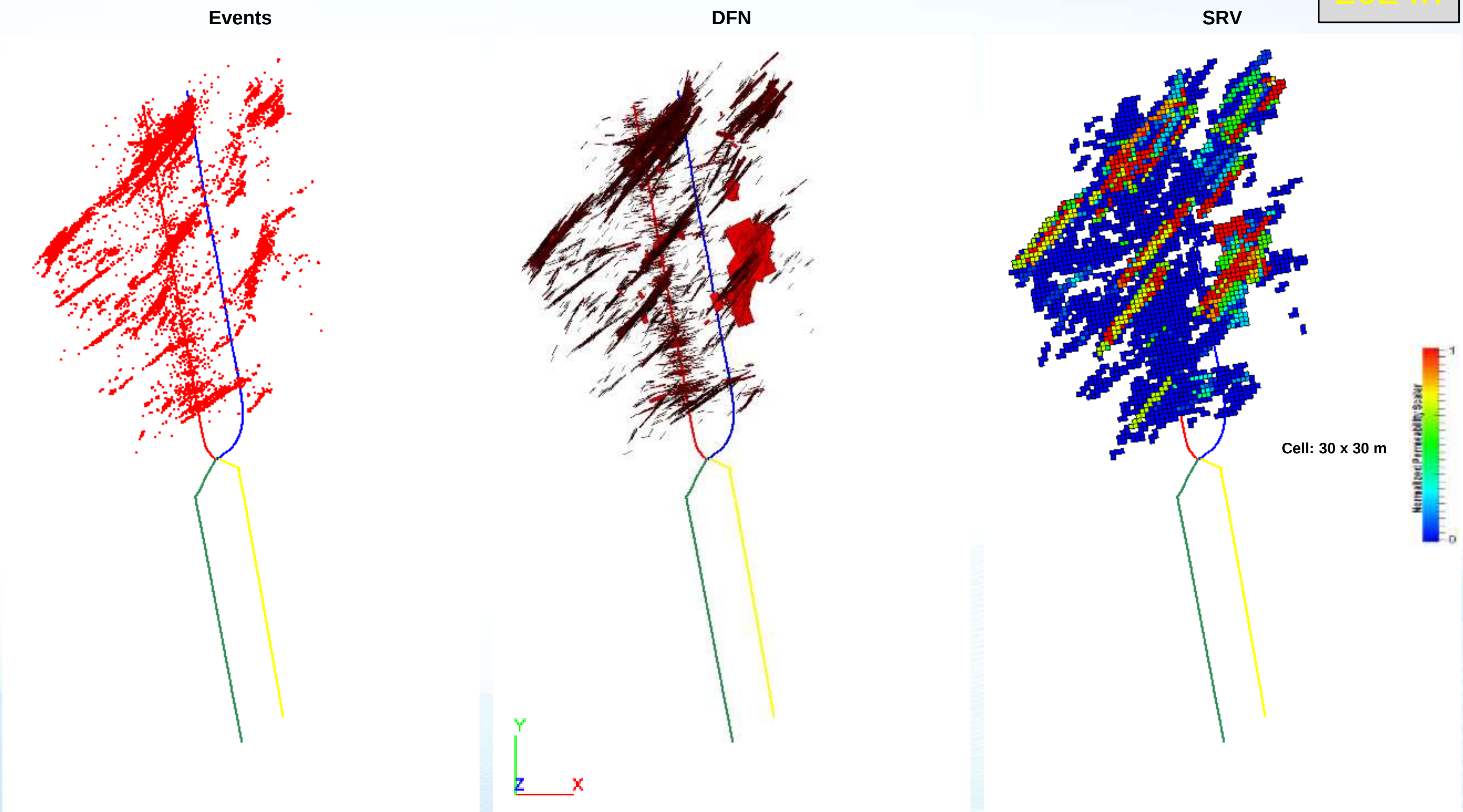
MicroSeismic

Descriptive Completions Evaluation Well-By-Well

MicroSeismic

Discrete Fracture Network Modeling – 2021h

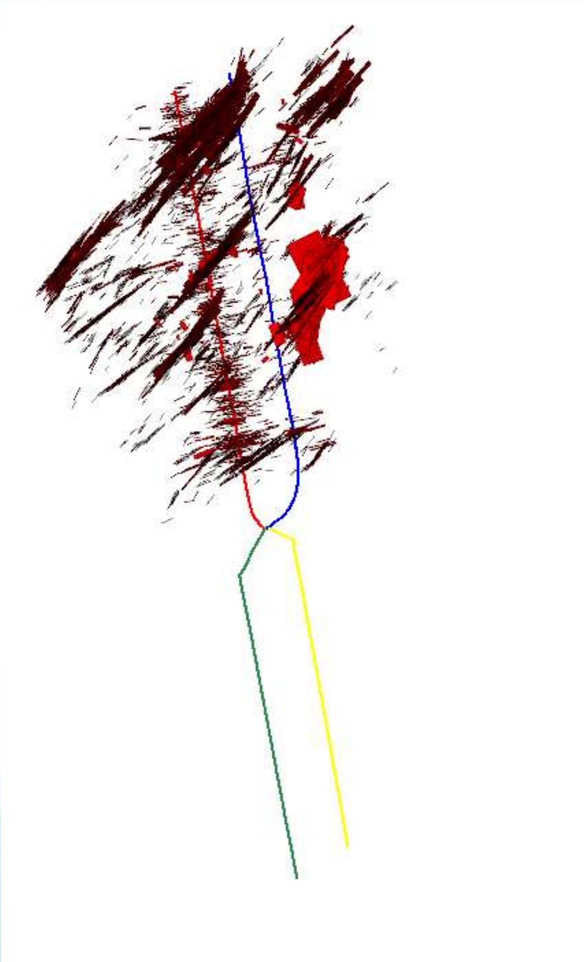
2021h
2022h
2023h
2024h



Discrete Fracture Network Modeling – 2021h

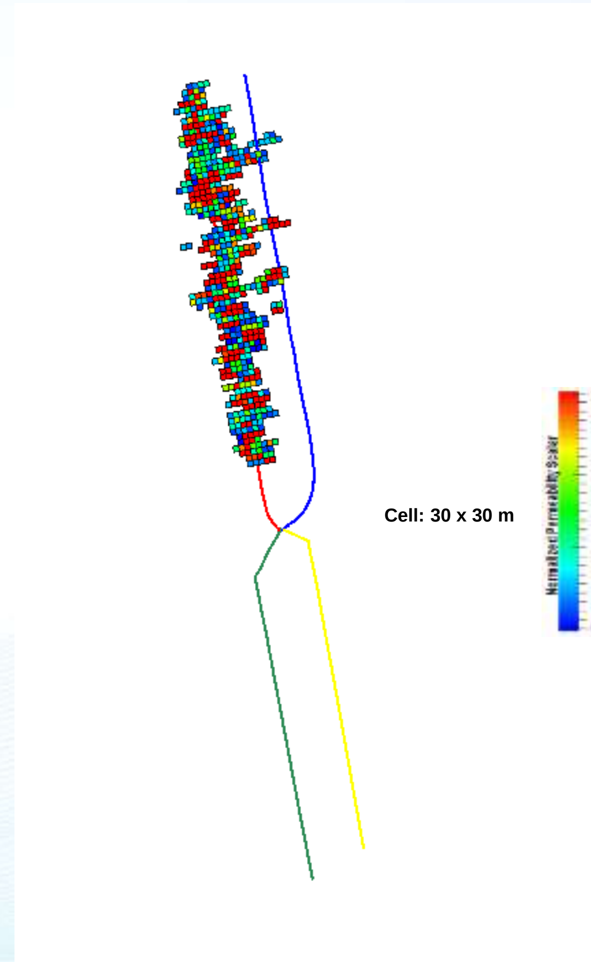
2021h
2022h
2023h
2024h

DFN

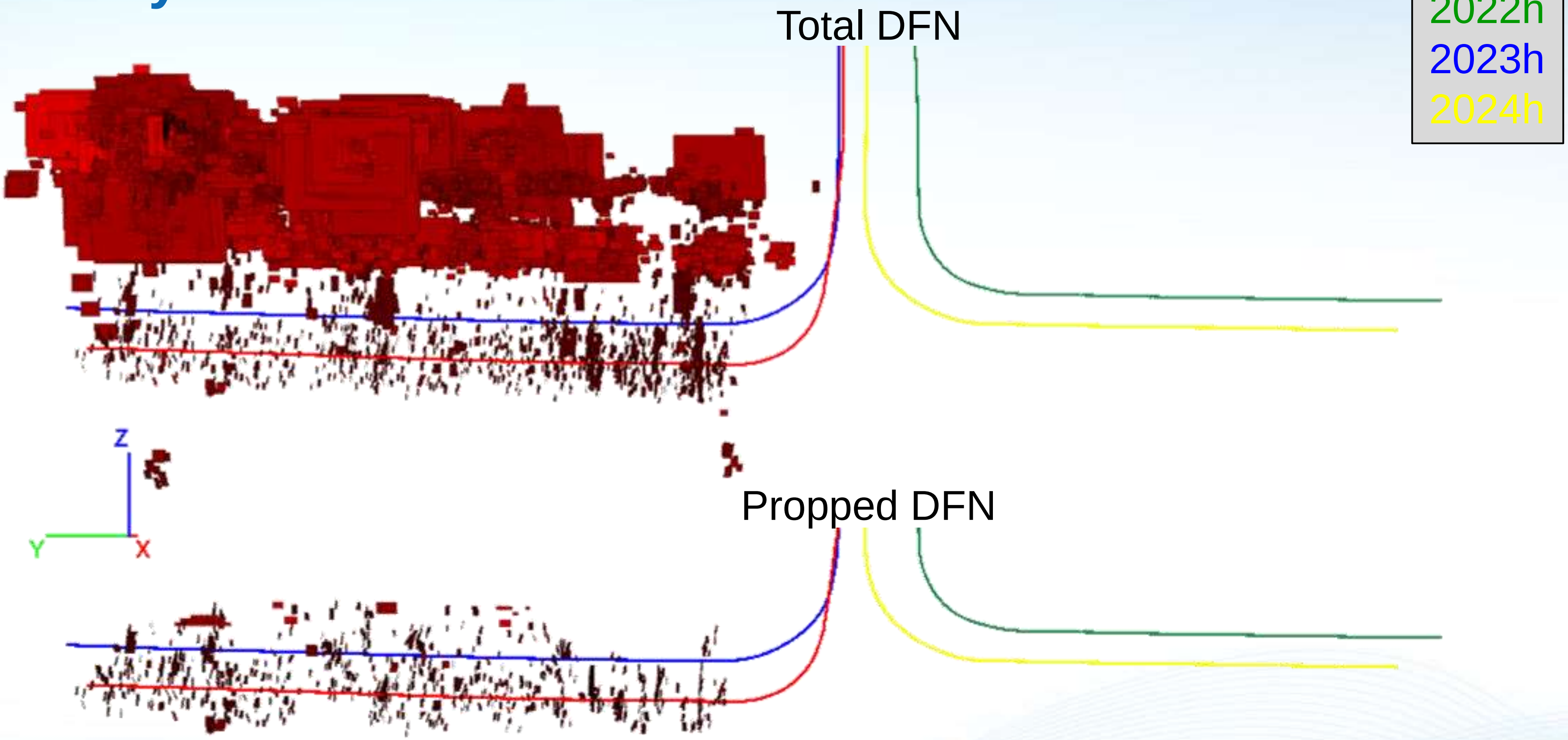


Propped DFN

Productive SRV®



DFN by Formation – 2021h



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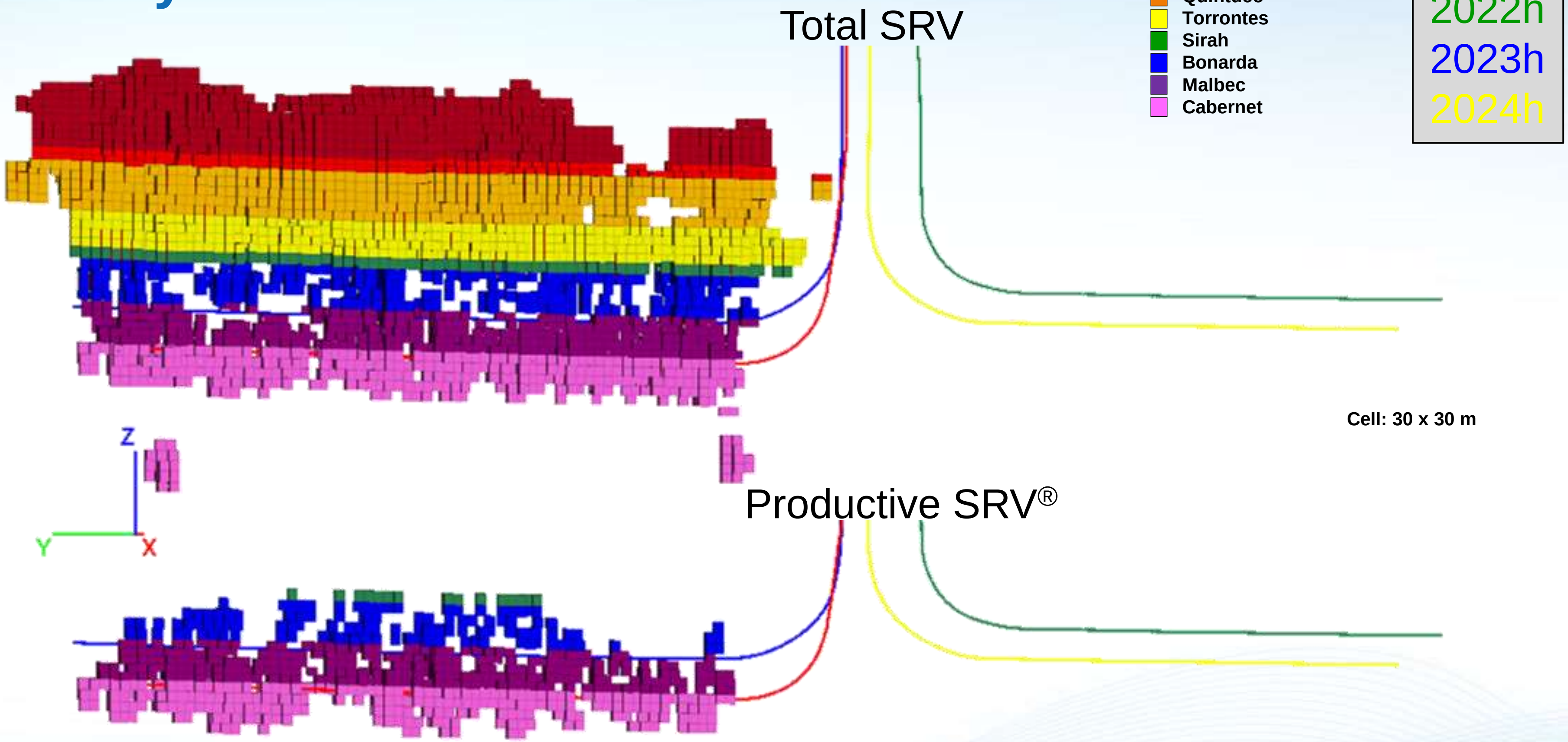
SRV by Formation – 2021h

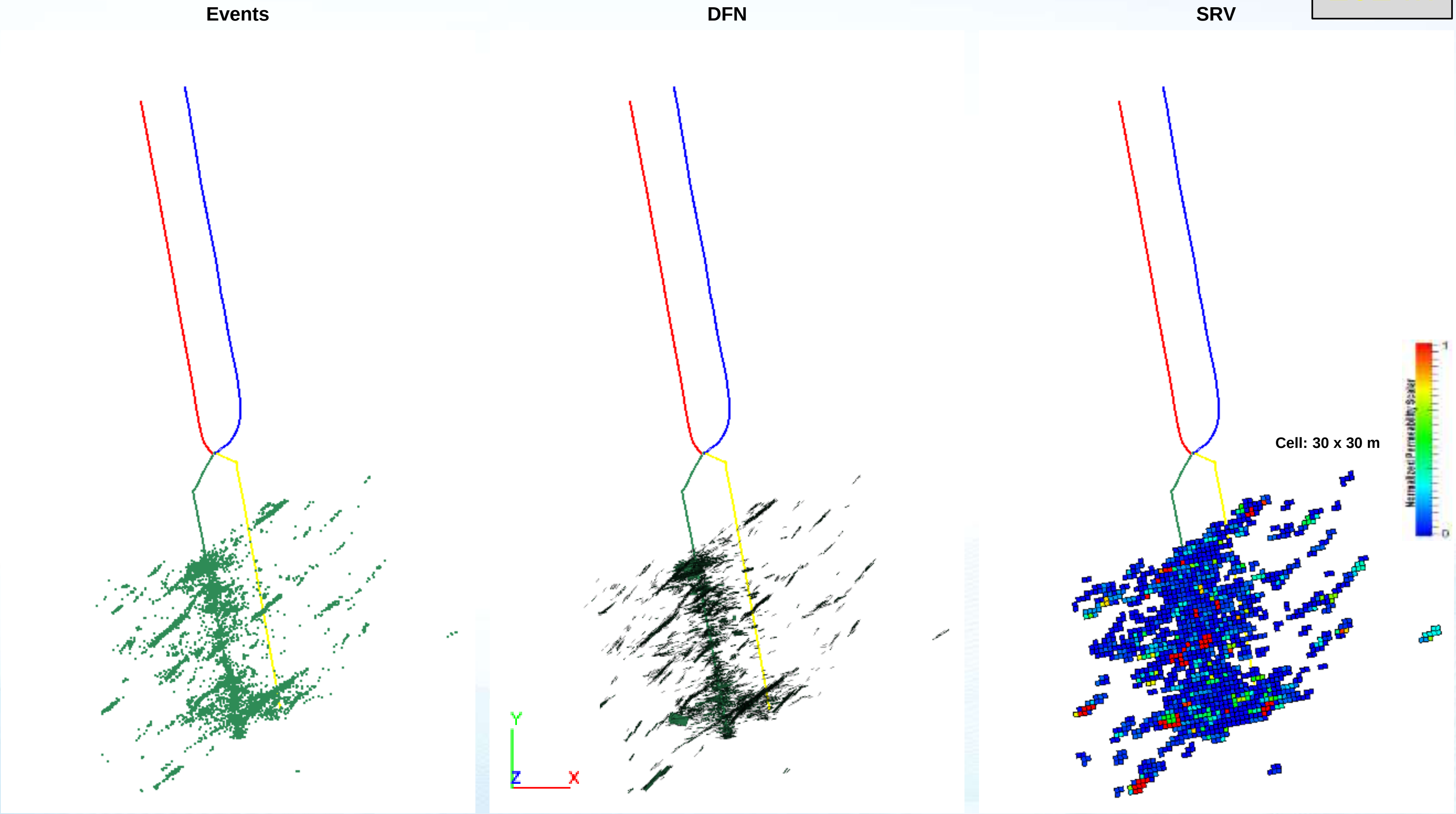


Total SRV (m^3):	5.23×10^8	100%	Productive SRV (m^3):	6.30×10^7	12%
Chachao	1.18×10^8	23%	Chachao	-	0%
Lw Mulichinco	4.10×10^7	8%	Lw Mulichinco	-	0%
Quintuco	1.41×10^8	27%	Quintuco	-	0%
Torrontes	8.30×10^7	16%	Torrontes	-	0%
Sirah	2.14×10^7	4%	Sirah	9.21×10^5	1%
Bonarda	3.33×10^7	6%	Bonarda	9.94×10^6	16%
Malbec	3.91×10^7	7%	Malbec	2.49×10^7	40%
Cabernet	4.70×10^7	9%	Cabernet	$2.72\ 10^7$	43%

MicroSeismic

Discrete Fracture Network Modeling – 2022h

2021h
2022h
2023h
2024h



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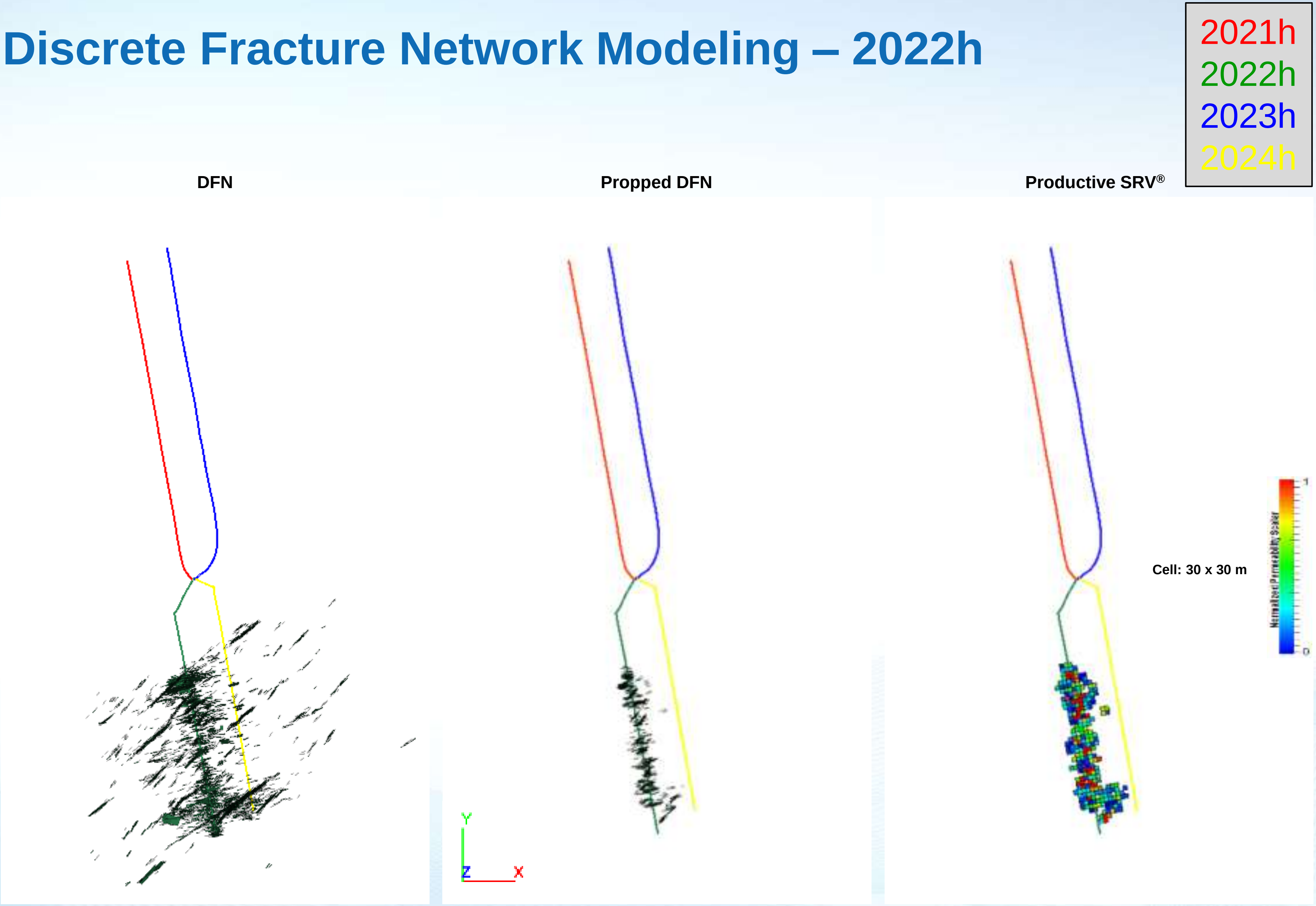
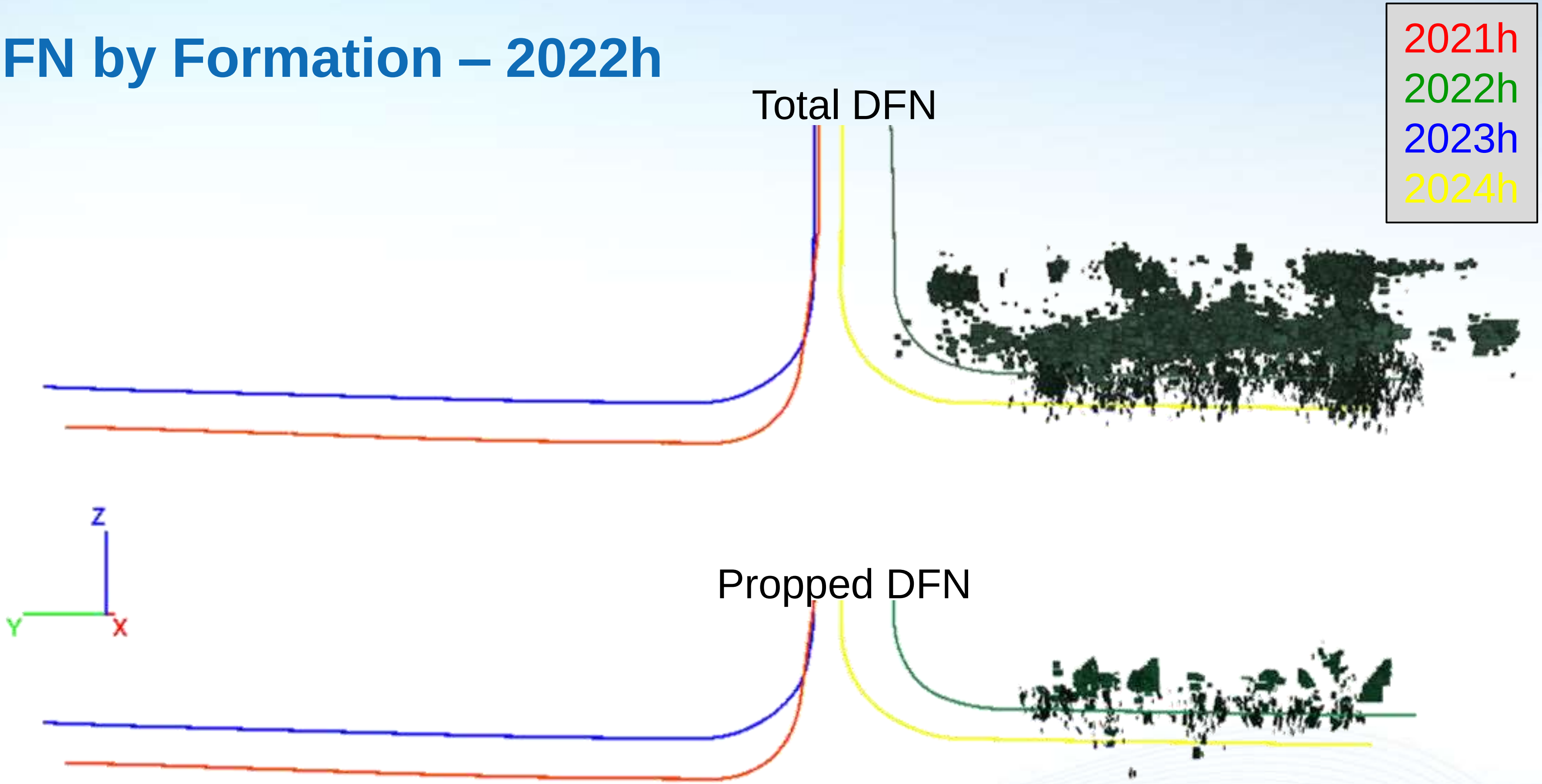
Discrete Fracture Network Modeling – 2022h



DFN by Formation – 2022h



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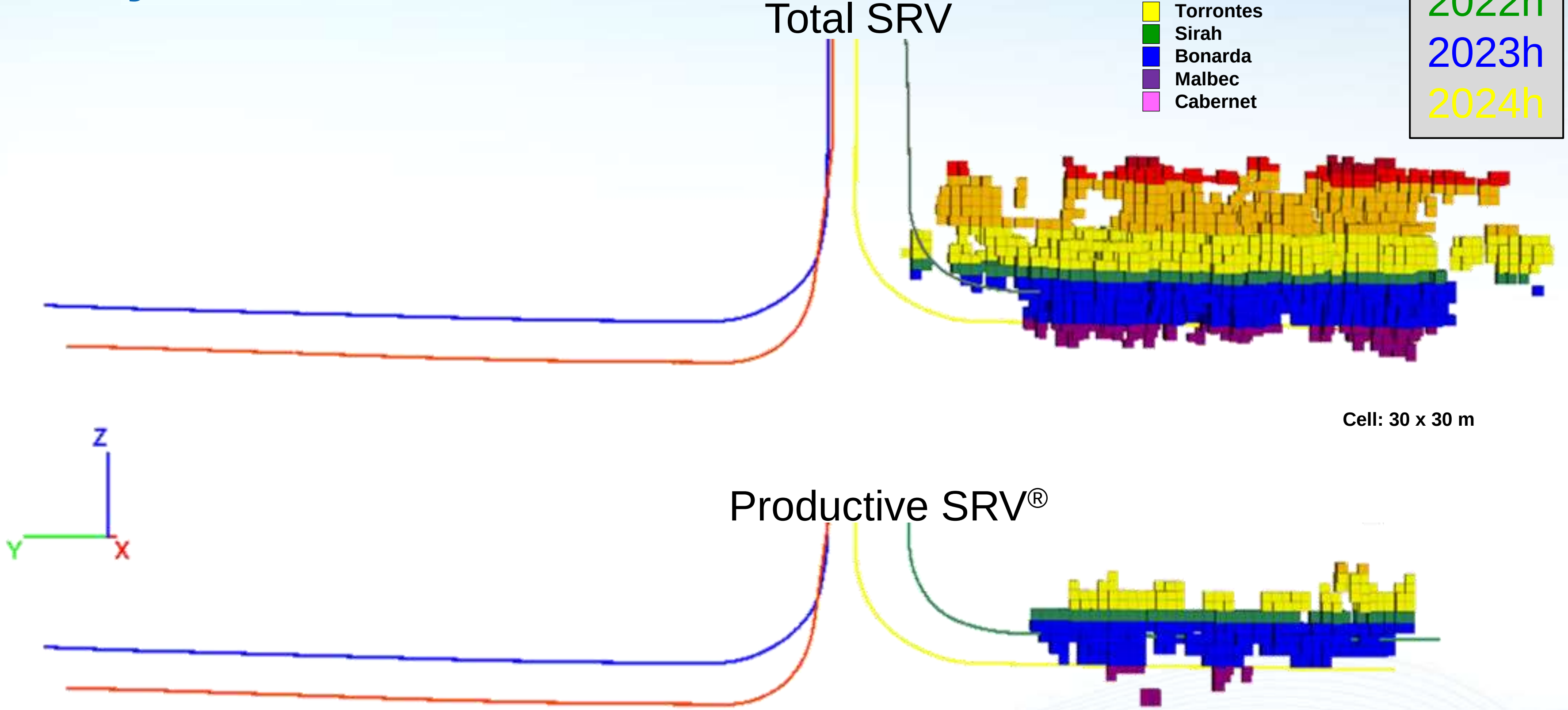
SRV by Formation – 2022h

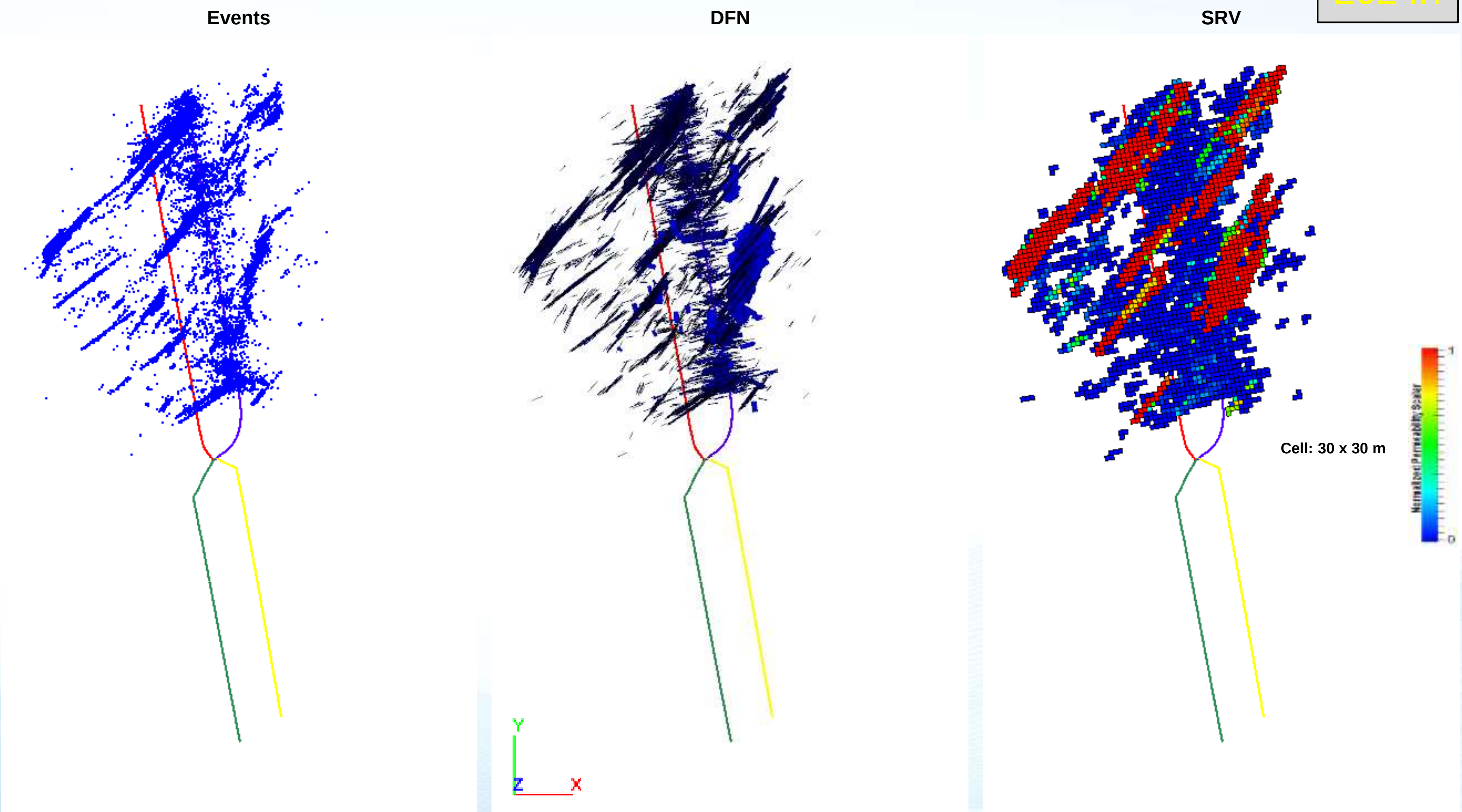


Total SRV (m^3):	2.09×10^8	100%	Productive SRV (m^3):	2.97×10^7	14%
Chachao	9.09×10^5	<1%	Chachao	-	0%
Lw Mulichinco	5.04×10^6	2%	Lw Mulichinco	3.94×10^4	<1%
Quintuco	2.91×10^7	14%	Quintuco	1.76×10^5	<1%
Torrontes	6.96×10^7	33%	Torrontes	5.59×10^6	19%
Sirah	2.57×10^7	12%	Sirah	5.08×10^6	17%
Bonarda	6.98×10^7	33%	Bonarda	1.77×10^7	60%
Malbec	8.98×10^6	4%	Malbec	1.04×10^6	33%
Cabernet	-	0%	Cabernet	-	0%

MicroSeismic

Discrete Fracture Network Modeling – 2023h

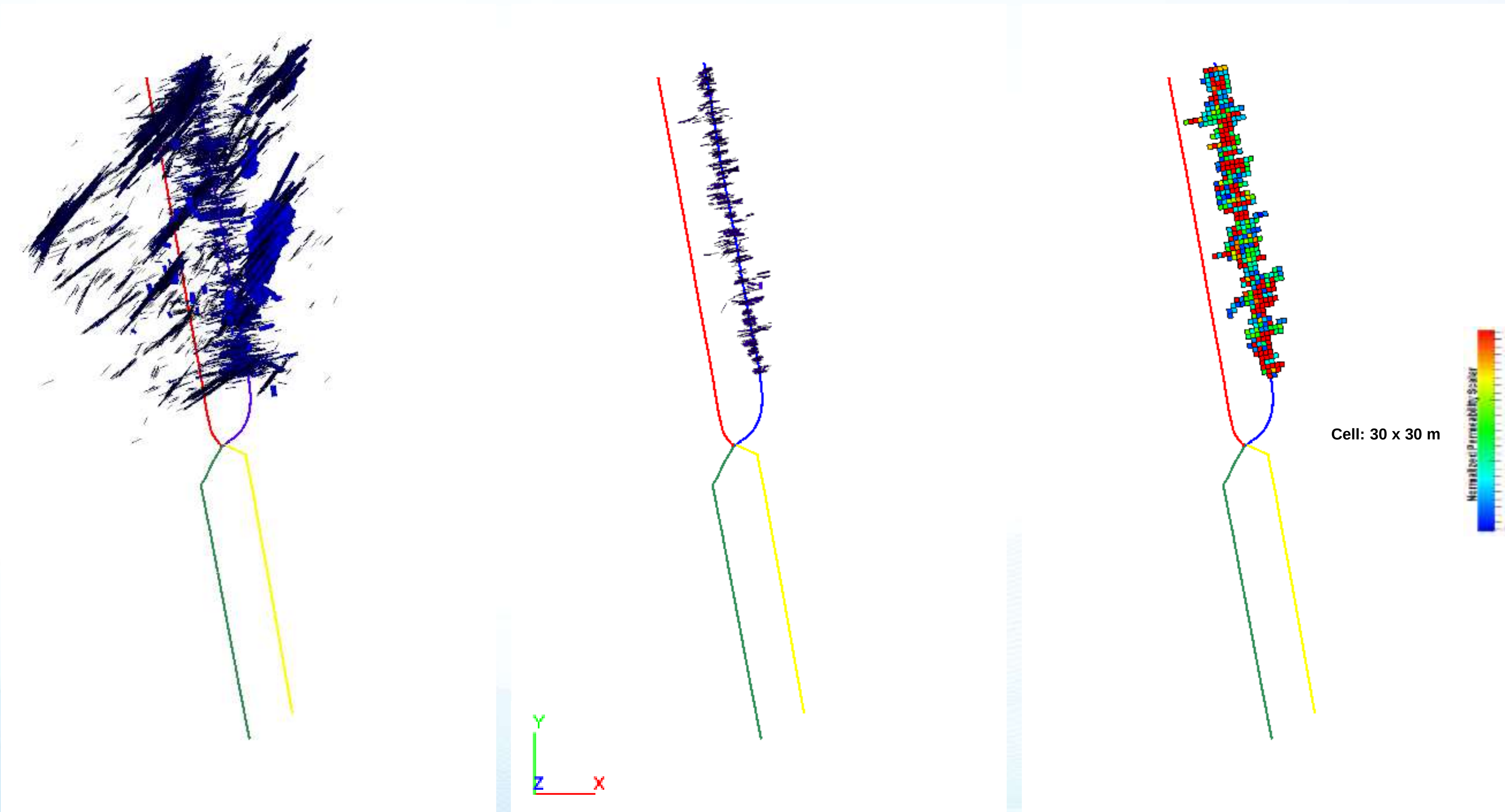
2021h
2022h
2023h
2024h



Discrete Fracture Network Modeling – 2023h

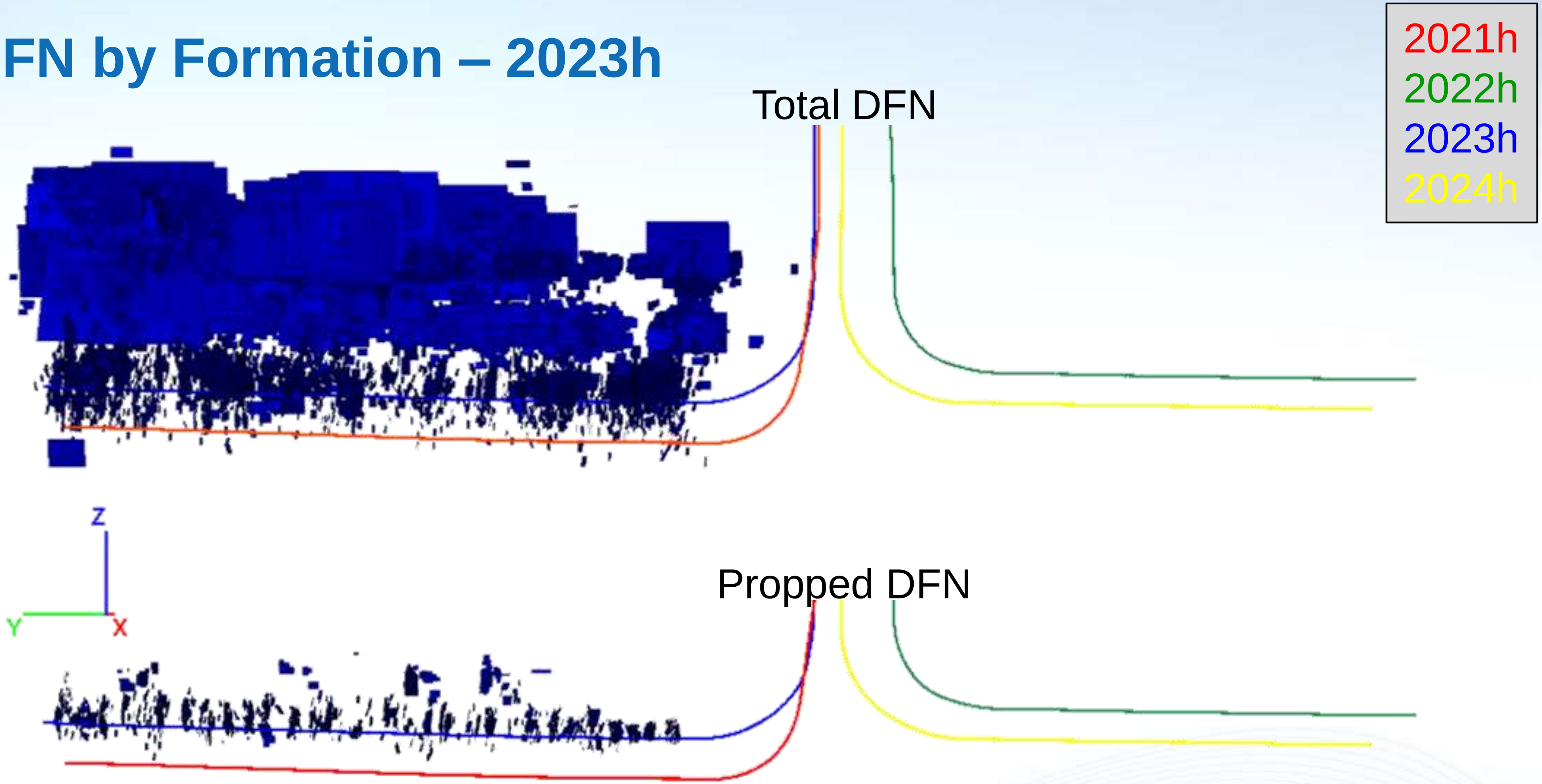
2021h
2022h
2023h
2024h

DFN | **Propped DFN** | **Productive SRV®**

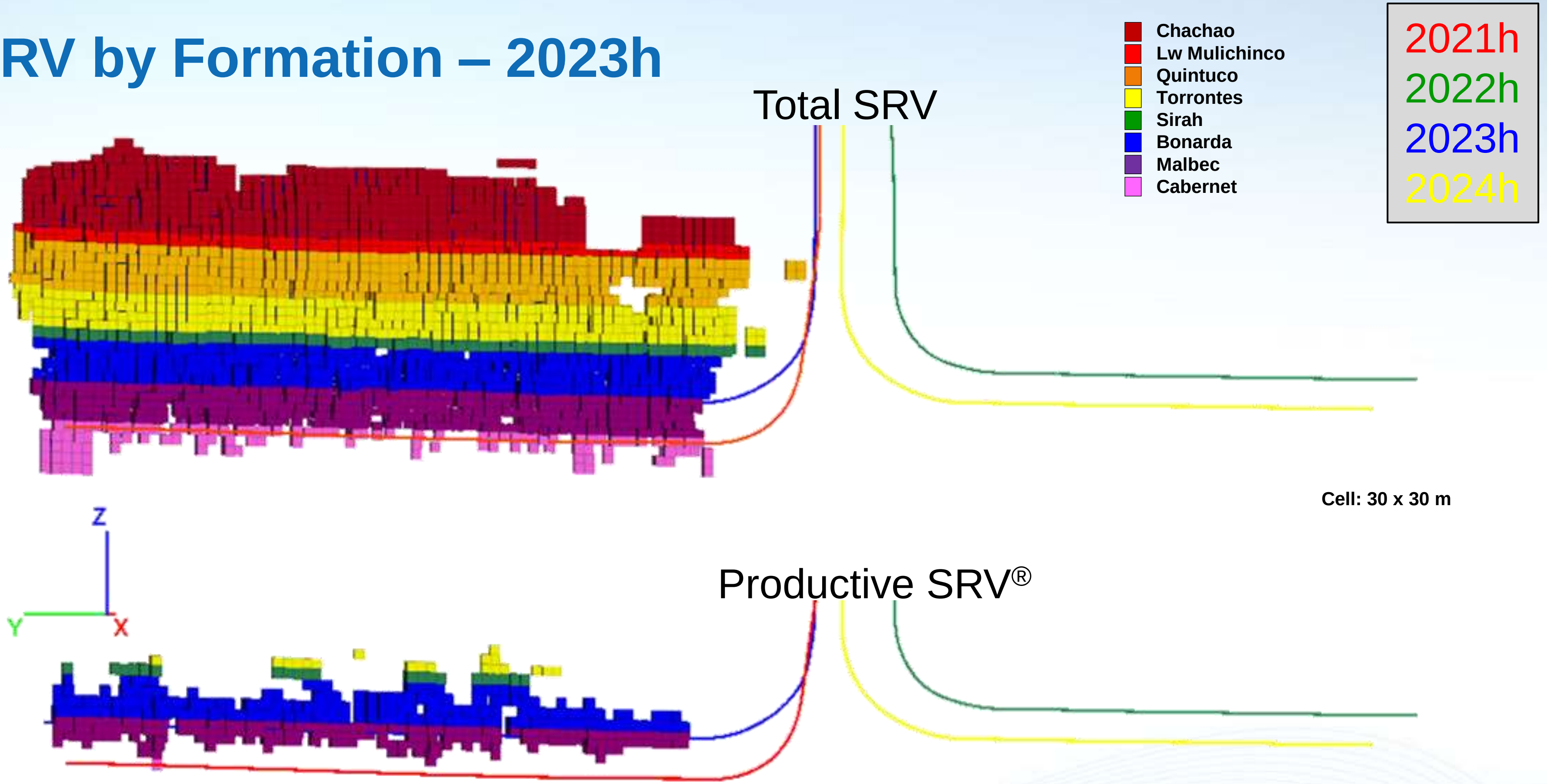


MicroSeismic

DFN by Formation – 2023h



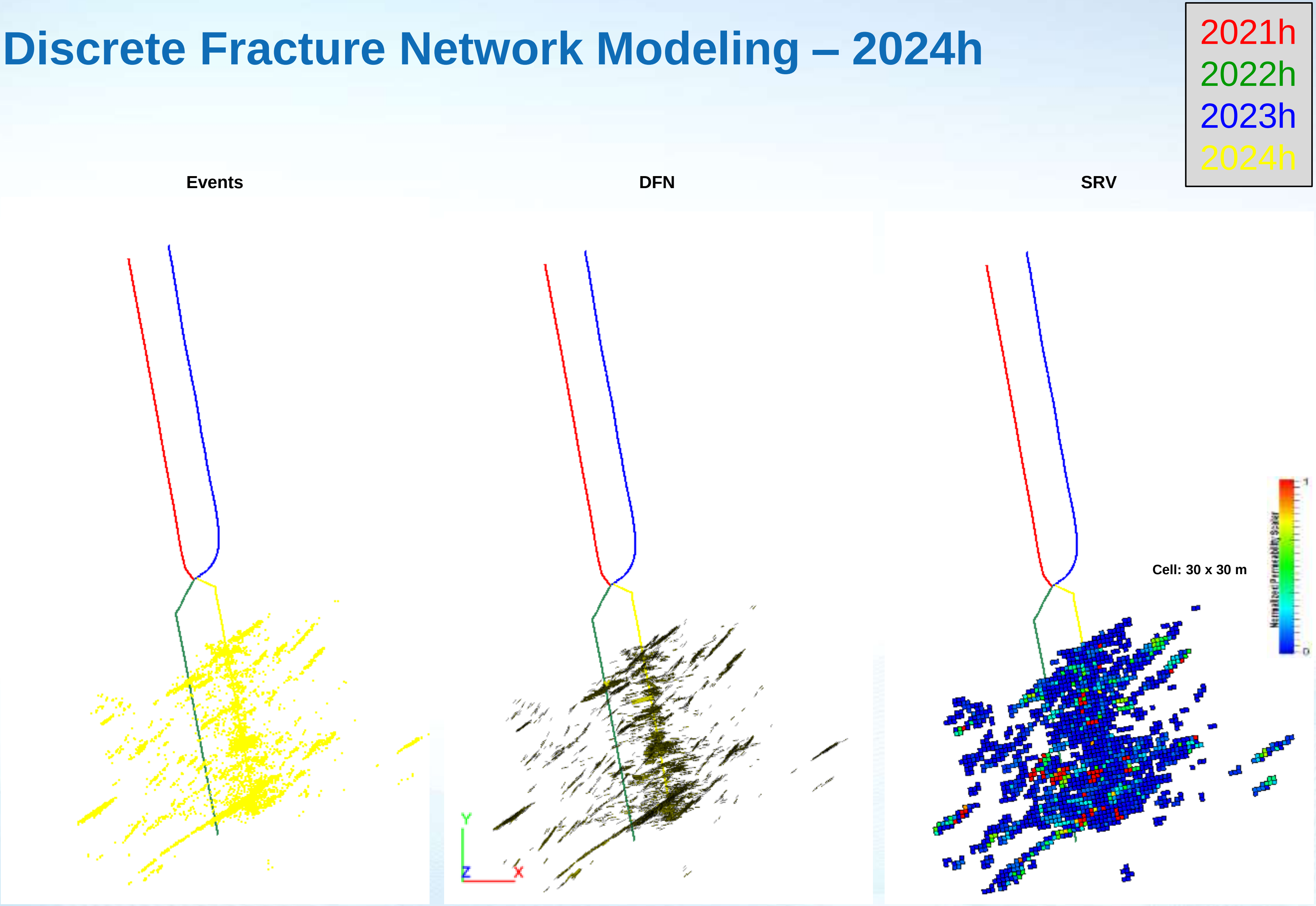
SRV by Formation – 2023h



Total SRV (m^3):	6.02×10^8	100%	Productive SRV (m^3):	4.26×10^7	7%
Chachao	1.20×10^8	20%	Chachao	-	0%
Lw Mulichinco	4.14×10^7	7%	Lw Mulichinco	-	0%
Quintuco	1.40×10^8	23%	Quintuco	-	<1%
Torrontes	9.44×10^7	16%	Torrontes	1.15×10^6	3%
Sirah	2.89×10^7	5%	Sirah	2.01×10^6	5%
Bonarda	9.98×10^7	17%	Bonarda	2.22×10^7	52%
Malbec	6.57×10^7	11%	Malbec	1.71×10^7	40%
Cabernet	1.12×10^7	2%	Cabernet	6.32×10^4	<1%

MicroSeismic

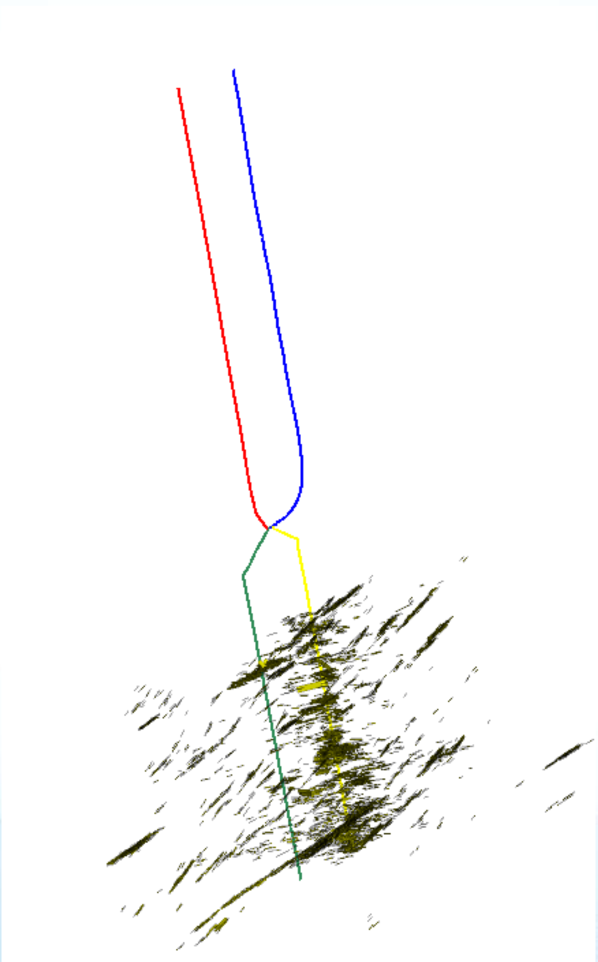
Discrete Fracture Network Modeling – 2024h



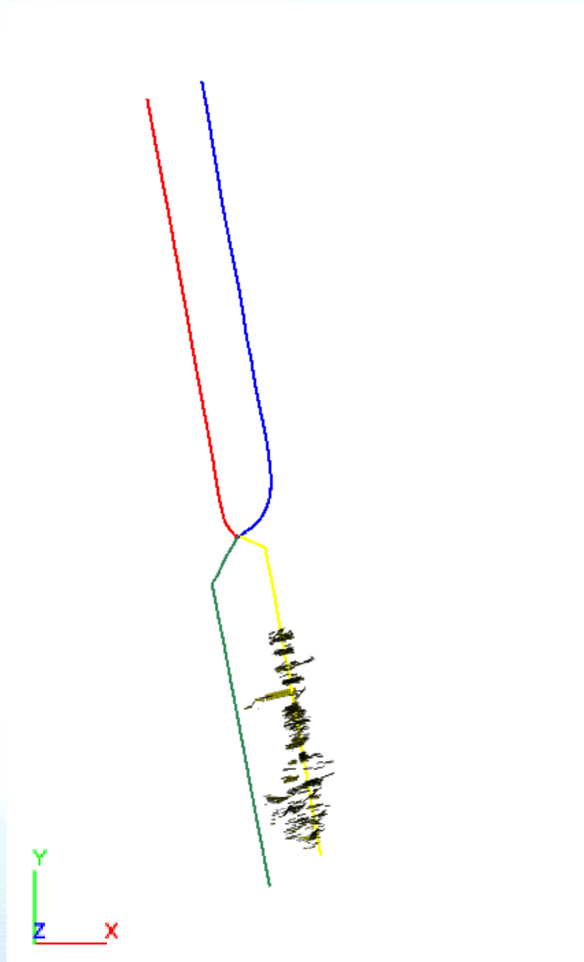
Discrete Fracture Network Modeling – 2024h

2021h
2022h
2023h
2024h

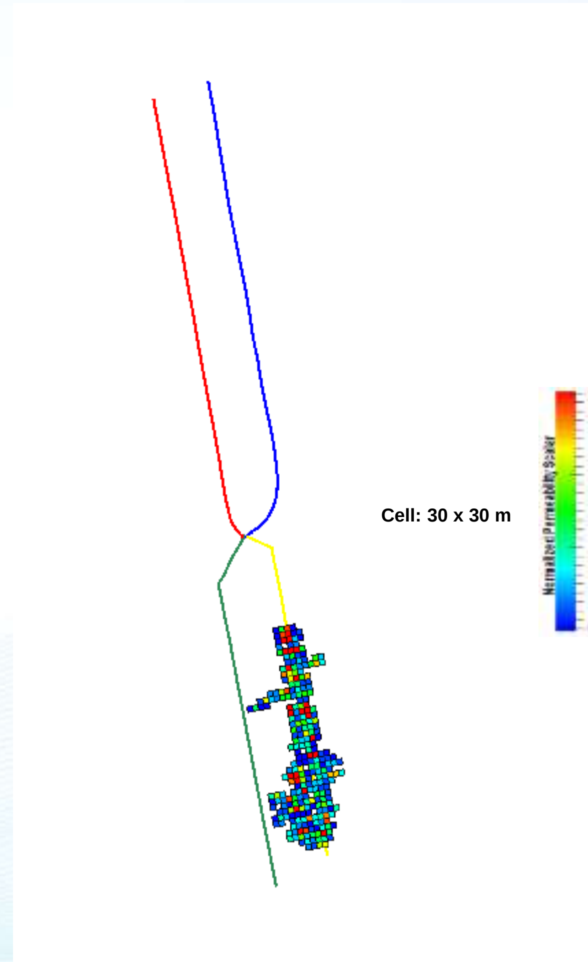
DFN



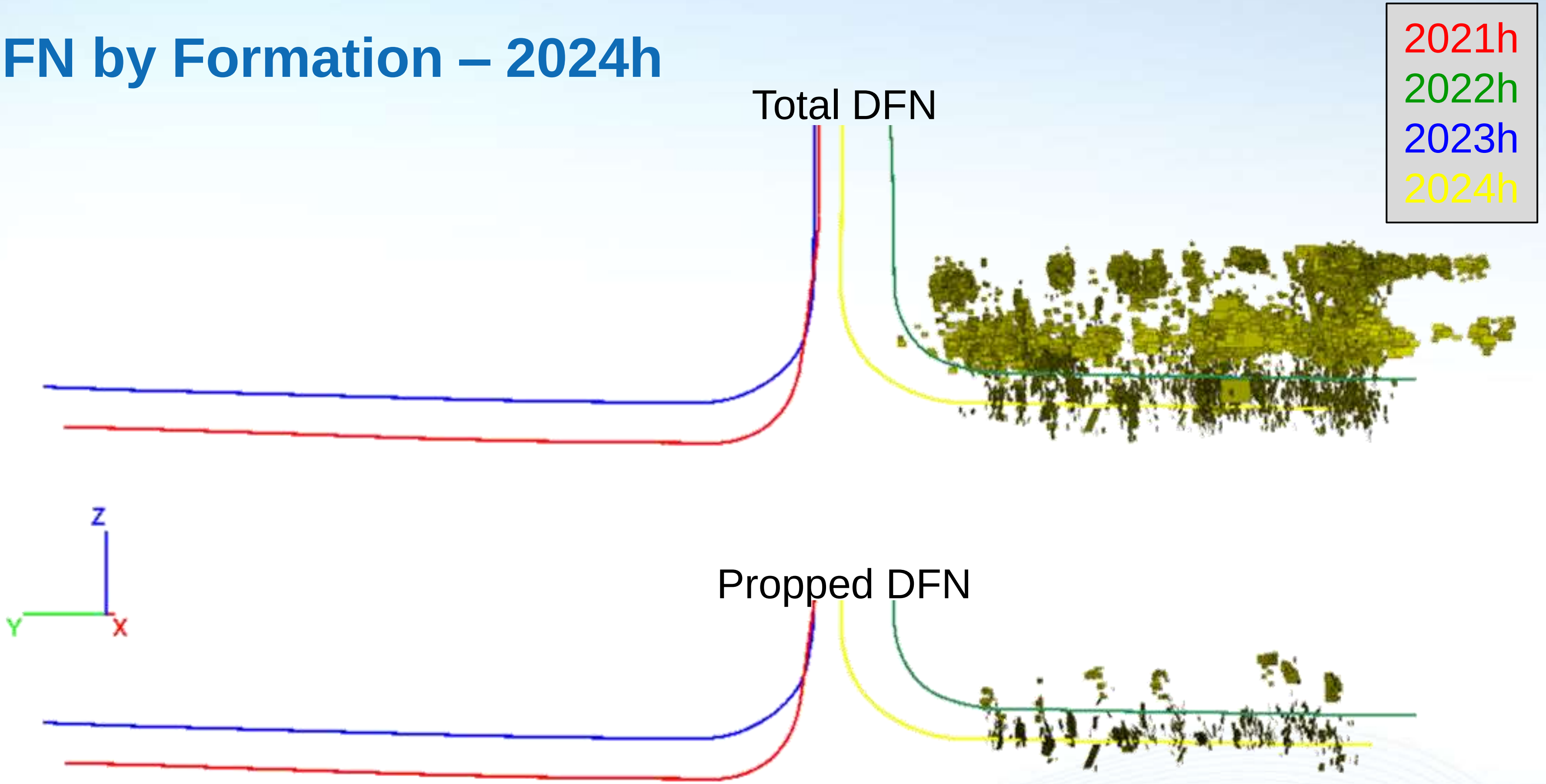
Propped DFN



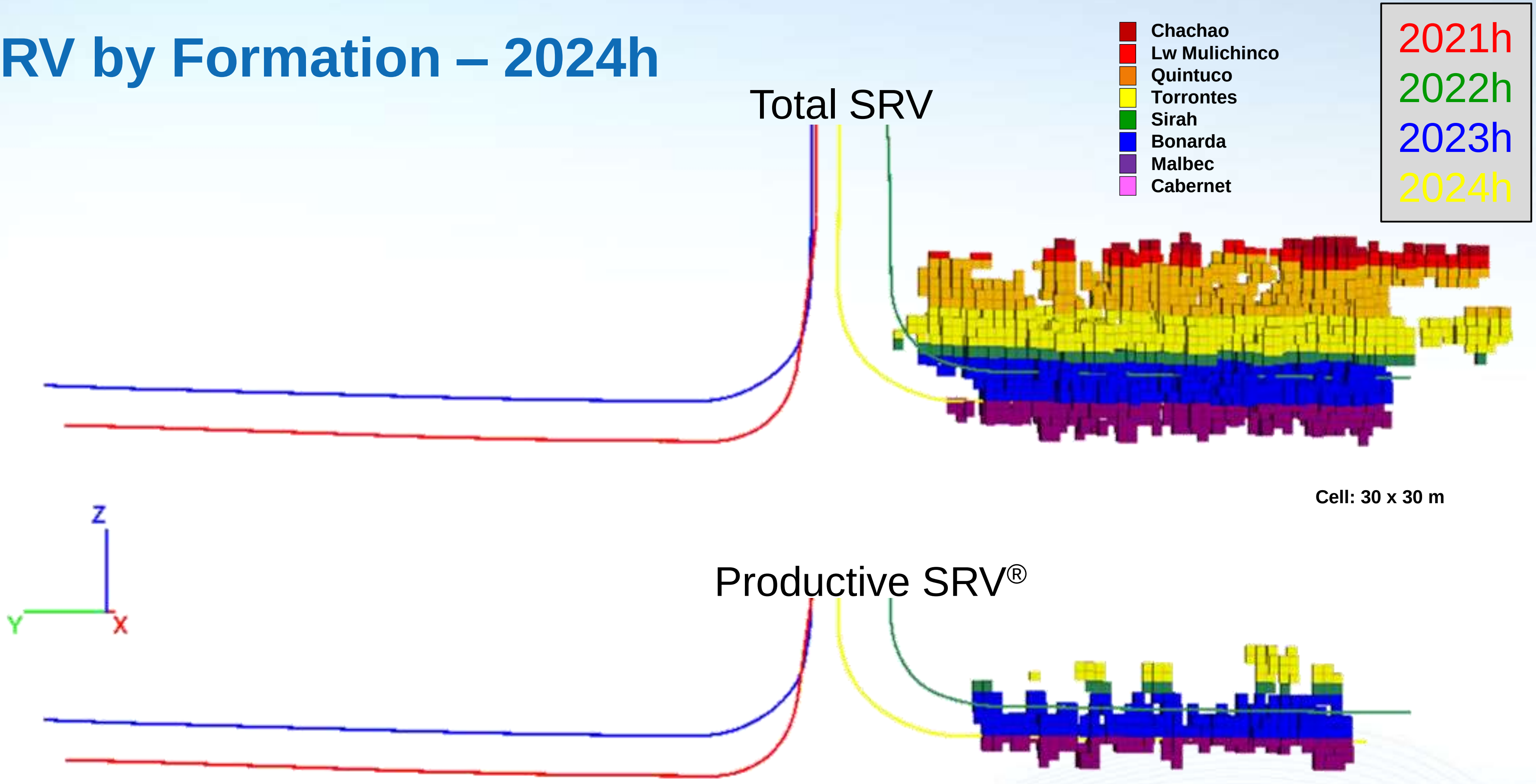
Productive SRV®



DFN by Formation – 2024h



SRV by Formation – 2024h



Total SRV (m^3):	2.22×10^8	100%	Productive SRV (m^3):	2.76×10^7	12%
Chachao	2.30×10^6	1%	Chachao	-	0%
Lw Mulichinco	7.12×10^6	3%	Lw Mulichinco	-	0%
Quintuco	3.29×10^7	15%	Quintuco	-	<1%
Torrontes	6.89×10^7	31%	Torrontes	1.86×10^6	7%
Sirah	2.19×10^7	10%	Sirah	9.55×10^5	3%
Bonarda	6.52×10^7	29%	Bonarda	1.69×10^7	61%
Malbec	2.39×10^7	11%	Malbec	7.82×10^6	28%
Cabernet	-	0%	Cabernet	-	0%

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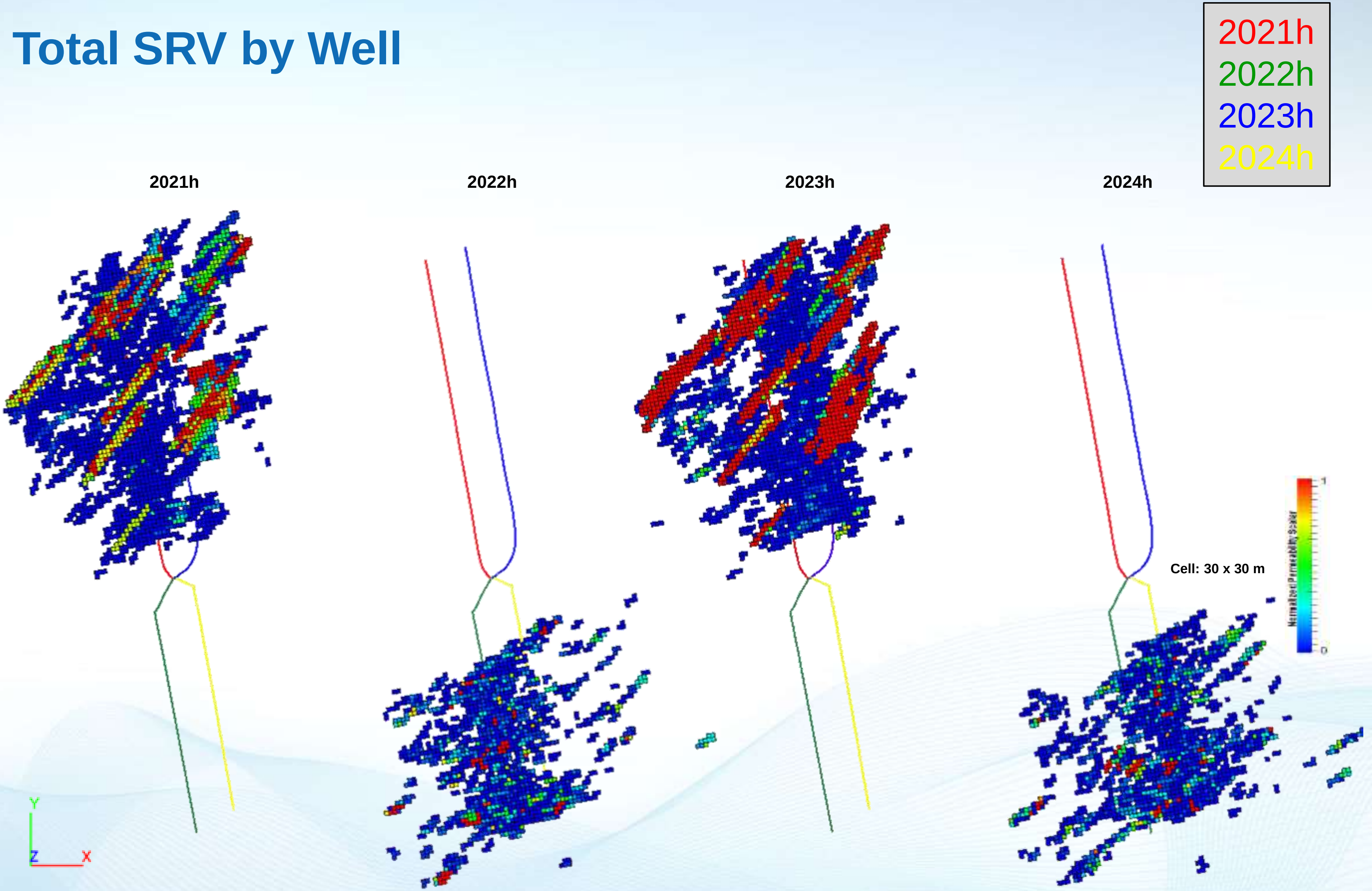
Total SRV by Well



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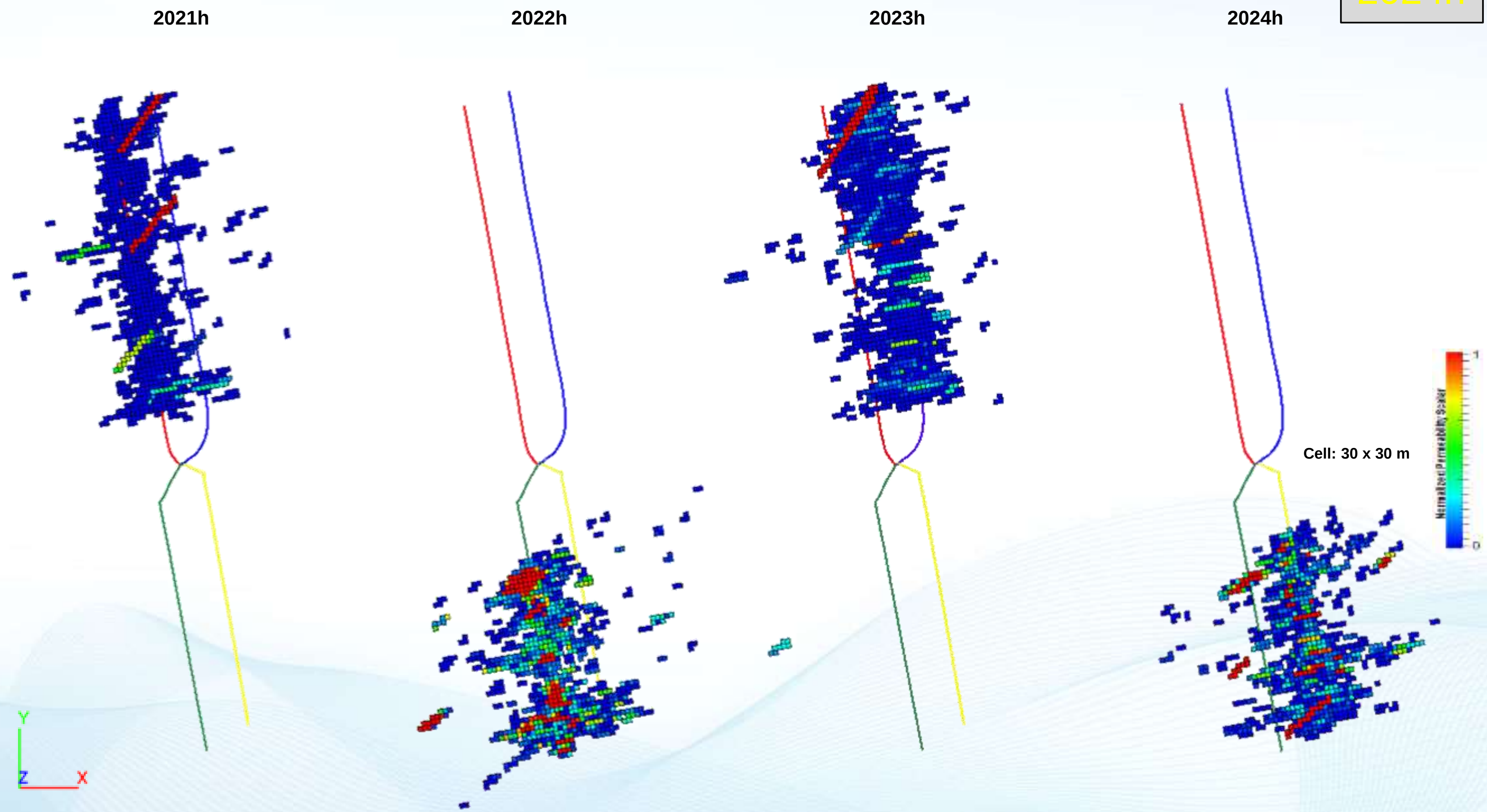
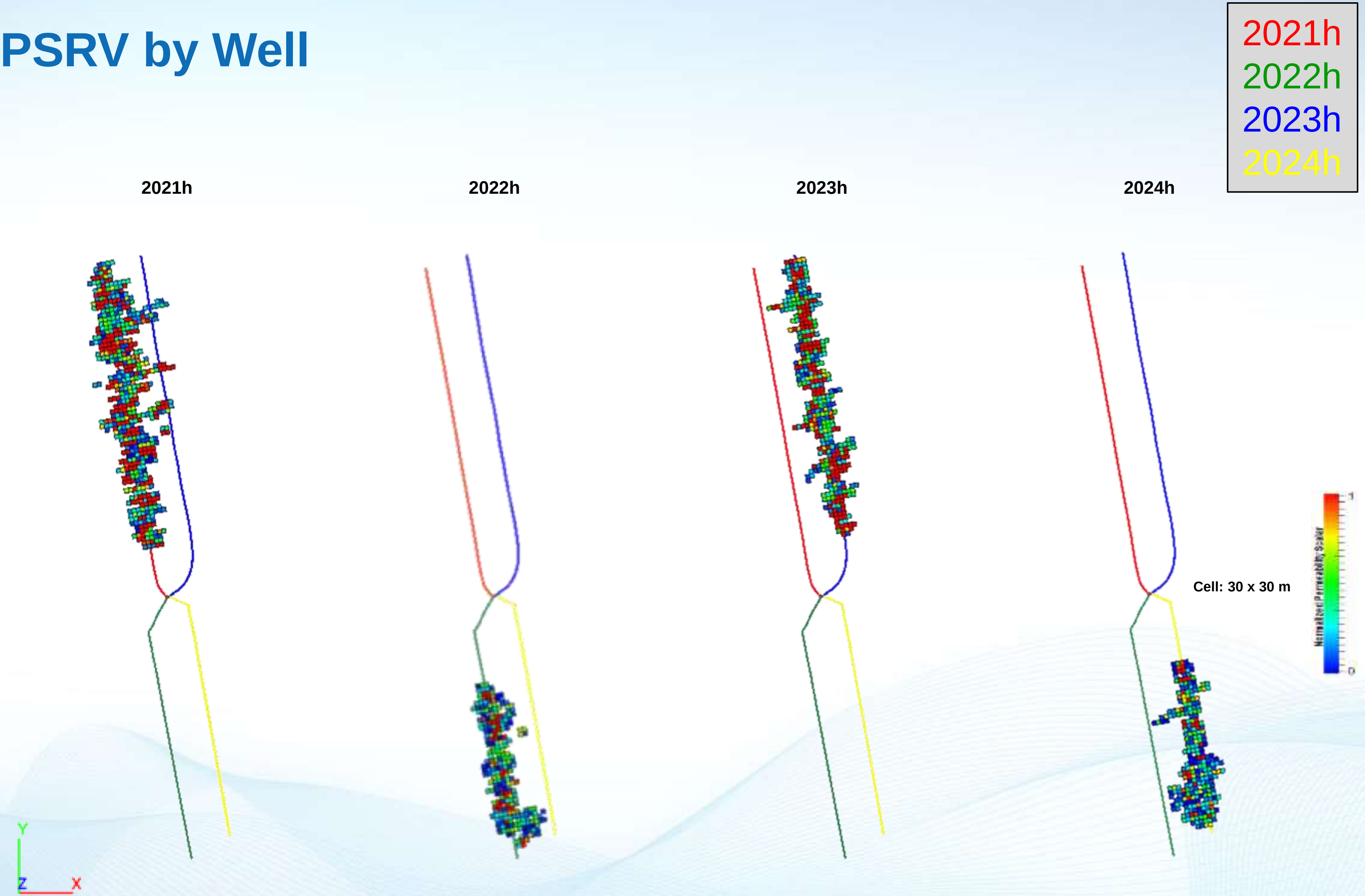
Total SRV below Sirah by Well

2021h
2022h
2023h
2024h



PSRV by Well



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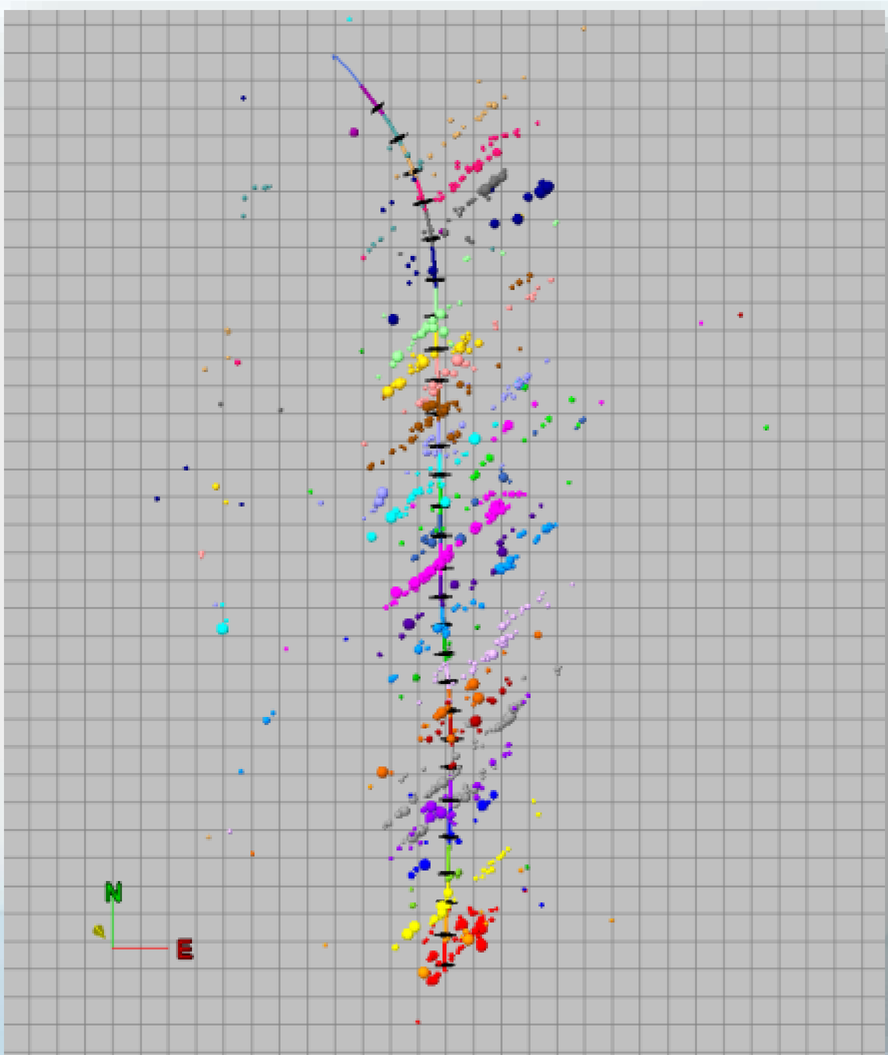
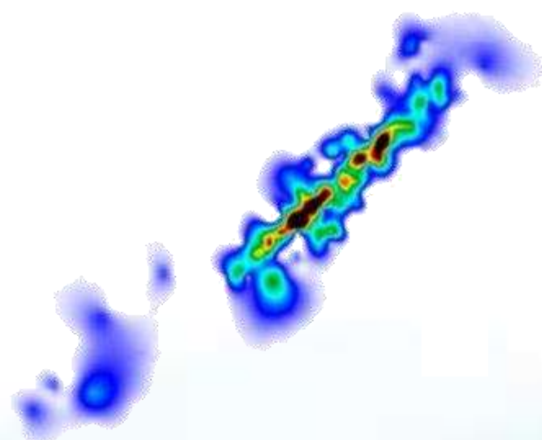
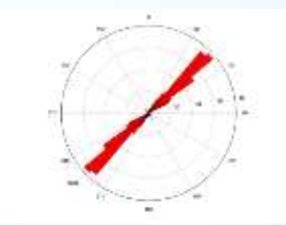
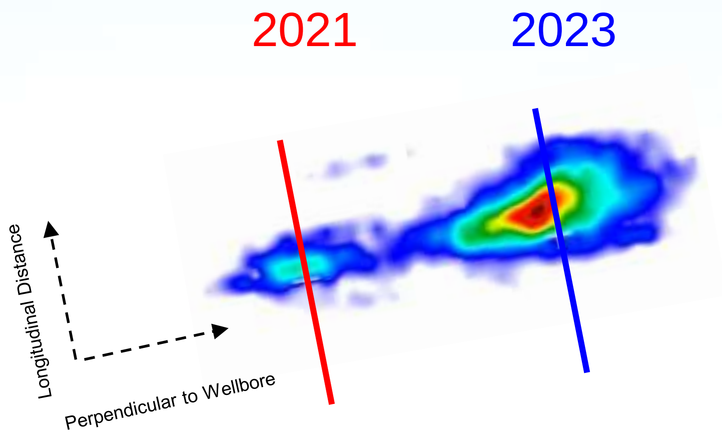
Stacking Stages Example

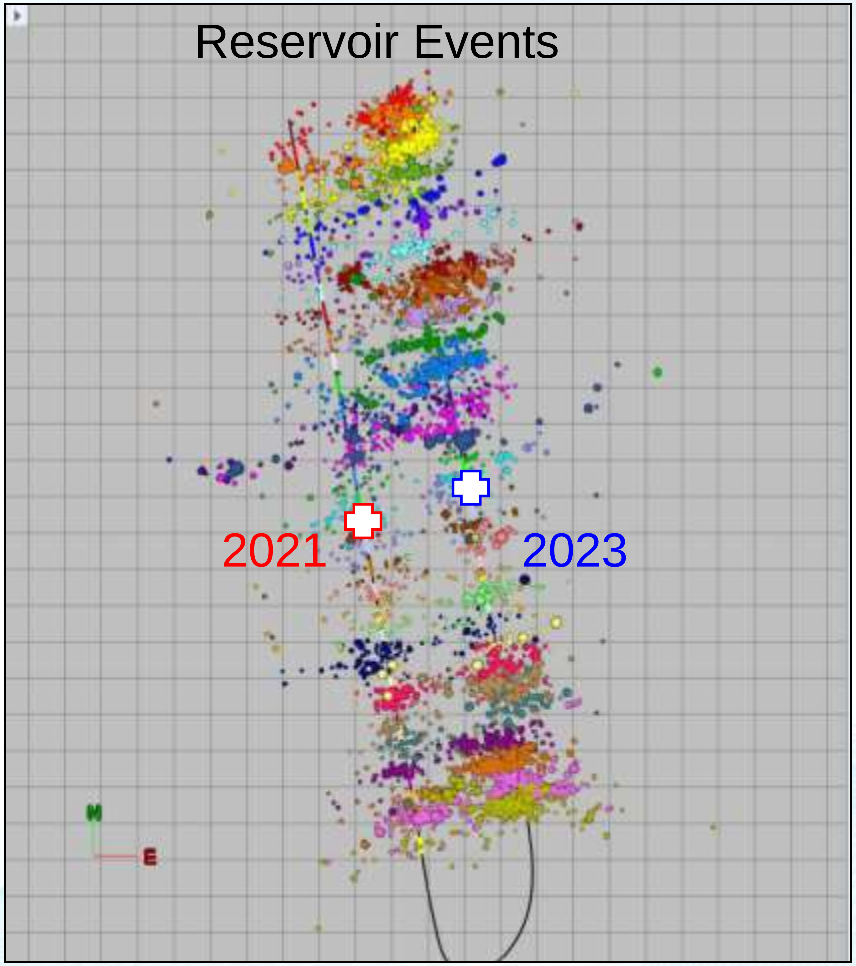




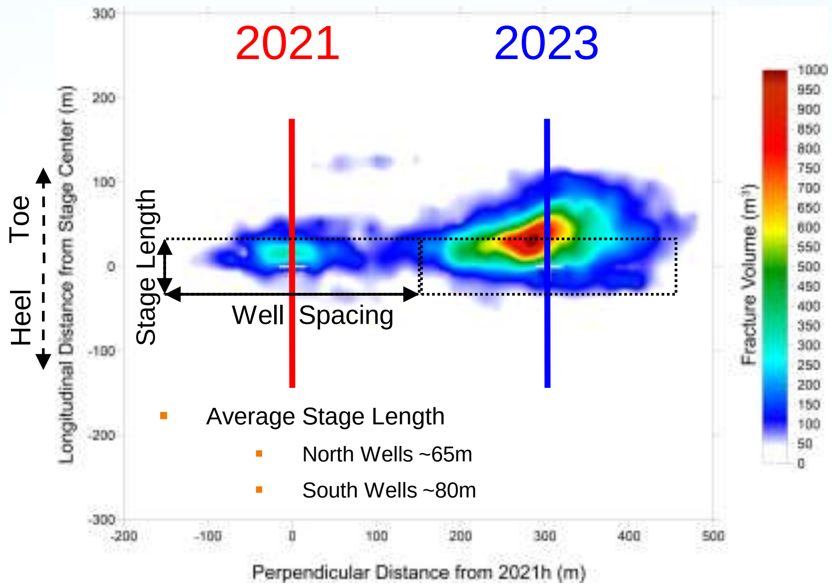


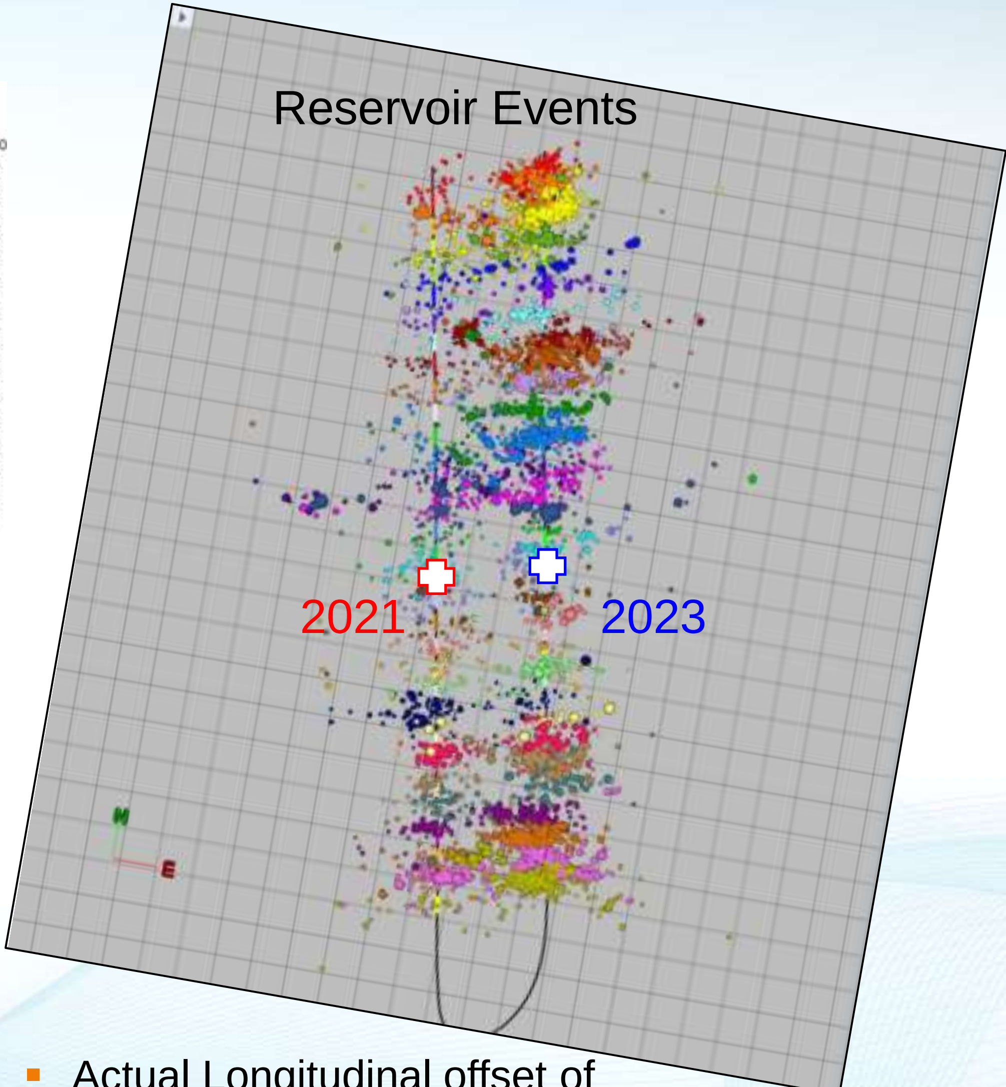
Wellbore Azimuth Relative Coordinates





Wellbore Azimuth Relative Coordinates

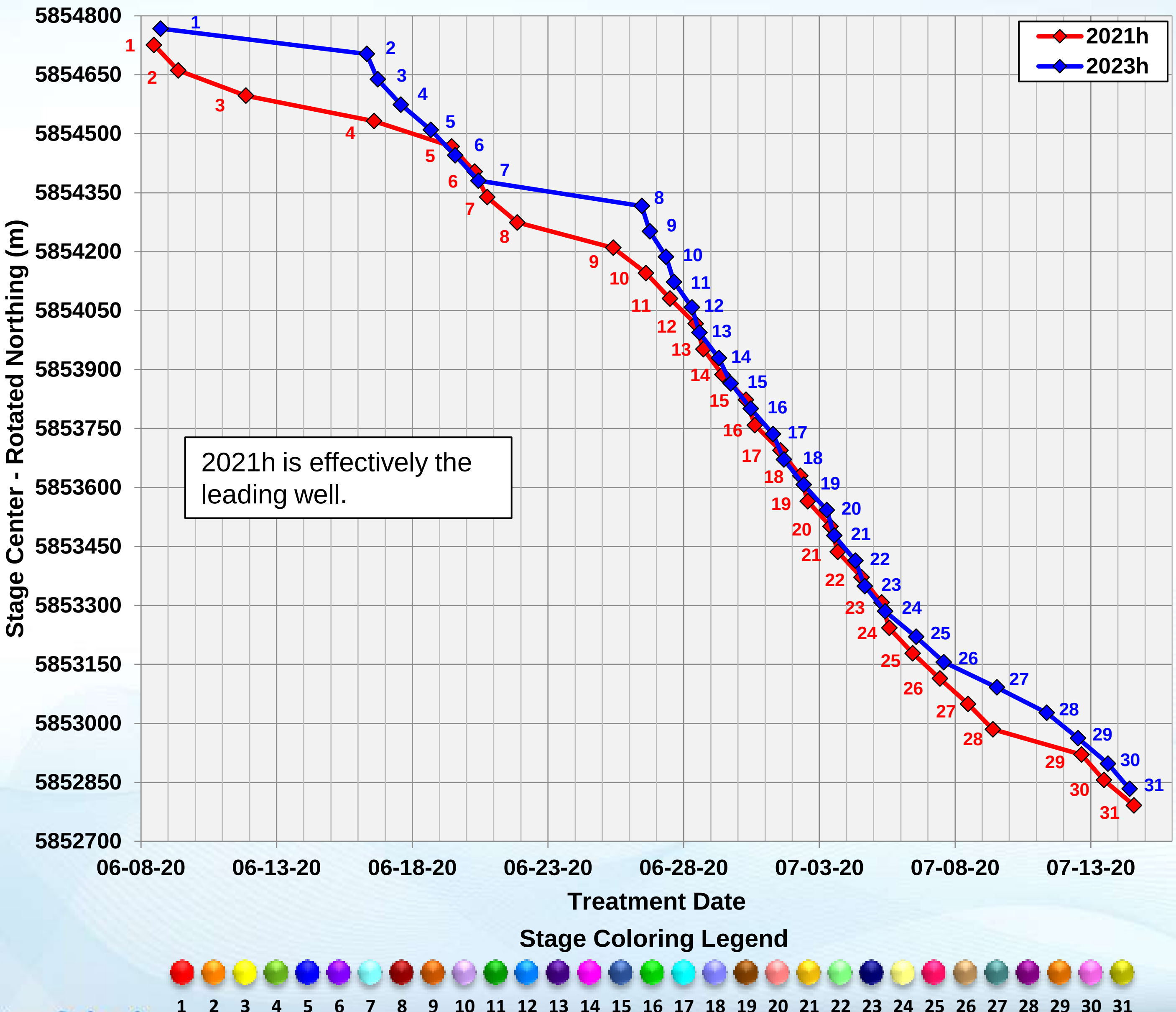


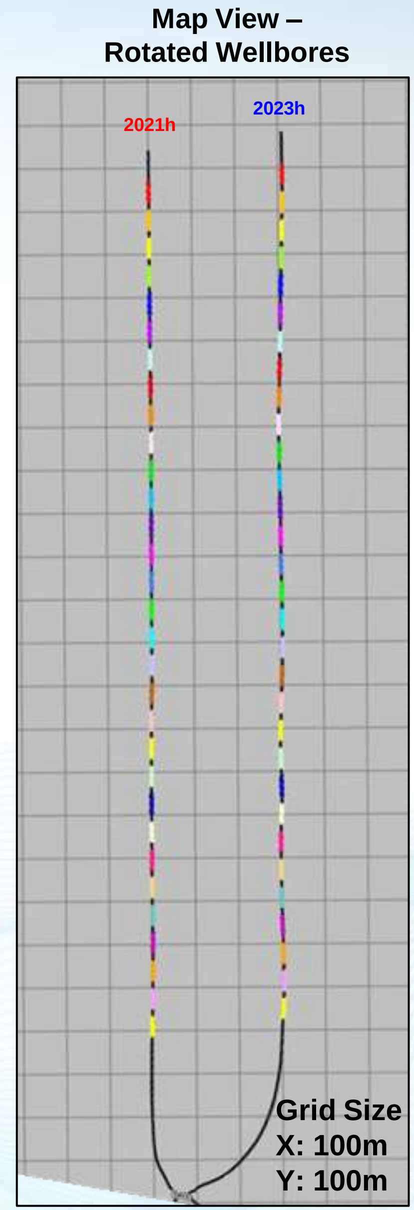


- Stacked stages represent average microseismic response to treatment
- Rotated coordinate system useful for determining optimal wellbore and stage spacing as well as identify treatment interaction relationships
- Slicing down to reservoir events (below Bonarda Top) reveals fractured volume around stages
- Actual Longitudinal offset of paired stages in rotated state
  - North Wells ~42m
  - South Wells ~105m

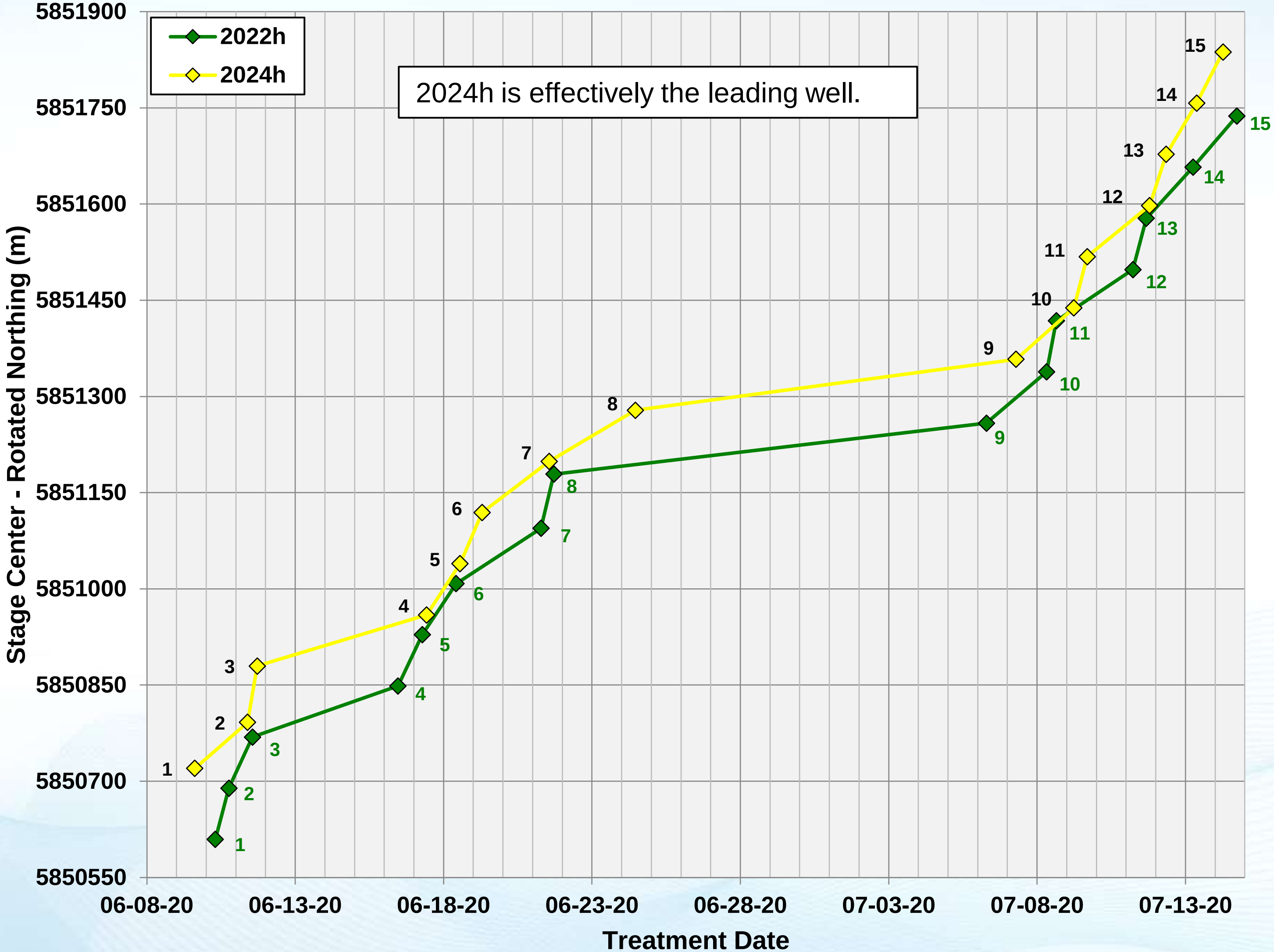
MicroSeismic

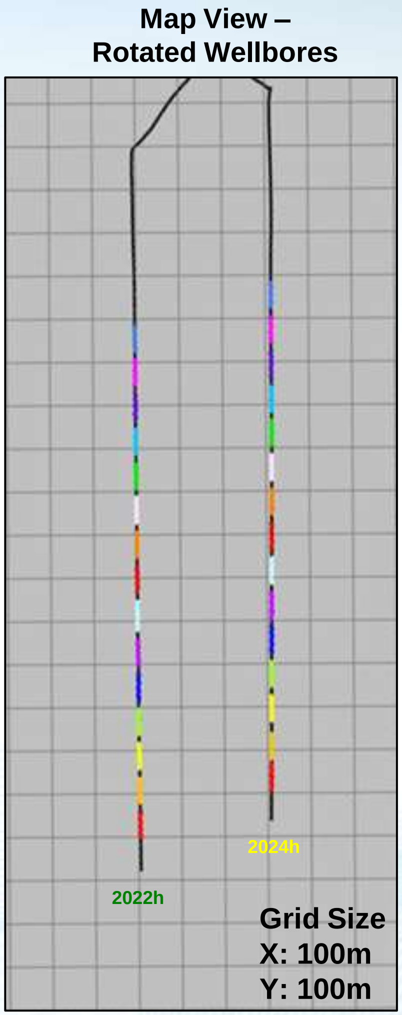
Treatment Order – 2021h & 2023h



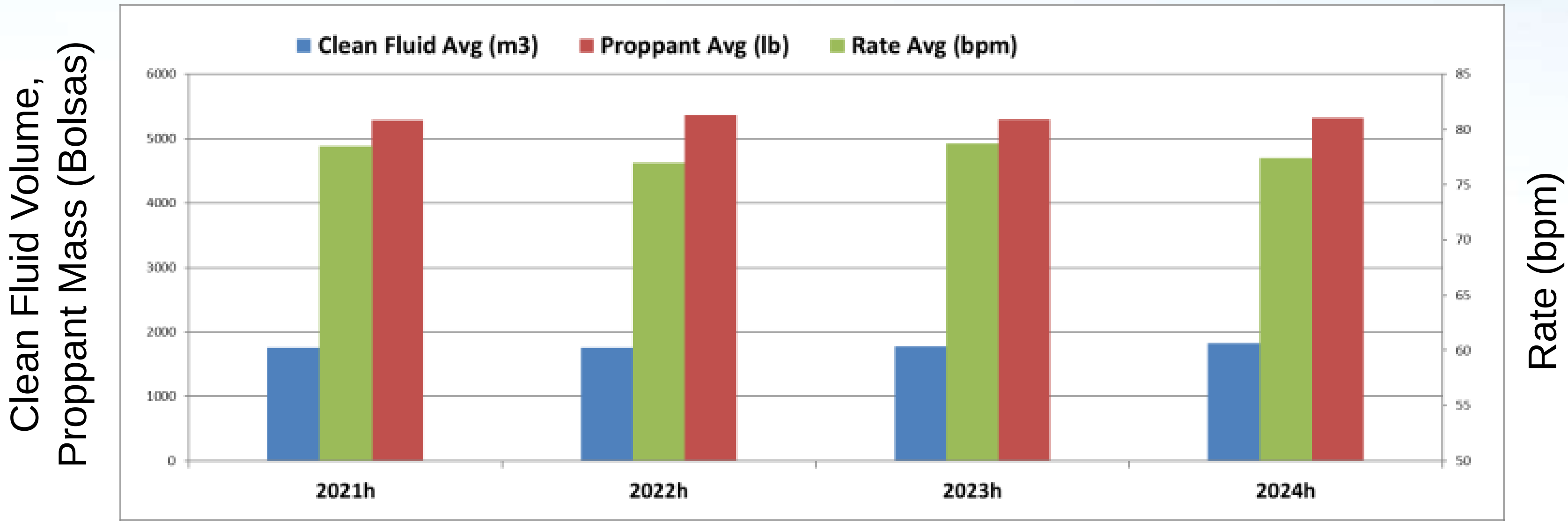


Treatment Order – 2022h & 2024h





Treatment Summary



North

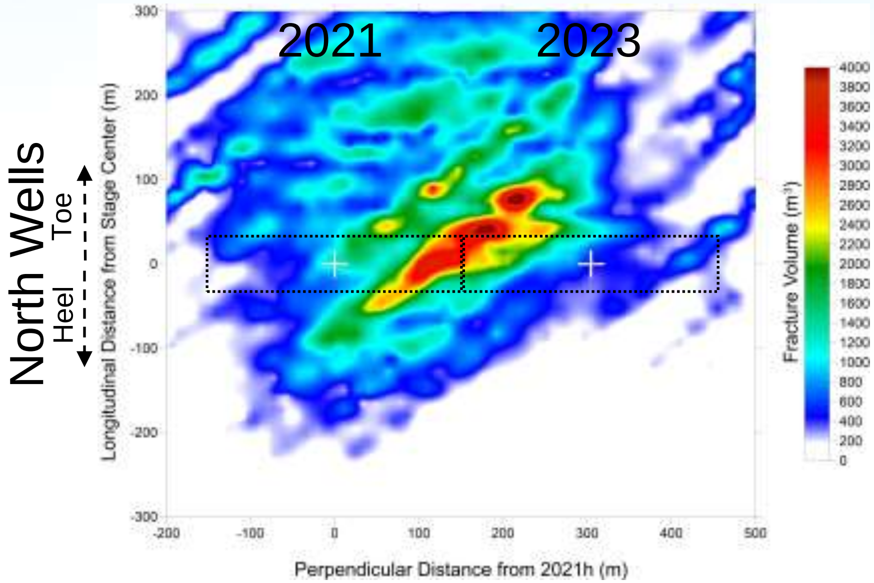
Well	Stages	Stage Length (m)	Clusters	Fluid Volume per Stage (m^3)	Proppant per Stage (lbs)	Slurry Rate (bpm)	Average Pressure (psi)	Fluid/m of completed lateral (m^3/m)	Proppant/m of completed lateral (lbs/m)
2021h	31	65	10	1,747	529,500	78.5	9,839	26.9	8,146
2023h	31	65	10	1,773	529,632	78.7	9,628	27.3	8,148

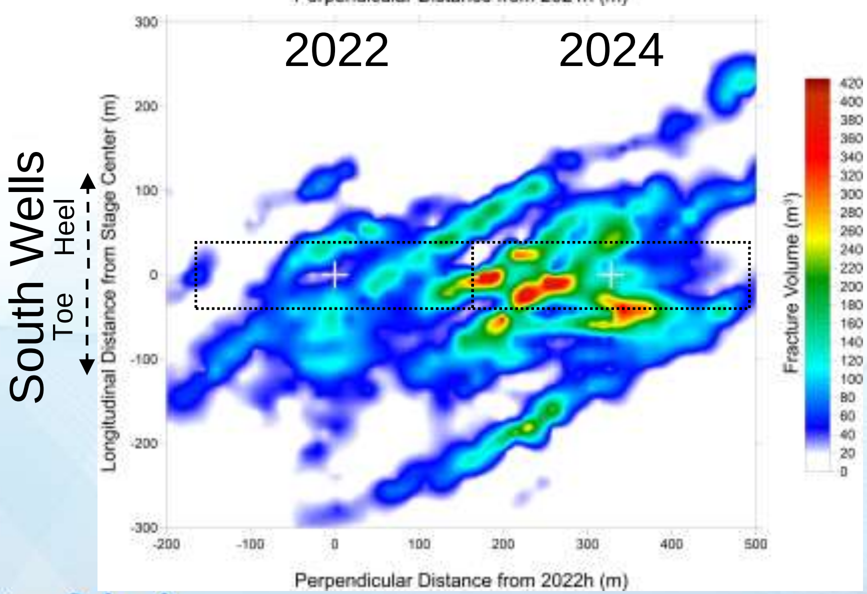
South

Well	Stages	Stage Length (m)	Clusters	Fluid Volume per Stage (m^3)	Proppant per Stage (lbs)	Slurry Rate (bpm)	Average Pressure (psi)	Fluid/m of completed lateral (m^3/m)	Proppant/m of completed lateral (lbs/m)
2022h	15	80	10	1,746	536,273	76.9	8,252	21.8	6,703
2024h	15	80	10	1,831	532,167	77.4	9,337	22.8	6,652

MicroSeismic

Well Spacing – Fracture Volume





- Fracture volume is elevated between stages and biased eastward

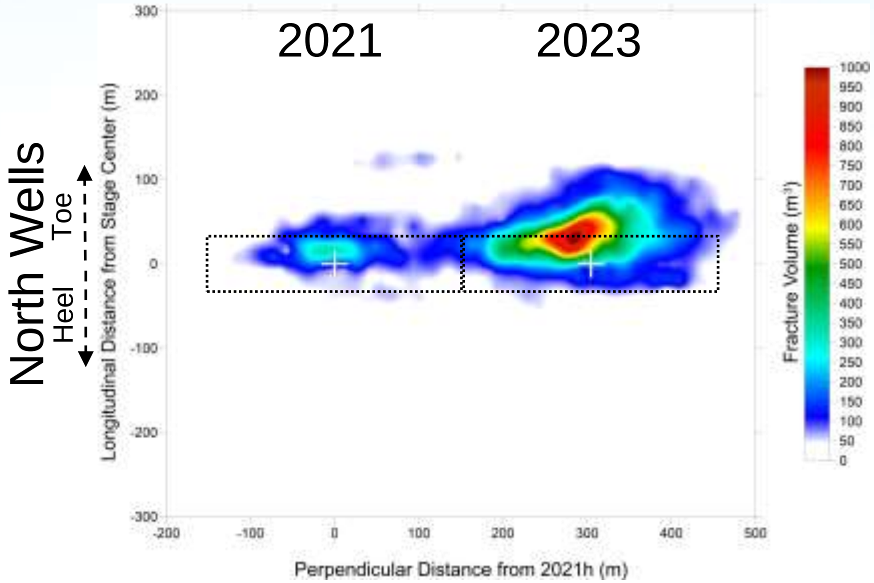
All Depths

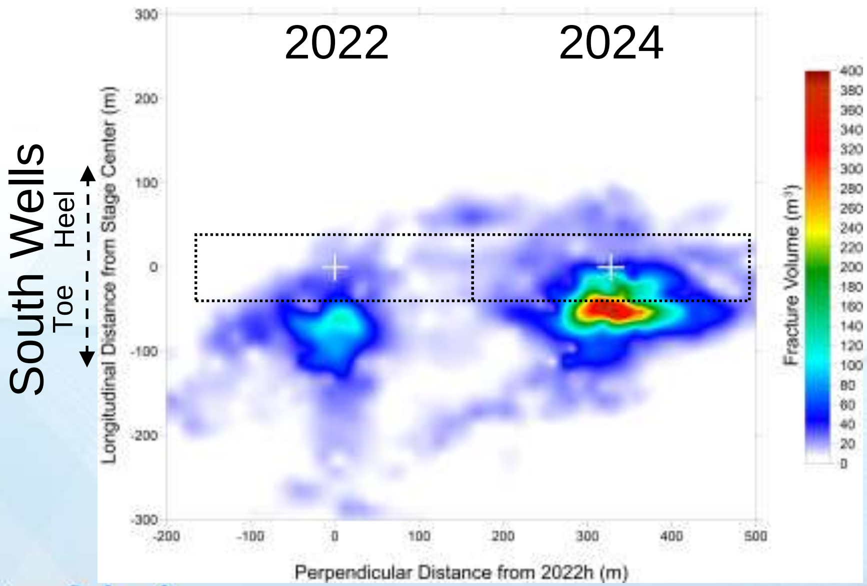
P90 Metric (m)	2021	2022	2023	2024
Propped Half-Length	103	70	67	84
Half-Length	683	451	712	837
Propped Height	249	198	189	248
Height	349	407	554	466
Propped Half-Width	49	60	31	48
Half-Width	705	229	744	303

Reservoir

P90 Metric (m)	2021	2022	2023	2024
Propped Half-Length	105	87	67	82
Half-Length	297	283	162	226
Propped Height	246	110	118	145
Height	354	132	192	166
Propped Half-Width	50	65	28	44
Half-Width	91	170	69	95

Well Spacing – Fracture Volume Sliced Below Bonarda Top





- Fracture volume is biased towards the toe of the wells
- Greater fracture volume within targeted zone on northern wells
- Greater toe-ward growth on southern wells

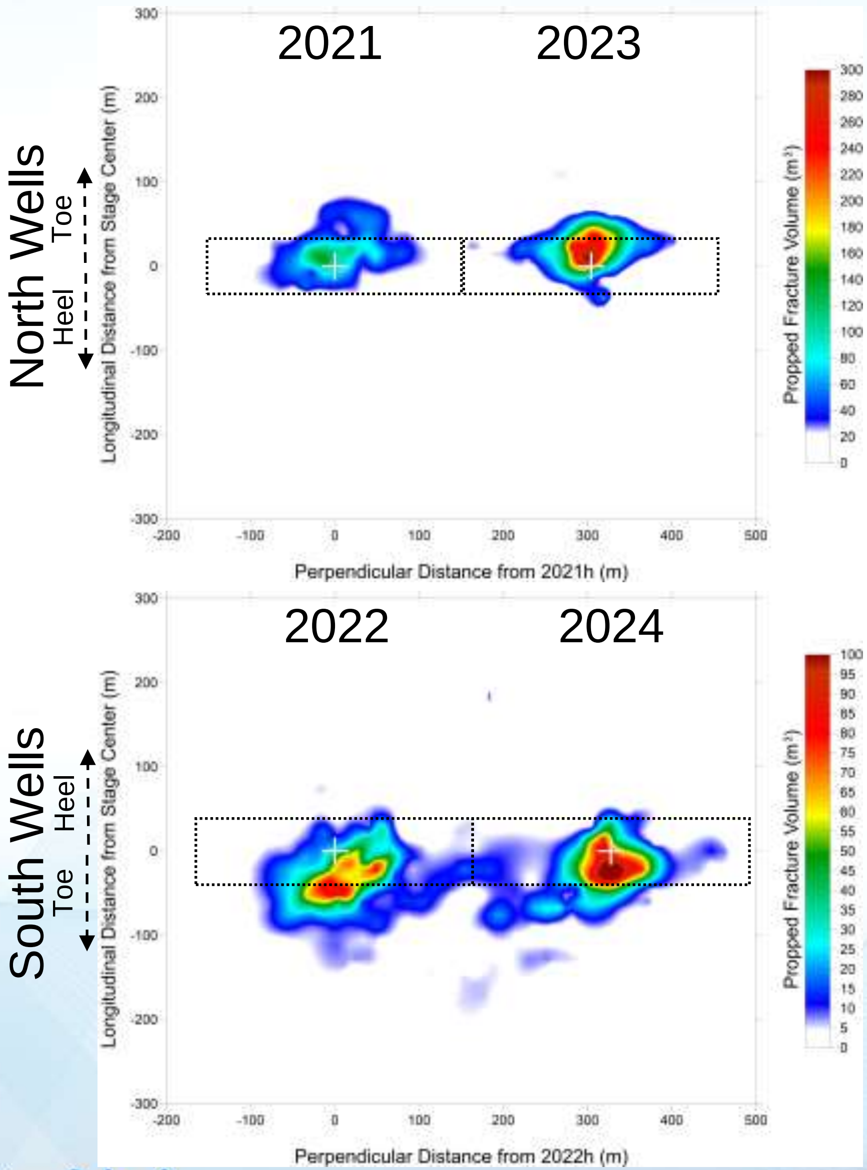
All Depths

P90 Metric (m)	2021	2022	2023	2024
Propped Half-Length	103	70	67	84
Half-Length	683	451	712	837
Propped Height	249	198	189	248
Height	349	407	554	466
Propped Half-Width	49	60	31	48
Half-Width	705	229	744	303

Reservoir

P90 Metric (m)	2021	2022	2023	2024
Propped Half-Length	105	87	67	82
Half-Length	297	283	162	226
Propped Height	246	110	118	145
Height	354	132	192	166
Propped Half-Width	50	65	28	44
Half-Width	91	170	69	95

Well Spacing – Propped Fracture Volume



- Highest proppant concentrations on eastern wells
- Proppant gap exists between neighboring wellbores

All Depths

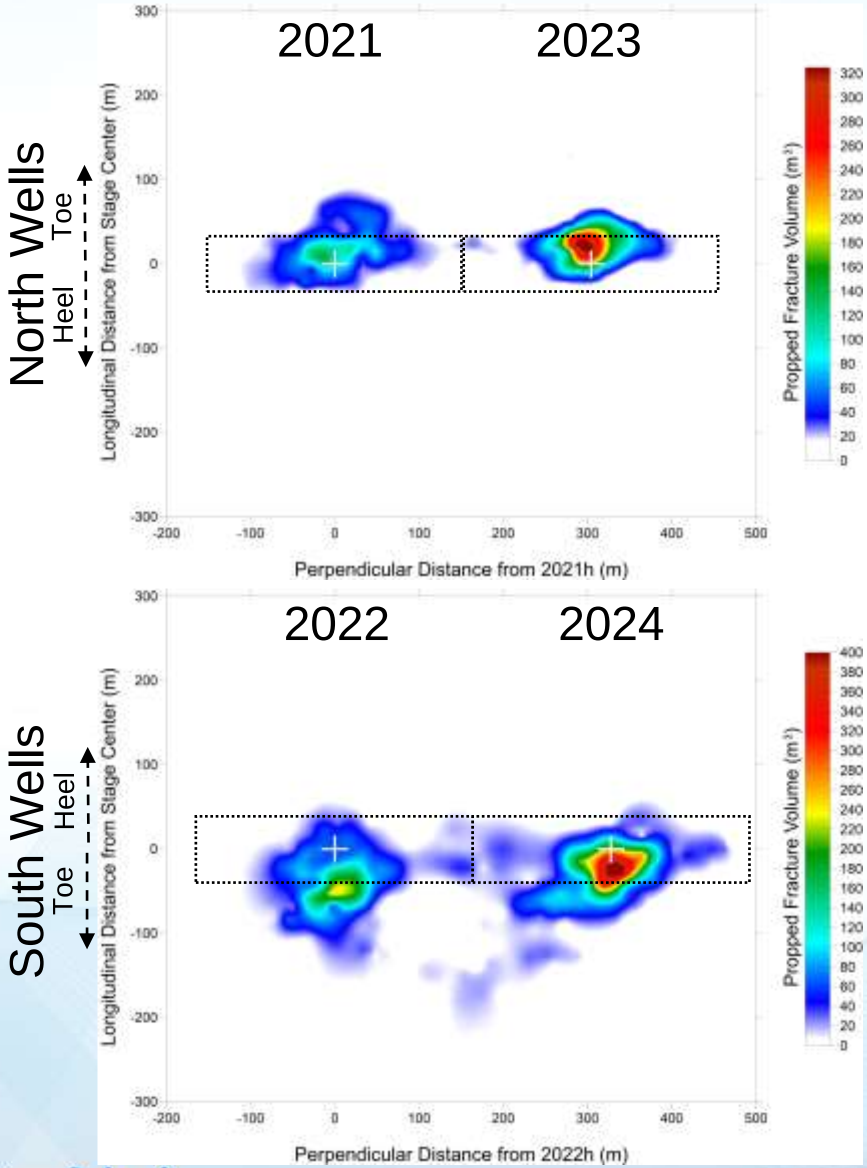
P90 Metric (m)	2021	2022	2023	2024
Propped Half-Length	103	70	67	84
Half-Length	683	451	712	837
Propped Height	249	198	189	248
Height	349	407	554	466
Propped Half-Width	49	60	31	48
Half-Width	705	229	744	303

Reservoir

P90 Metric (m)	2021	2022	2023	2024
Propped Half-Length	105	87	67	82
Half-Length	297	283	162	226
Propped Height	246	110	118	145
Height	354	132	192	166
Propped Half-Width	50	65	28	44
Half-Width	91	170	69	95

MicroSeismic

Well Spacing – Propped Fracture Volume
Sliced Below Bonarda Top



- Proppant biased towards toe-side of wellbore

All Depths

P90 Metric (m)	2021	2022	2023	2024
Propped Half-Length	103	70	67	84
Half-Length	683	451	712	837
Propped Height	249	198	189	248
Height	349	407	554	466
Propped Half-Width	49	60	31	48
Half-Width	705	229	744	303

Reservoir

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Propped Half-Length	105	87	67	82
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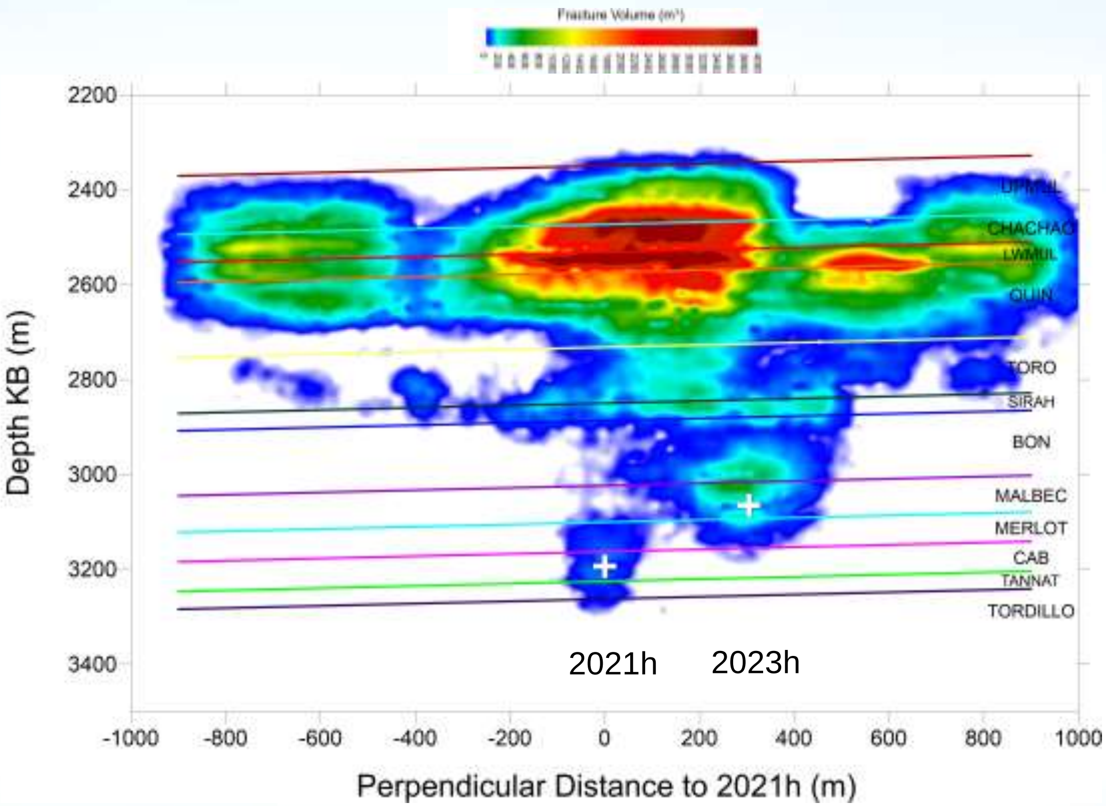
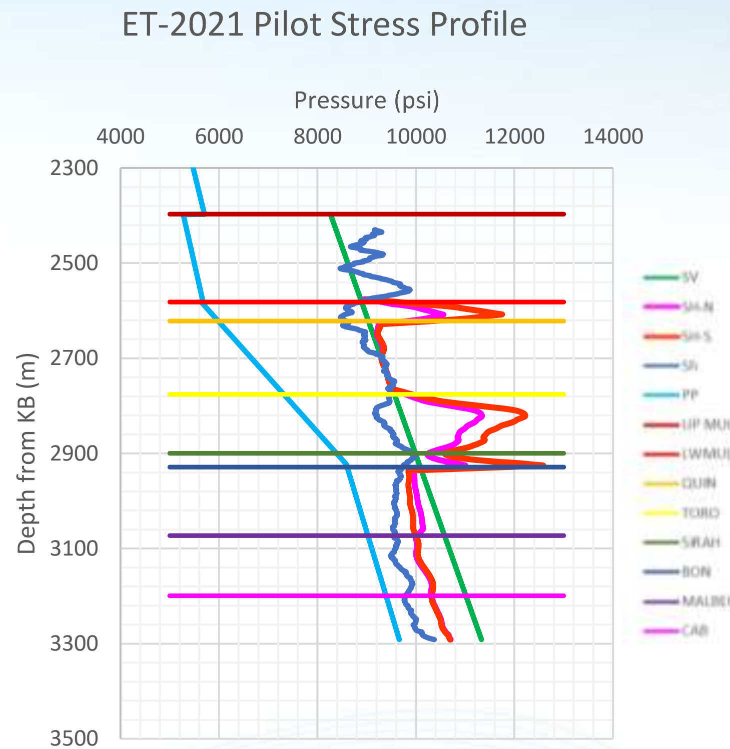
Propped Height	246	110	118	145
Height	354	132	192	166
Propped Half-Width	50	65	28	44
Half-Width	91	170	69	95

MicroSeismic

Fracture Volume – Depth View, Northern Wells





Stress Profile from 2021h Pilot Well
Depths shifted to match formation tops

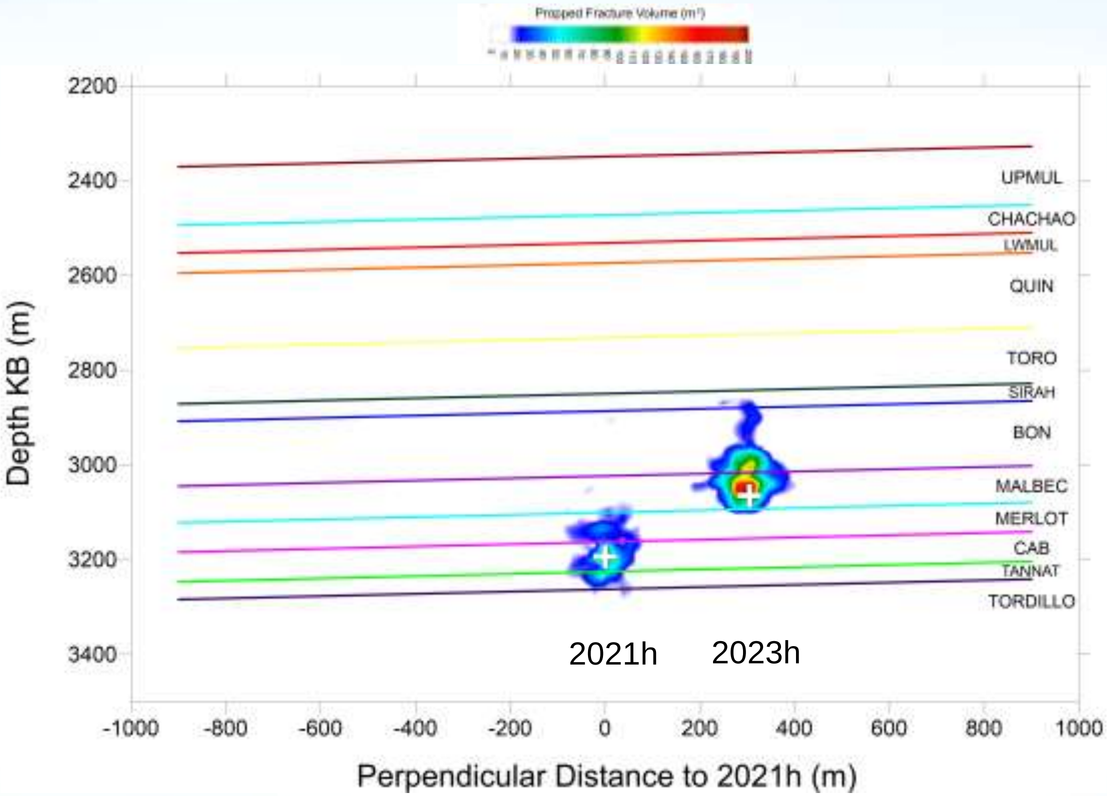
- Significant upward growth observed above Bonarda top where pore-pressure gradient is highest
- Formation tops with abrupt stress changes contain energy near the formation boundaries
- Leading 2021h well compounds pore-pressure on neighboring 2023h well resulting in significant upward growth between wells

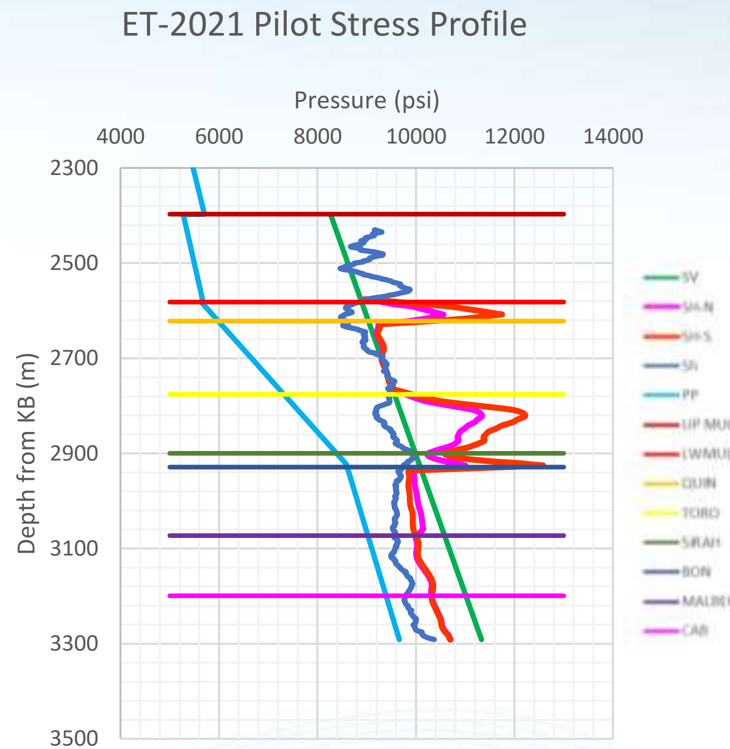
All Depths

P90 Metric (m)	2021	2022	2023	2024
Propped Half-Length	103	70	67	84
Half-Length	683	451	712	837
Propped Height	249	198	189	248
Height	349	407	554	466
Propped Half-Width	49	60	31	48
Half-Width	705	229	744	303

MicroSeismic

Propped Fracture Volume – Depth View, Northern Wells





Stress Profile from 2021h Pilot Well
Depths shifted to match formation tops

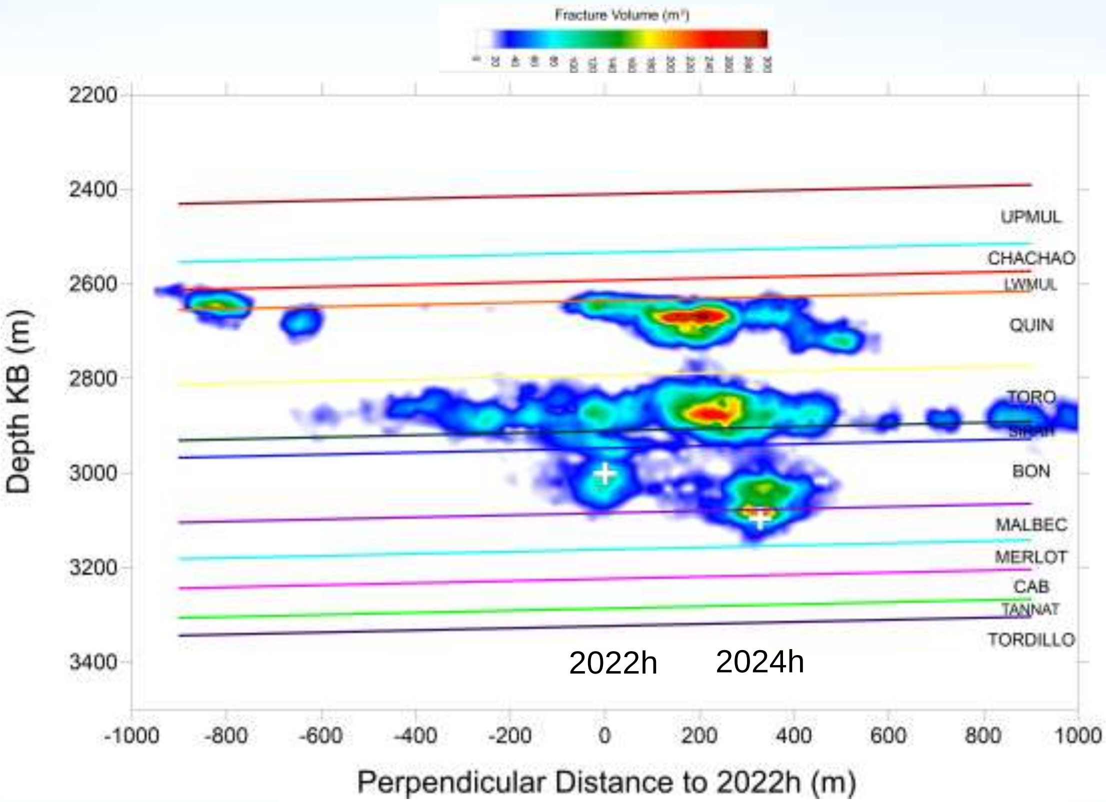
- Significant upward proppant growth
- Highest proppant concentration located close to 2023h and below MALBEC top

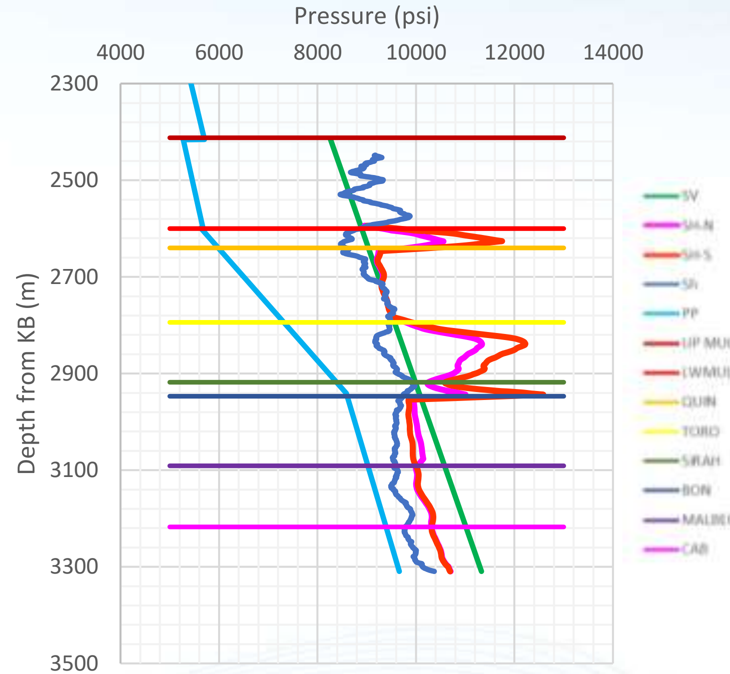
Reservoir Depths

P90 Metric (m)	2021	2022	2023	2024
Propped Half-Length	105	87	67	82
Half-Length	297	283	162	226
Propped Height	246	110	118	145
Height	354	132	192	166
Propped Half-Width	50	65	28	44
Half-Width	91	170	69	95

MicroSeismic

Fracture Volume – Depth View, Southern Wells





Stress Profile from 2021h Pilot Well
Depths shifted to match formation tops

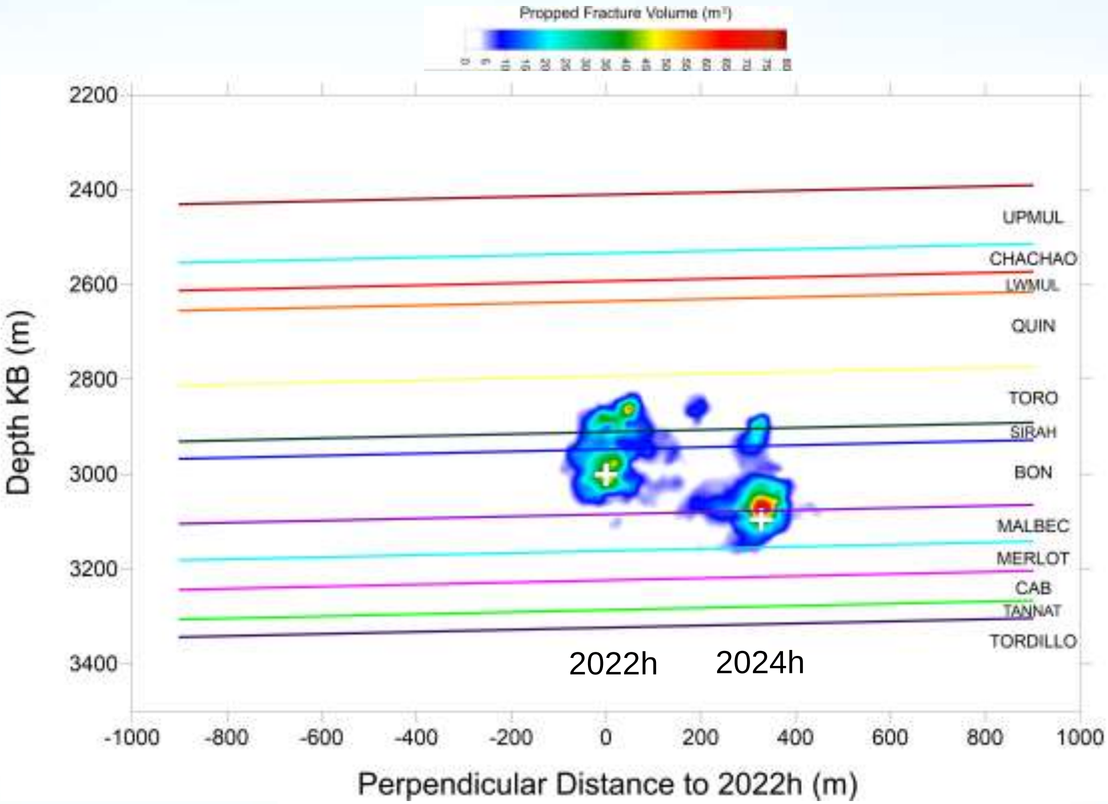
- Highest fracture volume within TORO and QUIN between treated wellbores
- Greater vertical than horizontal growth around treated wellbores

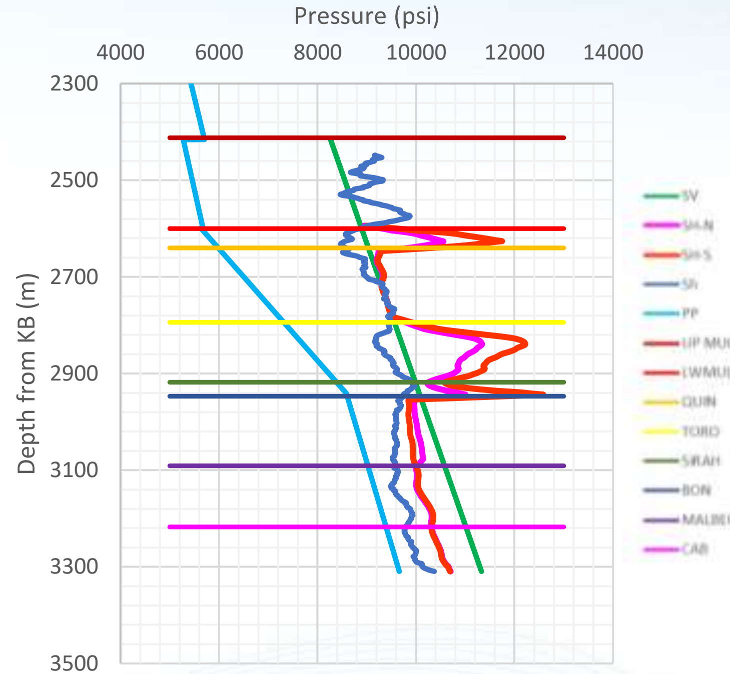
All Depths

P90 Metric (m)	2021	2022	2023	2024
Propped Half-Length	103	70	67	84
Half-Length	683	451	712	837
Propped Height	249	198	189	248
Height	349	407	554	466
Propped Half-Width	49	60	31	48
Half-Width	705	229	744	303

MicroSeismic

Propped Fracture Volume – Depth View, Southern Wells





Stress Profile from 2021h Pilot Well
Depths shifted to match formation tops

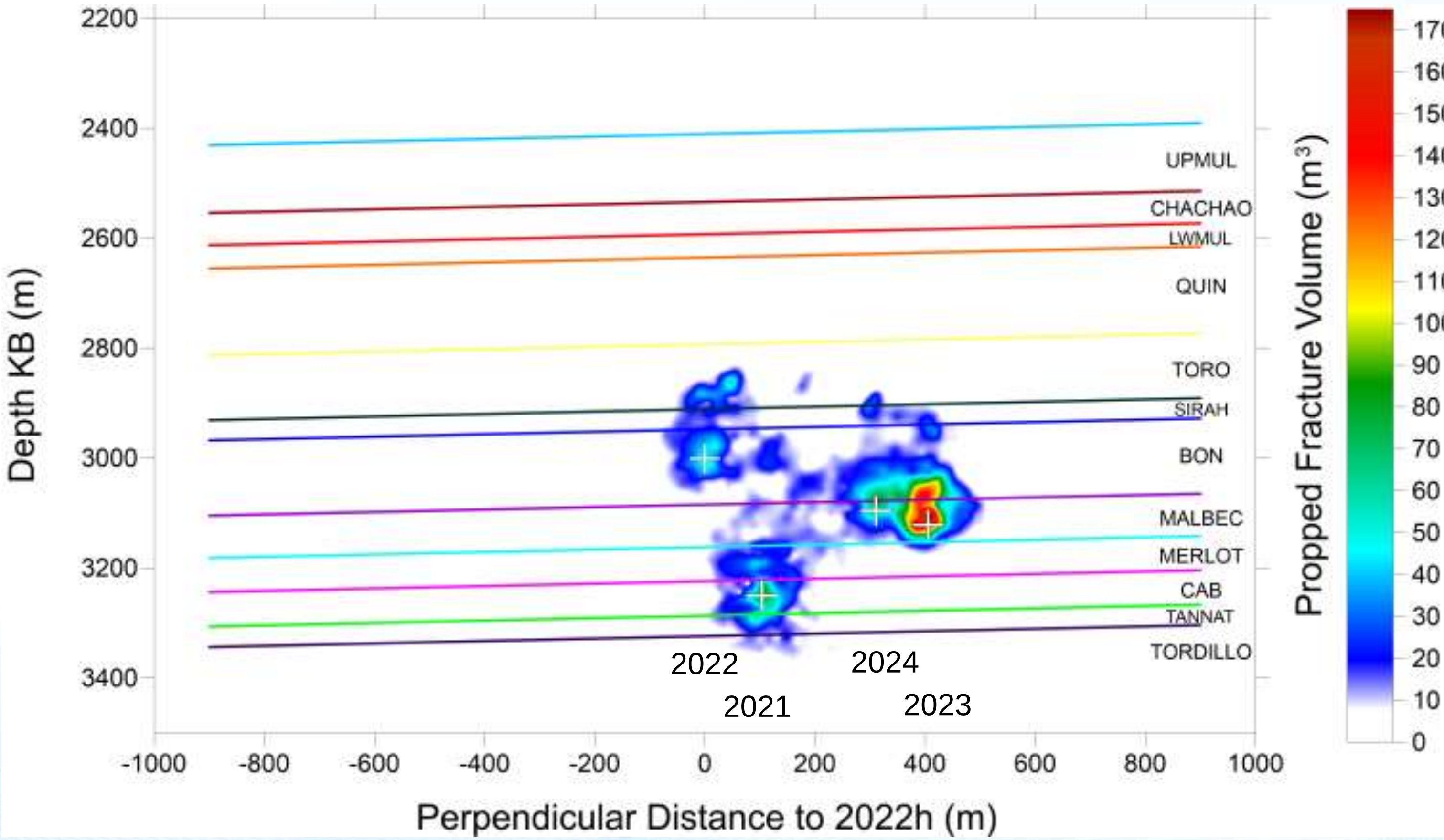
- Significant upward proppant growth
- Propped fracture volume extends towards neighboring wellbore where pore-pressures compound between treatments

Reservoir Depths

P90 Metric (m)	2021	2022	2023	2024
Propped Half-Length	105	87	67	82
Half-Length	297	283	162	226
Propped Height	246	110	118	145
Height	354	132	192	166
Propped Half-Width	50	65	28	44
Half-Width	91	170	69	95

MicroSeismic

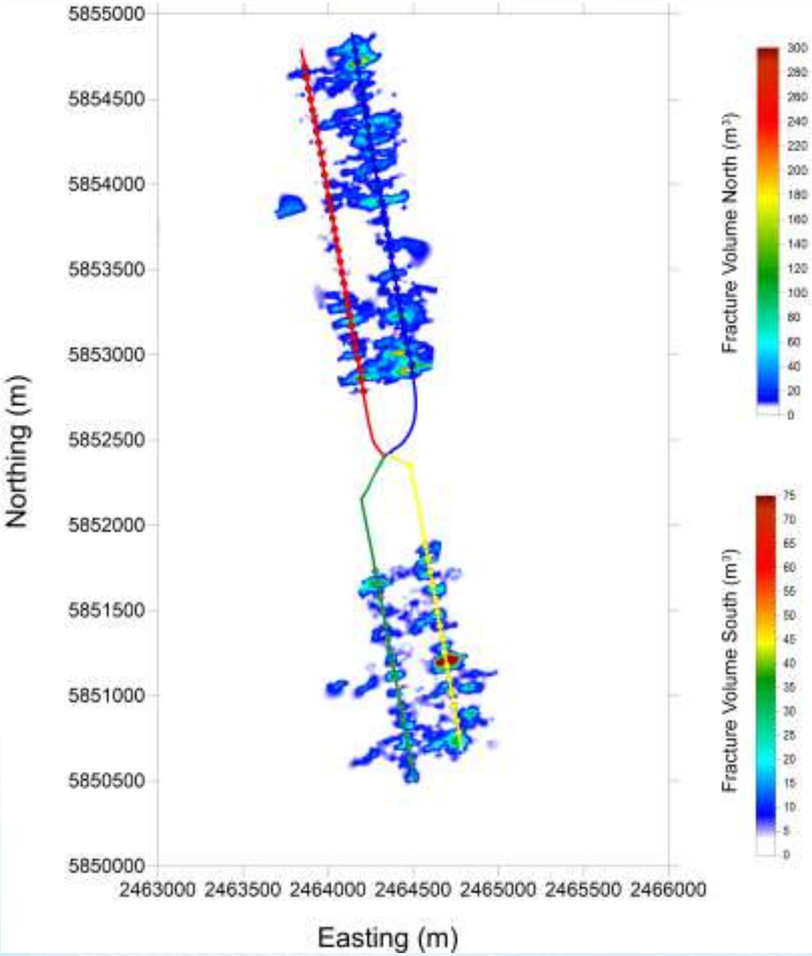
Propped Fracture Volume – Depth View, Composite



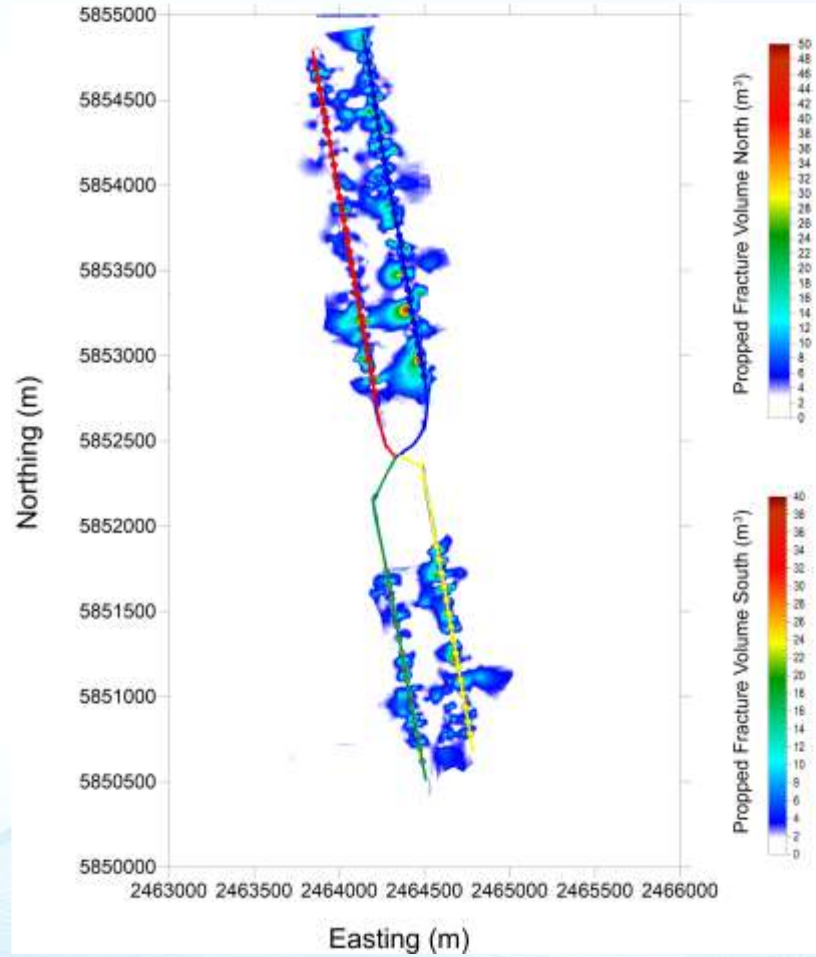
MicroSeismic

Reservoir Fracture Volume Variability
Sliced Below Bonarda Top

Fracture Volume



Propped Fracture Volume



- Lowest fracture volume along 2021h well results in low proppant concentration around wellbore
- Southern wells exhibited higher near-wellbore proppant concentrations

MicroSeismic

Conclusions

1. Fault Interaction
2. Determine Fracture Geometry
3. Determine Orientation of SHmax
4. Evaluate Treatment Efficiency

- Shallow fault activity was observed throughout the duration of recording
- Propped half-length ranges from 70-100 m
- Propped height ranges from 100-150 m
- Stress inversion results suggest a normal faulting stress regime below Sirah with an *SHmax* oriented towards an azimuth of ~80°
- Current wellbore orientation is good with horizontal wellbore perpendicular to *SHmax*
- Recommend top-down completions to reduce upward migration of pore-pressures

MicroSeismic

Key Findings

Microseismic Event Locations

- Shallow fault activity was observed throughout the duration of recording which extended ~500m above the Bonarda horizon in the north and ~390m above the Bonarda horizon in the south.
- There was one reported earthquake with a local magnitude of 3.3 (ML) that was recorded by the array that occurred along one of the shallow faults above the middle of the 2021h & 2023h laterals.
- The average event trend orientation for the reservoir events is ~70°.
- The primary source mechanism for the reservoir events is dip-slip to oblique-slip with strikes ranging from ~70° to 80°.
- The dominant source mechanism for the shallow events is strike-slip with strikes ranging from ~20° to 55°.

Geomechanical Completions Evaluation

- *SHmax* below Sirah is oriented ~80°.
- Wellbore orientation is optimally oriented to *Shmax.*
- Fracturing into high pore-pressure gradient above Bonarda may result in upward migration of pore-pressures resulting in reactivation of shallow faulting.

Descriptive Completions Evaluation

- Propped half-length: 70-100 m
- Propped height: 100-150 m
- Propped width: 30-70 m
- Compounding pore-pressures results in upward and toe-side fracture growth.

Appendix I: Processing and Calibration

MicroSeismic

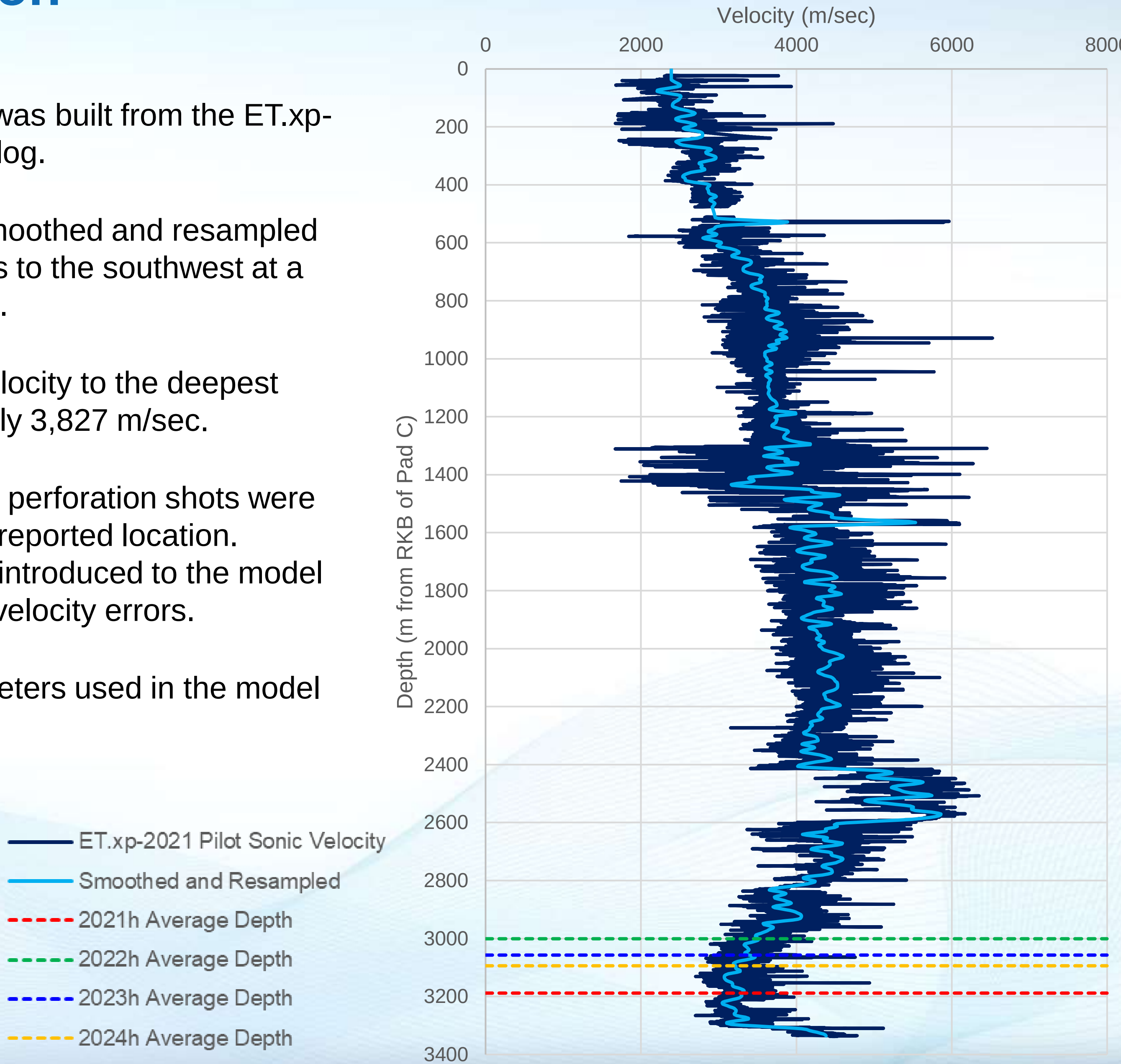
Processing Sequence

1. Conversion from SegD to Segy
2. Apply station geometry
3. Debias
4. Apply Residual Receiver Corrections
5. Noise attenuation filter
6. Bandpass filter 10-100 Hz
7. Resample from 2ms to 4ms
8. PSET® - Event Location

MicroSeismic

Velocity Function

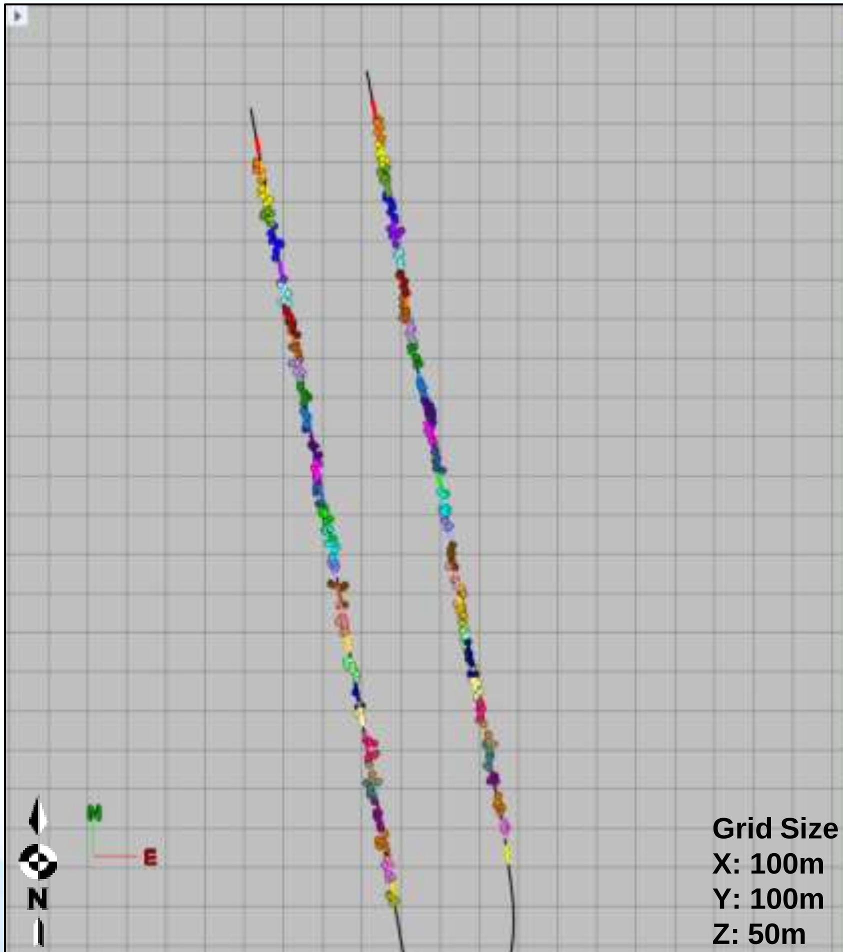
- A 1D velocity model was built from the ET.xp-2021 pilot well sonic log.
- The sonic log was smoothed and resampled and tilted 2.1 degrees to the southwest at a strike of 147 degrees.
- The average base velocity to the deepest target is approximately 3,827 m/sec.
- Using this model, the perforation shots were imaged back to their reported location. Anisotropy was then introduced to the model to minimize residual velocity errors.
- The Thomsen parameters used in the model are:
  - Epsilon=0.06
  - Delta=0.04



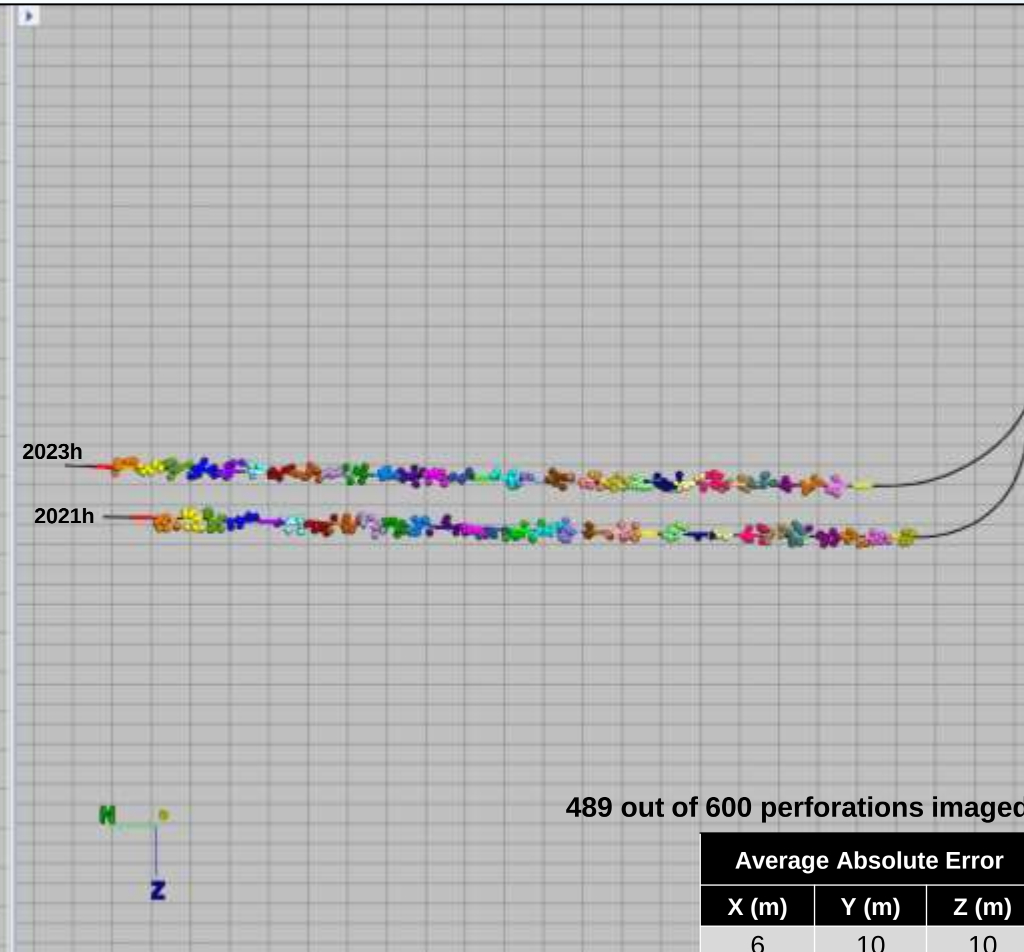
MicroSeismic

2021h & 2023h – Perforation Locations

Map View



Depth View – Facing East



Average Absolute Error		
X (m)	Y (m)	Z (m)
6	10	10

Perforations are sized the same and colored by stage.

Stage Coloring Legend

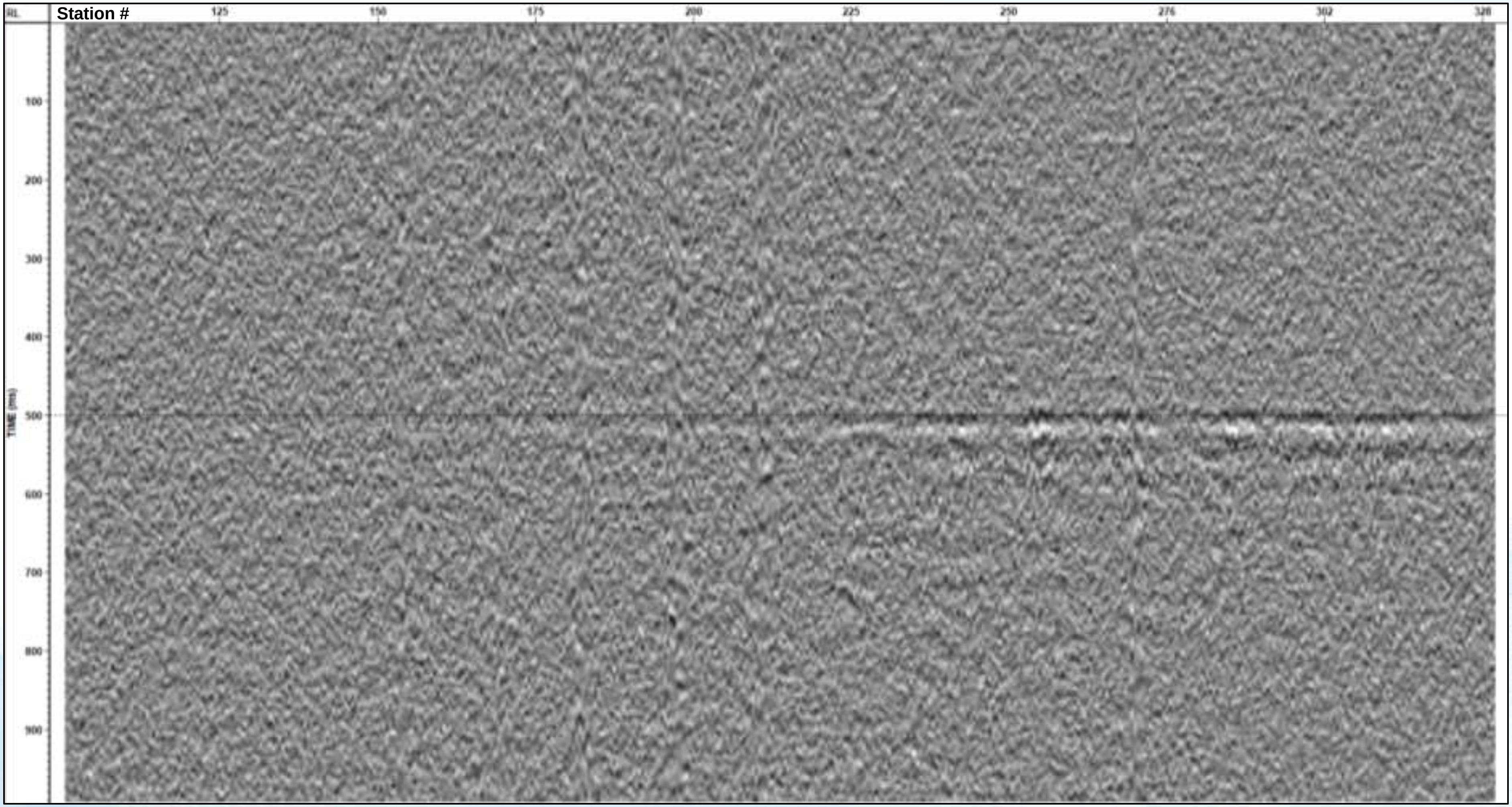
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

MicroSeismic

2021h Stage 4 Perforation Shot 1 – Processed Seismic

6/16/2020 08:45:36.716

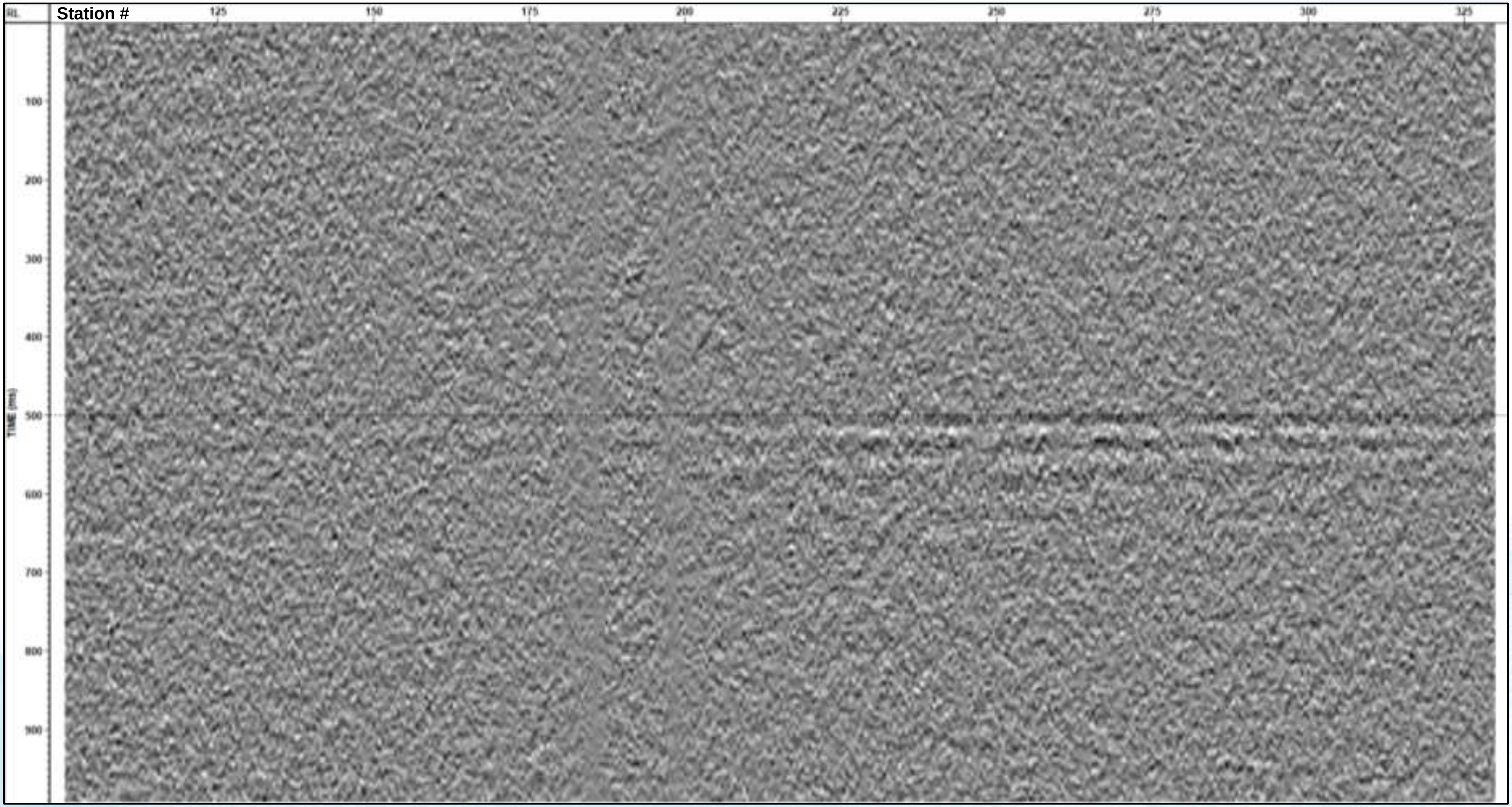
Velocity Corrected Perforation at 500 ms



2023h Stage 5 Perforation Shot 5 – Processed Seismic

6/17/2020 18:54:21.940

Velocity Corrected Perforation at 500 ms

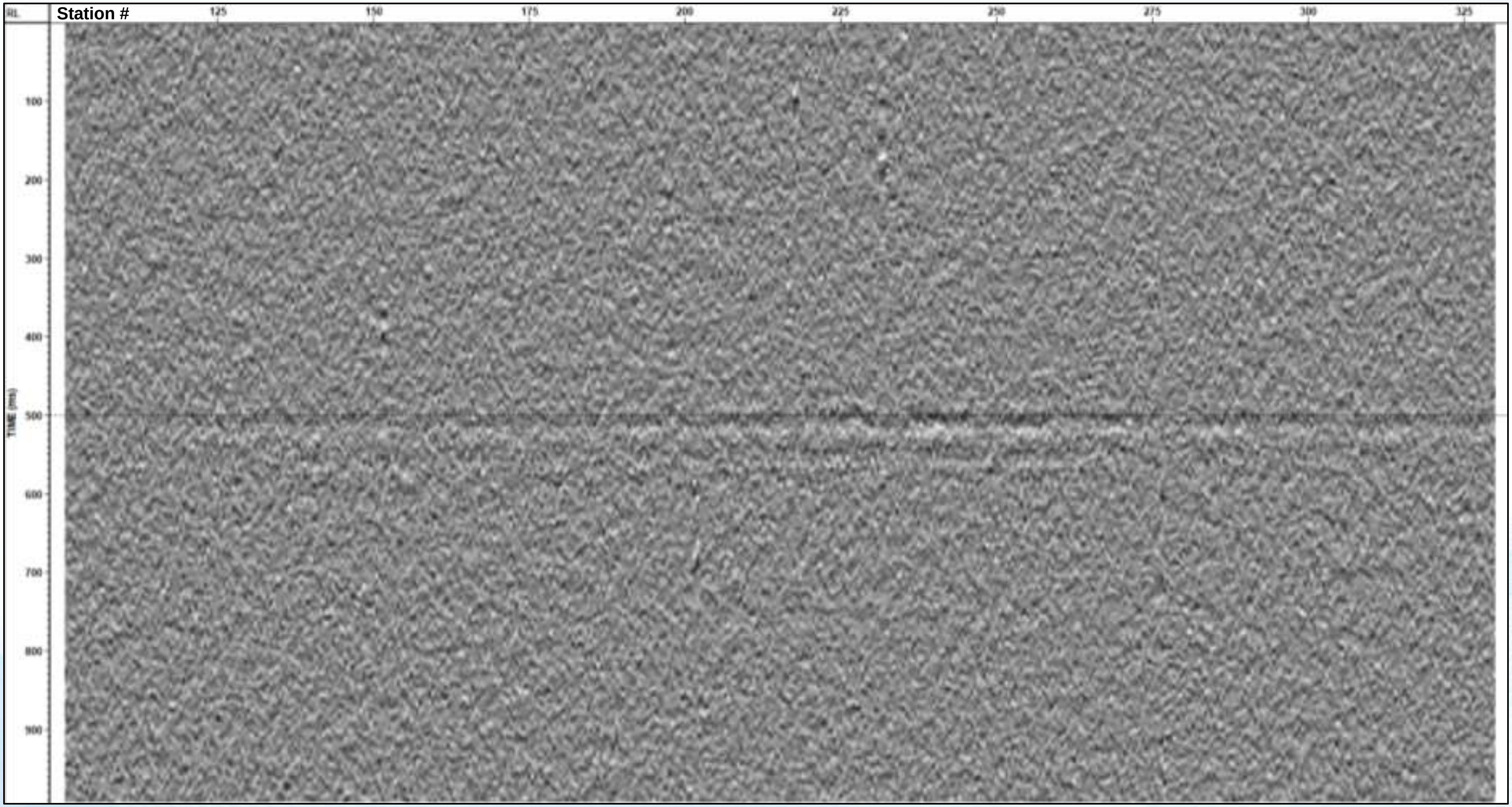


MicroSeismic

2021h Stage 20 Perforation Shot 7 – Processed Seismic

7/02/2020 17:54:18.848

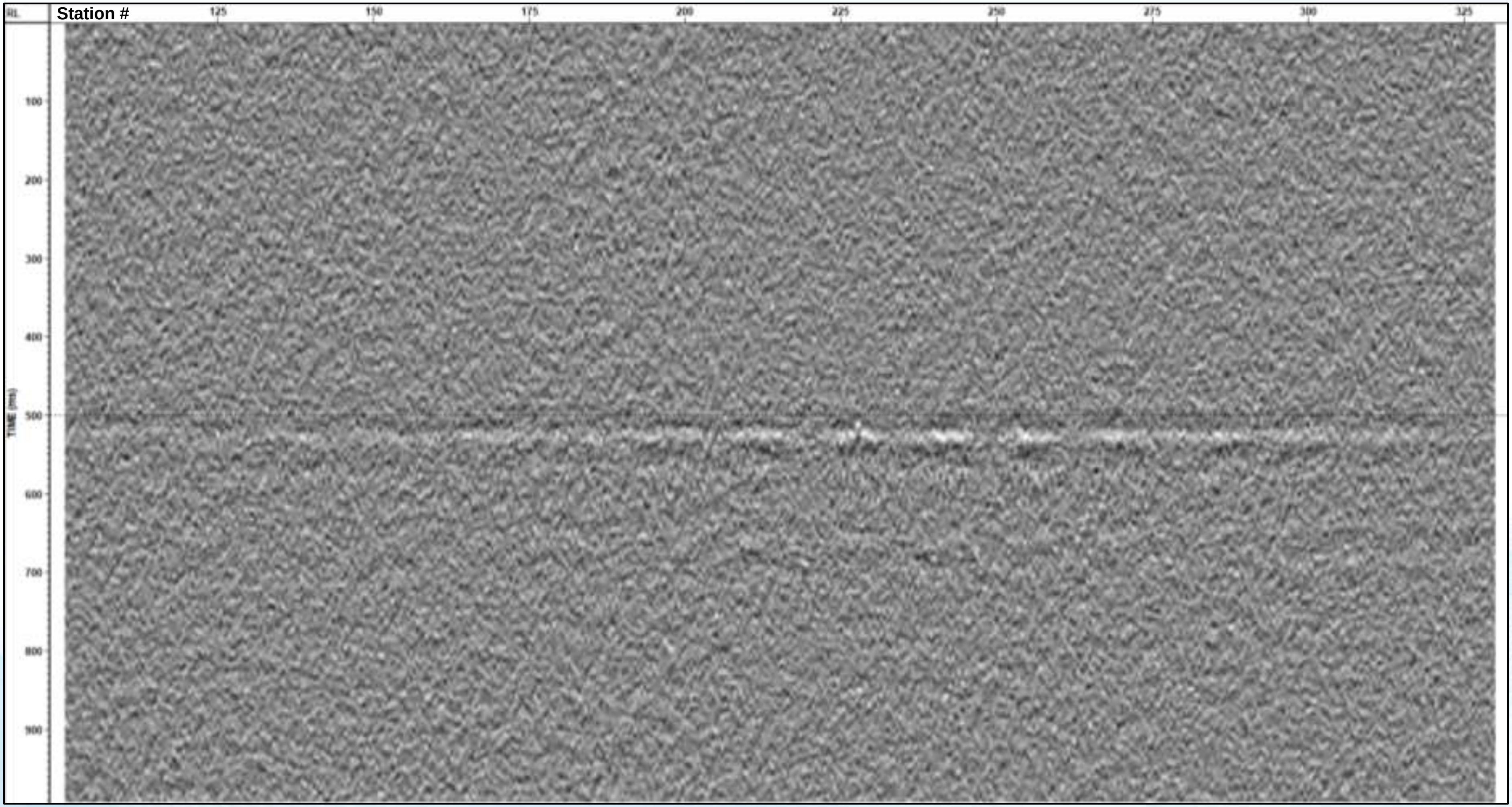
Velocity Corrected Perforation at 500 ms



2023h Stage 27 Perforation Shot 2 – Processed Seismic

7/07/2020 18:28:13.620

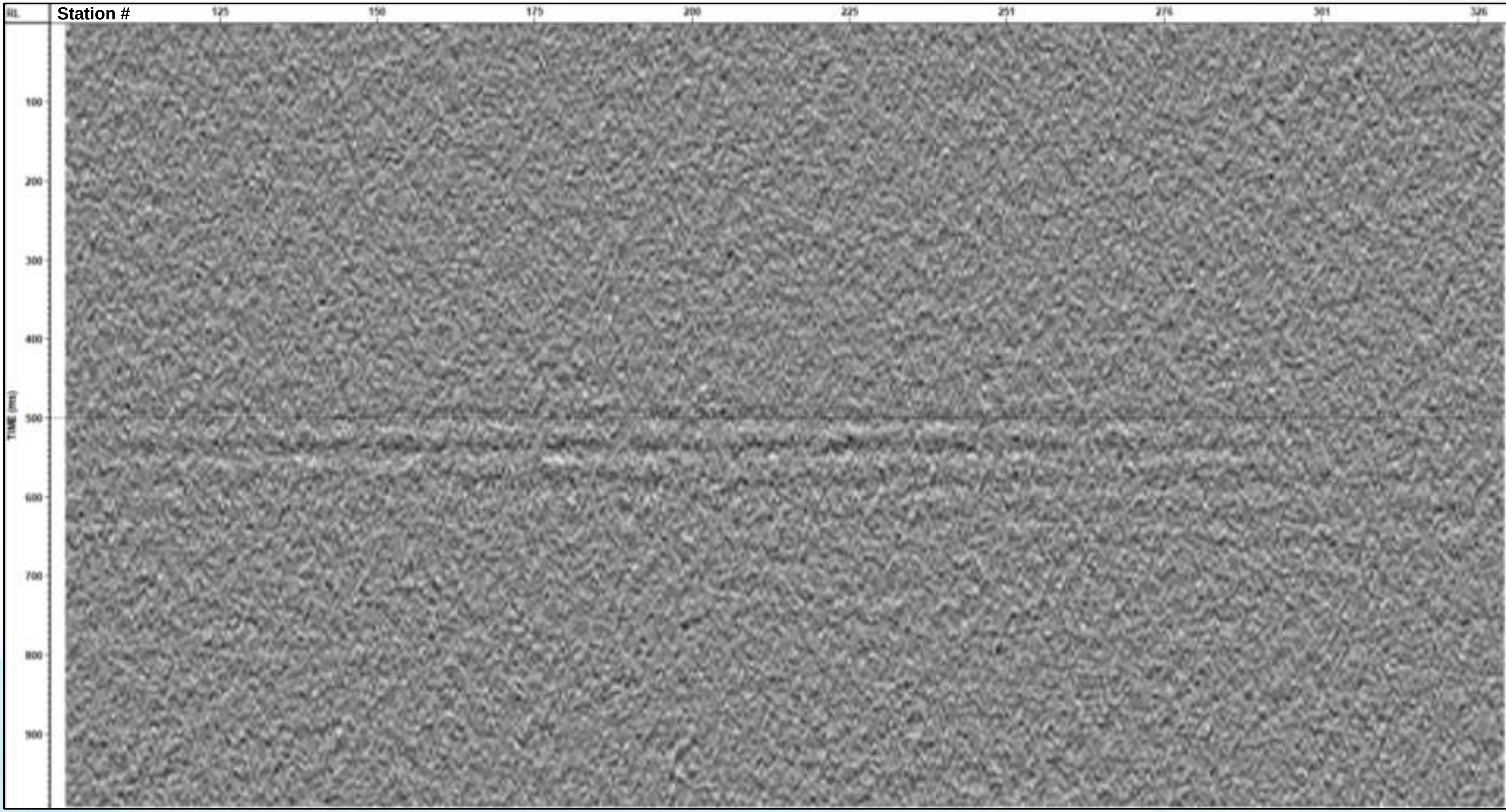
Velocity Corrected Perforation at 500 ms



2021h Stage 30 Perforation Shot 8 – Processed Seismic

7/13/2020 01:12:54.640

Velocity Corrected Perforation at 500 ms

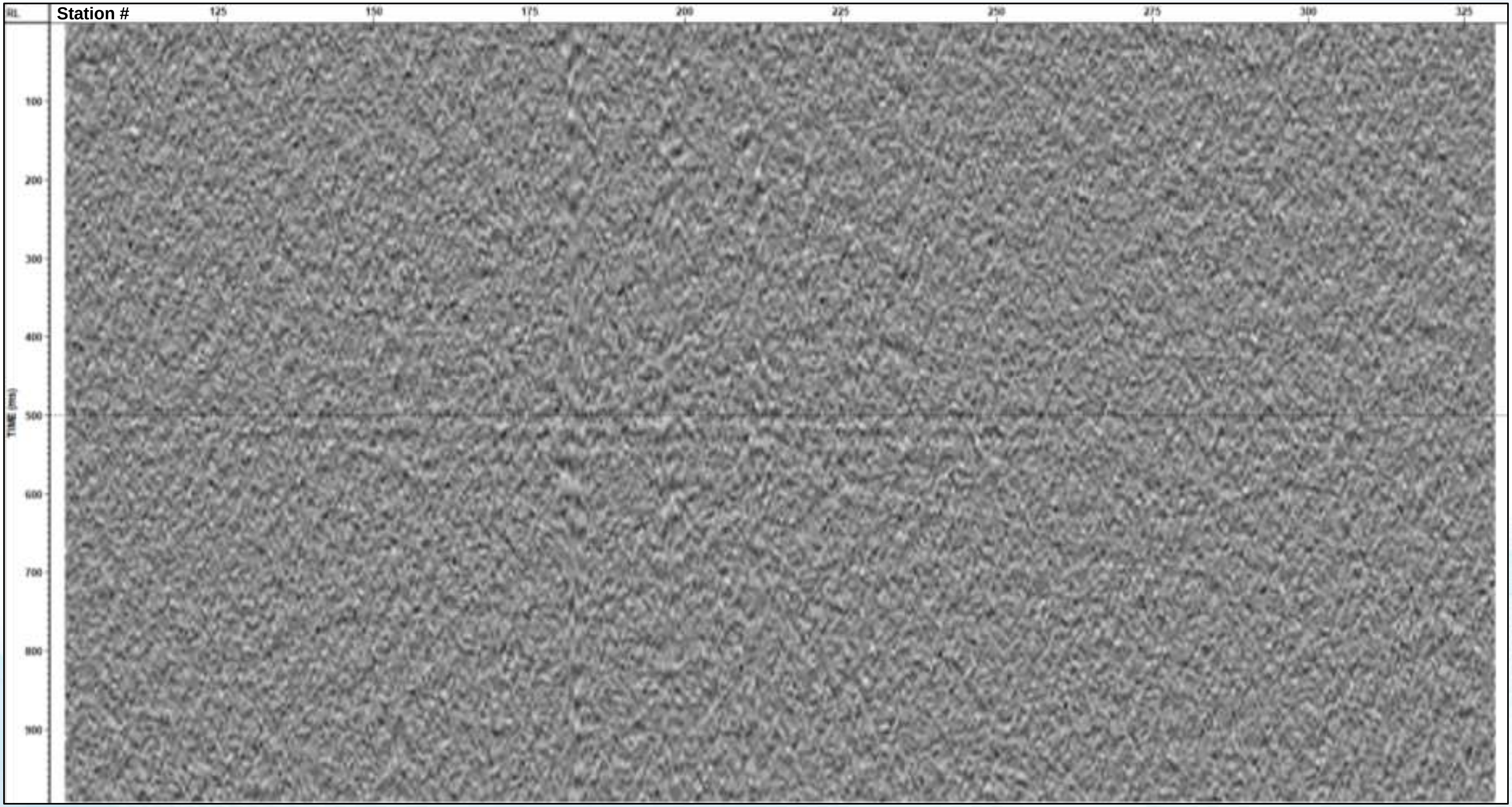


MicroSeismic

2023h Stage 29 Perforation Shot 4 – Processed Seismic

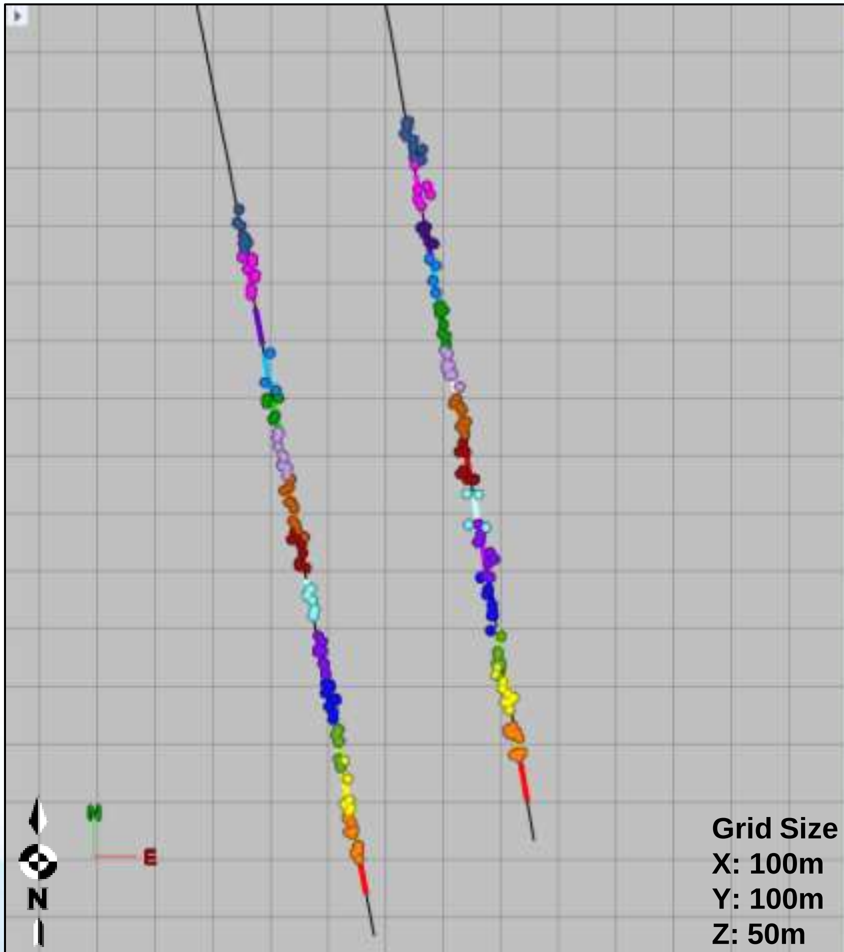
7/11/2020 23:10:27.348

Velocity Corrected Perforation at 500 ms

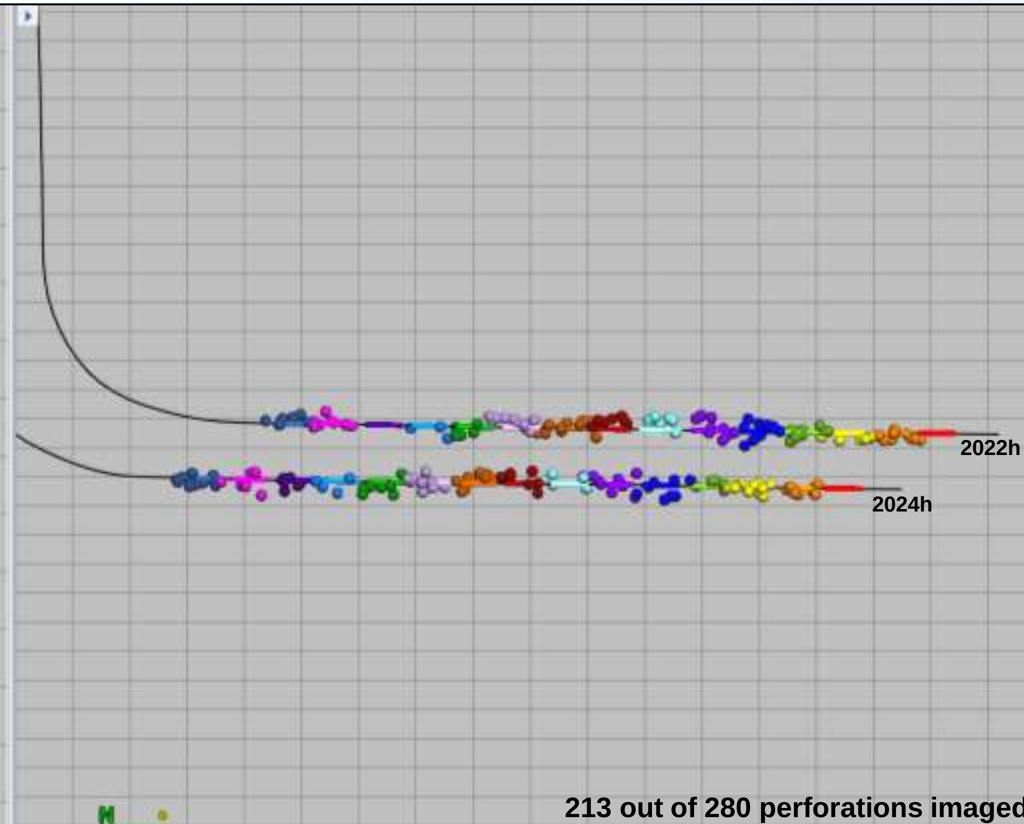


2022h & 2024h – Perforation Locations

Map View



Depth View – Facing East

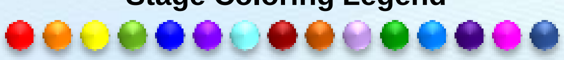


213 out of 280 perforations imaged

Average Absolute Error		
X (m)	Y (m)	Z (m)
5	10	10

Perforations are sized the same and colored by stage.

Stage Coloring Legend

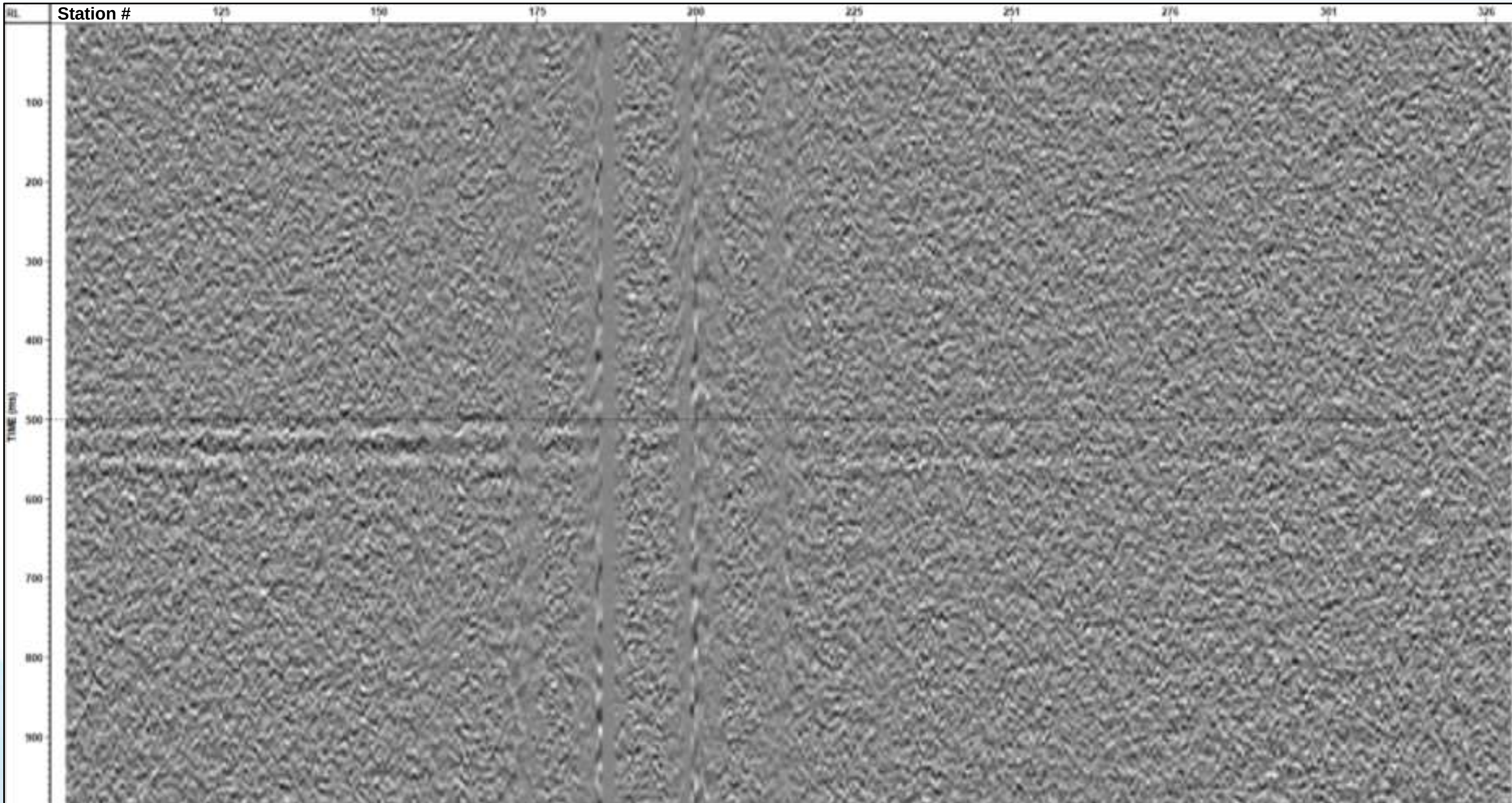


MicroSeismic

2024h Stage 9 Perforation Shot 5 – Processed Seismic

6/27/2020 23:30:06.348

Velocity Corrected Perforation at 500 ms

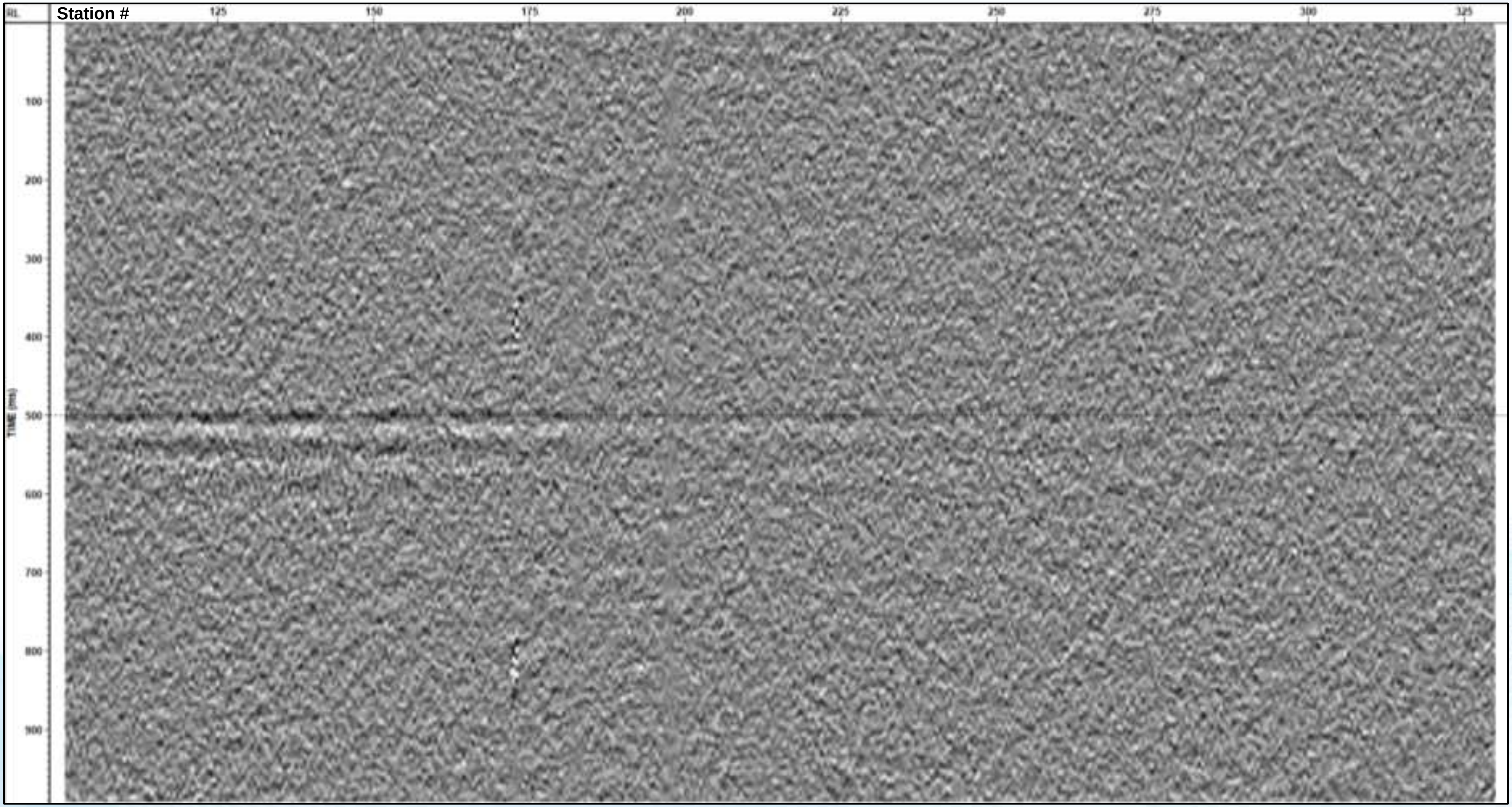


MicroSeismic

2022h Stage 10 Perforation Shot 6 – Processed Seismic

7/08/2020 02:45:14.408

Velocity Corrected Perforation at 500 ms

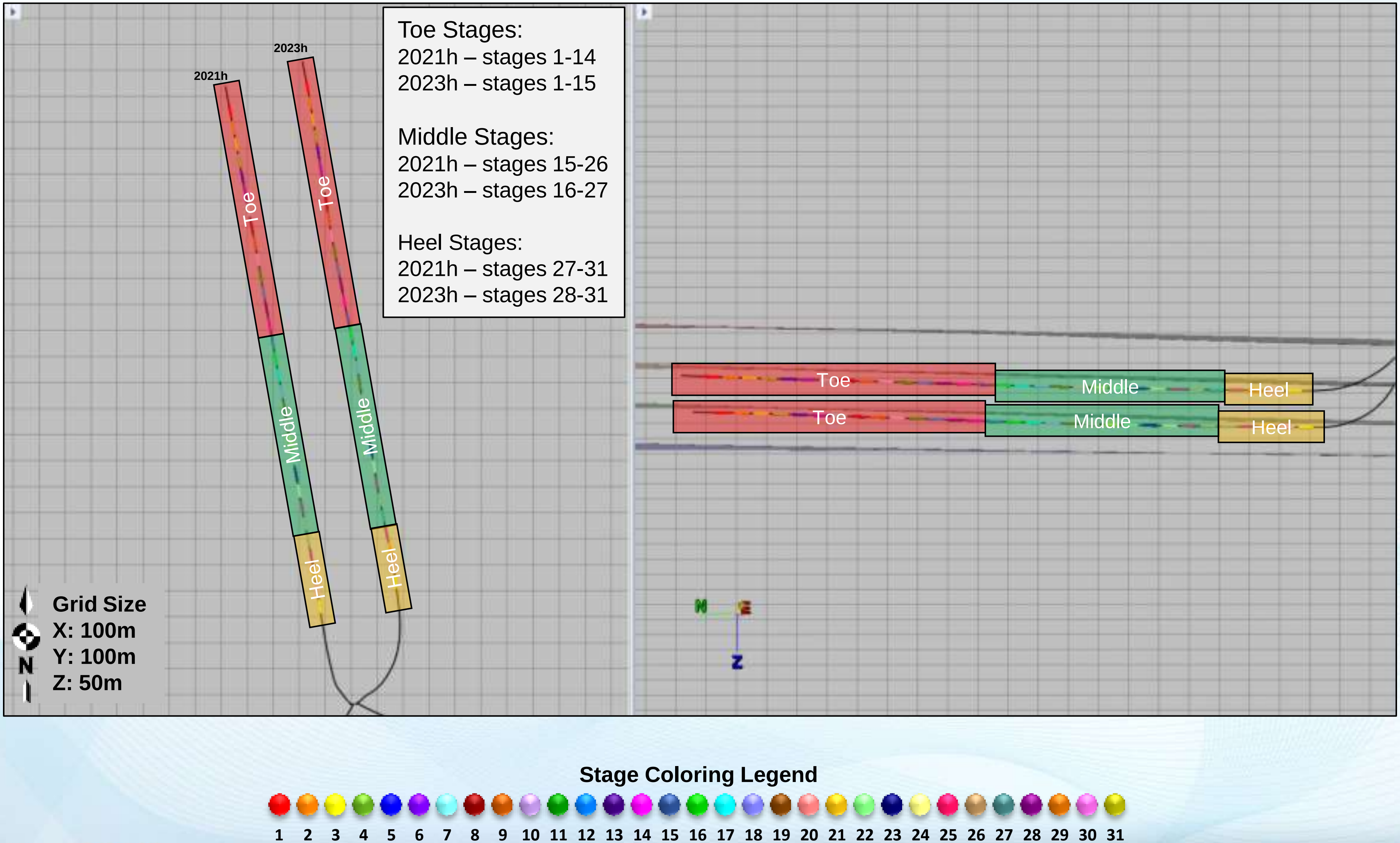


Receiver Corrections

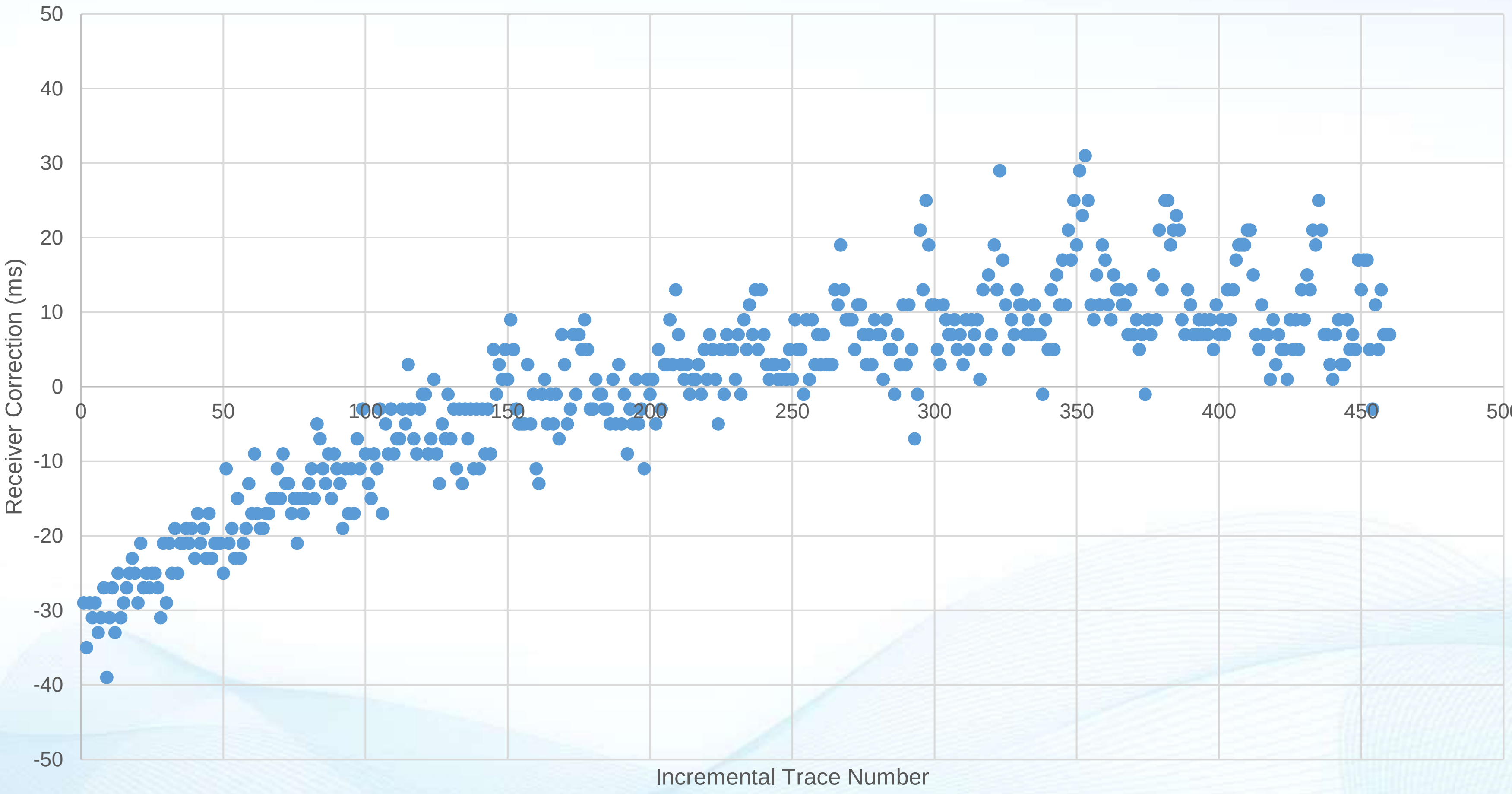
2021h & 2023h

MicroSeismic

2021h & 2023h – Receiver Correction Sections

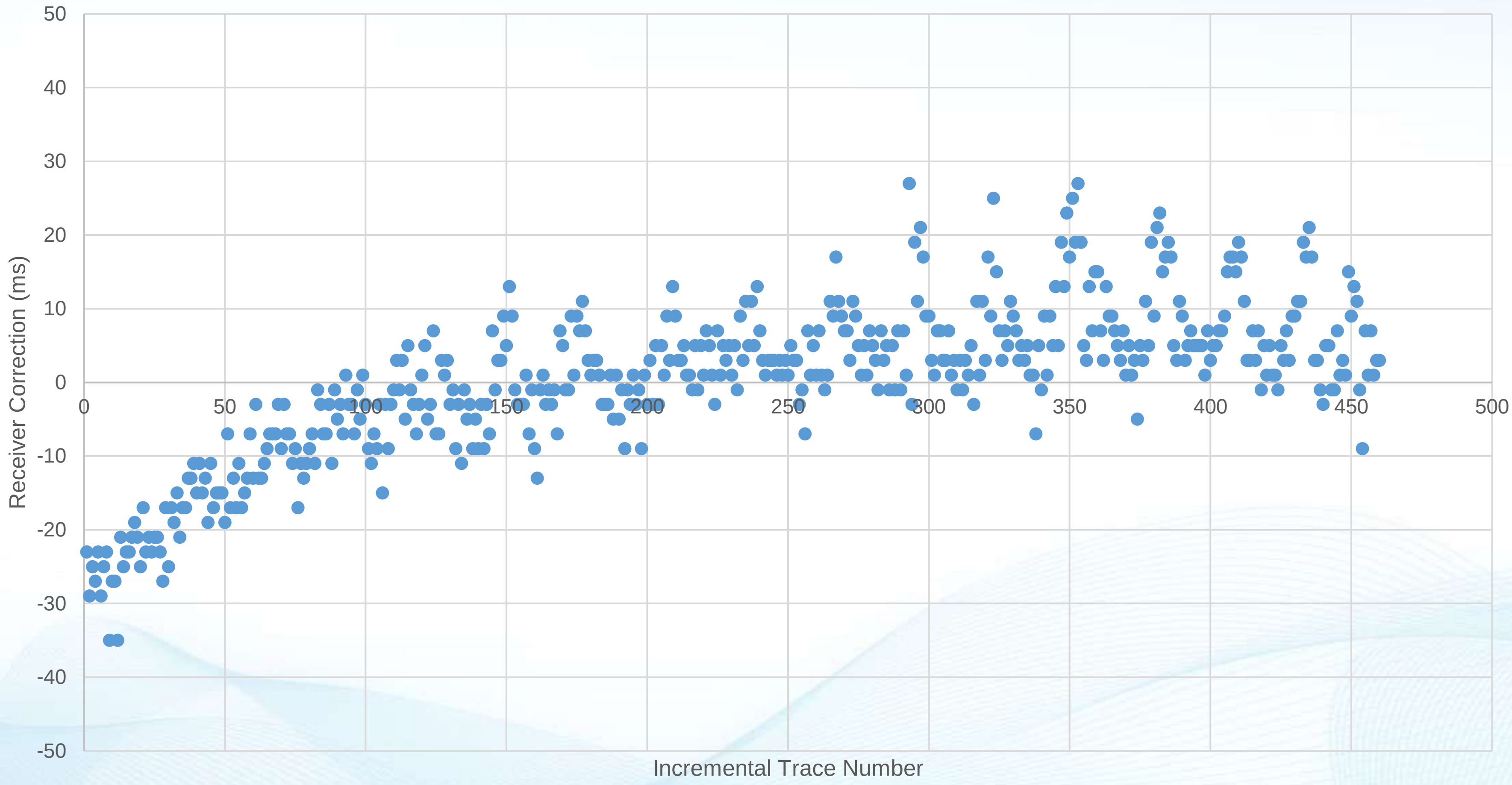


2021h & 2023h – Receiver Corrections – Toe

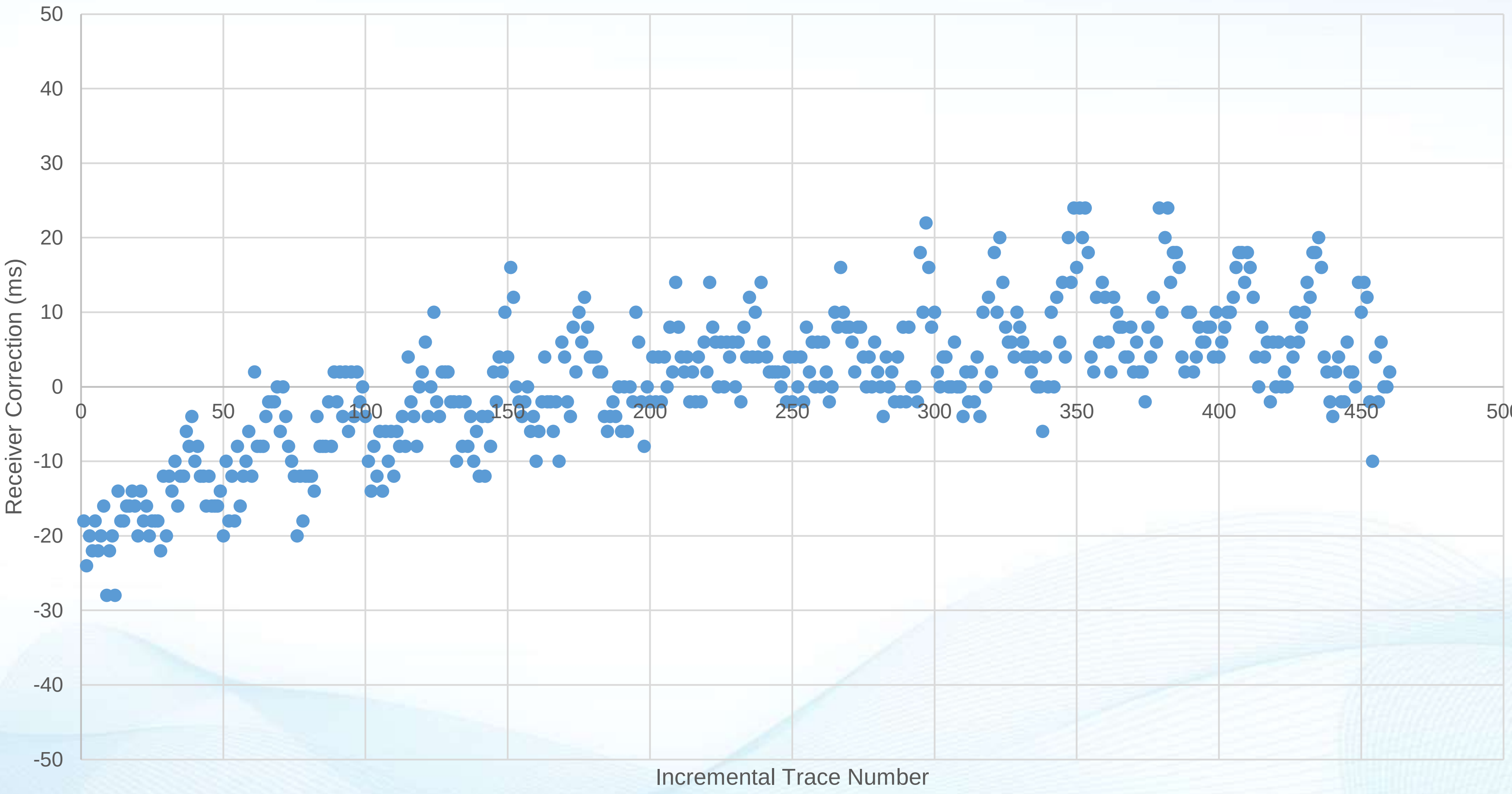


MicroSeismic

2021h & 2023h – Receiver Corrections – Mid



2021h & 2023h – Receiver Corrections – Heel



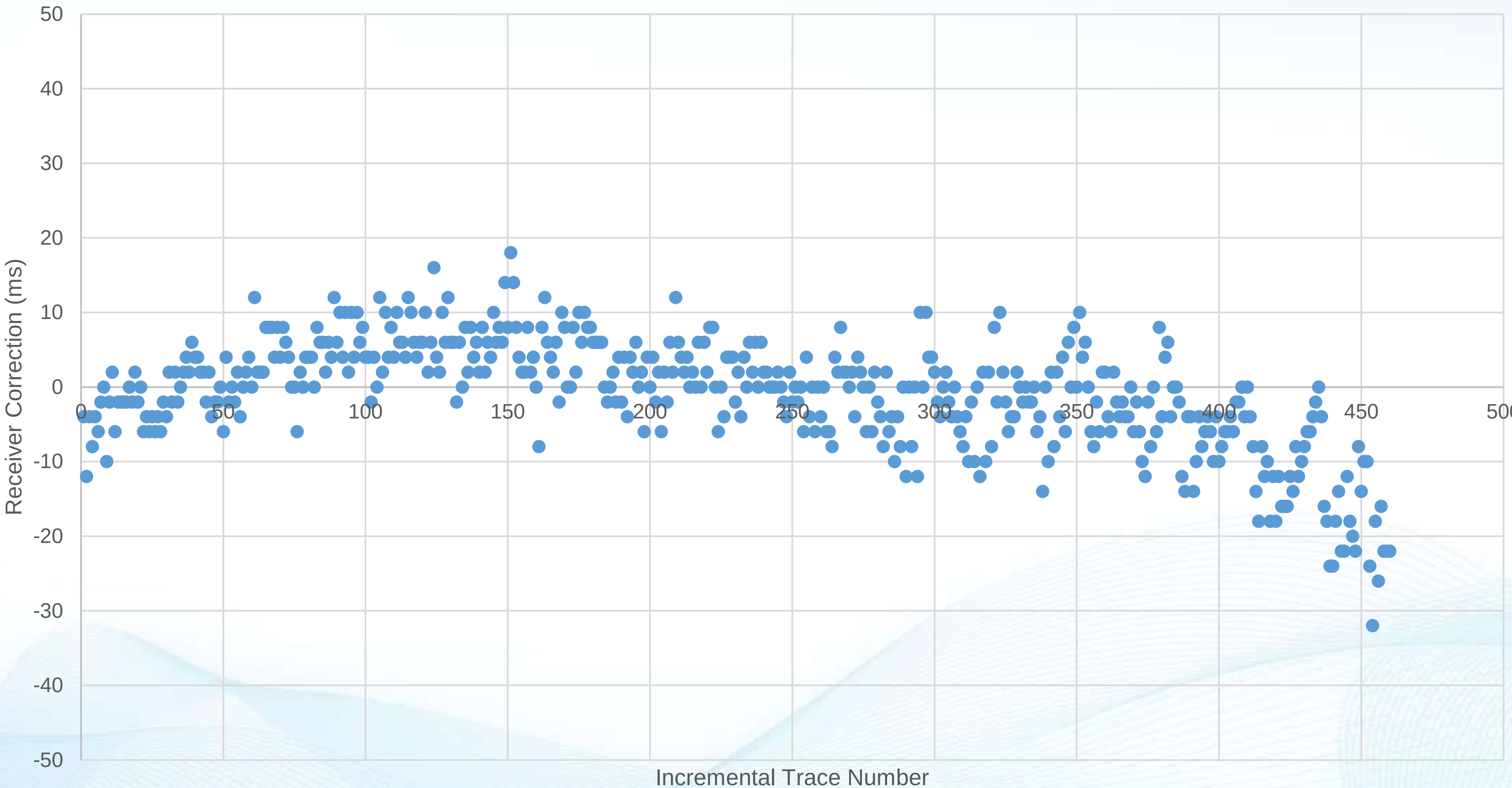
MicroSeismic

Receiver Corrections

2022h & 2024h

MicroSeismic

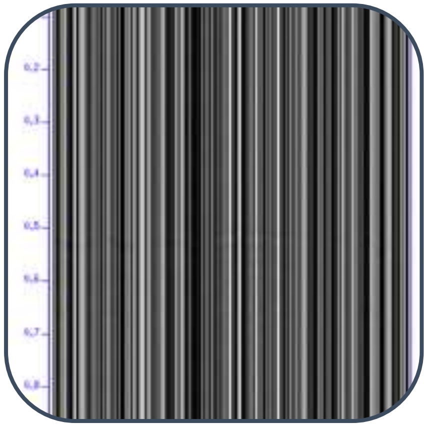
2022h & 2024h – Receiver Corrections – All stages



MicroSeismic

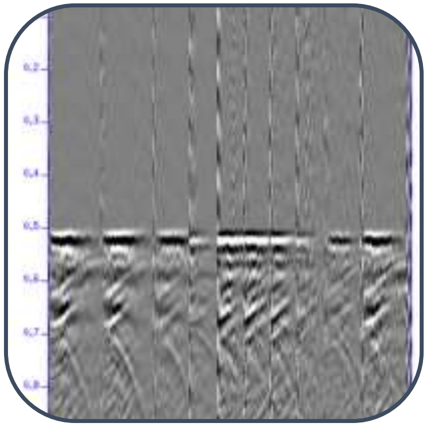
Step by Step Processing

Trace Processing Flow



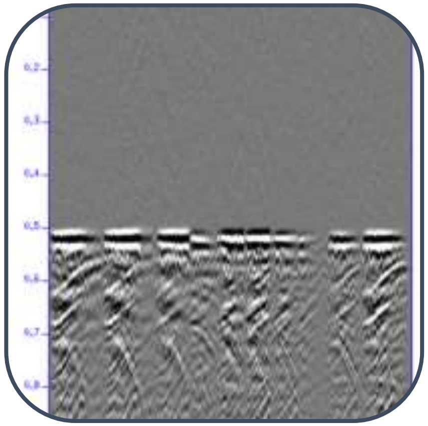
Geometry

- Field records do not contain receiver locations
- X,Y,Z coordinates must be paired on receiver line and station number
- 30 second files merged into 5 minute files



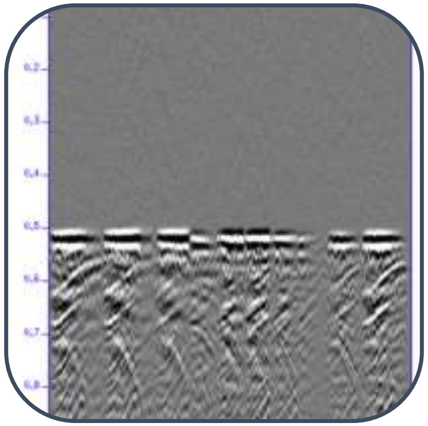
Debias

- DC bias removed



Bandpass

- Butterworth minimum phase filter
- Limits bandwidth to frequencies observed in the signal
- Limits cultural noise



Noise Attenuation

- Proprietary algorithm
- Removes coherent noise from data

MicroSeismic

2022h Stage 15 Event – Raw Data

7/14/2020 19:30:26.932

No Mechanism Correction

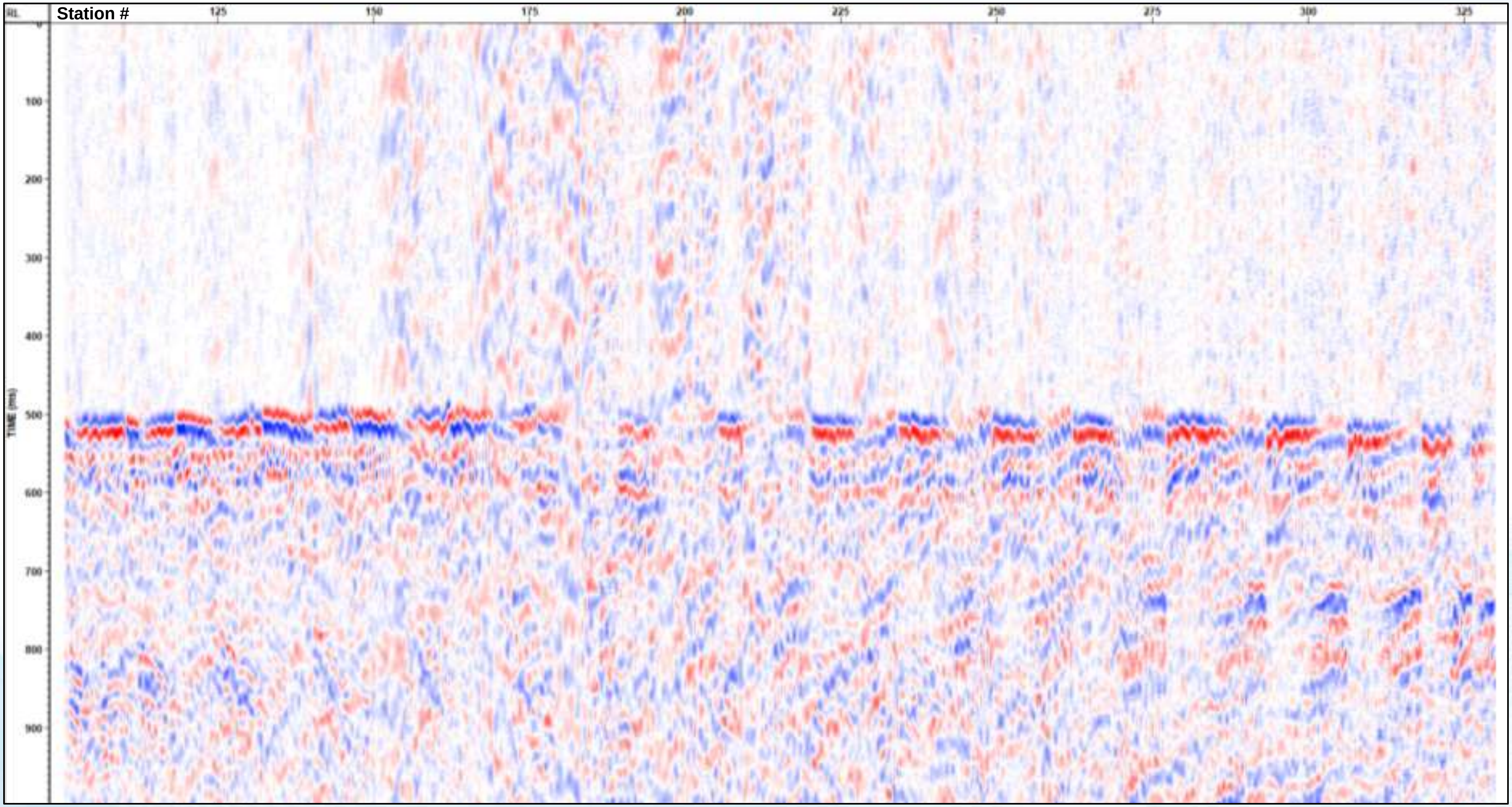
Velocity Corrected Event at 500 ms

2022h Stage 15 Event – Debias

7/14/2020 19:30:26.932

No Mechanism Correction

Velocity Corrected Event at 500 ms

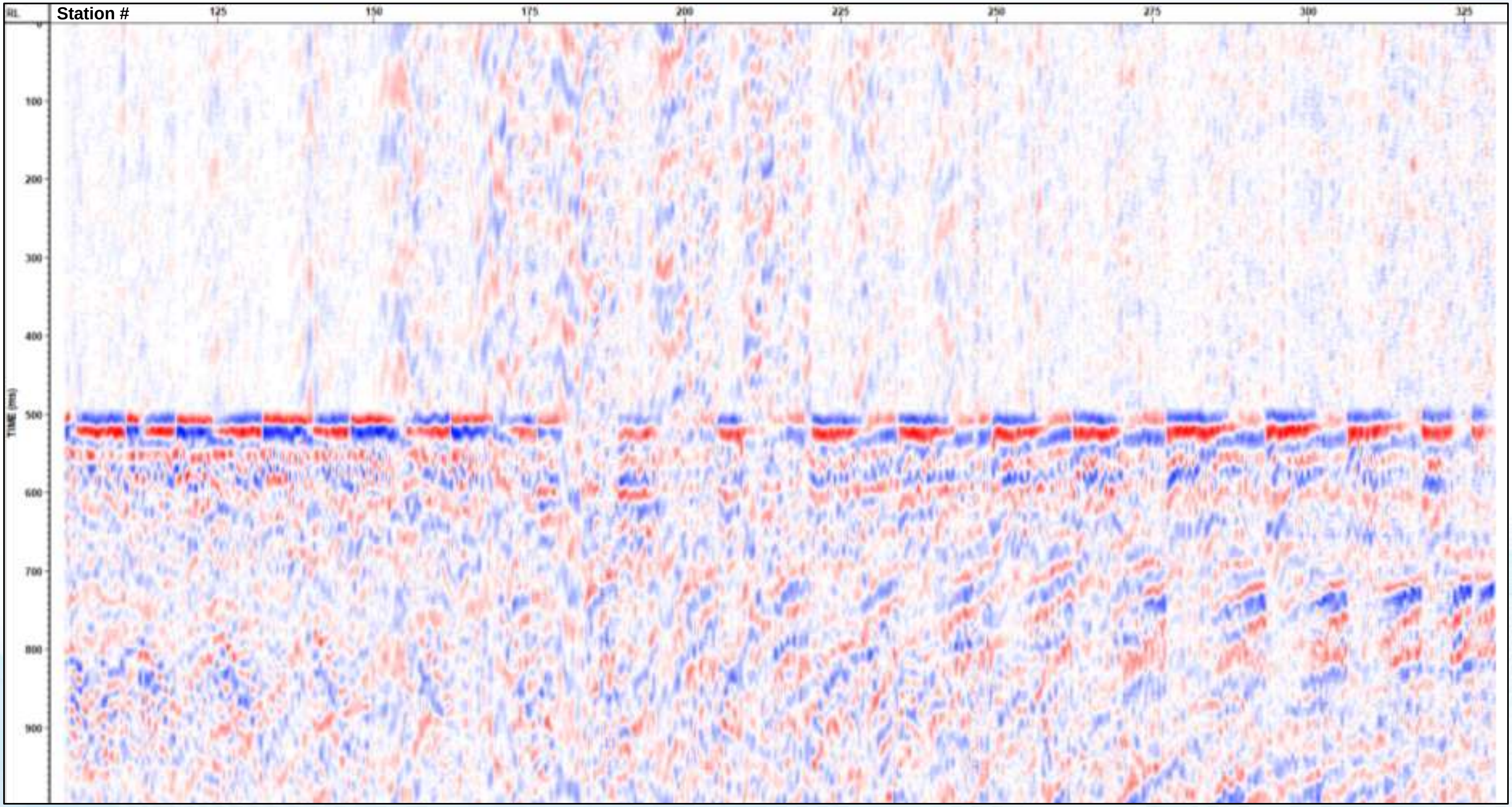


2022h Stage 15 Event – Receiver Correction

7/14/2020 19:30:26.932

No Mechanism Correction

Velocity Corrected Event at 500 ms

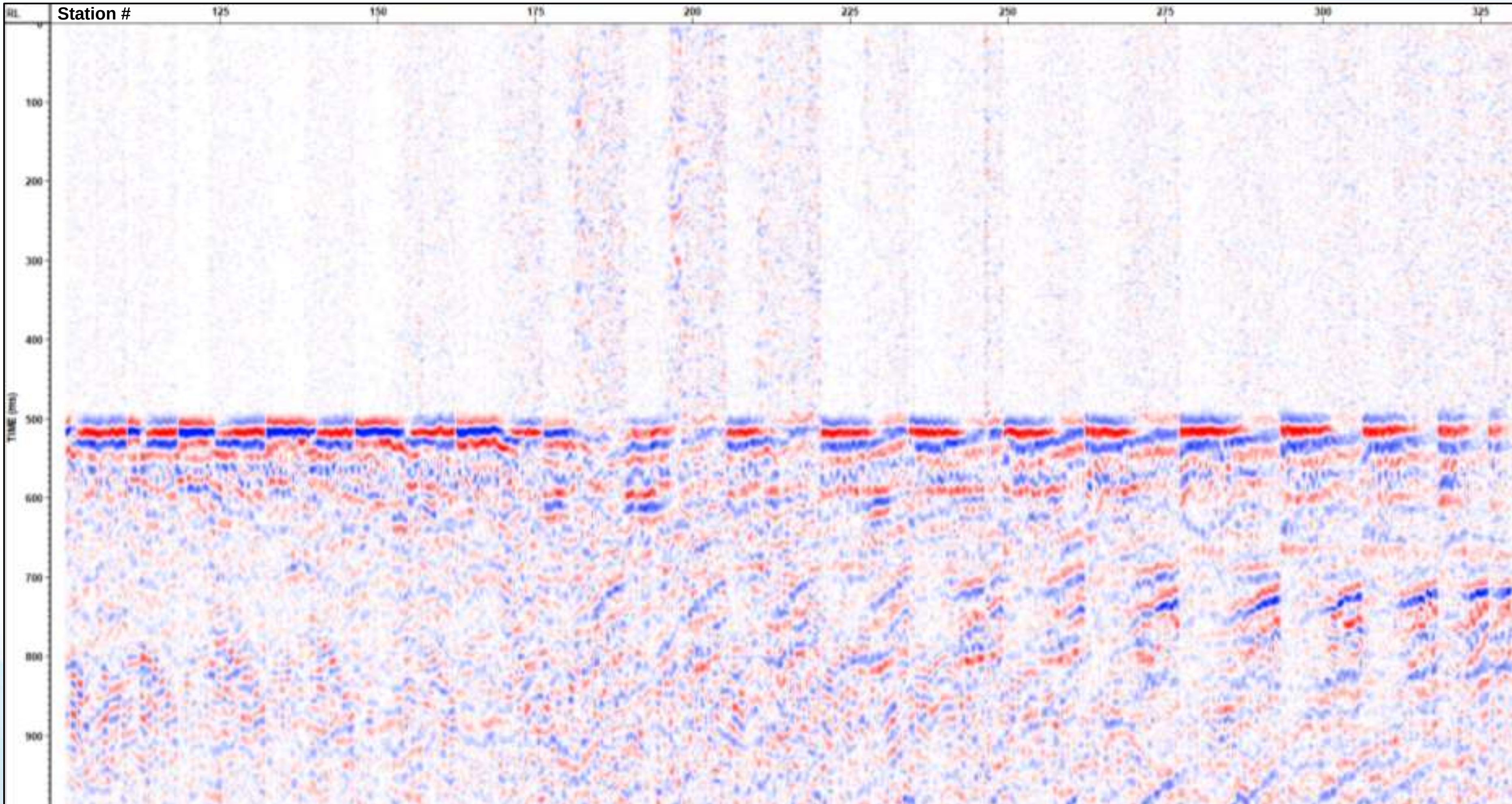


2022h Stage 15 Event – Noise Attenuation Filter

7/14/2020 19:30:26.932

No Mechanism Correction

Velocity Corrected Event at 500 ms

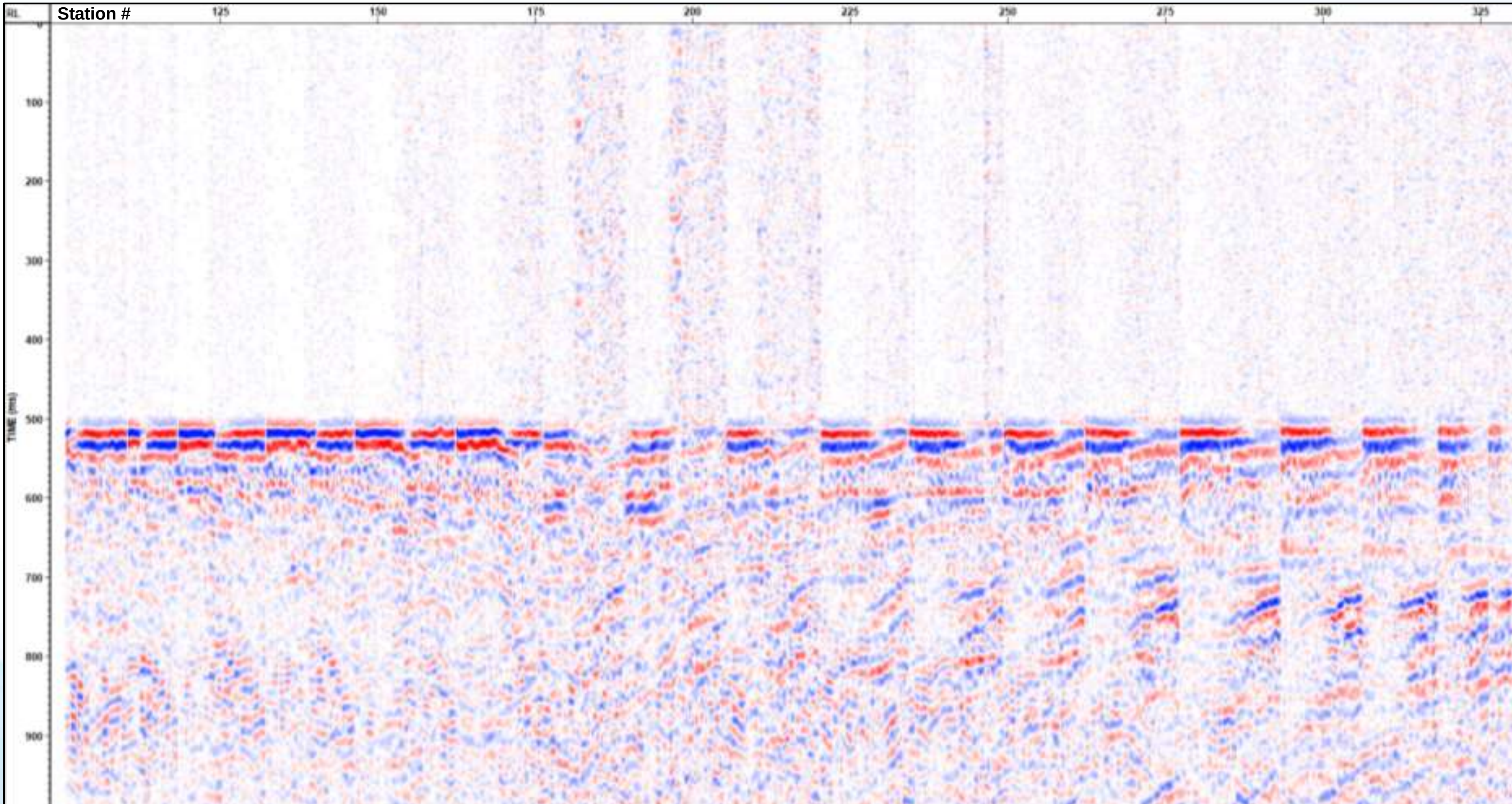


2022h Stage 15 Event – Butterworth Bandpass

7/14/2020 19:30:26.932

No Mechanism Correction

Velocity Corrected Event at 500 ms



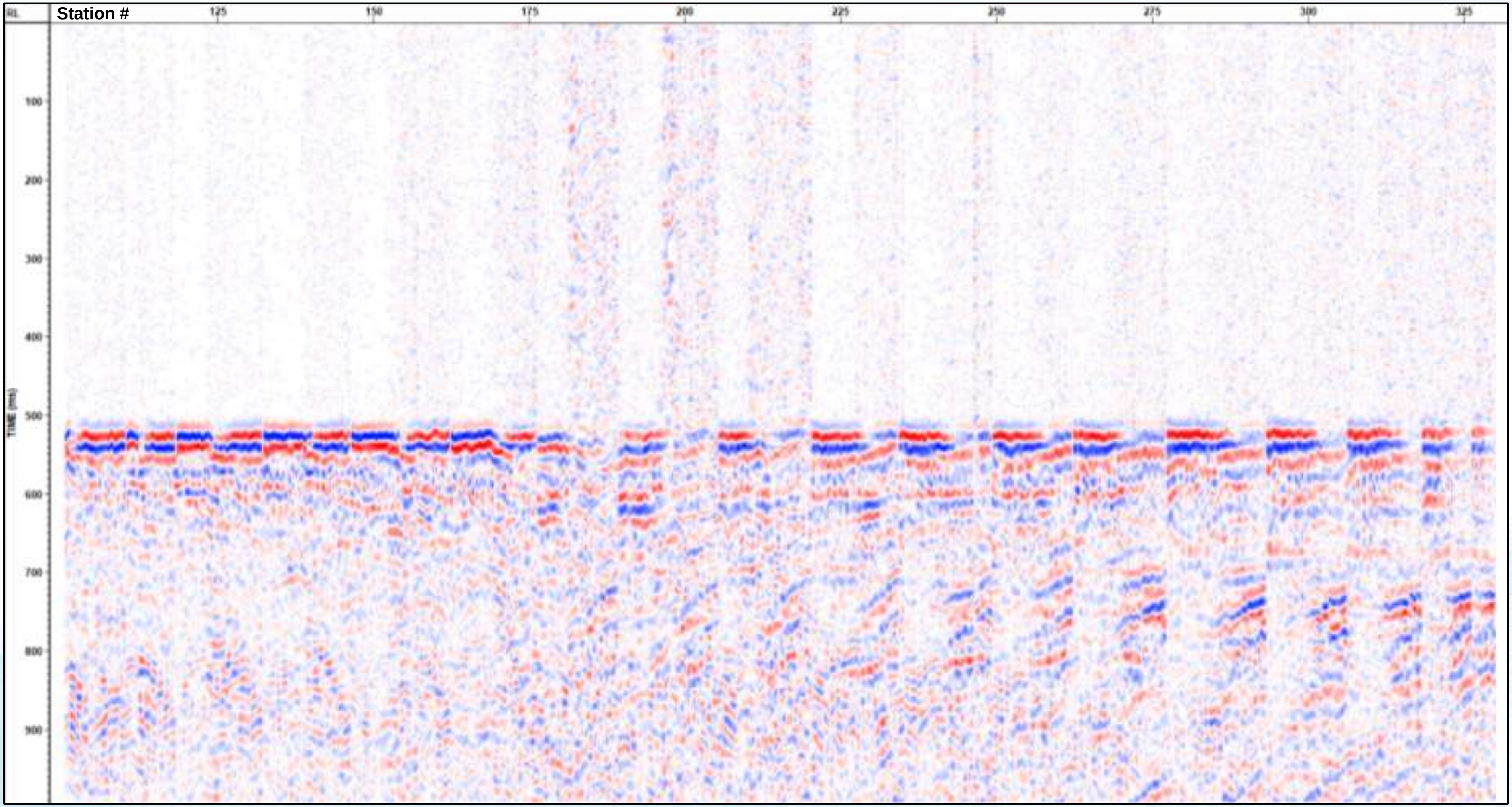
MicroSeismic

2022h Stage 15 Event – Resample from 2ms to 4ms

7/14/2020 19:30:26.932

No Mechanism Correction

Velocity Corrected Event at 500 ms

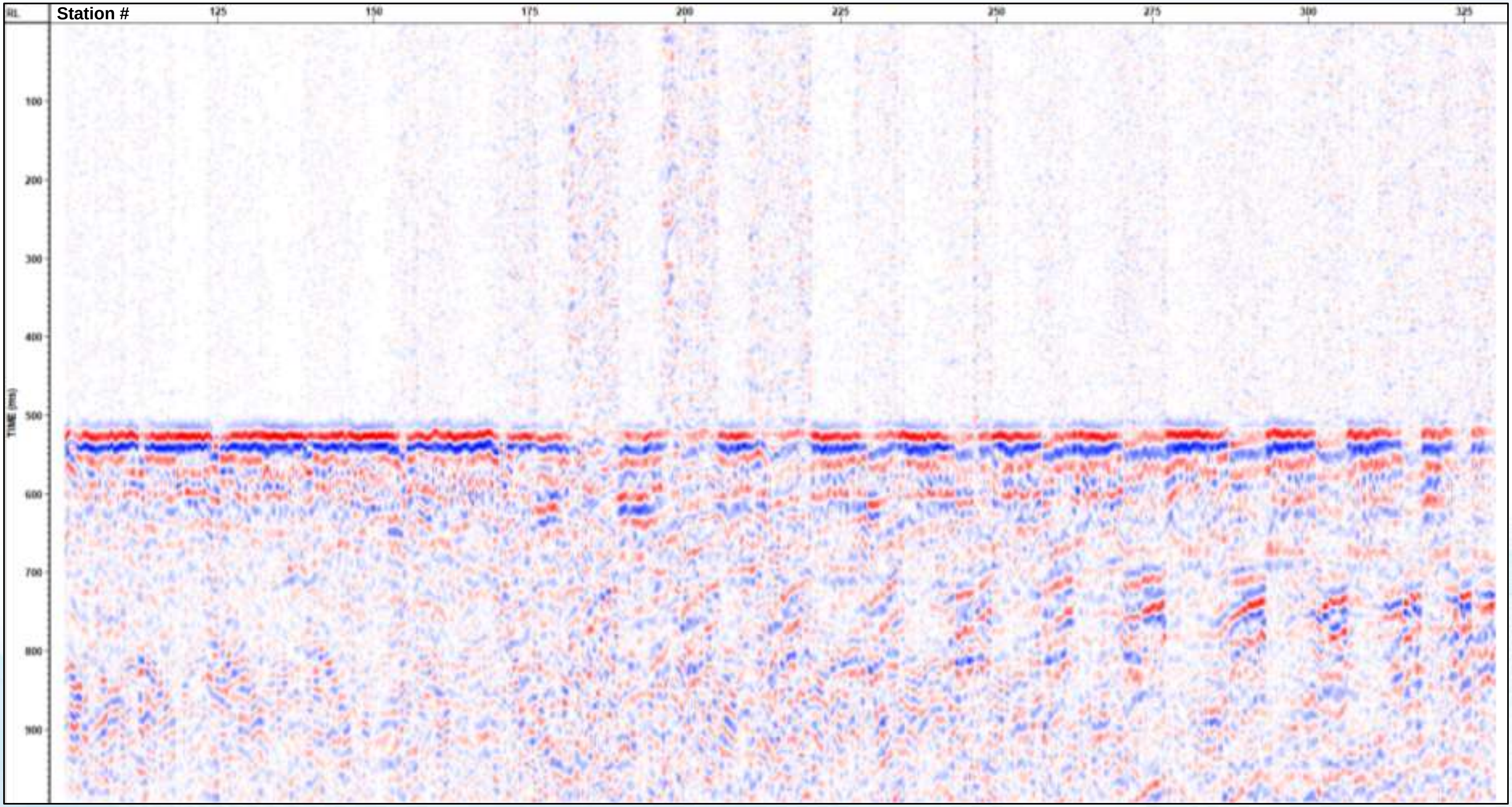


2022h Stage 15 Event – Mechanism Correction

7/14/2020 19:30:26.932

Mechanism Corrected

Velocity Corrected Event at 500 ms



Source Mechanisms

2021h & 2023h

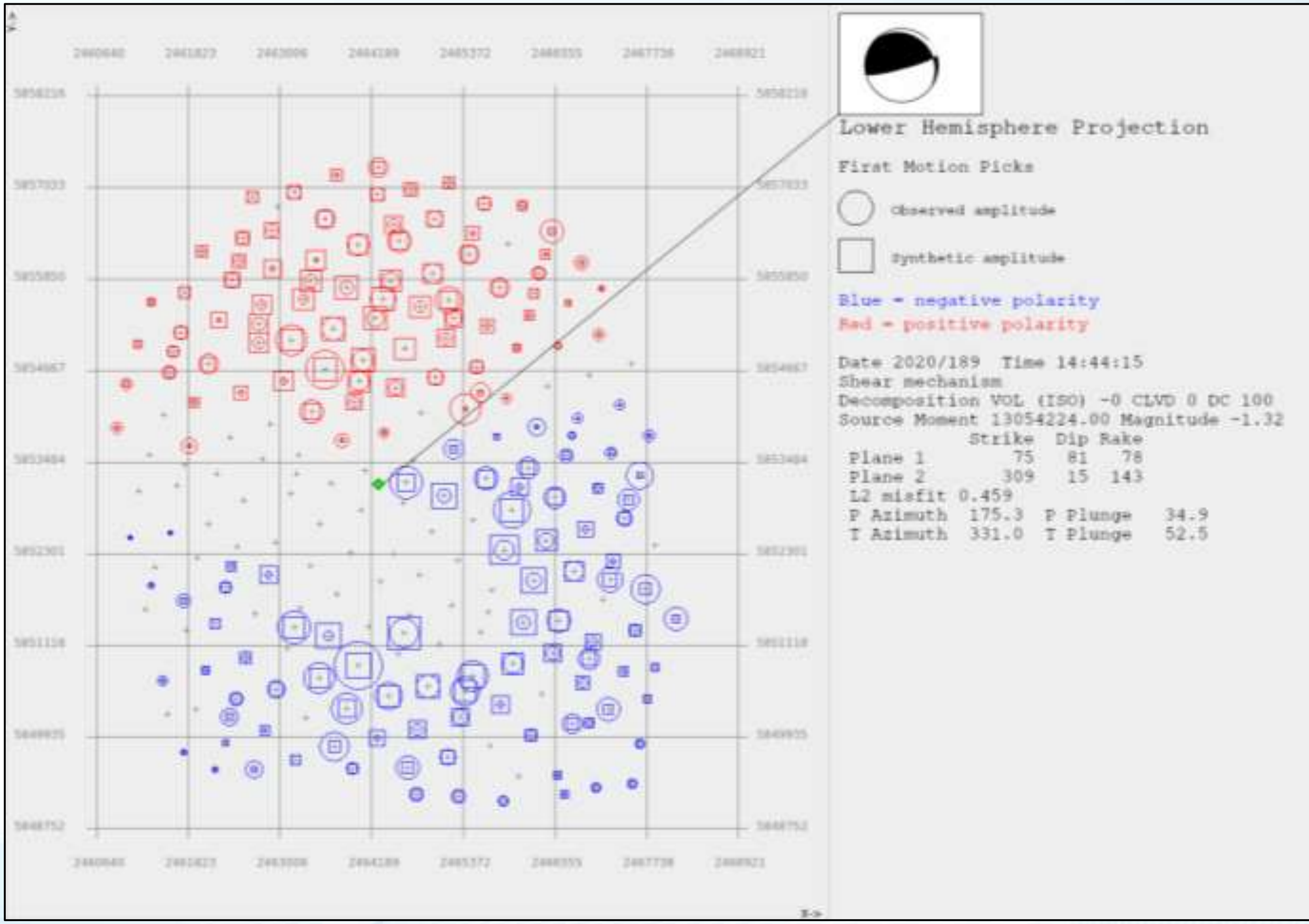
Source Mechanism – 2023h Stage 26 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
75	81	78

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -1.32



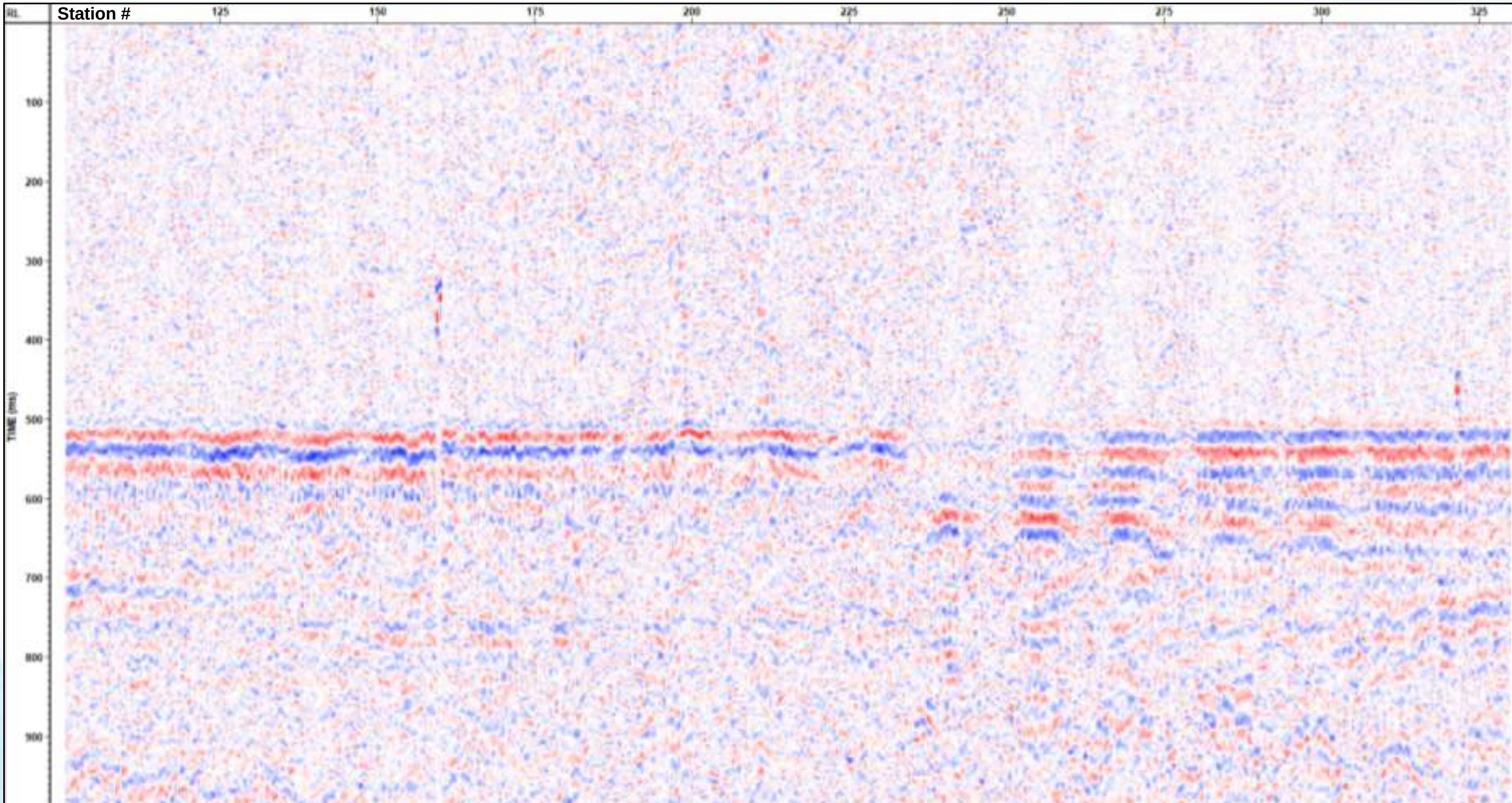
MicroSeismic

2023h Stage 26 Event – Processed Seismic

7/07/2020 14:44:15.140

No Mechanism Correction

Velocity Corrected Event at 500 ms



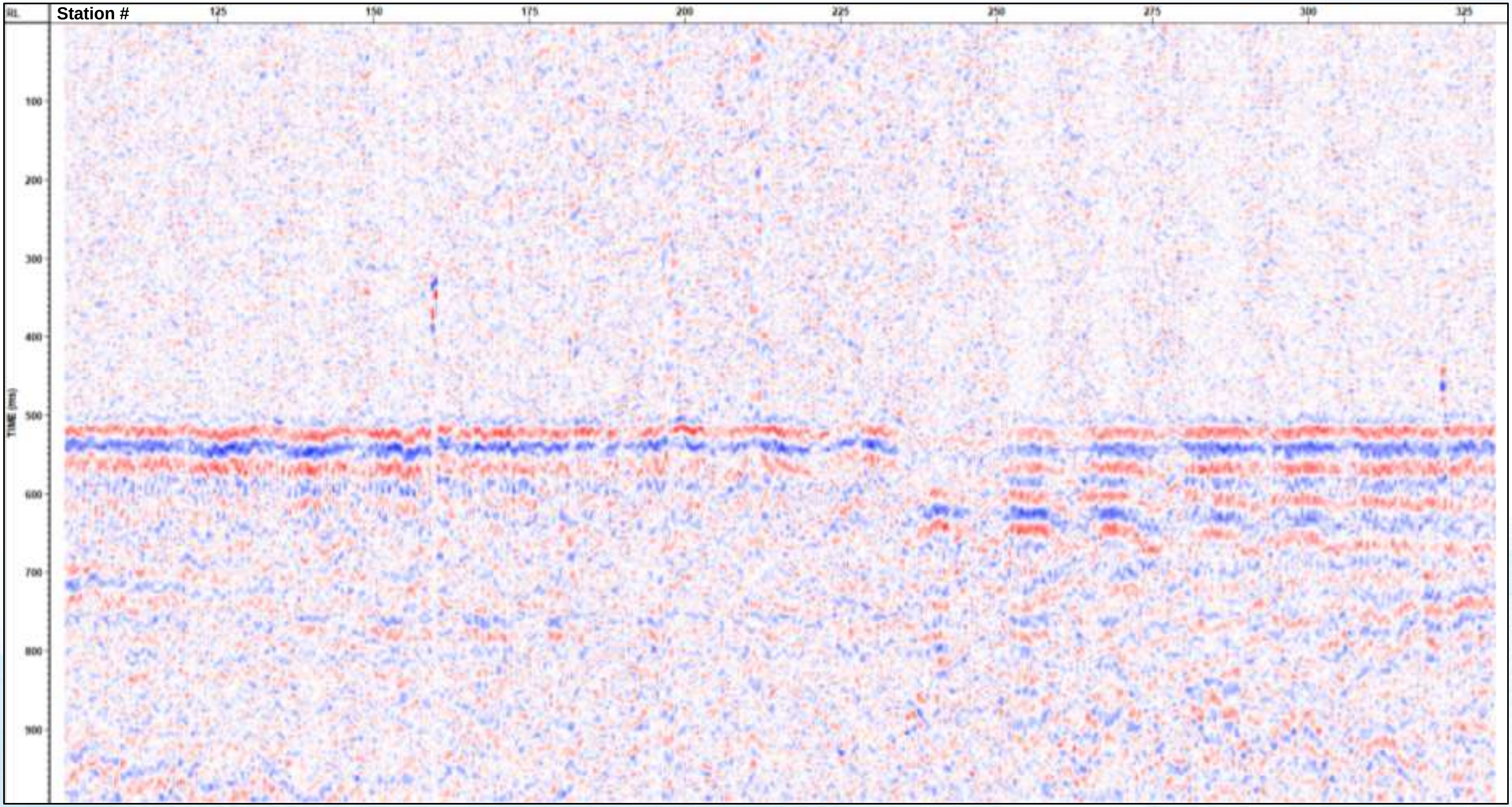
MicroSeismic

2023h Stage 26 Event – Processed Seismic

7/07/2020 14:44:15.140

Mechanism Corrected

Velocity Corrected Event at 500 ms



MicroSeismic

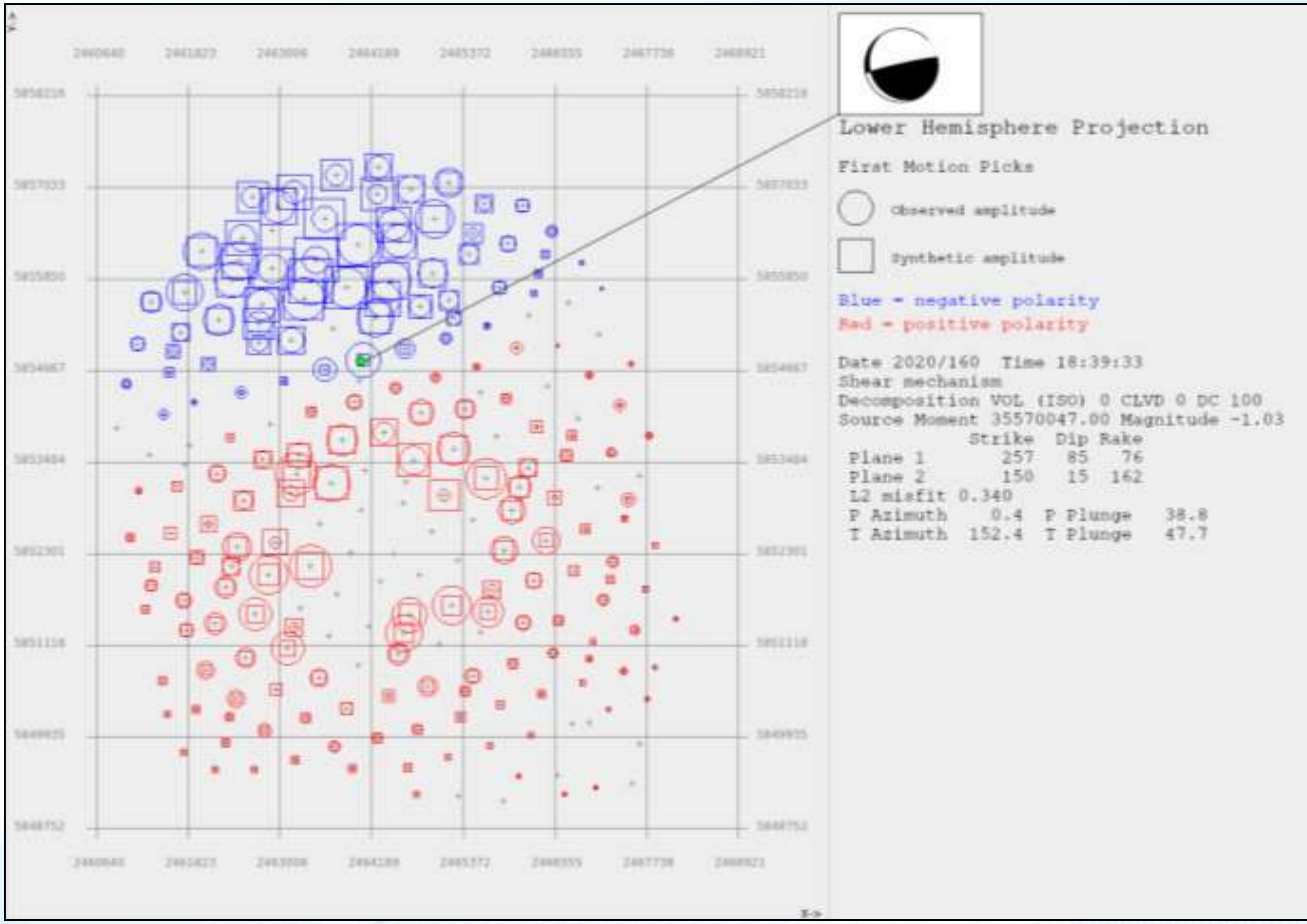
Source Mechanism – 2023h Stage 1 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
257	85	76

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -1.03

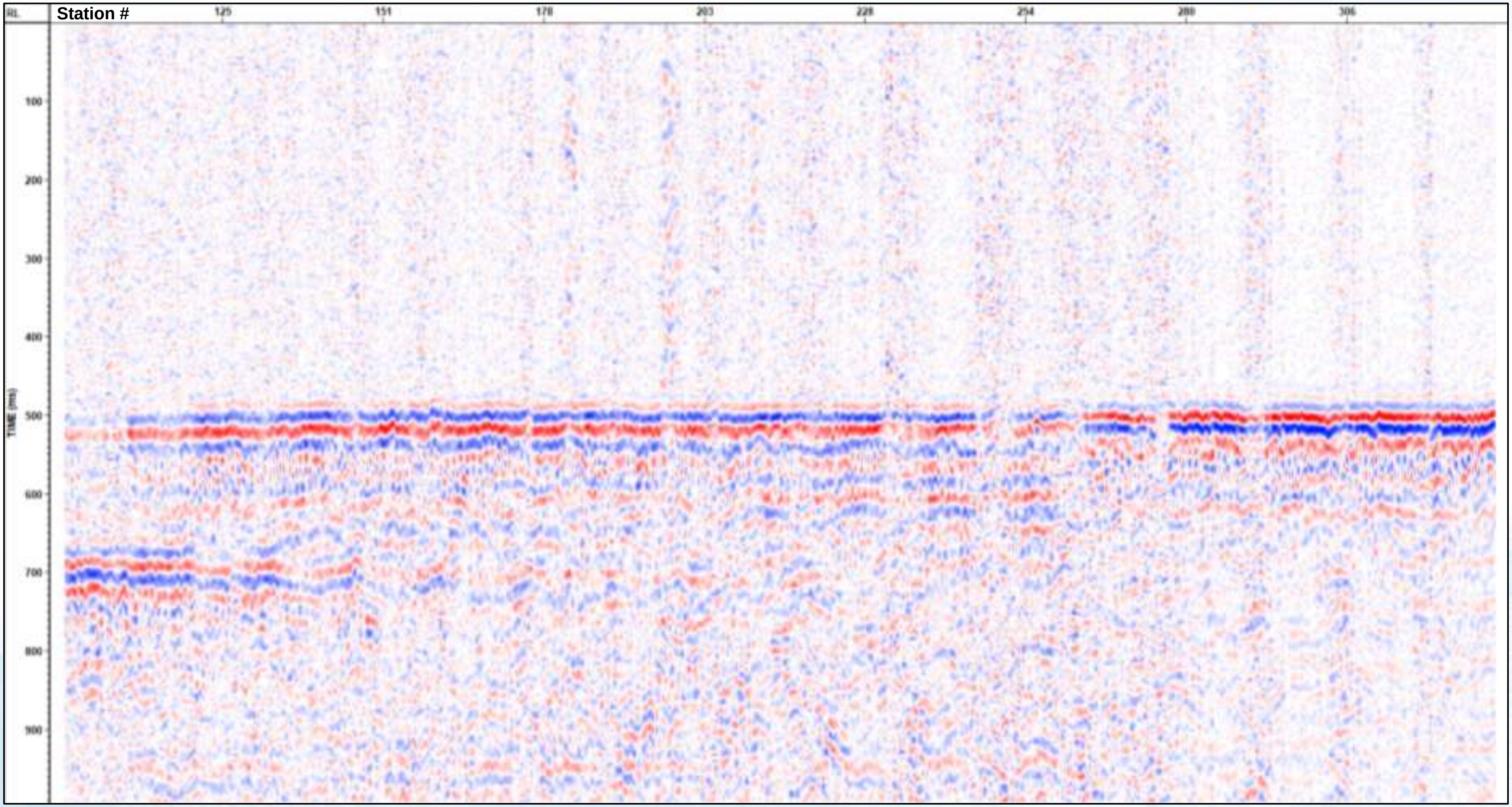


2023h Stage 1 Event – Processed Seismic

6/08/2020 18:39:32.956

No Mechanism Correction

Velocity Corrected Event at 500 ms

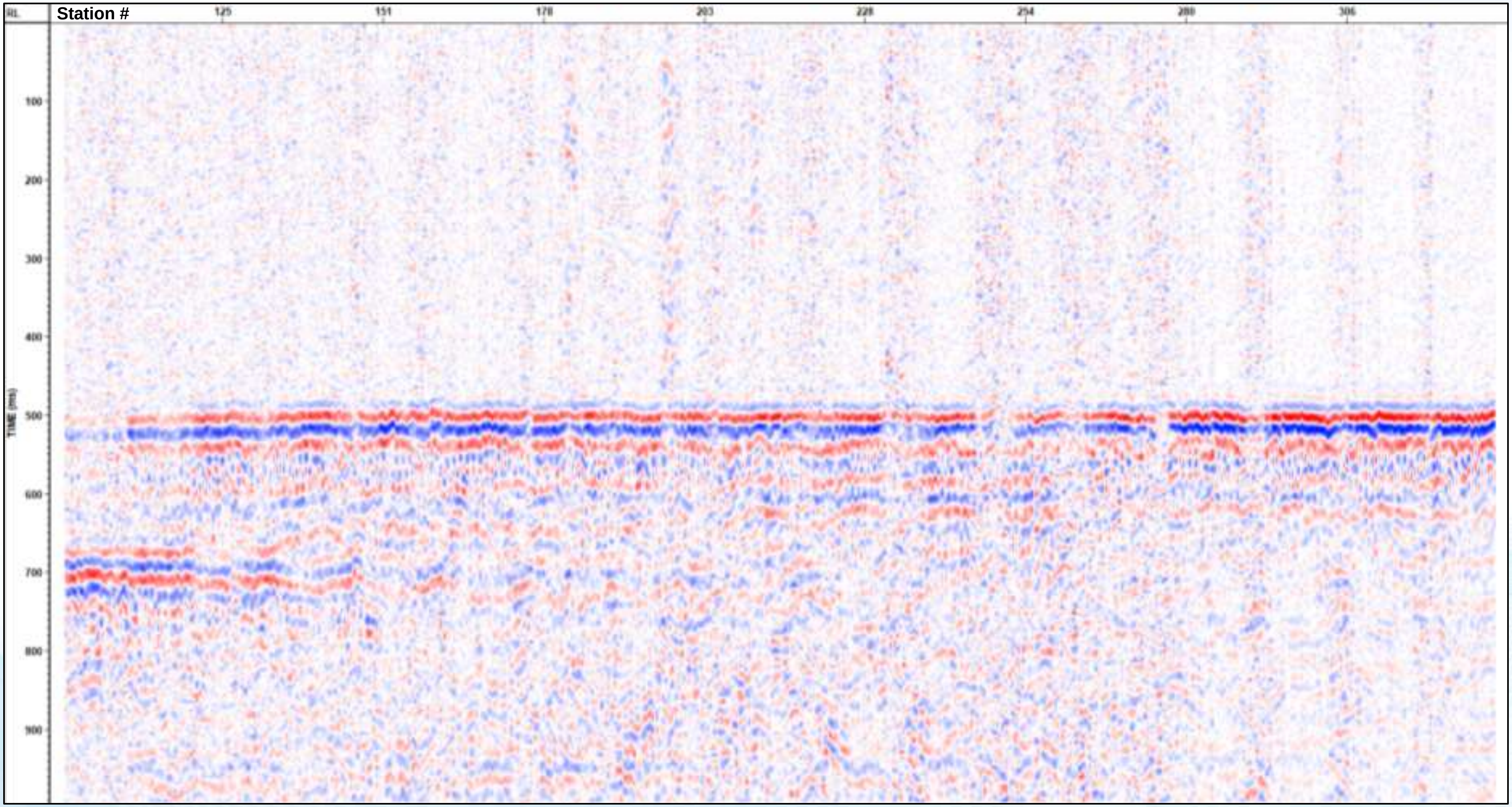


2023h Stage 1 Event – Processed Seismic

6/08/2020 18:39:32.956

Mechanism Corrected

Velocity Corrected Event at 500 ms



MicroSeismic

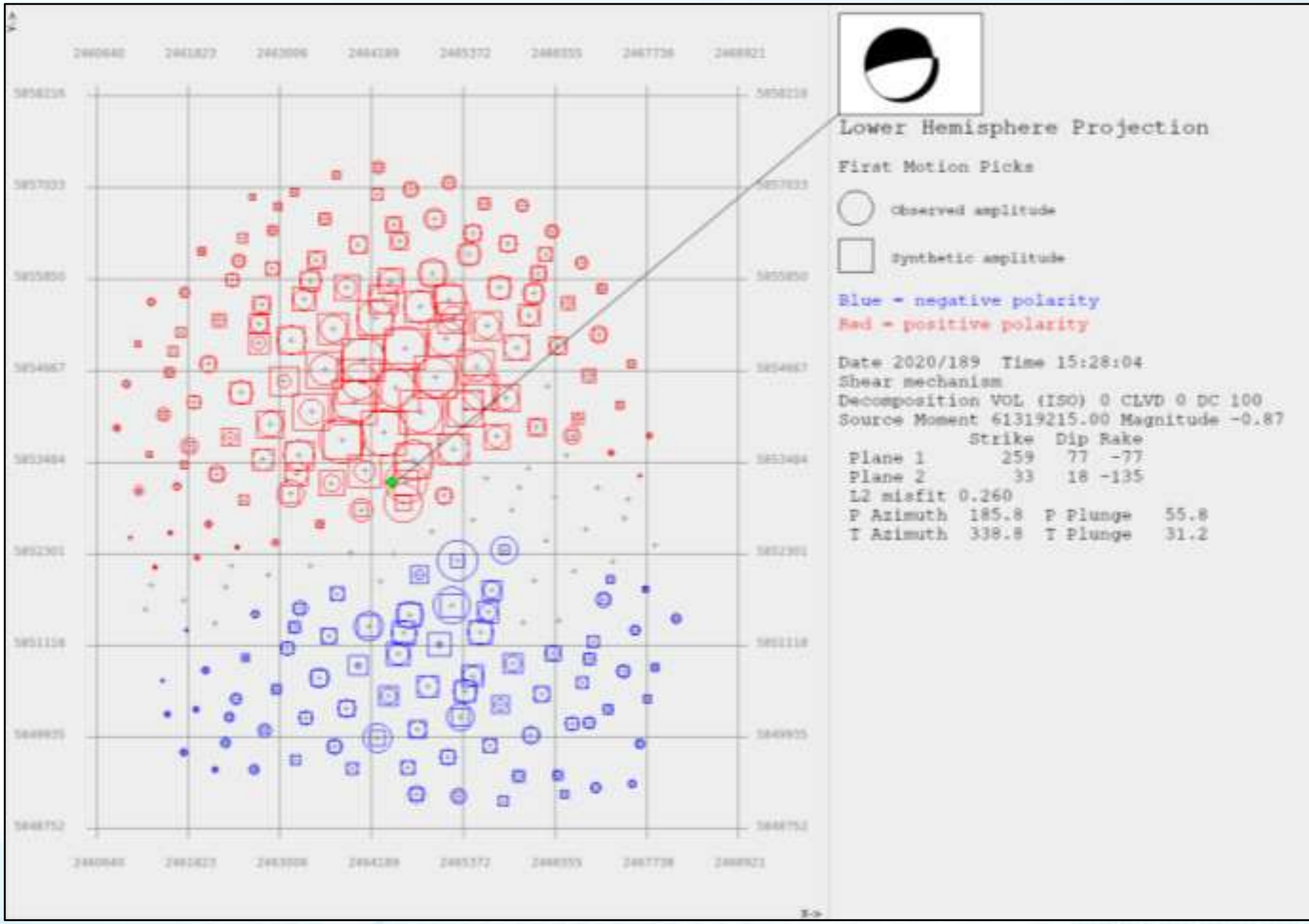
Source Mechanism – 2023h Stage 26 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
259	77	-77

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.87

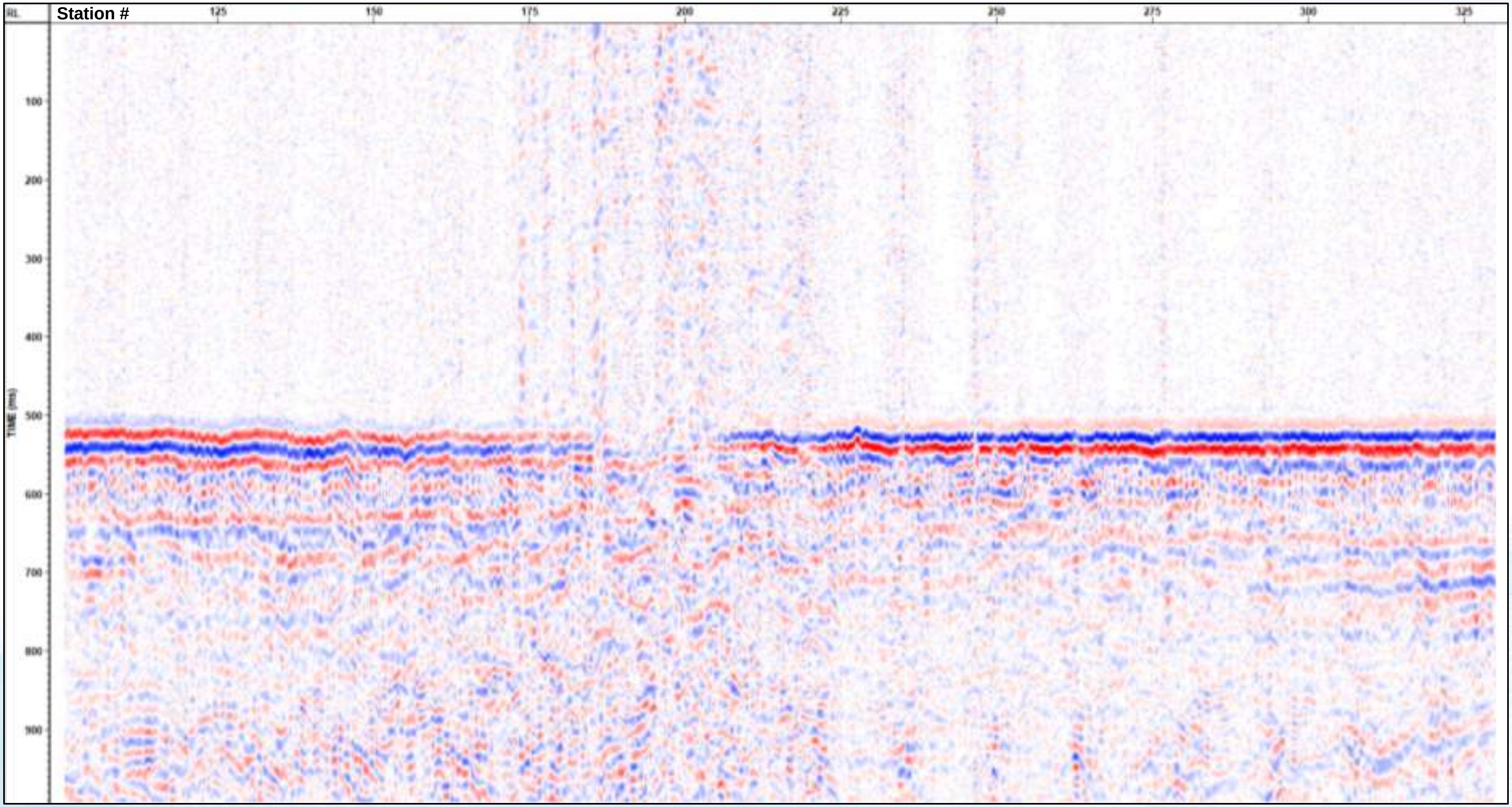


2023h Stage 26 Event – Processed Seismic

7/07/2020 15:28:04.124

No Mechanism Correction

Velocity Corrected Event at 500 ms



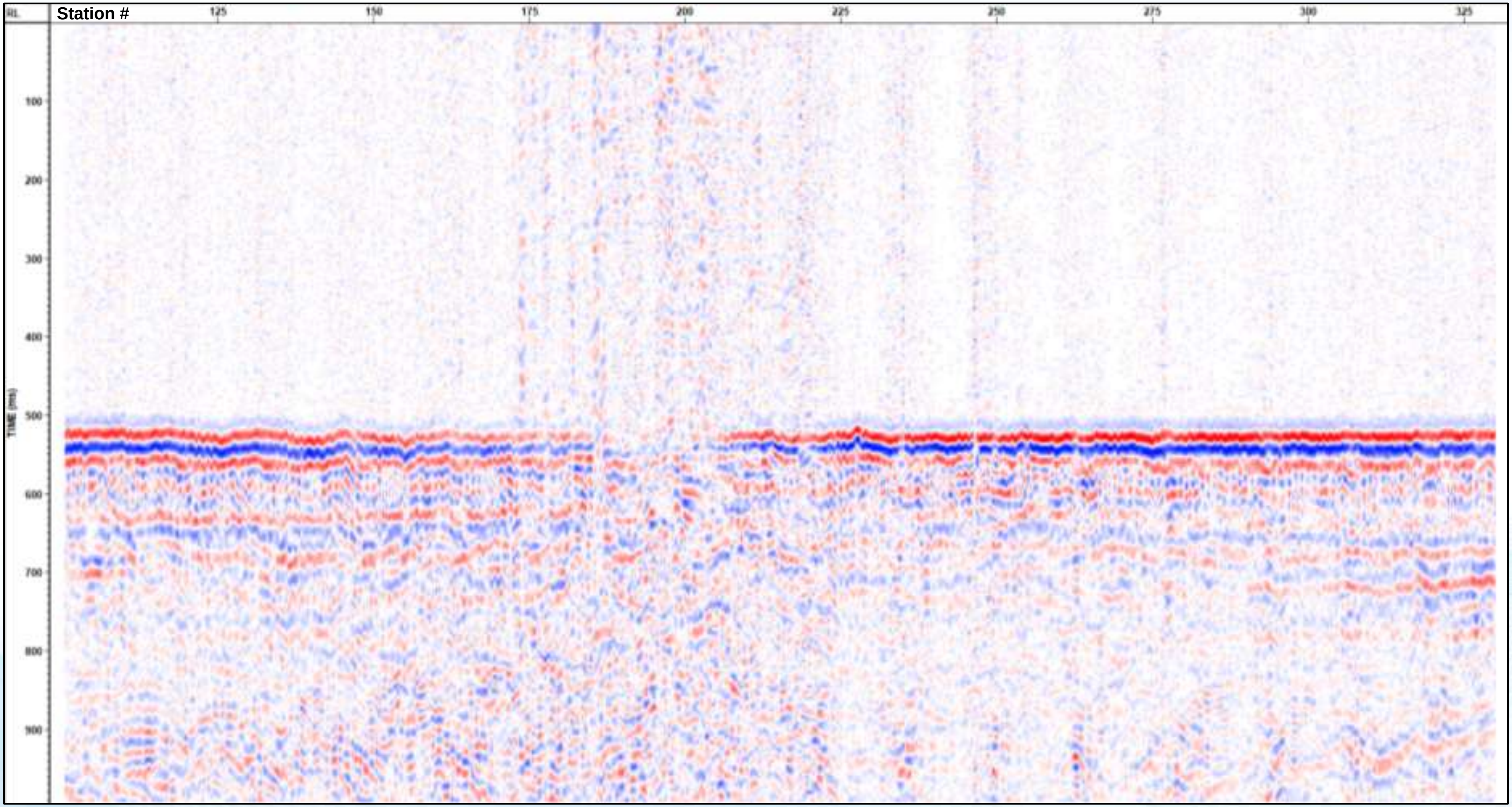
MicroSeismic

2023h Stage 26 Event – Processed Seismic

7/07/2020 15:28:04.124

Mechanism Corrected

Velocity Corrected Event at 500 ms



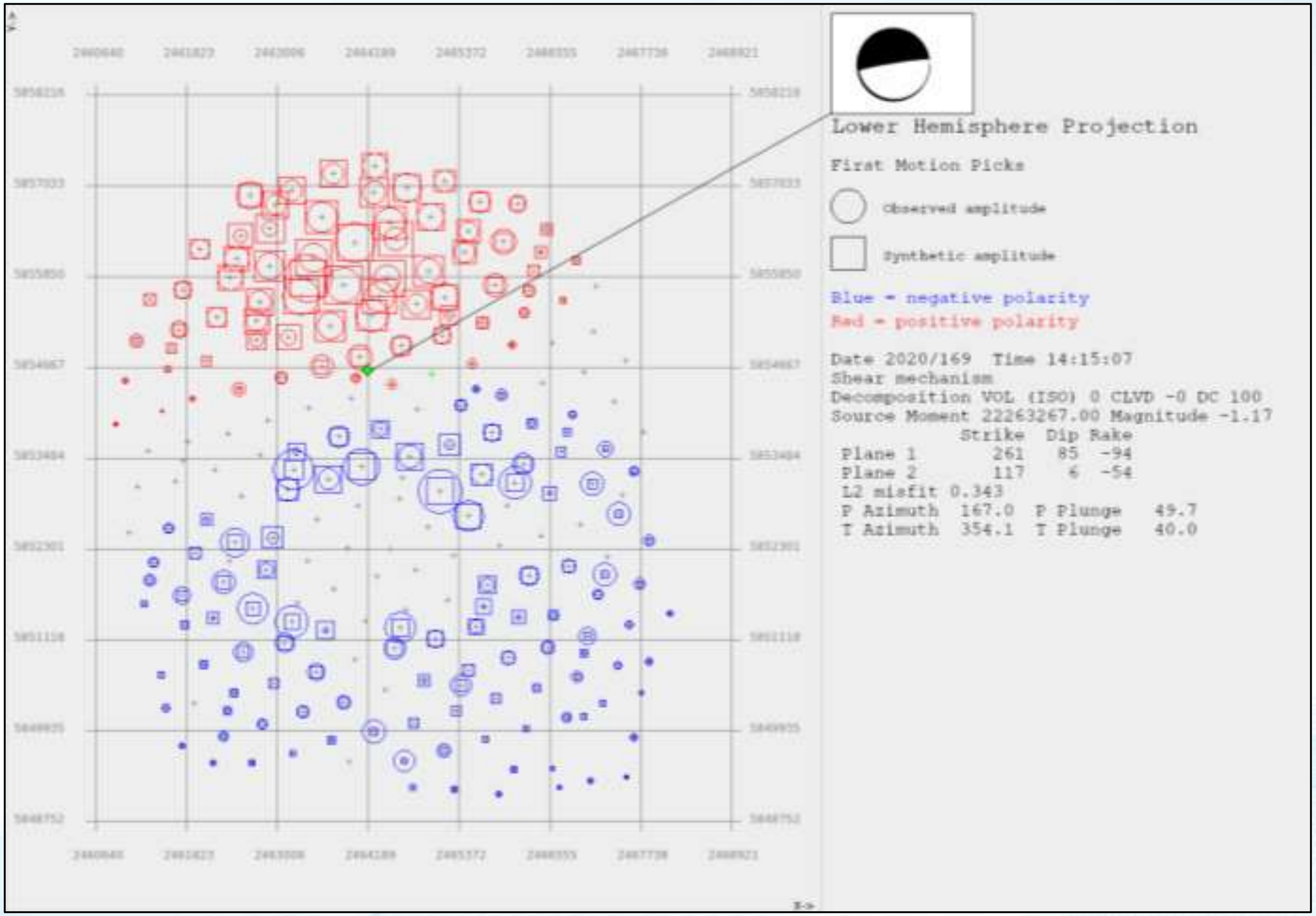
Source Mechanism – 2023h Stage 4 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
261	85	-94

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -1.17

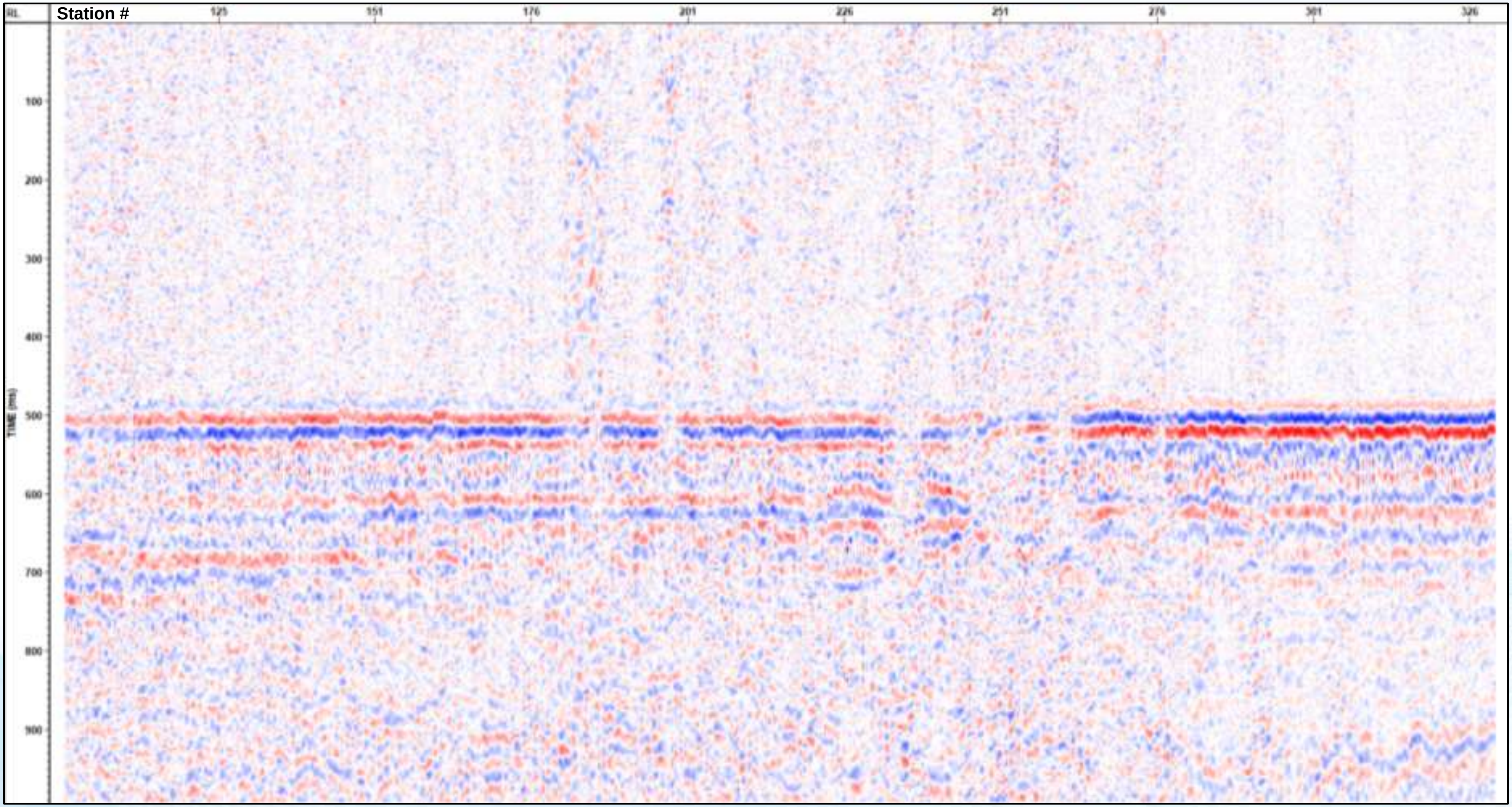


2023h Stage 4 Event – Processed Seismic

6/17/2020 14:15:06.384

No Mechanism Correction

Velocity Corrected Event at 500 ms



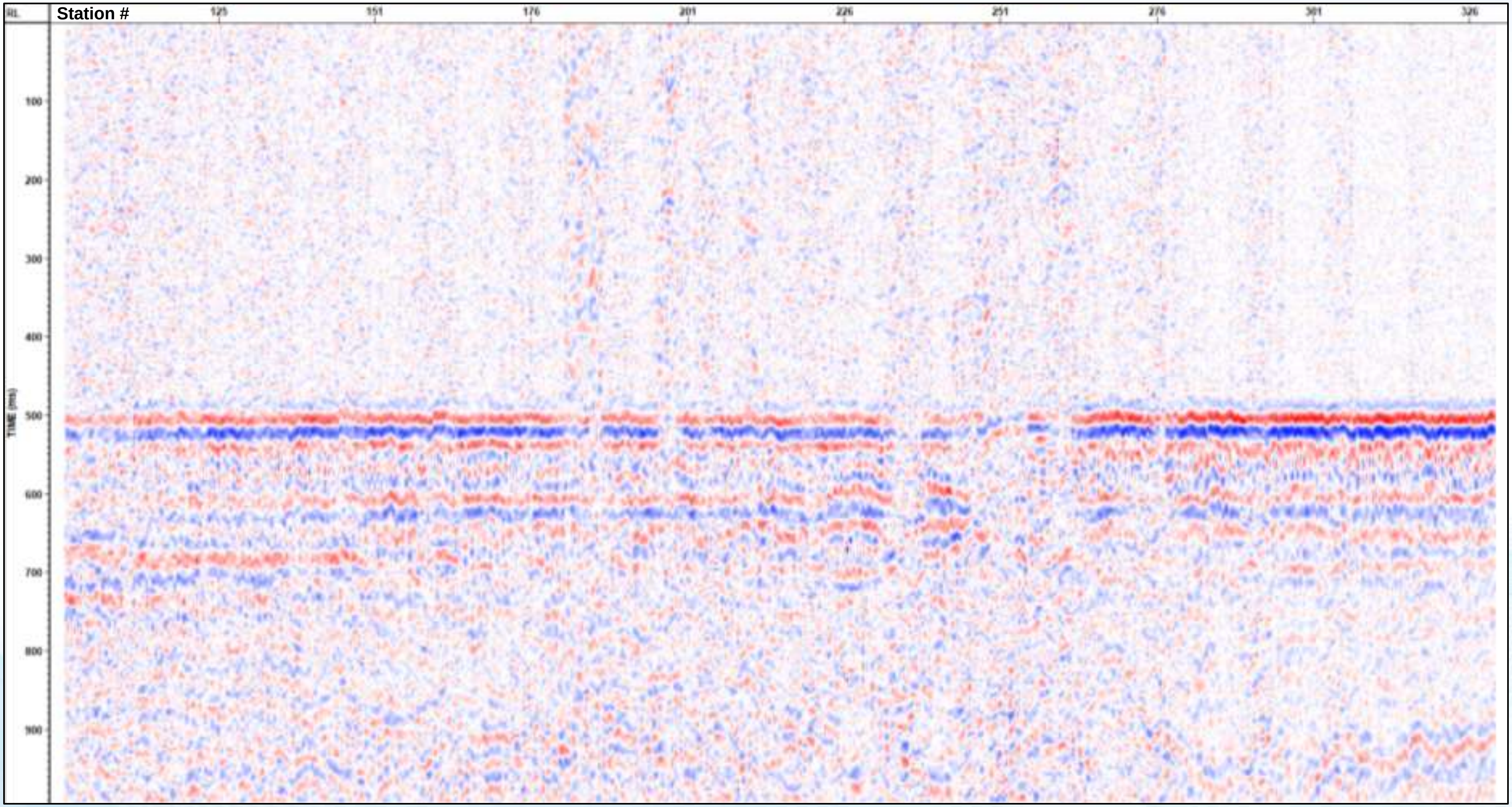
MicroSeismic

2023h Stage 4 Event – Processed Seismic

6/17/2020 14:15:06.384

Mechanism Corrected

Velocity Corrected Event at 500 ms



MicroSeismic

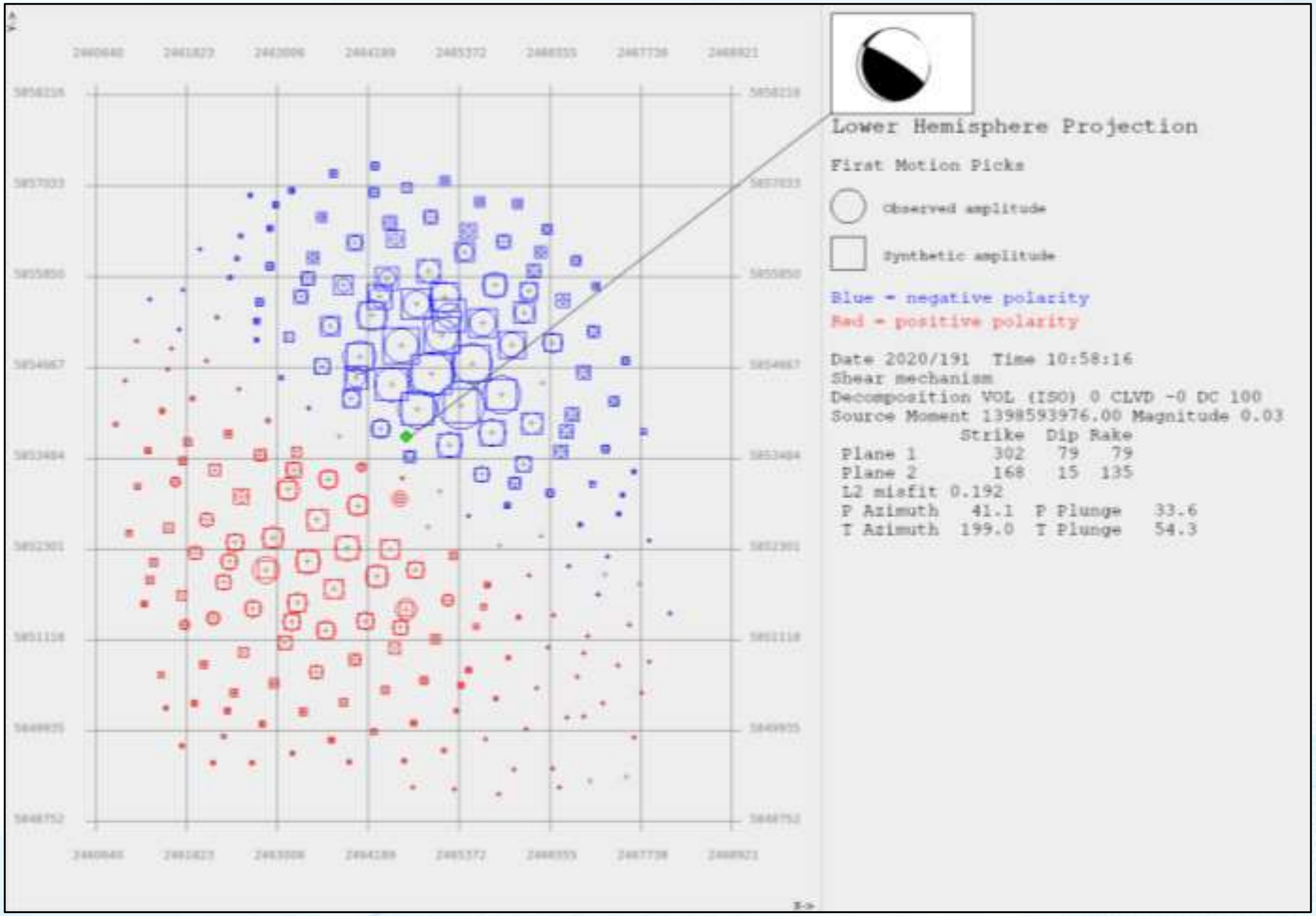
Source Mechanism – 2021h Stage 28 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
302	79	79

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: 0.03

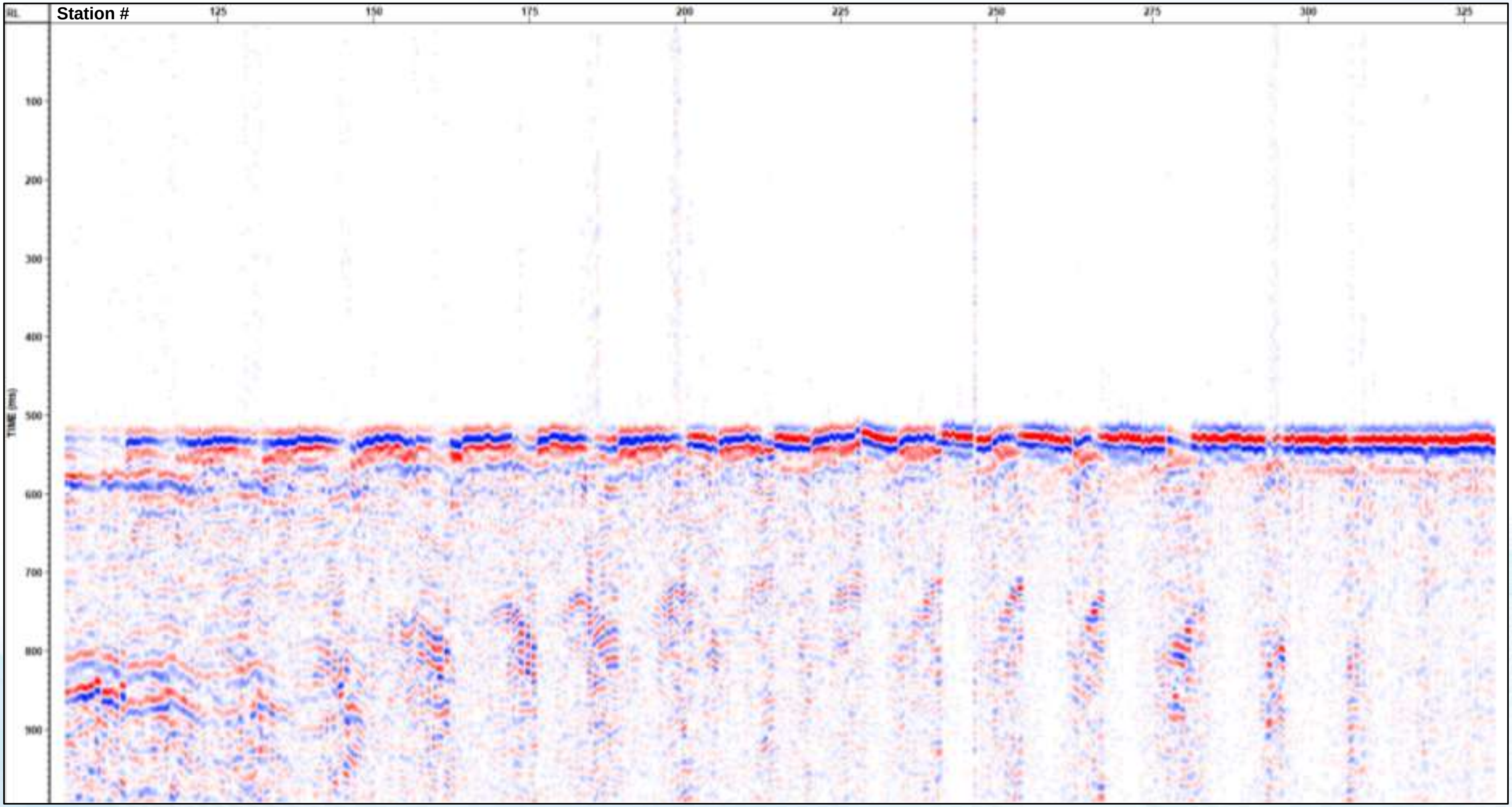


2021h Stage 28 Event – Processed Seismic

7/09/2020 10:58:16.236

No Mechanism Correction

Velocity Corrected Event at 500 ms



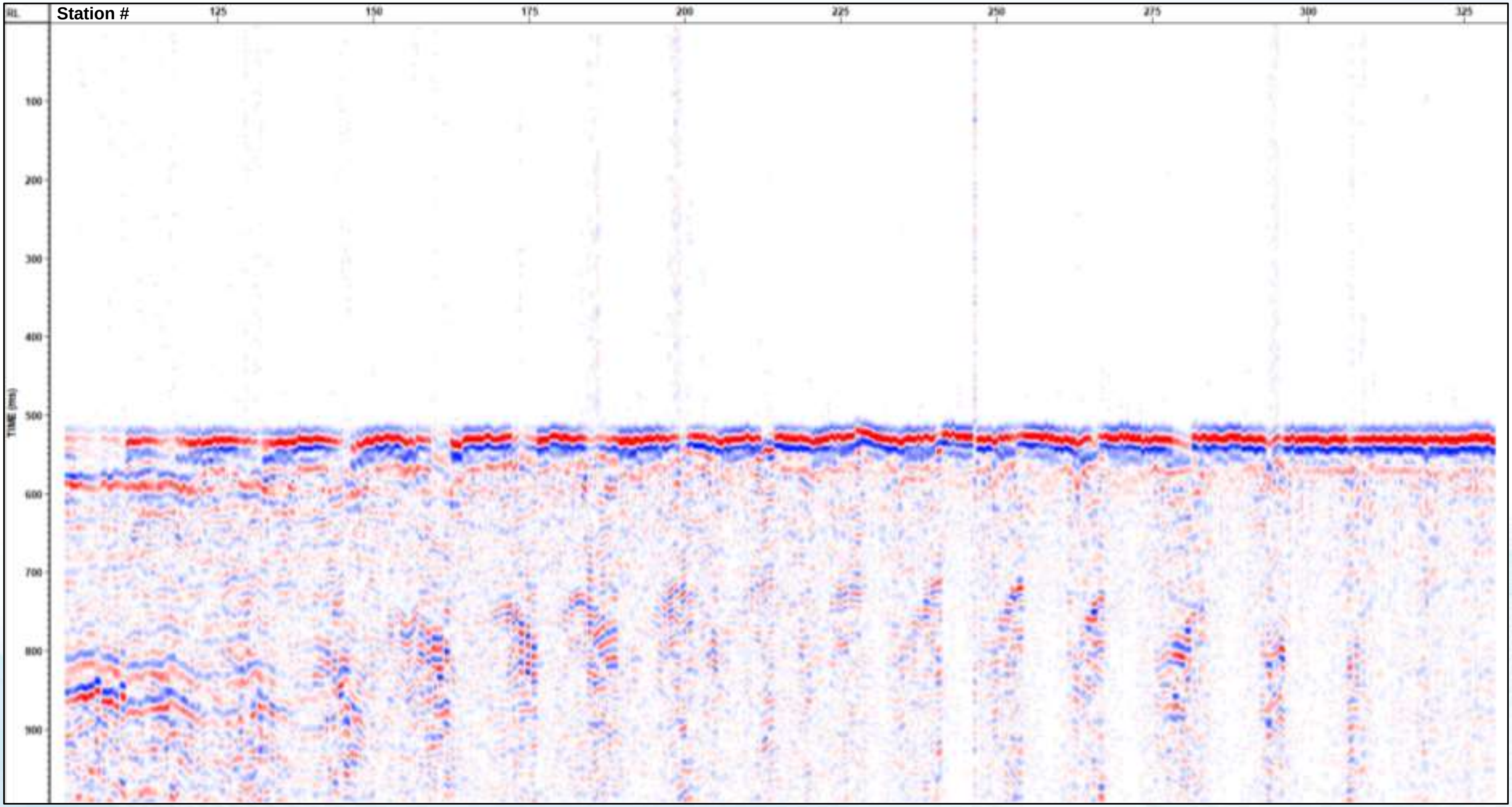
MicroSeismic

2021h Stage 28 Event – Processed Seismic

7/09/2020 10:58:16.236

Mechanism Corrected

Velocity Corrected Event at 500 ms



MicroSeismic

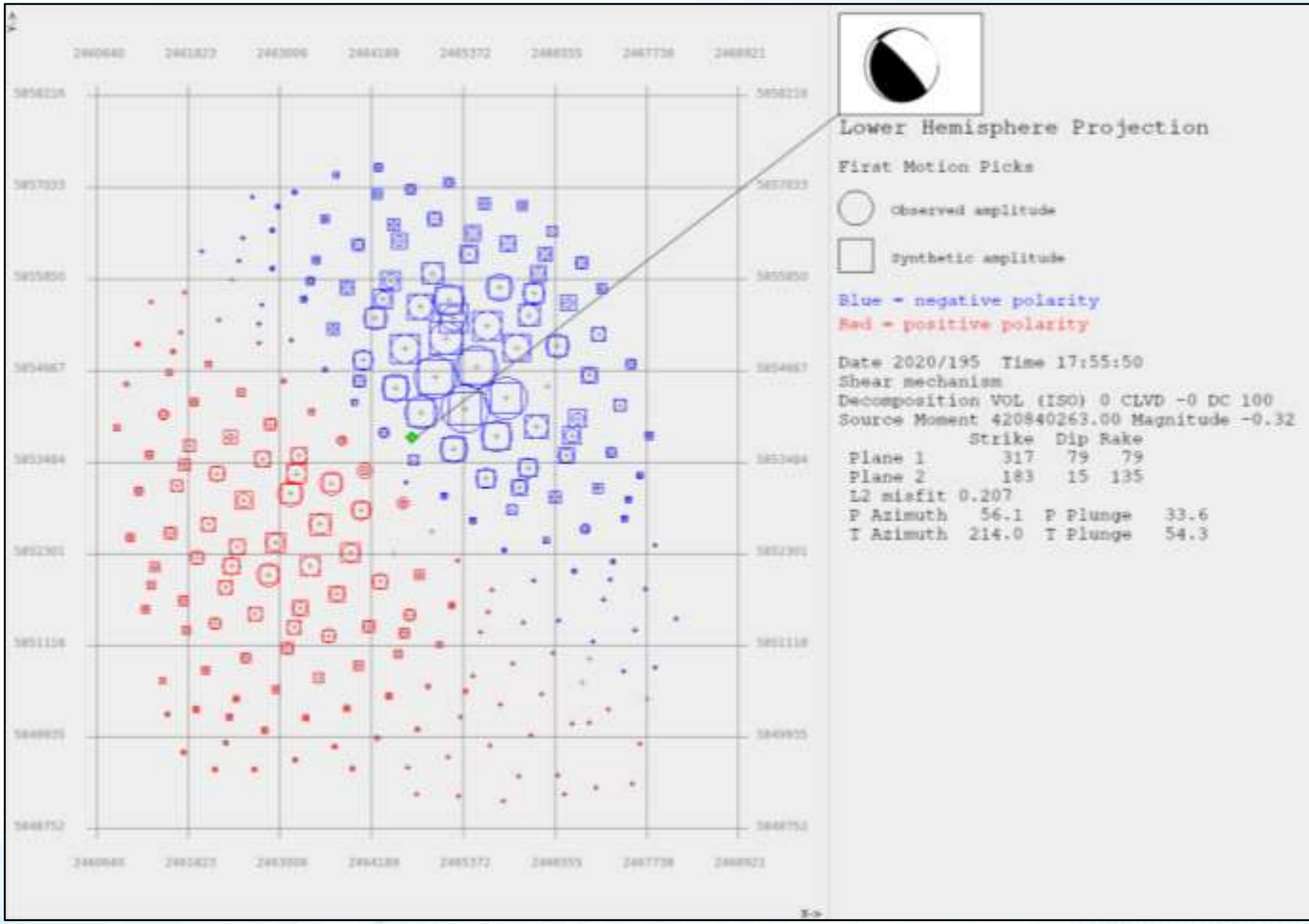
Source Mechanism – 2023h Stage 30 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
317	79	79

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.32



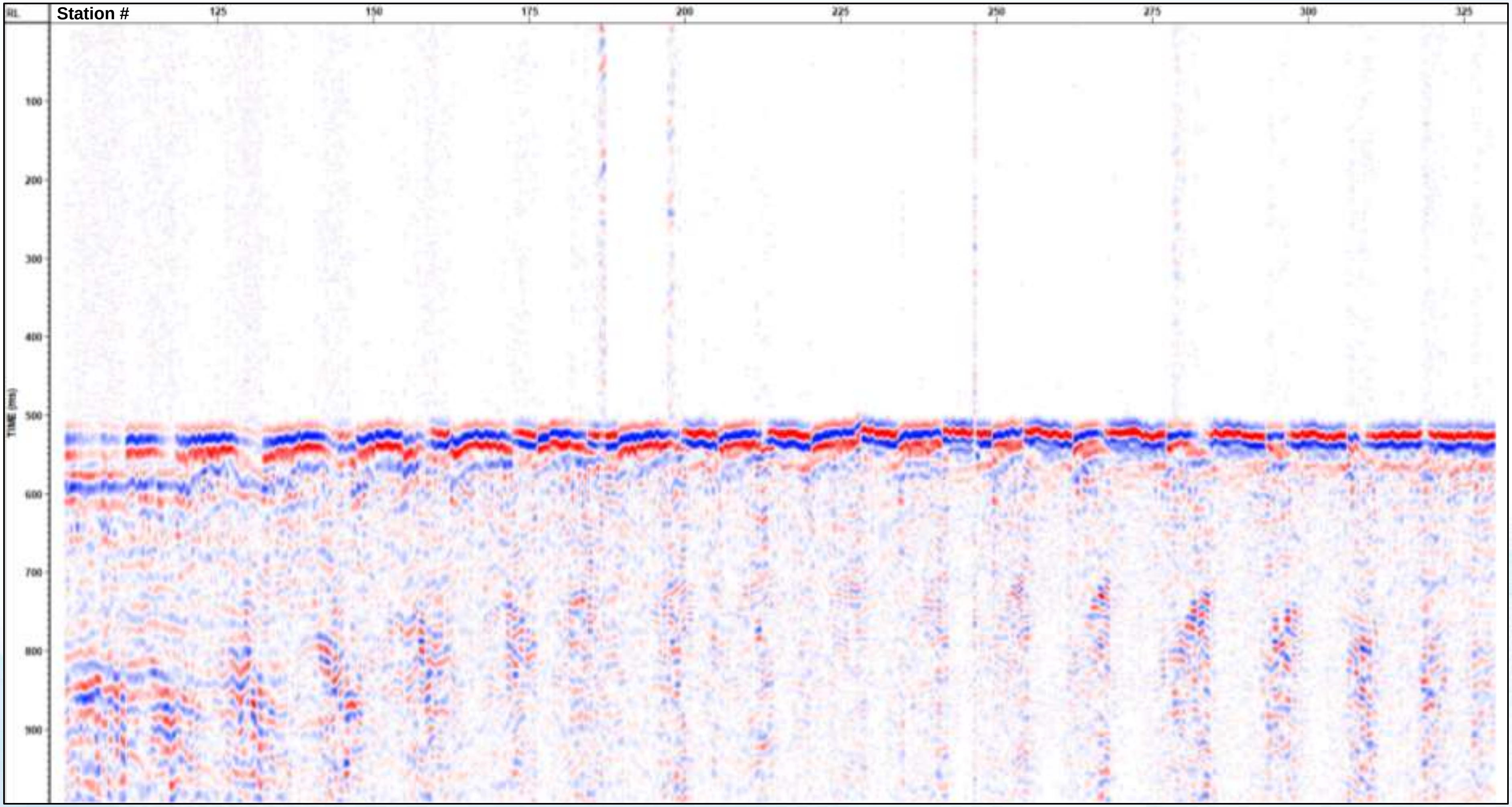
MicroSeismic

2023h Stage 30 Event – Processed Seismic

7/13/2020 17:55:49.424

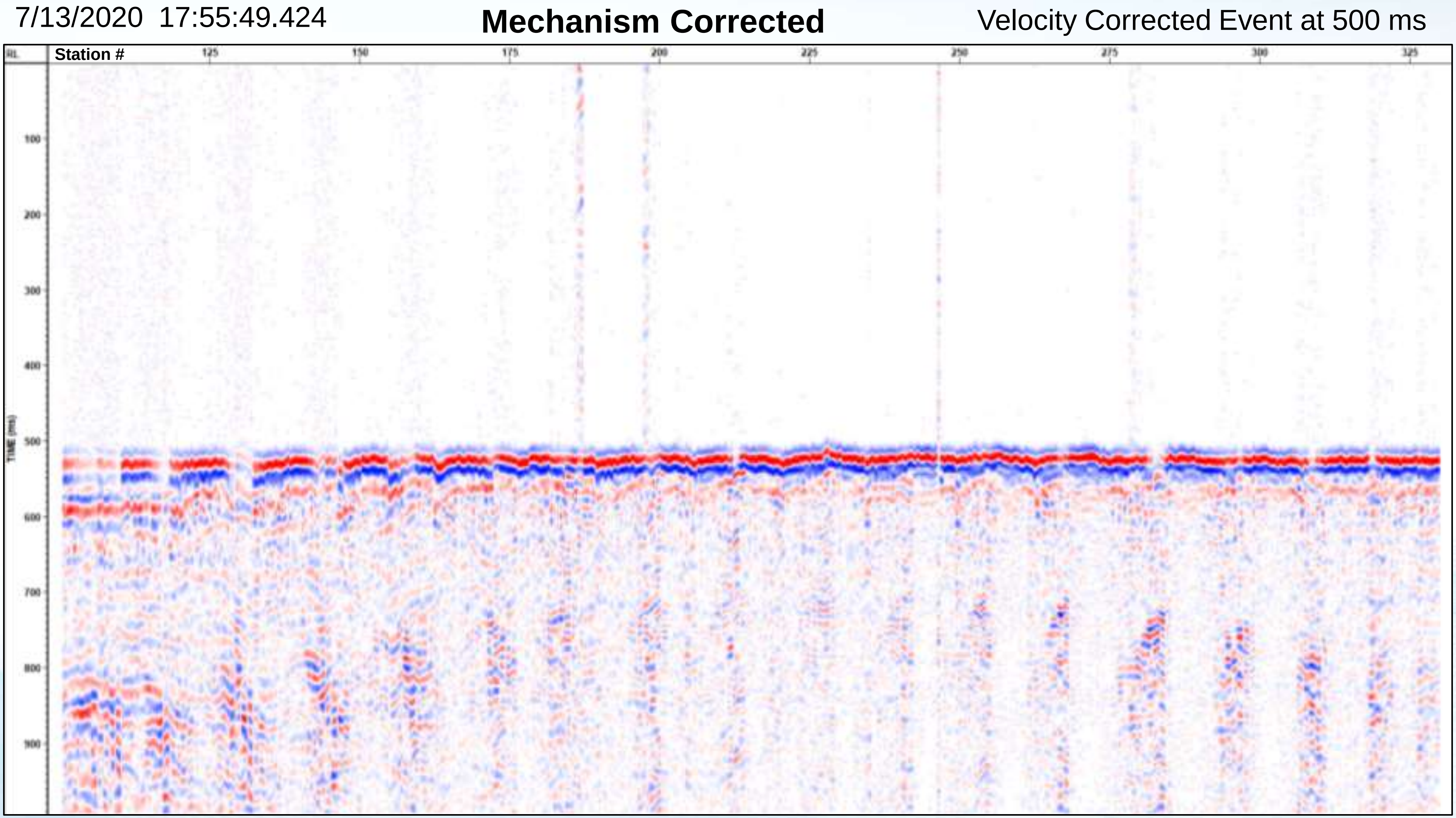
No Mechanism Correction

Velocity Corrected Event at 500 ms



MicroSeismic

2023h Stage 30 Event – Processed Seismic



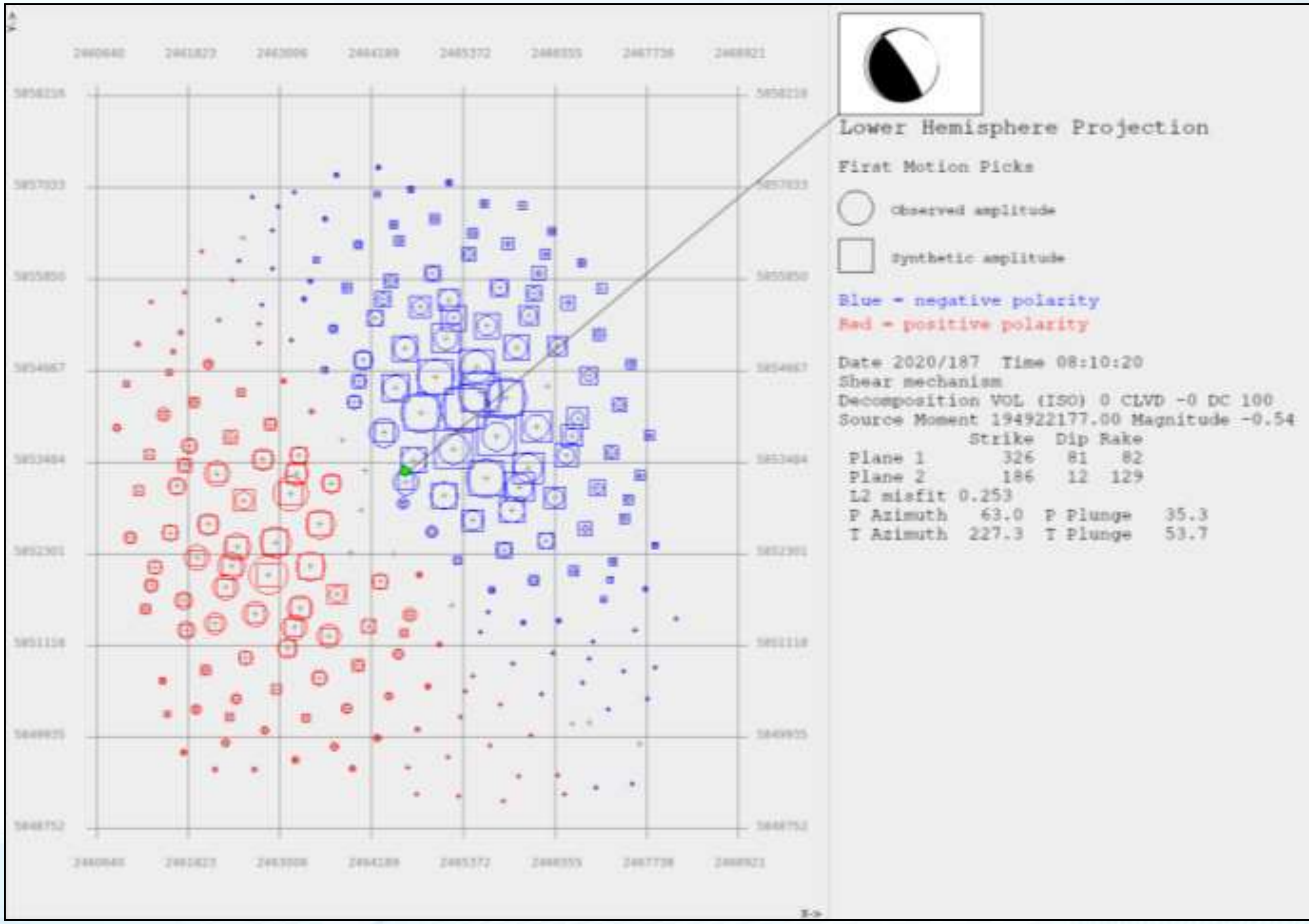
Source Mechanism – 2021h Stage 23 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
326	81	82

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.54



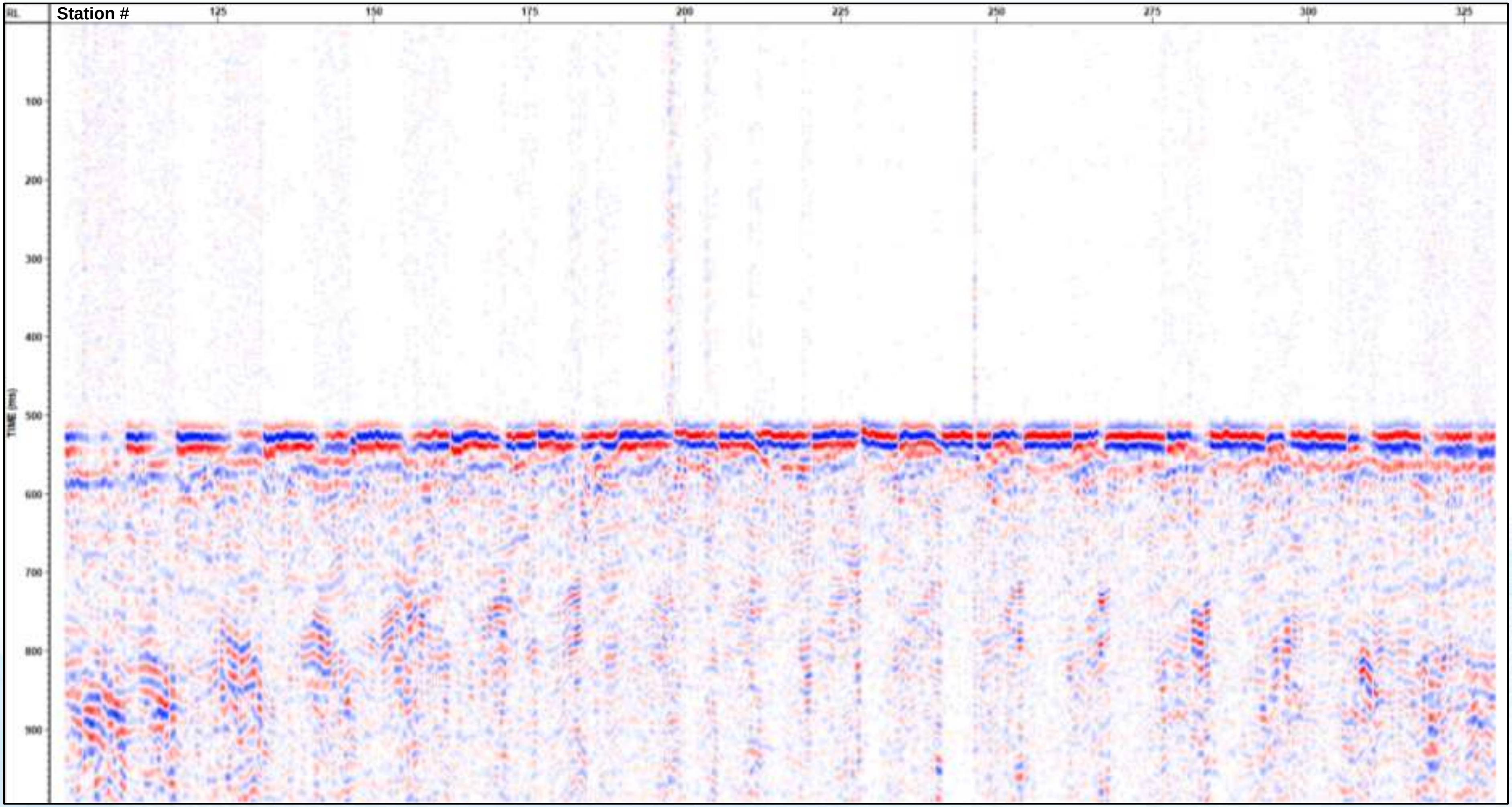
MicroSeismic

2021h Stage 23 Event – Processed Seismic

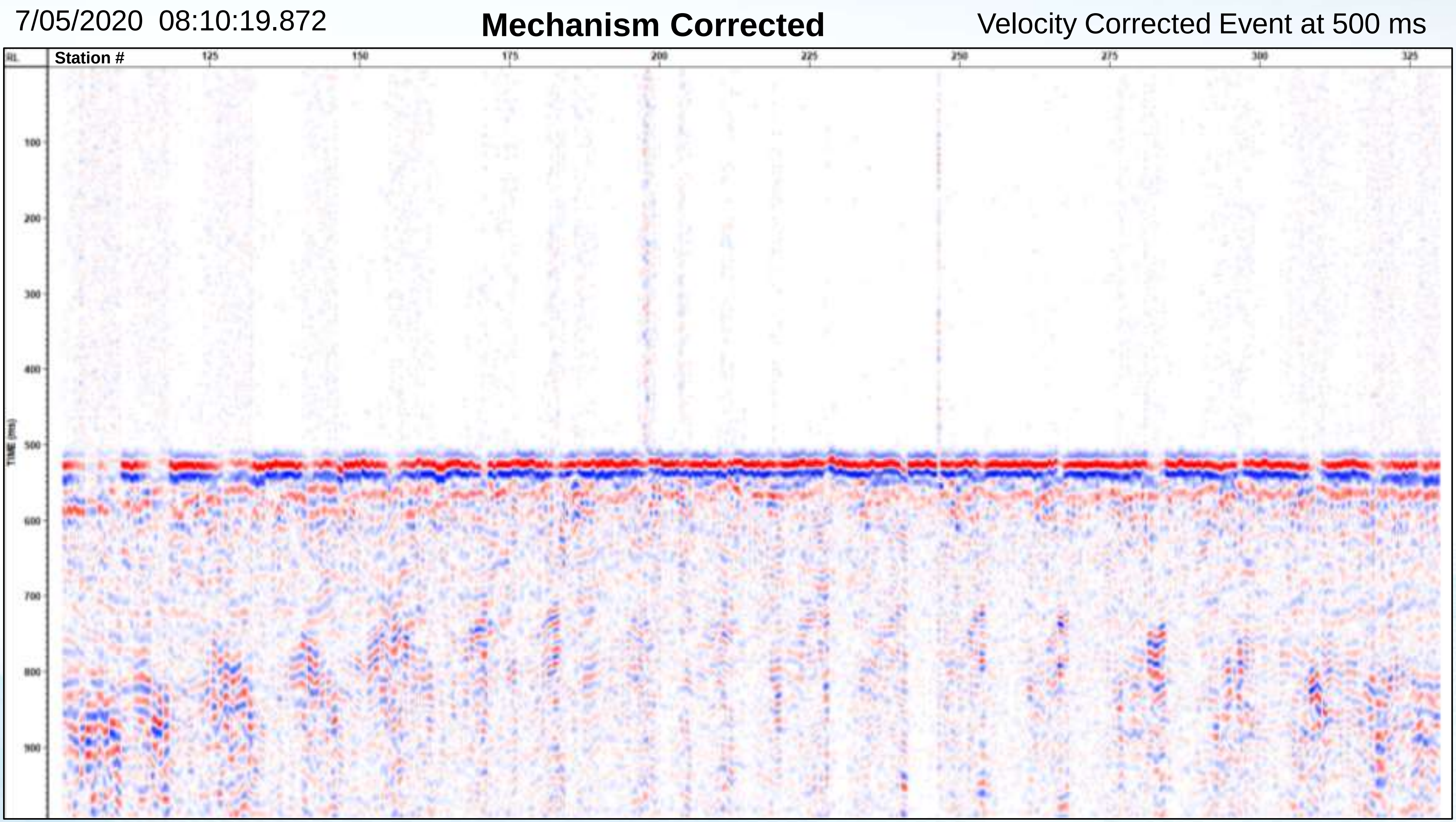
7/05/2020 08:10:19.872

No Mechanism Correction

Velocity Corrected Event at 500 ms



2021h Stage 23 Event – Processed Seismic



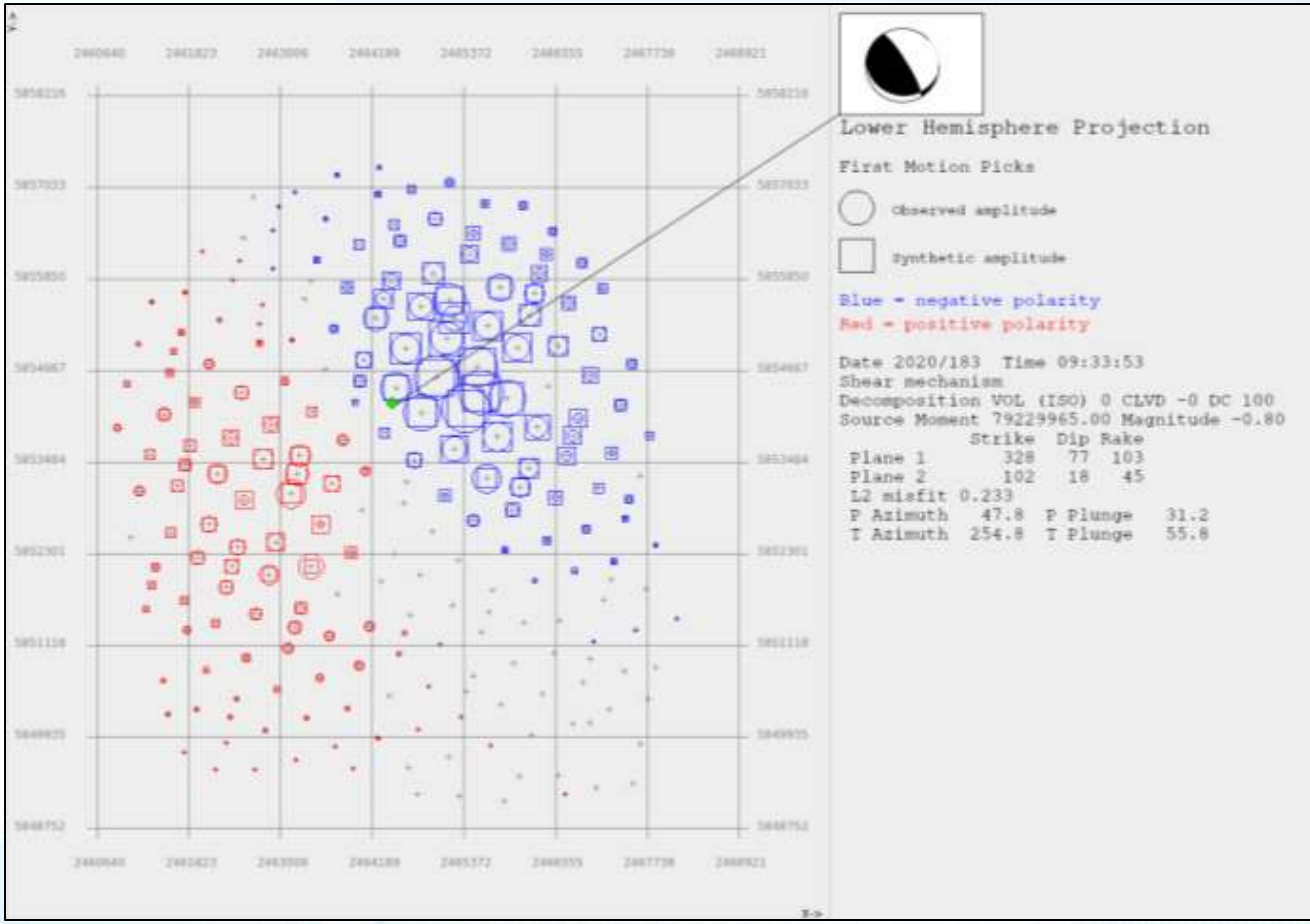
Source Mechanism – 2023h Stage 17 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
328	77	103

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.80



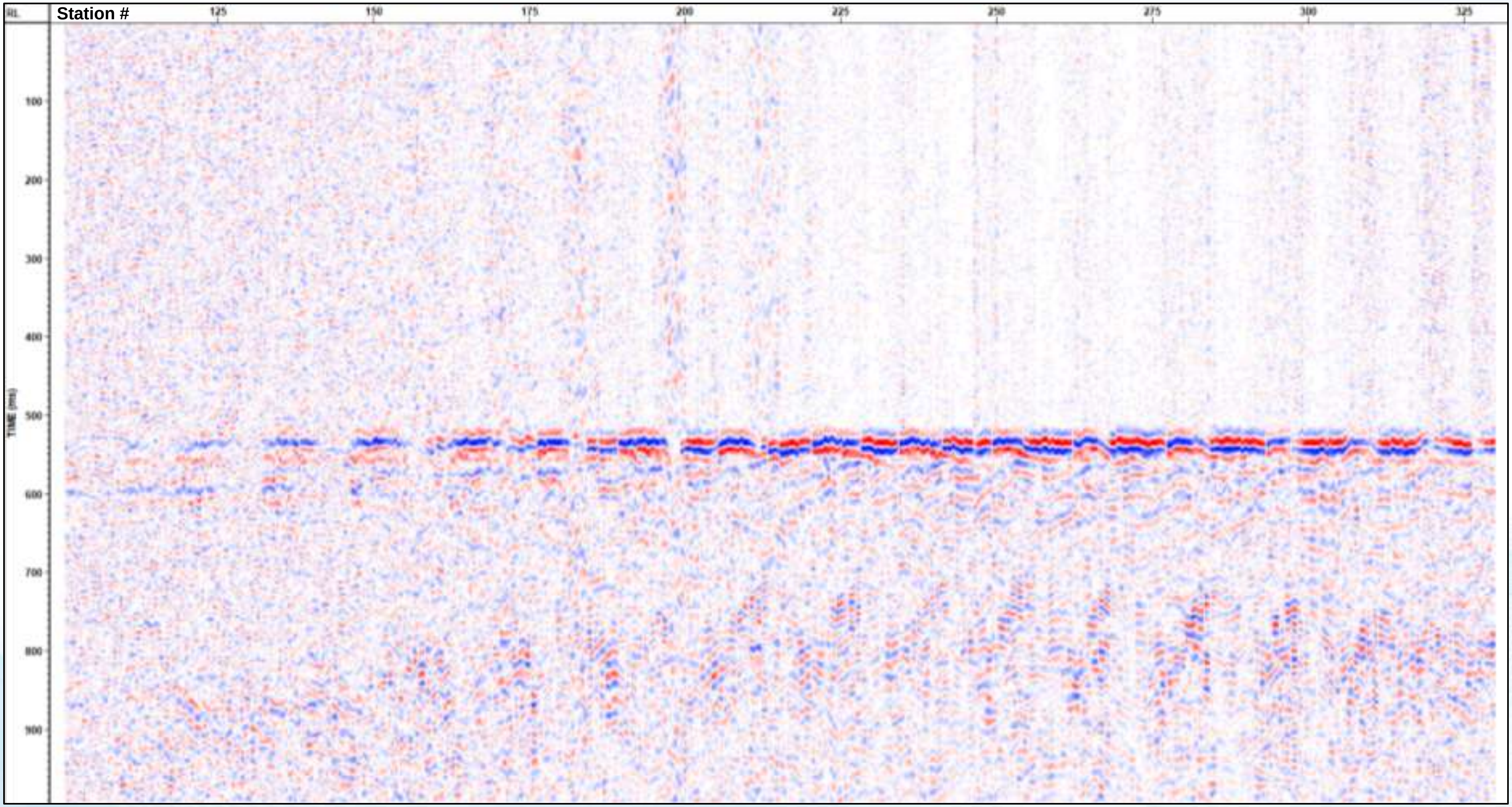
MicroSeismic

2023h Stage 17 Event – Processed Seismic

7/01/2020 09:33:52.496

No Mechanism Correction

Velocity Corrected Event at 500 ms



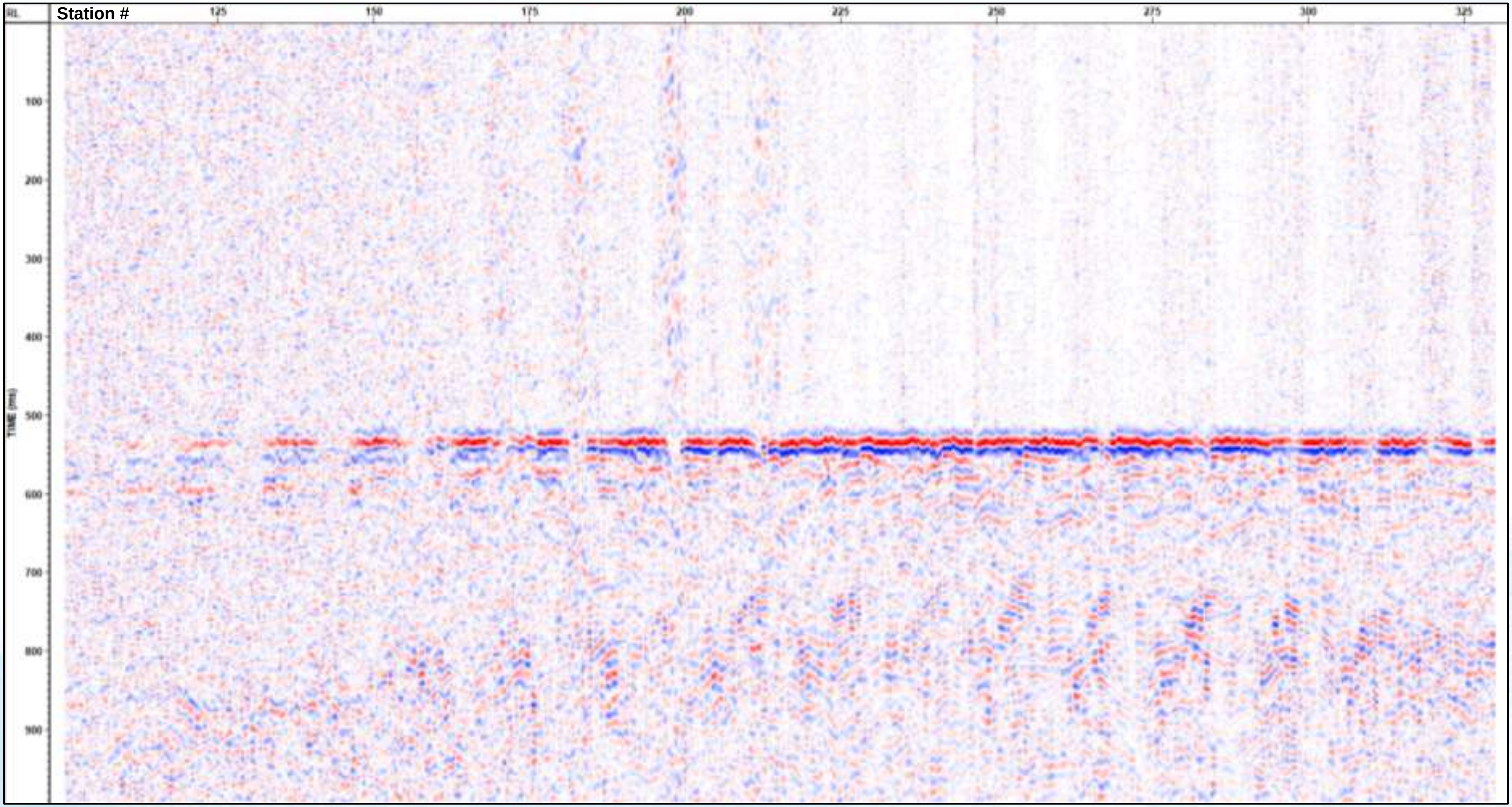
MicroSeismic

2023h Stage 17 Event – Processed Seismic

7/01/2020 09:33:52.496

Mechanism Corrected

Velocity Corrected Event at 500 ms



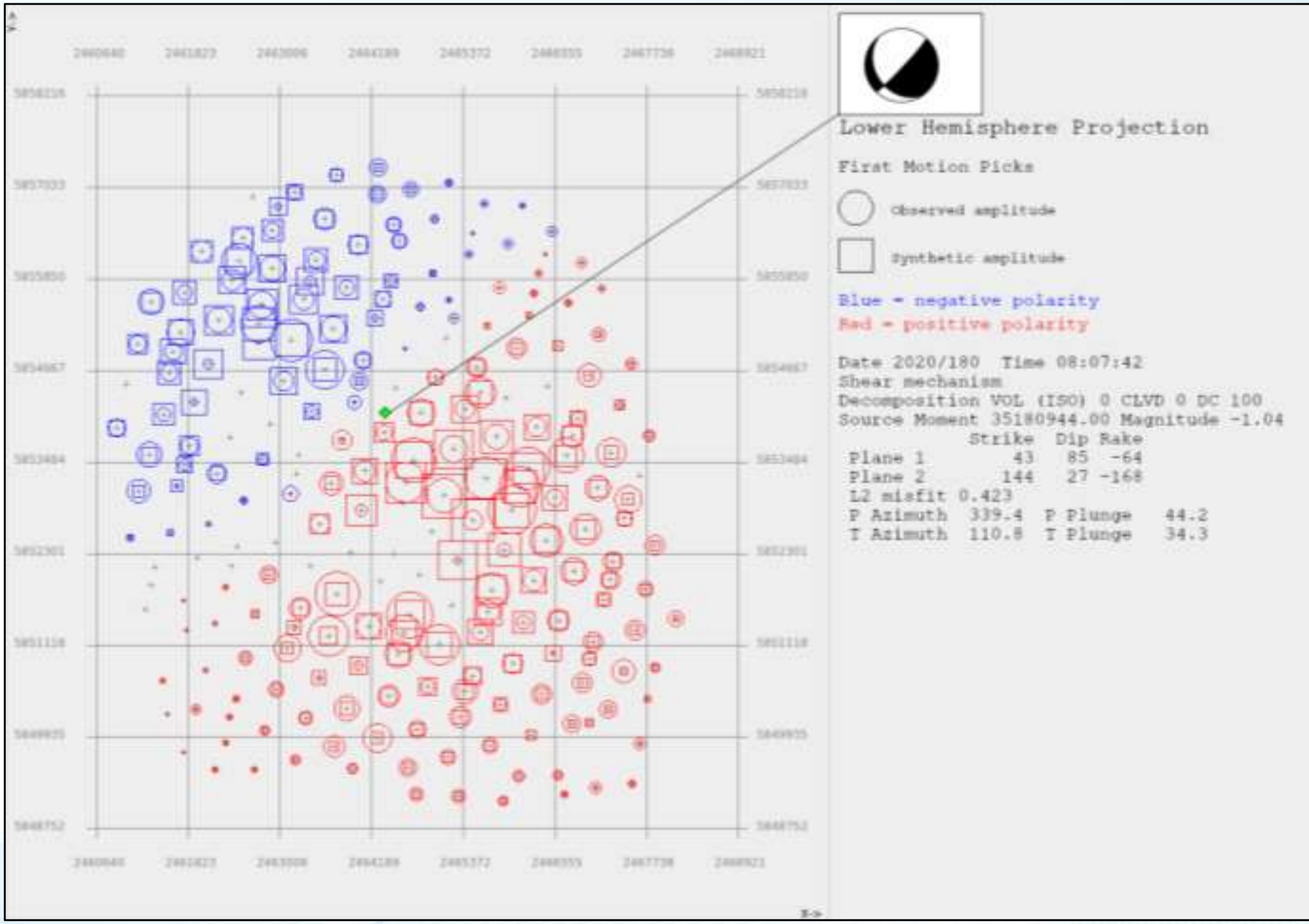
Source Mechanism – 2023h Stage 12 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
43	85	-64

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -1.04



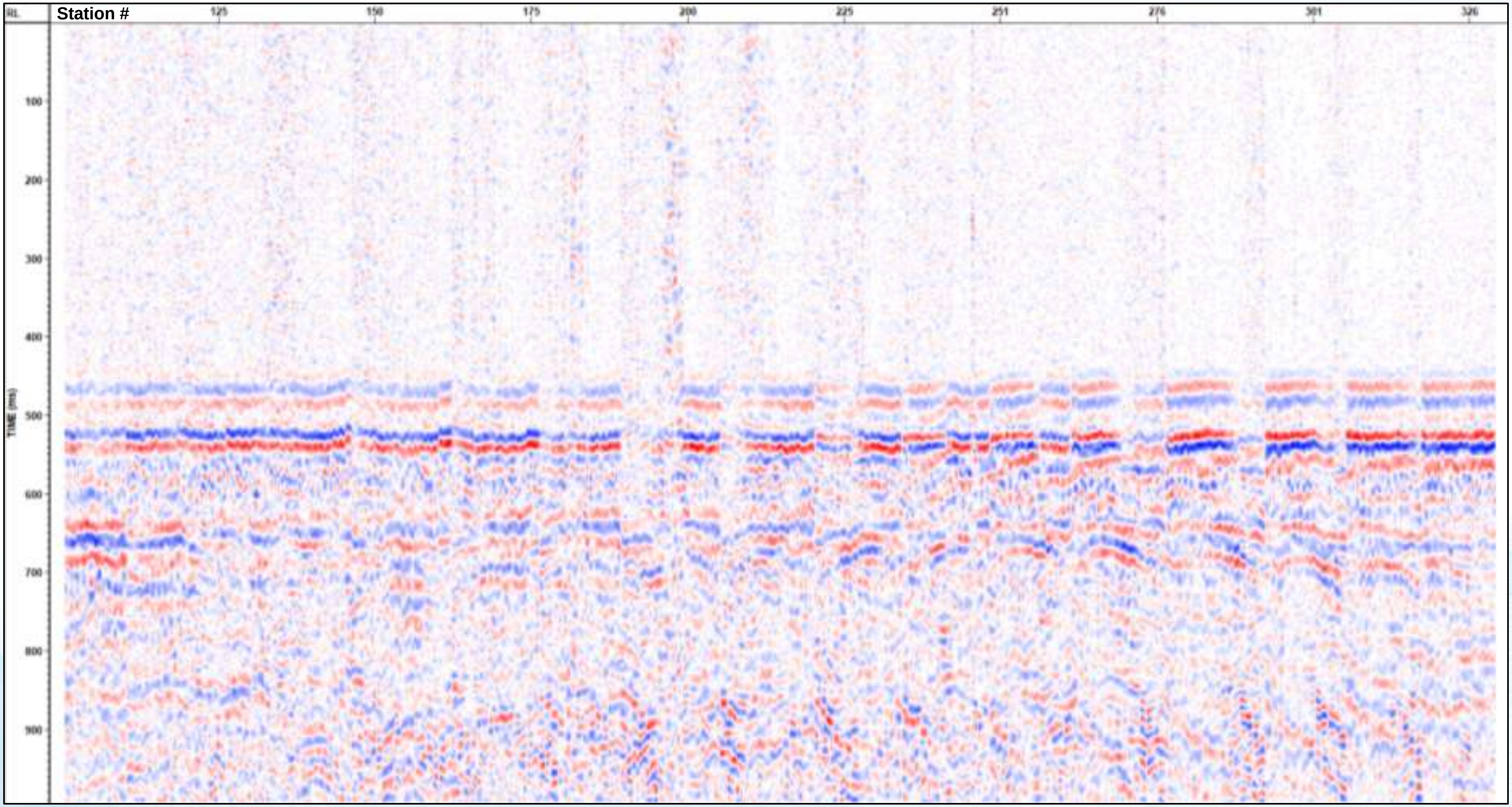
MicroSeismic

2023h Stage 12 Event – Processed Seismic

6/28/2020 08:07:41.712

No Mechanism Correction

Velocity Corrected Event at 500 ms

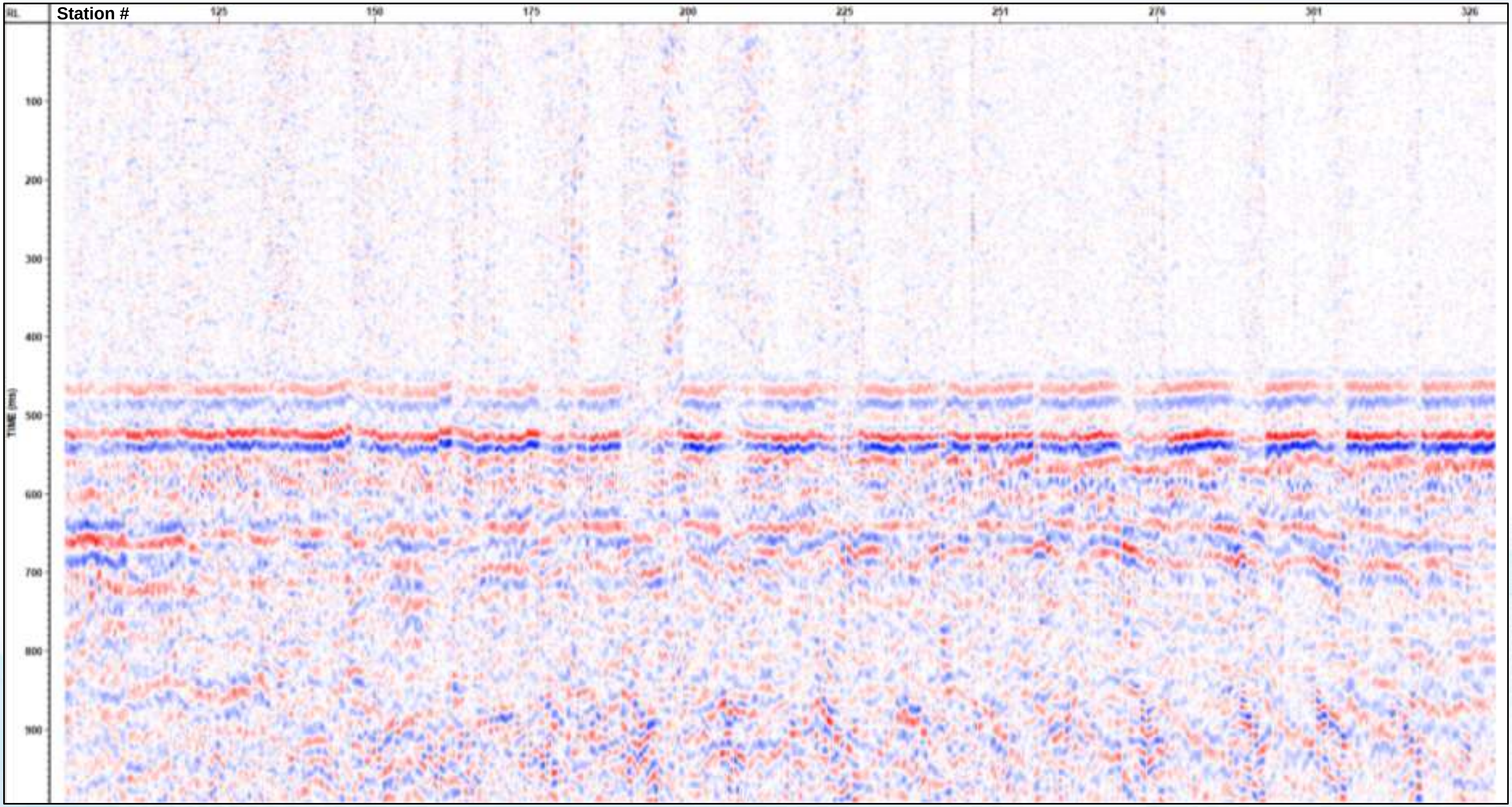


2023h Stage 12 Event – Processed Seismic

6/28/2020 08:07:41.712

Mechanism Corrected

Velocity Corrected Event at 500 ms



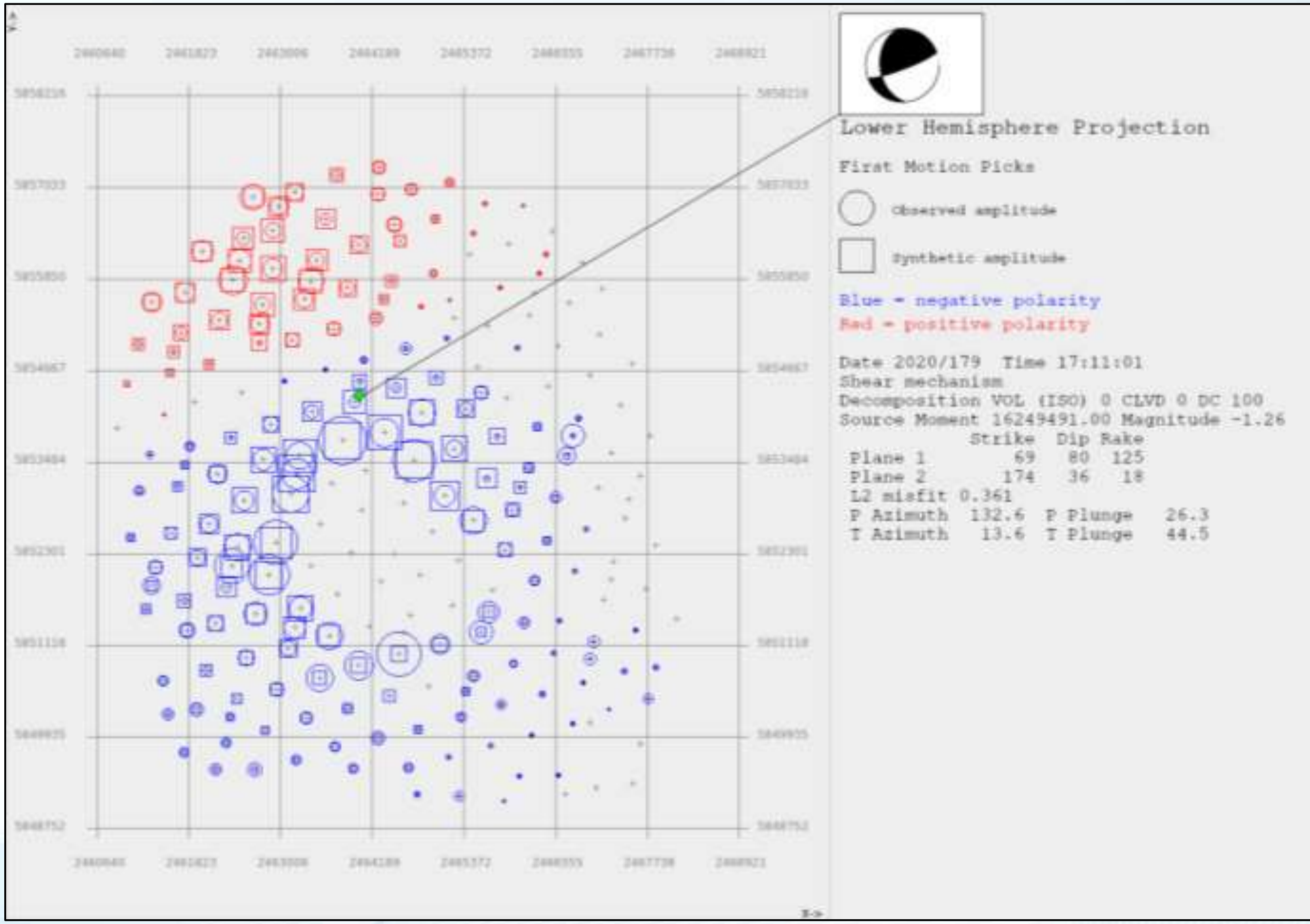
Source Mechanism – 2023h Stage 11 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
69	80	125

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -1.26



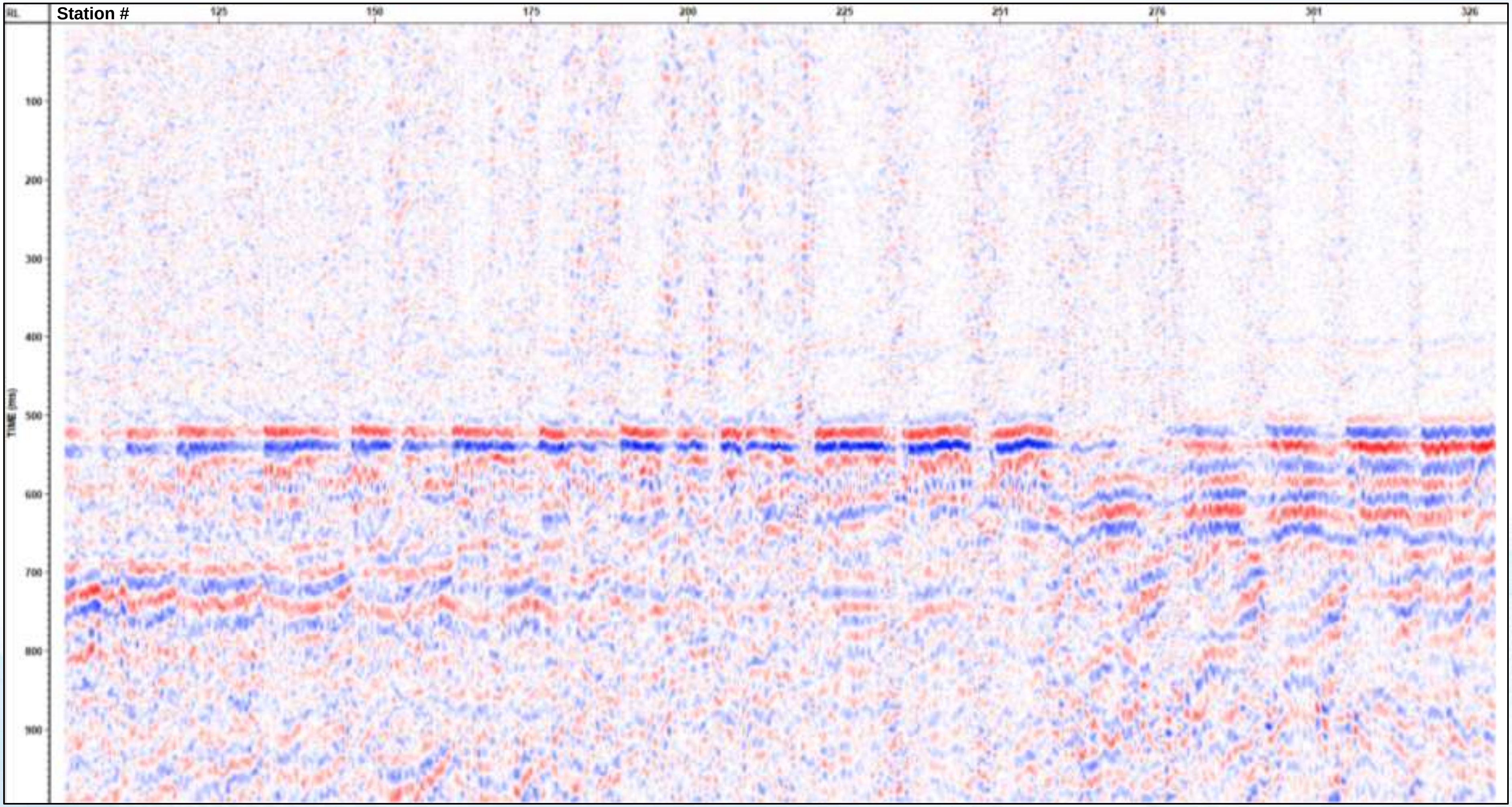
MicroSeismic

2023h Stage 11 Event – Processed Seismic

6/27/2020 17:11:00.356

No Mechanism Correction

Velocity Corrected Event at 500 ms



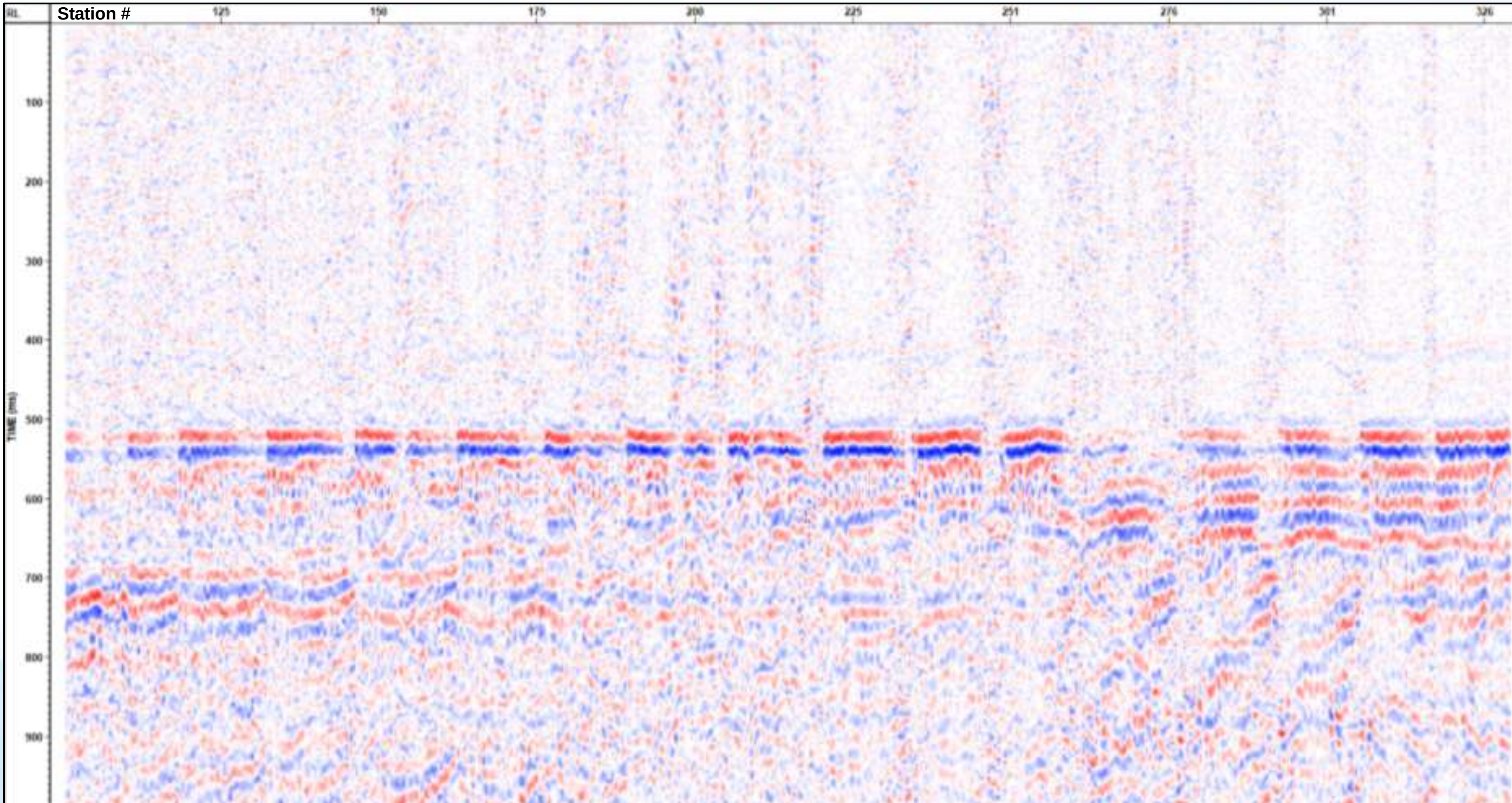
MicroSeismic

2023h Stage 11 Event – Processed Seismic

6/27/2020 17:11:00.356

Mechanism Corrected

Velocity Corrected Event at 500 ms



MicroSeismic

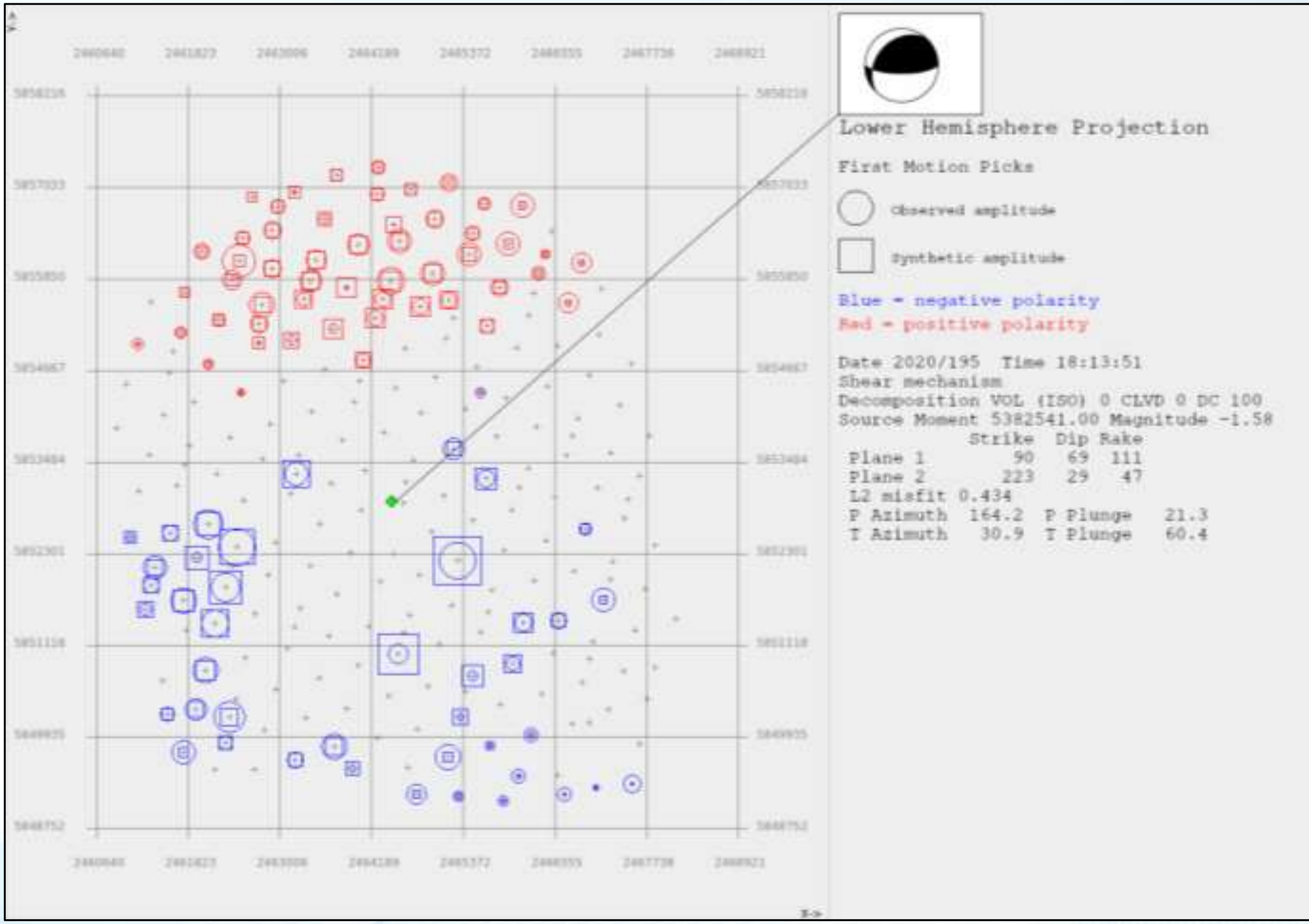
Source Mechanism – 2023h Stage 30 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
90	69	111

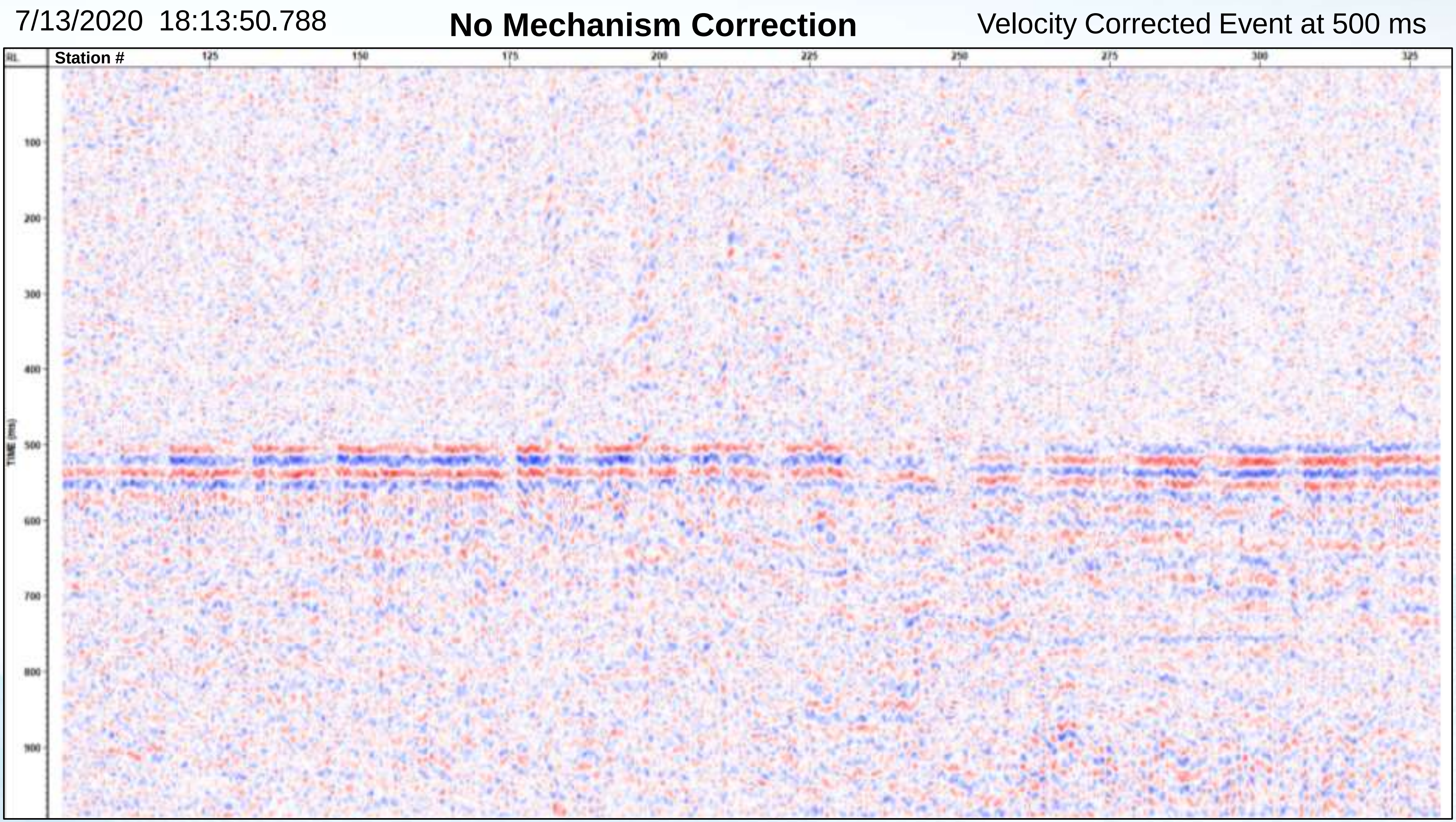
- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -1.58



MicroSeismic

2023h Stage 30 Event – Processed Seismic

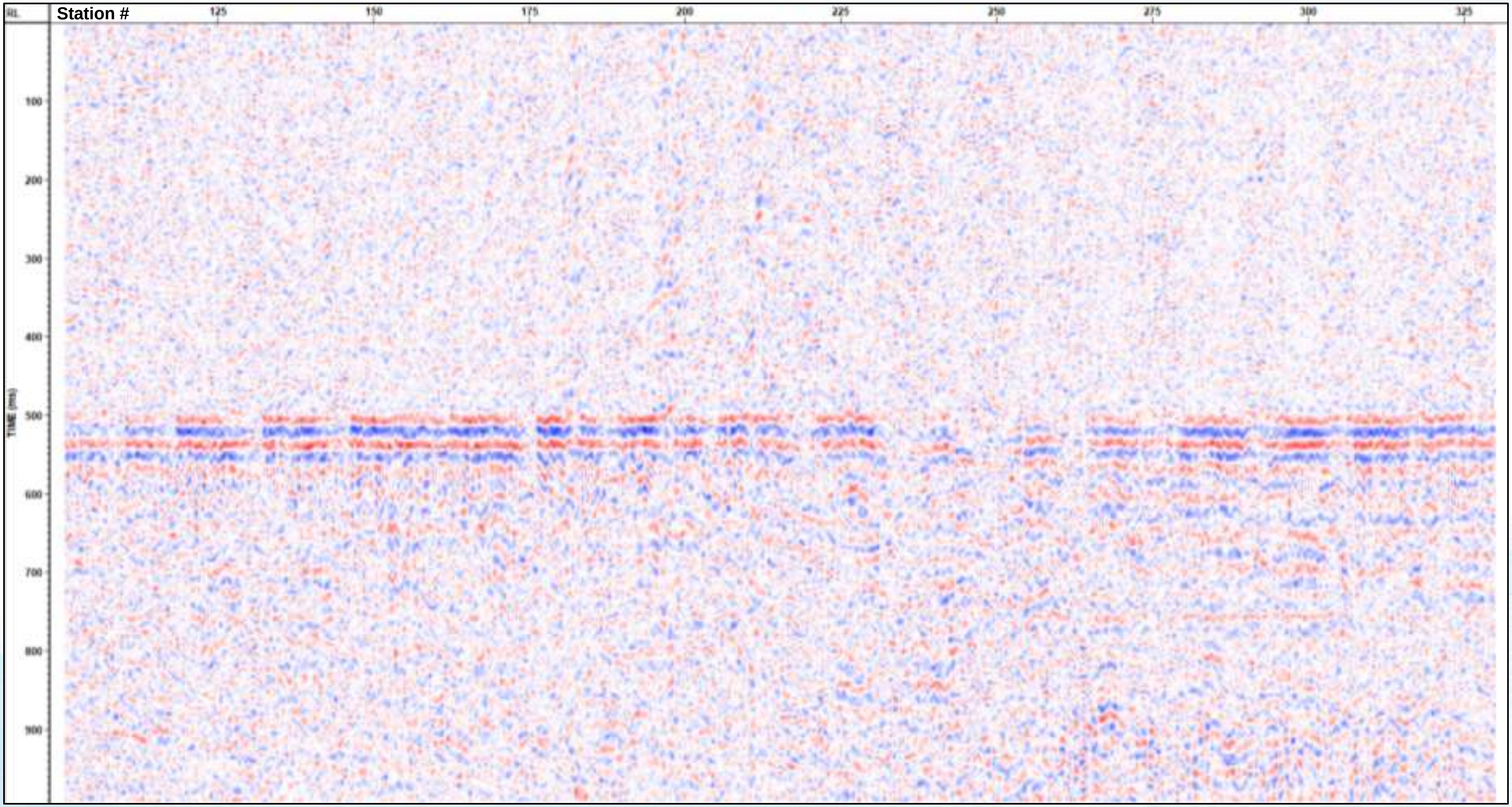


2023h Stage 30 Event – Processed Seismic

7/13/2020 18:13:50.788

Mechanism Corrected

Velocity Corrected Event at 500 ms



MicroSeismic

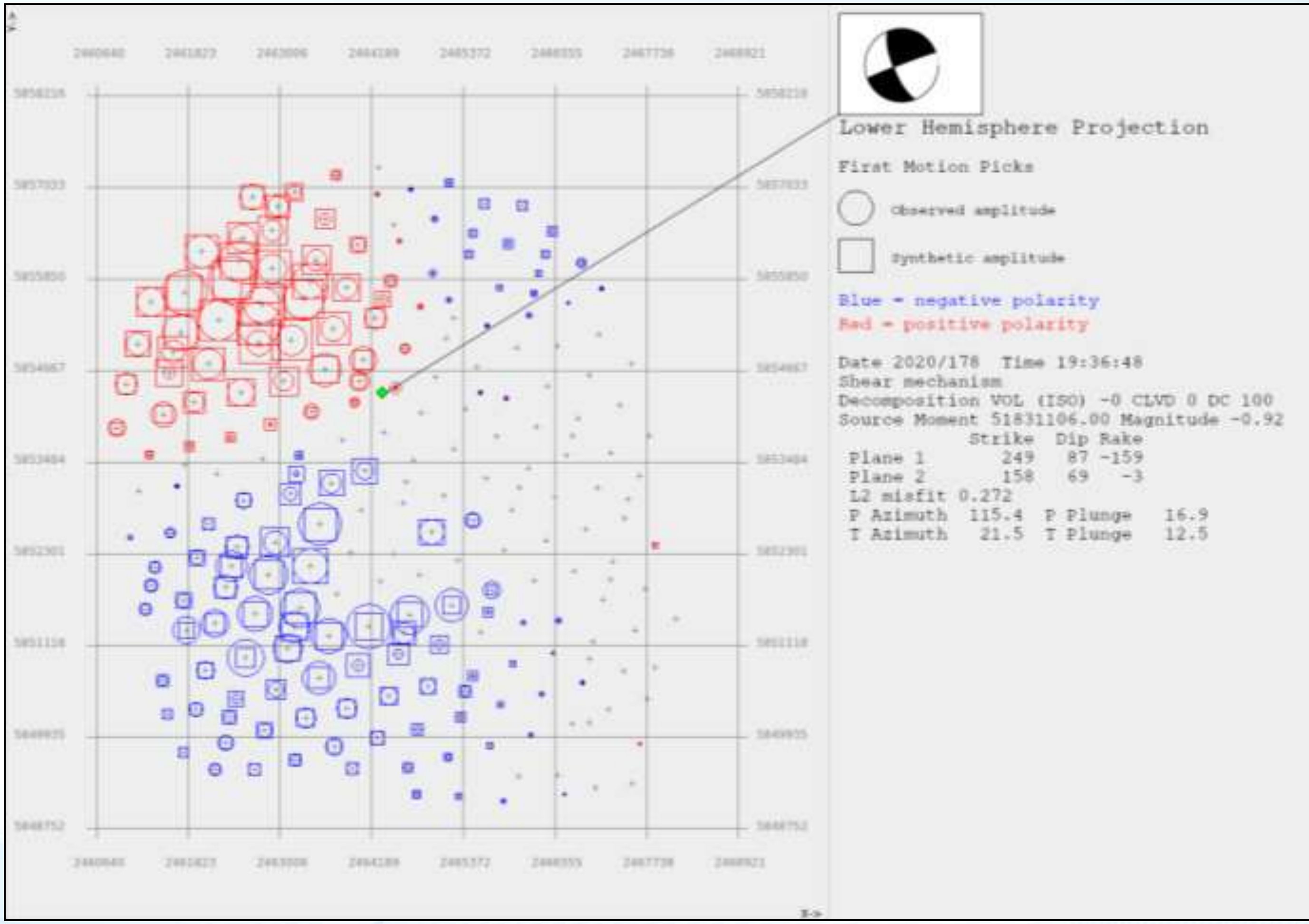
Source Mechanism – 2023h Stage 9 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
249	87	-159

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.92

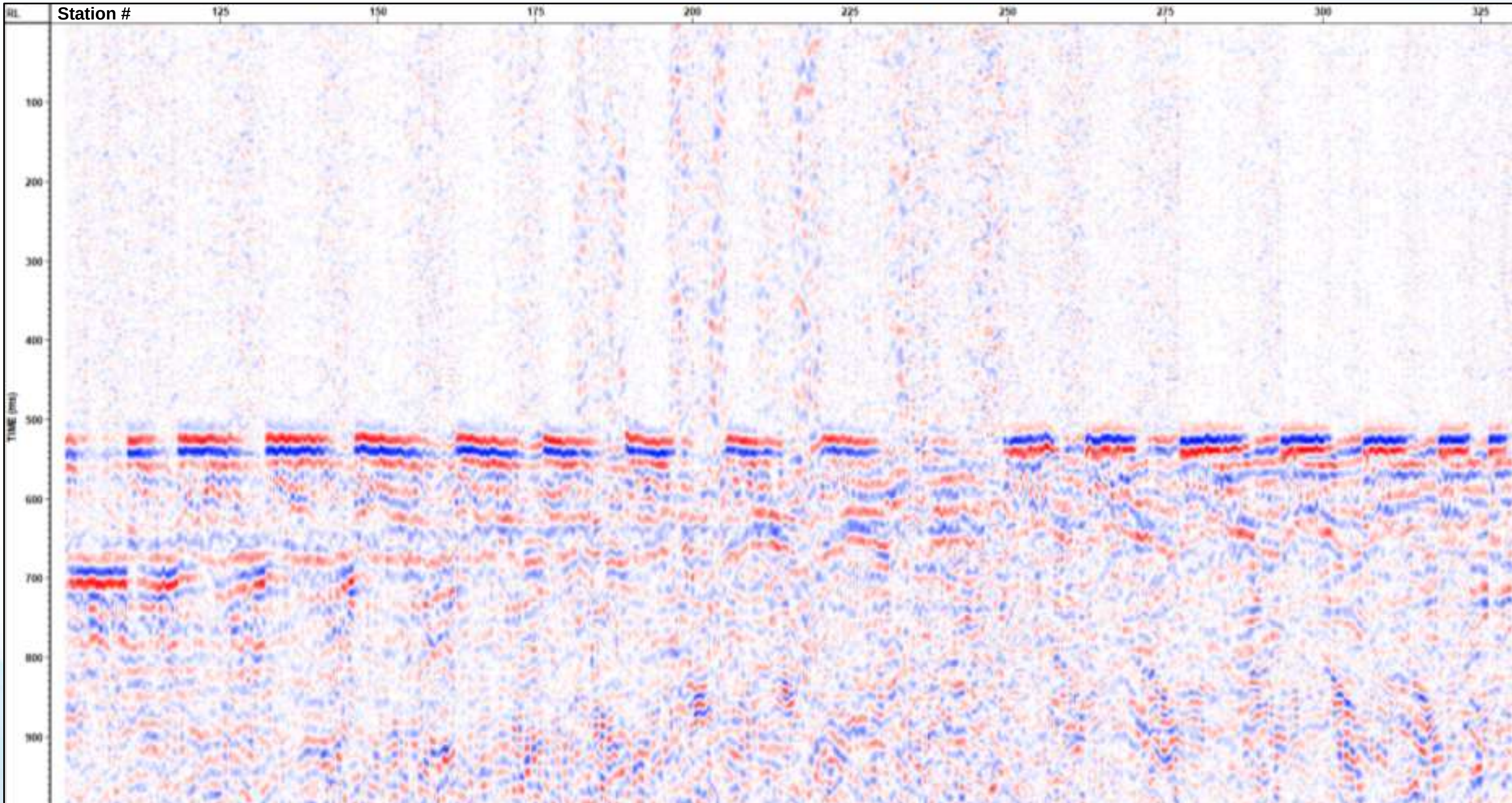


2023h Stage 9 Event – Processed Seismic

6/26/2020 19:36:47.832

No Mechanism Correction

Velocity Corrected Event at 500 ms



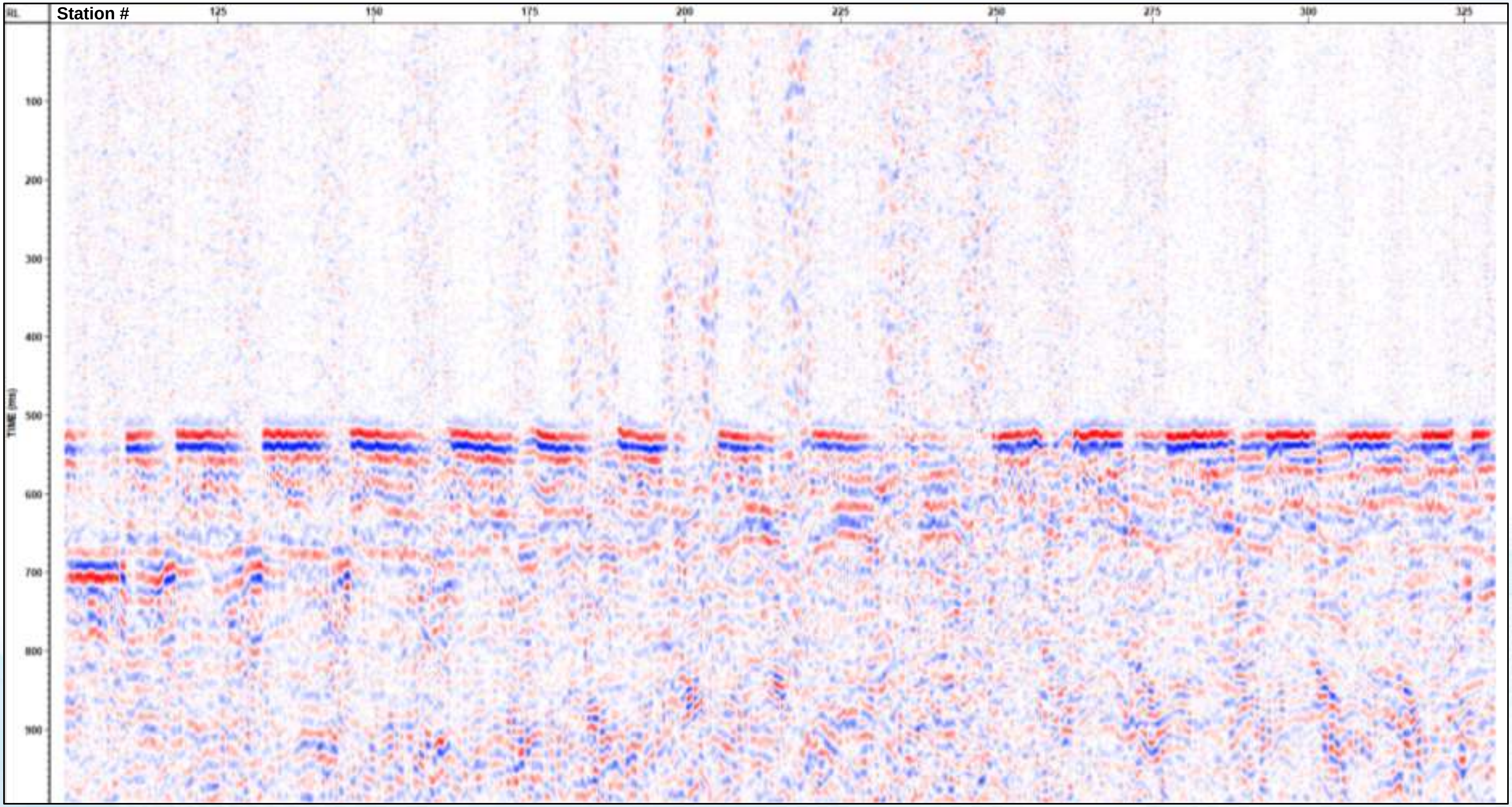
MicroSeismic

2023h Stage 9 Event – Processed Seismic

6/26/2020 19:36:47.832

Mechanism Corrected

Velocity Corrected Event at 500 ms



MicroSeismic

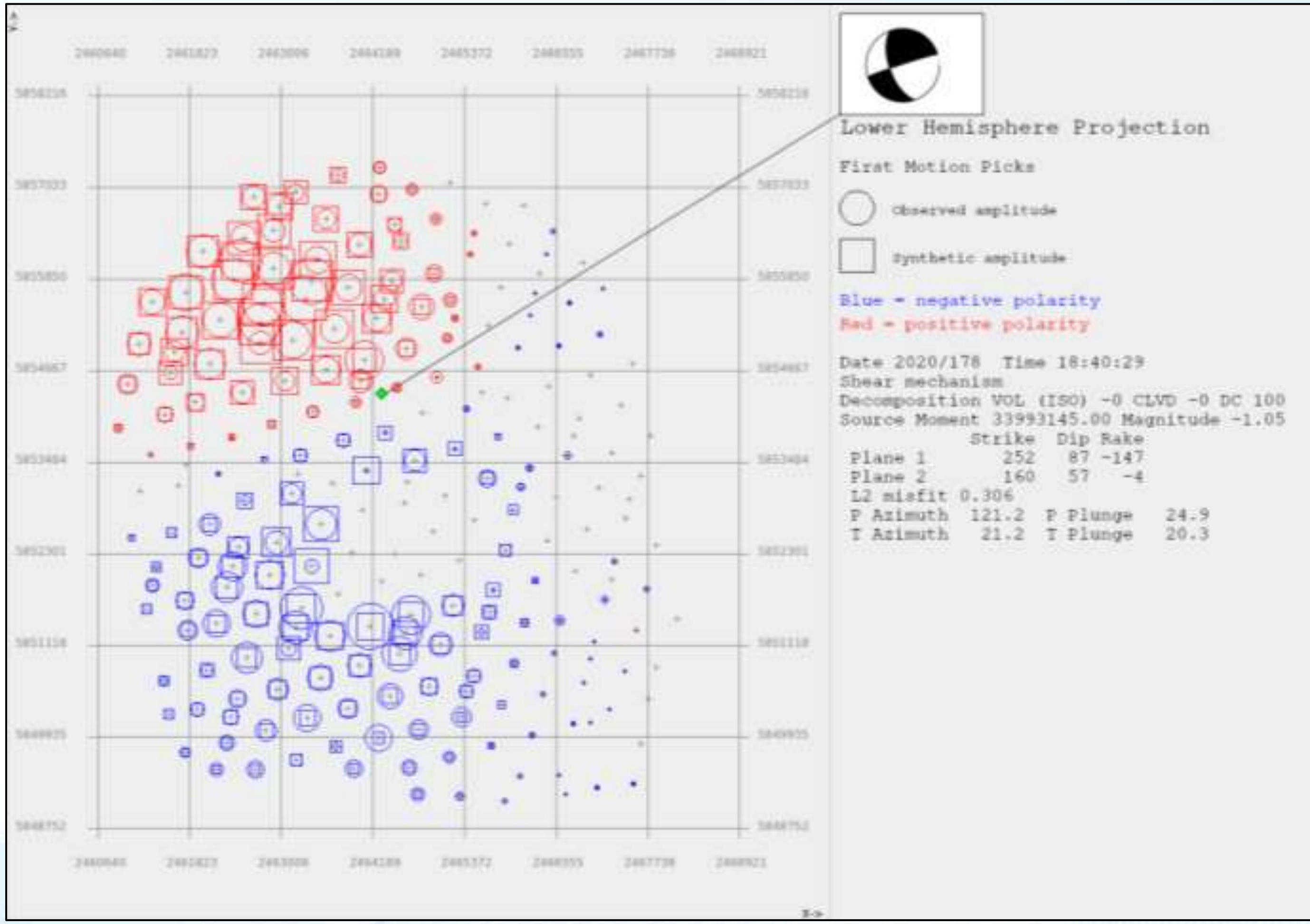
Source Mechanism – 2023h Stage 9 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
252	87	-147

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -1.05



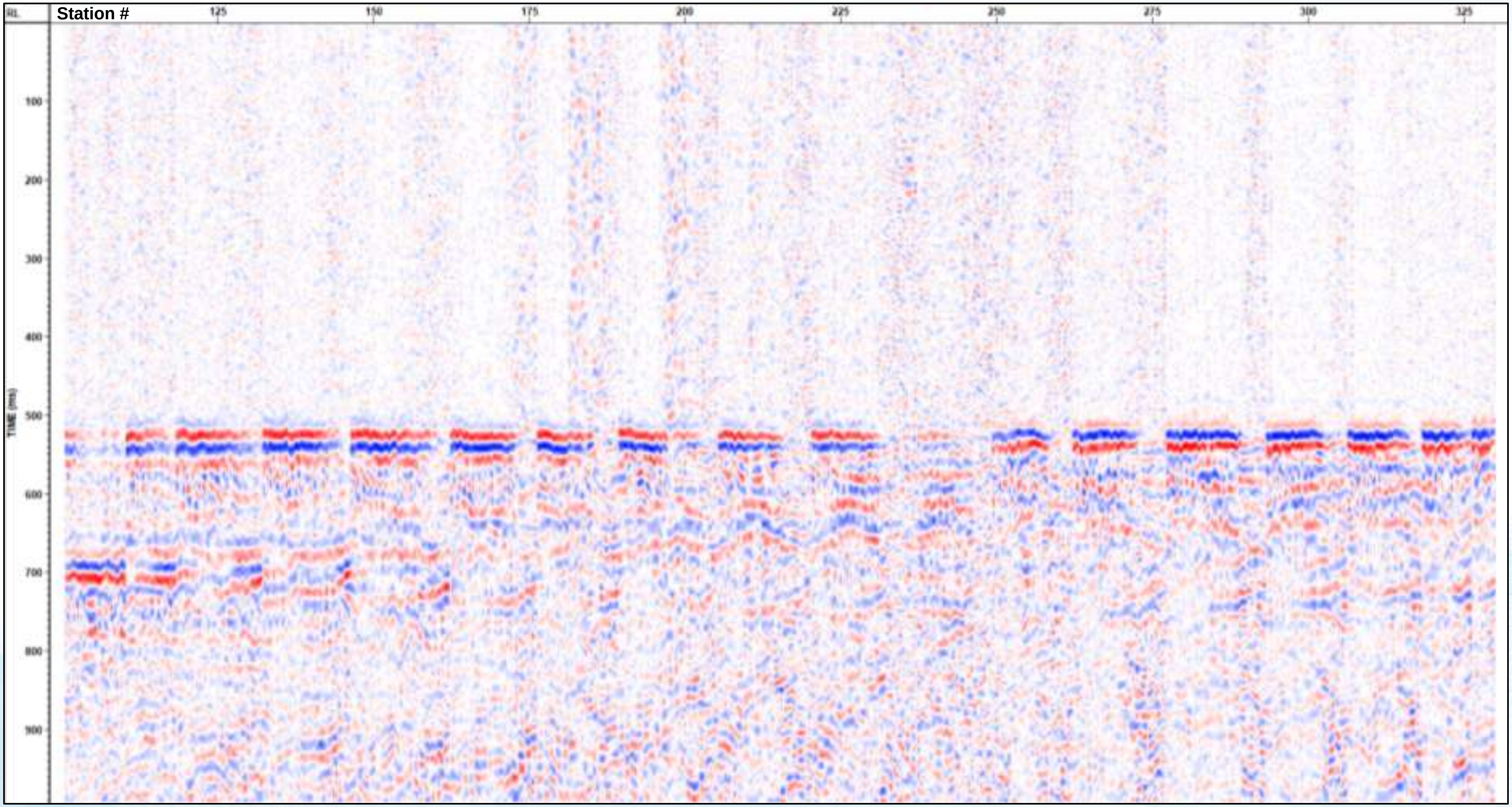
MicroSeismic

2023h Stage 9 Event – Processed Seismic

6/26/2020 18:40:28.312

No Mechanism Correction

Velocity Corrected Event at 500 ms



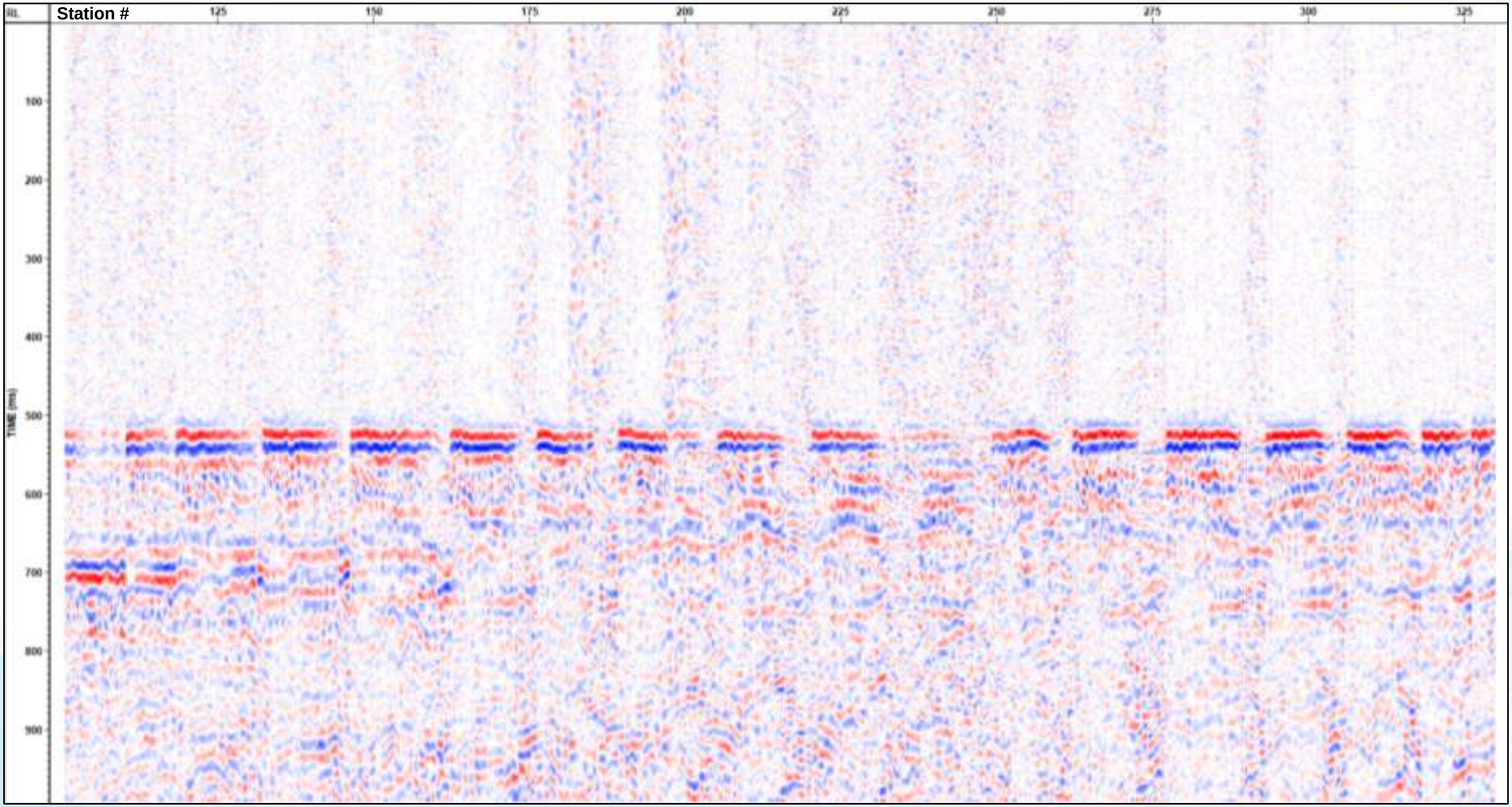
MicroSeismic

2023h Stage 9 Event – Processed Seismic

6/26/2020 18:40:28.312

Mechanism Corrected

Velocity Corrected Event at 500 ms



MicroSeismic

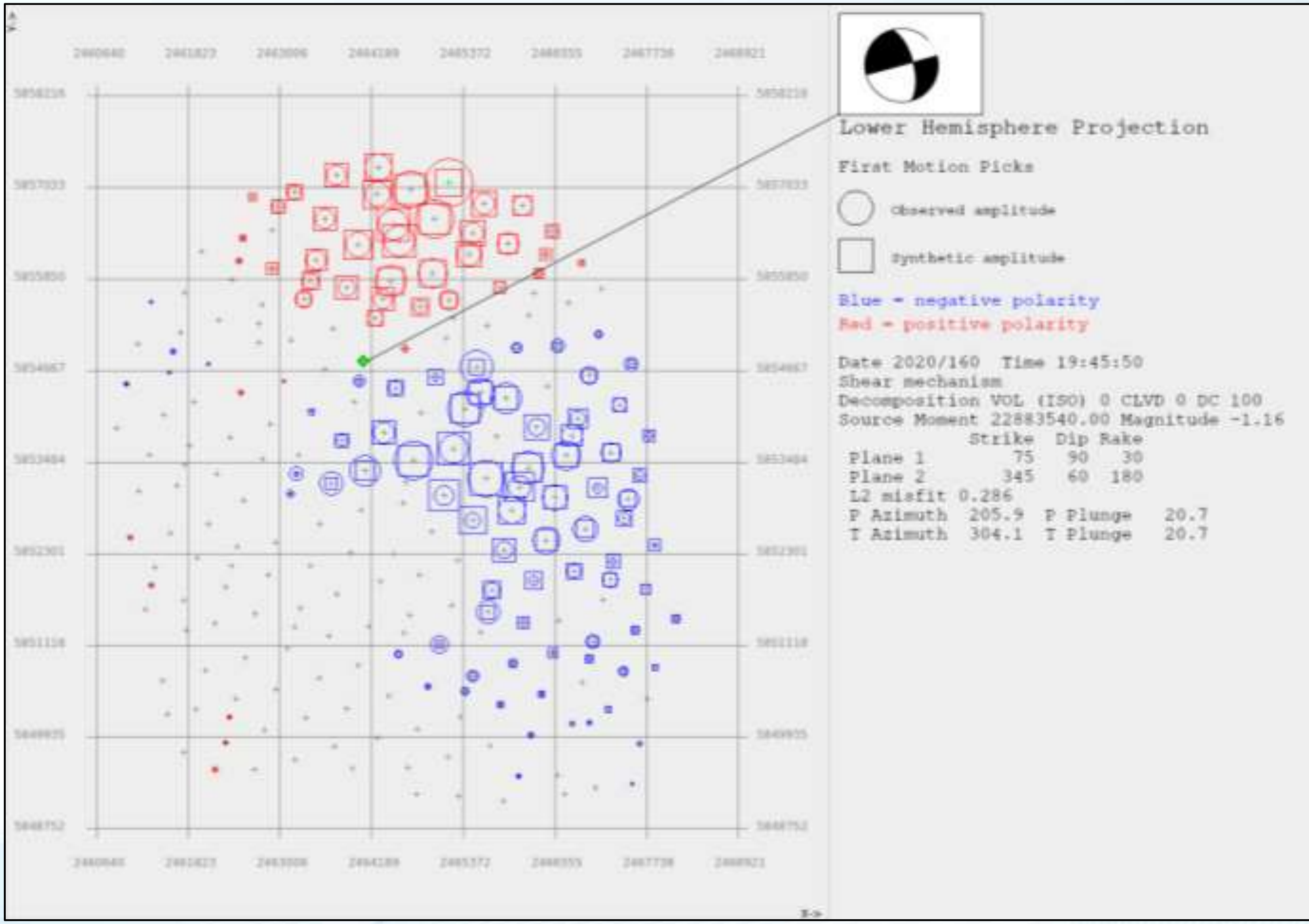
Source Mechanism – 2023h Stage 1 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
75	90	30

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -1.16

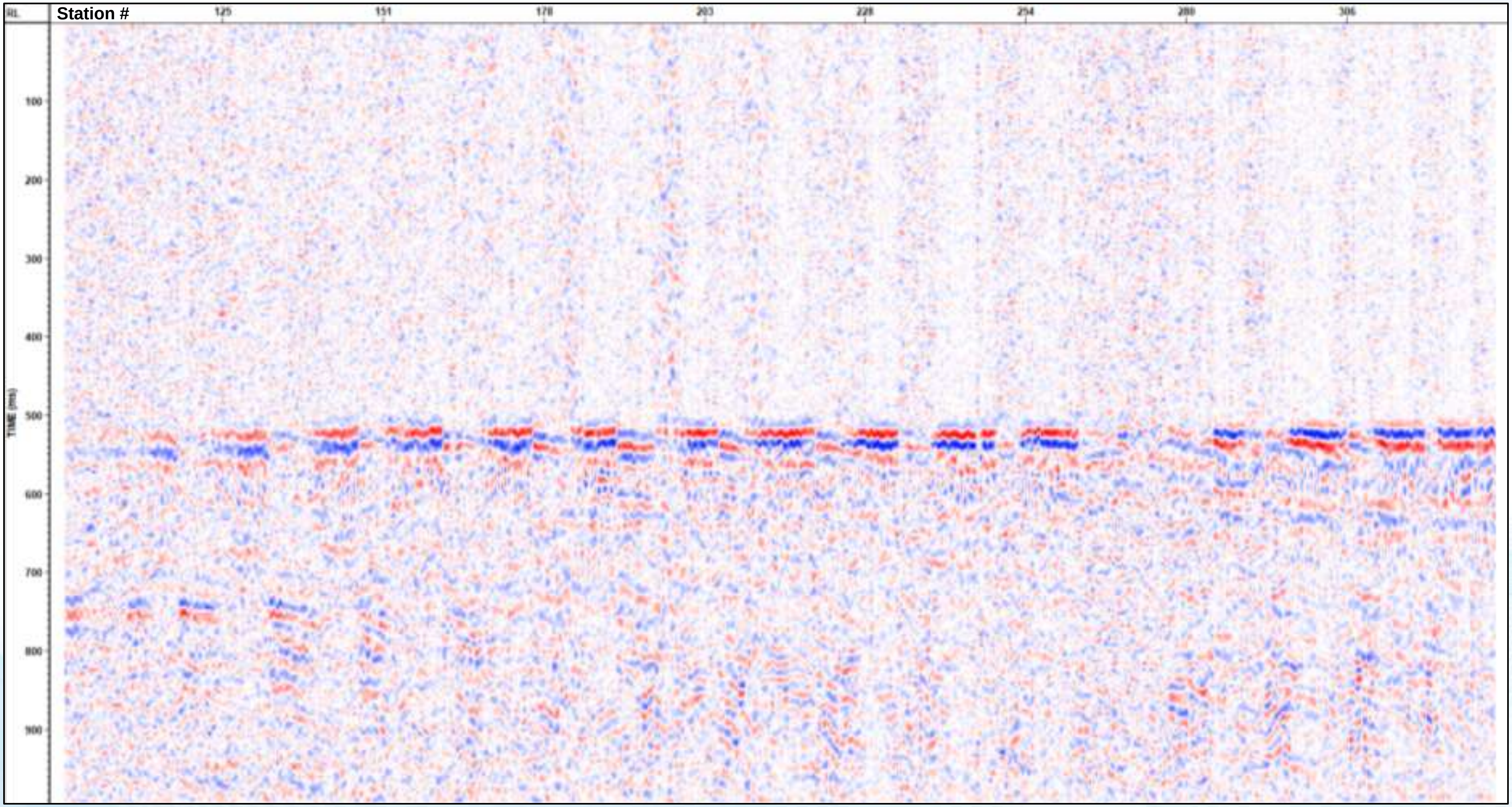


2023h Stage 1 Event – Processed Seismic

6/08/2020 19:45:49.252

No Mechanism Correction

Velocity Corrected Event at 500 ms



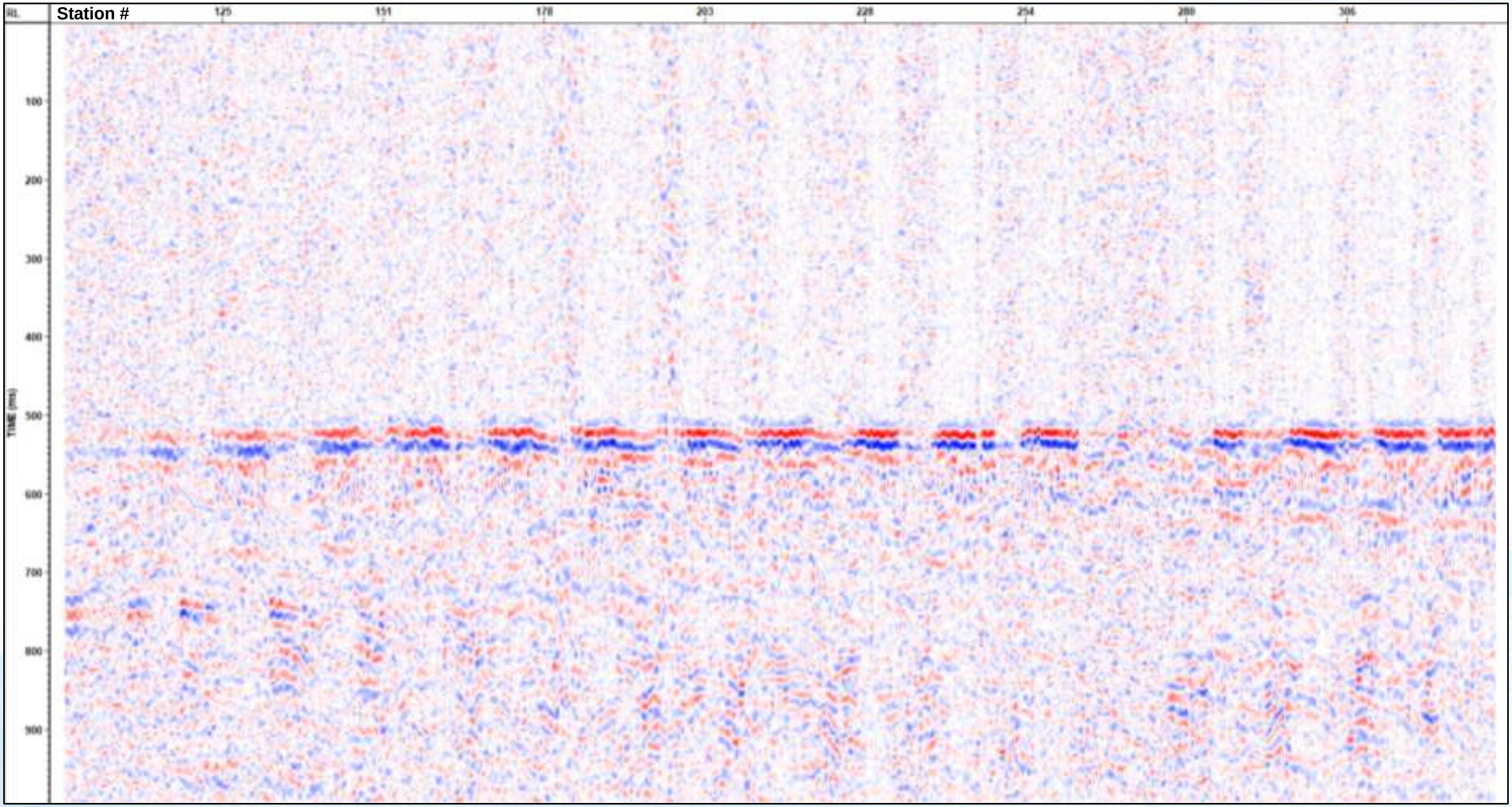
MicroSeismic

2023h Stage 1 Event – Processed Seismic

6/08/2020 19:45:49.252

Mechanism Corrected

Velocity Corrected Event at 500 ms



MicroSeismic

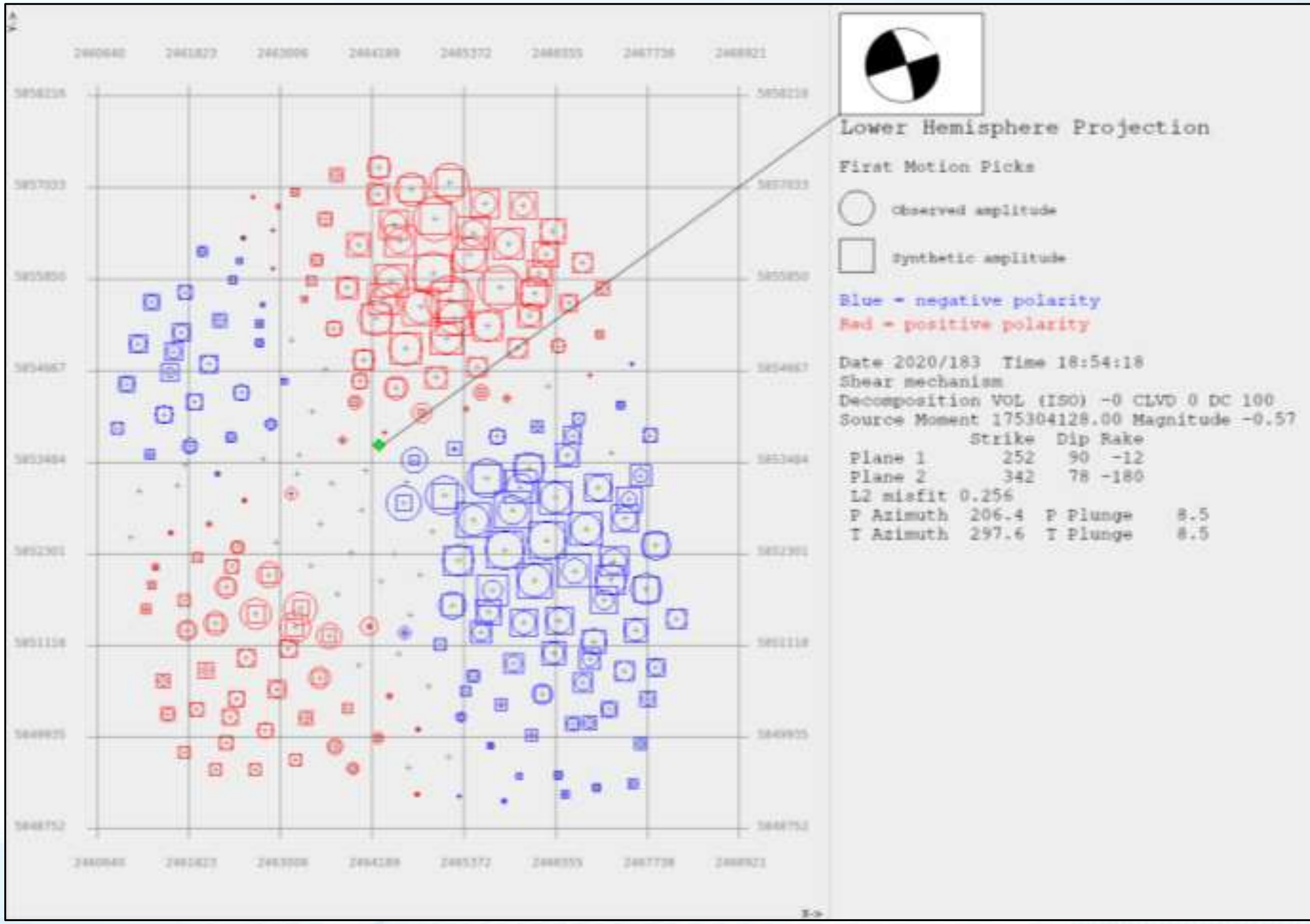
Source Mechanism – 2023h Stage 18 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
252	90	-12

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

  Mw: -0.57



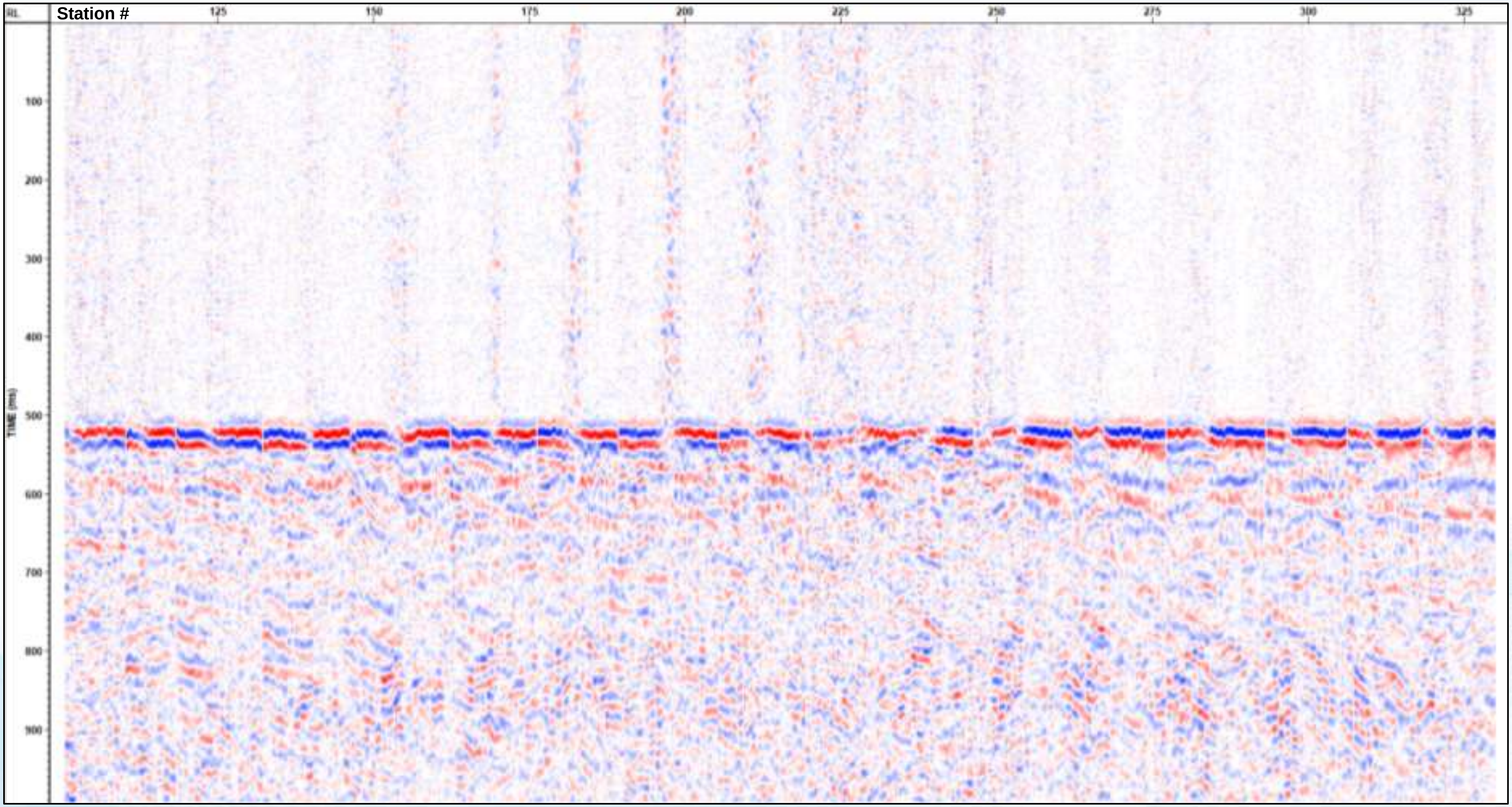
MicroSeismic

2023h Stage 18 Event – Processed Seismic

7/01/2020 18:54:18.028

No Mechanism Correction

Velocity Corrected Event at 500 ms



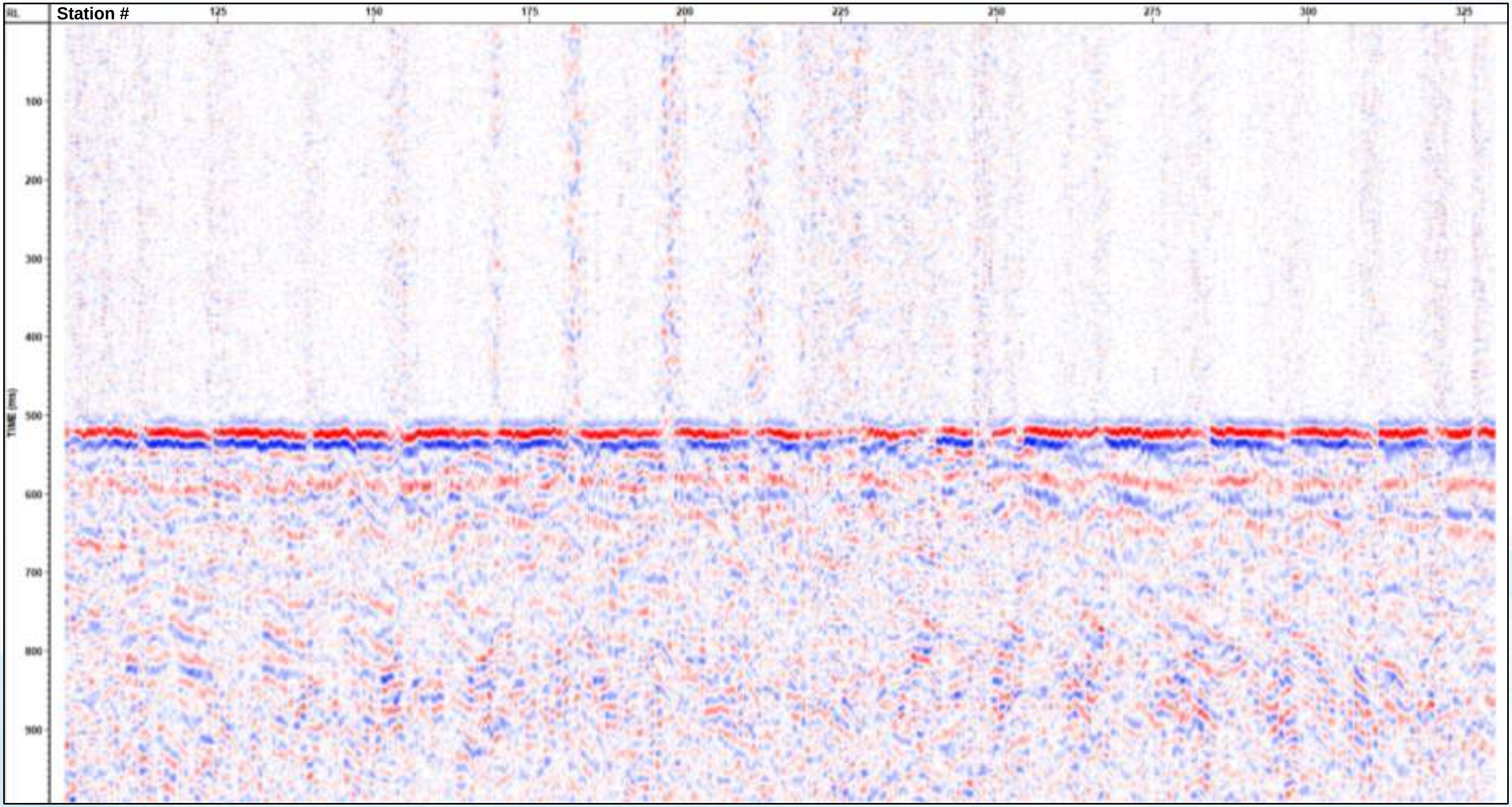
MicroSeismic

2023h Stage 18 Event – Processed Seismic

7/01/2020 18:54:18.028

Mechanism Corrected

Velocity Corrected Event at 500 ms



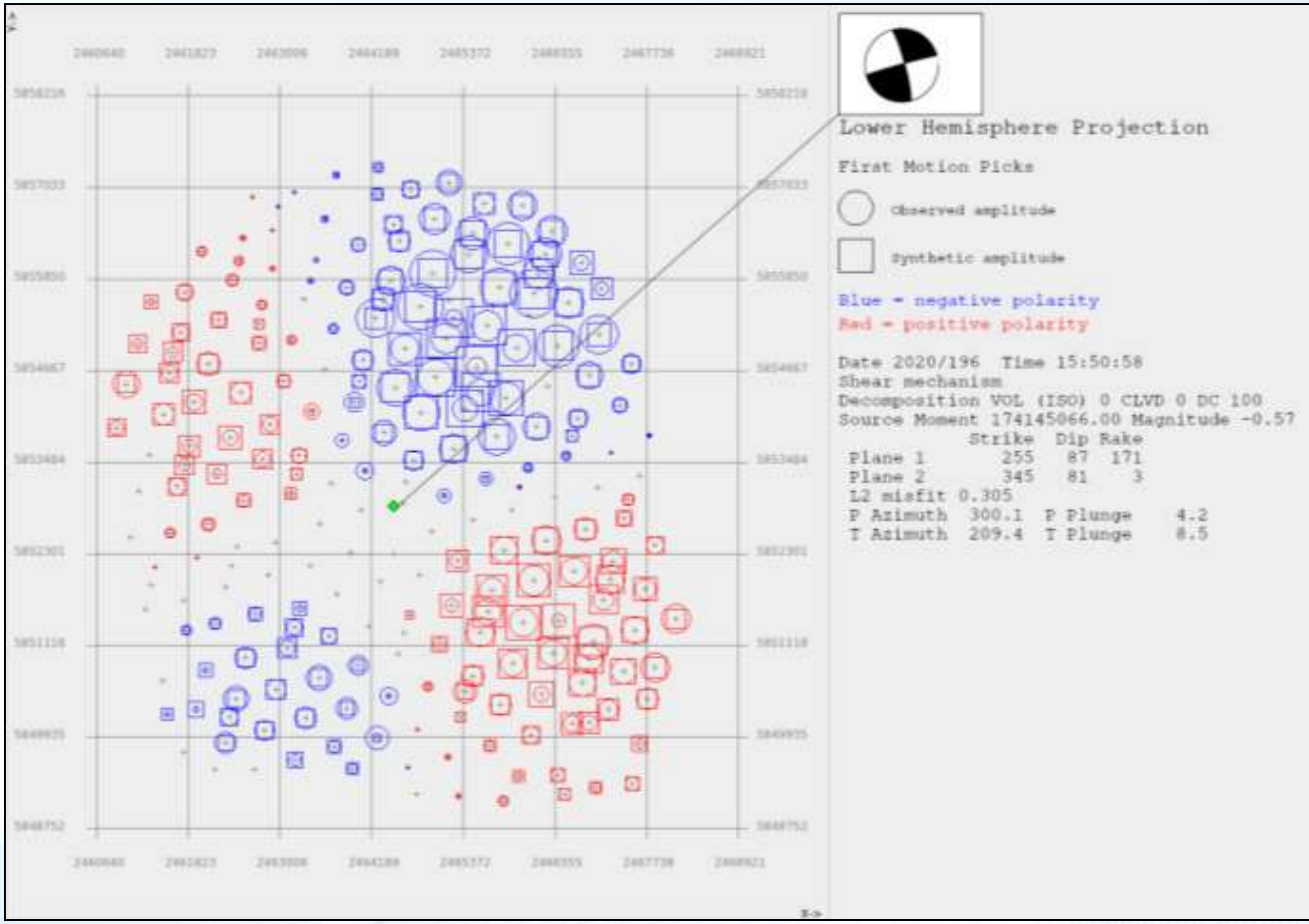
Source Mechanism – 2021h Stage 31 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
255	87	171

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.57

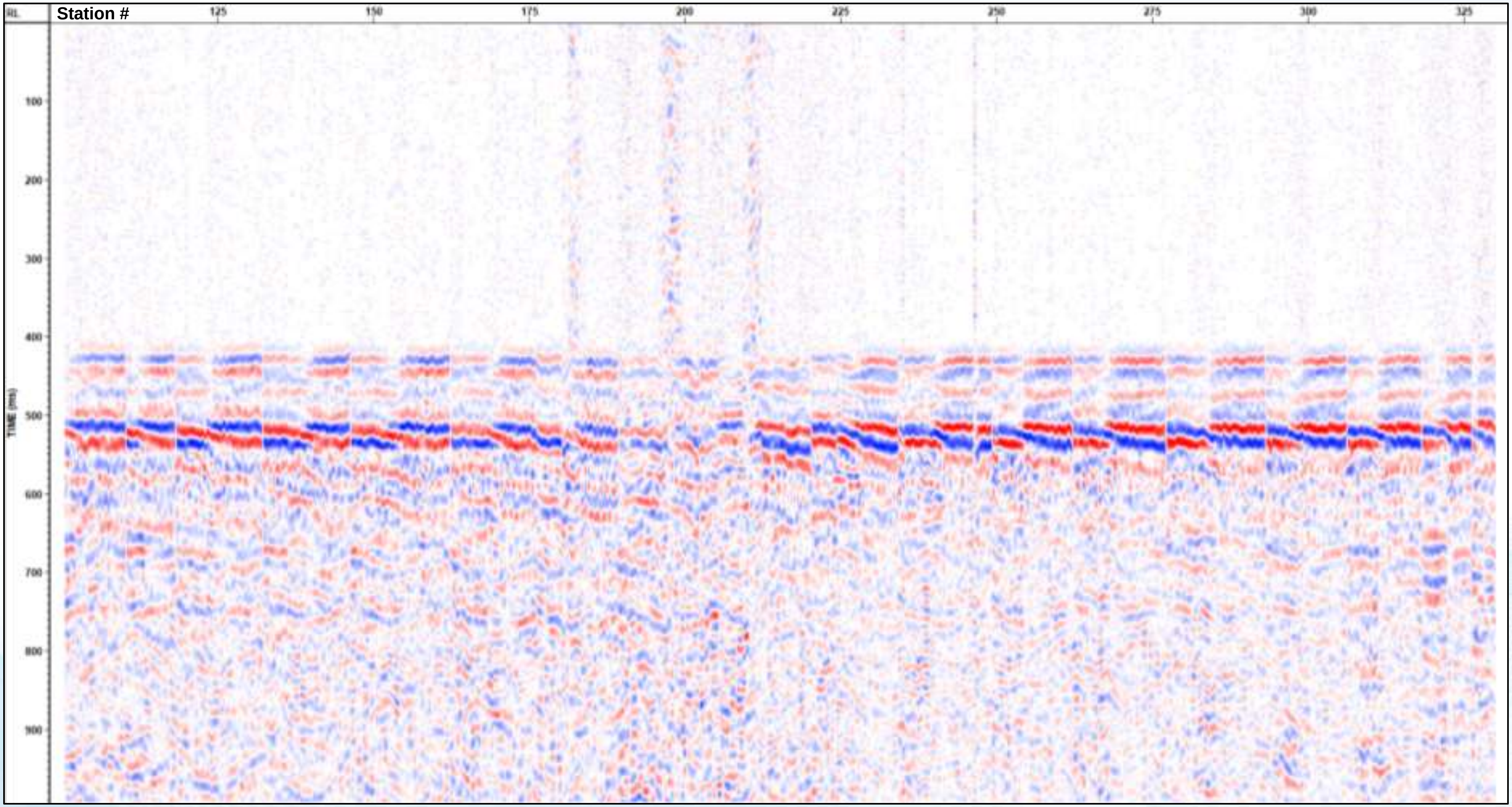


2021h Stage 31 Event – Processed Seismic

7/14/2020 15:50:57.404

No Mechanism Correction

Velocity Corrected Event at 500 ms



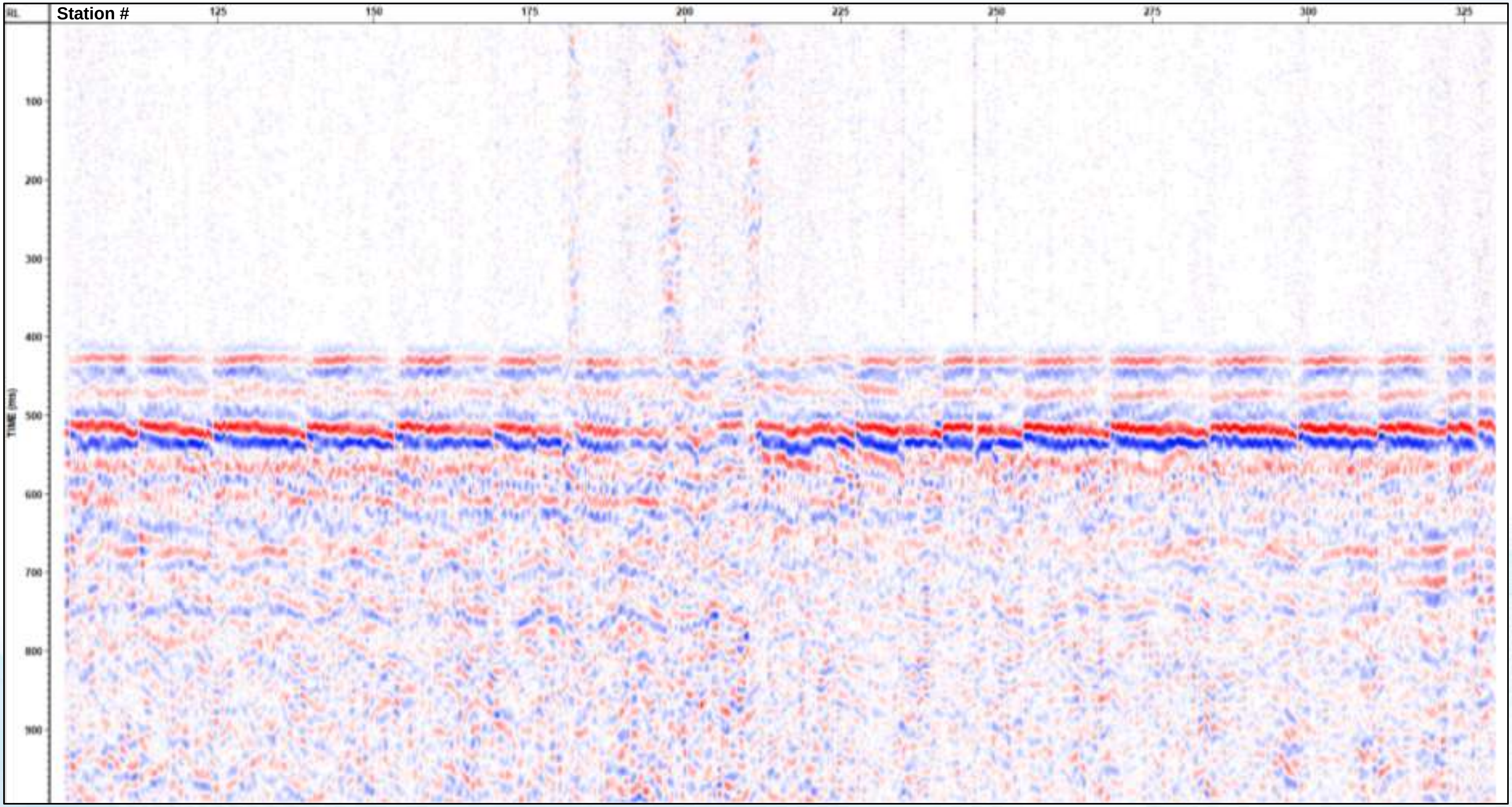
MicroSeismic

2021h Stage 31 Event – Processed Seismic

7/14/2020 15:50:57.404

Mechanism Corrected

Velocity Corrected Event at 500 ms



MicroSeismic

Source Mechanism – 2023h Stage 9 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
261	87	0

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -1.52

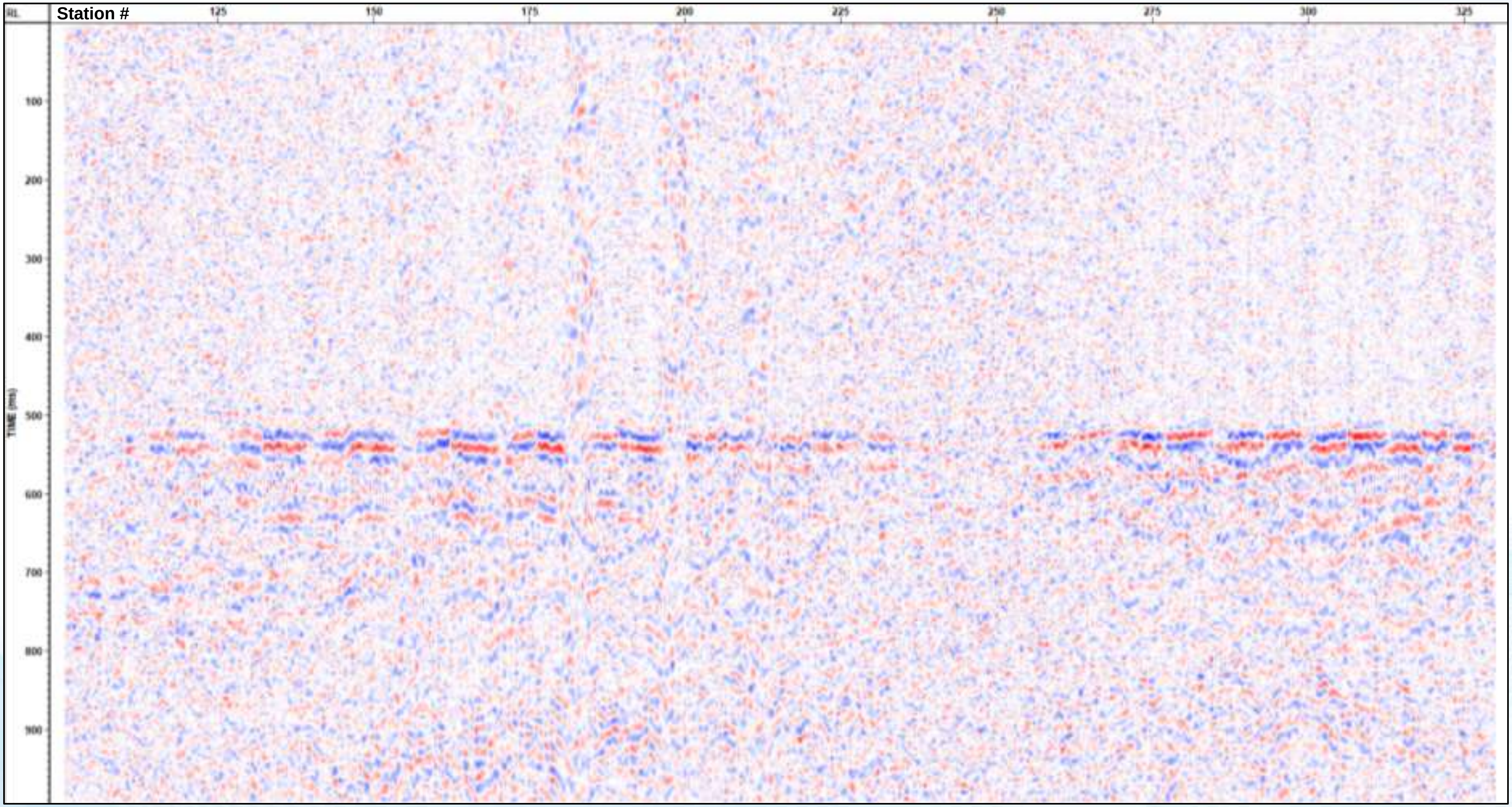
MicroSeismic

2023h Stage 9 Event – Processed Seismic

6/26/2020 20:28:03.152

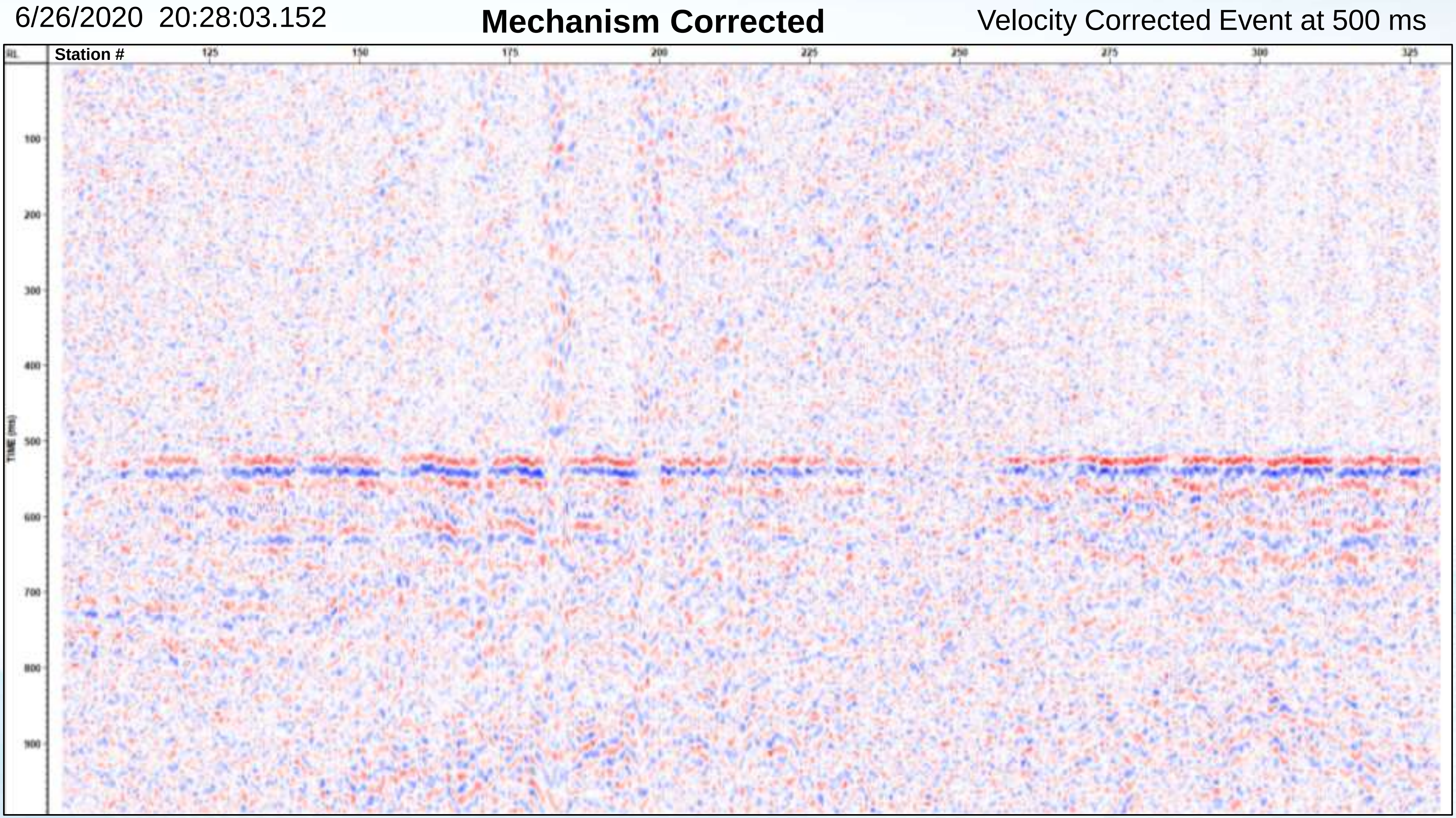
No Mechanism Correction

Velocity Corrected Event at 500 ms



MicroSeismic

2023h Stage 9 Event – Processed Seismic



MicroSeismic

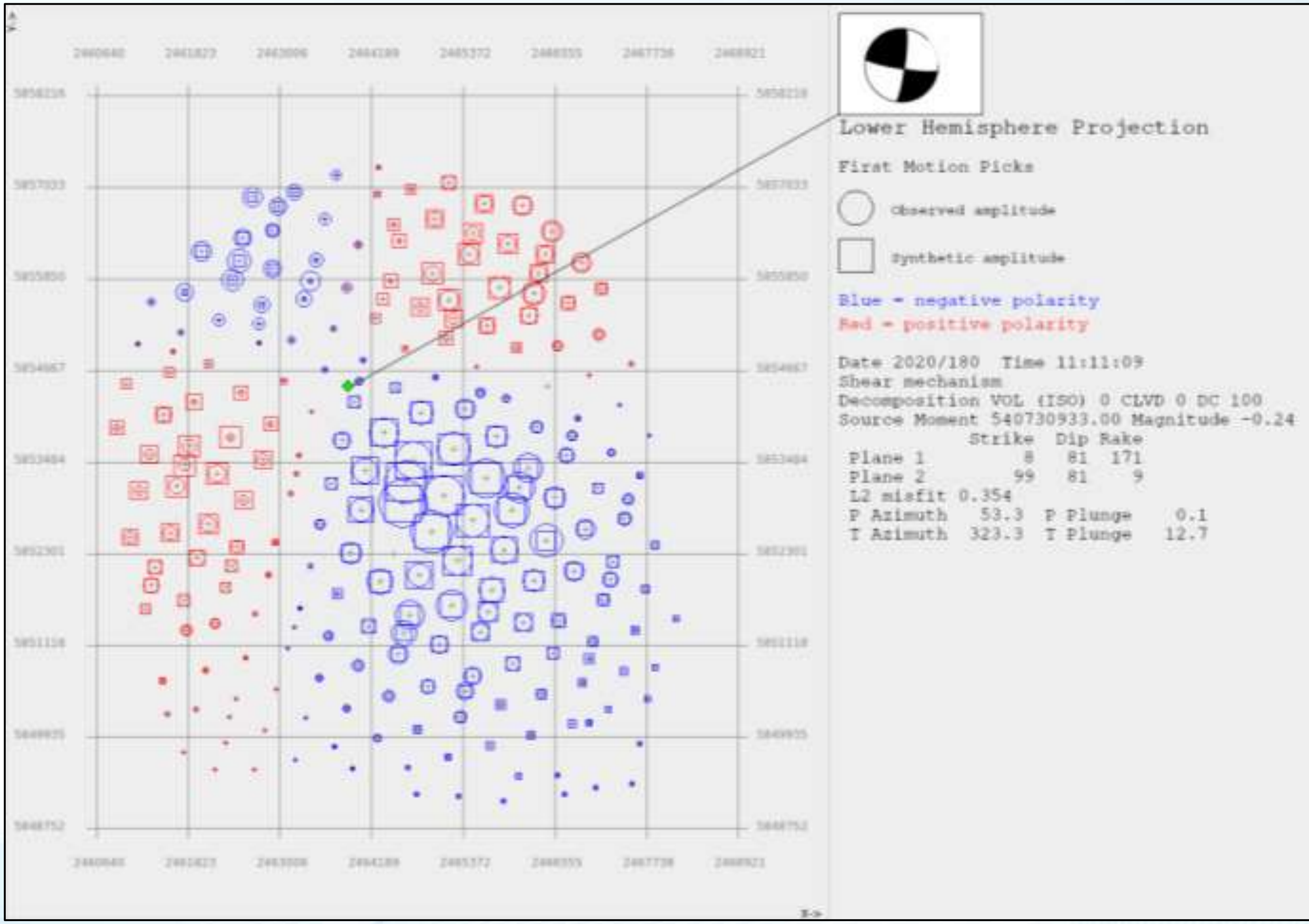
Source Mechanism – 2021h Stage 12 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
8	81	171

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.24

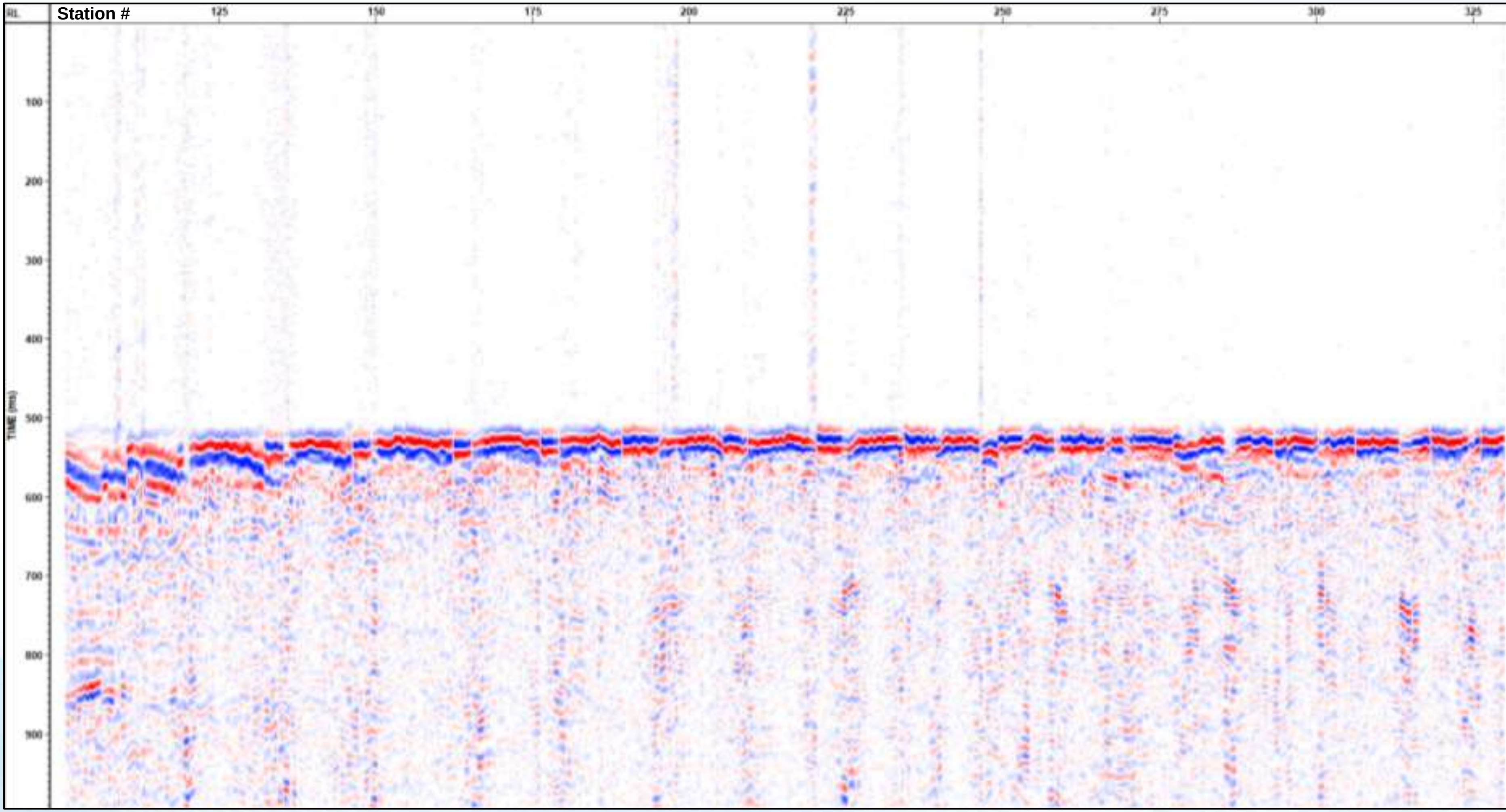


2021h Stage 12 Event – Processed Seismic

6/28/2020 11:11:08.508

No Mechanism Correction

Velocity Corrected Event at 500 ms

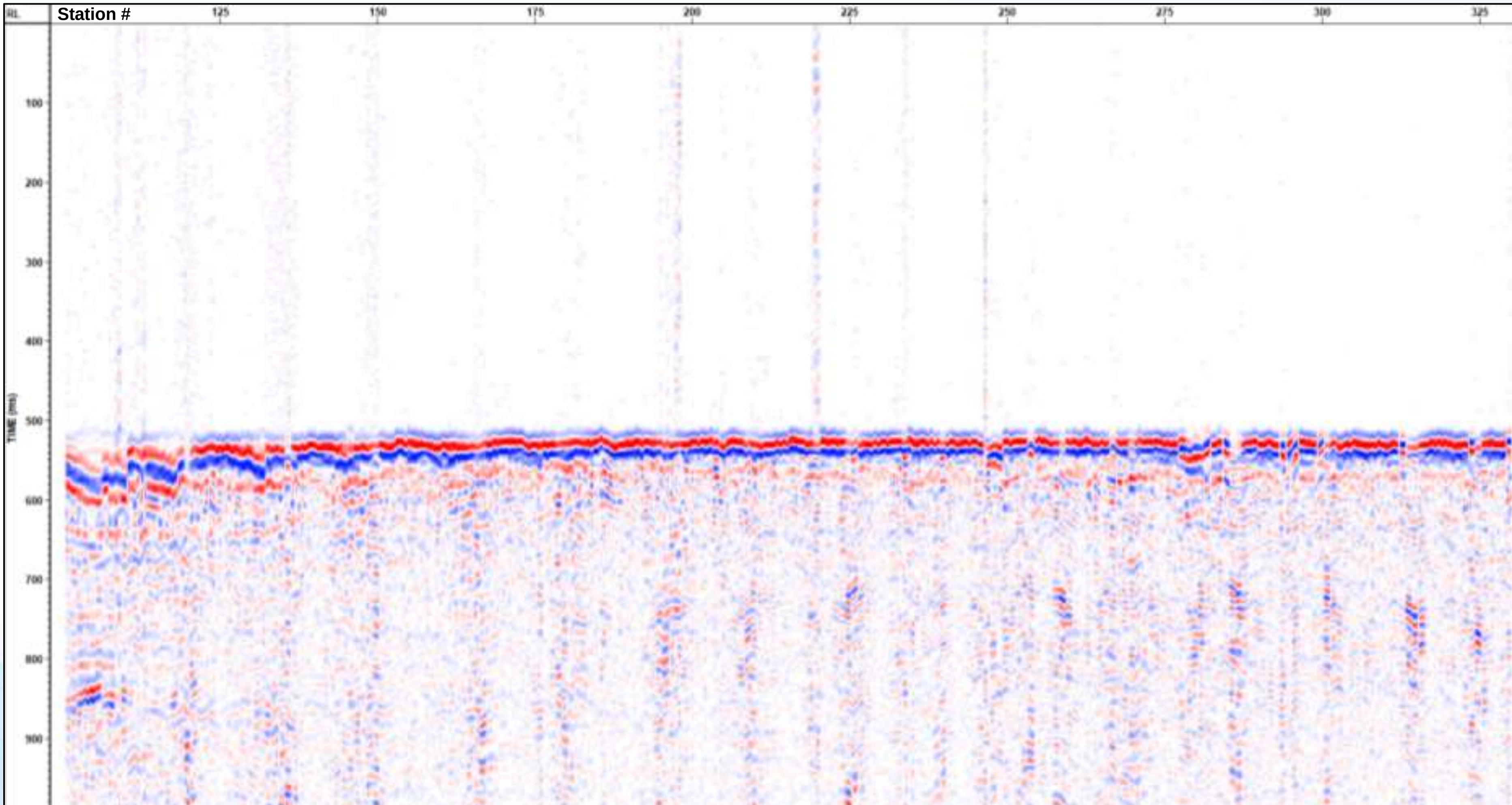


2021h Stage 12 Event – Processed Seismic

6/28/2020 11:11:08.508

Mechanism Corrected

Velocity Corrected Event at 500 ms



MicroSeismic

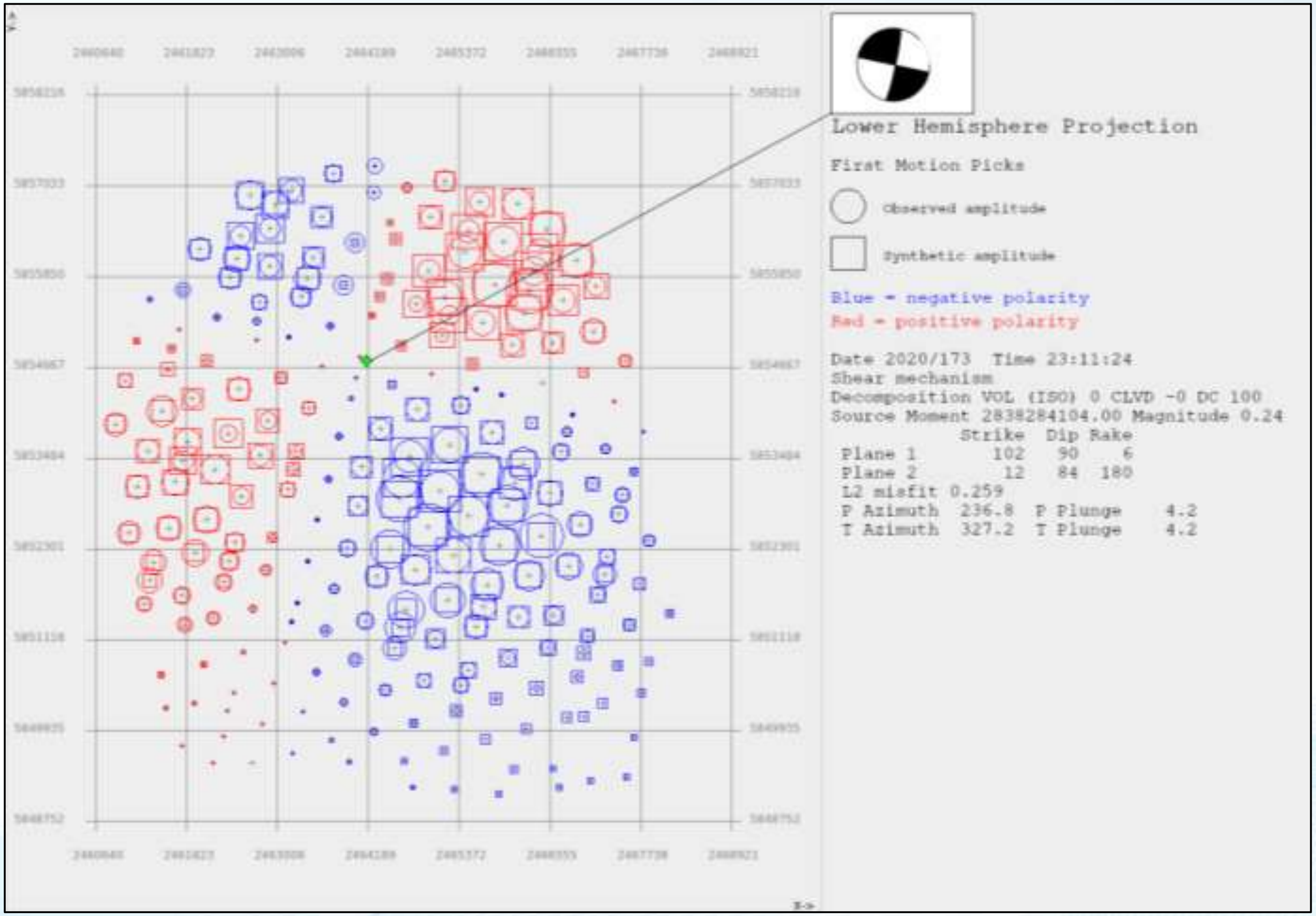
Source Mechanism – 2021h Stage 8 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
12	84	180

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: 0.24

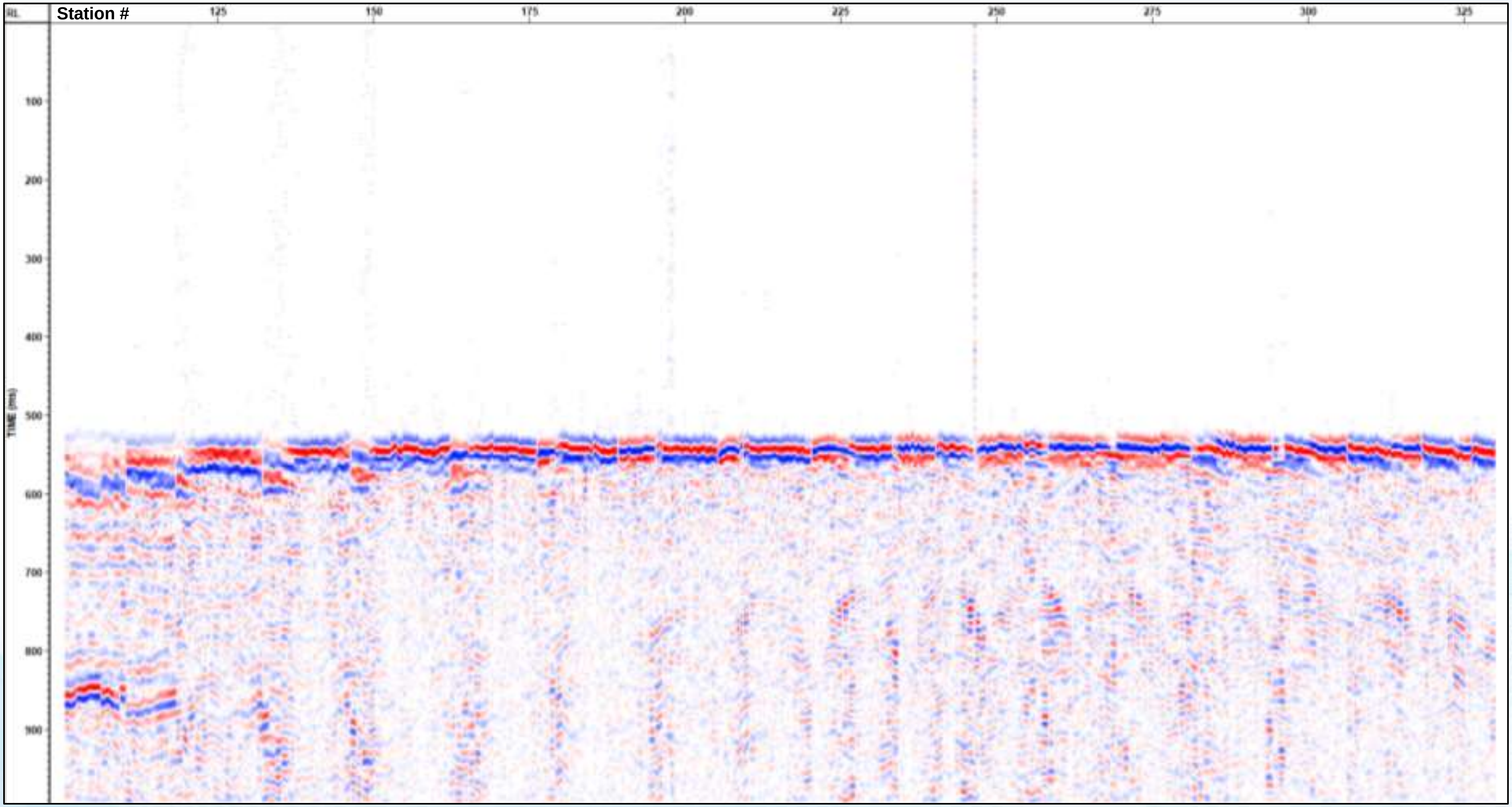


2021h Stage 8 Event – Processed Seismic

6/21/2020 23:11:23.400

No Mechanism Correction

Velocity Corrected Event at 500 ms



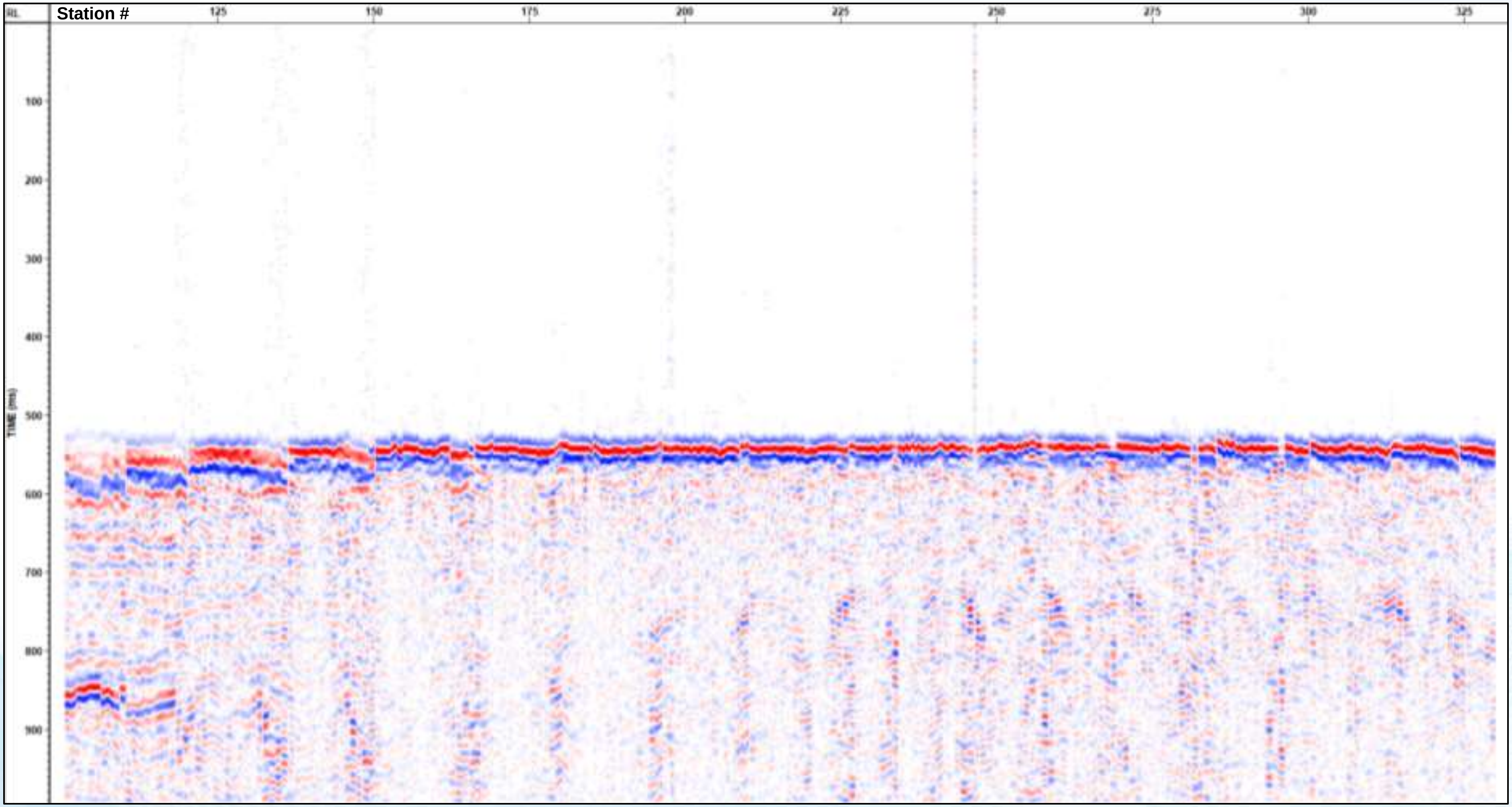
MicroSeismic

2021h Stage 8 Event – Processed Seismic

6/21/2020 23:11:23.400

Mechanism Corrected

Velocity Corrected Event at 500 ms



MicroSeismic

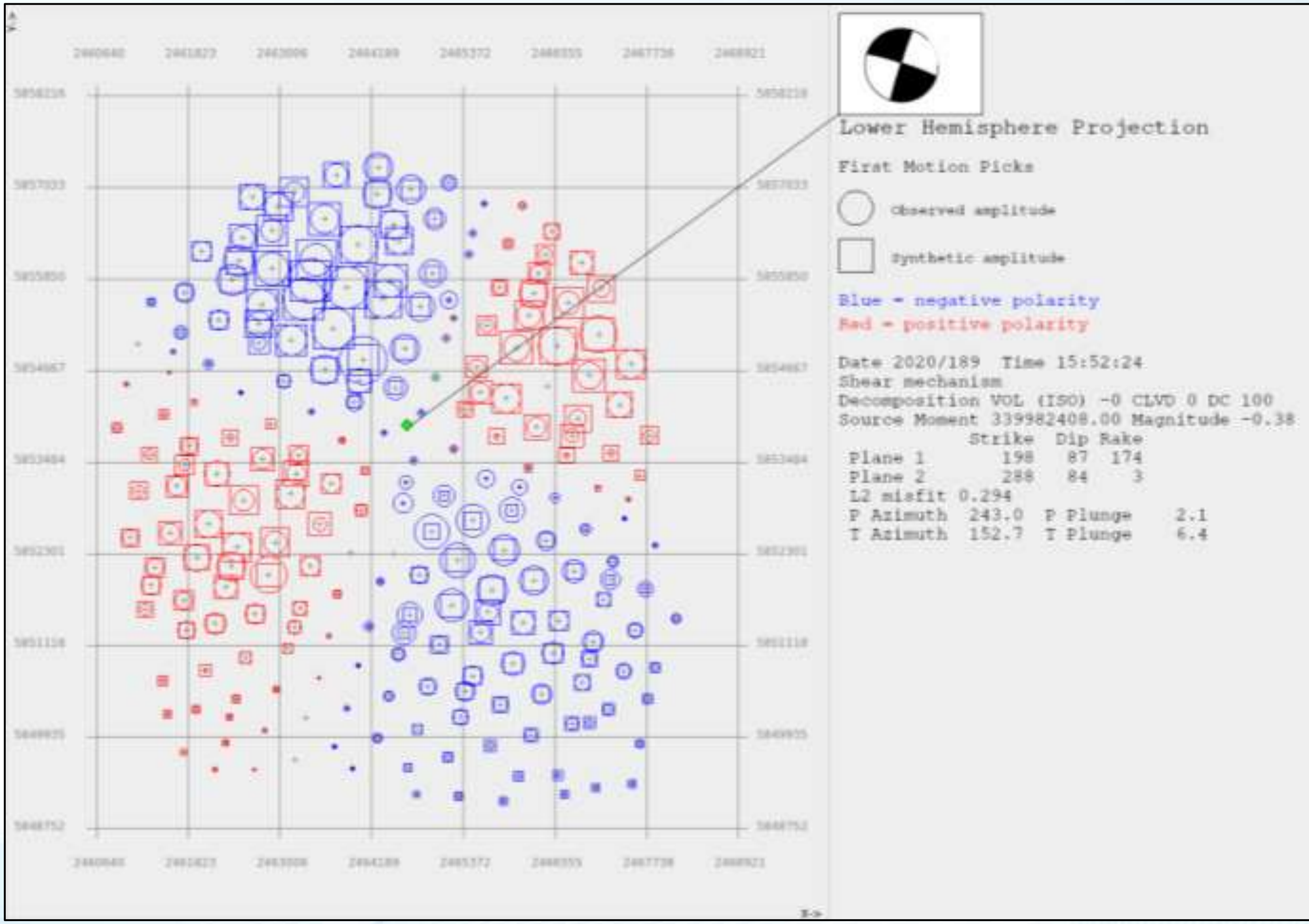
Source Mechanism – 2023h Stage 26 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
198	87	174

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.38



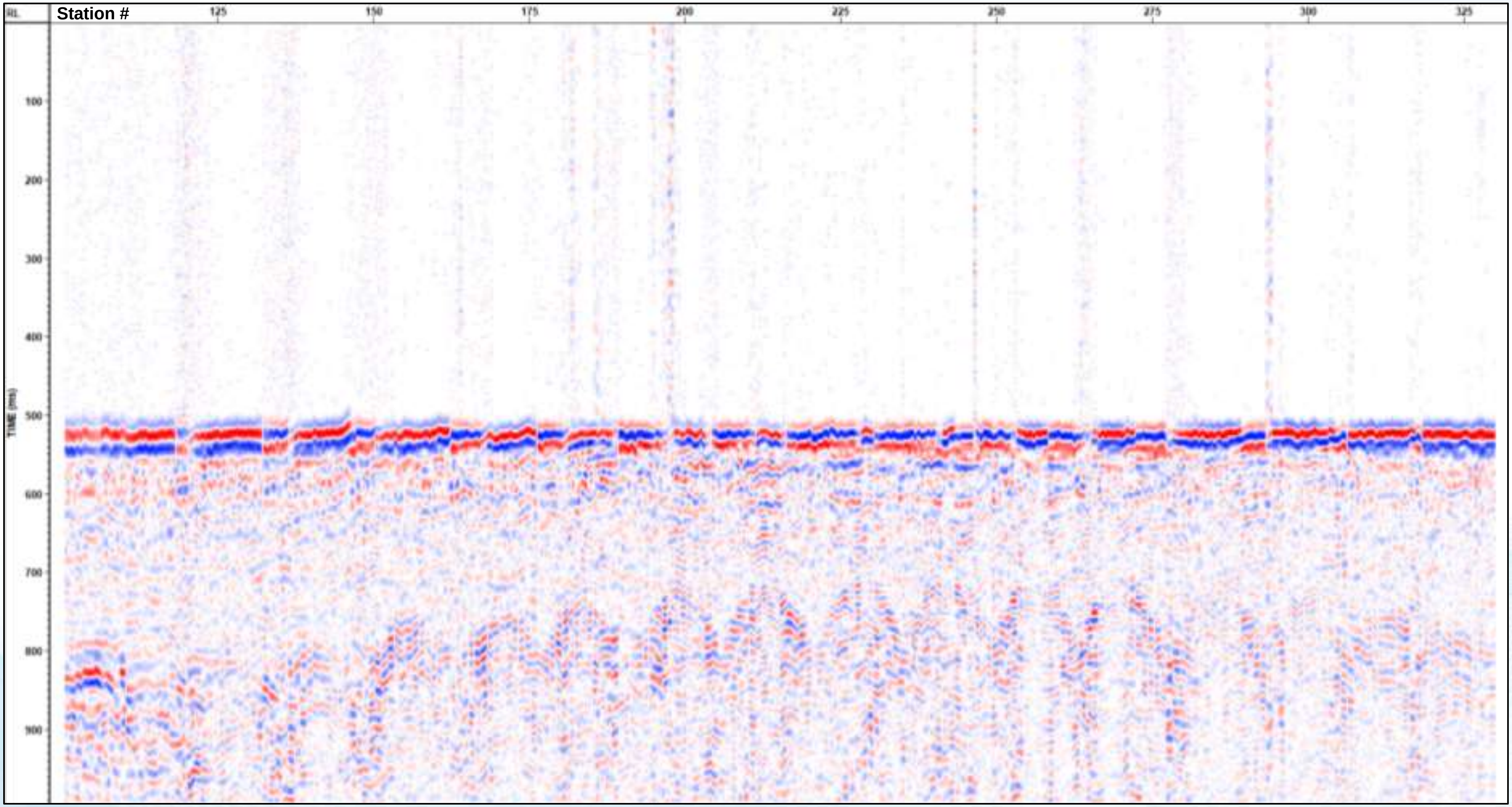
MicroSeismic

2023h Stage 26 Event – Processed Seismic

7/07/2020 15:52:23.884

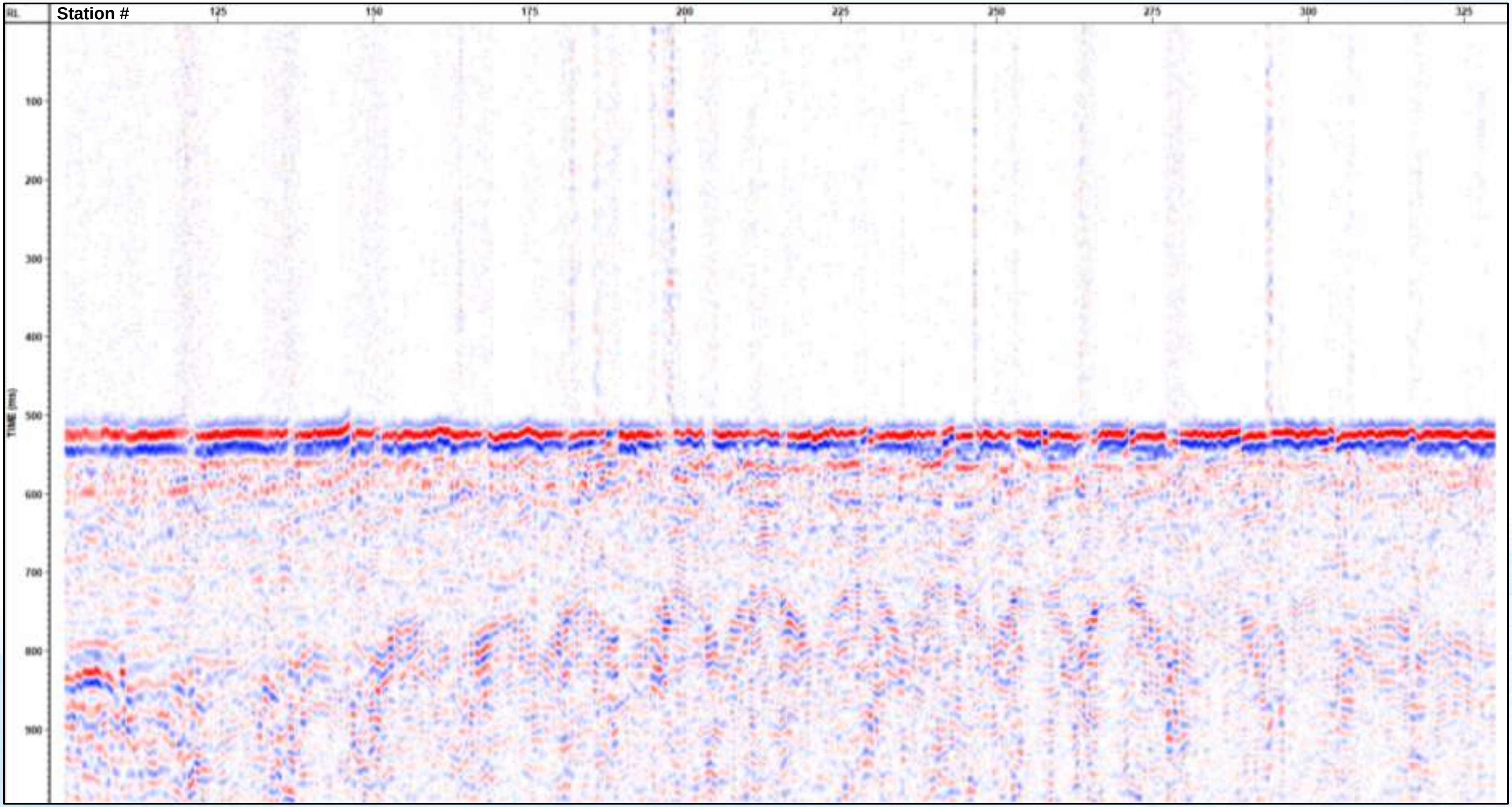
No Mechanism Correction

Velocity Corrected Event at 500 ms



2023h Stage 26 Event – Processed Seismic

7/07/2020 15:52:23.884 **Mechanism Corrected** Velocity Corrected Event at 500 ms



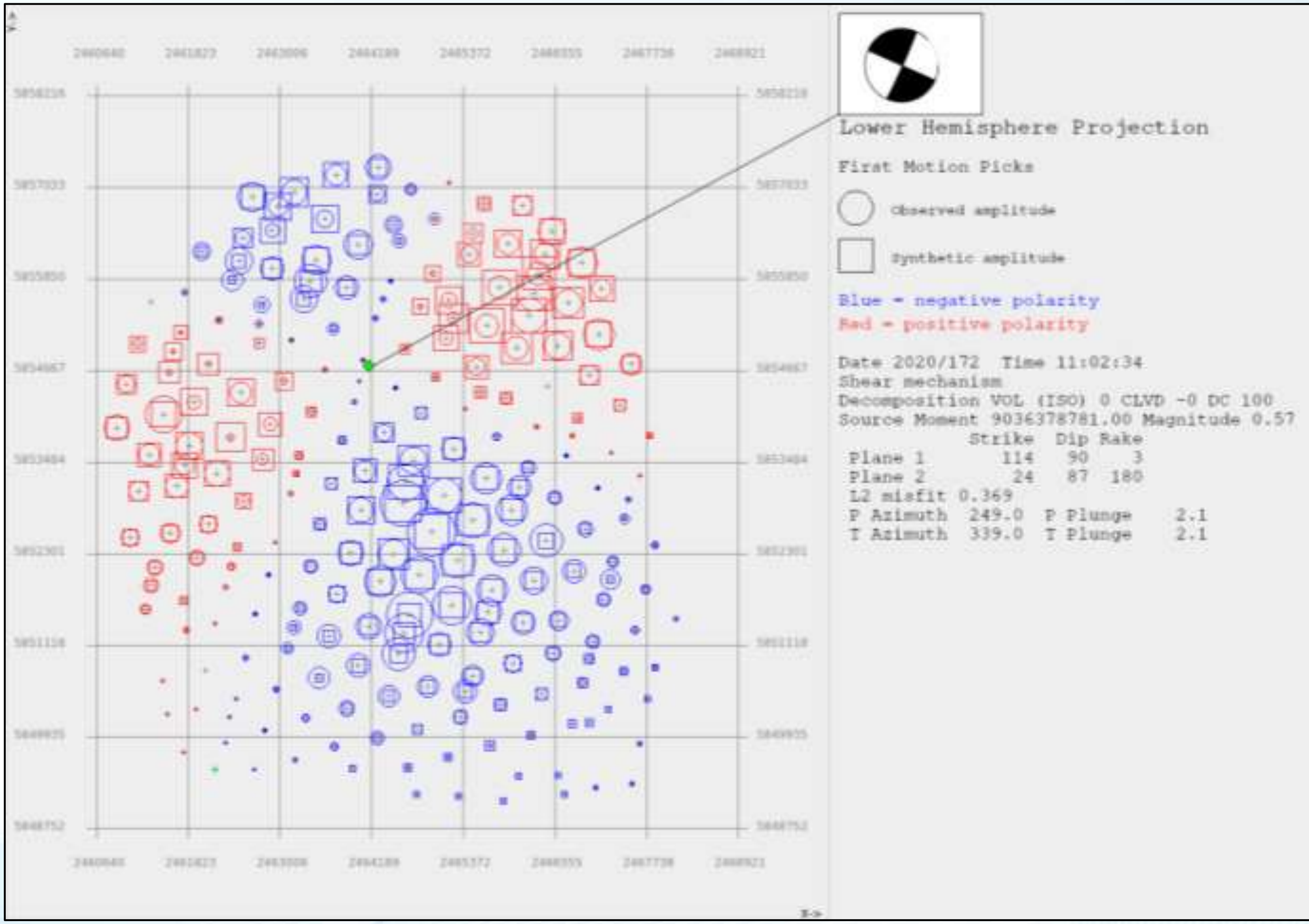
MicroSeismic

Source Mechanism – 2023h Stage 7 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
24	87	180

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.



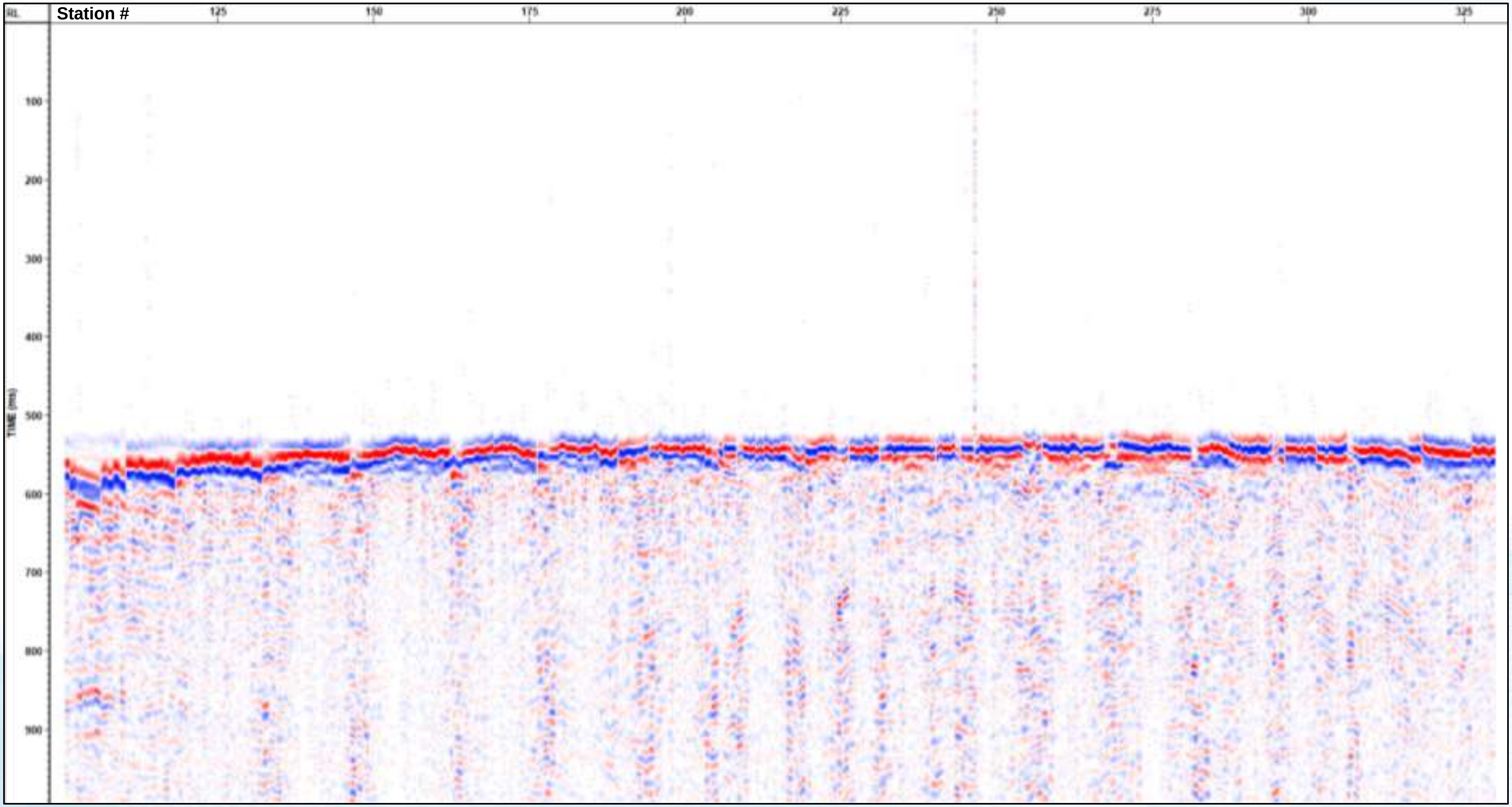
***The moment magnitude for this event is too large to be accurately measured.**

2023h Stage 7 Event – Processed Seismic

6/20/2020 11:02:33.156

No Mechanism Correction

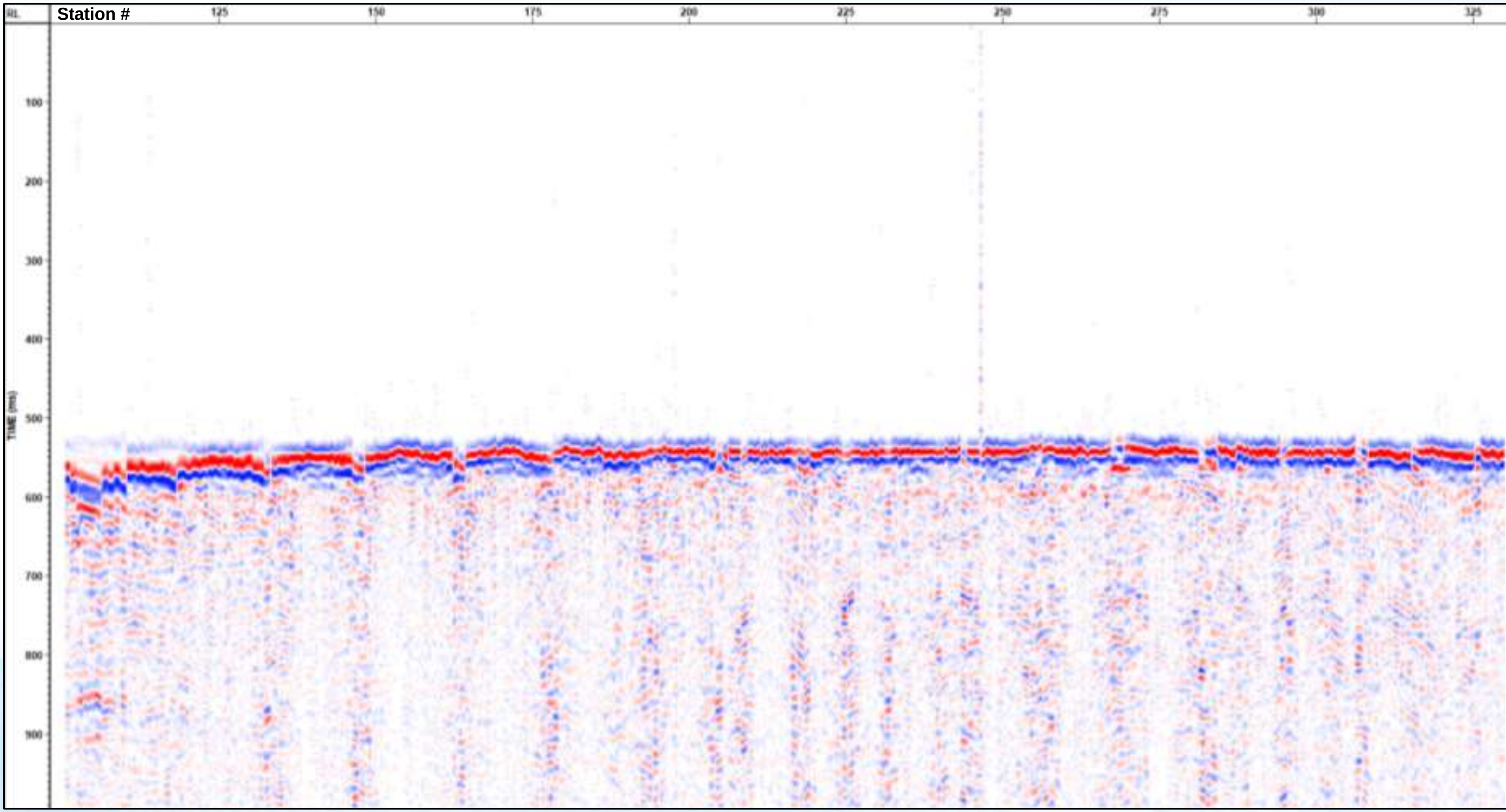
Velocity Corrected Event at 500 ms



MicroSeismic

2023h Stage 7 Event – Processed Seismic

6/20/2020 11:02:33.156 **Mechanism Corrected** Velocity Corrected Event at 500 ms



MicroSeismic

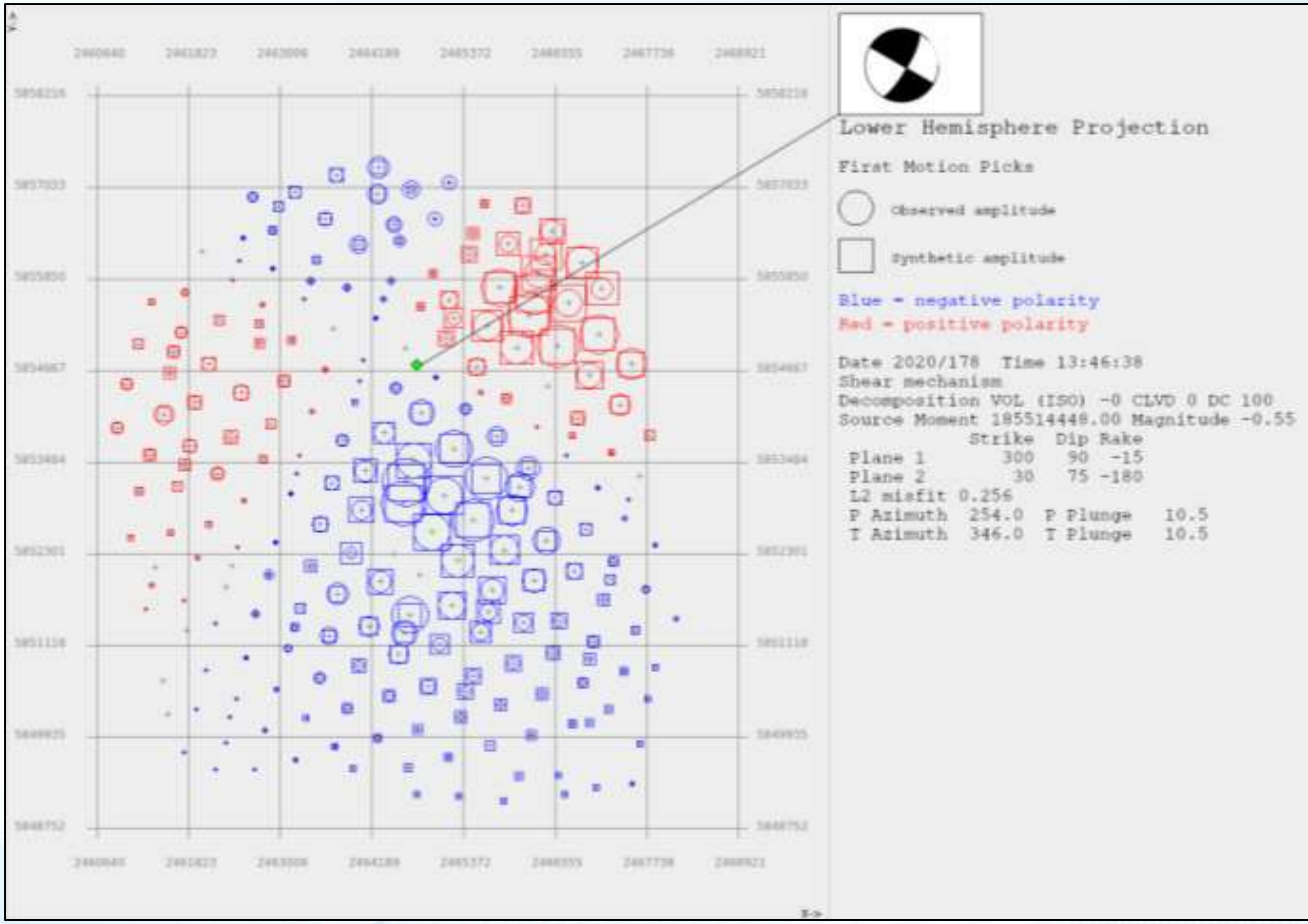
Source Mechanism – 2023h Stage 8 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
30	75	-180

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.55



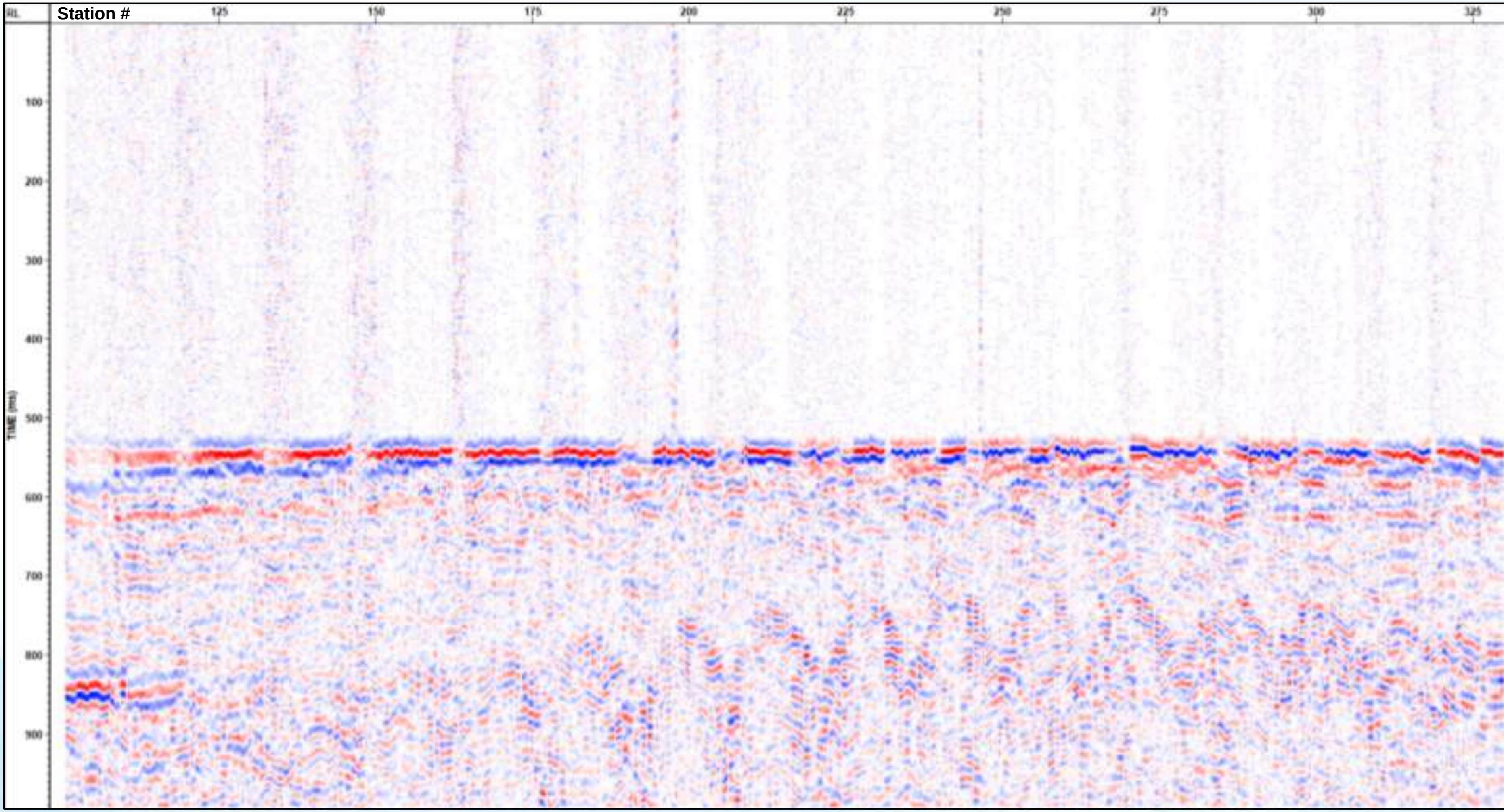
MicroSeismic

2023h Stage 8 Event – Processed Seismic

6/26/2020 13:46:37.572

No Mechanism Correction

Velocity Corrected Event at 500 ms

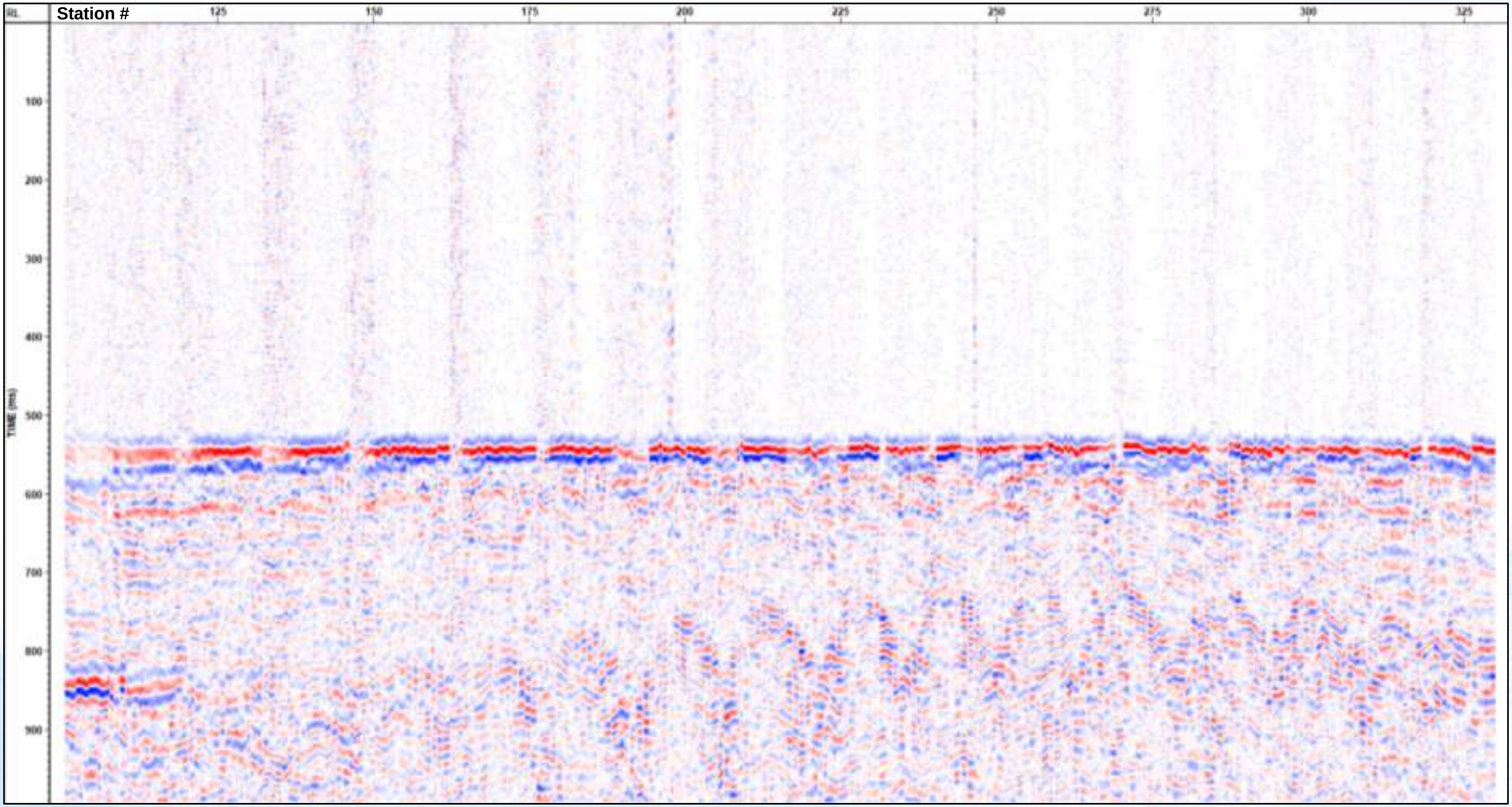


2023h Stage 8 Event – Processed Seismic

6/26/2020 13:46:37.572

Mechanism Corrected

Velocity Corrected Event at 500 ms



MicroSeismic

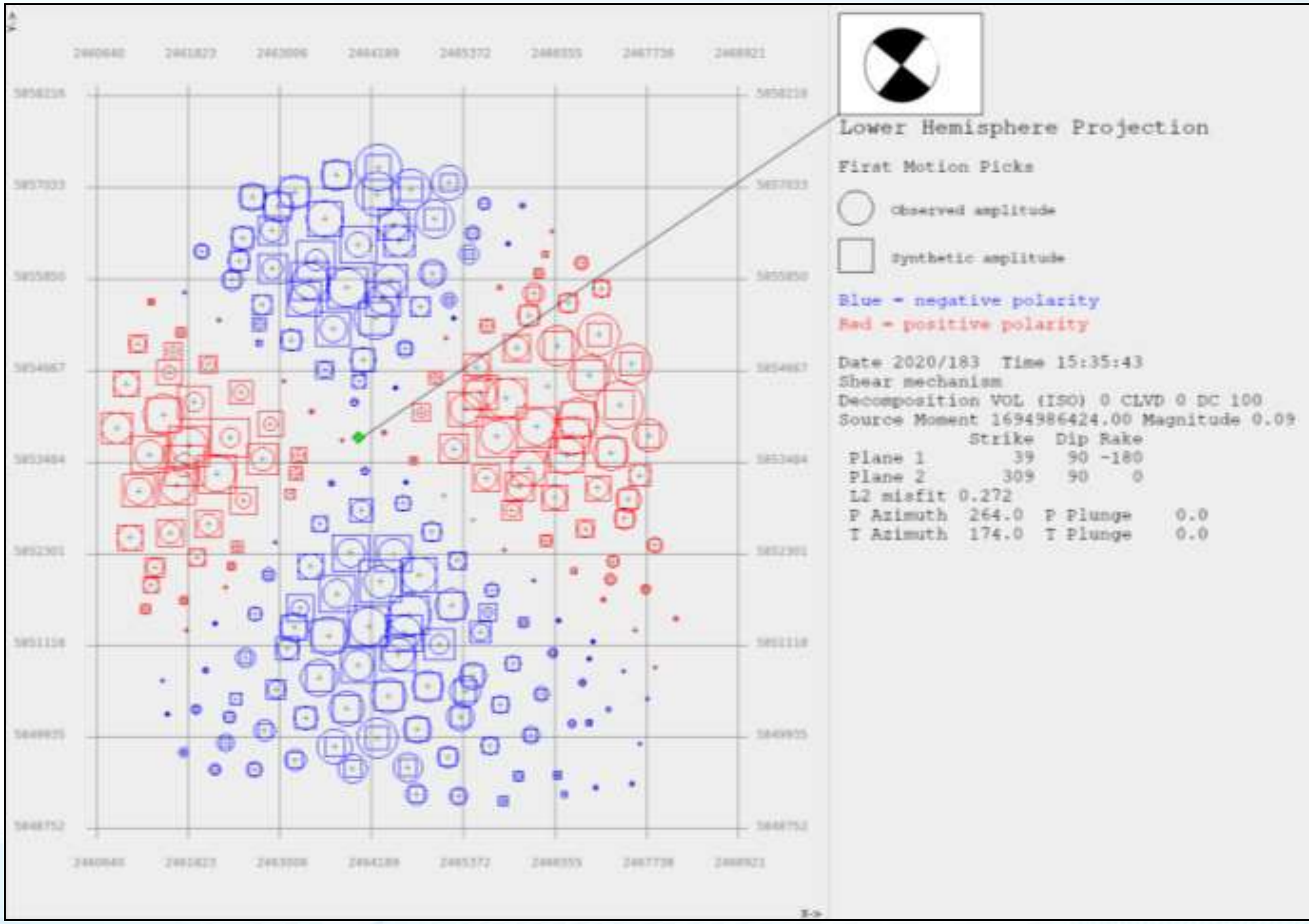
Source Mechanism – 2021h Stage 17 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
39	90	-180

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: 0.09

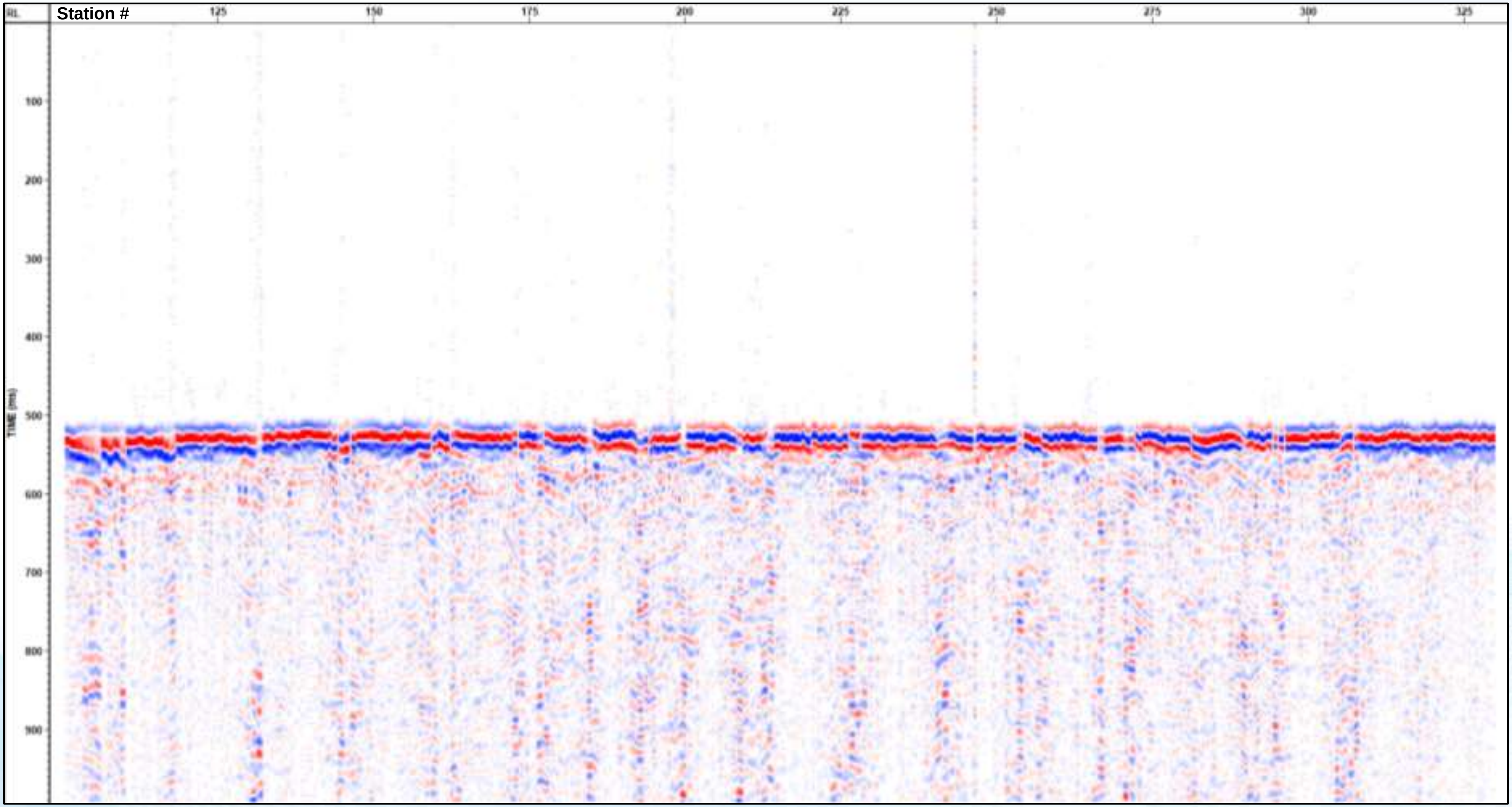


2021h Stage 17 Event – Processed Seismic

7/01/2020 15:35:42.316

No Mechanism Correction

Velocity Corrected Event at 500 ms

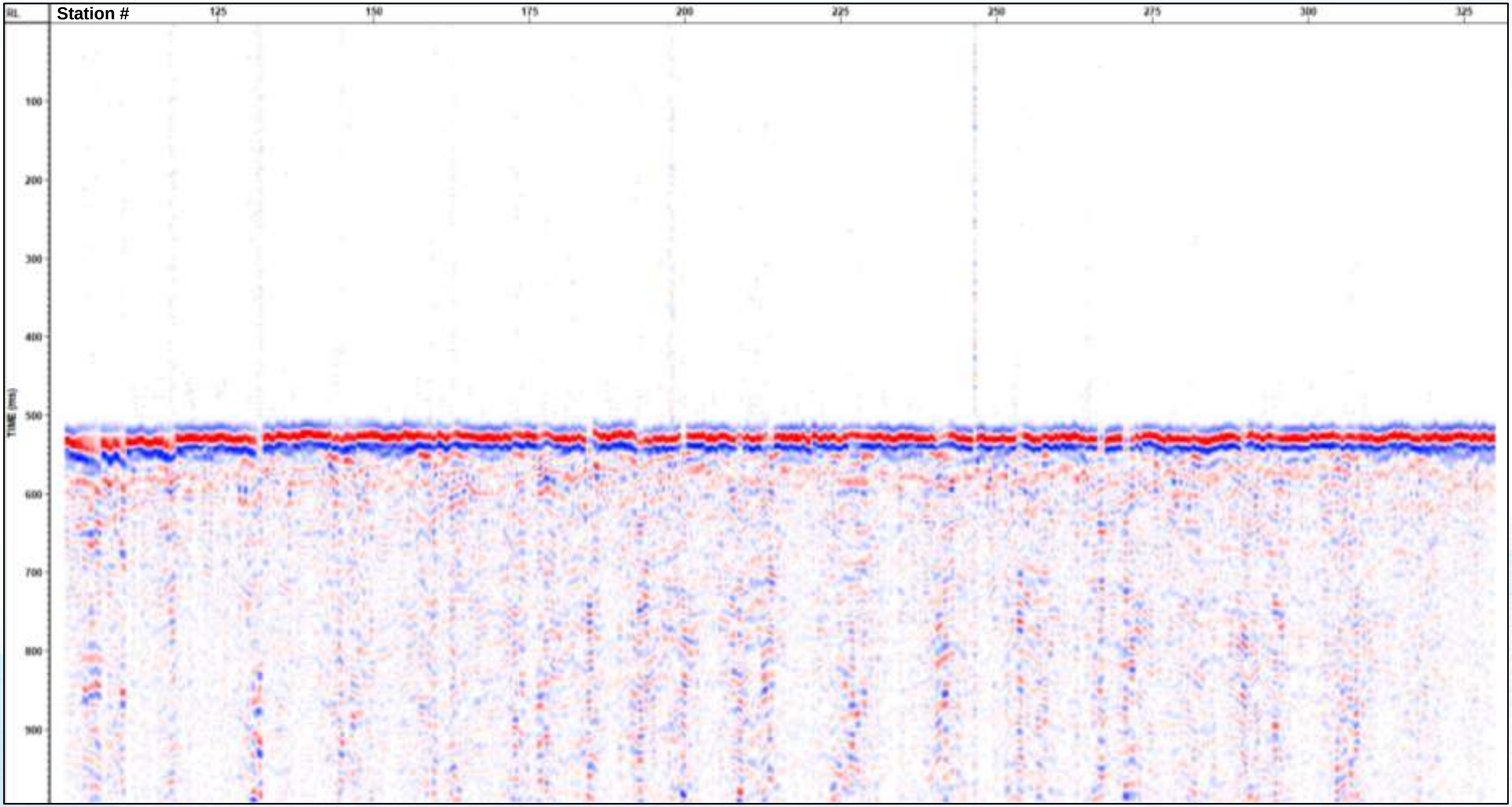


2021h Stage 17 Event – Processed Seismic

7/01/2020 15:35:42.316

Mechanism Corrected

Velocity Corrected Event at 500 ms



MicroSeismic

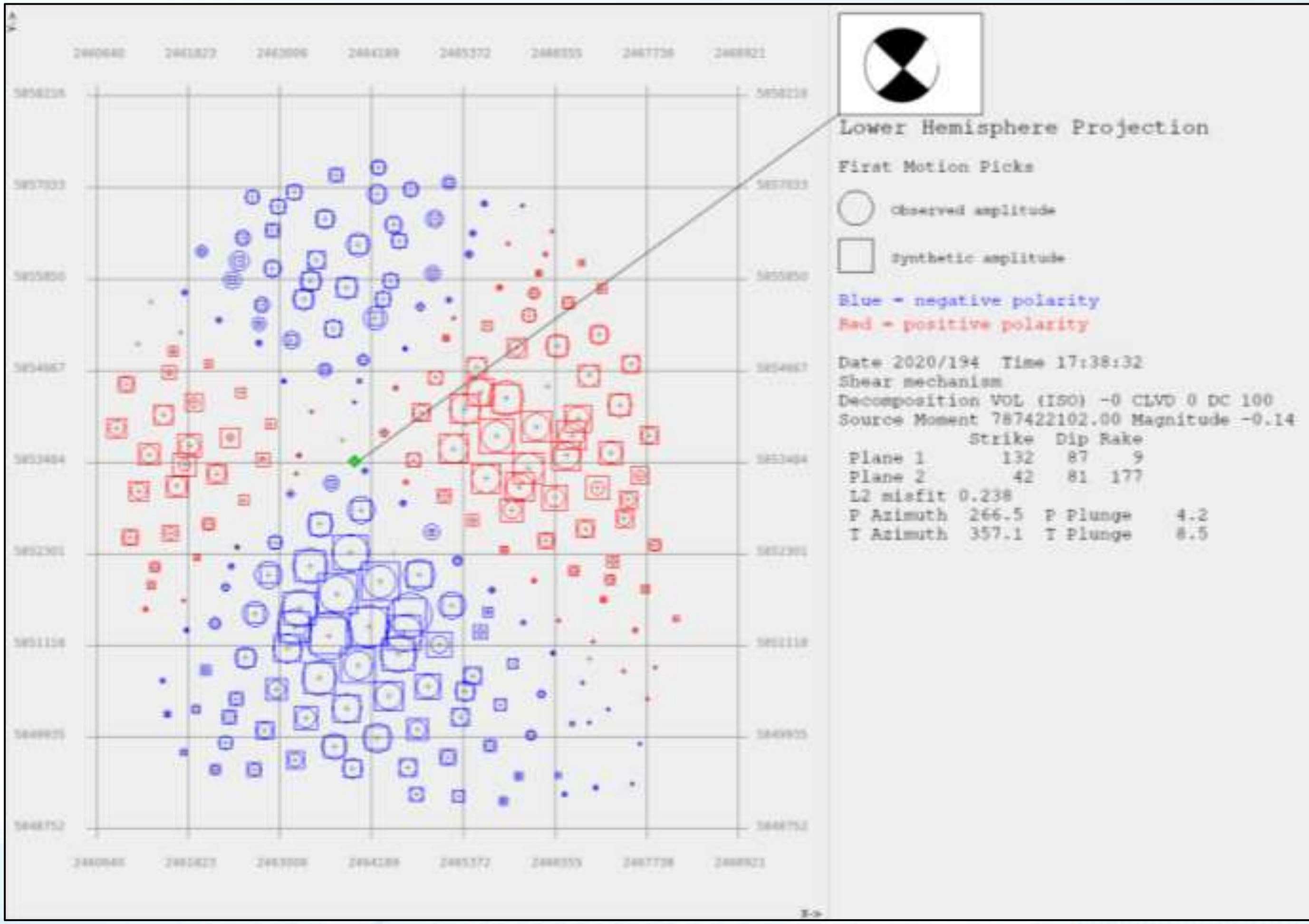
Source Mechanism – 2021h Stage 29 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
42	81	177

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.14

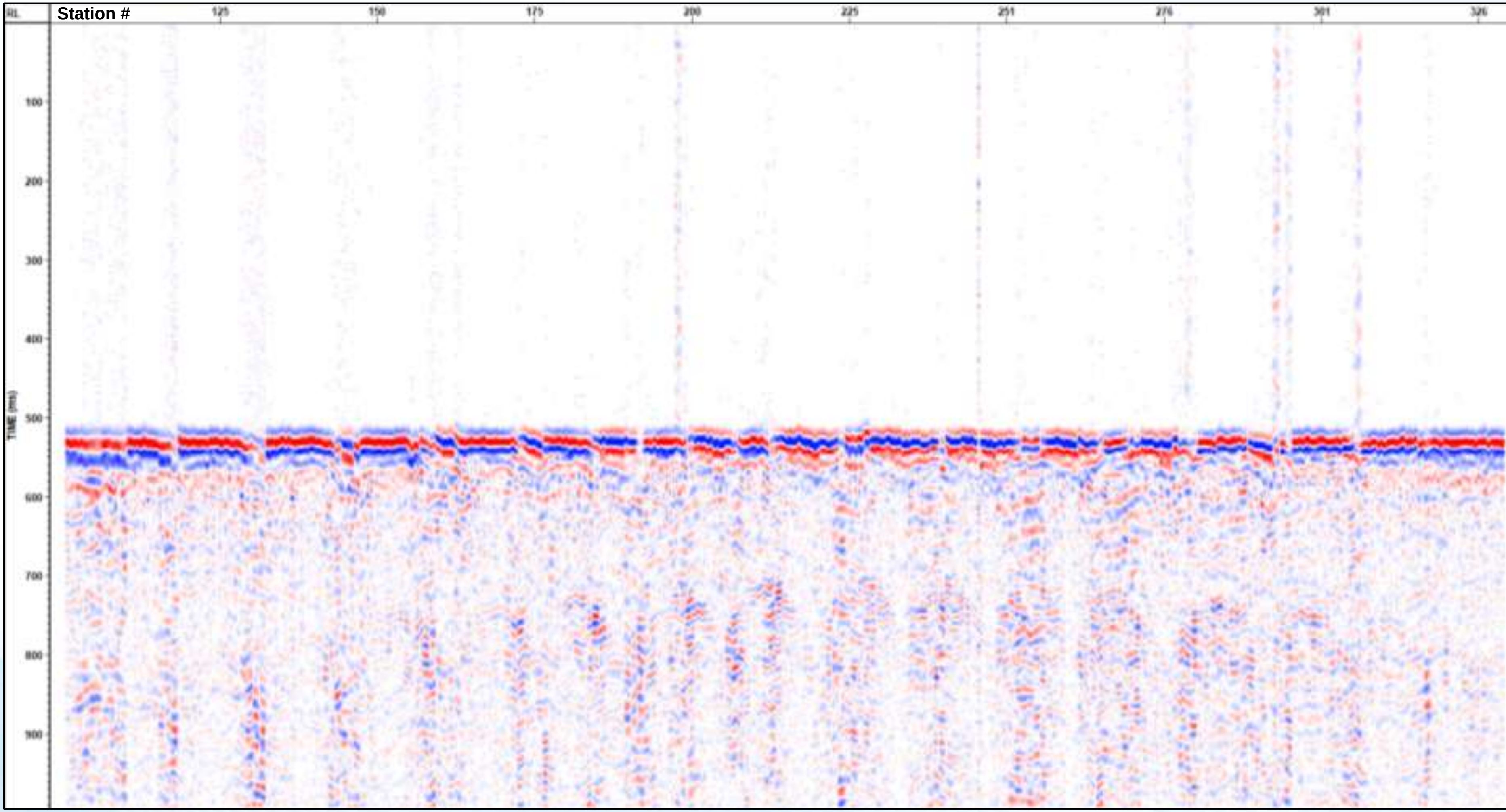


2021h Stage 29 Event – Processed Seismic

7/12/2020 17:38:31.320

No Mechanism Correction

Velocity Corrected Event at 500 ms

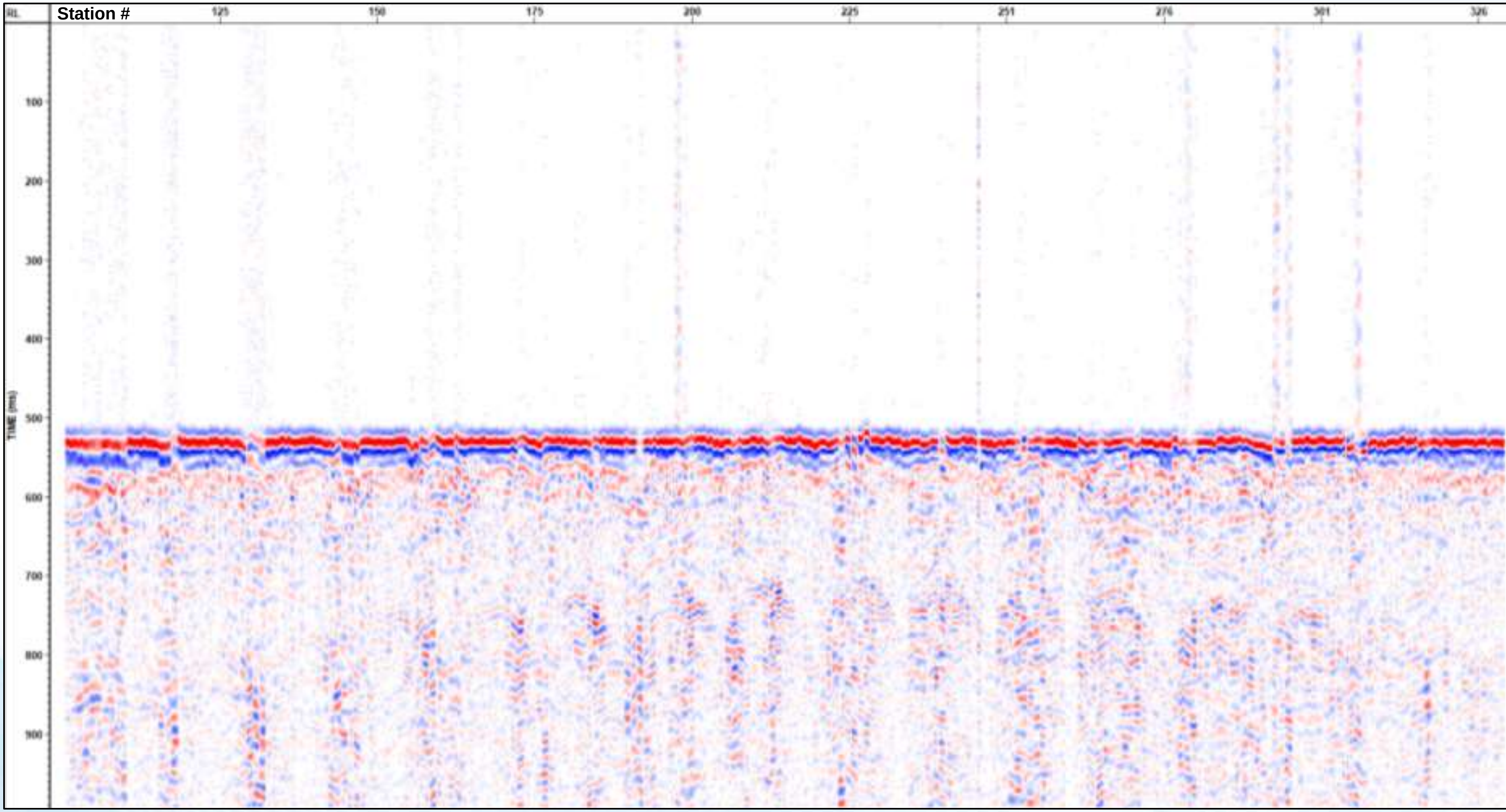


2021h Stage 29 Event – Processed Seismic

7/12/2020 17:38:31.320

Mechanism Corrected

Velocity Corrected Event at 500 ms



MicroSeismic

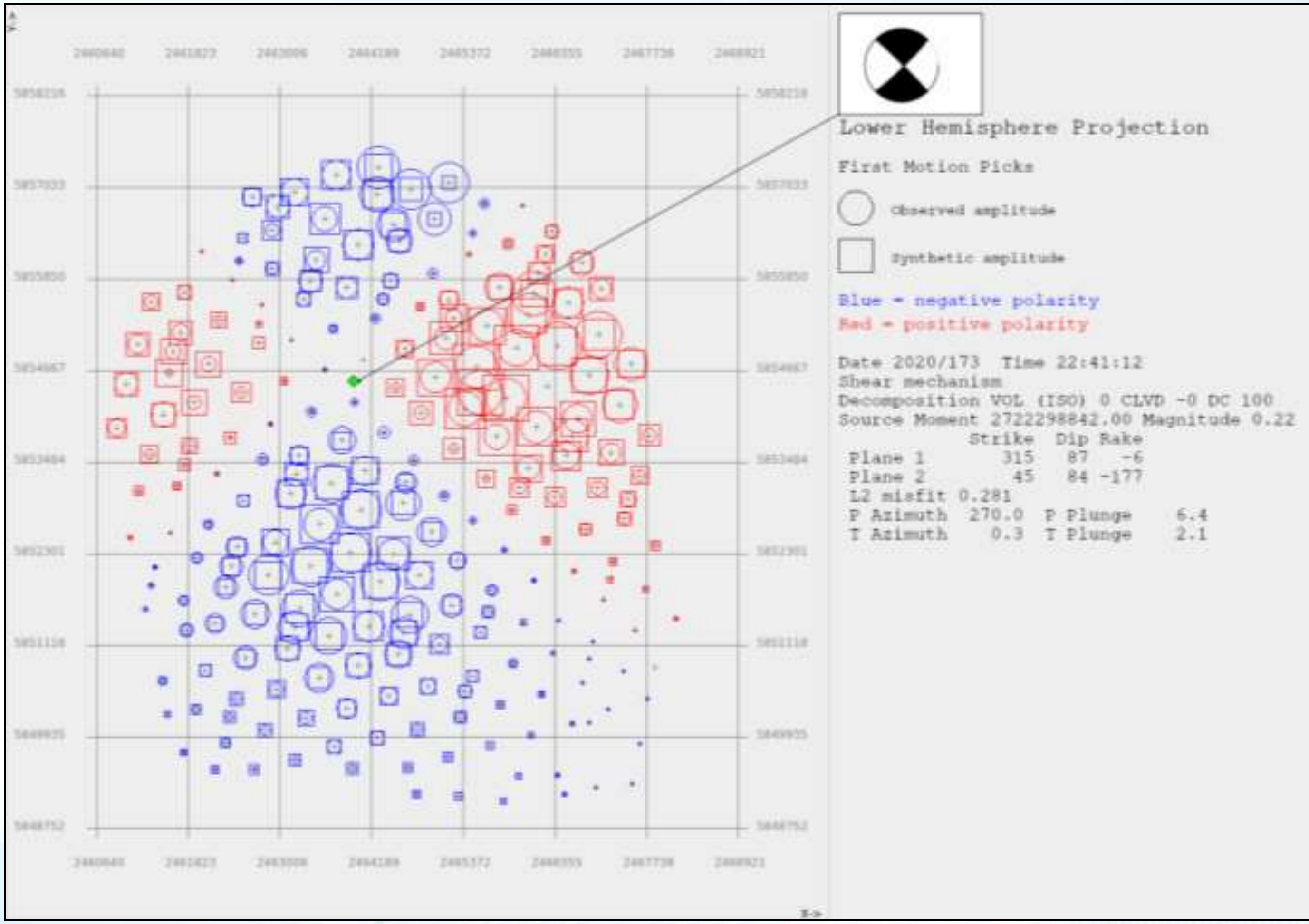
Source Mechanism – 2021h Stage 8 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
45	84	-177

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: 0.22



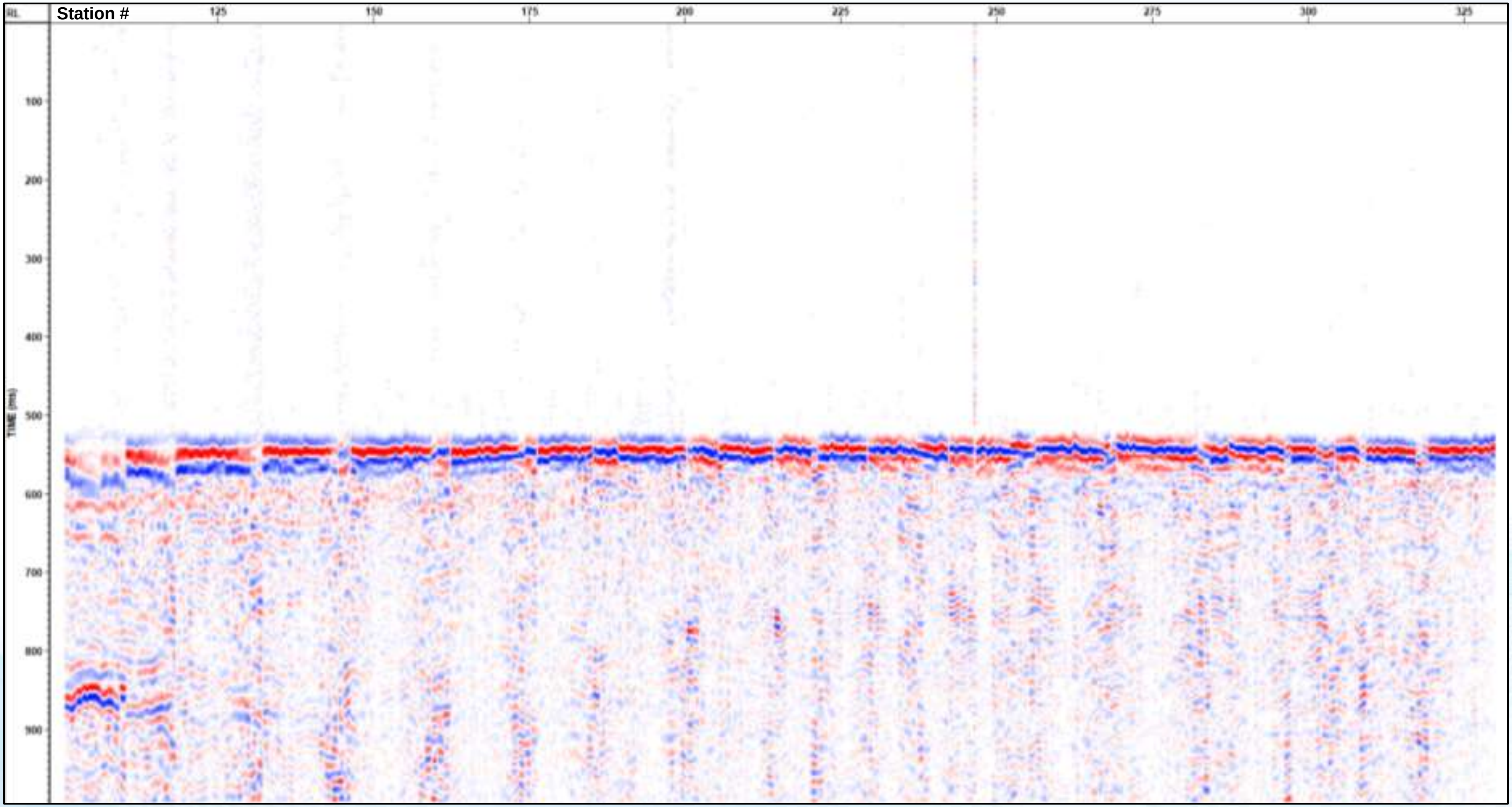
MicroSeismic

2021h Stage 8 Event – Processed Seismic

6/21/2020 22:41:11.536

No Mechanism Correction

Velocity Corrected Event at 500 ms



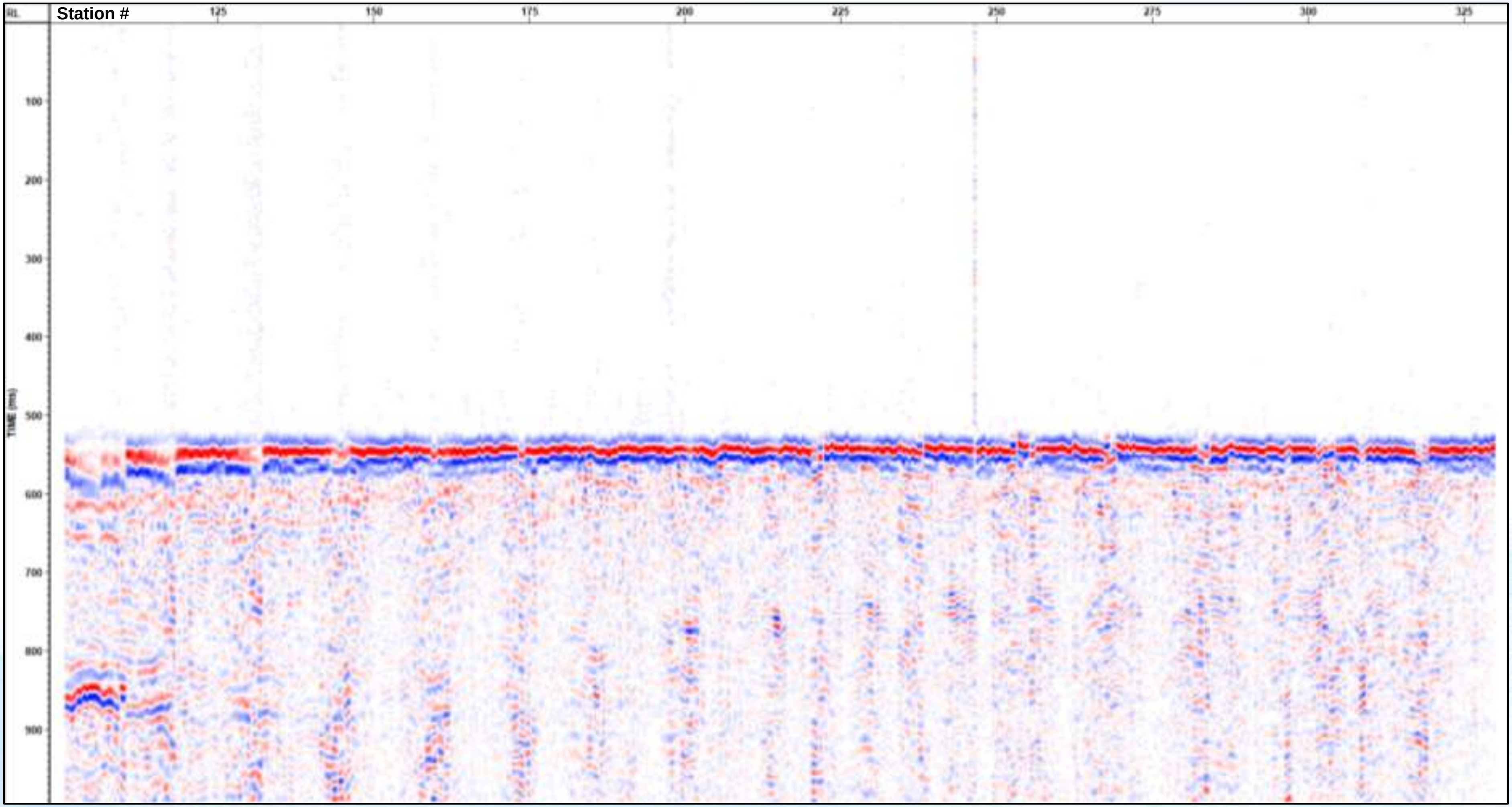
MicroSeismic

2021h Stage 8 Event – Processed Seismic

6/21/2020 22:41:11.536

Mechanism Corrected

Velocity Corrected Event at 500 ms



MicroSeismic

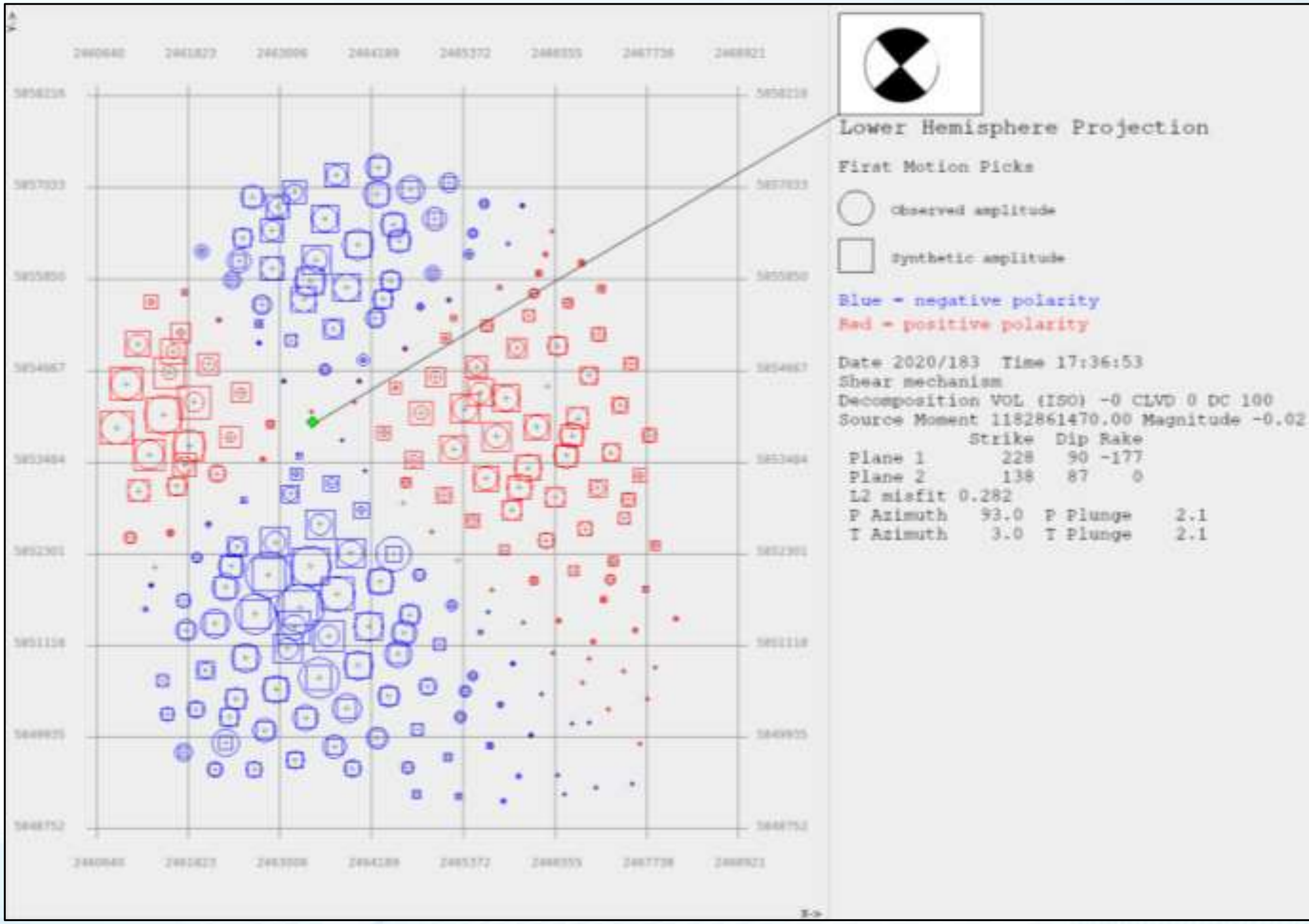
Source Mechanism – 2023h Stage 18 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
228	90	-177

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.02

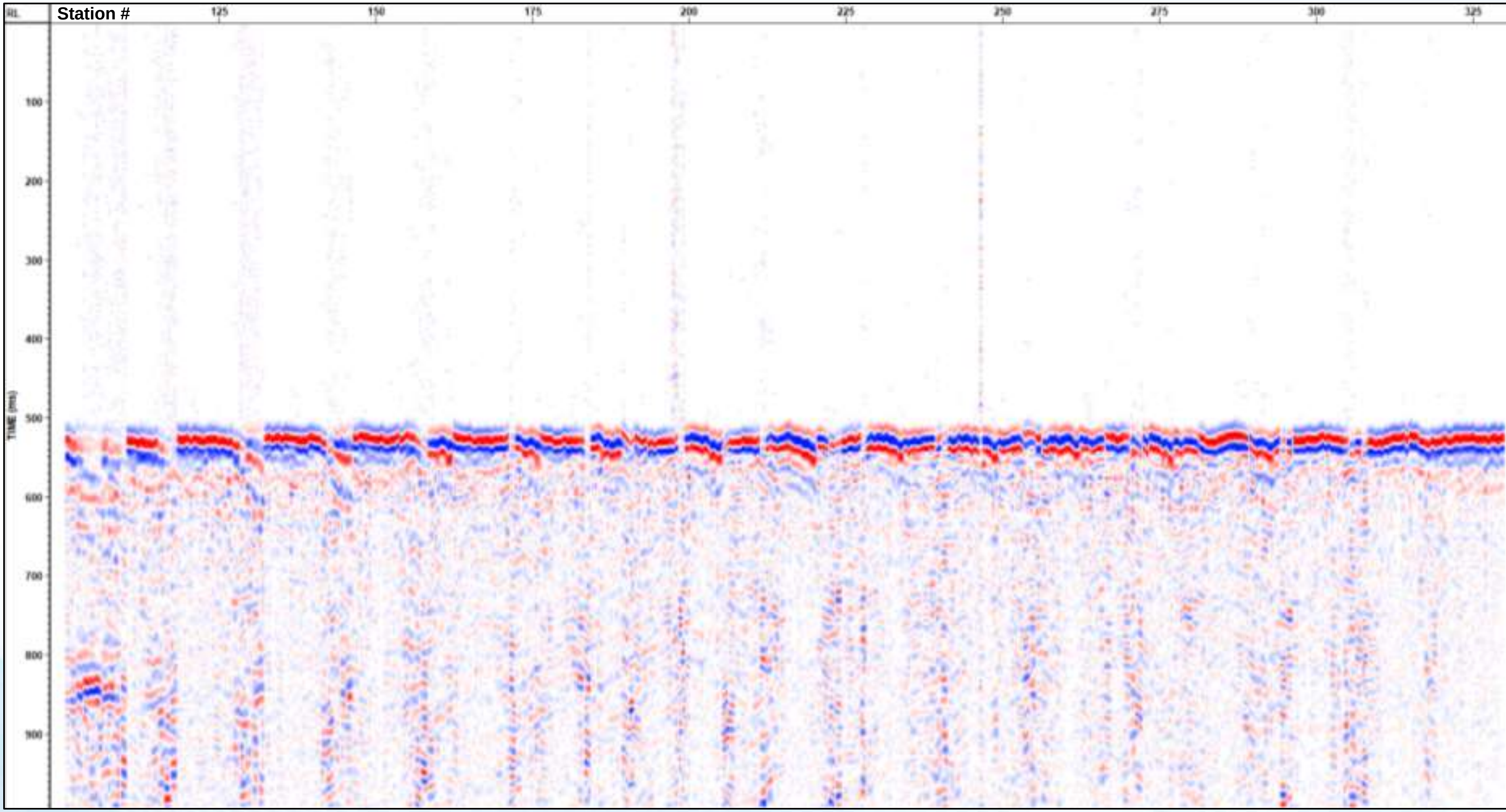


2023h Stage 18 Event – Processed Seismic

7/01/2020 17:36:53.156

No Mechanism Correction

Velocity Corrected Event at 500 ms

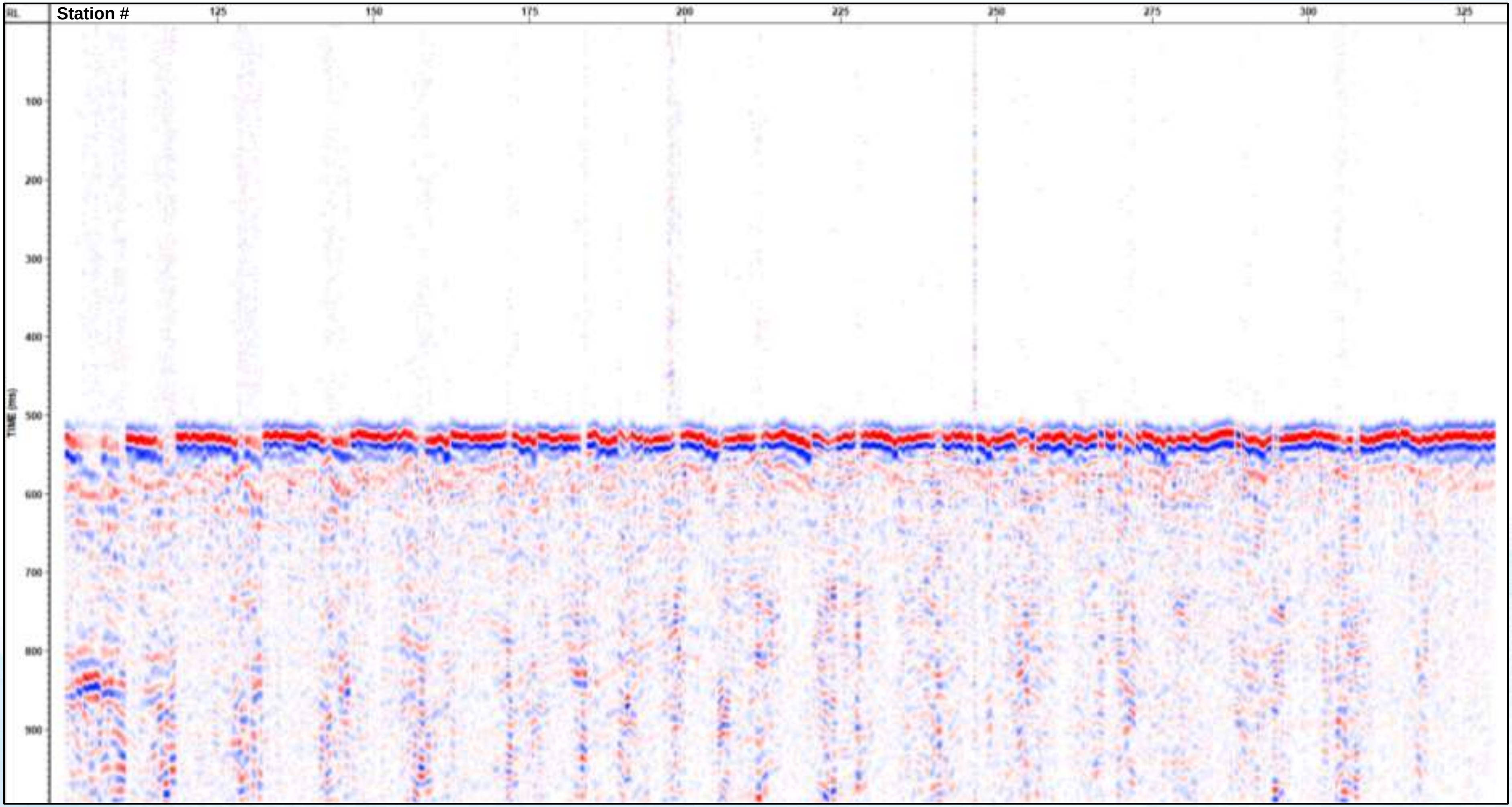


2023h Stage 18 Event – Processed Seismic

7/01/2020 17:36:53.156

Mechanism Corrected

Velocity Corrected Event at 500 ms



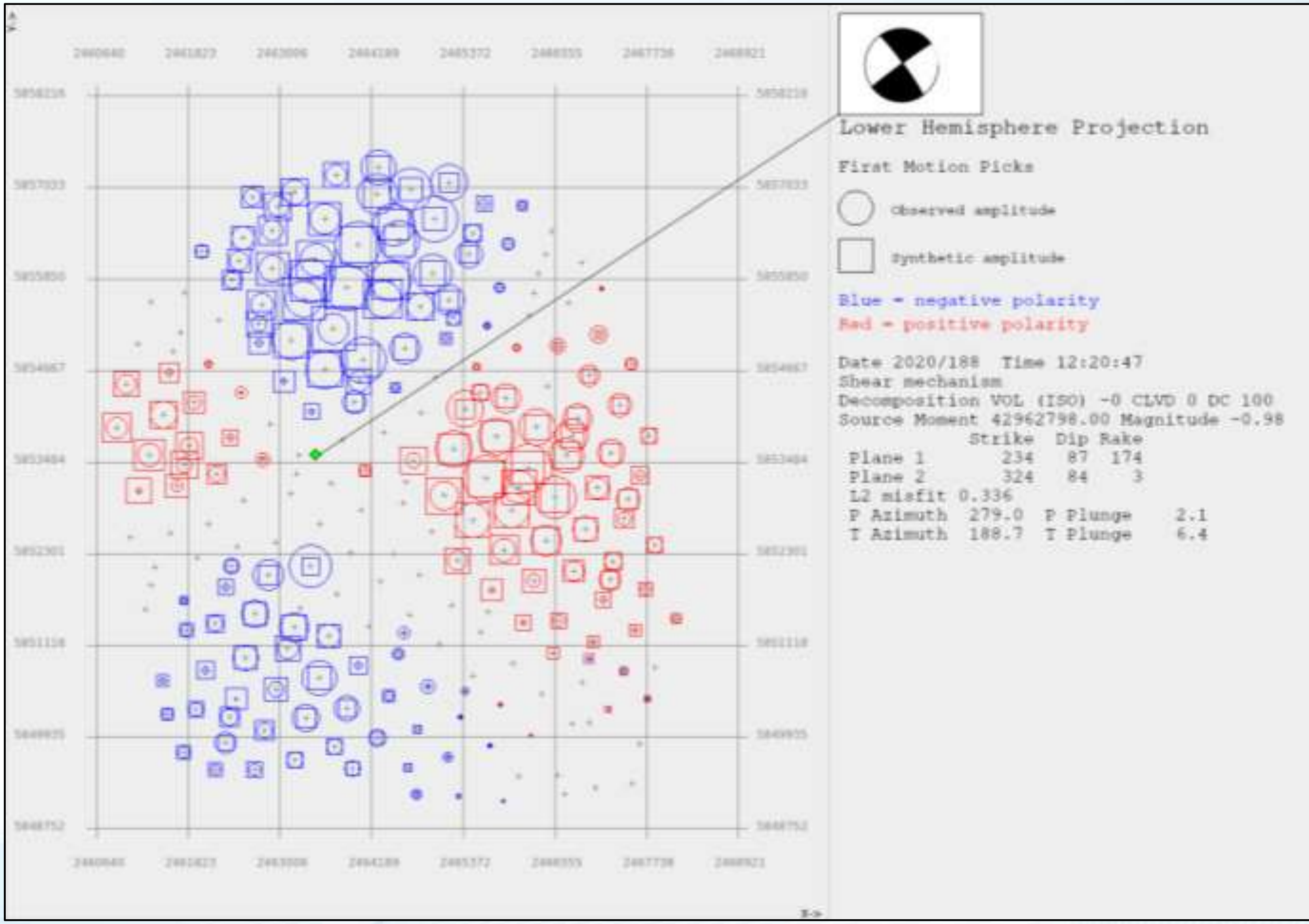
Source Mechanism – 2021h Stage 25 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
234	87	174

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.98

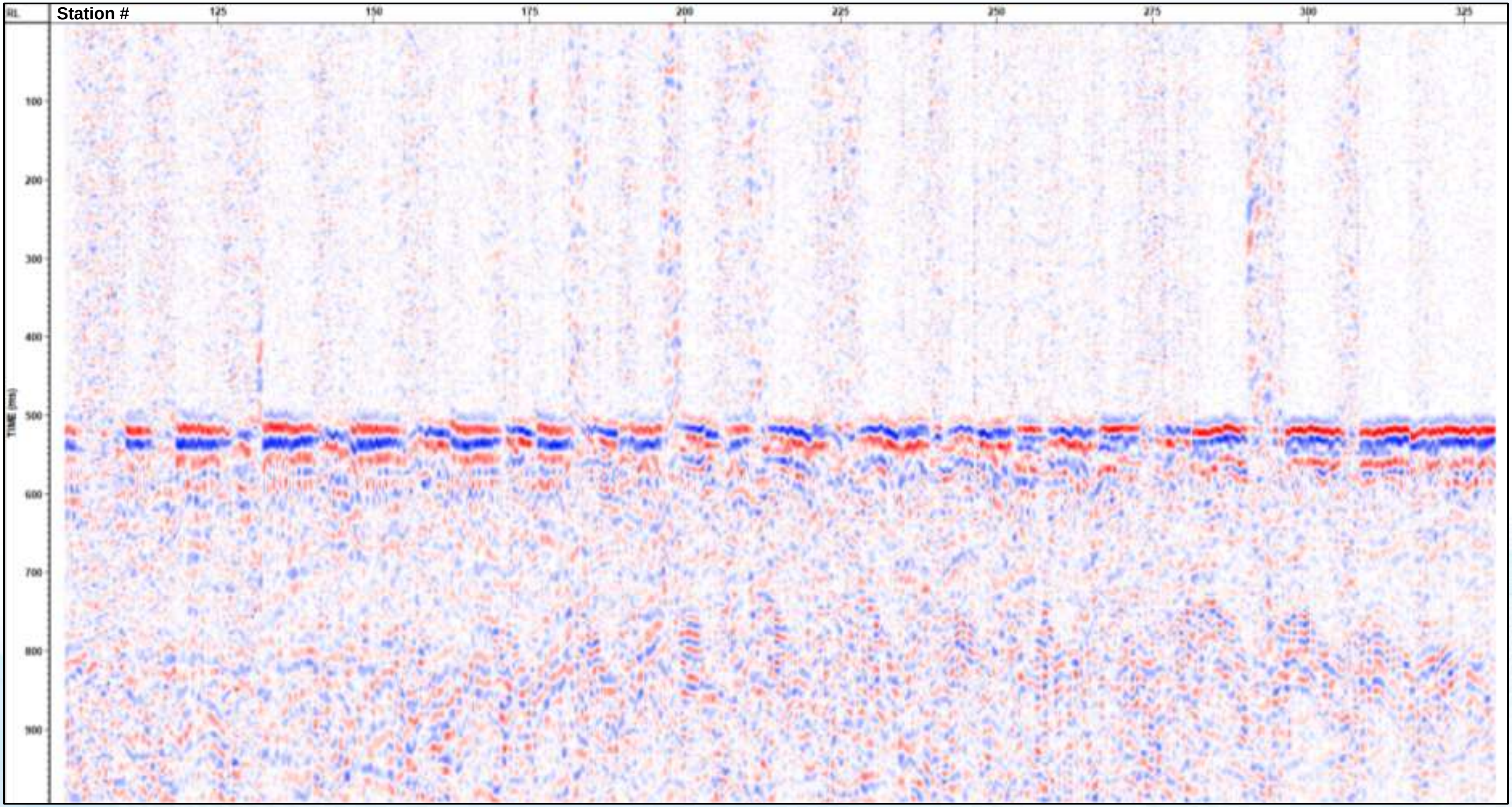


2021h Stage 25 Event – Processed Seismic

7/06/2020 12:20:46.356

No Mechanism Correction

Velocity Corrected Event at 500 ms



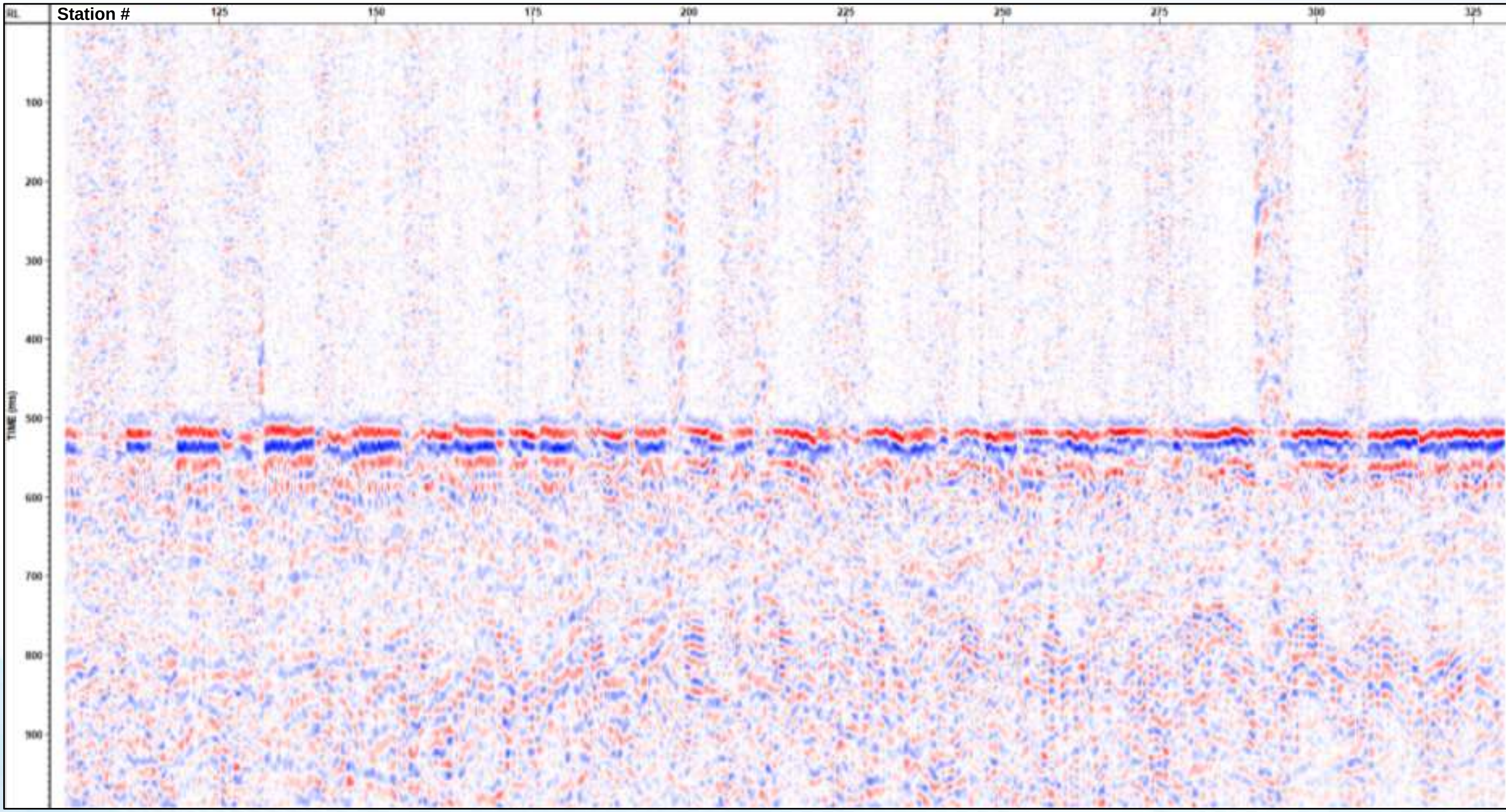
MicroSeismic

2021h Stage 25 Event – Processed Seismic

7/06/2020 12:20:46.356

Mechanism Corrected

Velocity Corrected Event at 500 ms



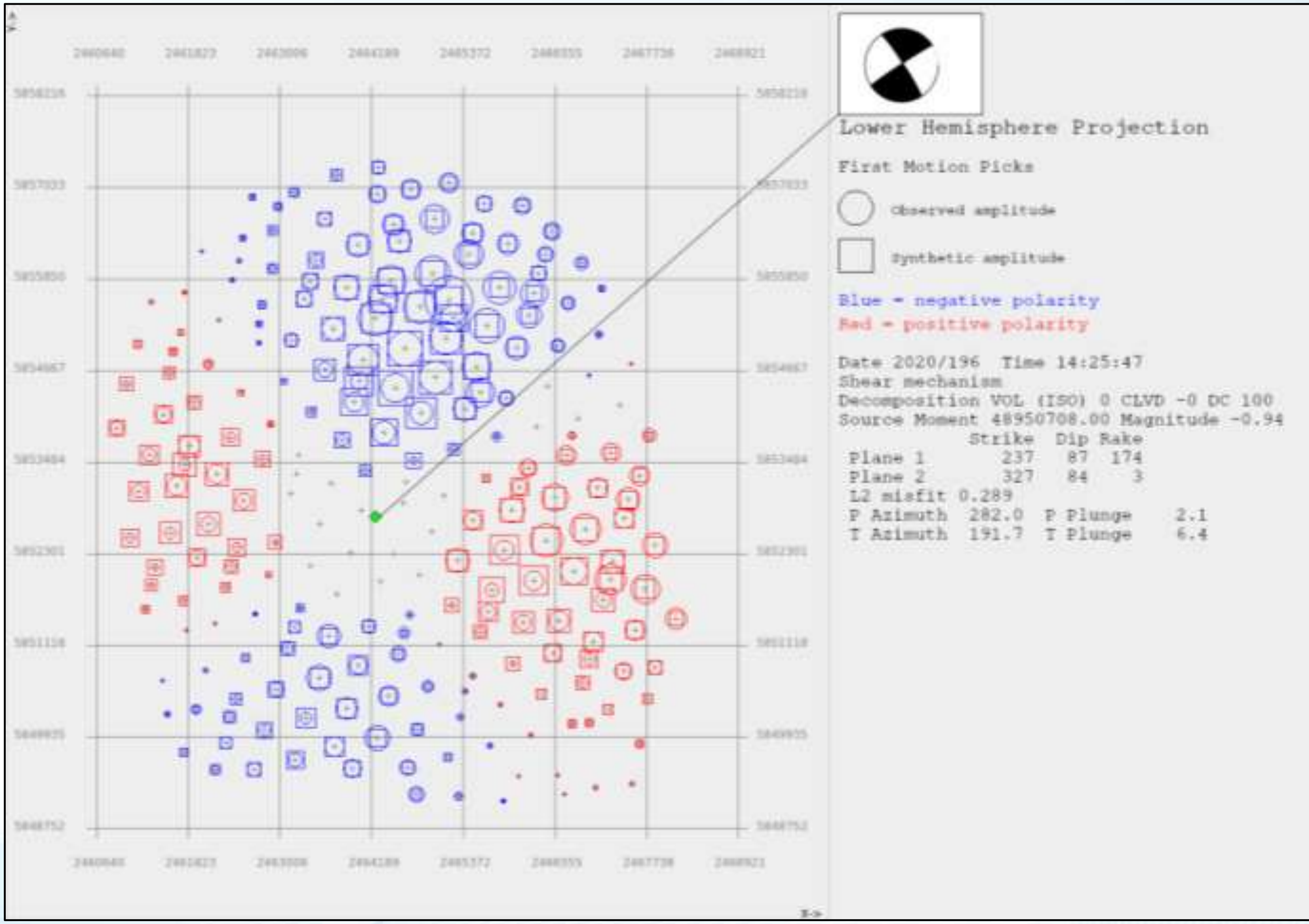
Source Mechanism – 2021h Stage 31 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
237	87	174

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.94



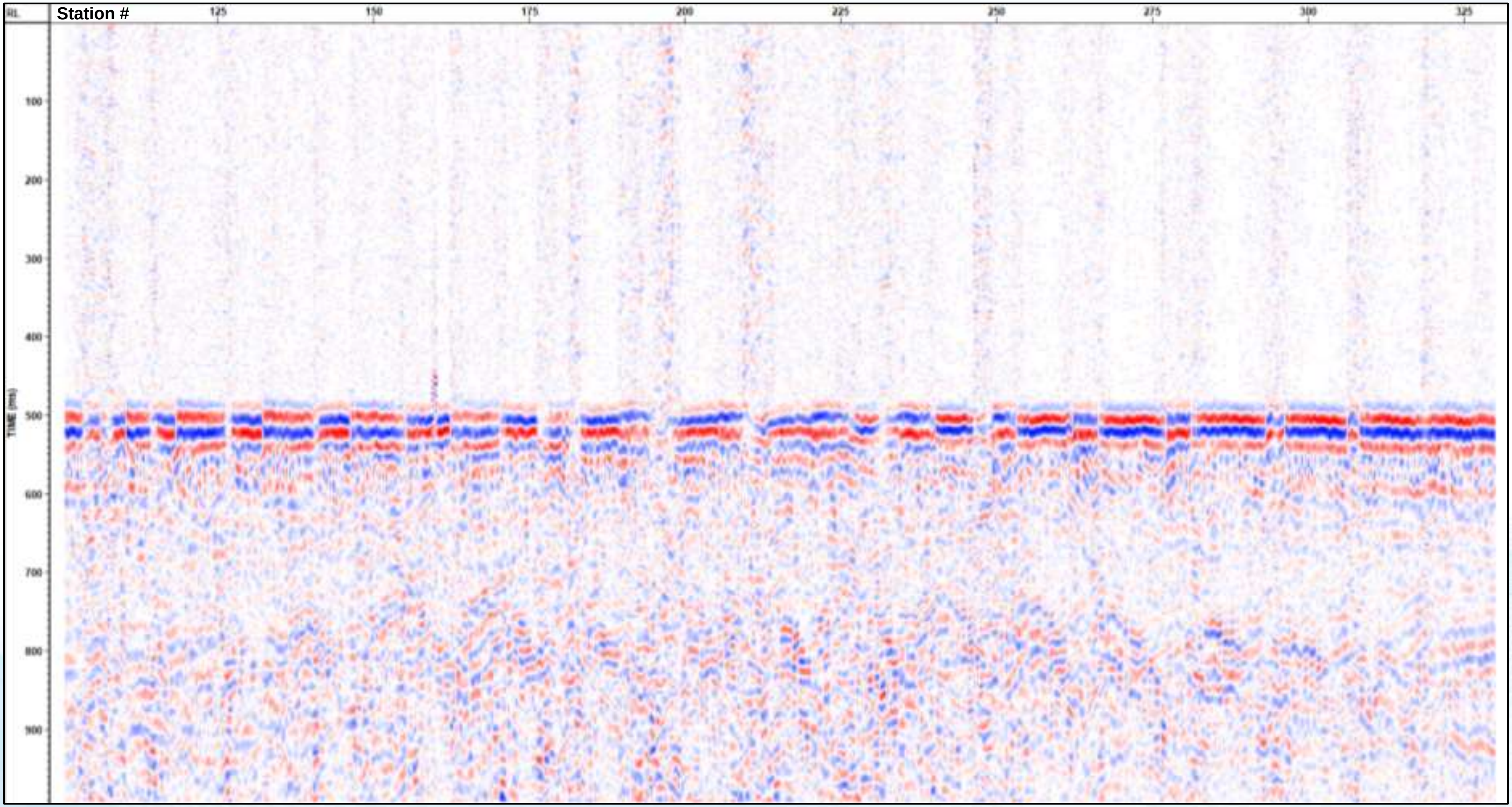
MicroSeismic

2021h Stage 31 Event – Processed Seismic

7/14/2020 14:25:46.964

No Mechanism Correction

Velocity Corrected Event at 500 ms

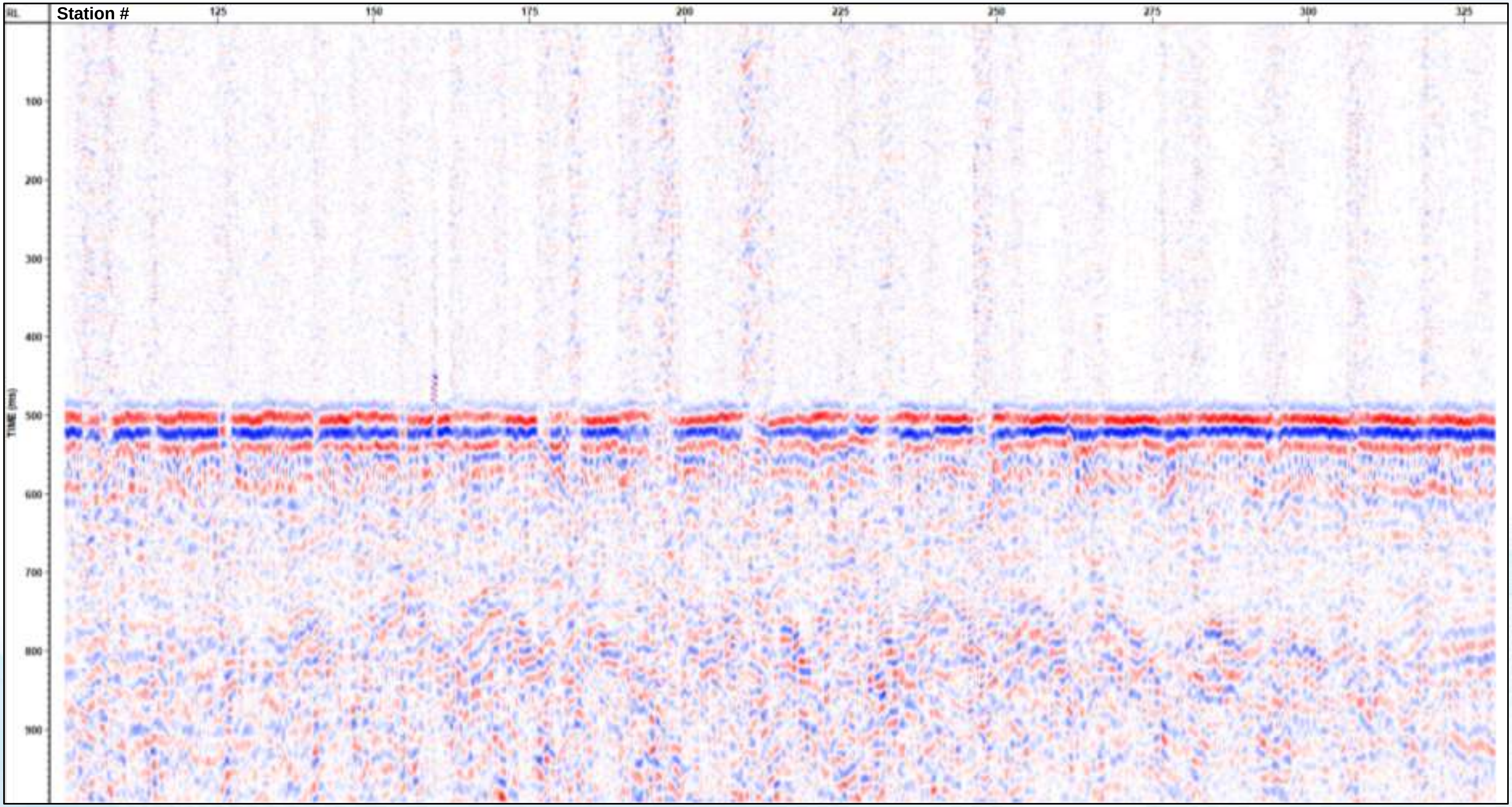


2021h Stage 31 Event – Processed Seismic

7/14/2020 14:25:46.964

Mechanism Corrected

Velocity Corrected Event at 500 ms



MicroSeismic

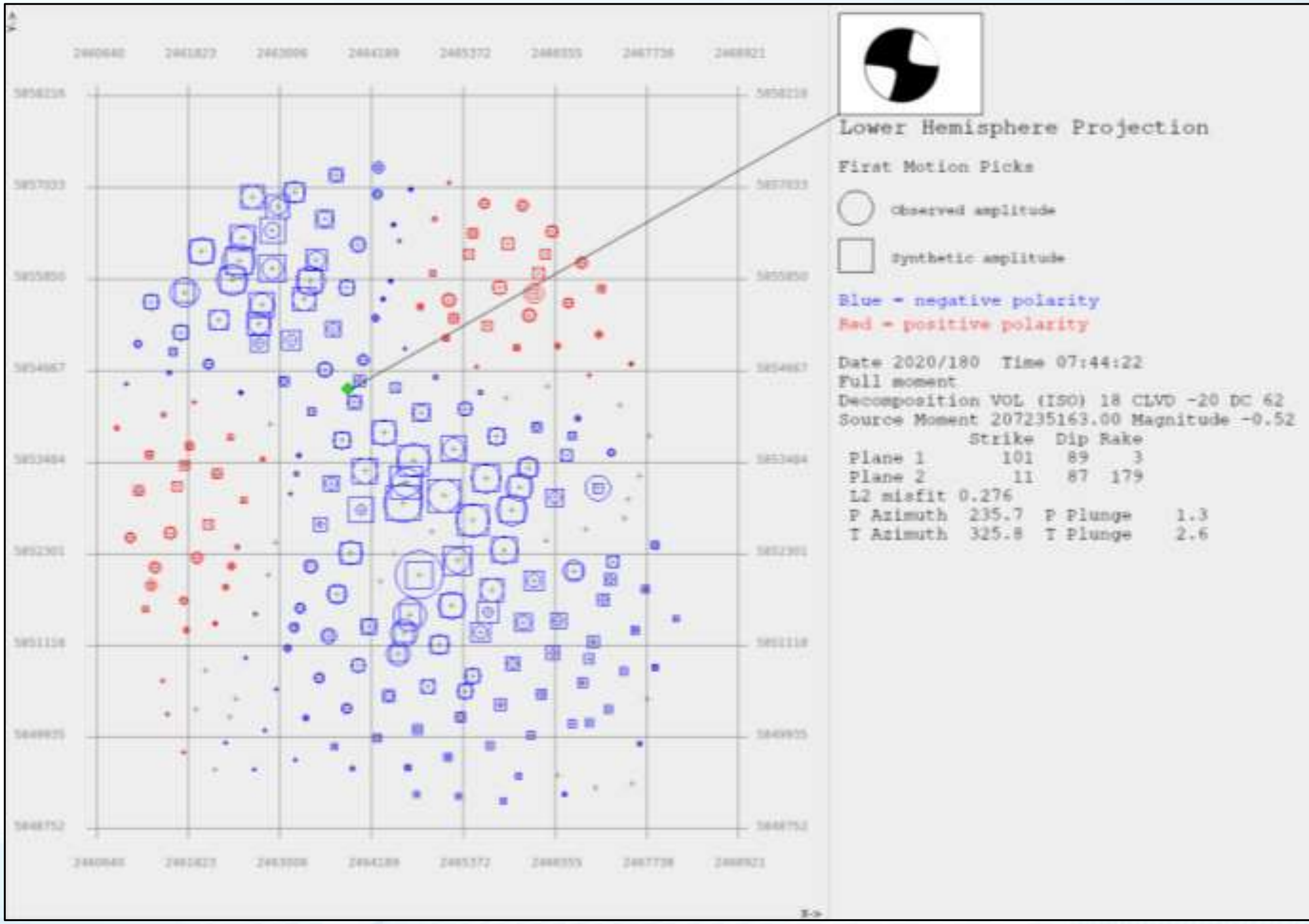
Source Mechanism – 2023h Stage 12 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
11	87	179

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.52



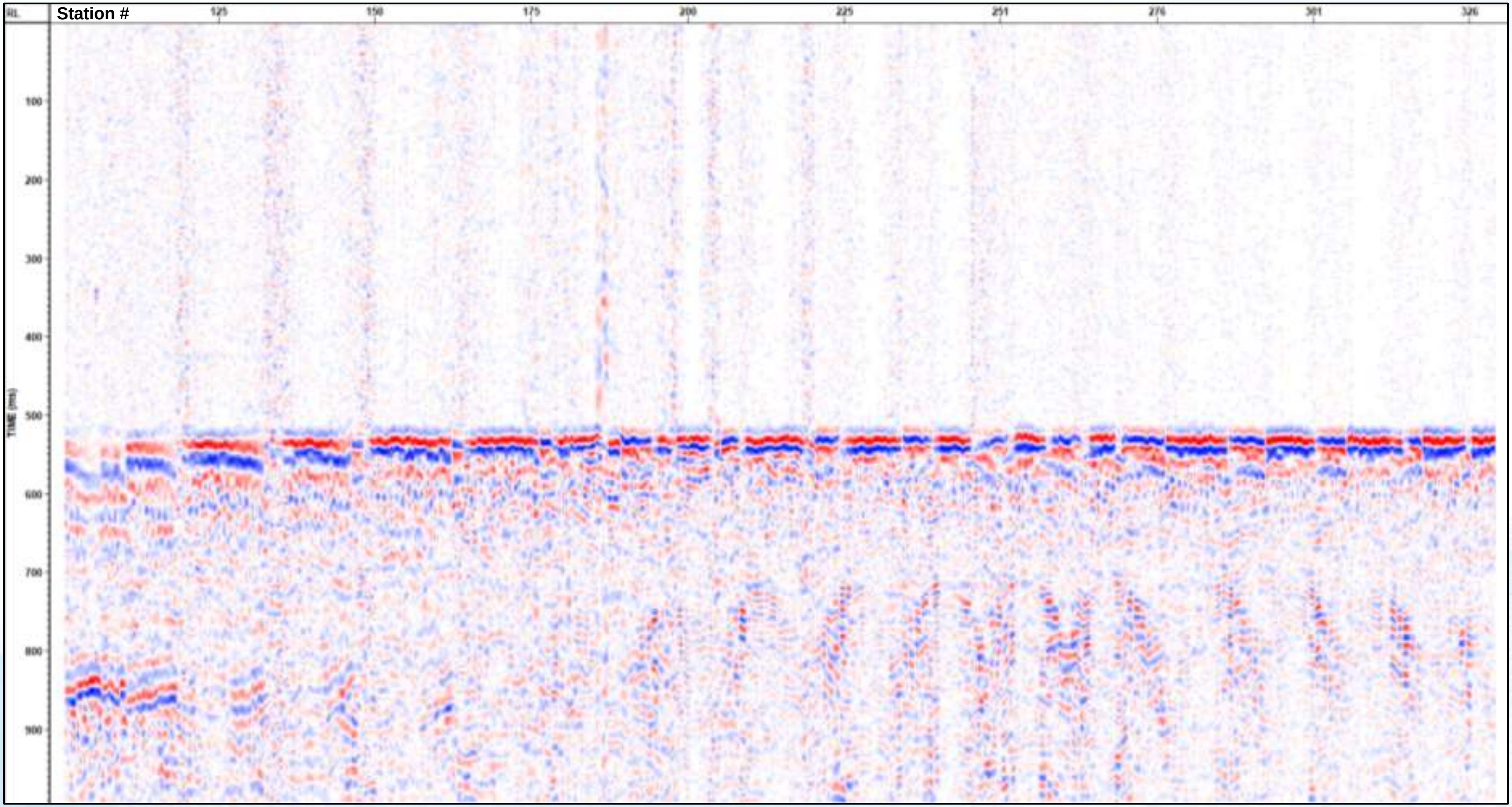
MicroSeismic

2023h Stage 12 Event – Processed Seismic

6/28/2020 07:44:21.184

No Mechanism Correction

Velocity Corrected Event at 500 ms

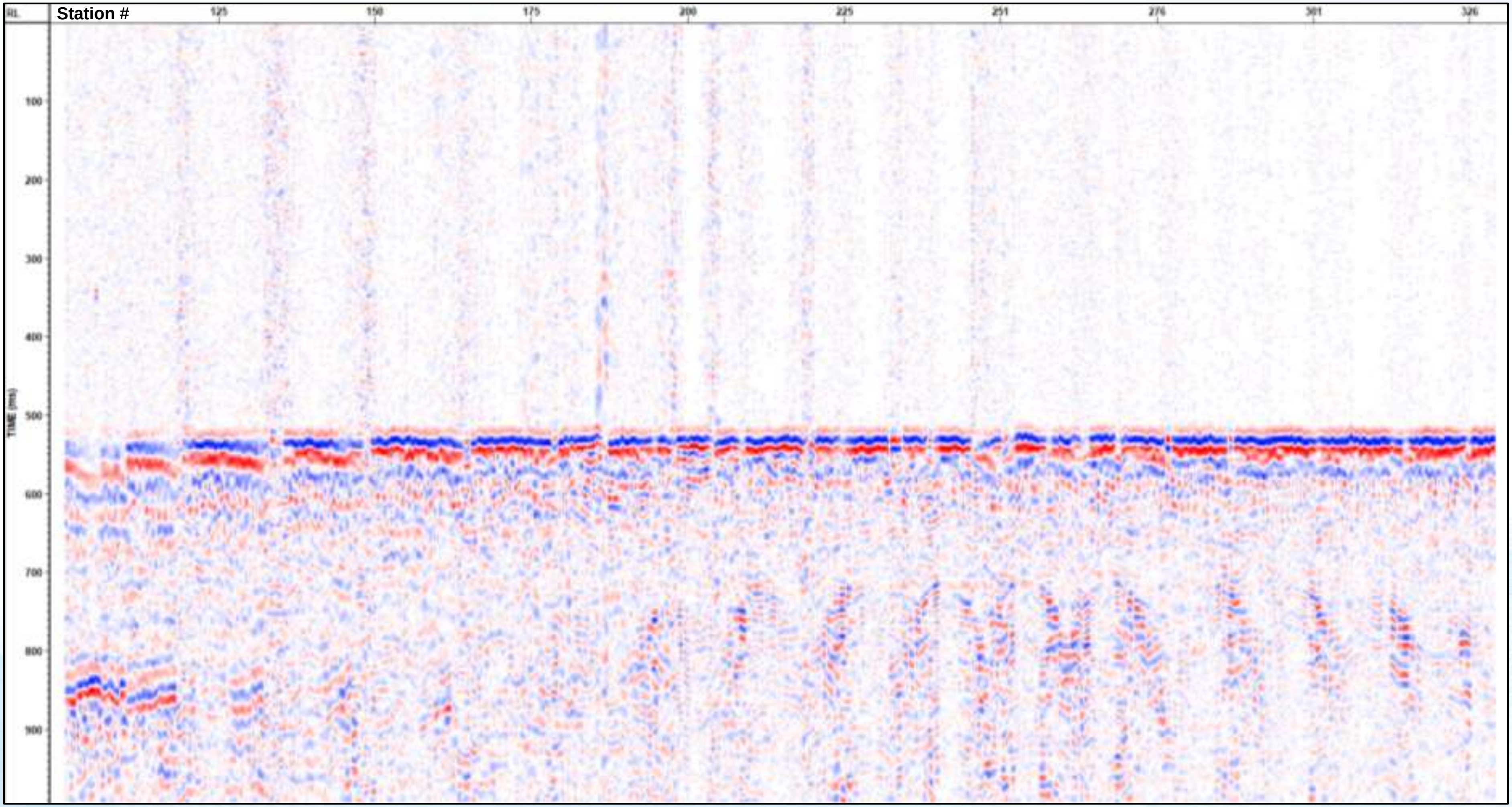


2023h Stage 12 Event – Processed Seismic

6/28/2020 07:44:21.184

Mechanism Corrected

Velocity Corrected Event at 500 ms



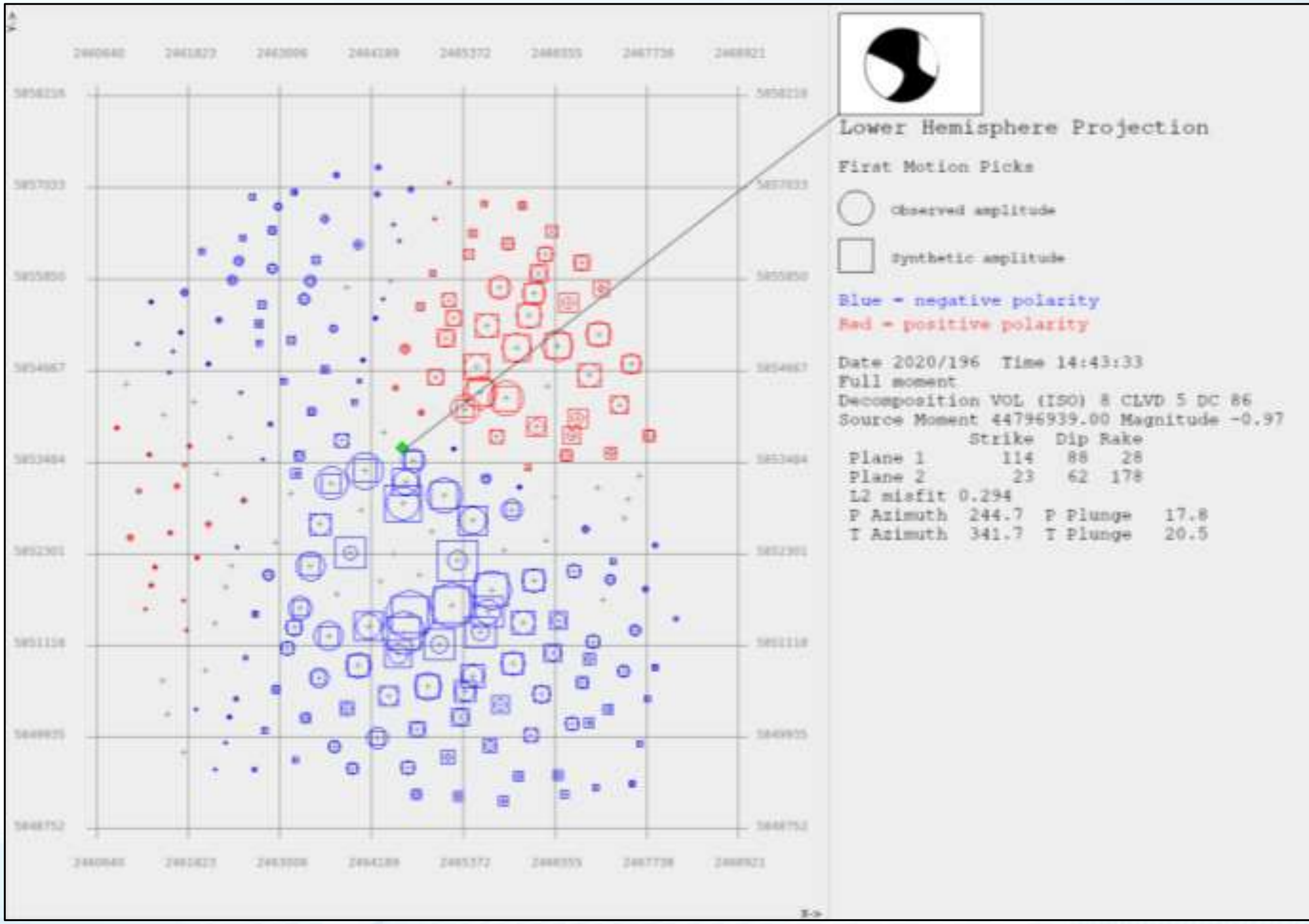
Source Mechanism – 2021h Stage 31 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
23	62	178

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.97

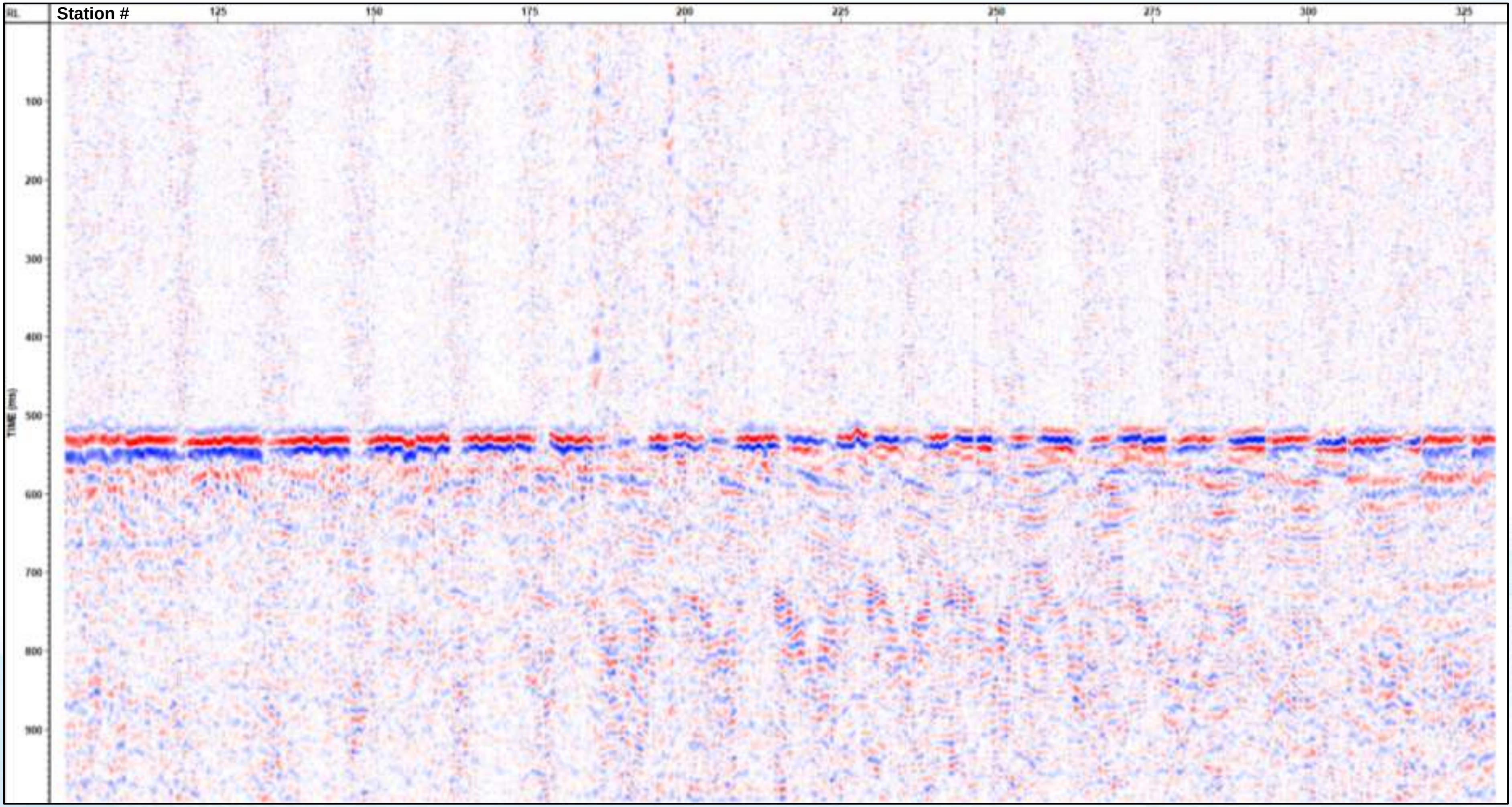


2021h Stage 31 Event – Processed Seismic

7/14/2020 14:43:32.608

No Mechanism Correction

Velocity Corrected Event at 500 ms



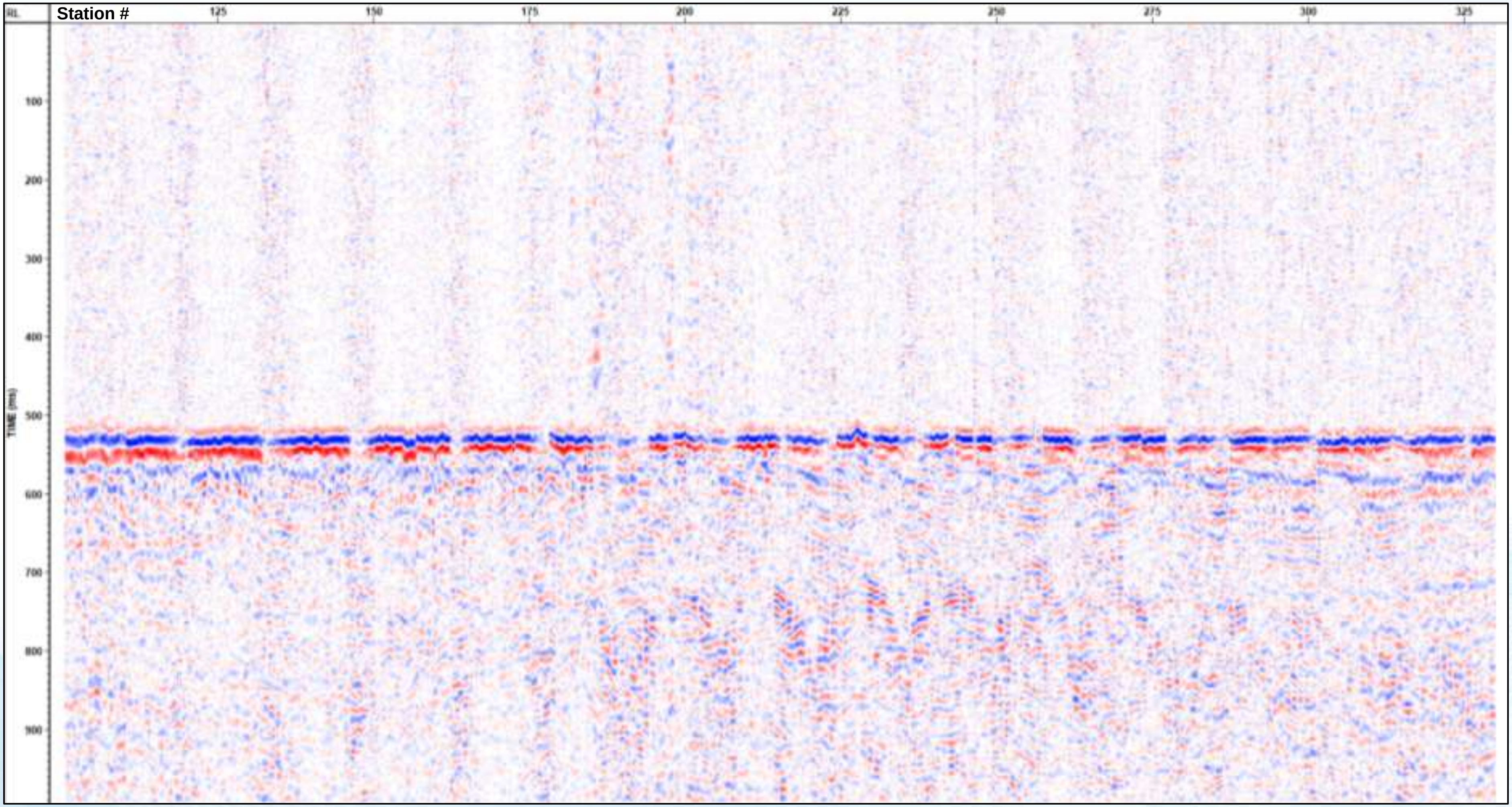
MicroSeismic

2021h Stage 31 Event – Processed Seismic

7/14/2020 14:43:32.608

Mechanism Corrected

Velocity Corrected Event at 500 ms



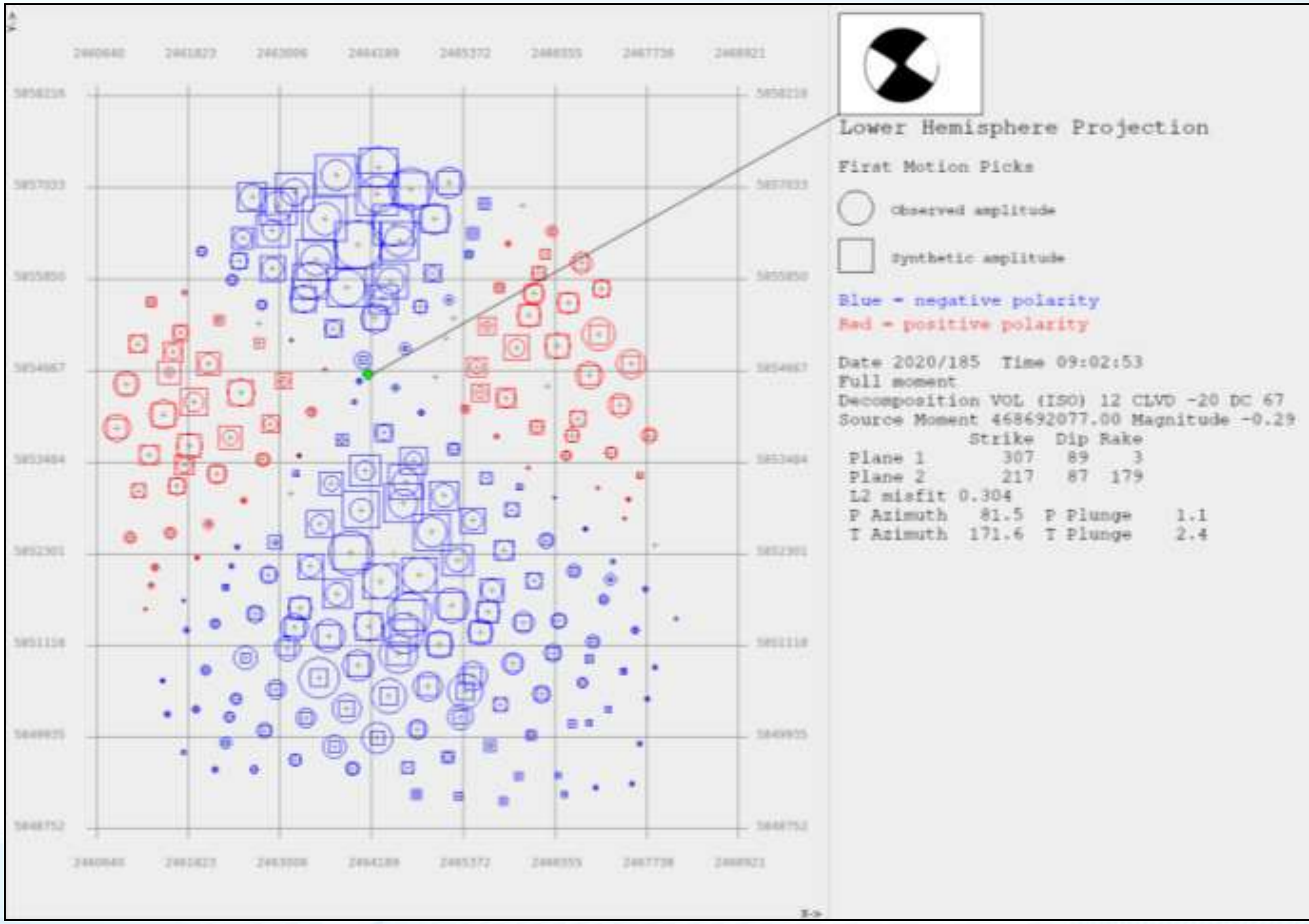
Source Mechanism – 2023h Stage 20 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
217	87	179

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.29

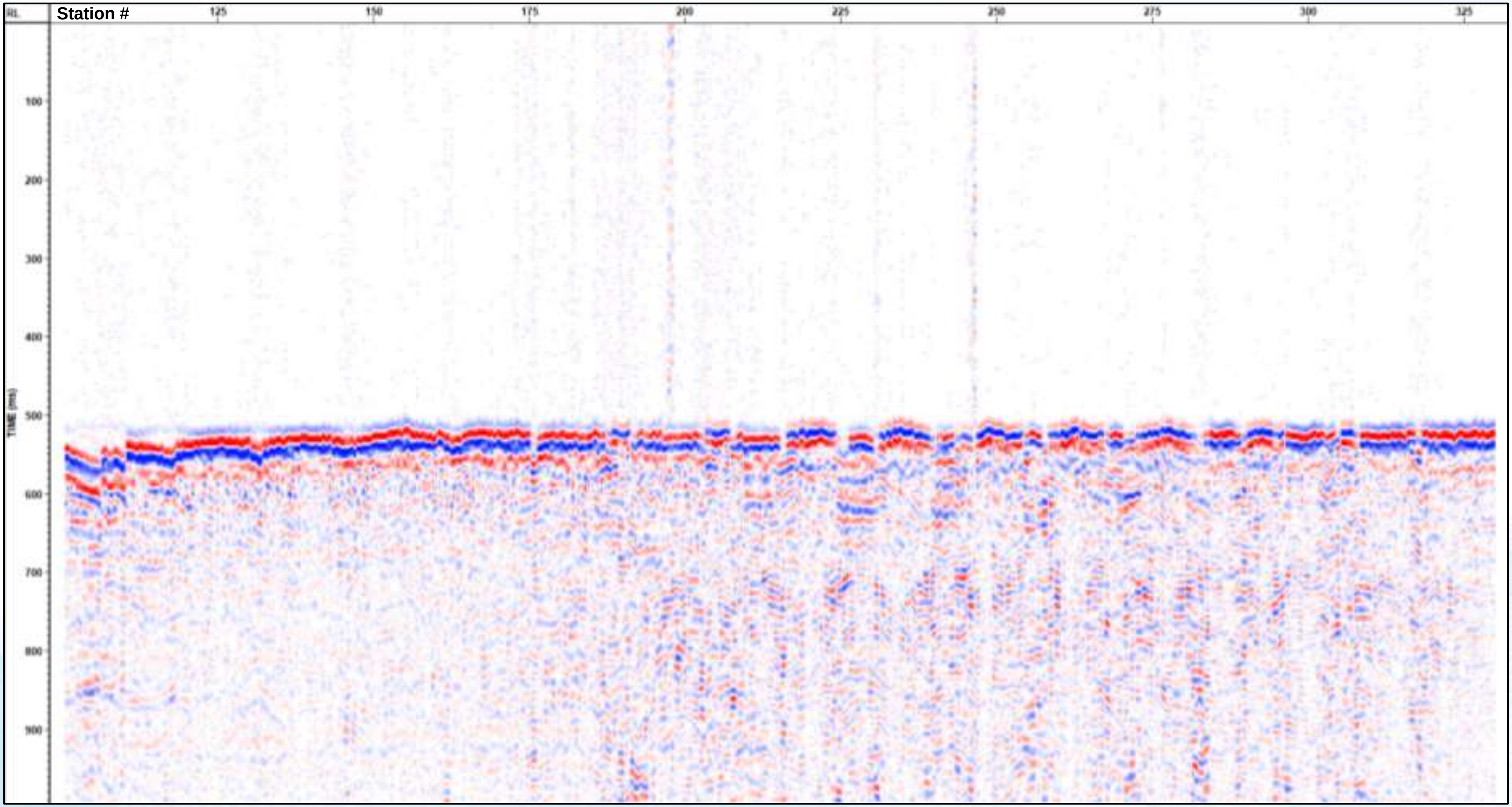


2023h Stage 20 Event – Processed Seismic

7/03/2020 09:02:52.756

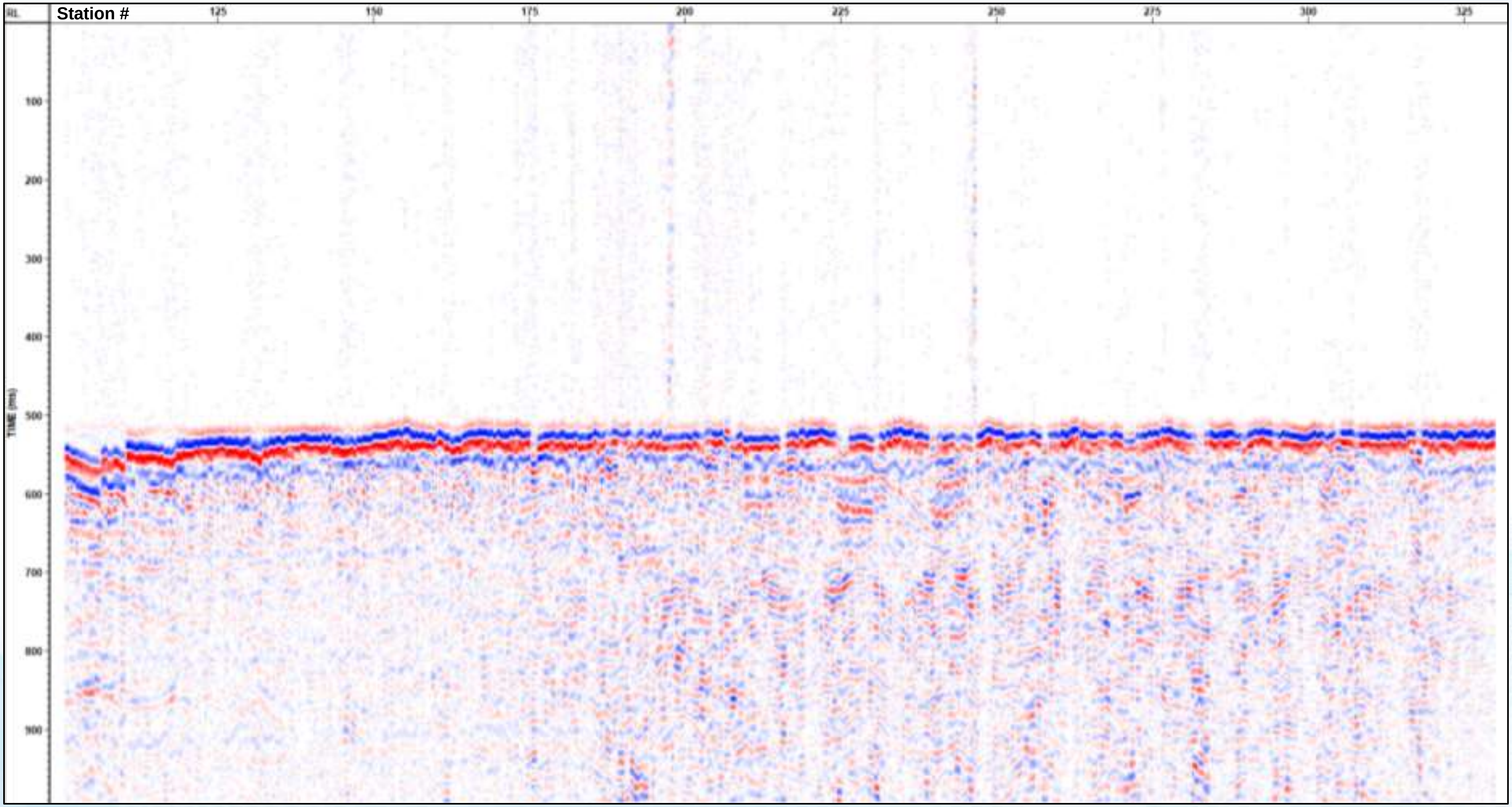
No Mechanism Correction

Velocity Corrected Event at 500 ms



2023h Stage 20 Event – Processed Seismic

7/03/2020 09:02:52.756 **Mechanism Corrected** Velocity Corrected Event at 500 ms



MicroSeismic

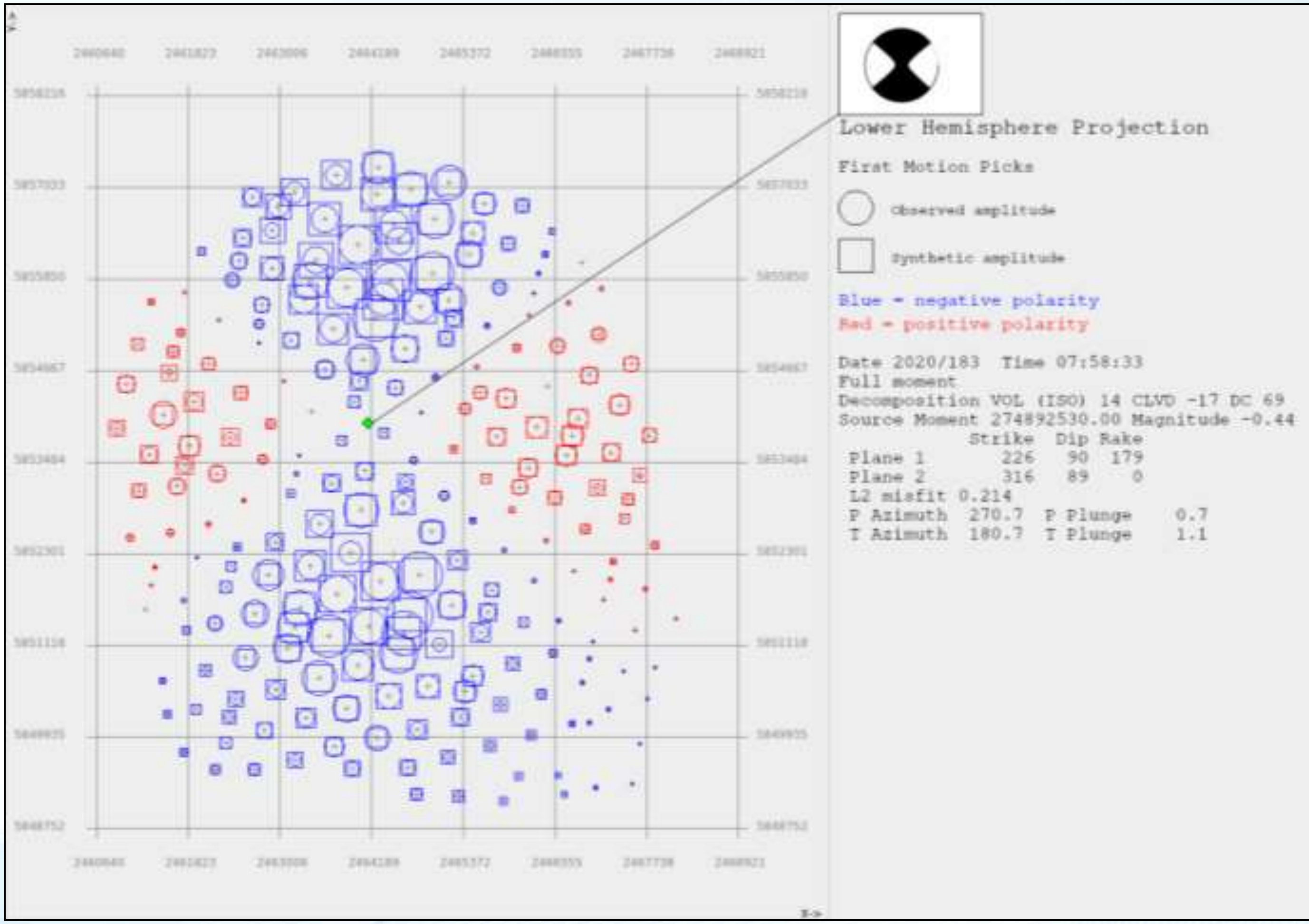
Source Mechanism – 2023h Stage 17 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
226	90	179

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.44



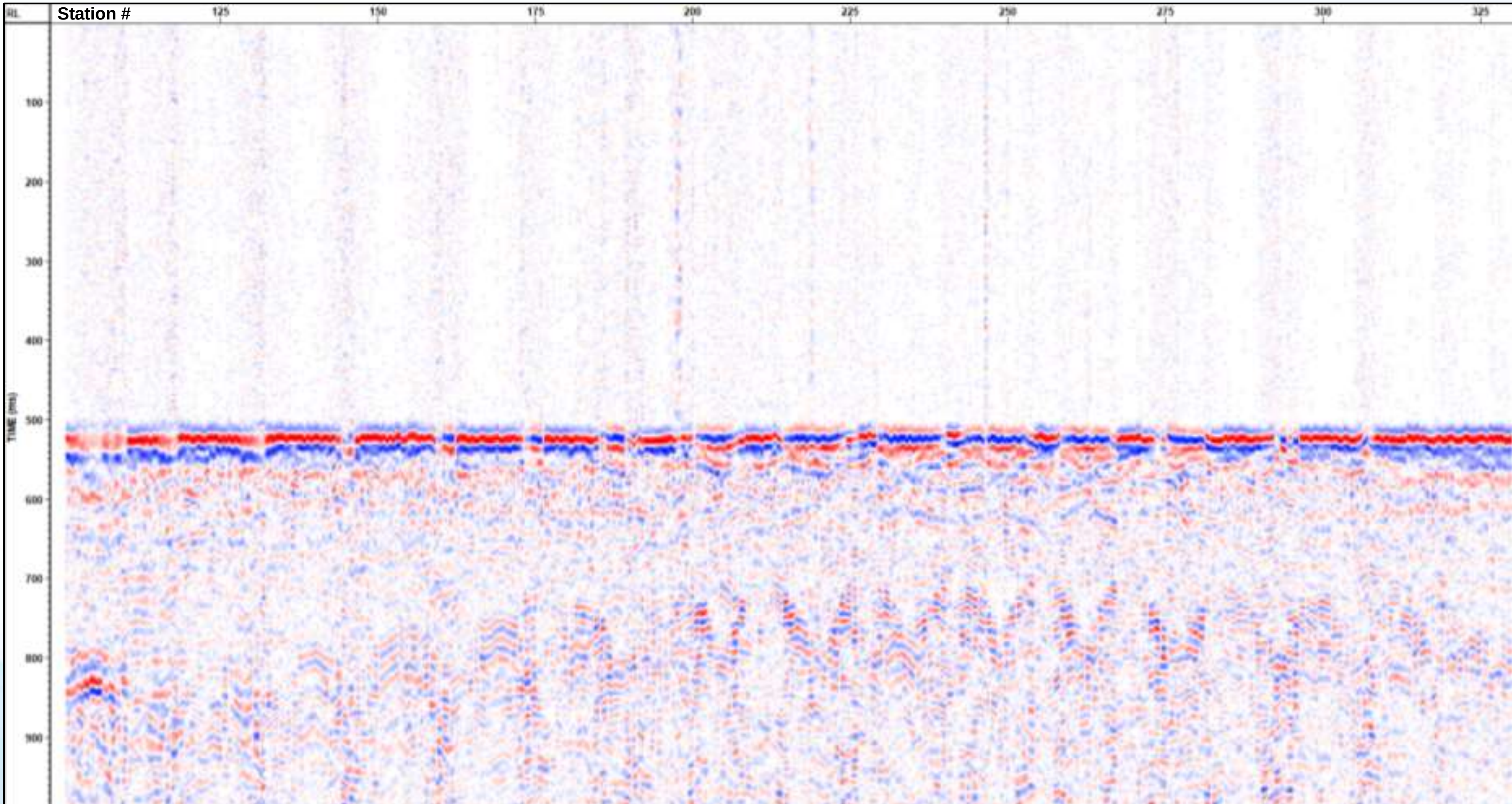
MicroSeismic

2023h Stage 17 Event – Processed Seismic

7/01/2020 07:58:32.668

No Mechanism Correction

Velocity Corrected Event at 500 ms



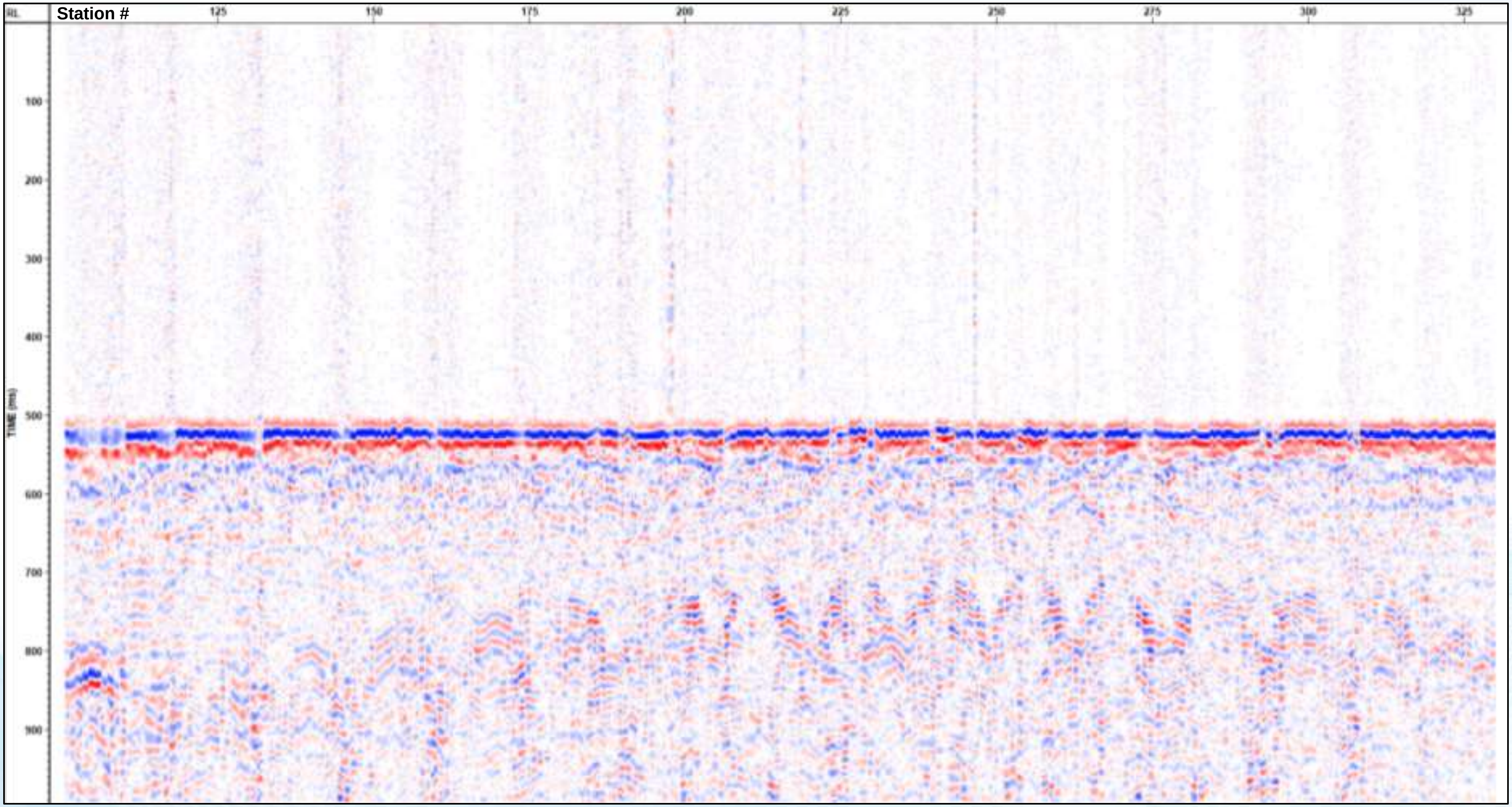
MicroSeismic

2023h Stage 17 Event – Processed Seismic

7/01/2020 07:58:32.668

Mechanism Corrected

Velocity Corrected Event at 500 ms



MicroSeismic

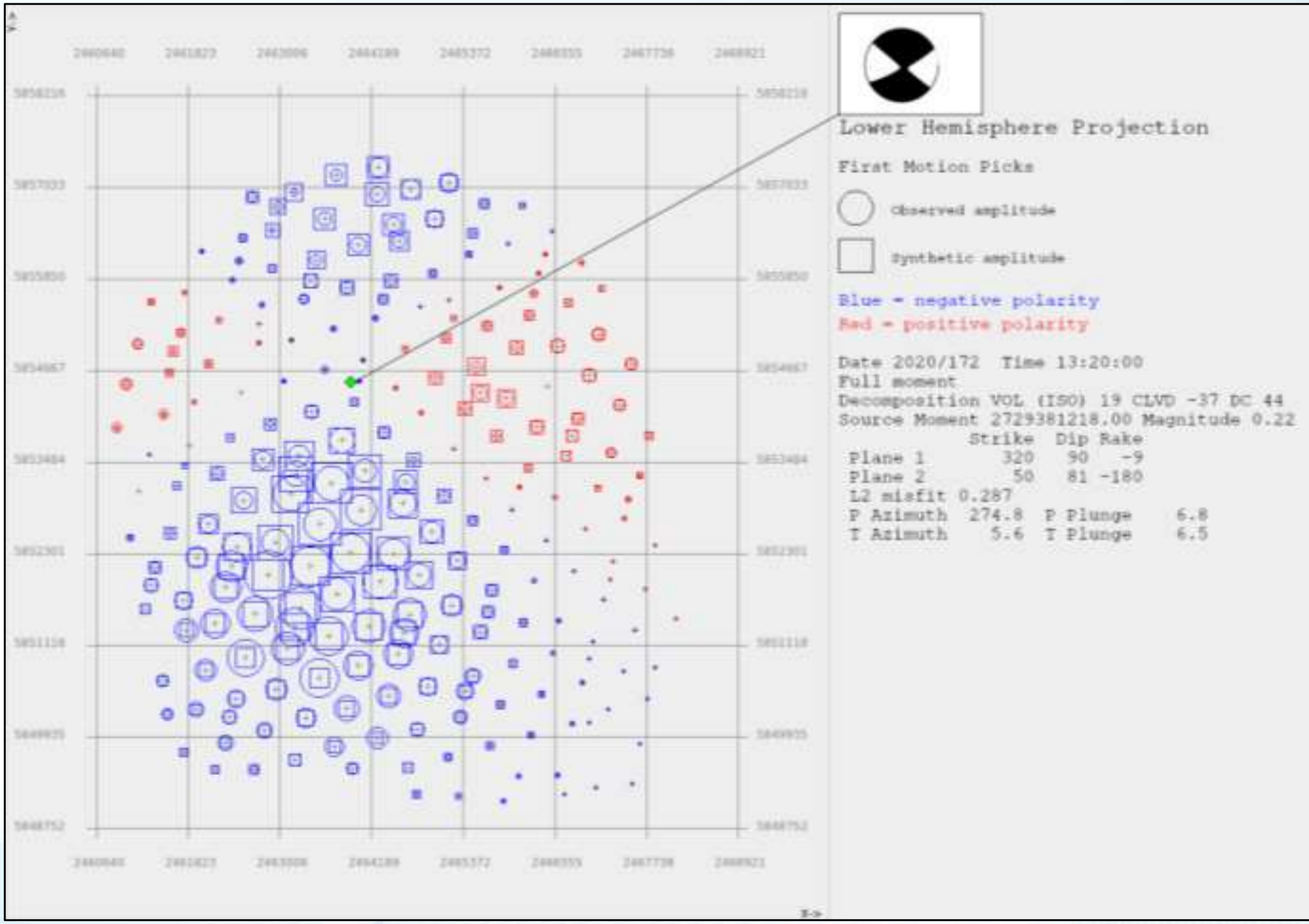
Source Mechanism – 2023h Stage 7 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
50	81	-180

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: 0.22



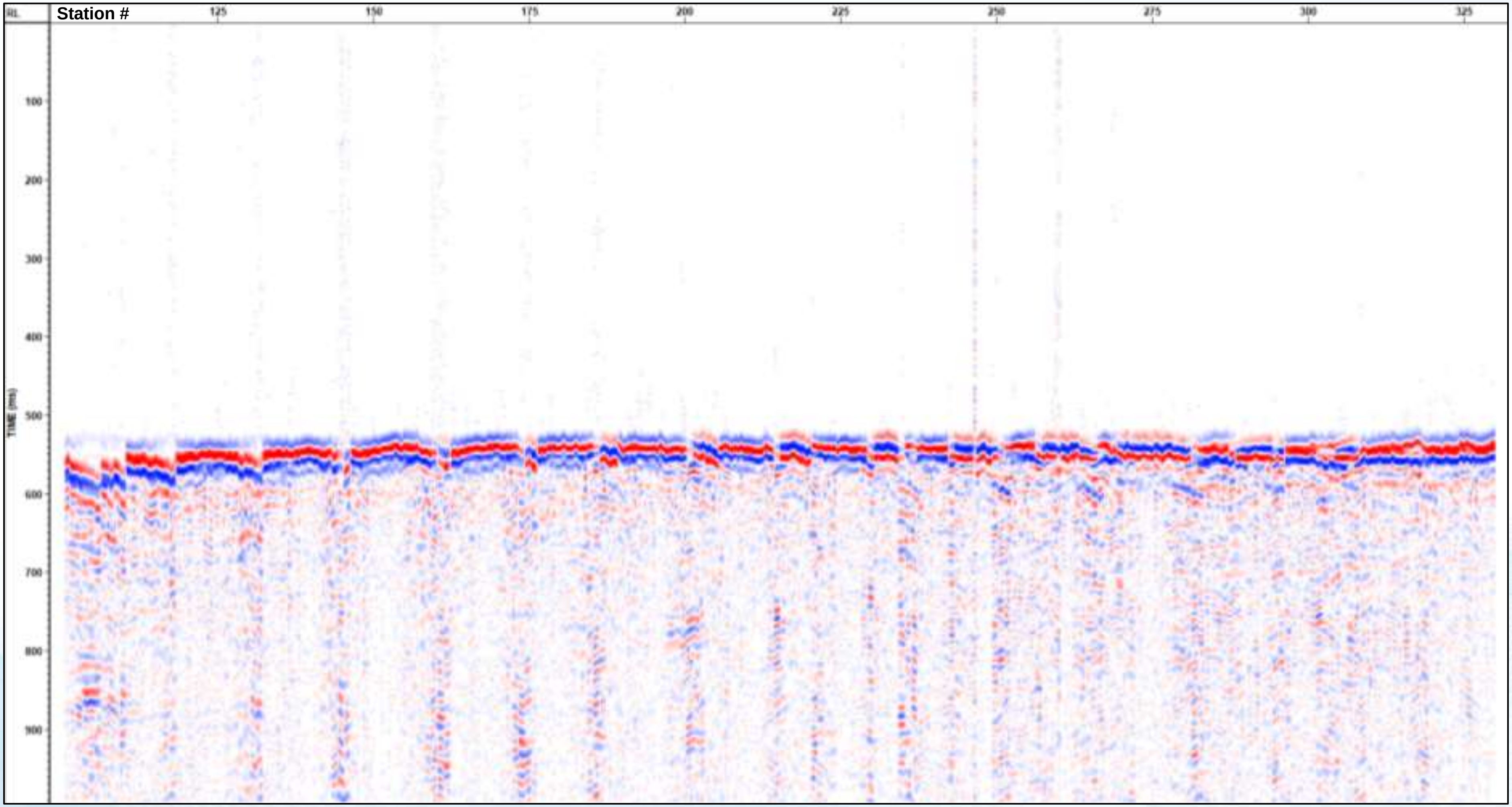
MicroSeismic

2023h Stage 7 Event – Processed Seismic

6/20/2020 13:19:59.652

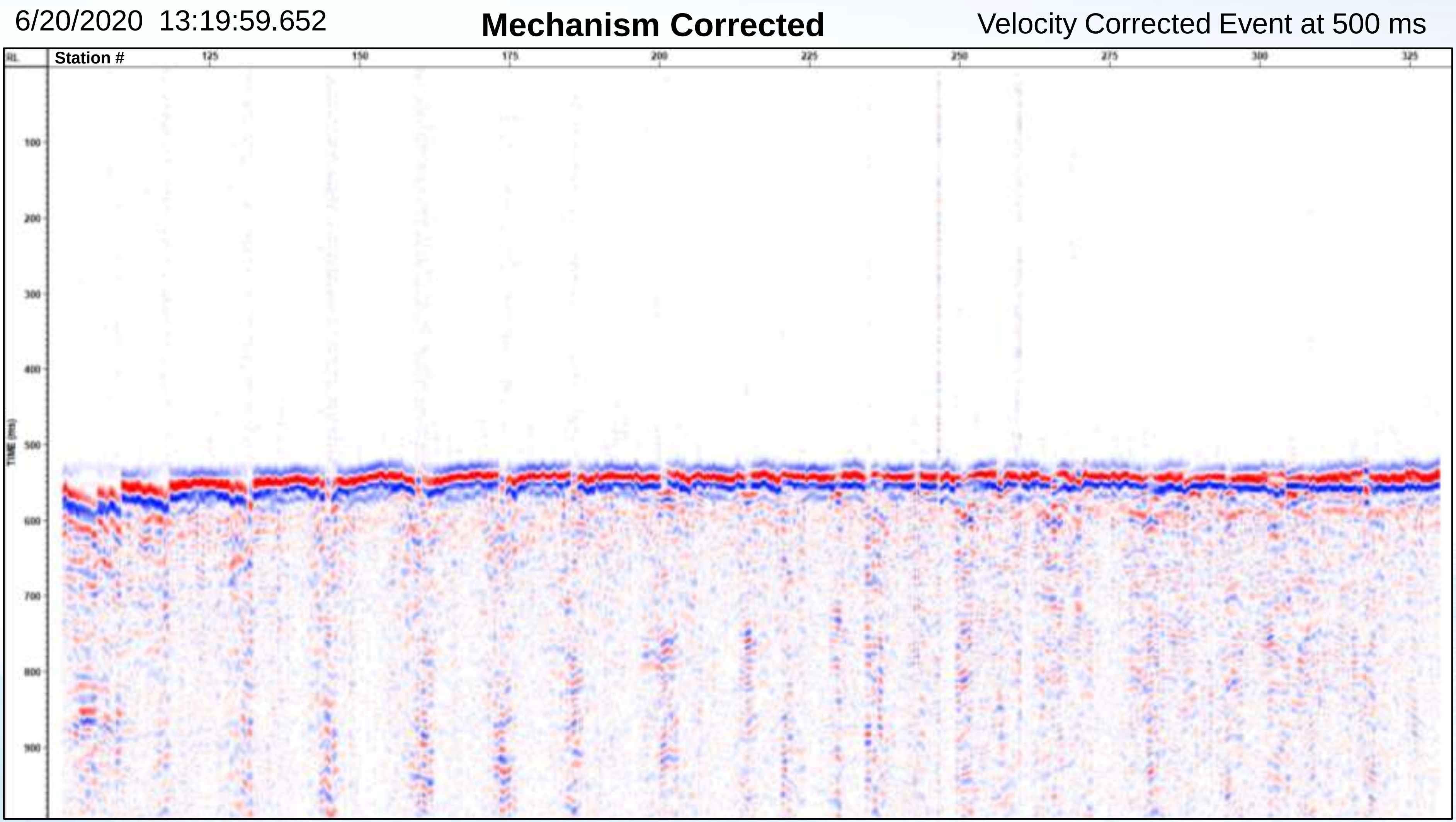
No Mechanism Correction

Velocity Corrected Event at 500 ms



MicroSeismic

2023h Stage 7 Event – Processed Seismic



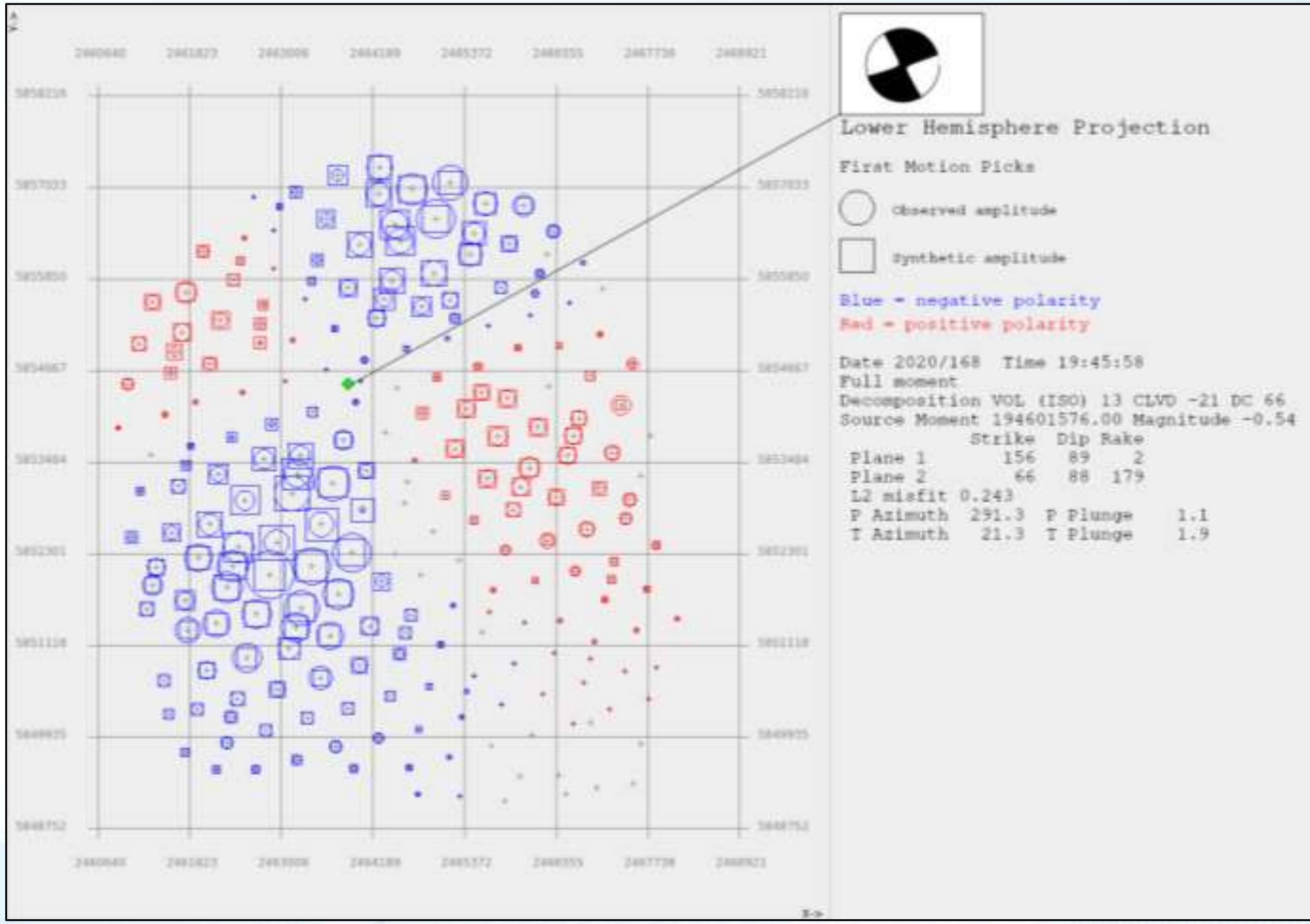
Source Mechanism – 2023h Stage 3 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
66	88	179

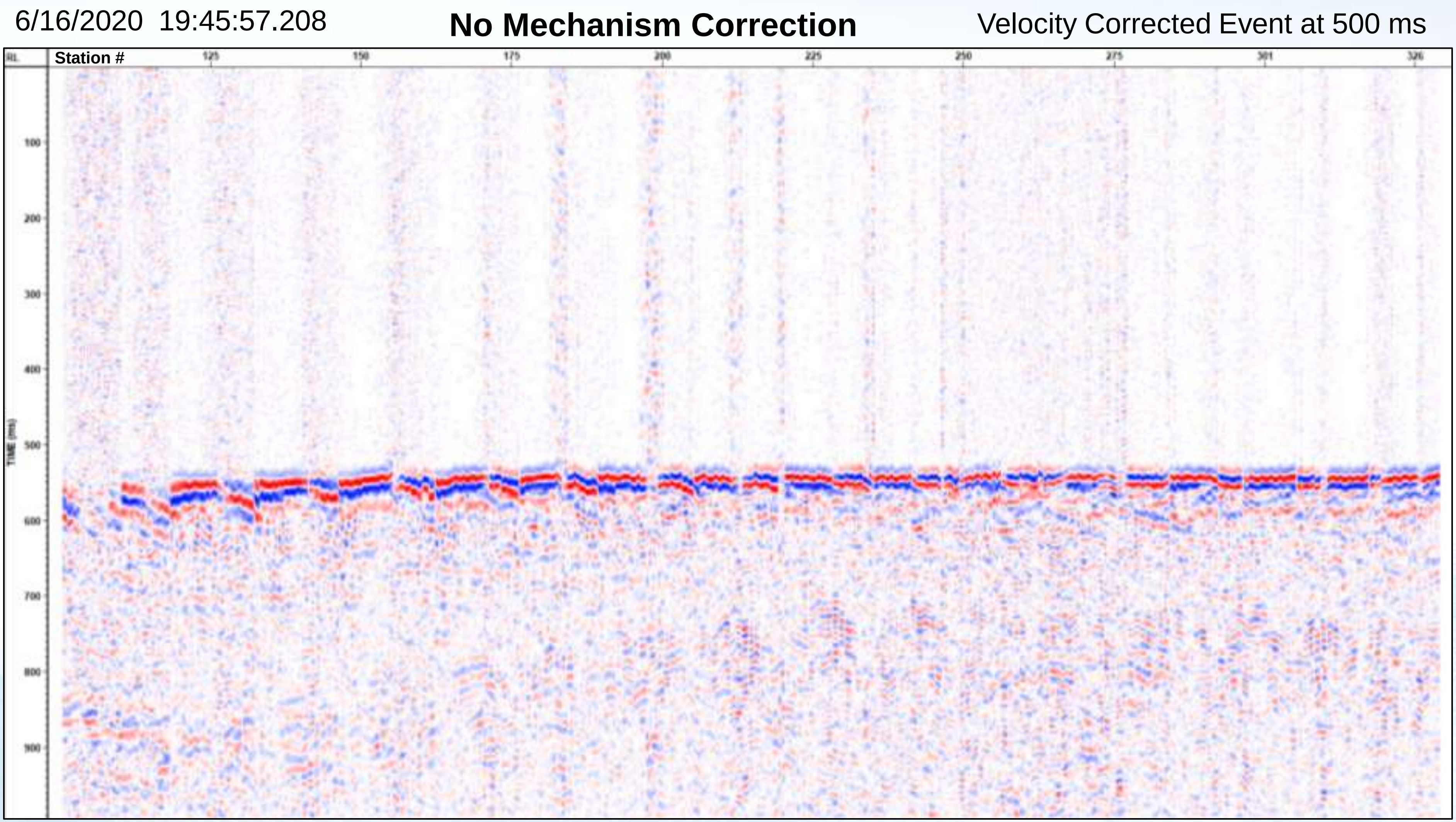
- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.54



MicroSeismic

2023h Stage 3 Event – Processed Seismic

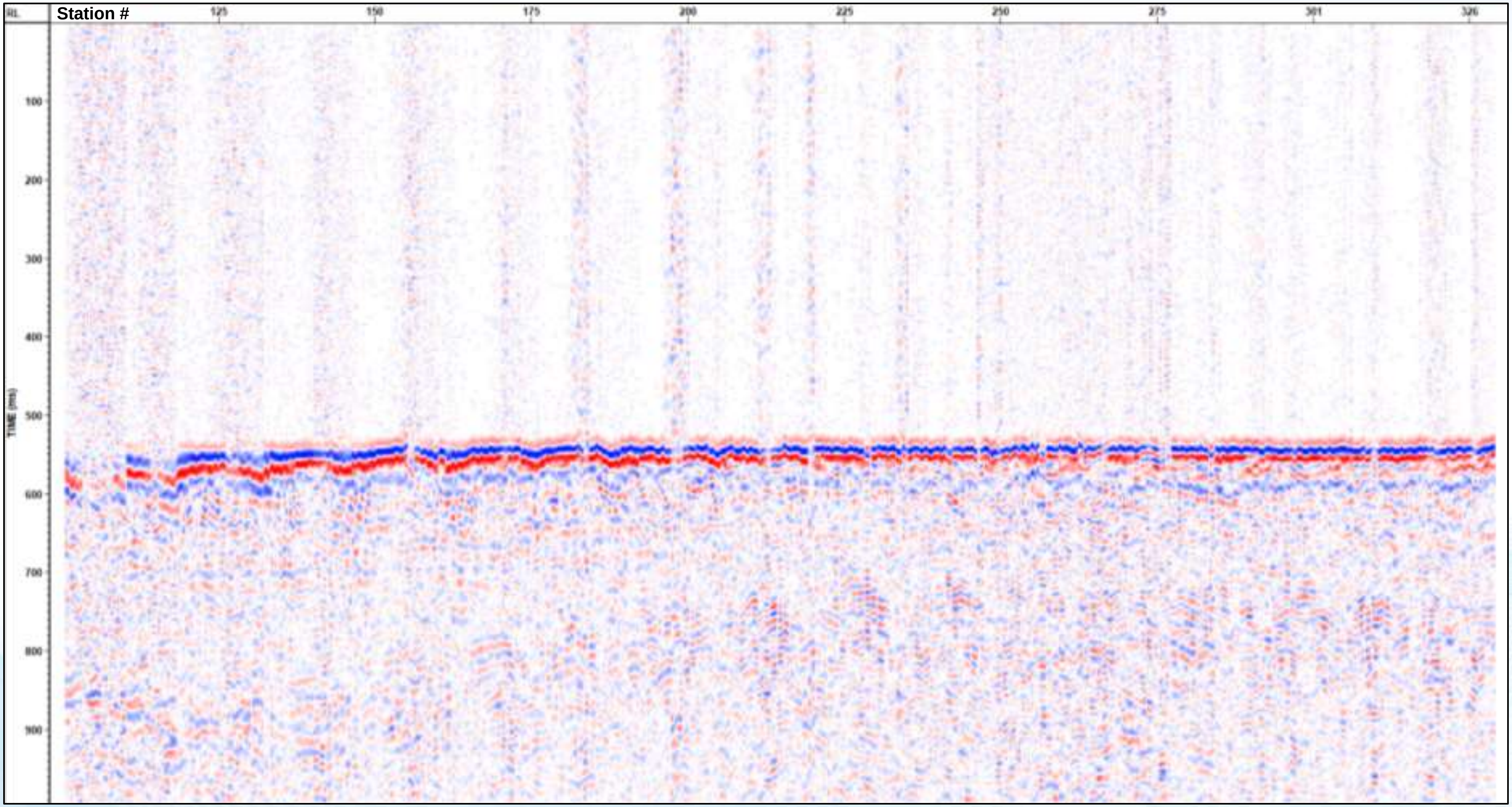


2023h Stage 3 Event – Processed Seismic

6/16/2020 19:45:57.208

Mechanism Corrected

Velocity Corrected Event at 500 ms



Source Mechanism – 2023h Stage 21 Event

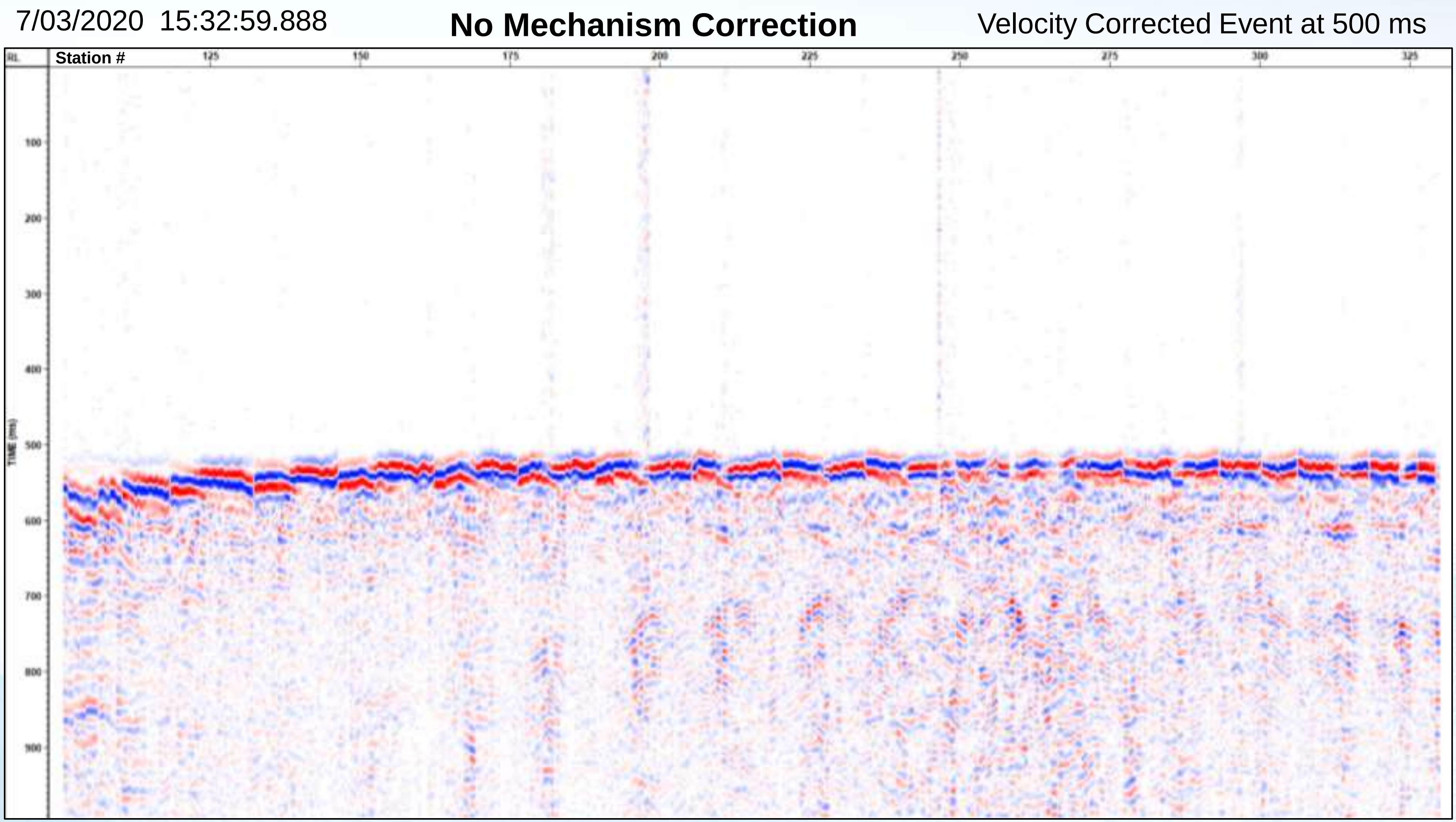
- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
269	89	-1

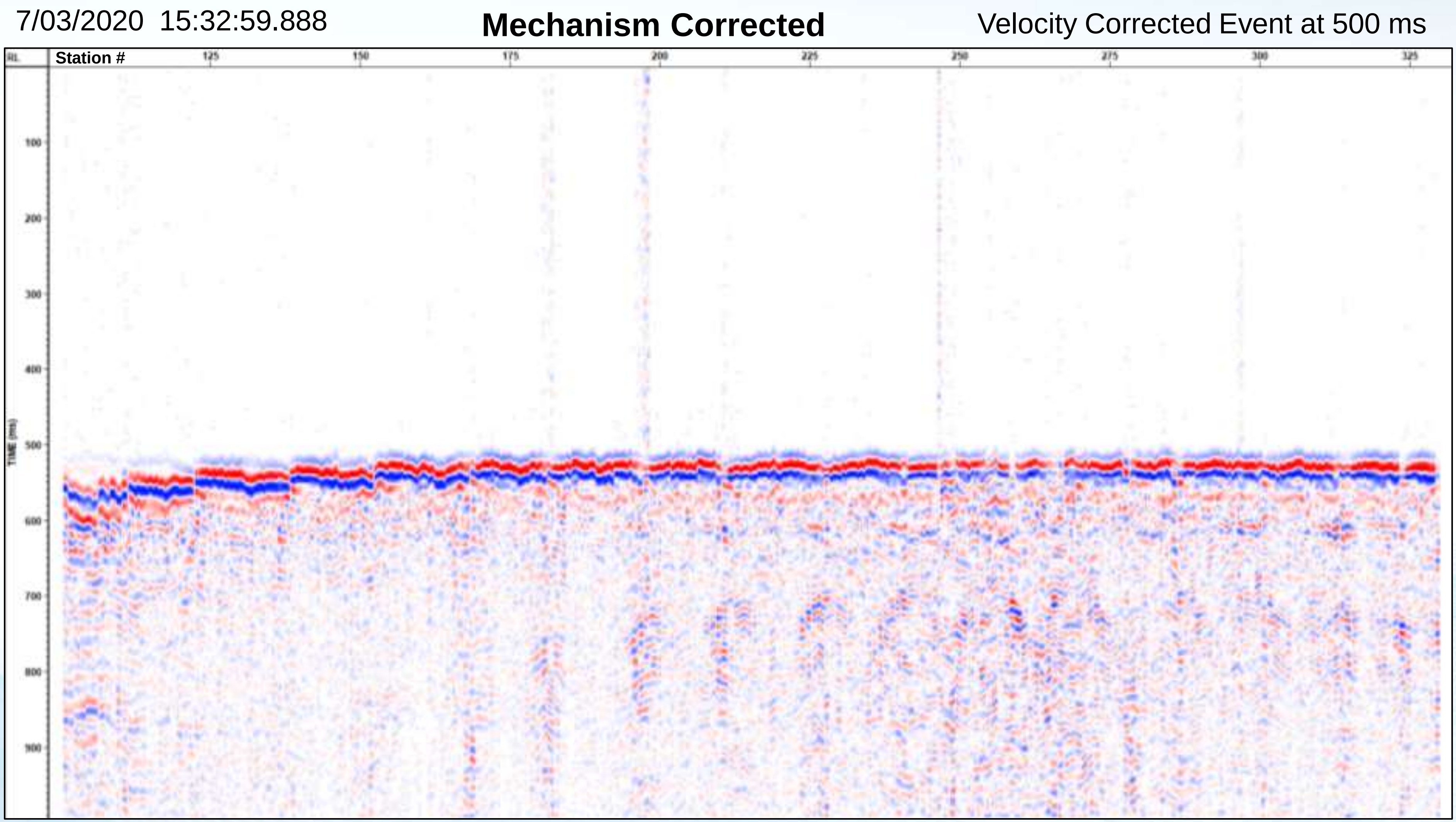
- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.18

2023h Stage 21 Event – Processed Seismic



2023h Stage 21 Event – Processed Seismic



MicroSeismic

Source Mechanisms

2022h & 2024h

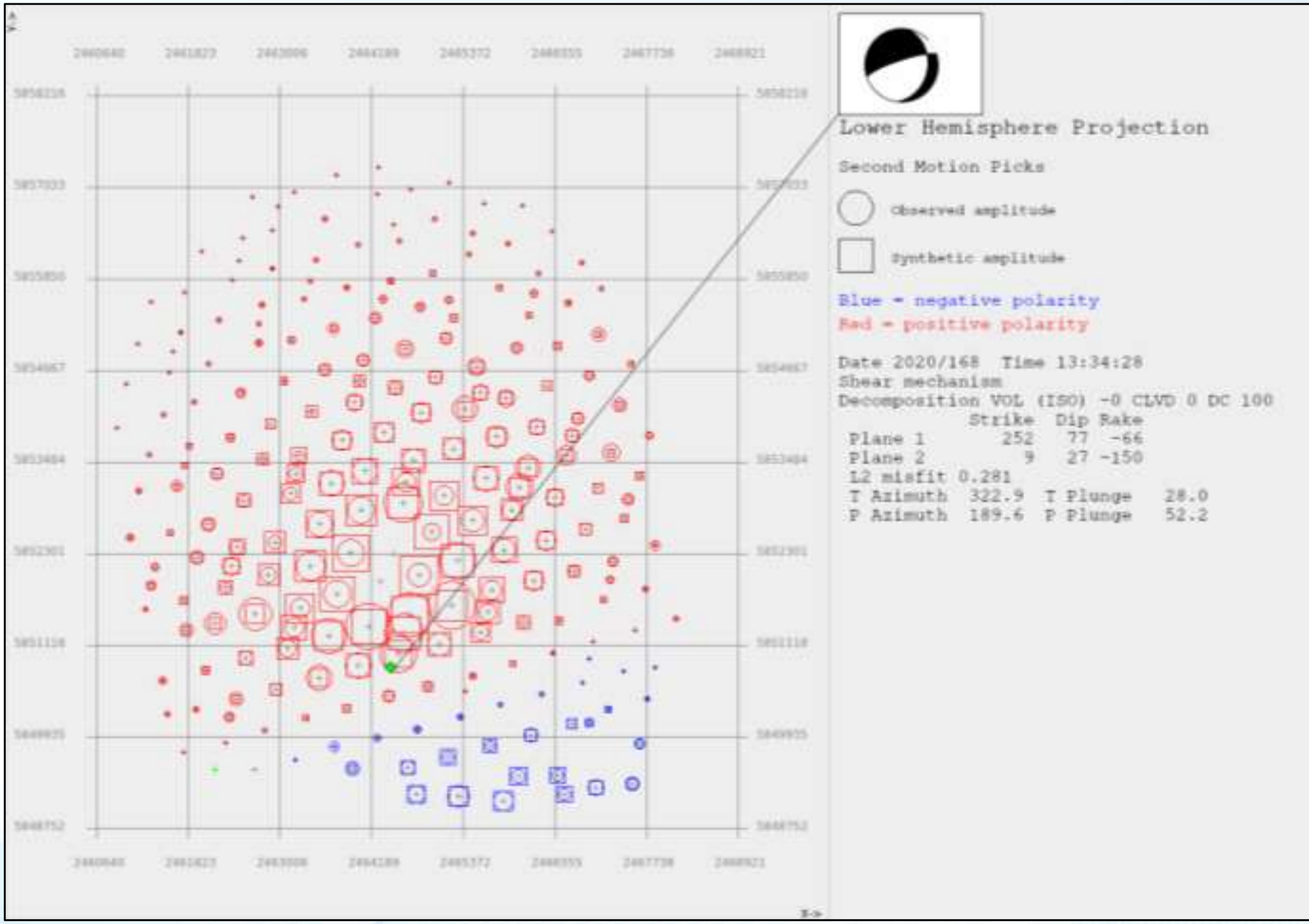
MicroSeismic

Source Mechanism – 2022h Stage 4 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
252	77	-66

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.



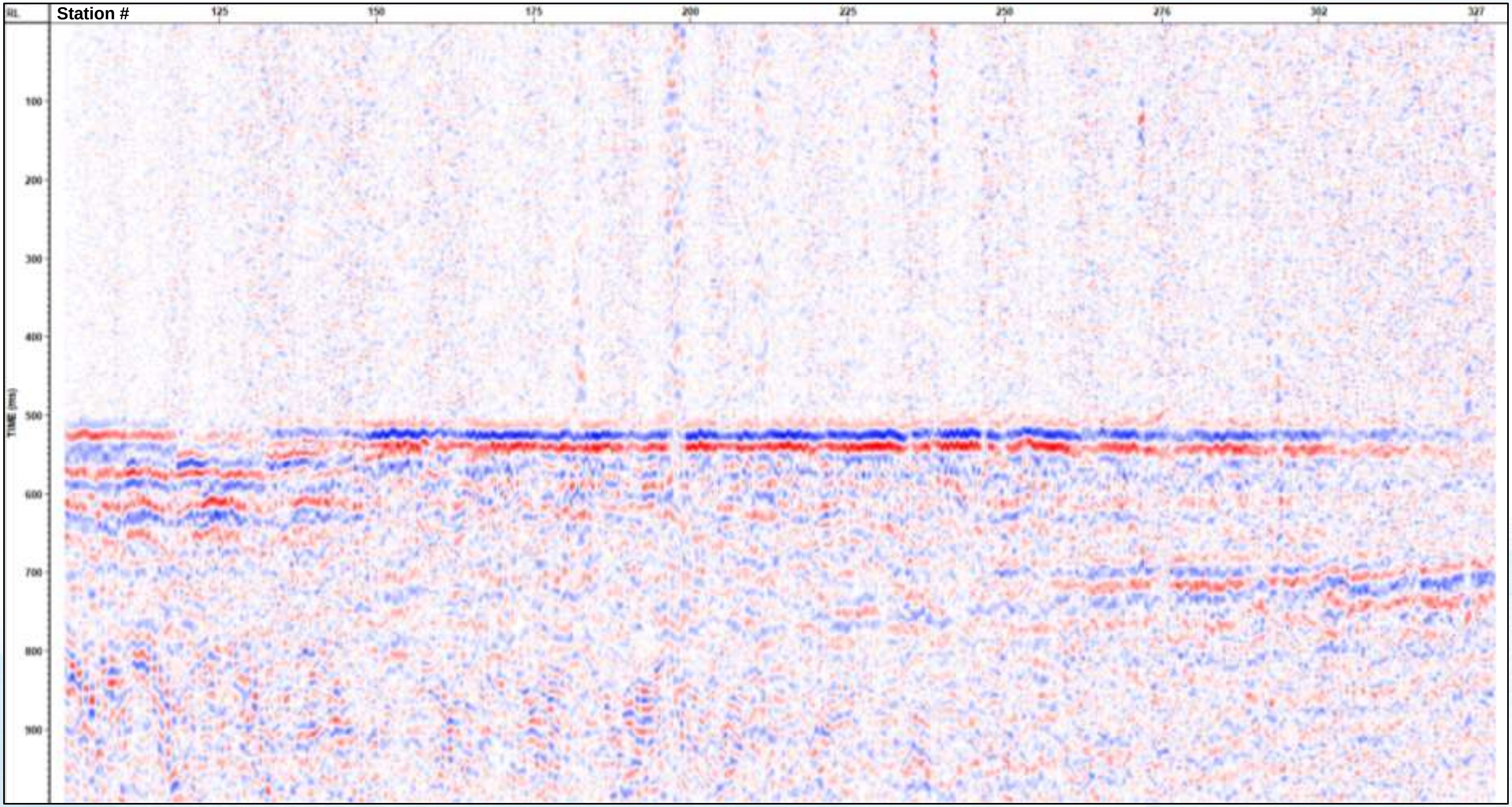
MicroSeismic

2022h Stage 4 Event – Processed Seismic

6/16/2020 13:34:28.312

No Mechanism Correction

Velocity Corrected Event at 500 ms

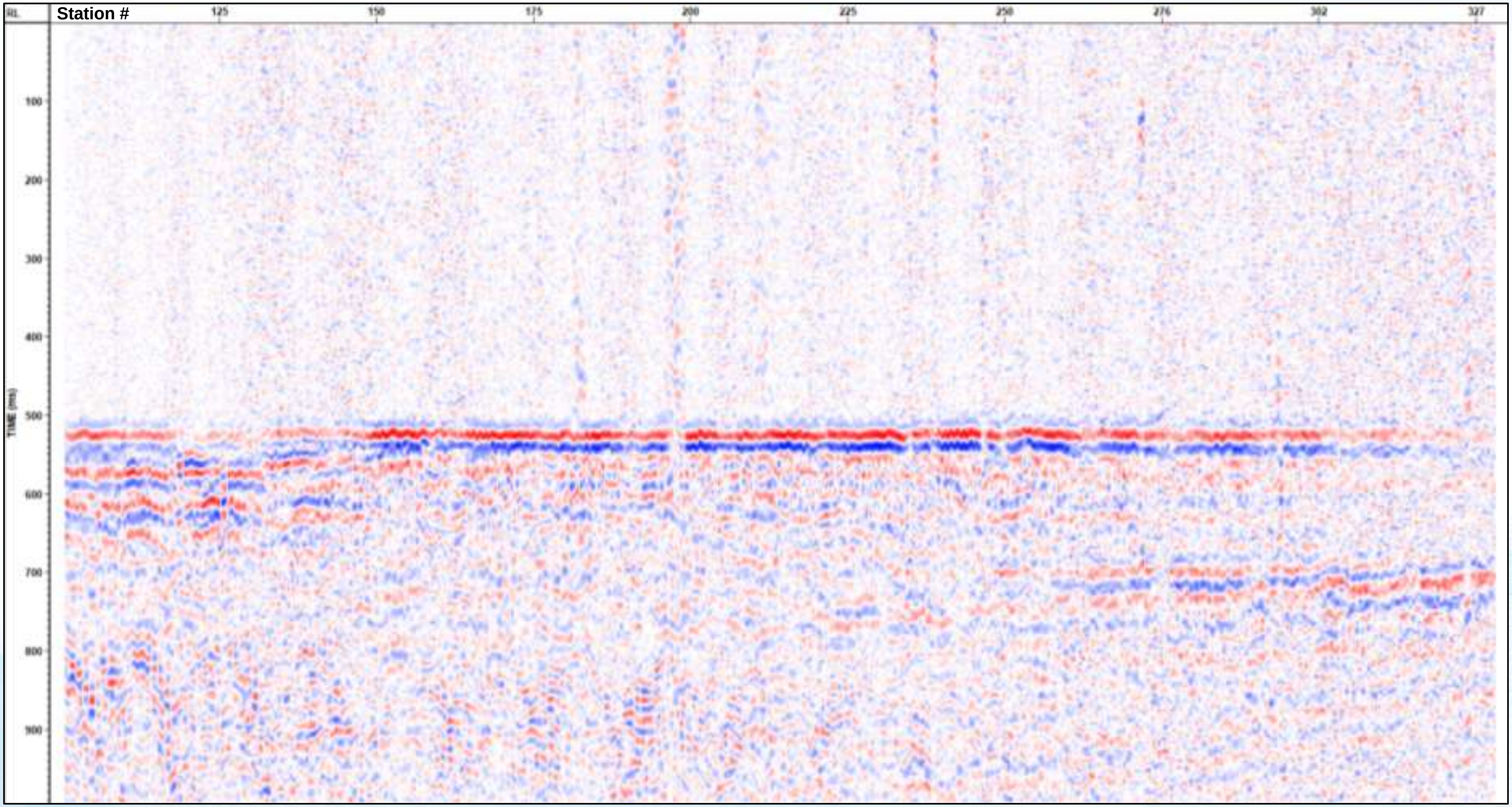


2022h Stage 4 Event – Processed Seismic

6/16/2020 13:34:28.312

Mechanism Corrected

Velocity Corrected Event at 500 ms



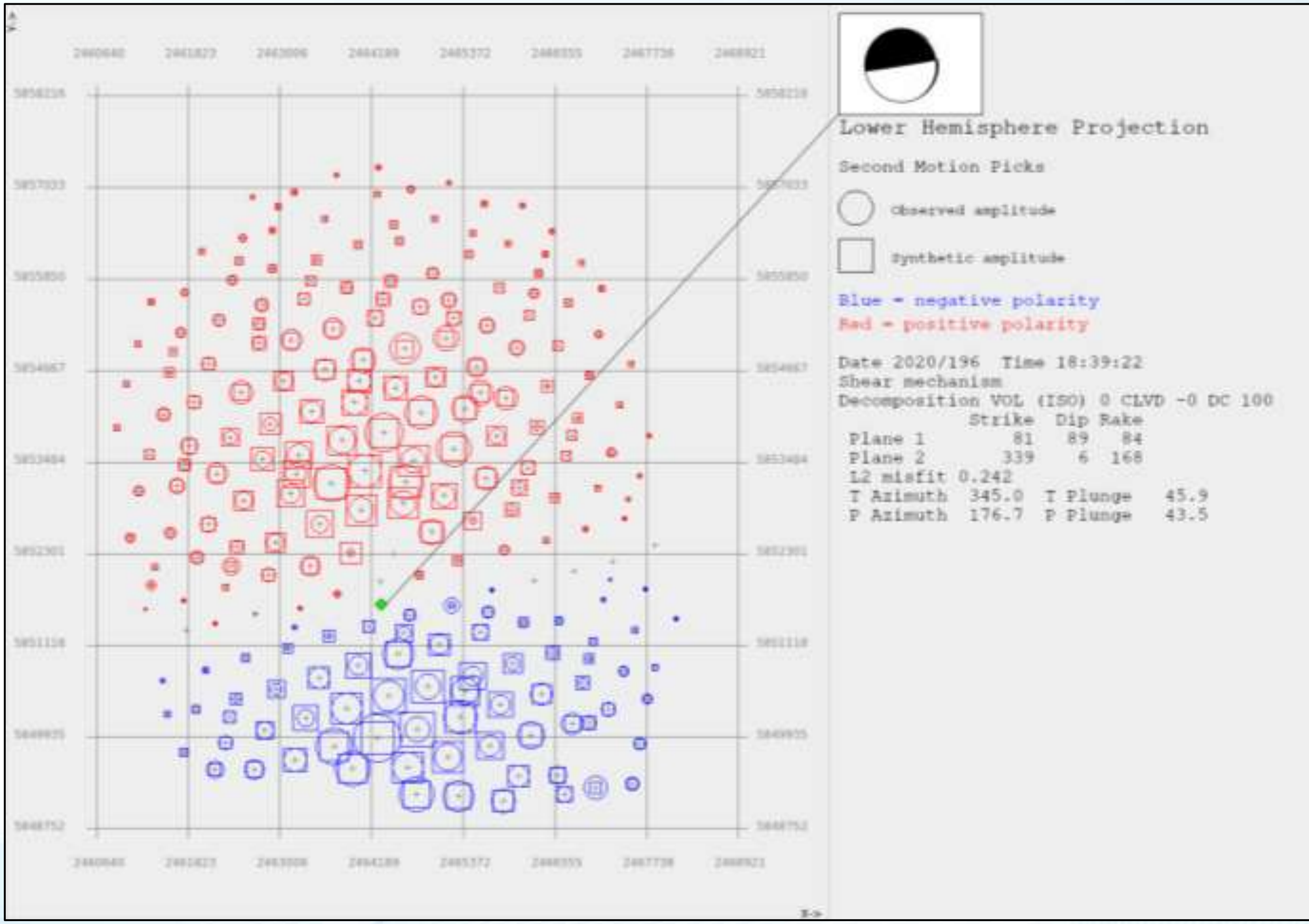
MicroSeismic

Source Mechanism – 2022h Stage 15 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
81	89	84

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.



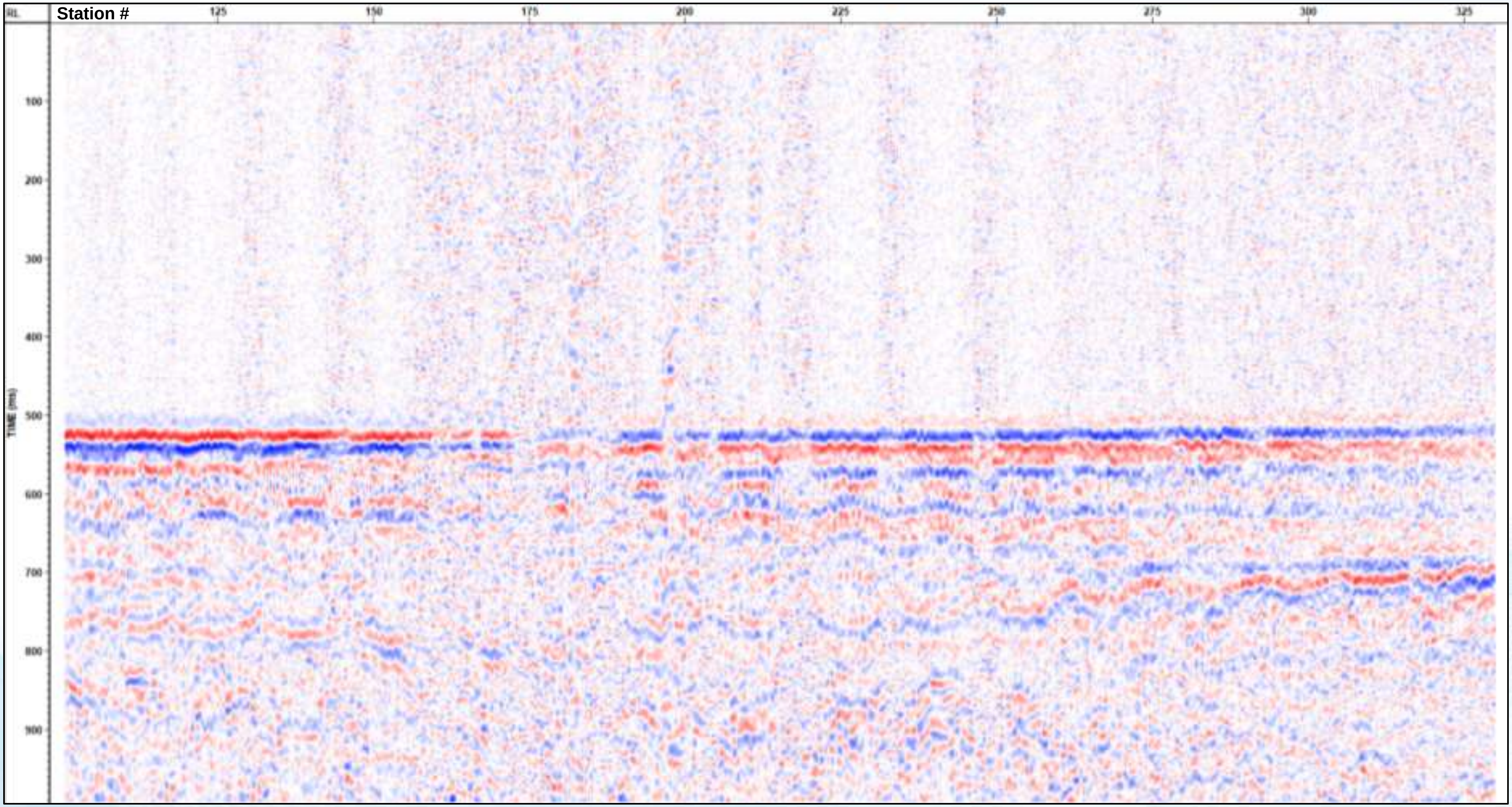
MicroSeismic

2022h Stage 15 Event – Processed Seismic

7/14/2020 18:39:22.300

No Mechanism Correction

Velocity Corrected Event at 500 ms



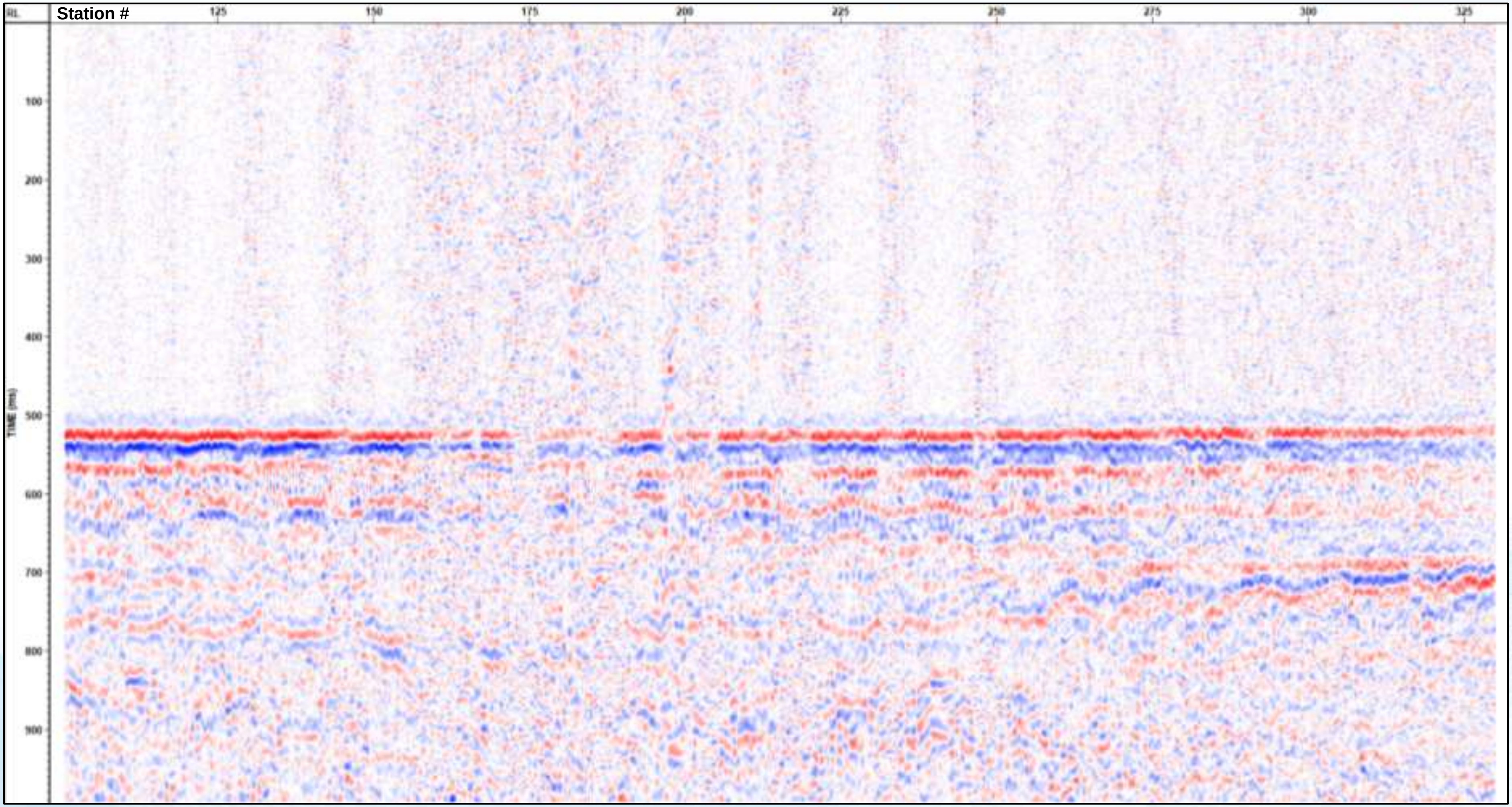
MicroSeismic

2022h Stage 15 Event – Processed Seismic

7/14/2020 18:39:22.300

Mechanism Corrected

Velocity Corrected Event at 500 ms



MicroSeismic

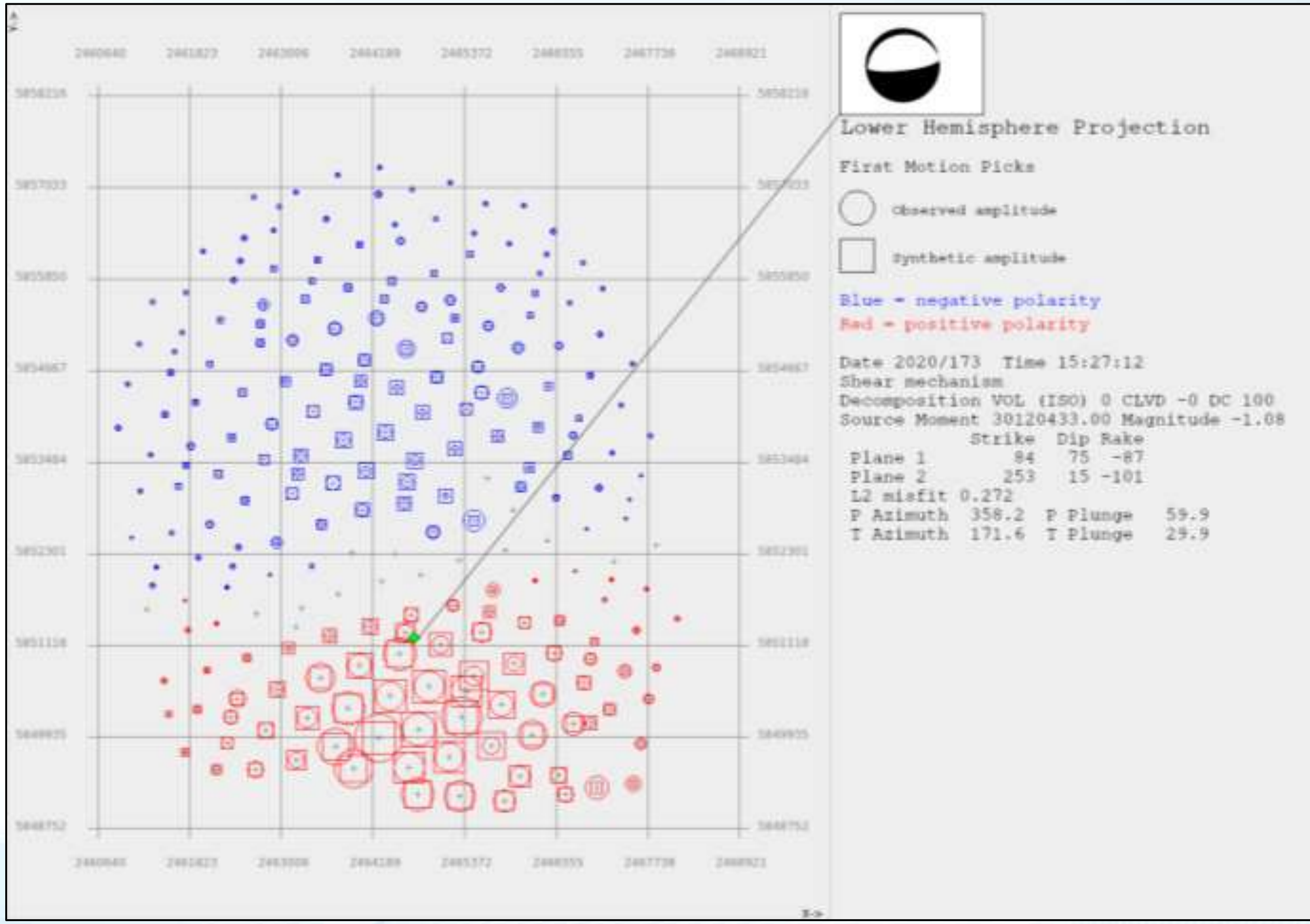
Source Mechanism – 2024h Stage 7 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
84	75	-87

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -1.08

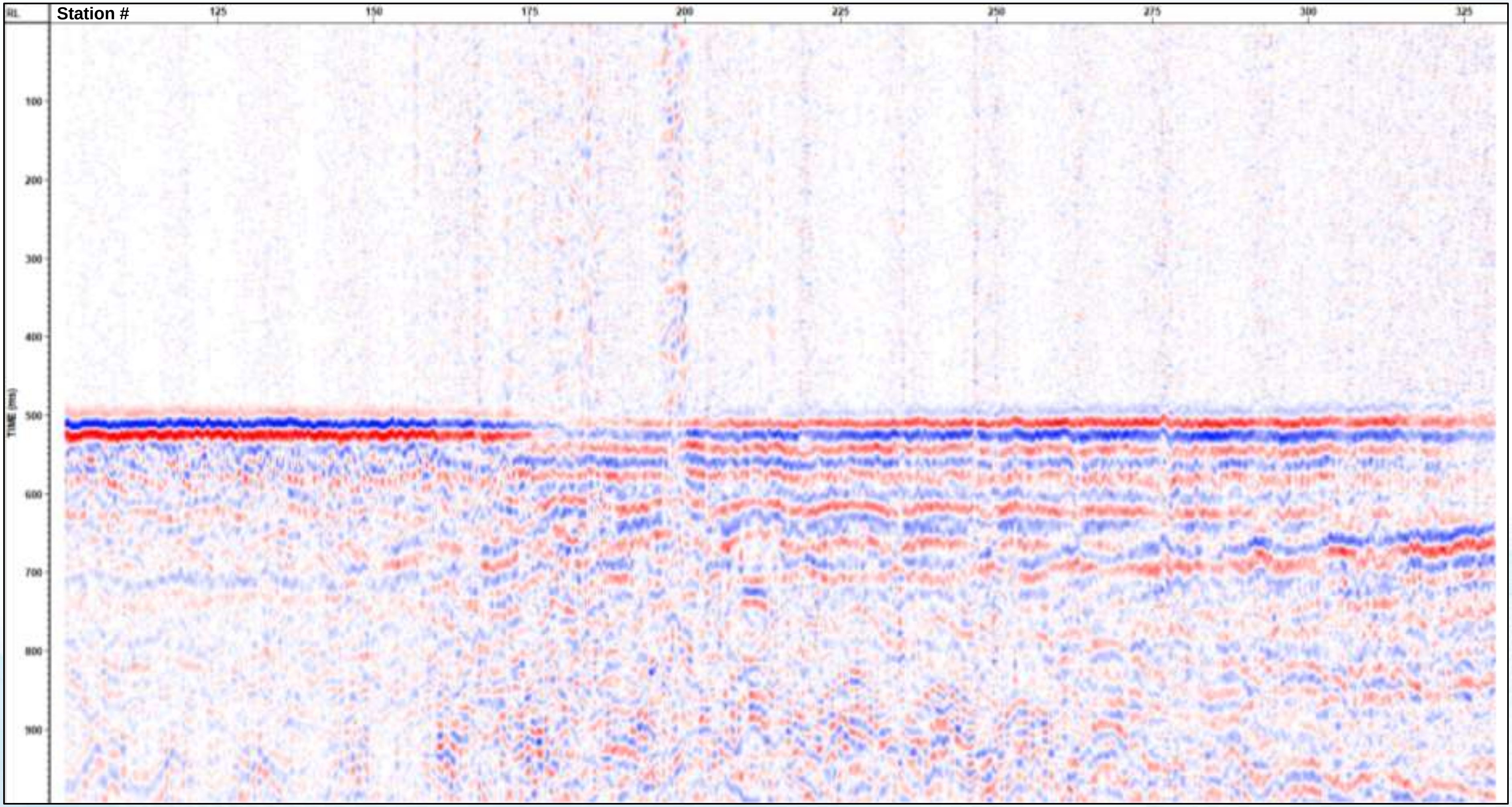


2024h Stage 7 Event – Processed Seismic

6/21/2020 15:27:12.328

No Mechanism Correction

Velocity Corrected Event at 500 ms



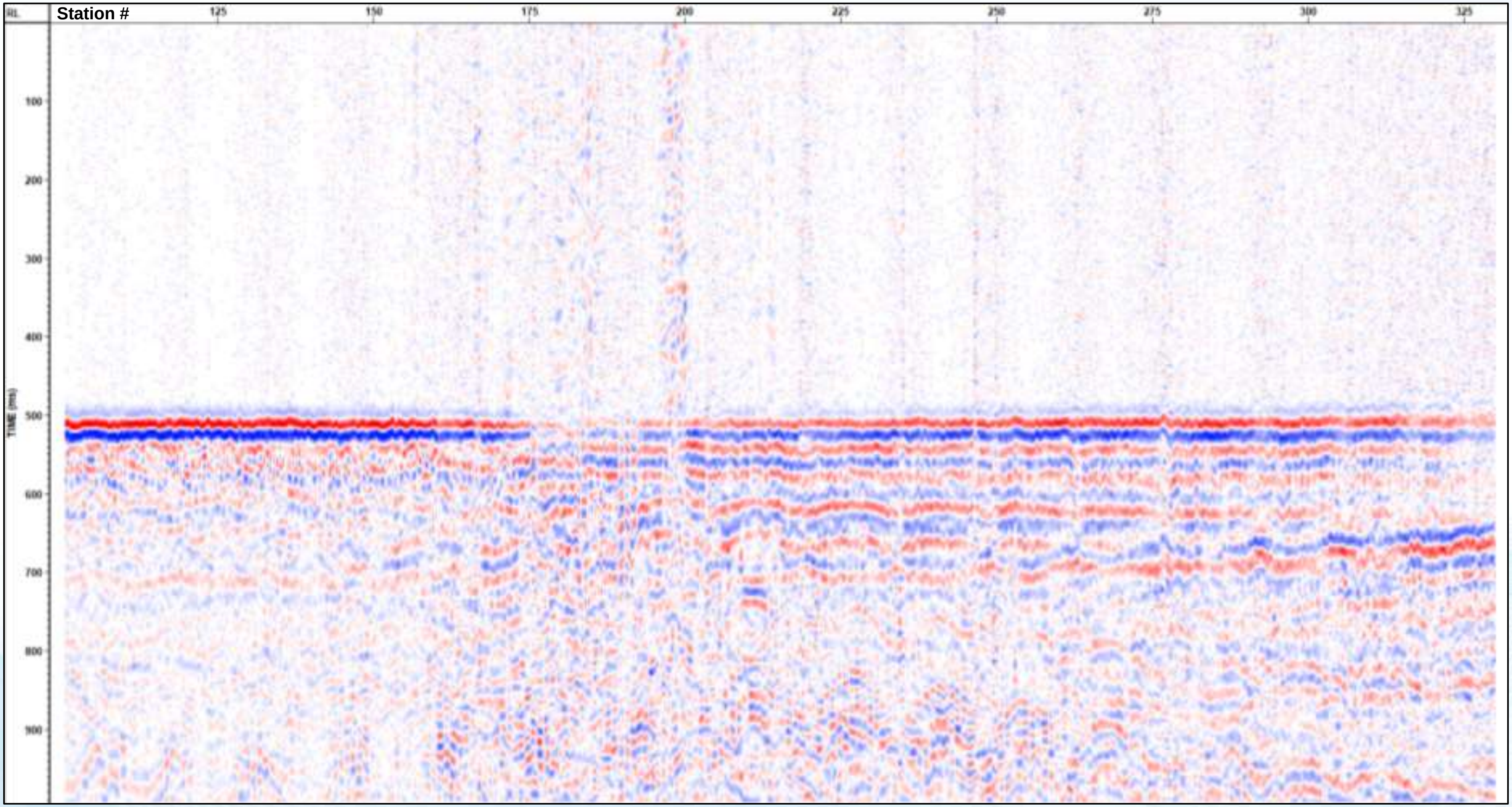
MicroSeismic

2024h Stage 7 Event – Processed Seismic

6/21/2020 15:27:12.328

Mechanism Corrected

Velocity Corrected Event at 500 ms



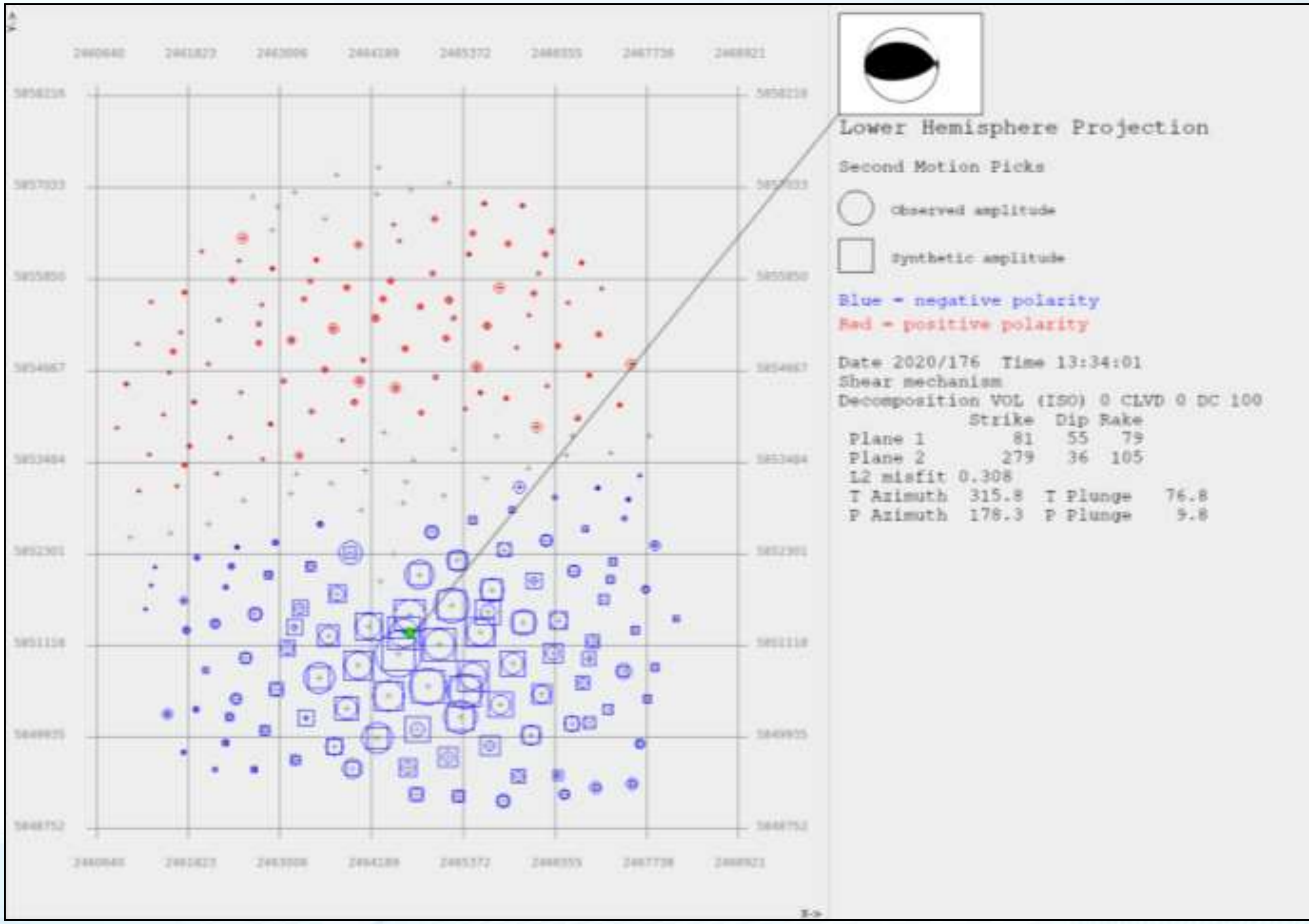
MicroSeismic

Source Mechanism – 2024h Stage 8 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

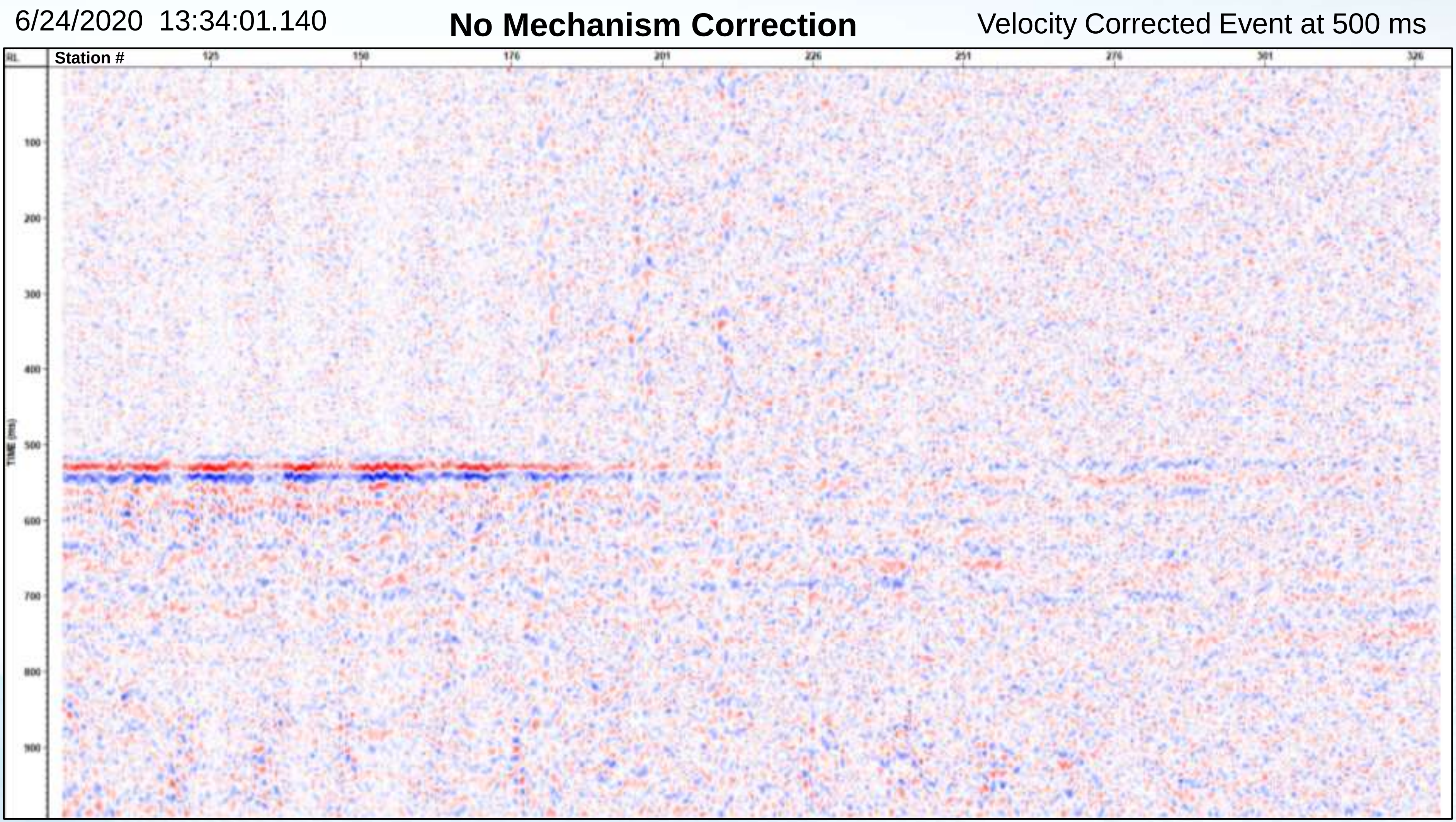
Strike	Dip	Rake
81	55	79

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.



MicroSeismic

2024h Stage 8 Event – Processed Seismic

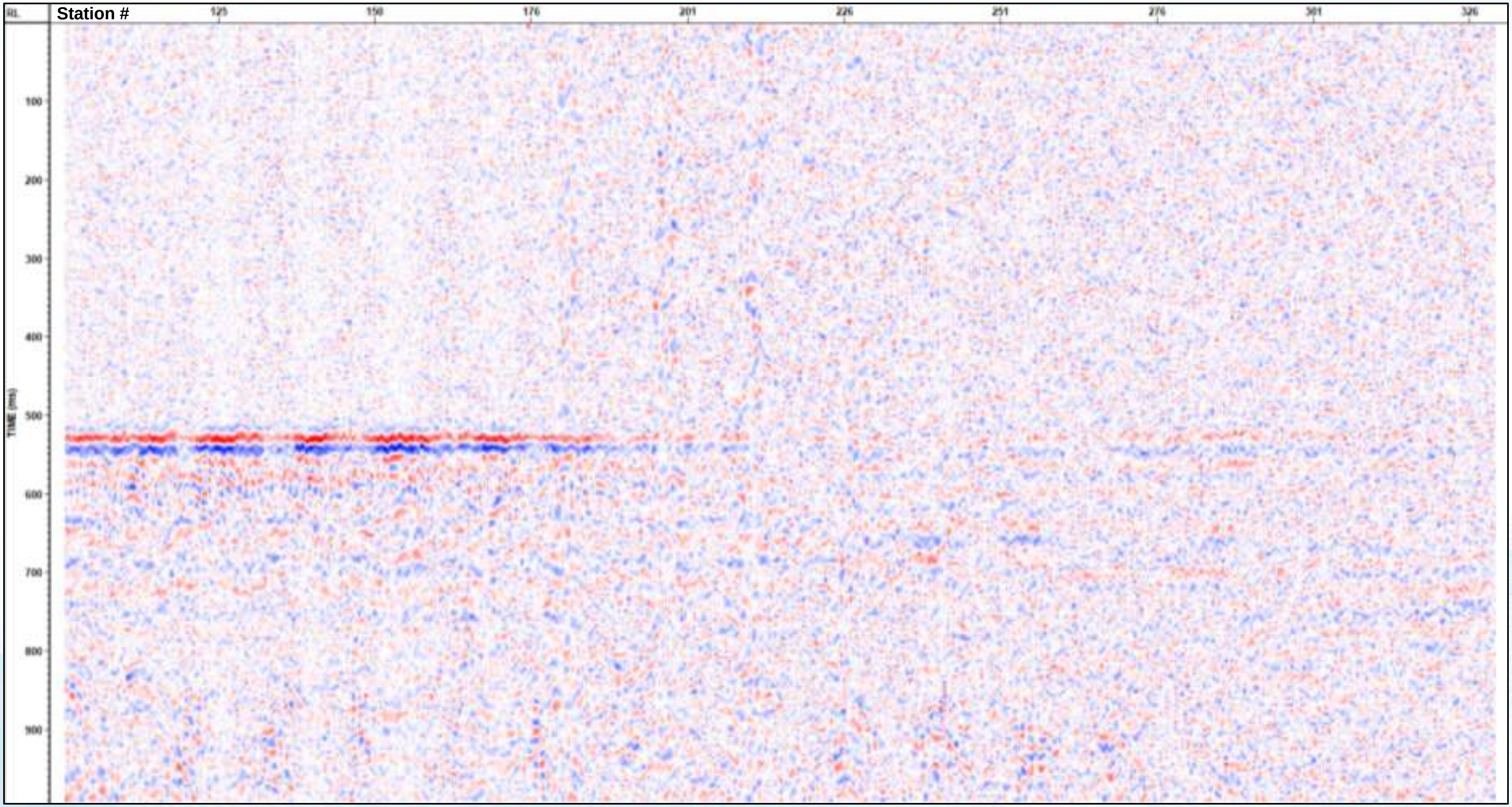


2024h Stage 8 Event – Processed Seismic

6/24/2020 13:34:01.140

Mechanism Corrected

Velocity Corrected Event at 500 ms



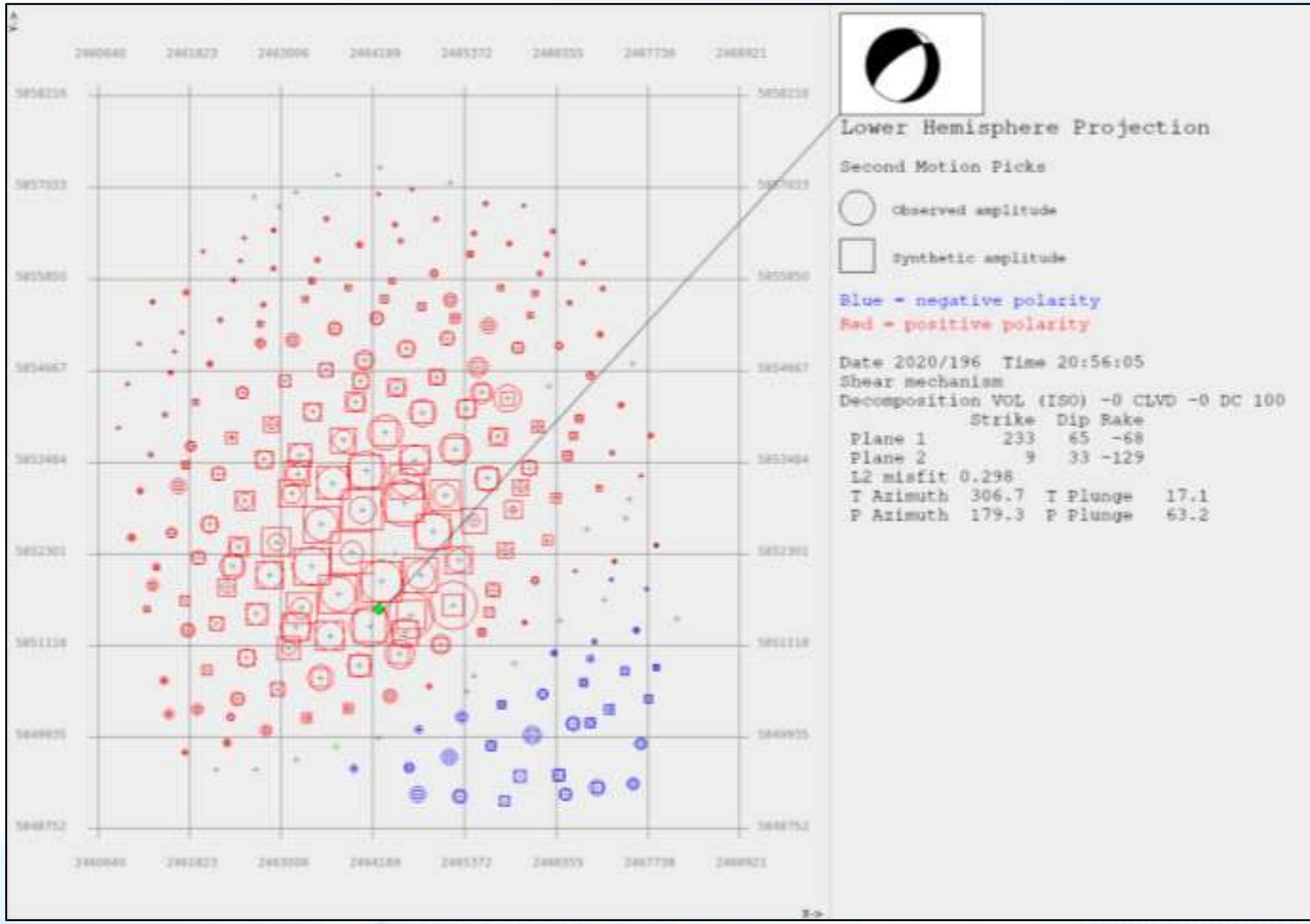
MicroSeismic

Source Mechanism – 2022h Stage 15 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
233	65	-68

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.

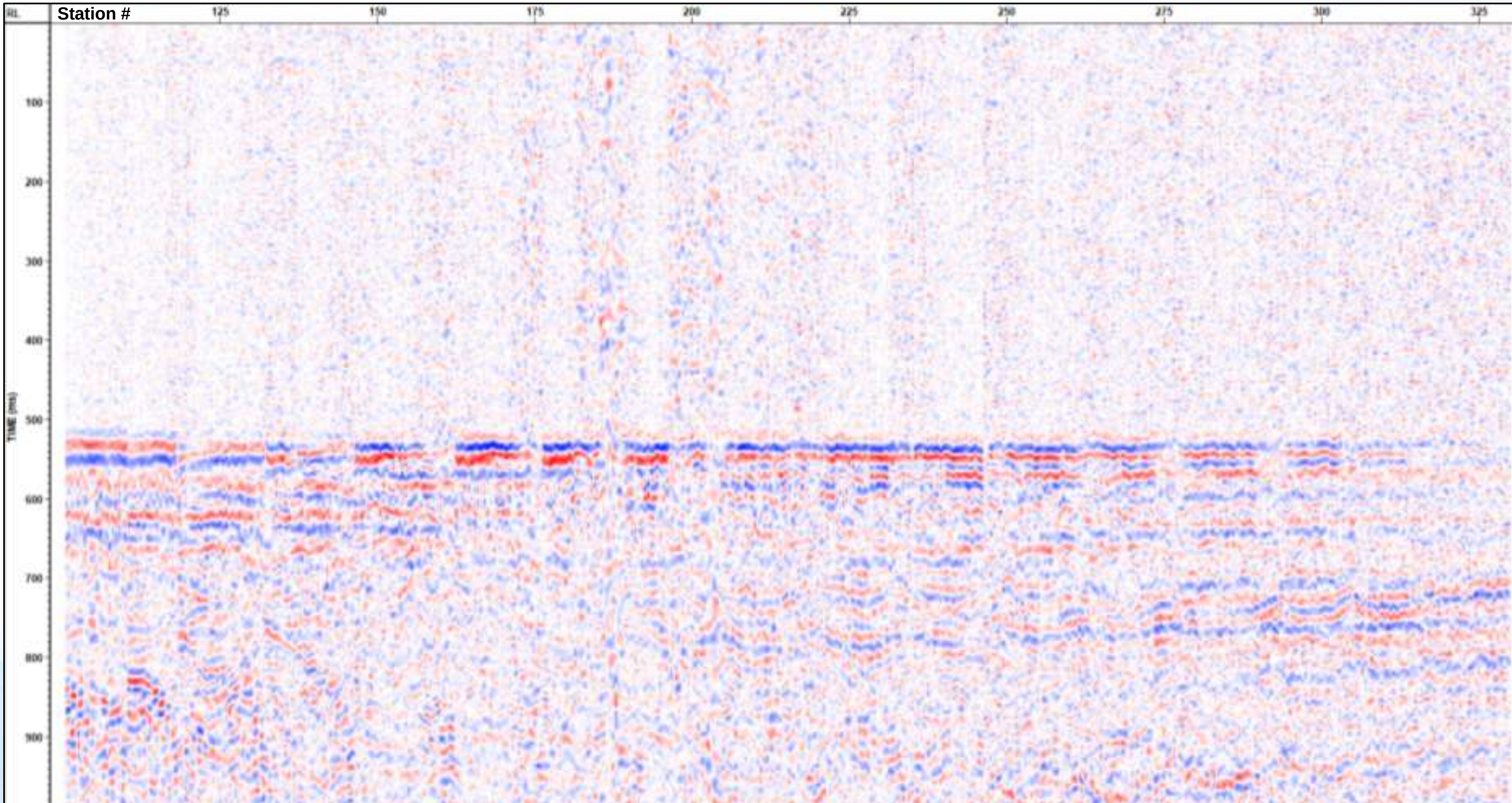


2022h Stage 15 Event – Processed Seismic

7/14/2020 20:56:04.608

No Mechanism Correction

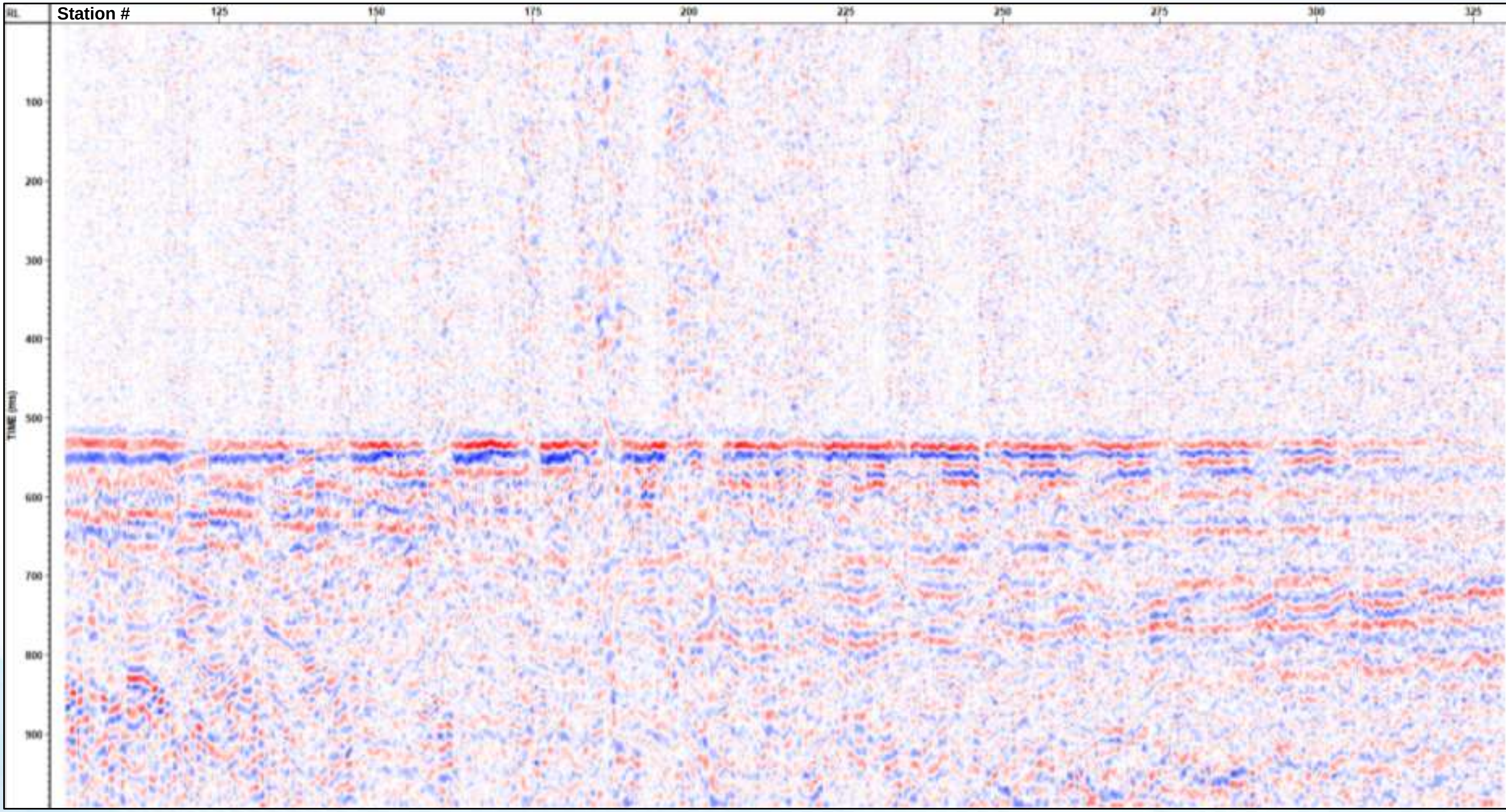
Velocity Corrected Event at 500 ms



MicroSeismic

2022h Stage 15 Event – Processed Seismic

7/14/2020 20:56:04.608 **Mechanism Corrected** Velocity Corrected Event at 500 ms



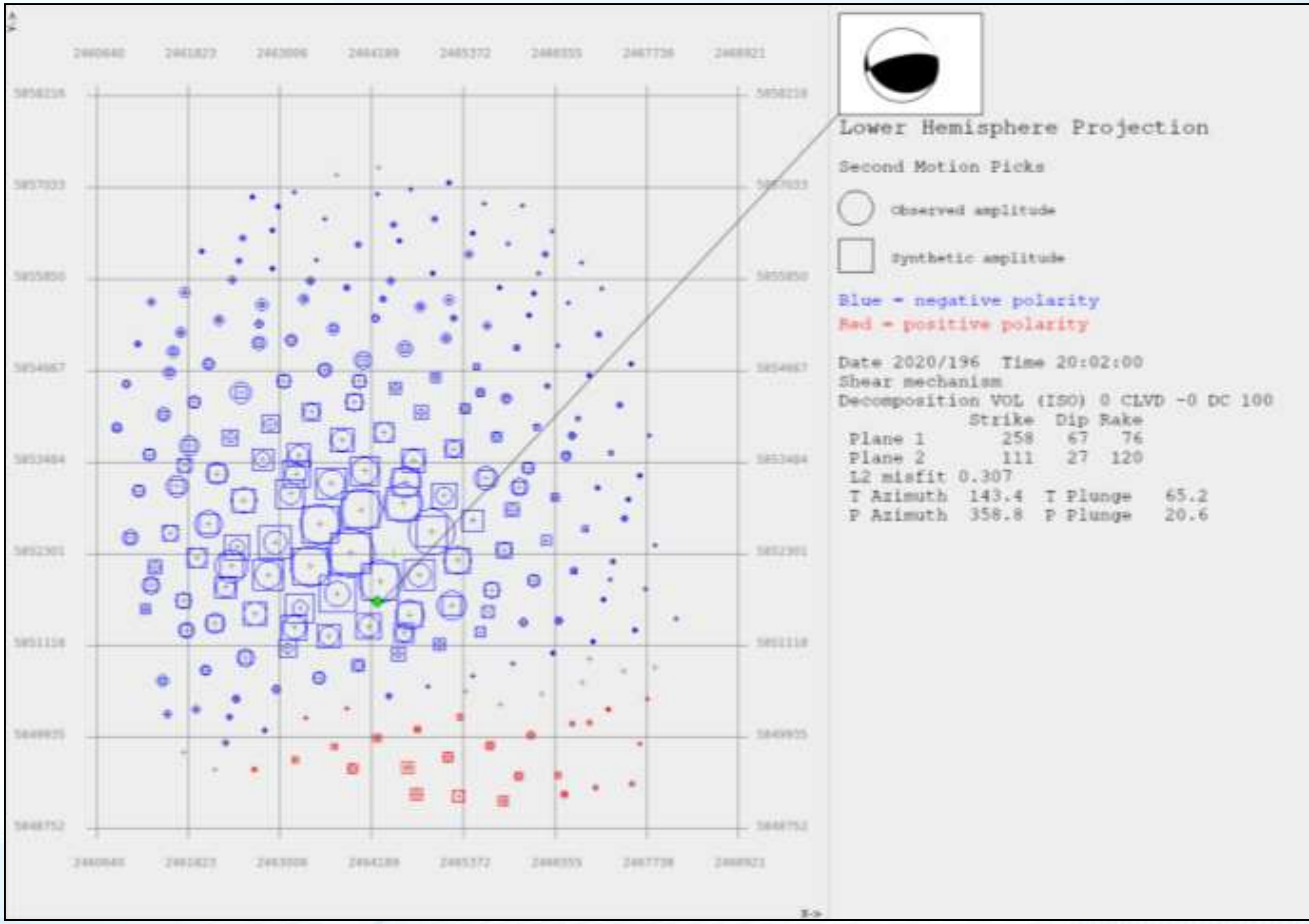
MicroSeismic

Source Mechanism – 2022h Stage 15 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
258	67	76

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.



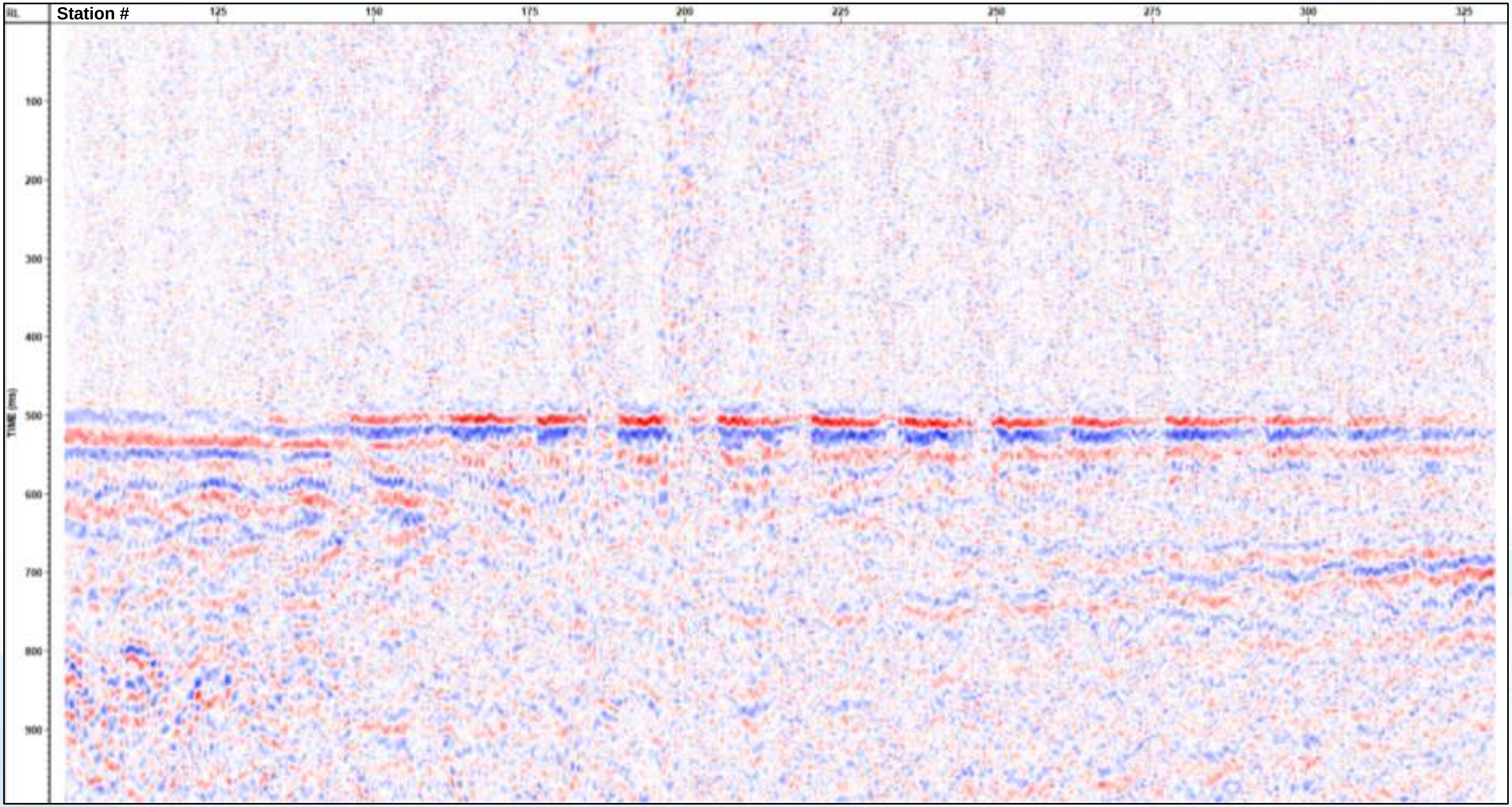
MicroSeismic

2022h Stage 15 Event – Processed Seismic

7/14/2020 20:02:00.104

No Mechanism Correction

Velocity Corrected Event at 500 ms



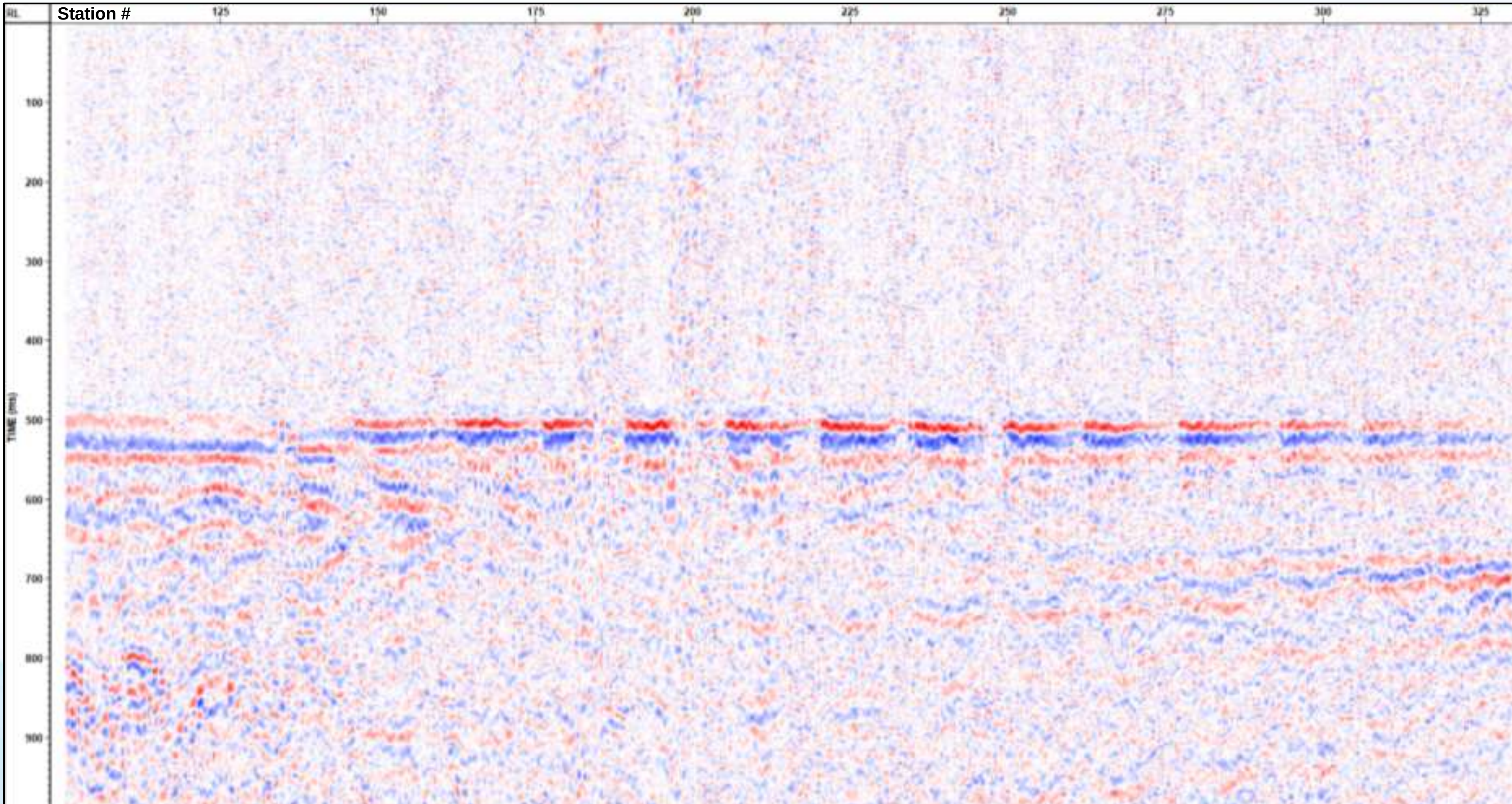
MicroSeismic

2022h Stage 15 Event – Processed Seismic

7/14/2020 20:02:00.104

Mechanism Corrected

Velocity Corrected Event at 500 ms

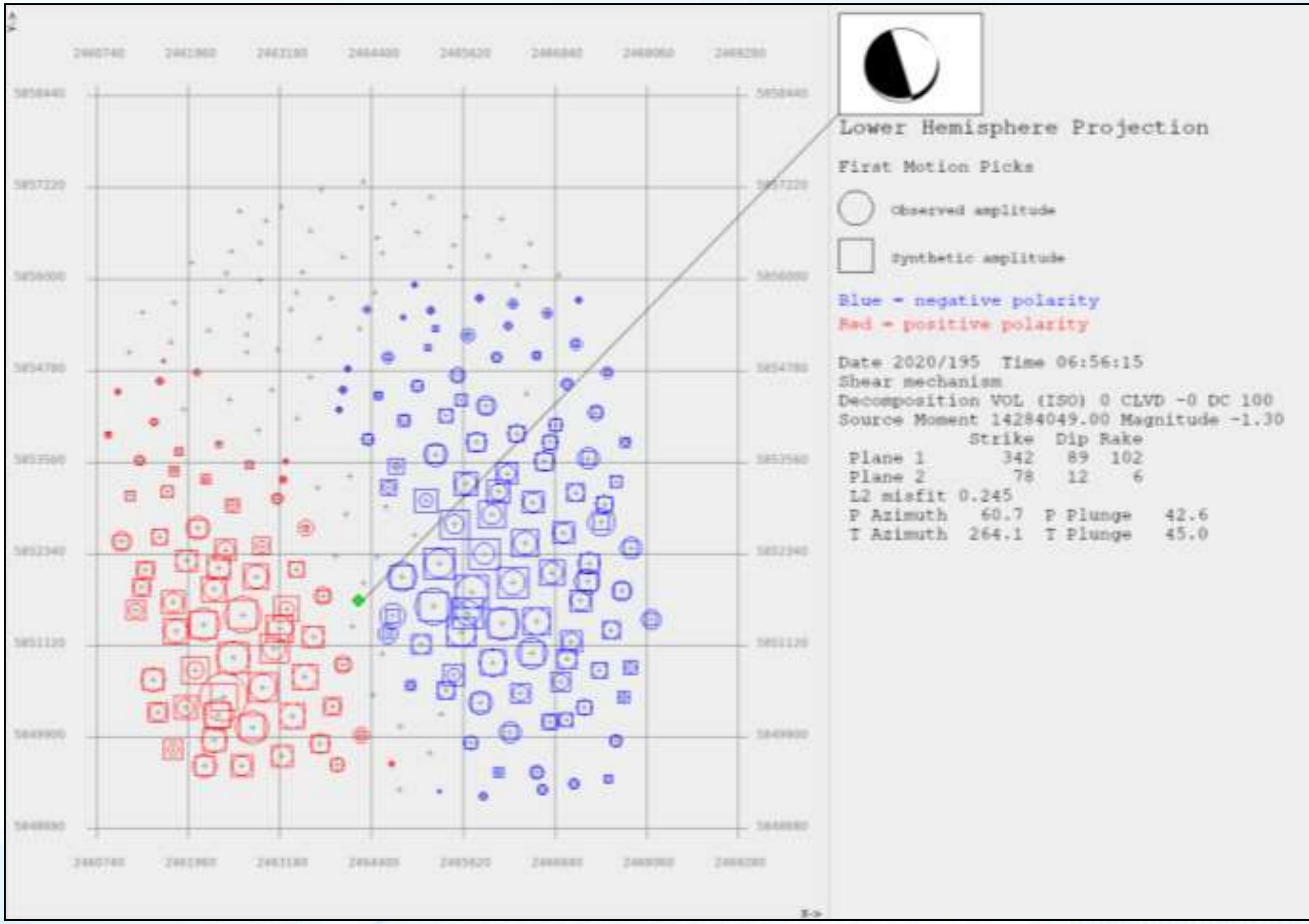


Source Mechanism – 2022h Stage 14 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
342	89	102

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.

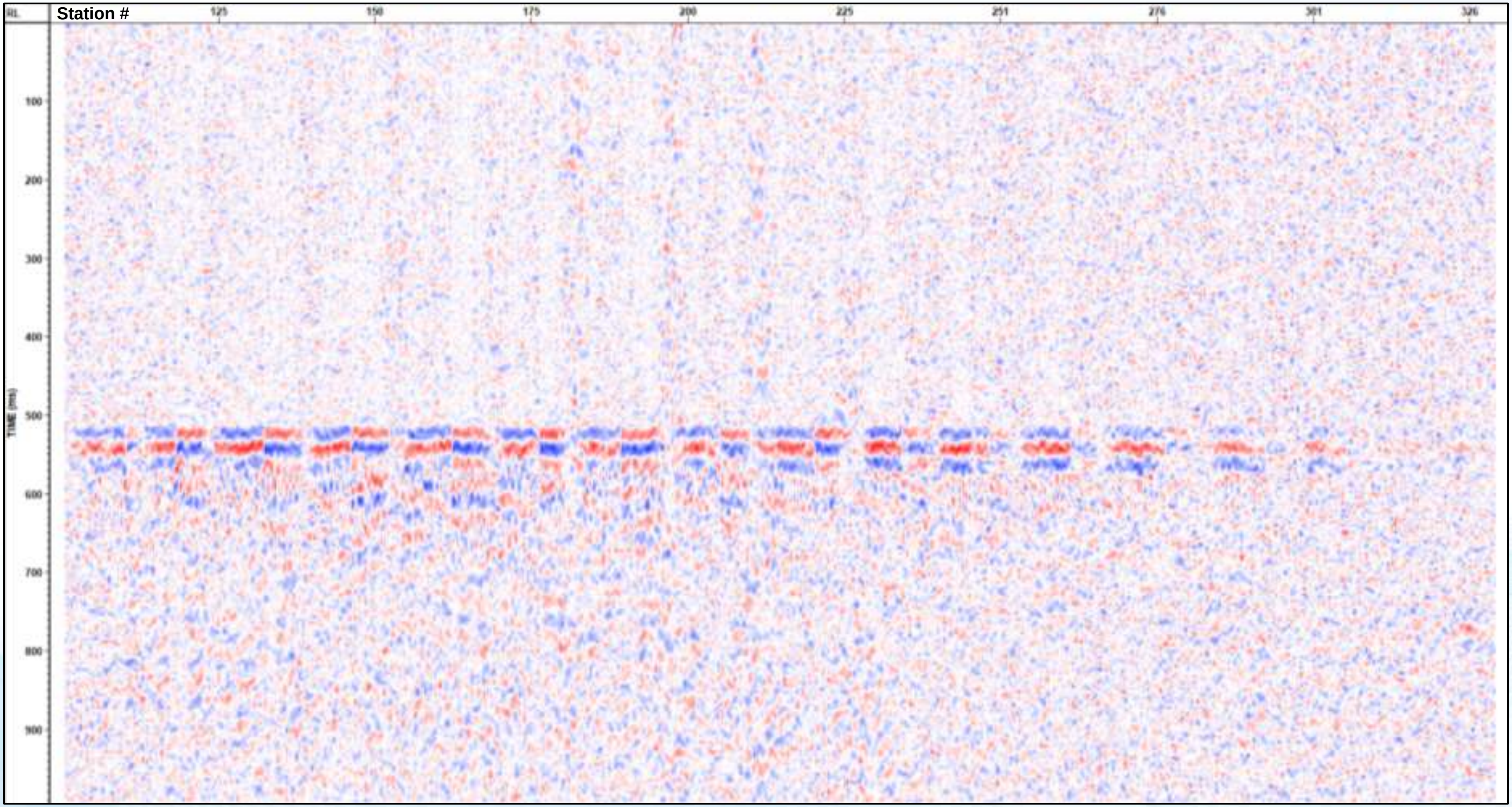


2022h Stage 14 Event – Processed Seismic

7/13/2020 06:56:14.708

No Mechanism Correction

Velocity Corrected Event at 500 ms



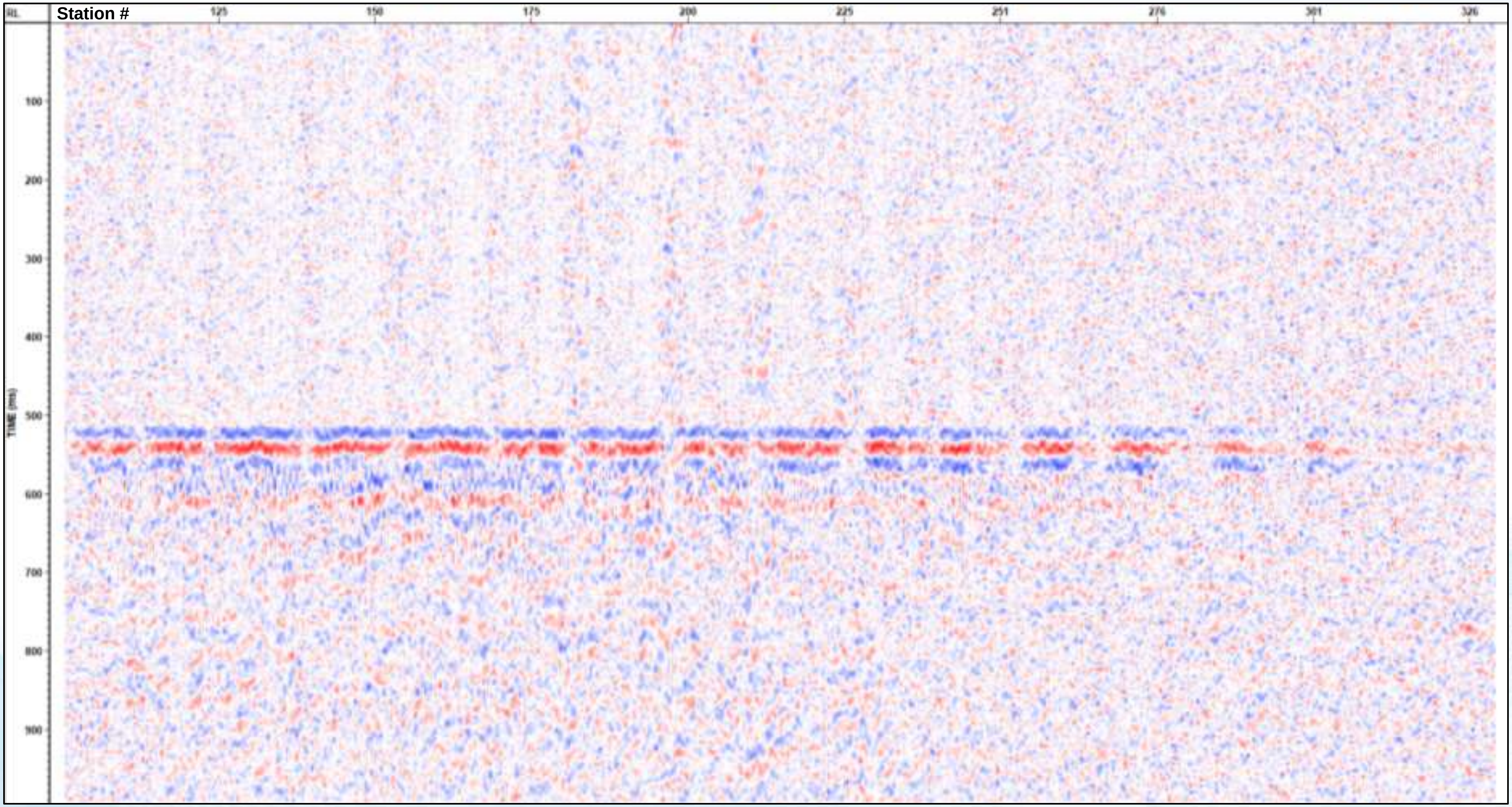
MicroSeismic

2022h Stage 14 Event – Processed Seismic

7/13/2020 06:56:14.708

Mechanism Corrected

Velocity Corrected Event at 500 ms

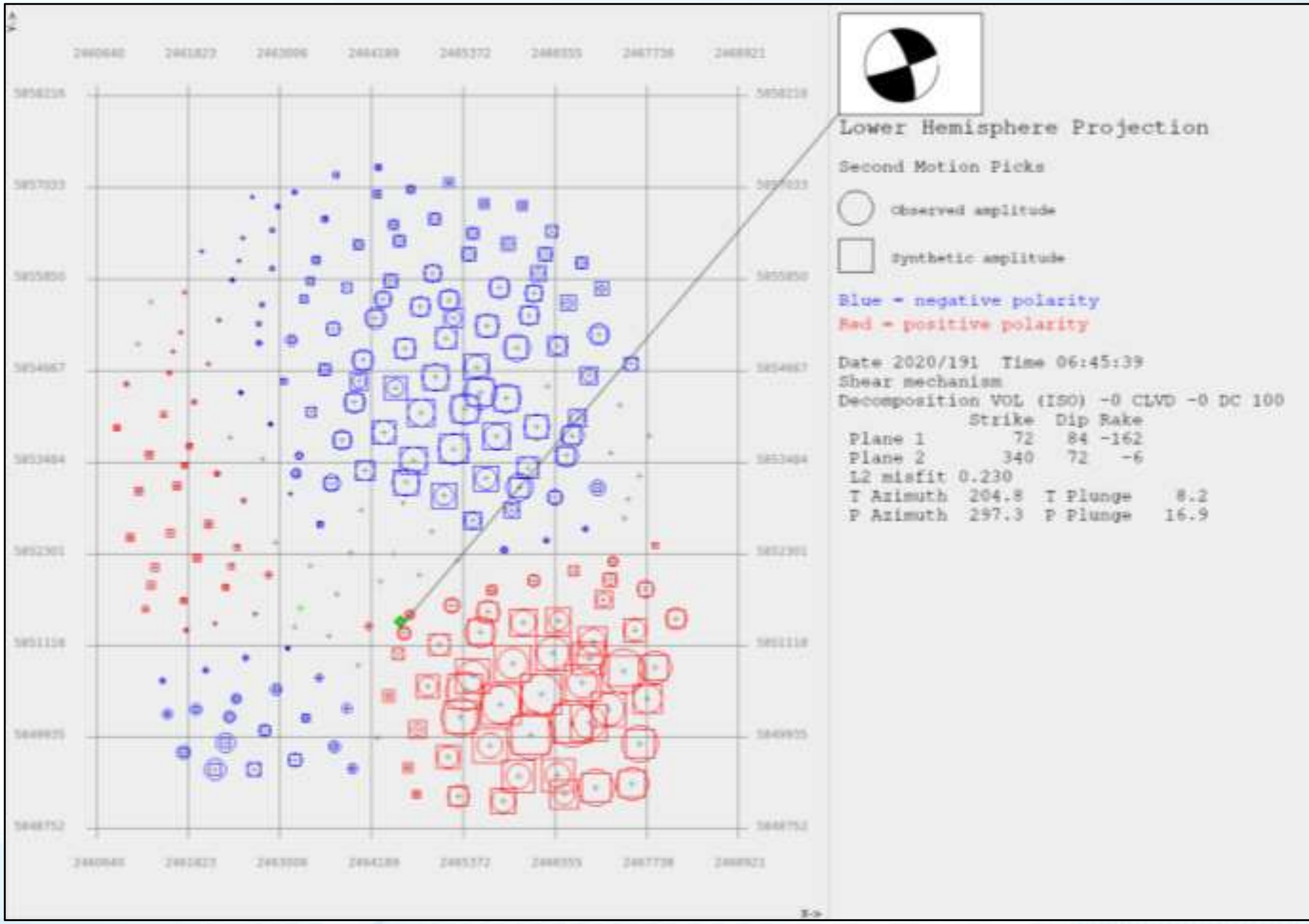


Source Mechanism – 2024h Stage 10 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
72	84	-162

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.

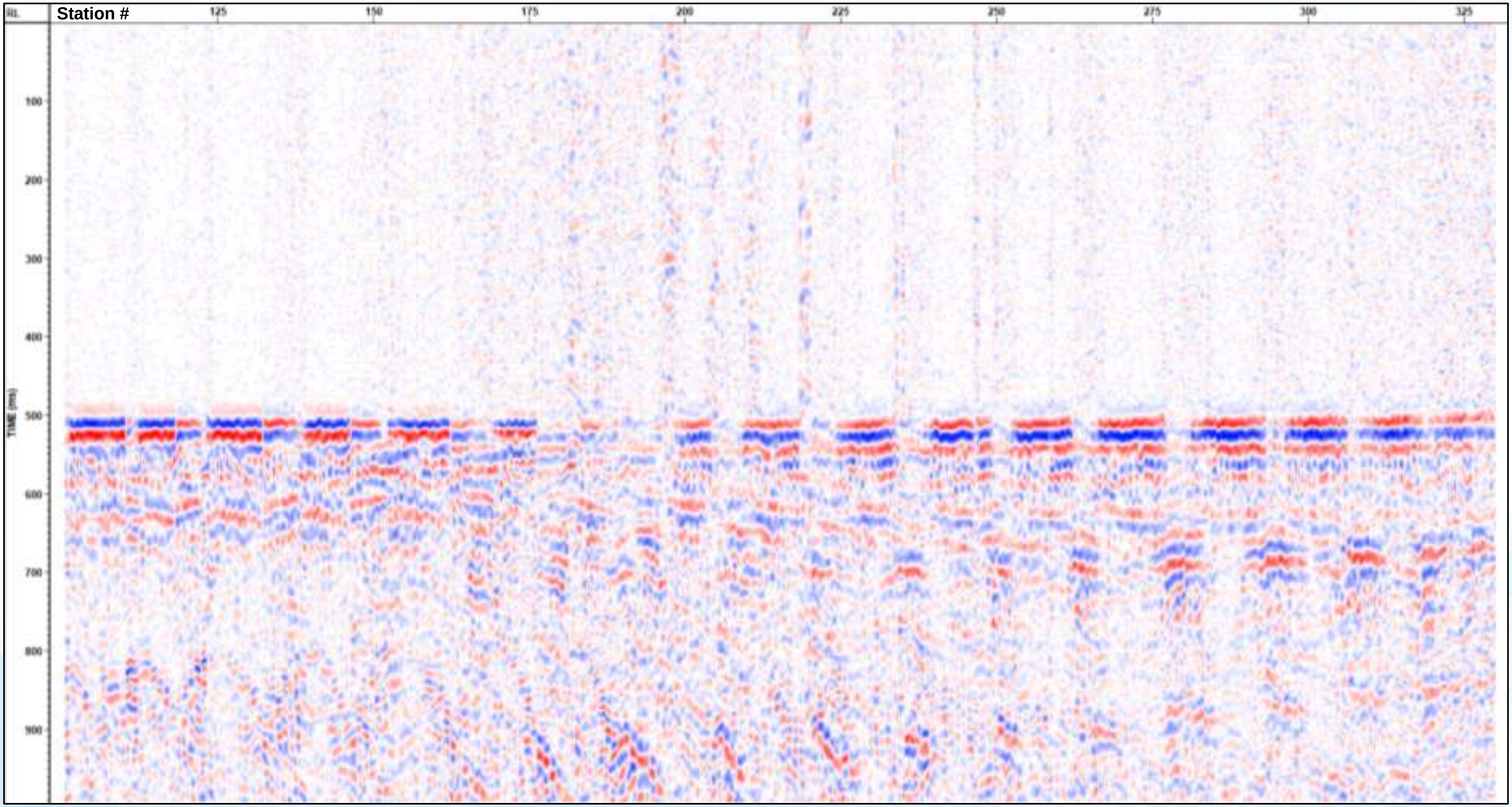


2024h Stage 10 Event – Processed Seismic

7/09/2020 06:45:39.248

No Mechanism Correction

Velocity Corrected Event at 500 ms



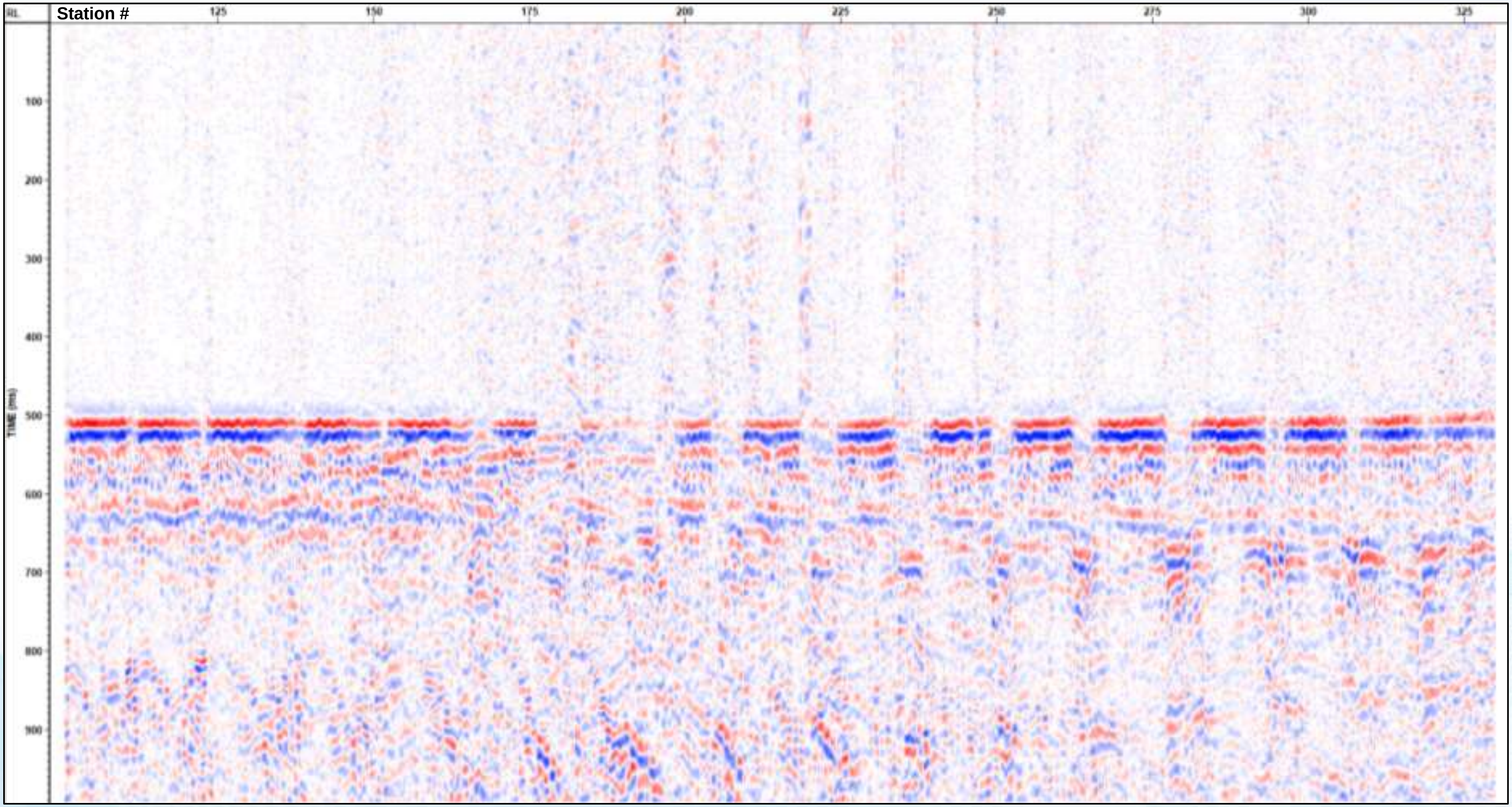
MicroSeismic

2024h Stage 10 Event – Processed Seismic

7/09/2020 06:45:39.248

Mechanism Corrected

Velocity Corrected Event at 500 ms



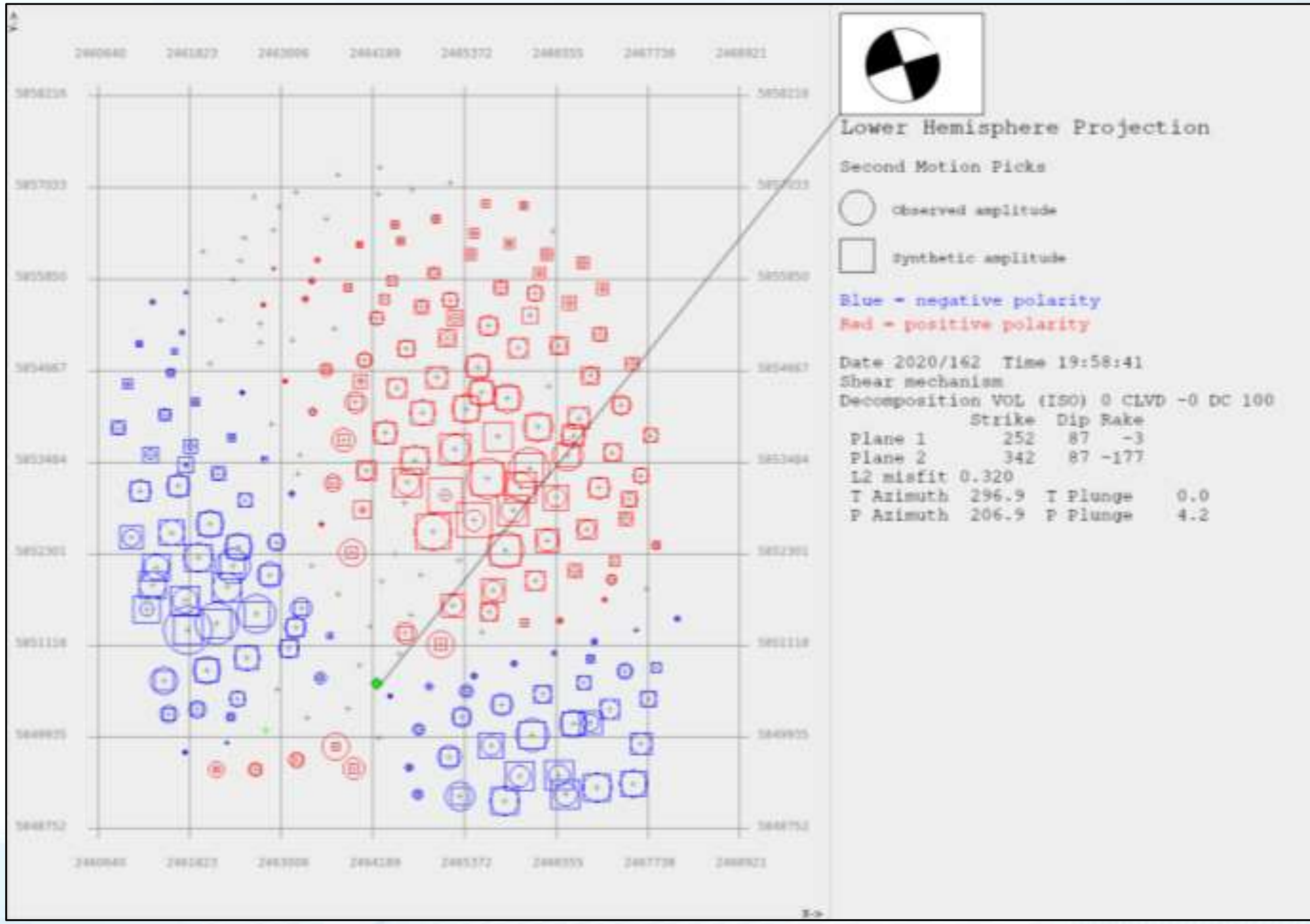
MicroSeismic

Source Mechanism – 2022h Stage 2 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
252	87	-3

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.

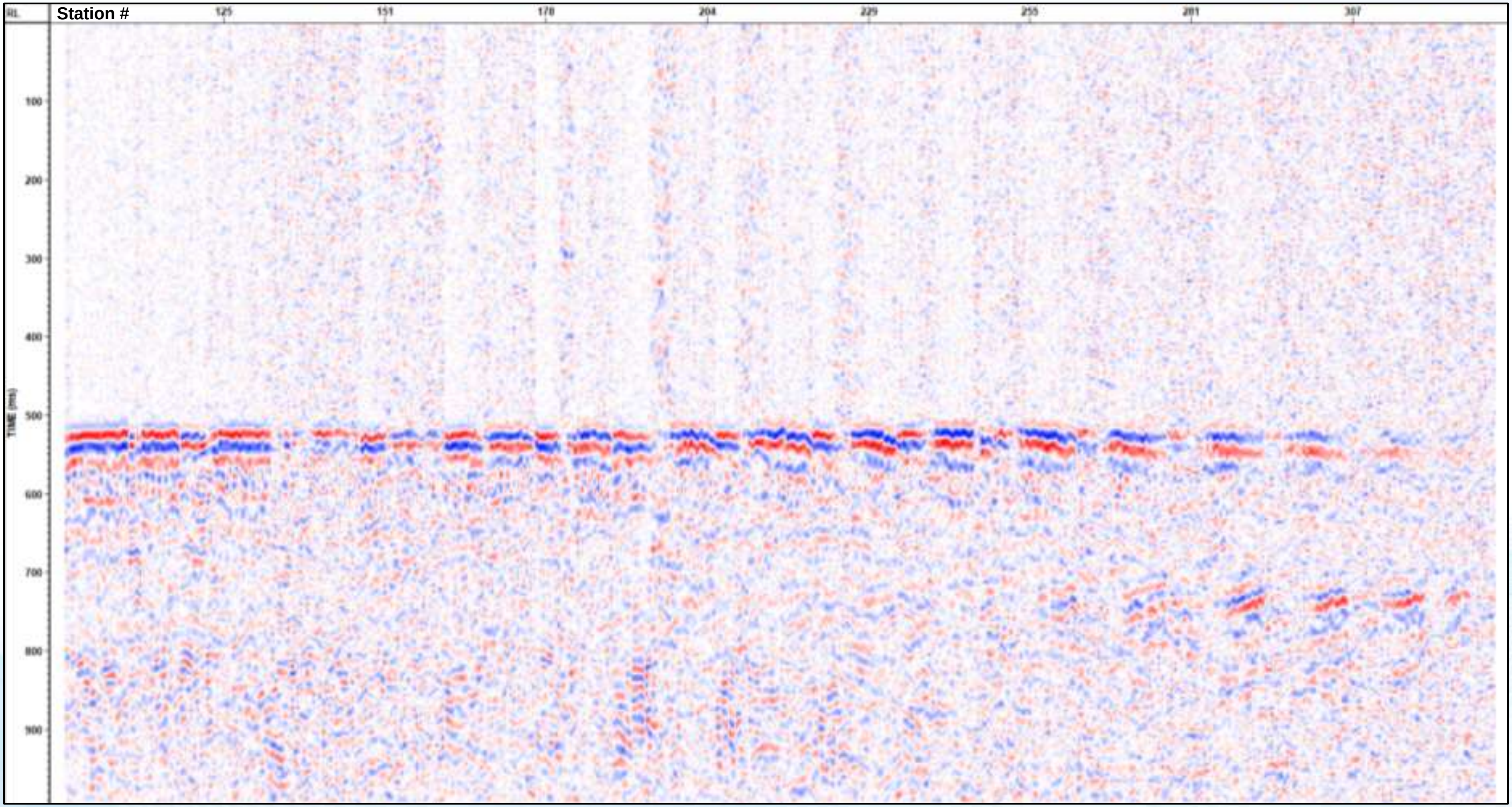


2022h Stage 2 Event – Processed Seismic

6/10/2020 19:58:41.252

No Mechanism Correction

Velocity Corrected Event at 500 ms



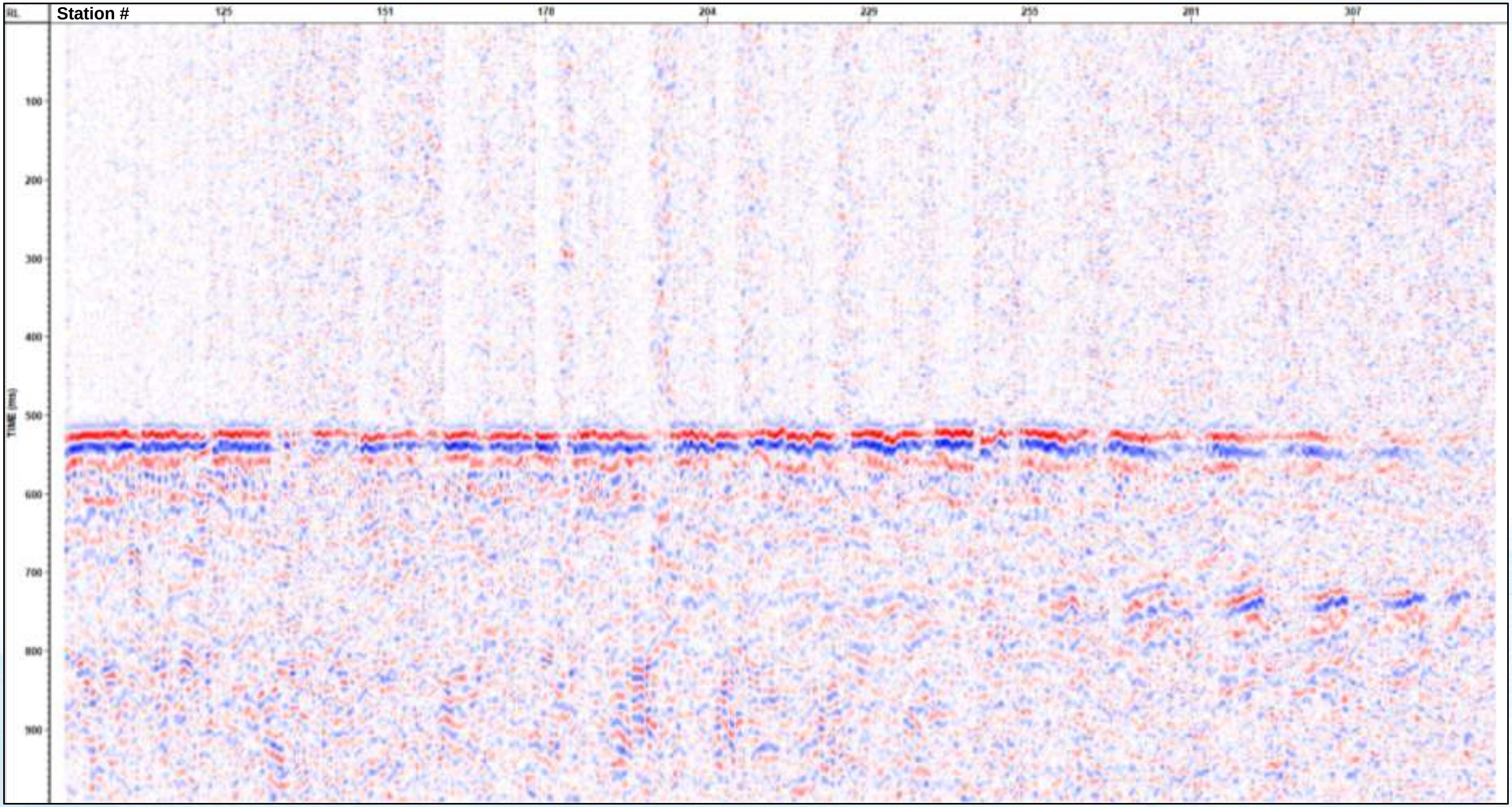
MicroSeismic

2022h Stage 2 Event – Processed Seismic

6/10/2020 19:58:41.252

Mechanism Corrected

Velocity Corrected Event at 500 ms



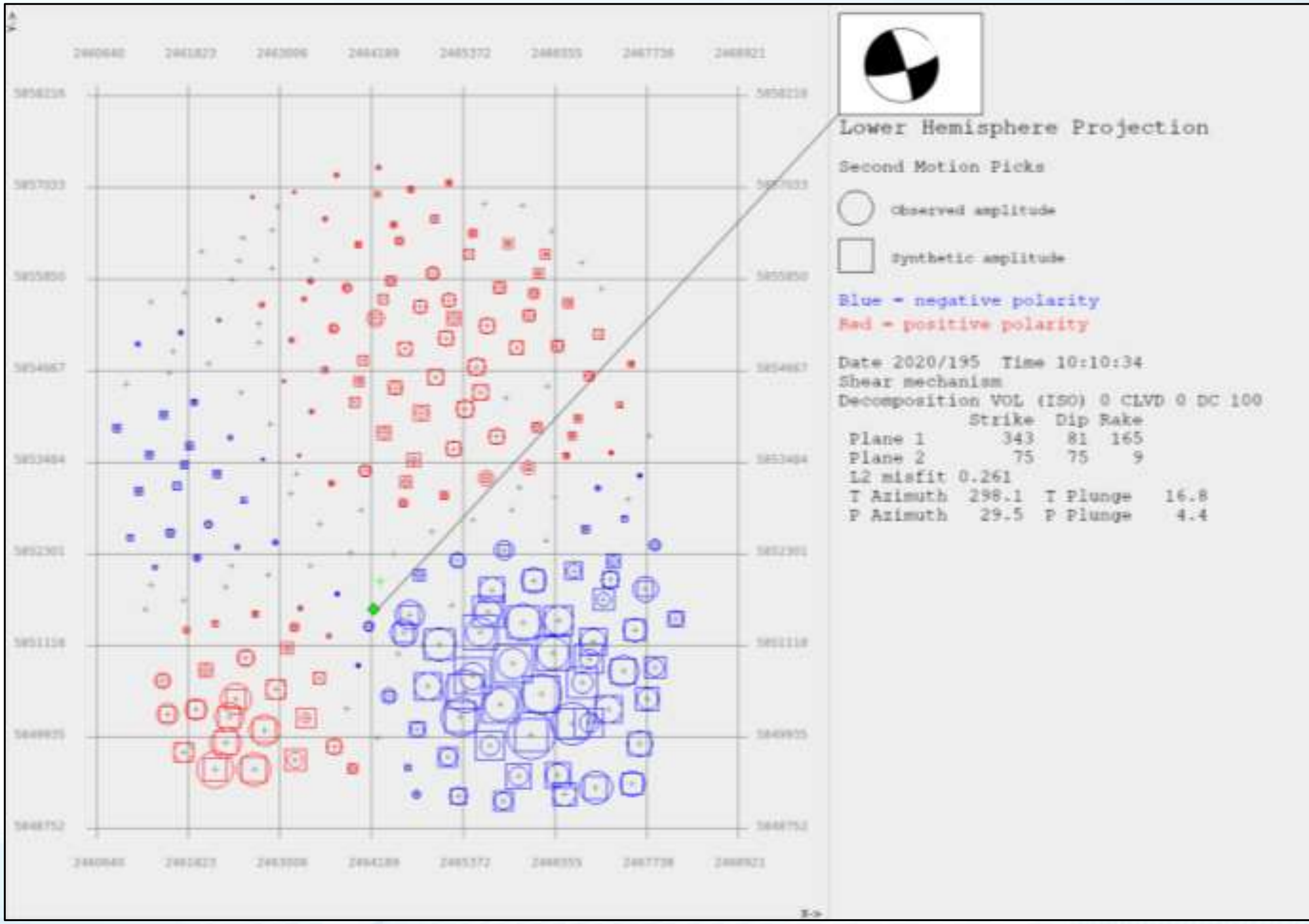
MicroSeismic

Source Mechanism – 2024h Stage 14 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
75	75	9

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.

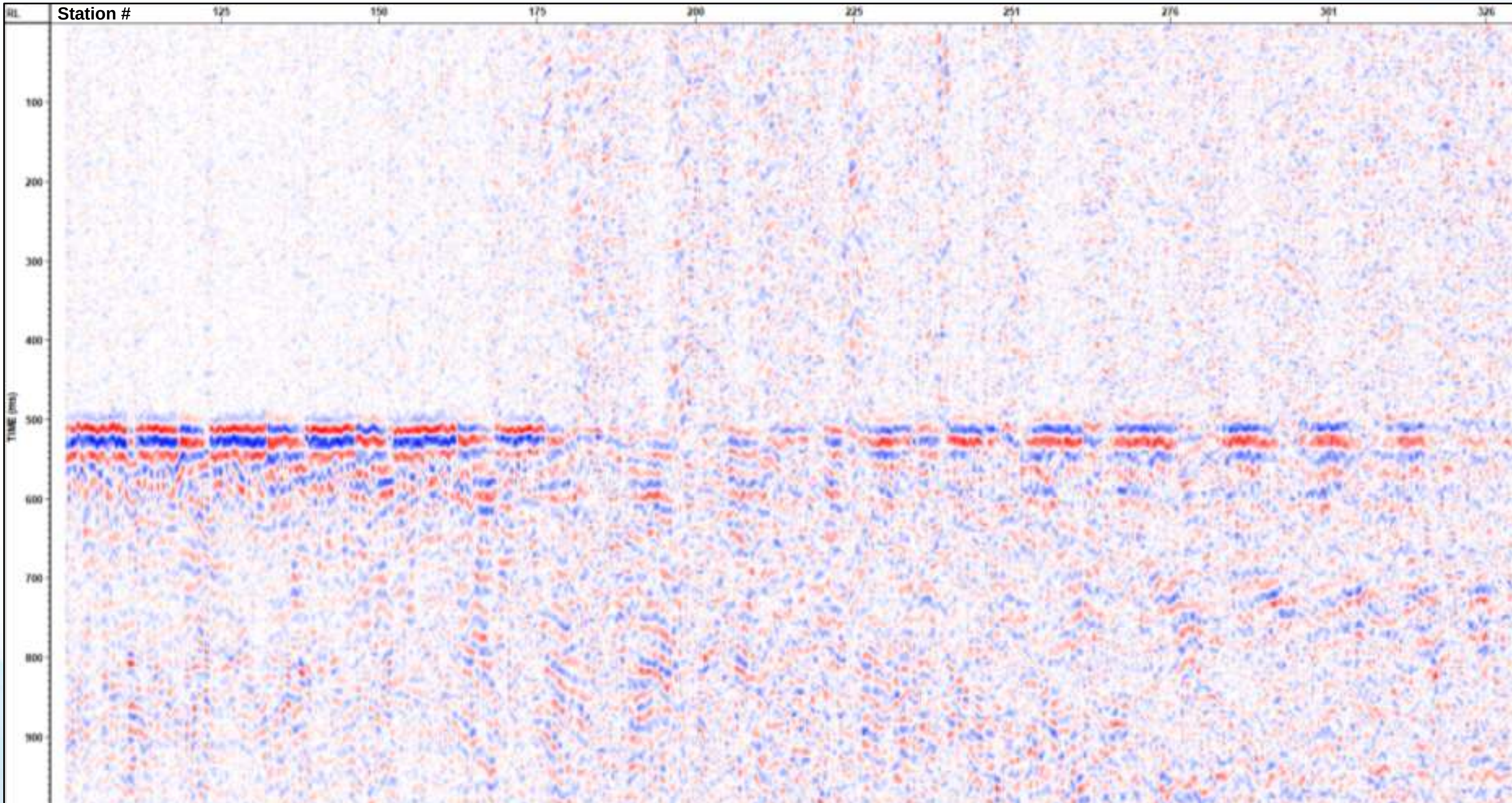


2024h Stage 14 Event – Processed Seismic

7/13/2020 10:10:33.840

No Mechanism Correction

Velocity Corrected Event at 500 ms

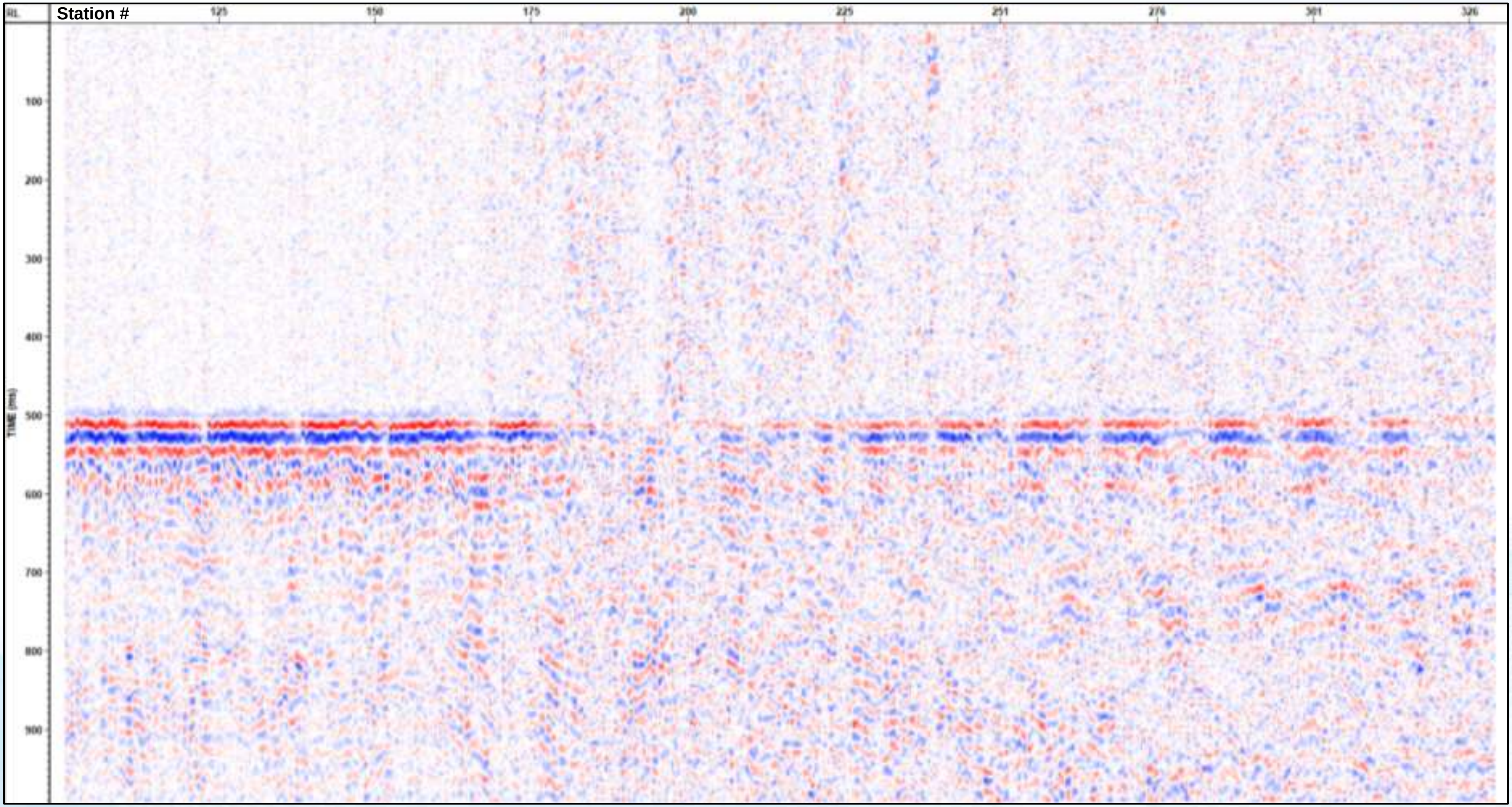


2024h Stage 14 Event – Processed Seismic

7/13/2020 10:10:33.840

Mechanism Corrected

Velocity Corrected Event at 500 ms



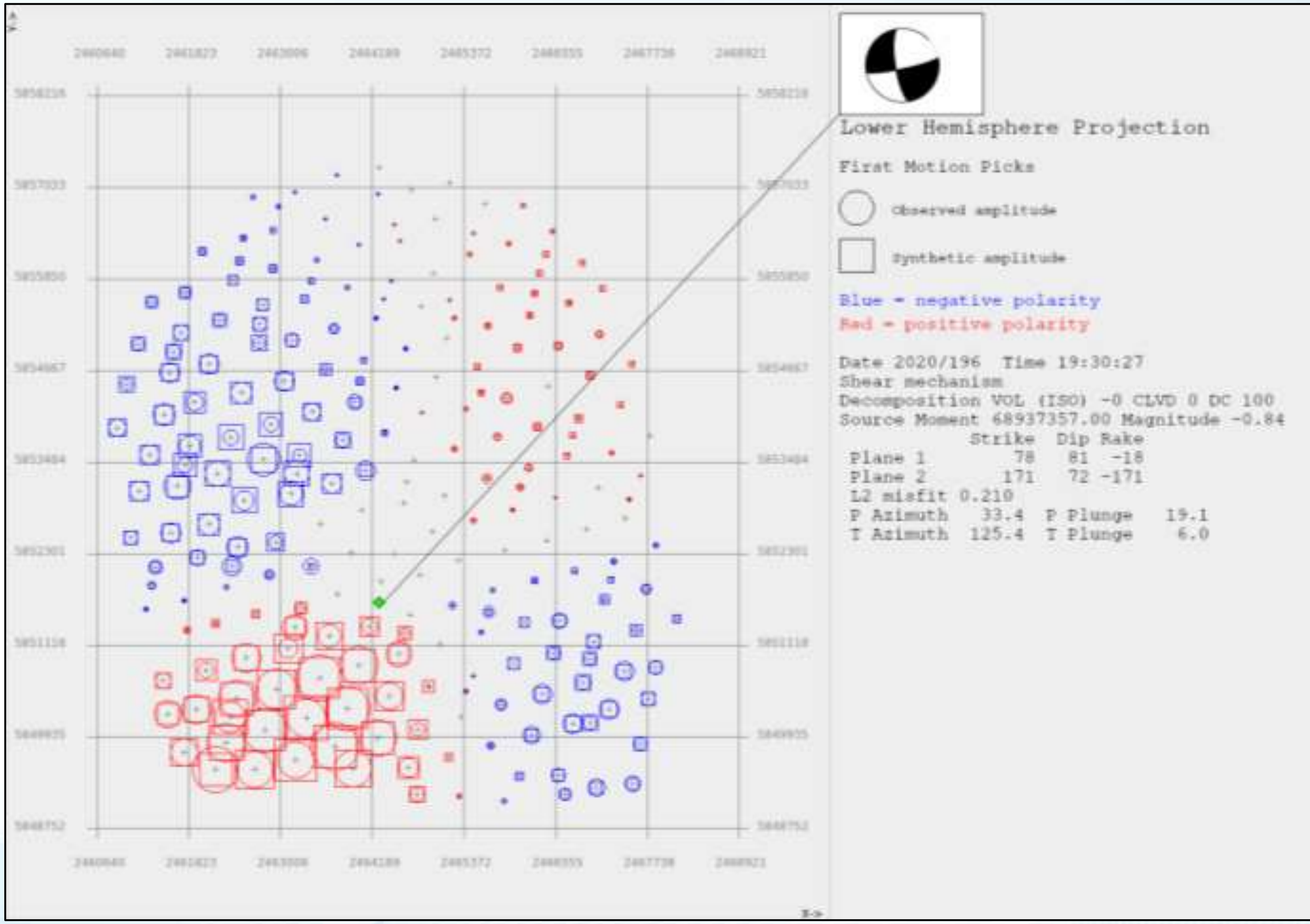
Source Mechanism – 2022h Stage 15 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
78	81	-18

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.84



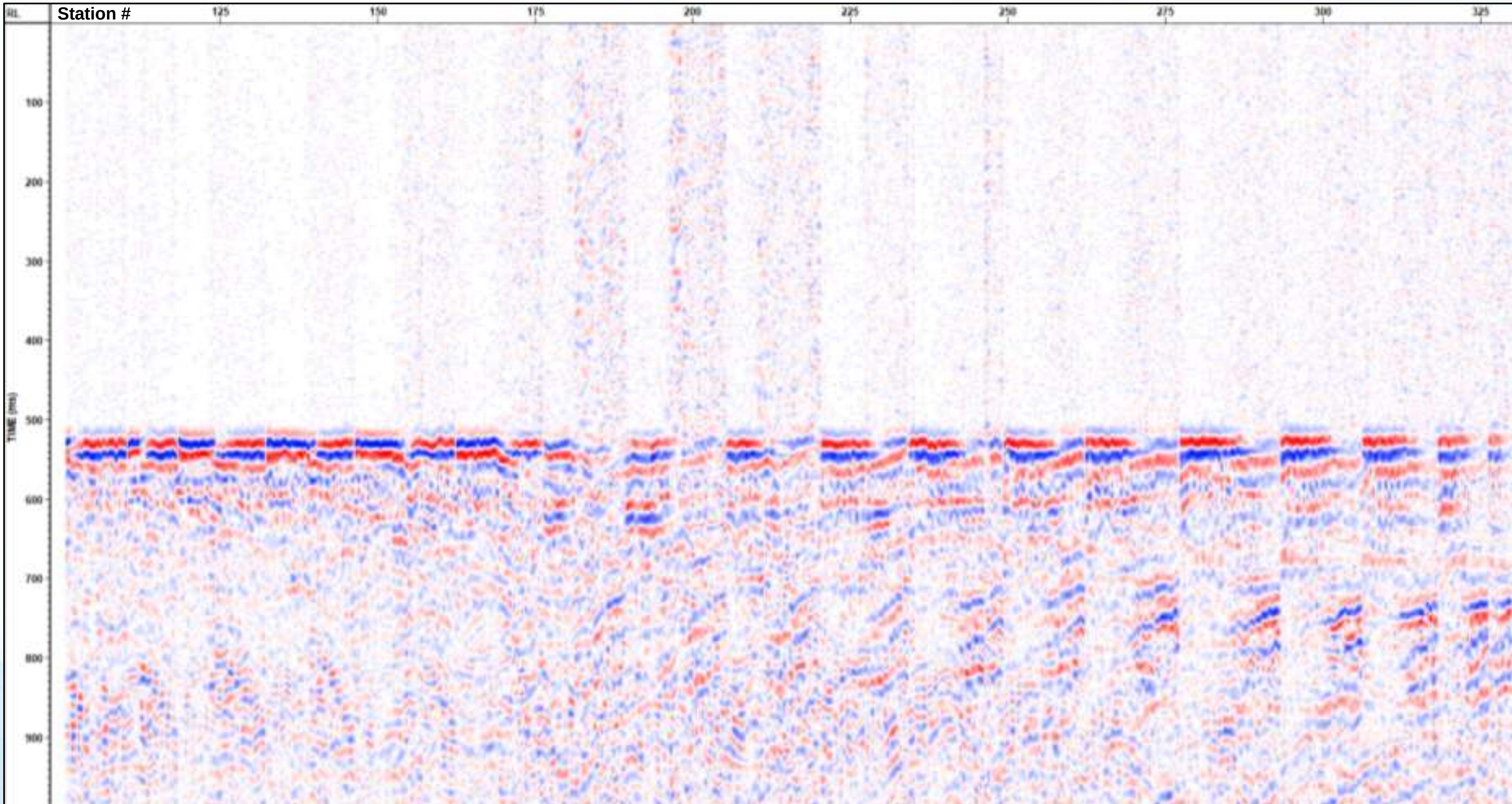
MicroSeismic

2022h Stage 15 Event – Processed Seismic

7/14/2020 19:30:26.932

No Mechanism Correction

Velocity Corrected Event at 500 ms

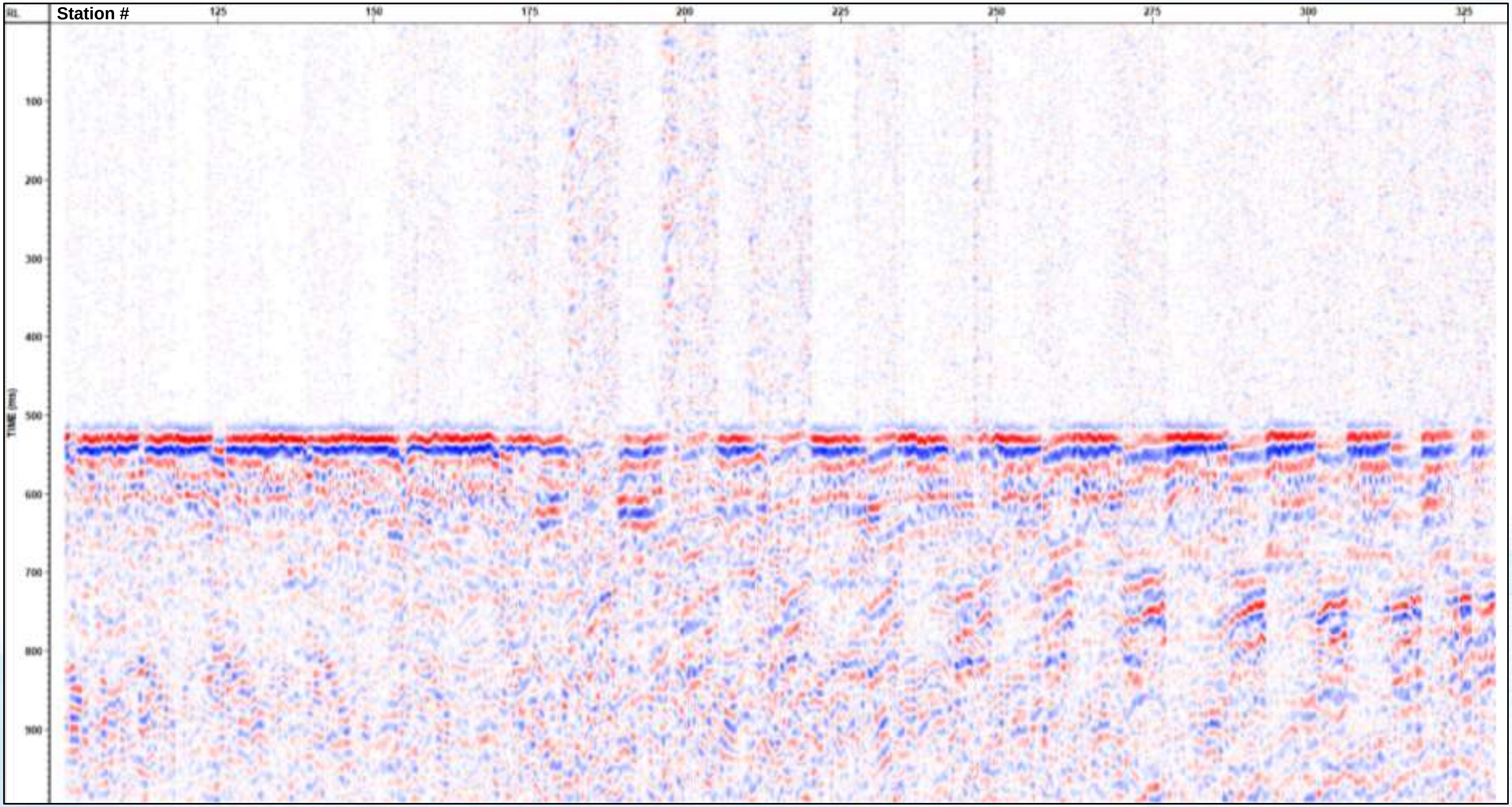


2022h Stage 15 Event – Processed Seismic

7/14/2020 19:30:26.932

Mechanism Corrected

Velocity Corrected Event at 500 ms



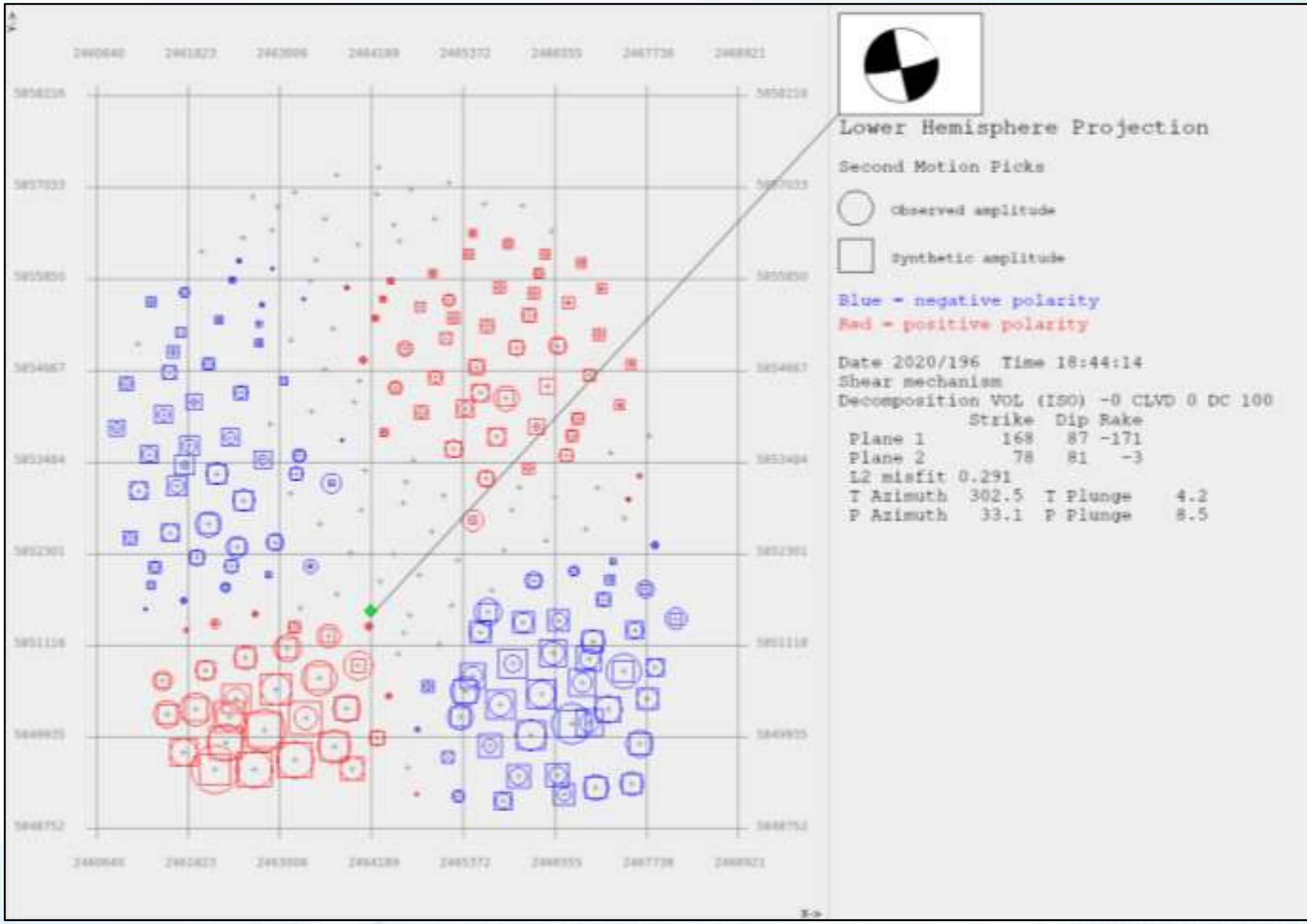
MicroSeismic

Source Mechanism – 2022h Stage 15 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
78	81	-3

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.

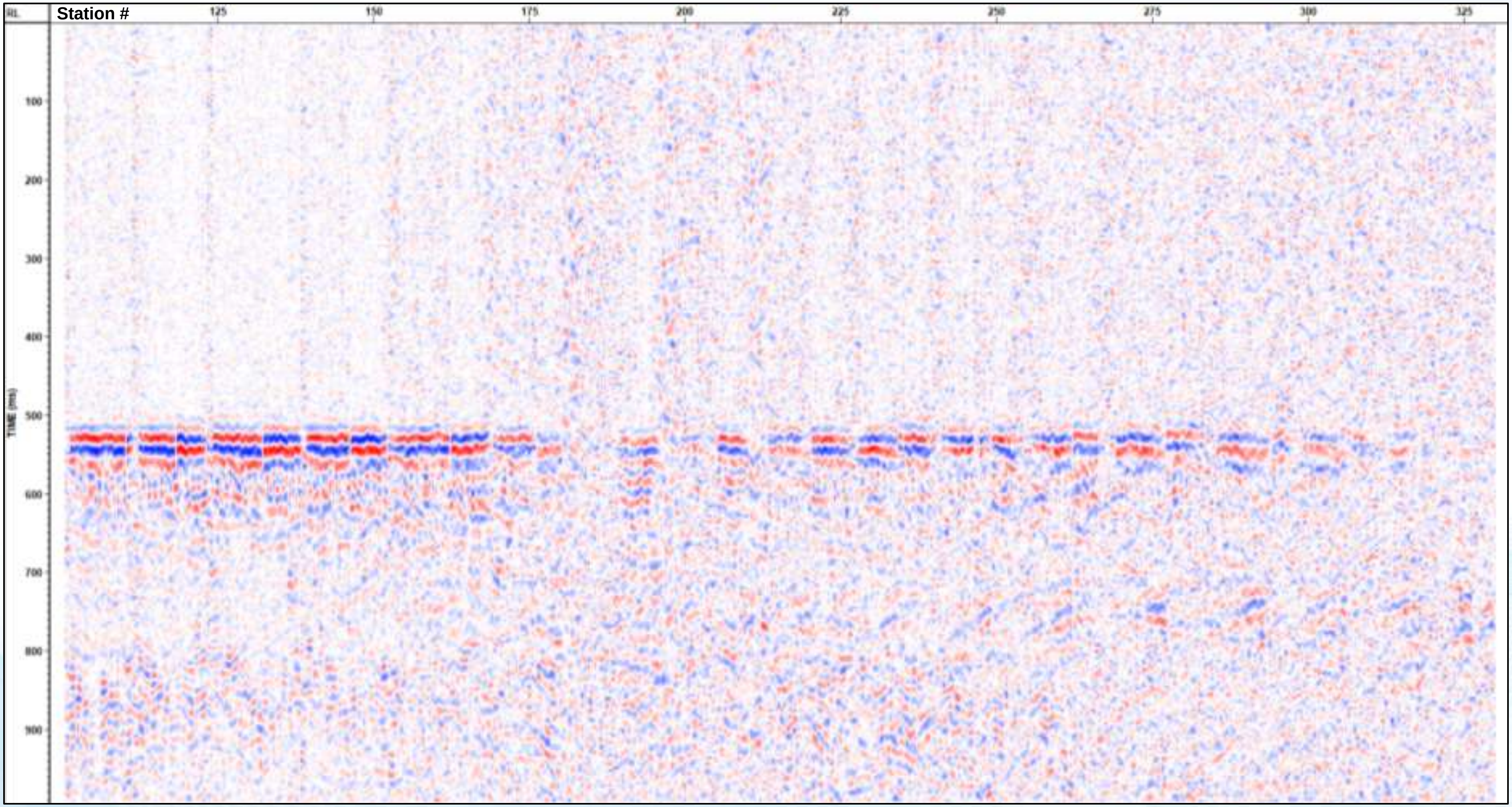


2022h Stage 15 Event – Processed Seismic

7/14/2020 18:44:13.644

No Mechanism Correction

Velocity Corrected Event at 500 ms



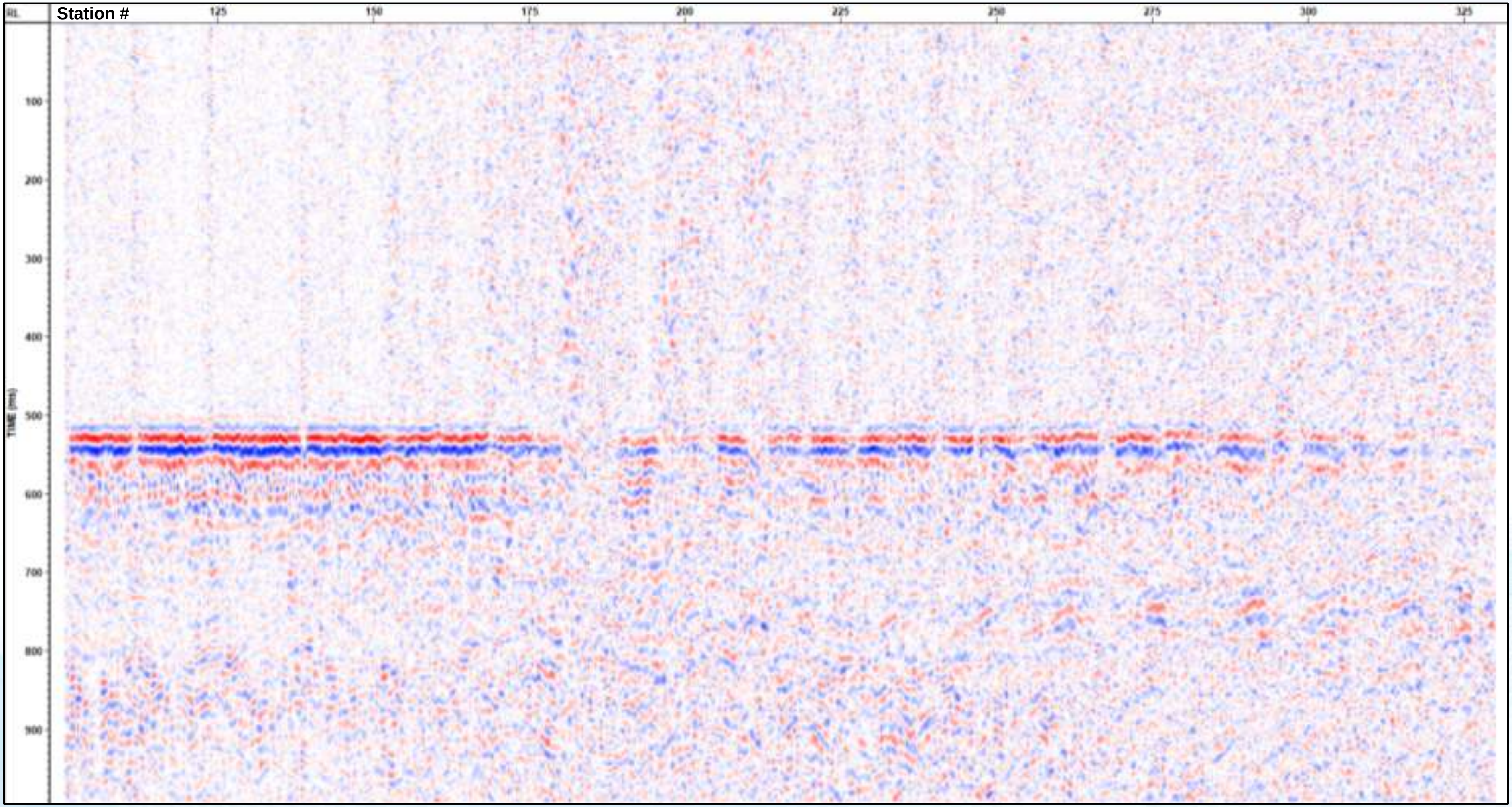
MicroSeismic

2022h Stage 15 Event – Processed Seismic

7/14/2020 18:44:13.644

Mechanism Corrected

Velocity Corrected Event at 500 ms



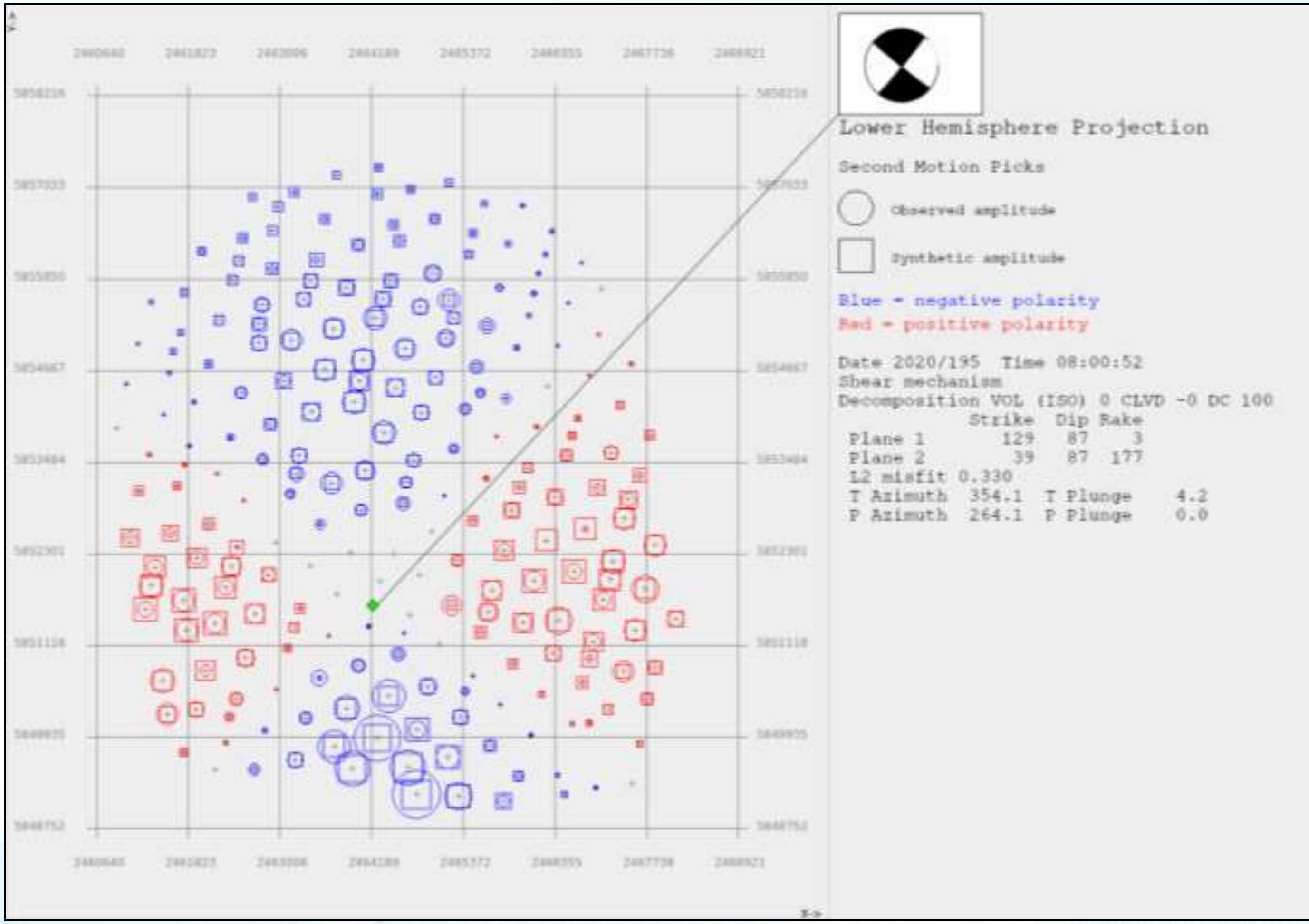
MicroSeismic

Source Mechanism – 2022h Stage 14 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
39	87	177

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.



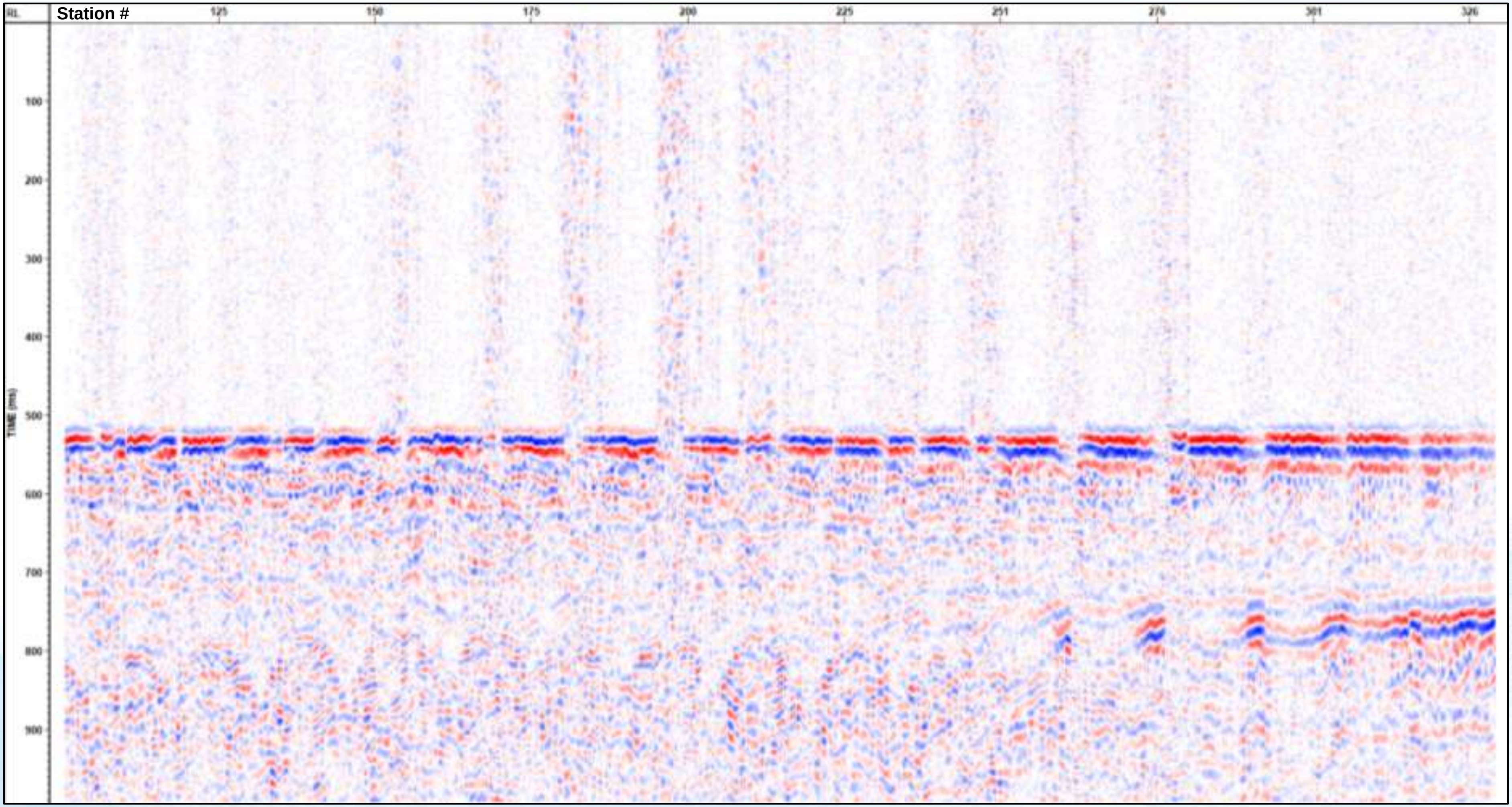
MicroSeismic

2022h Stage 14 Event – Processed Seismic

7/13/2020 08:00:51.660

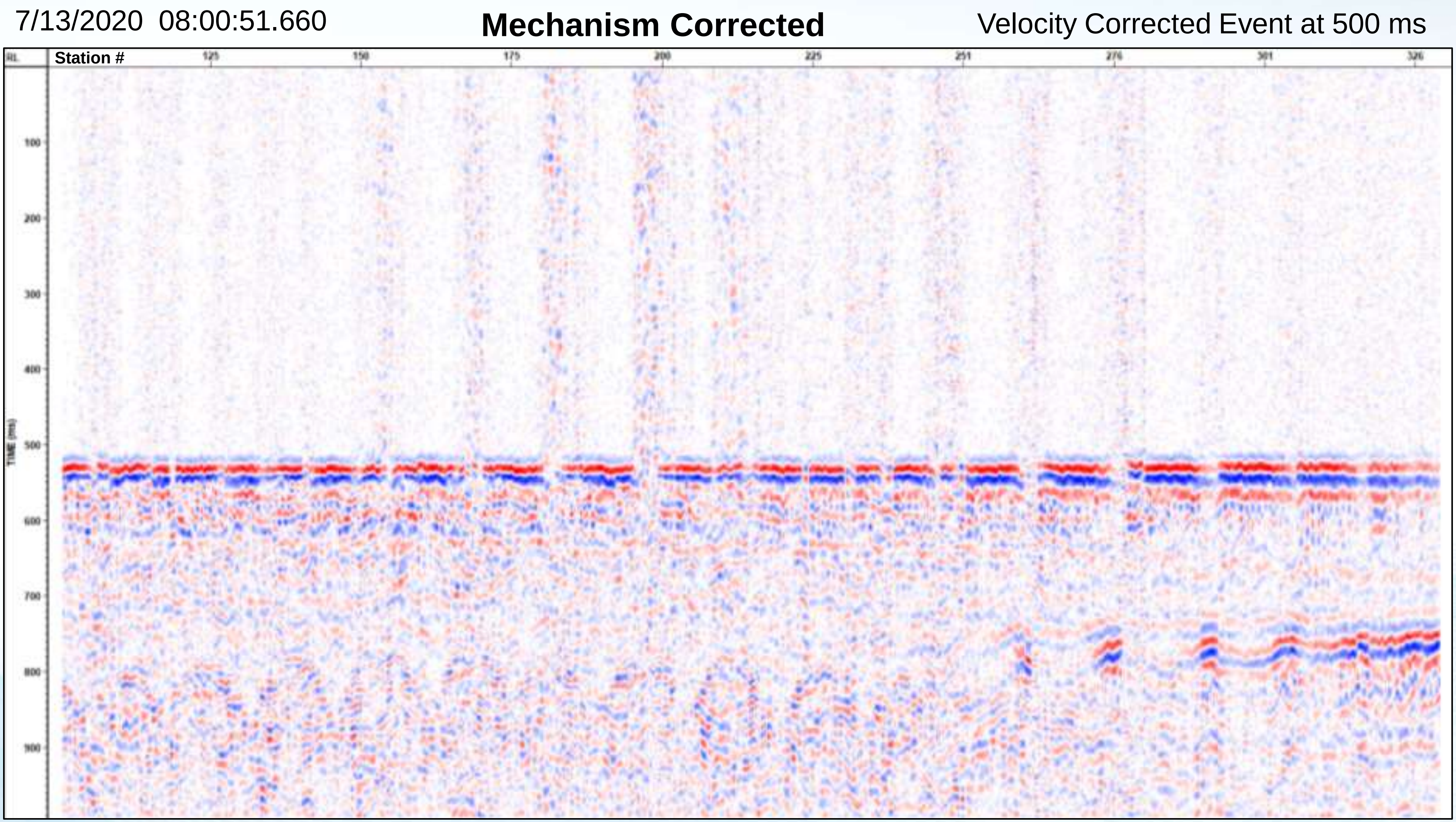
No Mechanism Correction

Velocity Corrected Event at 500 ms



MicroSeismic

2022h Stage 14 Event – Processed Seismic



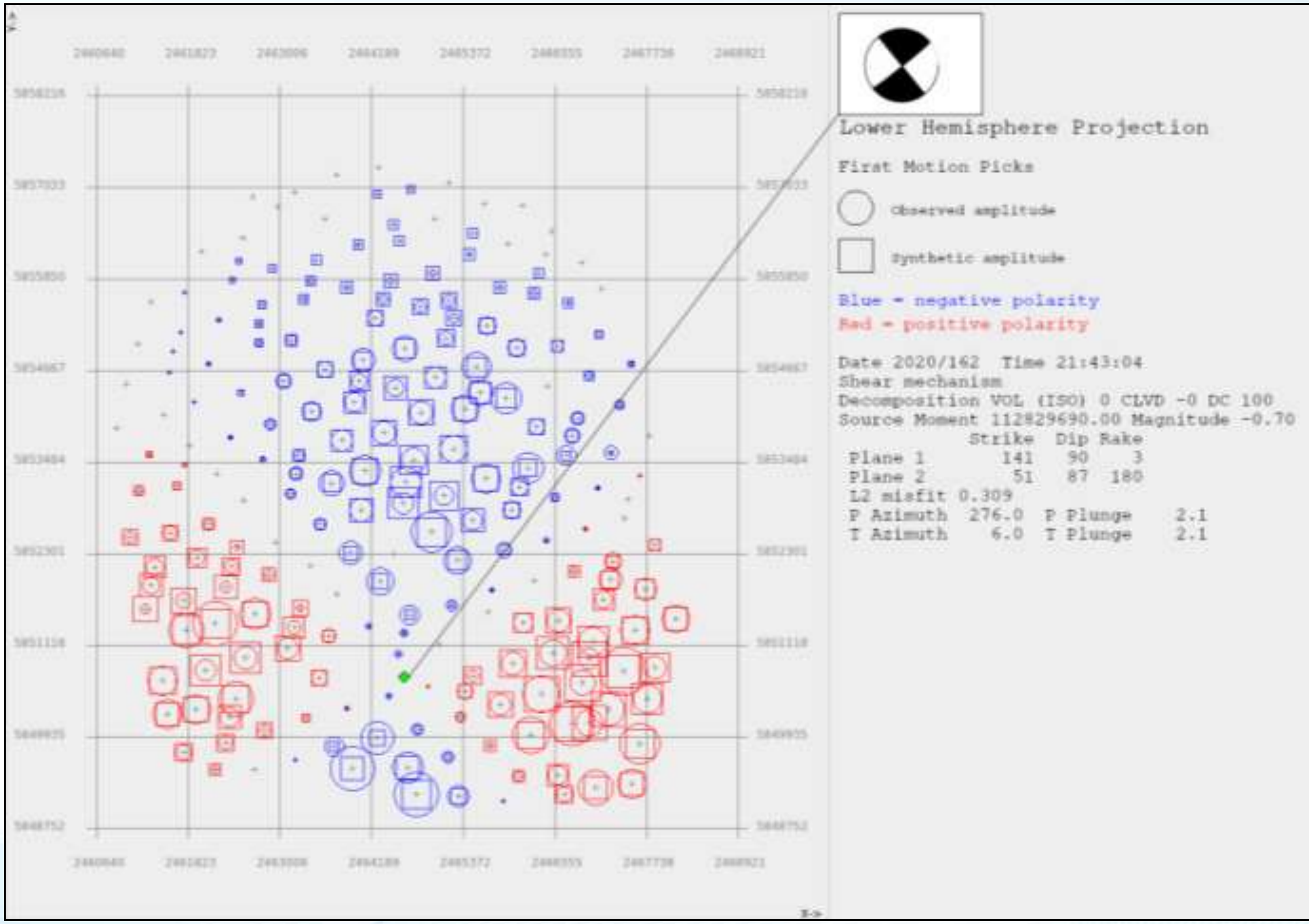
Source Mechanism – 2022h Stage 2 Event

- On the right is one of the focal mechanism solution used for imaging the microseismic data.
- The dip, strike, and rake for the solution is:

Strike	Dip	Rake
51	87	180

- Source mechanisms are used to obtain the best stack of each microseismic event by correcting the polarity of the first arrival at each station and reducing the error in the location for each event.
- The moment magnitude of this event is:

Mw: -0.70

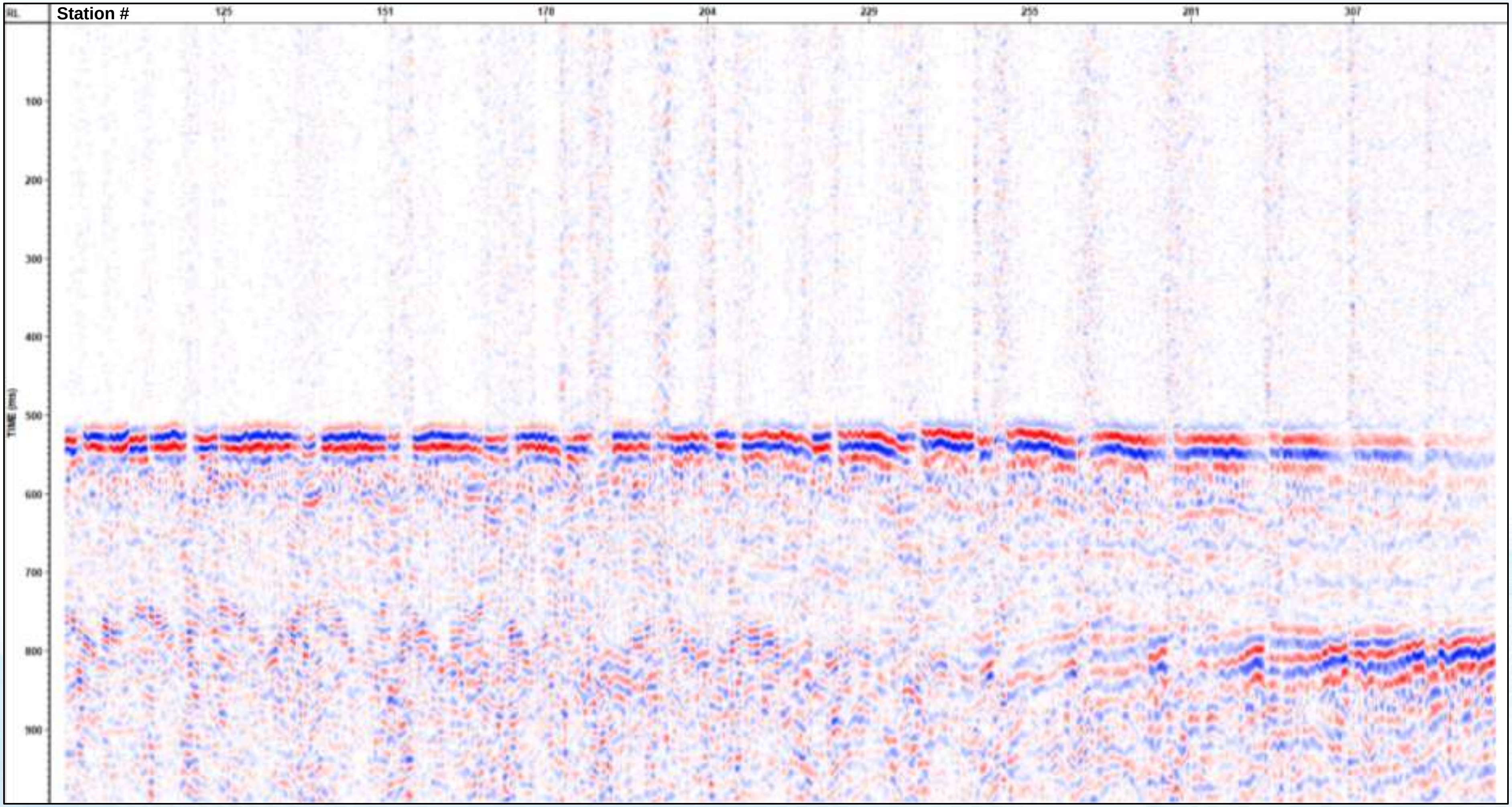


2022h Stage 2 Event – Processed Seismic

6/10/2020 21:43:04.692

No Mechanism Correction

Velocity Corrected Event at 500 ms



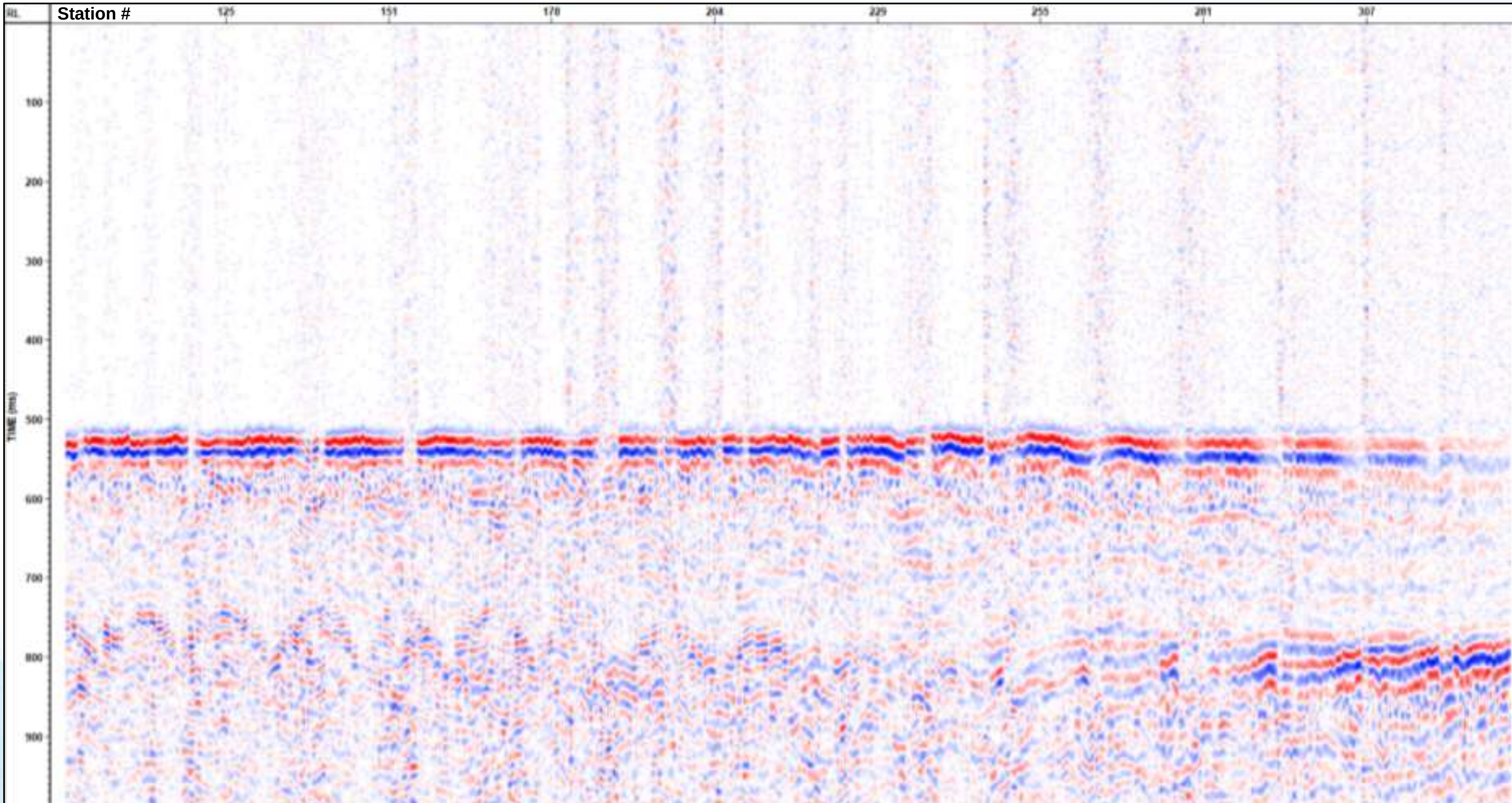
MicroSeismic

2022h Stage 2 Event – Processed Seismic

6/10/2020 21:43:04.692

Mechanism Corrected

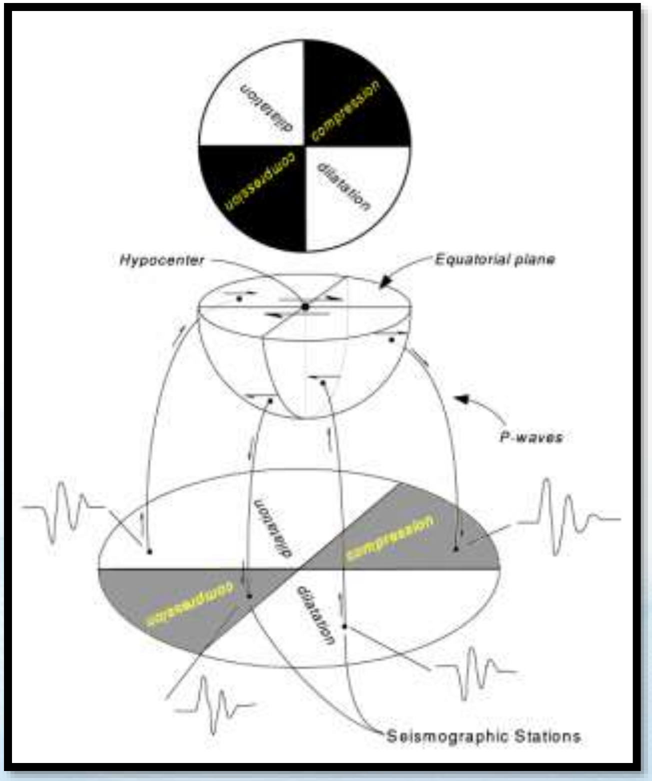
Velocity Corrected Event at 500 ms

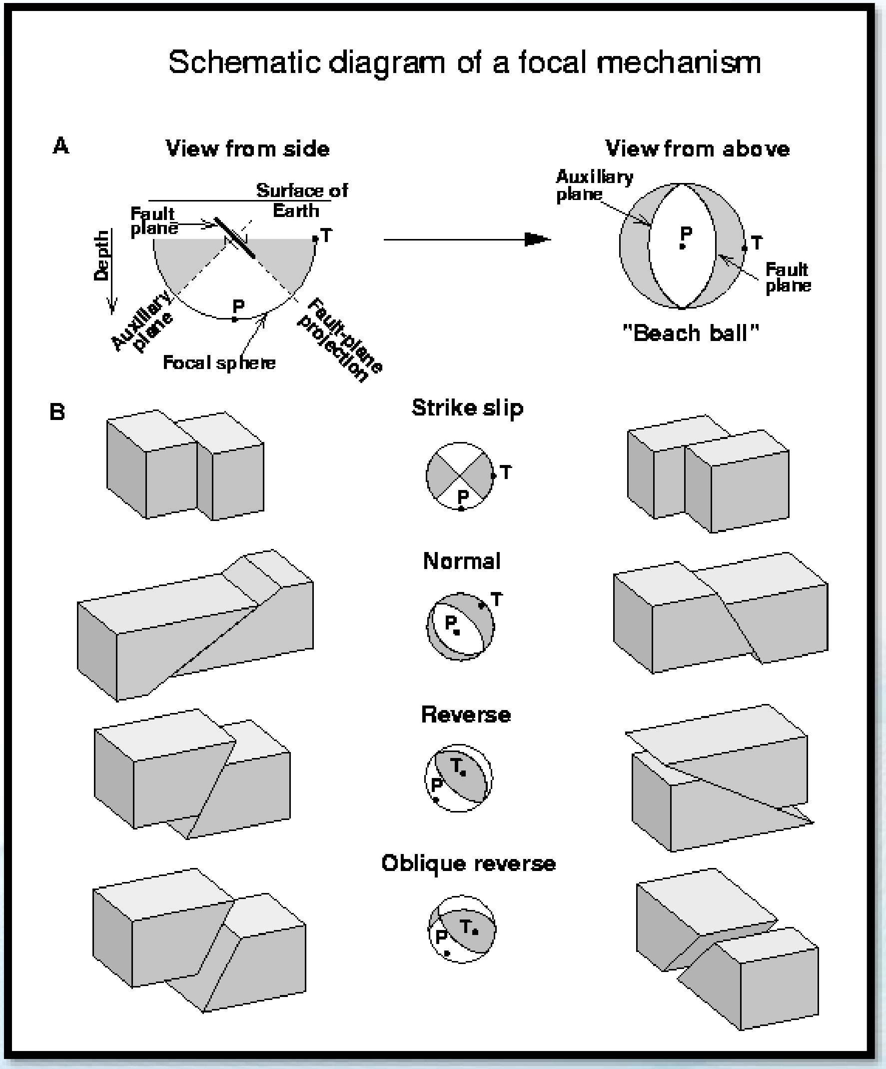


MicroSeismic

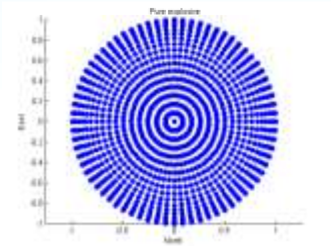
Shear Event Beach Balls

When reading a focal mechanism, imagine that you are looking into the lower hemisphere of a globe that has been cut in half.

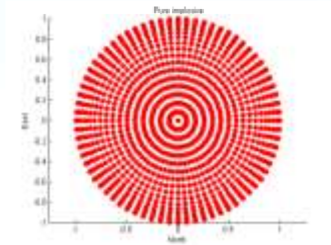




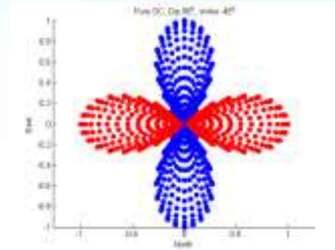
Source Mechanism Representations



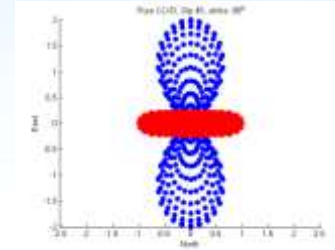
VOL=100%
CLVD=0%
DC=0%



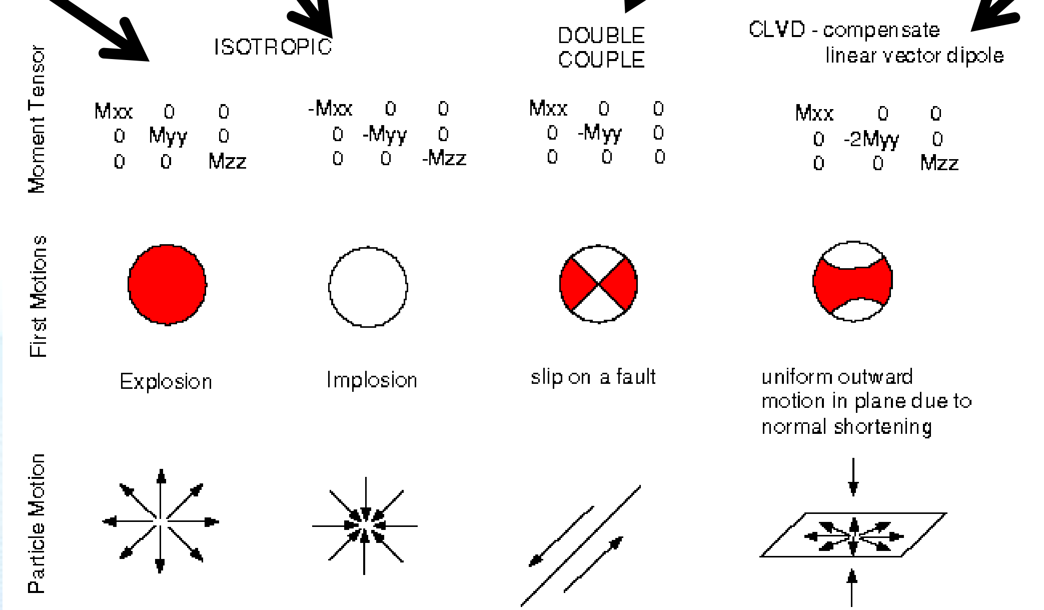
VOL=-100%
CLVD=0%
DC=0%



VOL=0%
CLVD=0%
DC=100%



VOL=0%
CLVD=100%
DC=0%

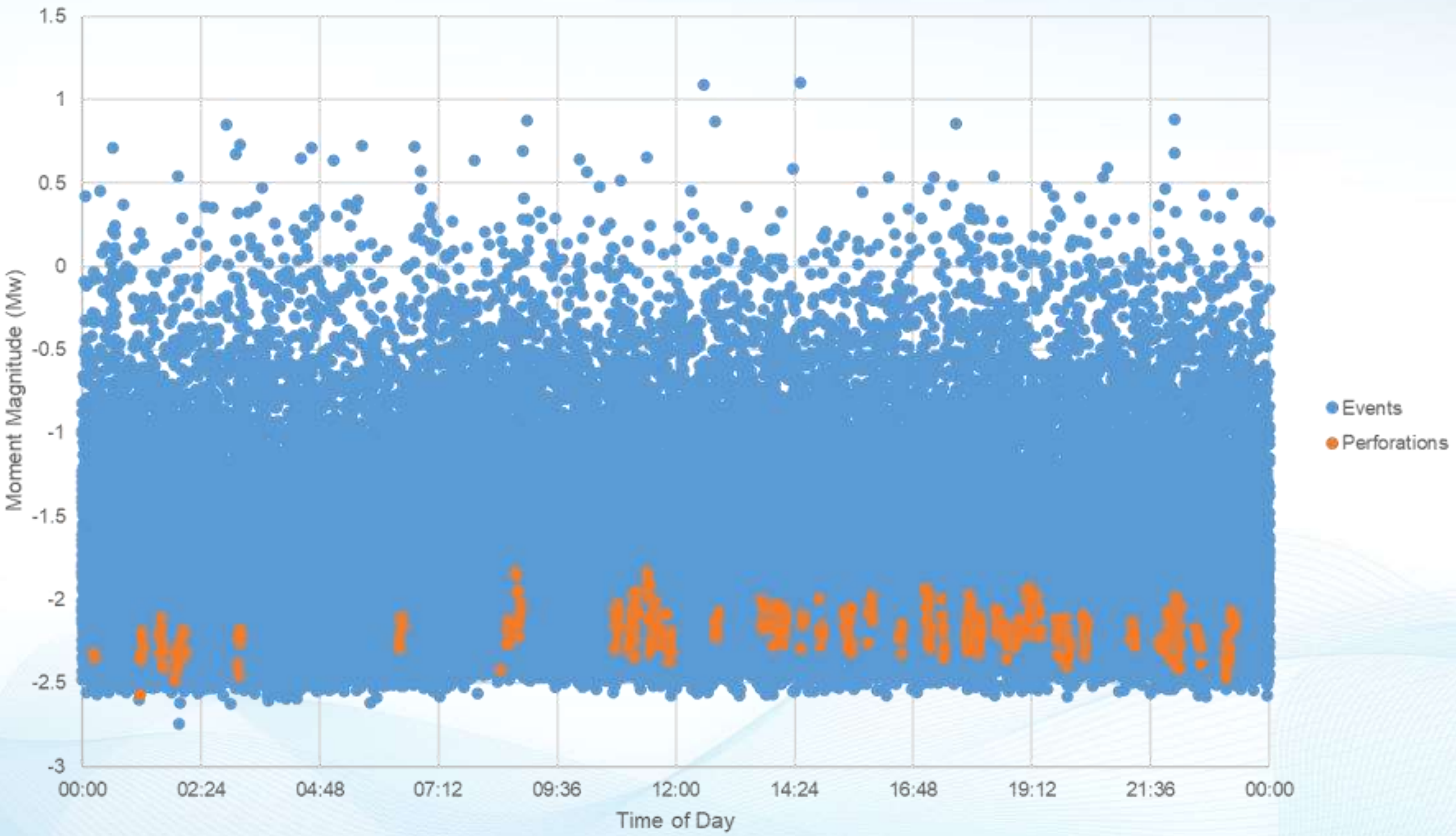


USGS

Data Quality

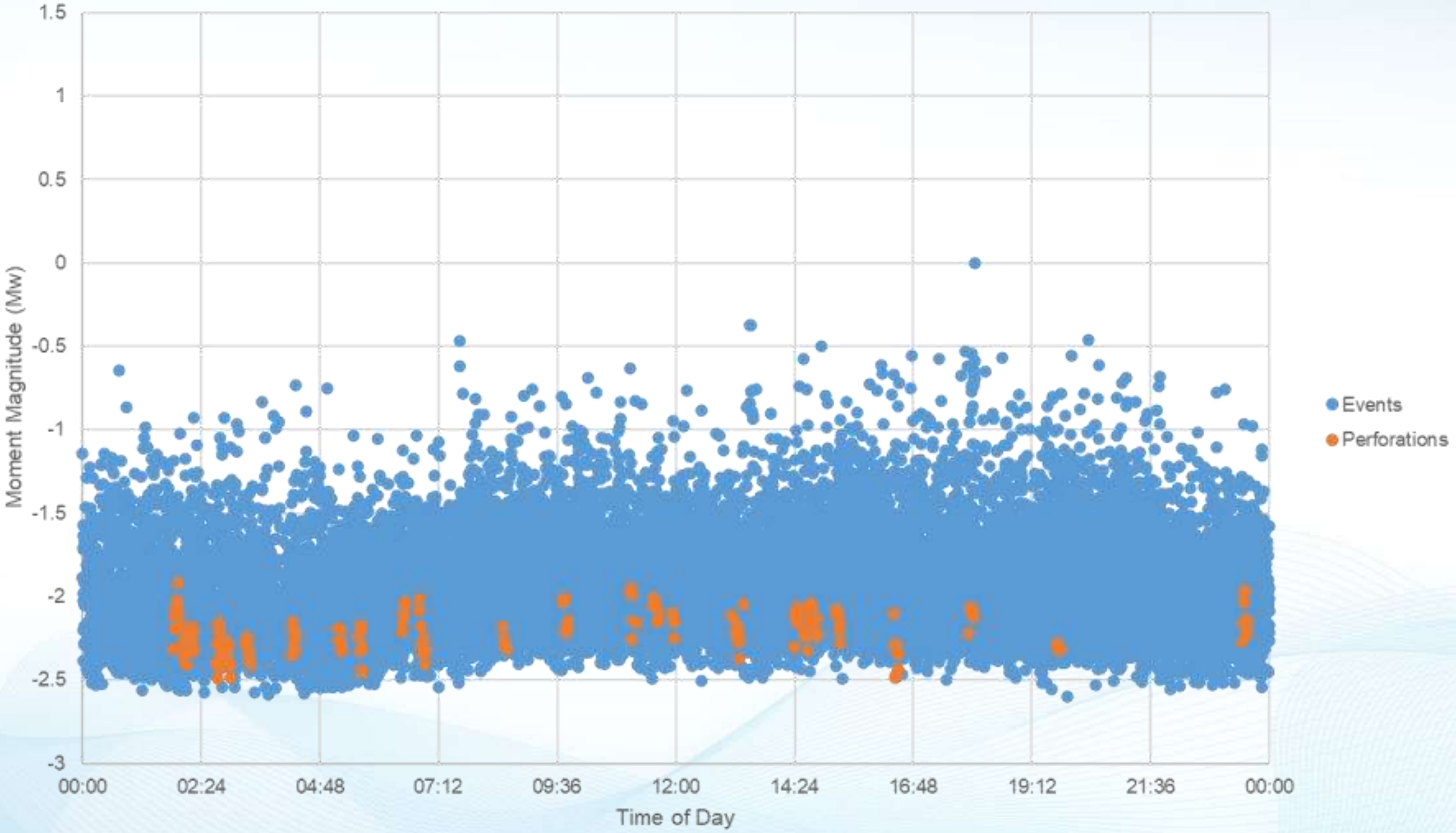
MicroSeismic

Magnitude vs Time of Day – 2021h & 2023h



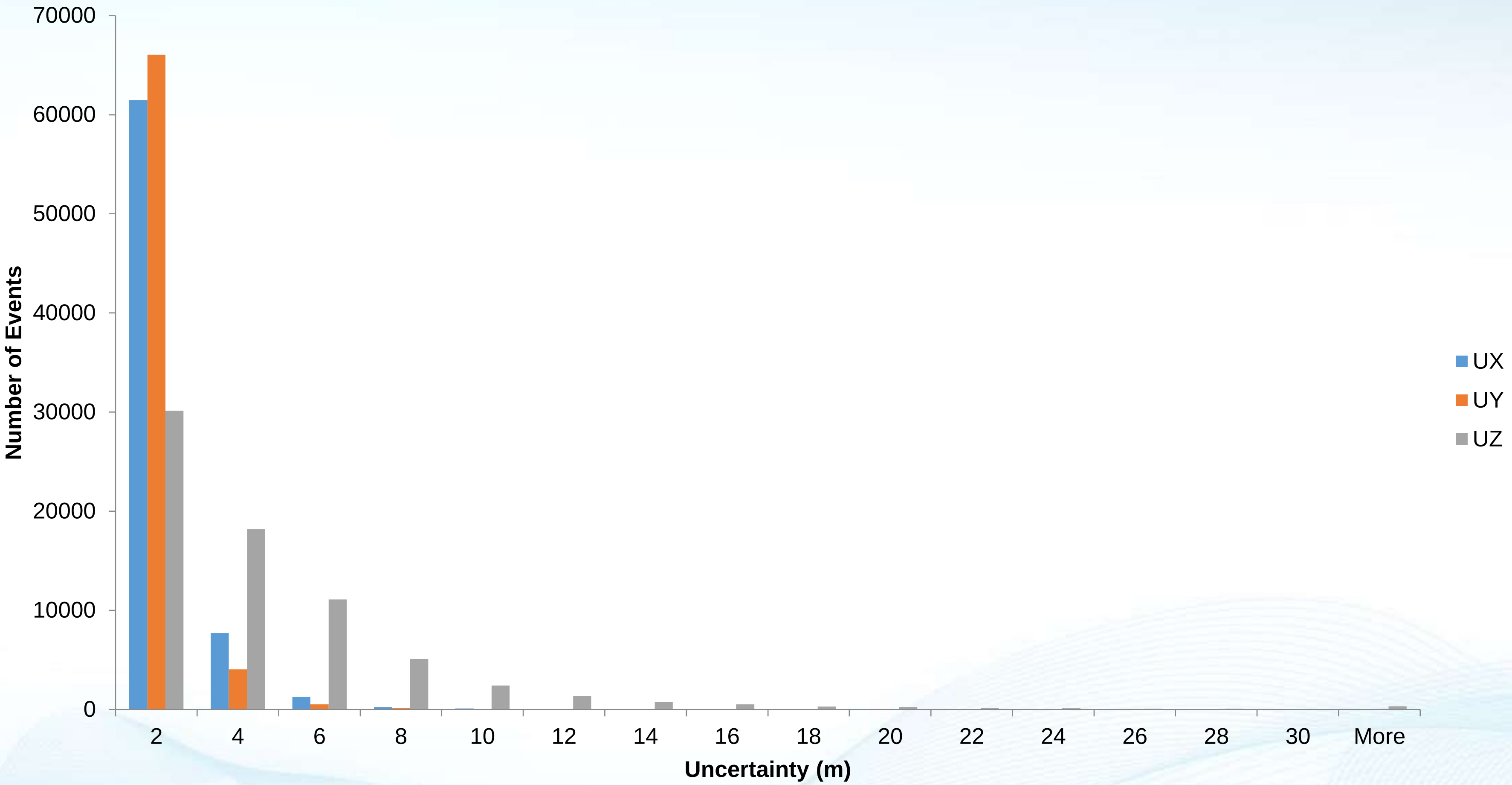
MicroSeismic

Magnitude vs Time of Day – 2022h & 2024h



MicroSeismic

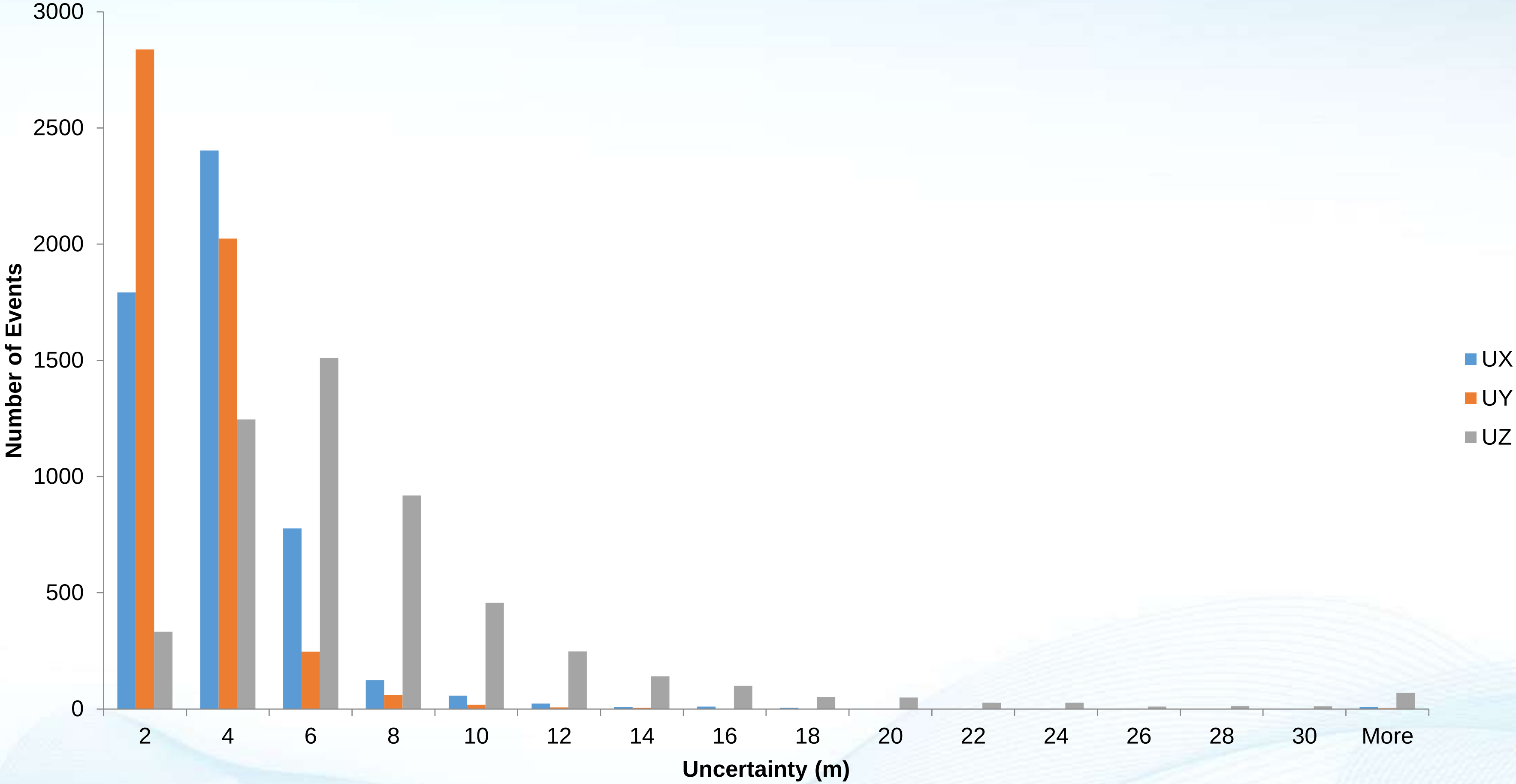
Event Location Uncertainties – 2021h & 2023h – All Events



Uncertainty (m)	UX	UY	UZ
Minimum	1	1	1
Maximum	50	70	156
Average	1	1	4
Median	1	1	3

MicroSeismic

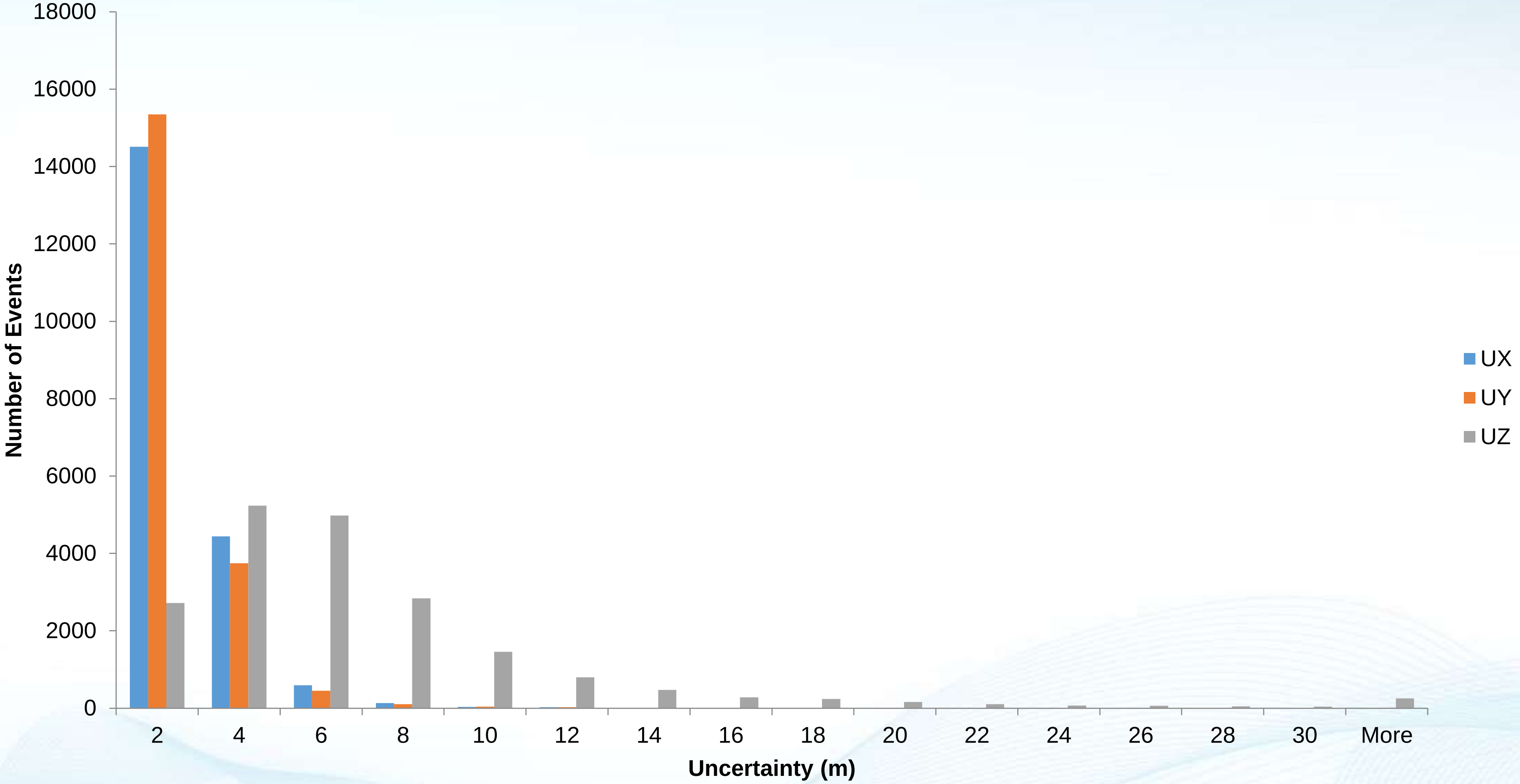
Event Location Uncertainties – 2021h & 2023h – Reservoir



Uncertainty (m)	UX	UY	UZ
Minimum	1	1	1
Maximum	48	38	135
Average	3	2	7
Median	3	2	5

MicroSeismic

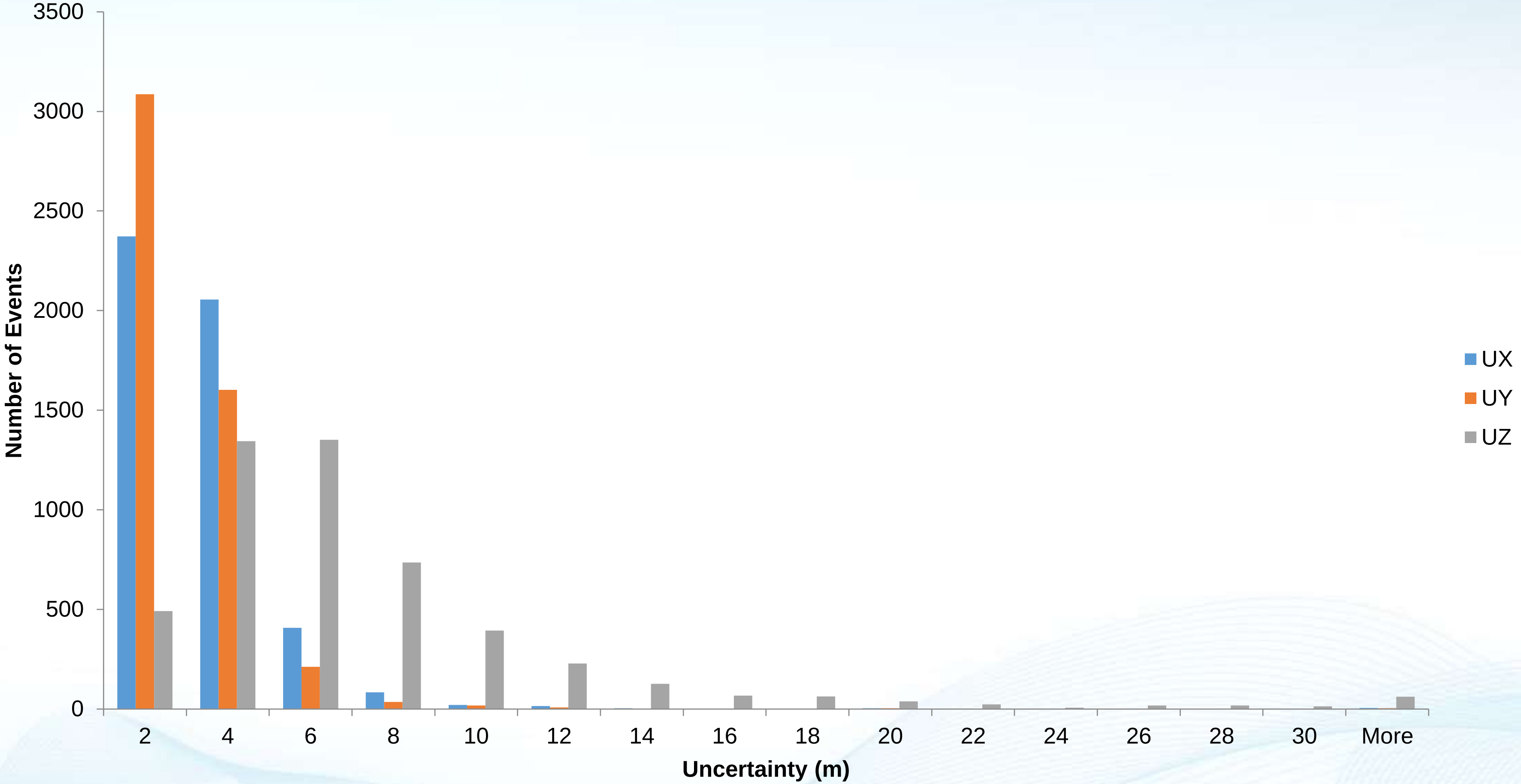
Event Location Uncertainties – 2022h & 2024h – All Events



Uncertainty (m)	UX	UY	UZ
Minimum	1	1	1
Maximum	41	68	127
Average	2	1	6
Median	1	1	5

MicroSeismic

Event Location Uncertainties – 2022h & 2024h – Reservoir



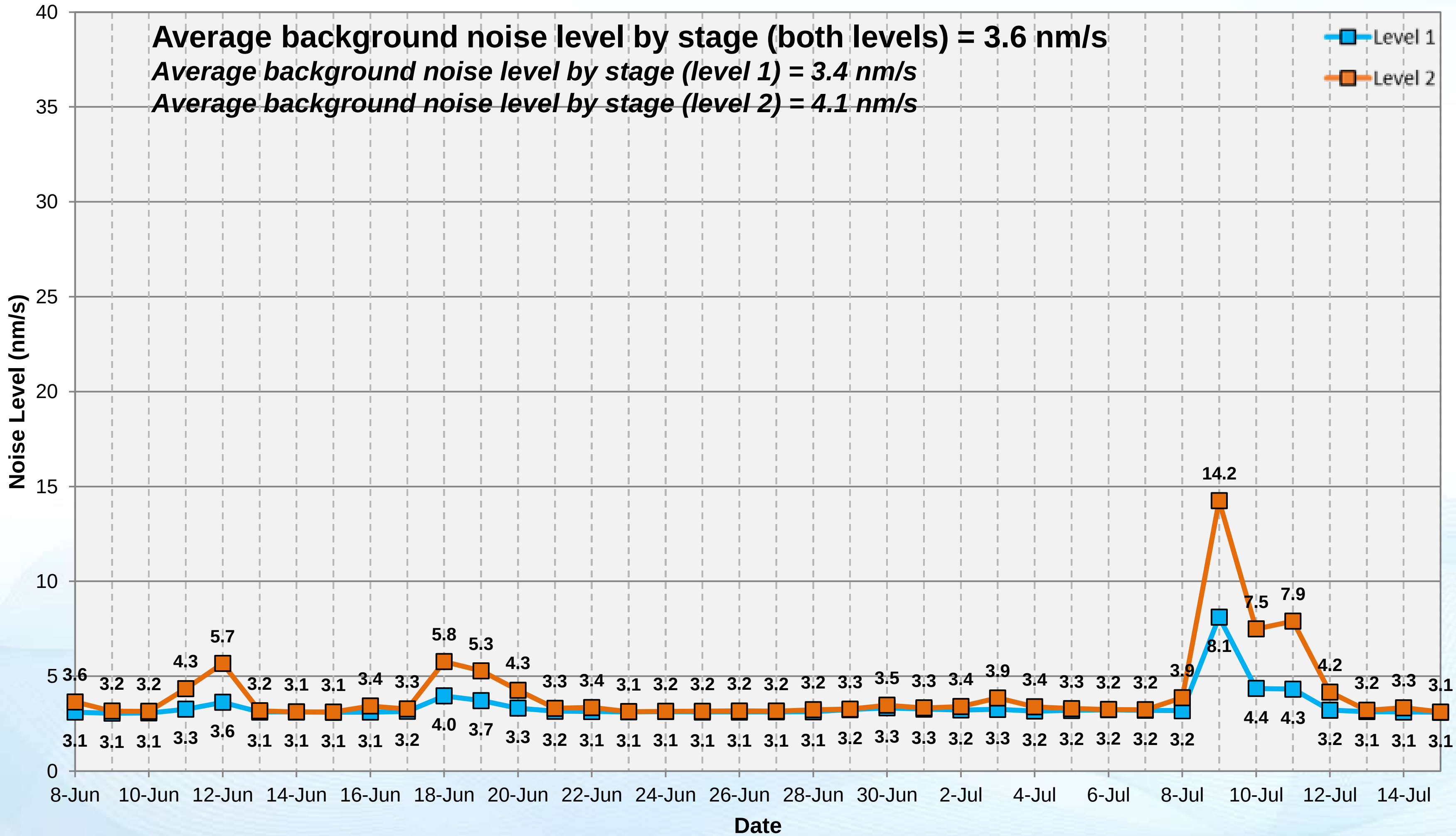
Uncertainty (m)	UX	UY	UZ
Minimum	1	1	1
Maximum	41	68	125
Average	2	2	6
Median	2	2	5

MicroSeismic

Noise Analysis

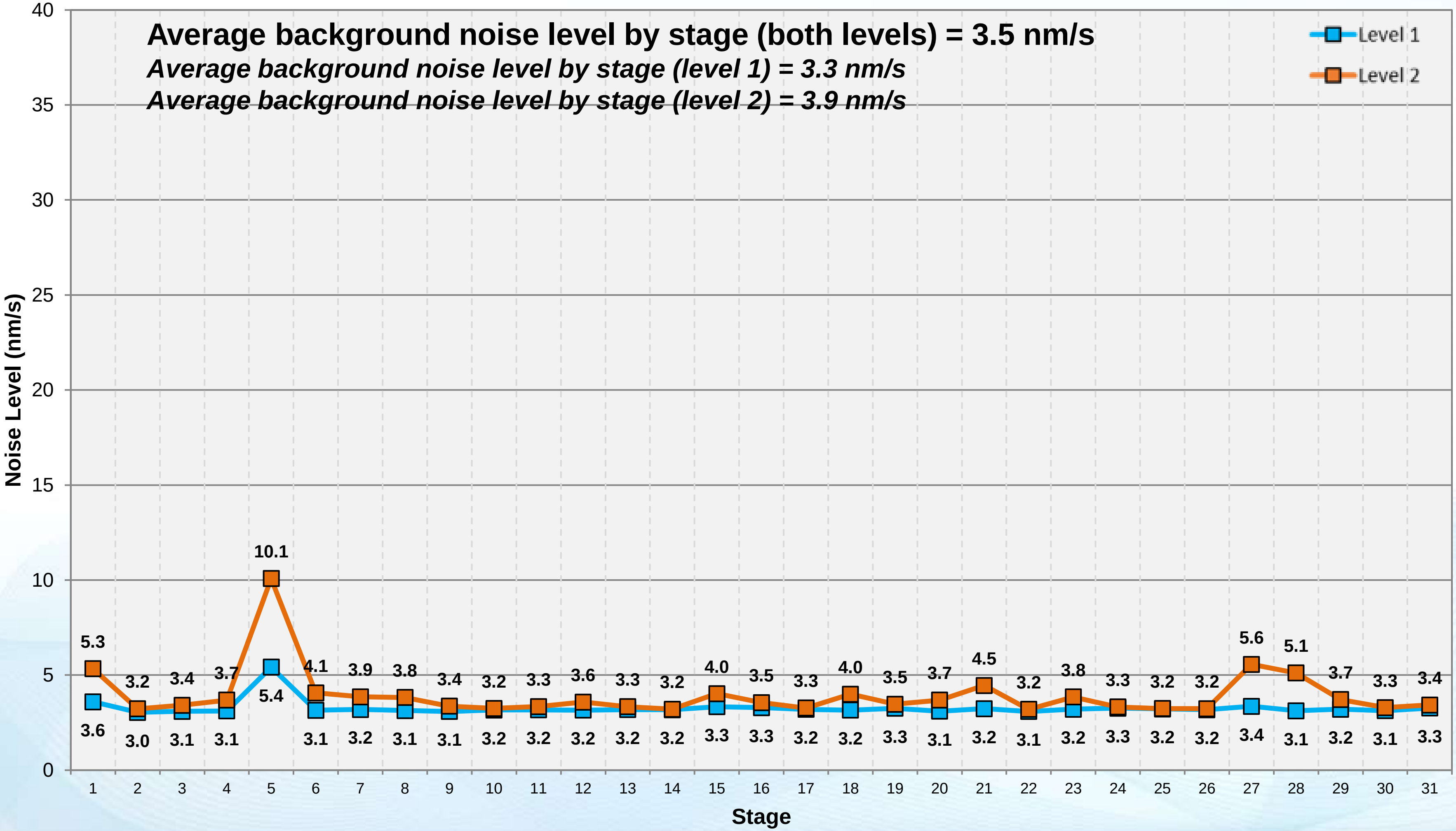
Noise Analysis – Day

- Background noise values are calculated as a percentile of 1 second rms values over the data. Average values are given by stage at the 50th percentile.
- The historical noise values are: 63 nm/s highest, 12 nm/s average, and 3 nm/s lowest.



Noise Analysis – Stage – 2021h

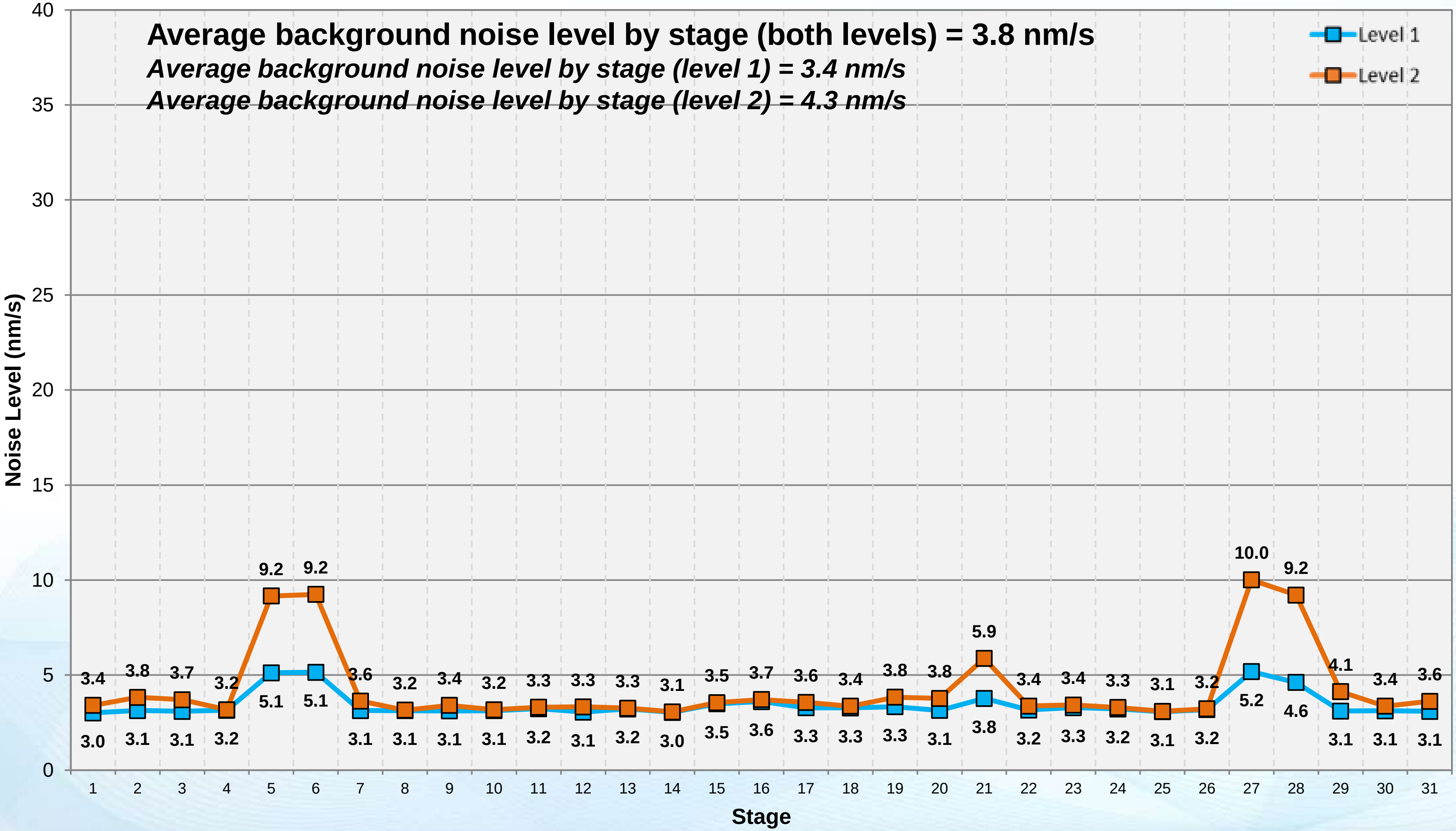
- Background noise values are calculated as a percentile of 1 second rms values over the data. Average values are given by stage at the 50^{th} percentile.
- The historical noise values are: 63 nm/s highest, 12 nm/s average, and 3 nm/s lowest.



MicroSeismic

Noise Analysis – Stage – 2023h

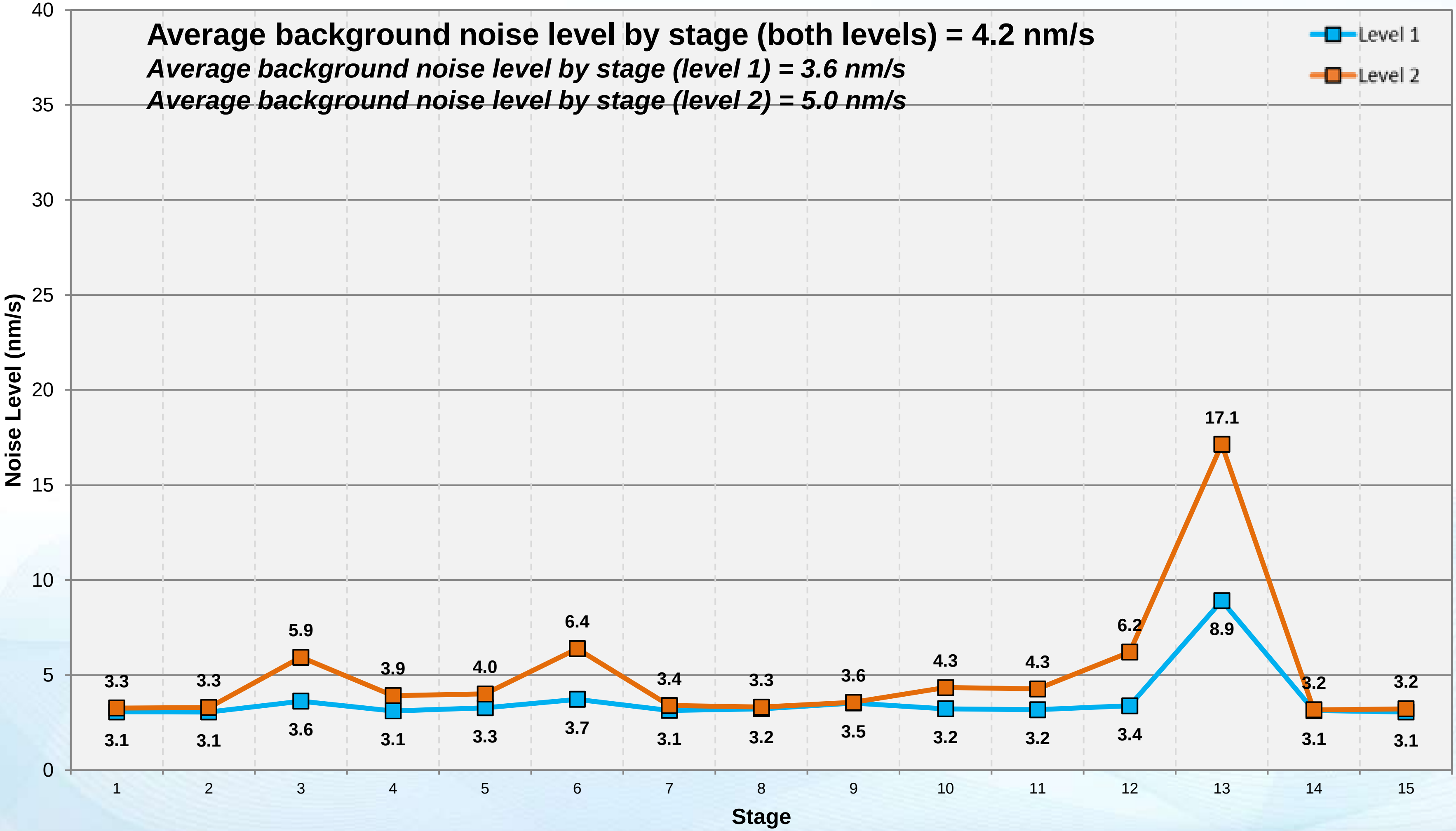
- Background noise values are calculated as a percentile of 1 second rms values over the data. Average values are given by stage at the 50th percentile.
- The historical noise values are: 63 nm/s highest, 12 nm/s average, and 3 nm/s lowest.



MicroSeismic

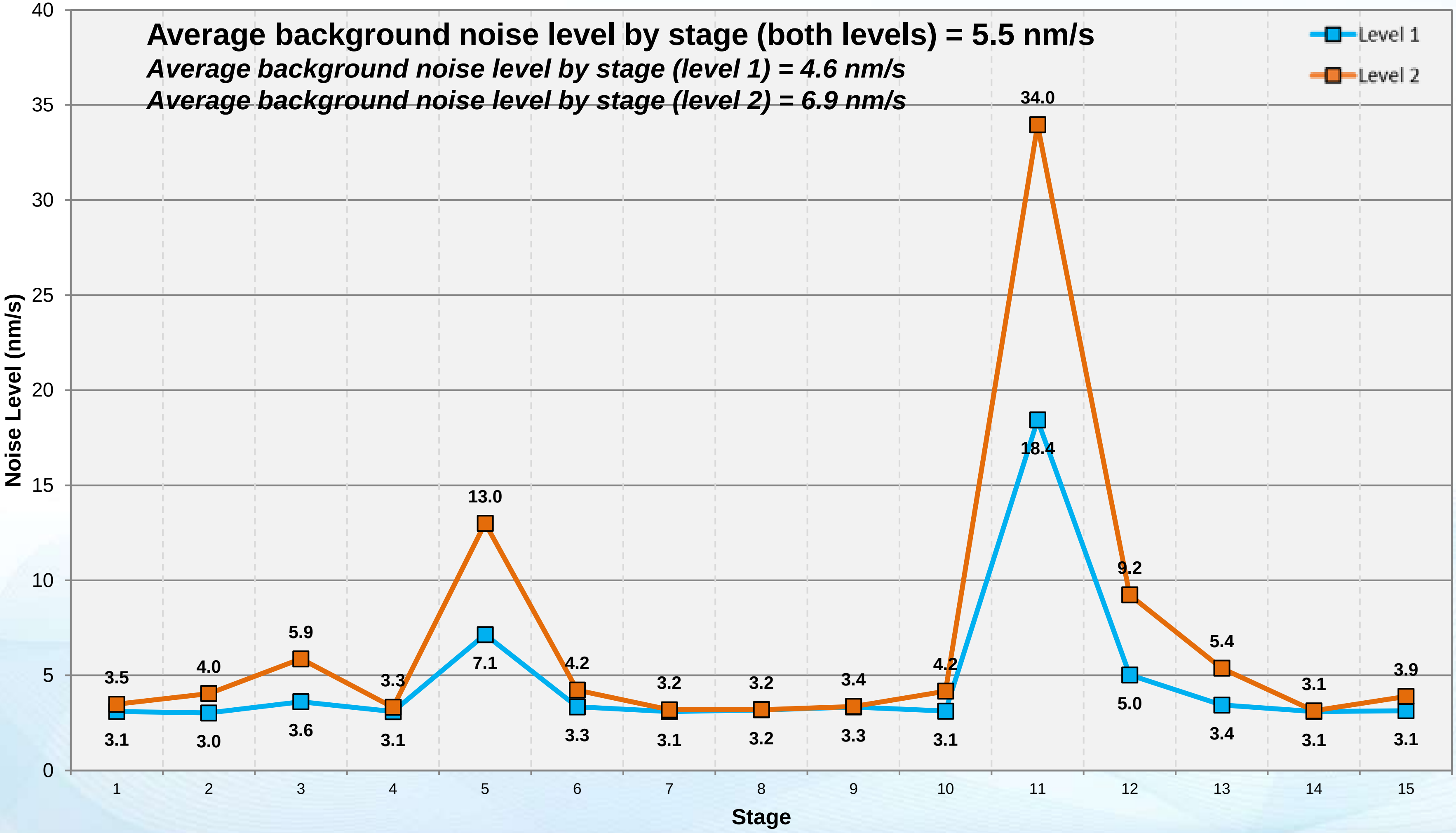
Noise Analysis – Stage – 2022h

- Background noise values are calculated as a percentile of 1 second rms values over the data. Average values are given by stage at the 50th percentile.
- The historical noise values are: 63 nm/s highest, 12 nm/s average, and 3 nm/s lowest.



Noise Analysis – Stage – 2024h

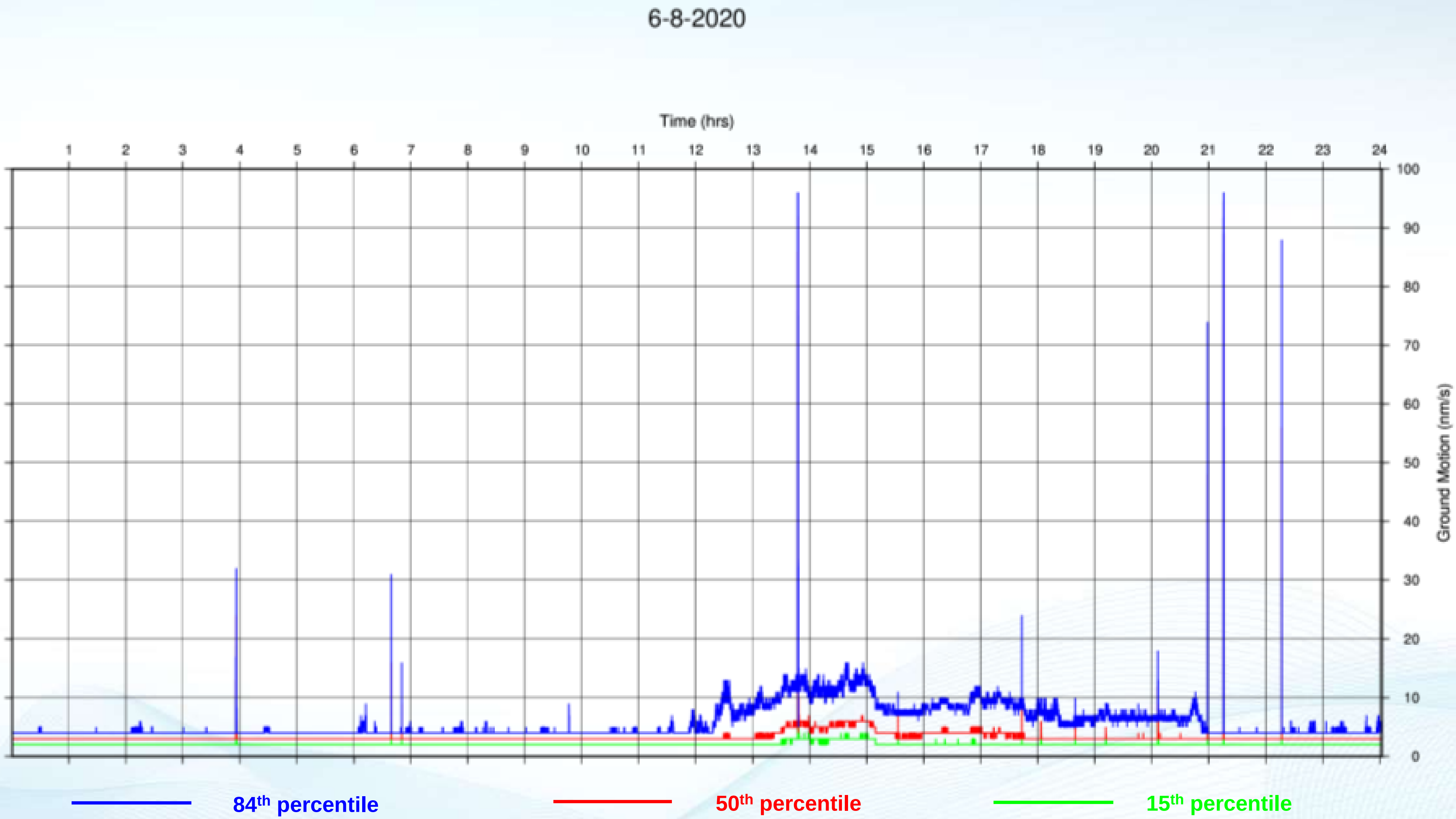
- Background noise values are calculated as a percentile of 1 second rms values over the data. Average values are given by stage at the 50th percentile.
- The historical noise values are: 63 nm/s highest, 12 nm/s average, and 3 nm/s lowest.



Day by Day Noise Histogram Plots

MicroSeismic

Noise Analysis – Day 160

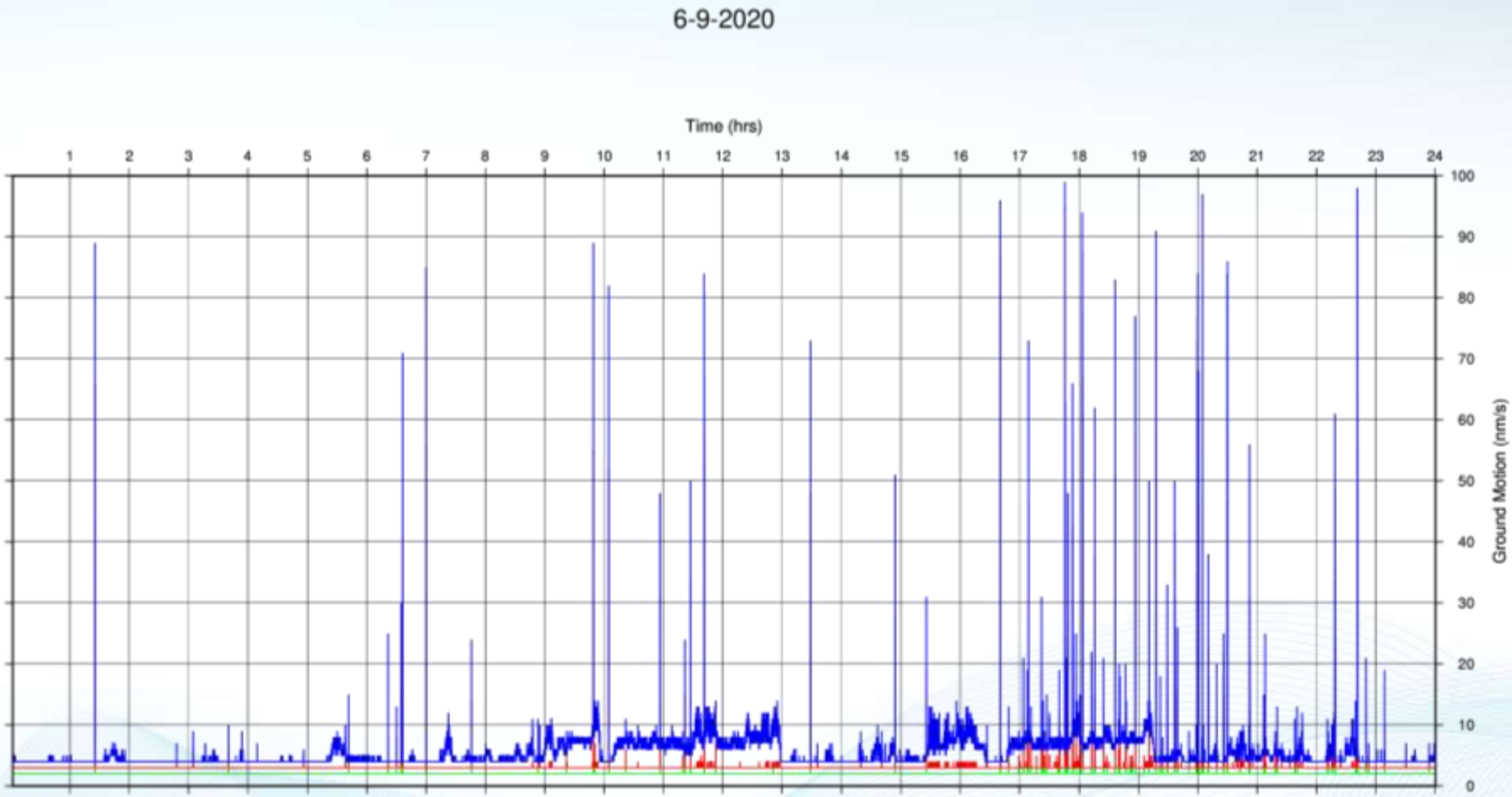


Monday, June 8, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

Noise Analysis – Day 161

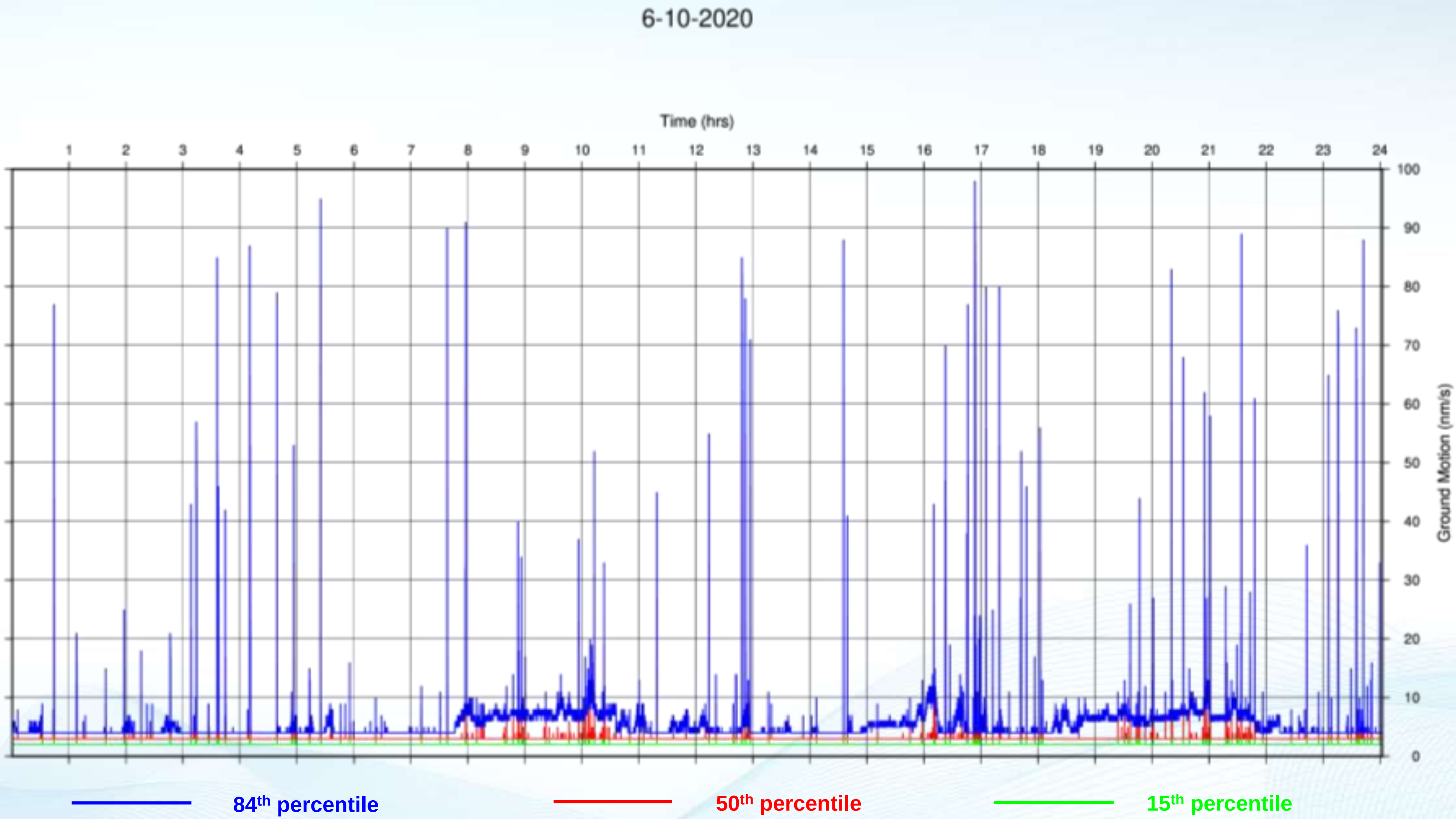


84th percentile   50th percentile   15th percentile

Tuesday, June 9, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

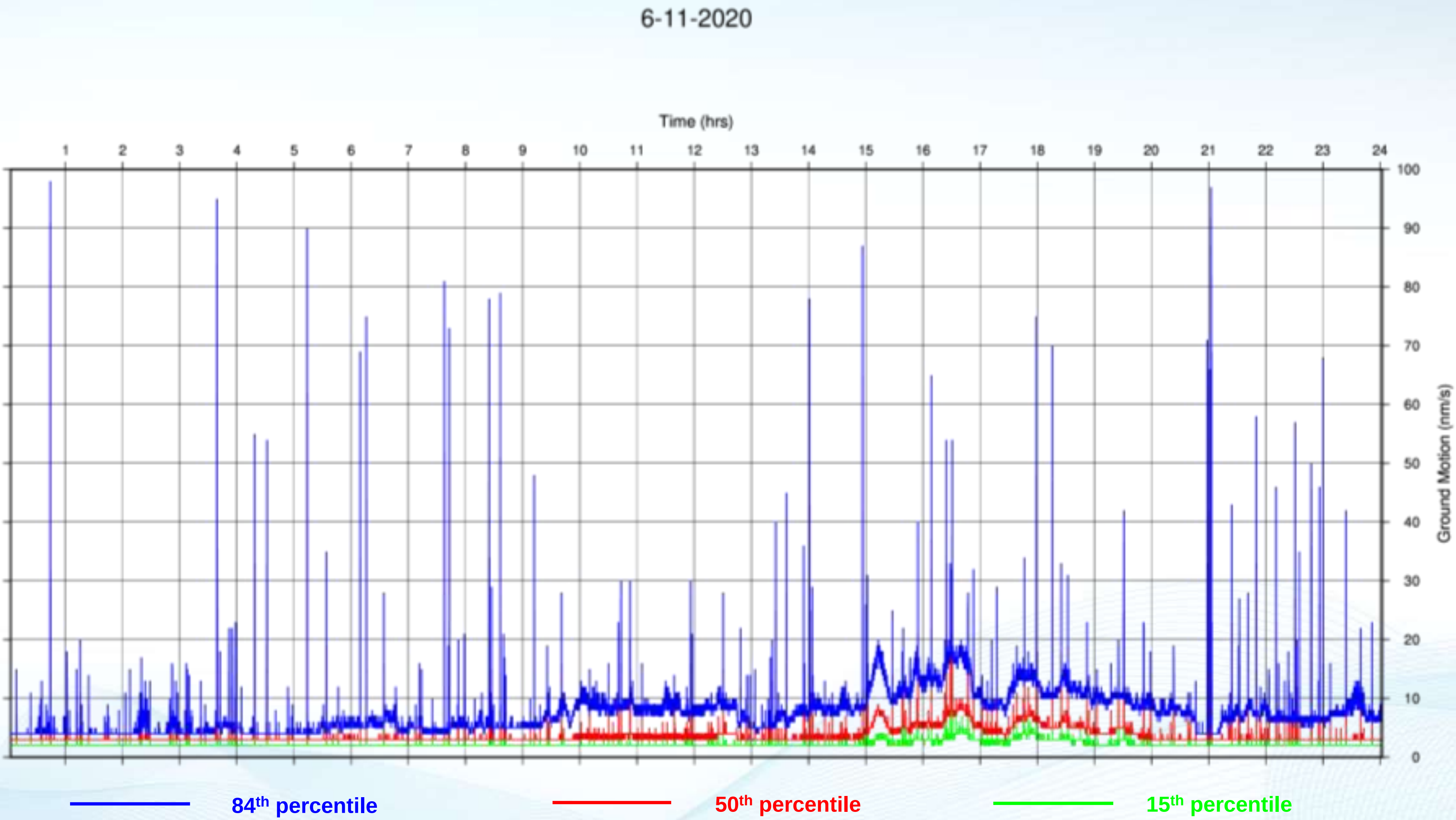
Noise Analysis – Day 162



Wednesday, June 10, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

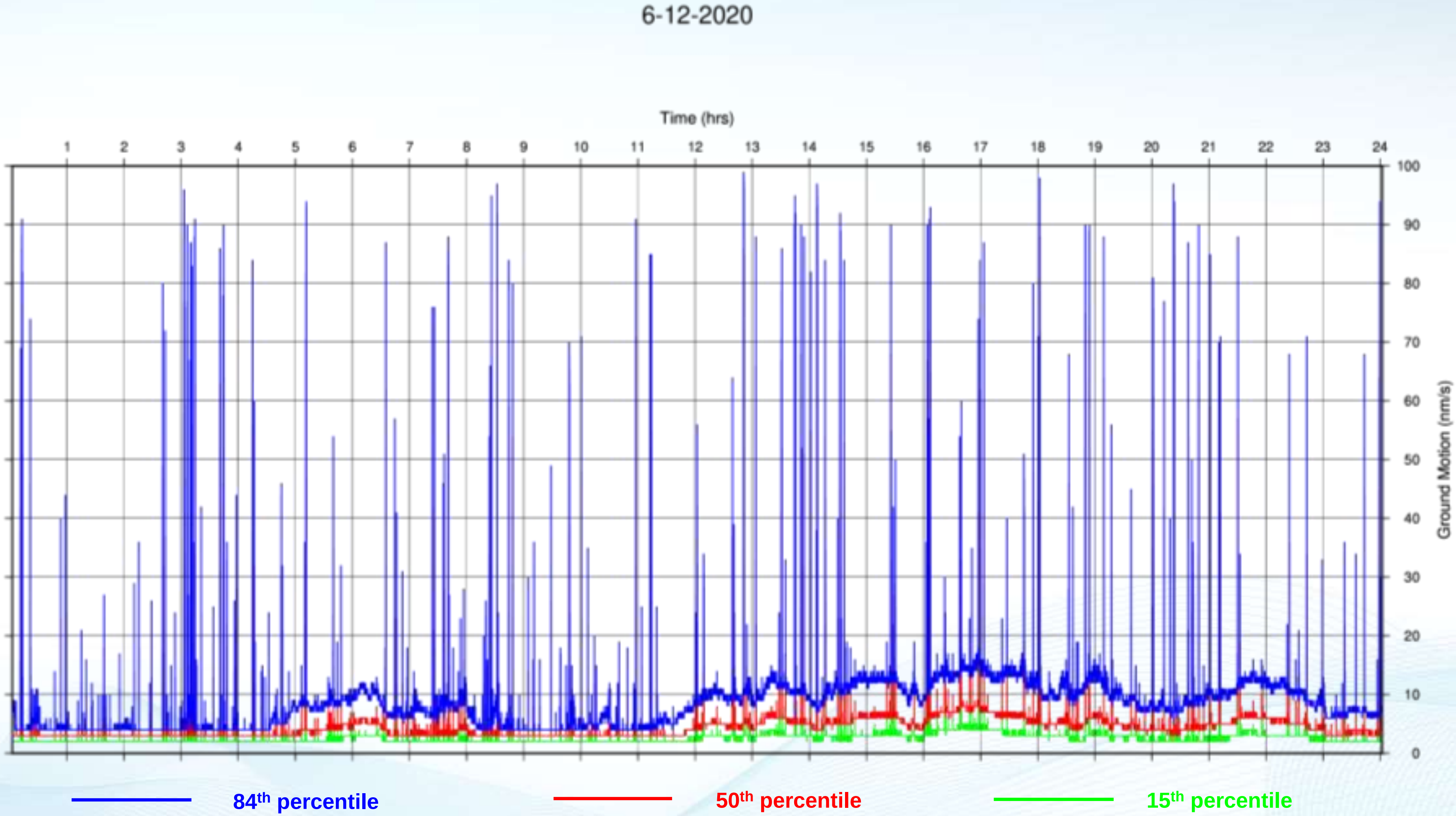
Noise Analysis – Day 163



Thursday, June 11, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

Noise Analysis – Day 164

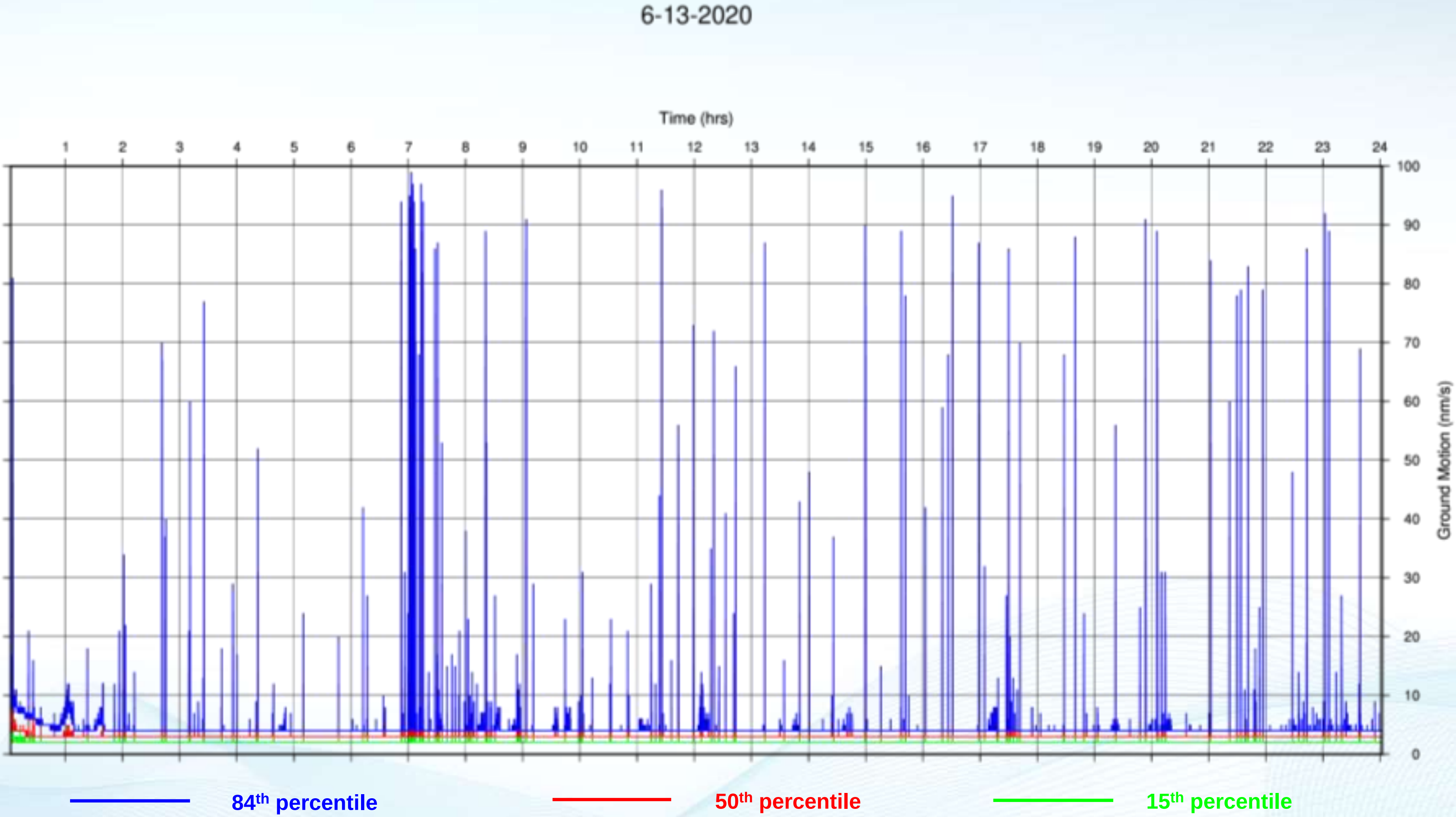


Friday, June 12, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

Noise Analysis – Day 165

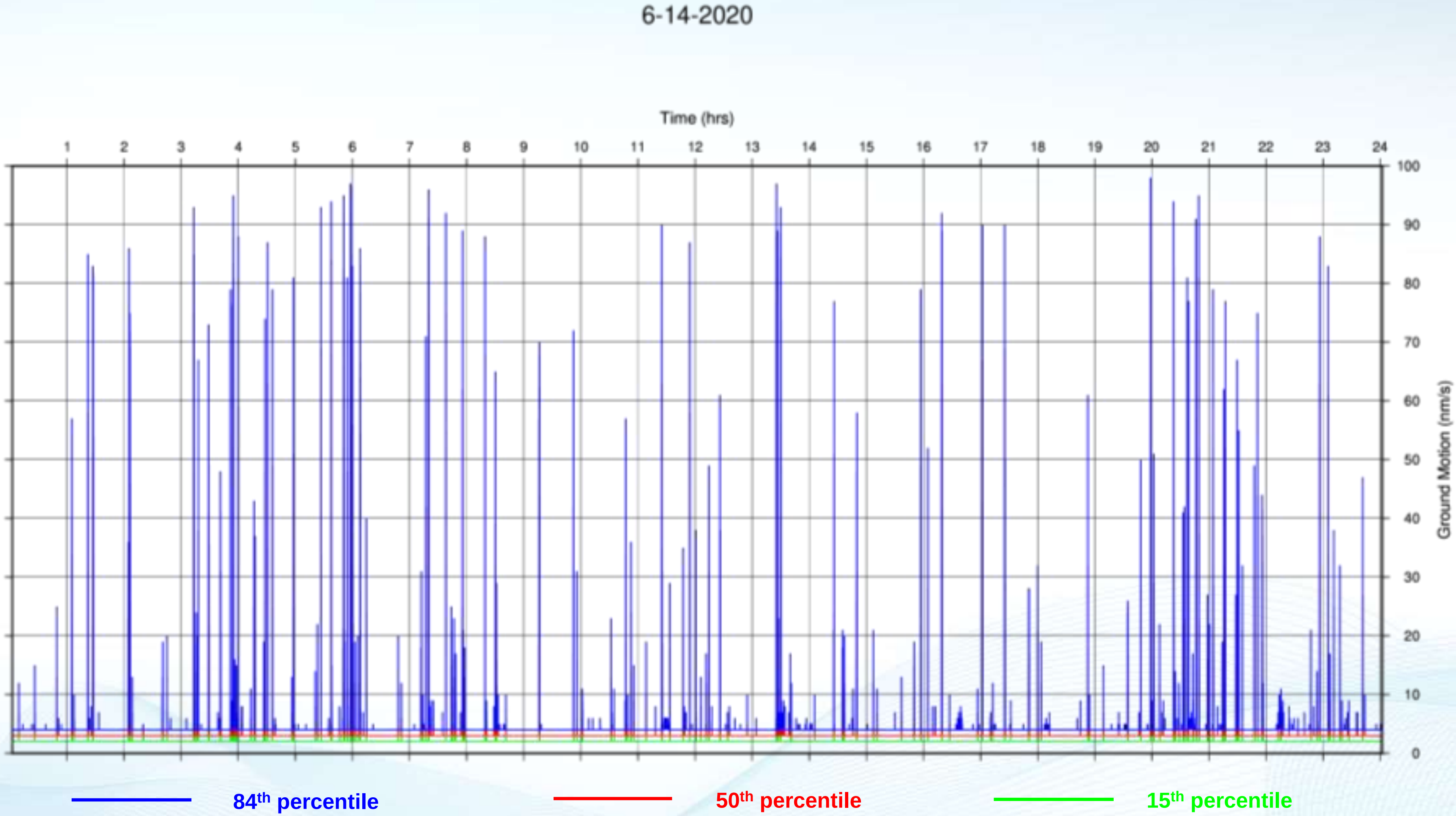


Saturday, June 13, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

Noise Analysis – Day 166

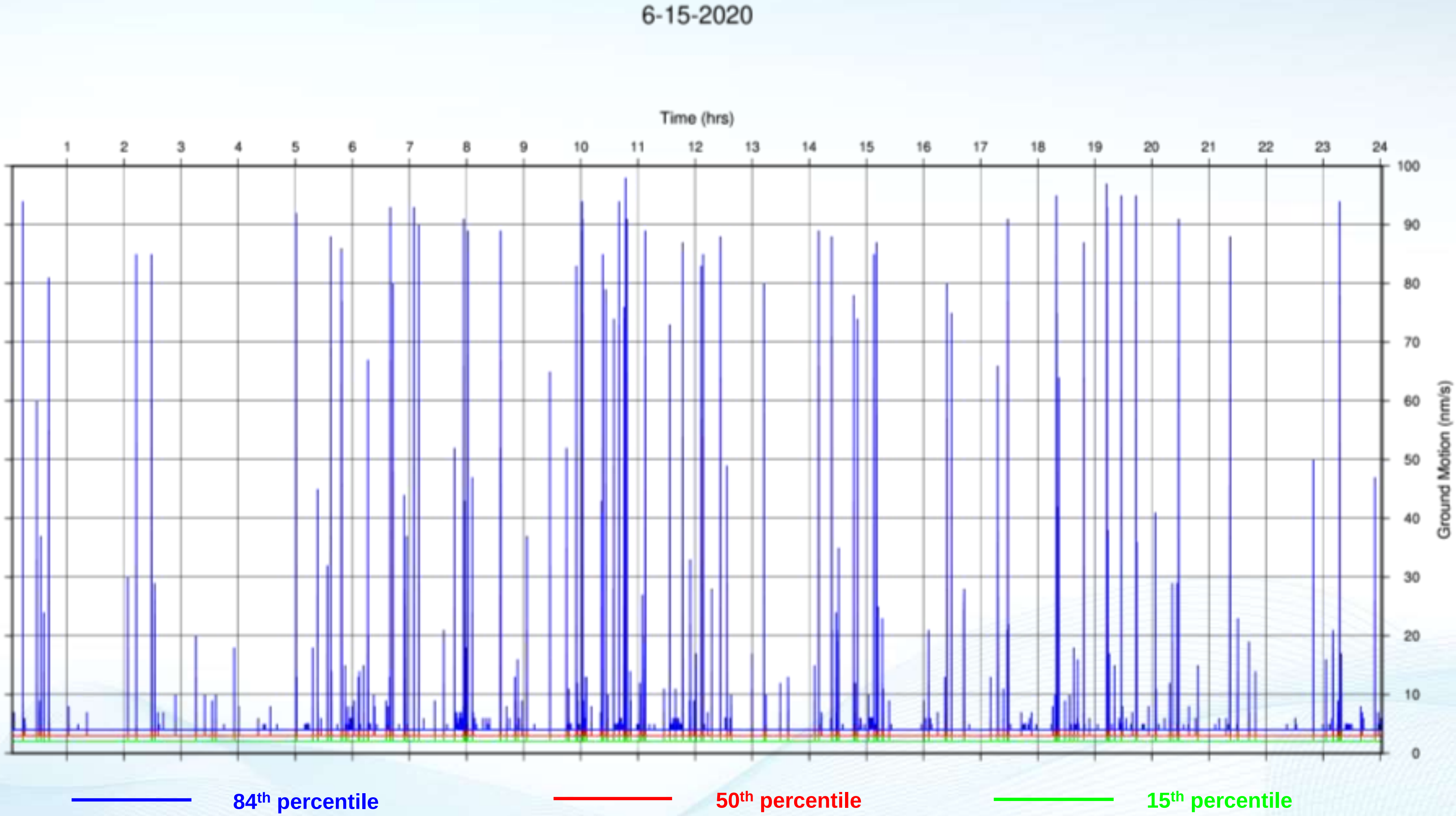


Sunday, June 14, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

Noise Analysis – Day 167

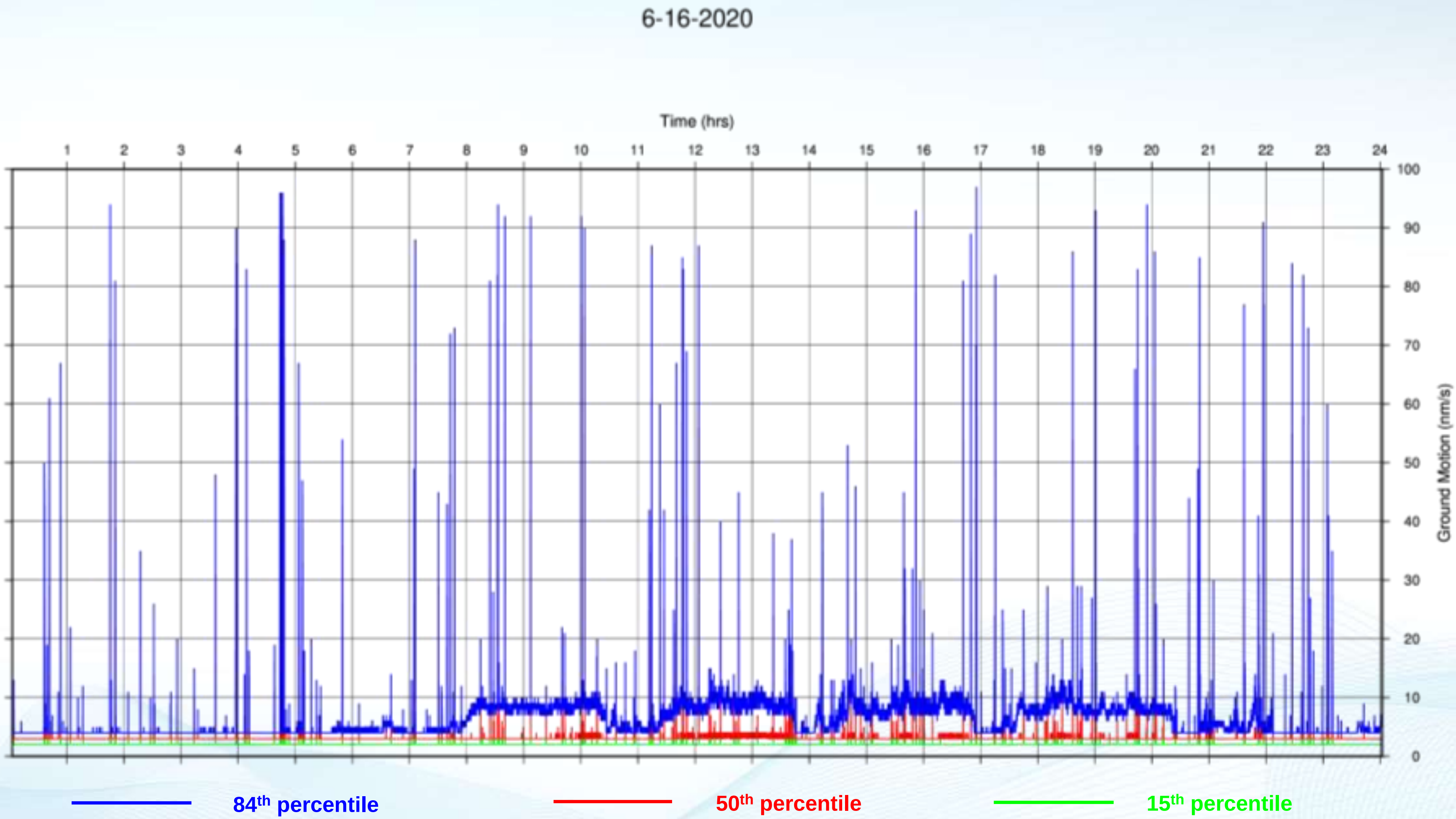


Monday, June 15, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

Noise Analysis – Day 168

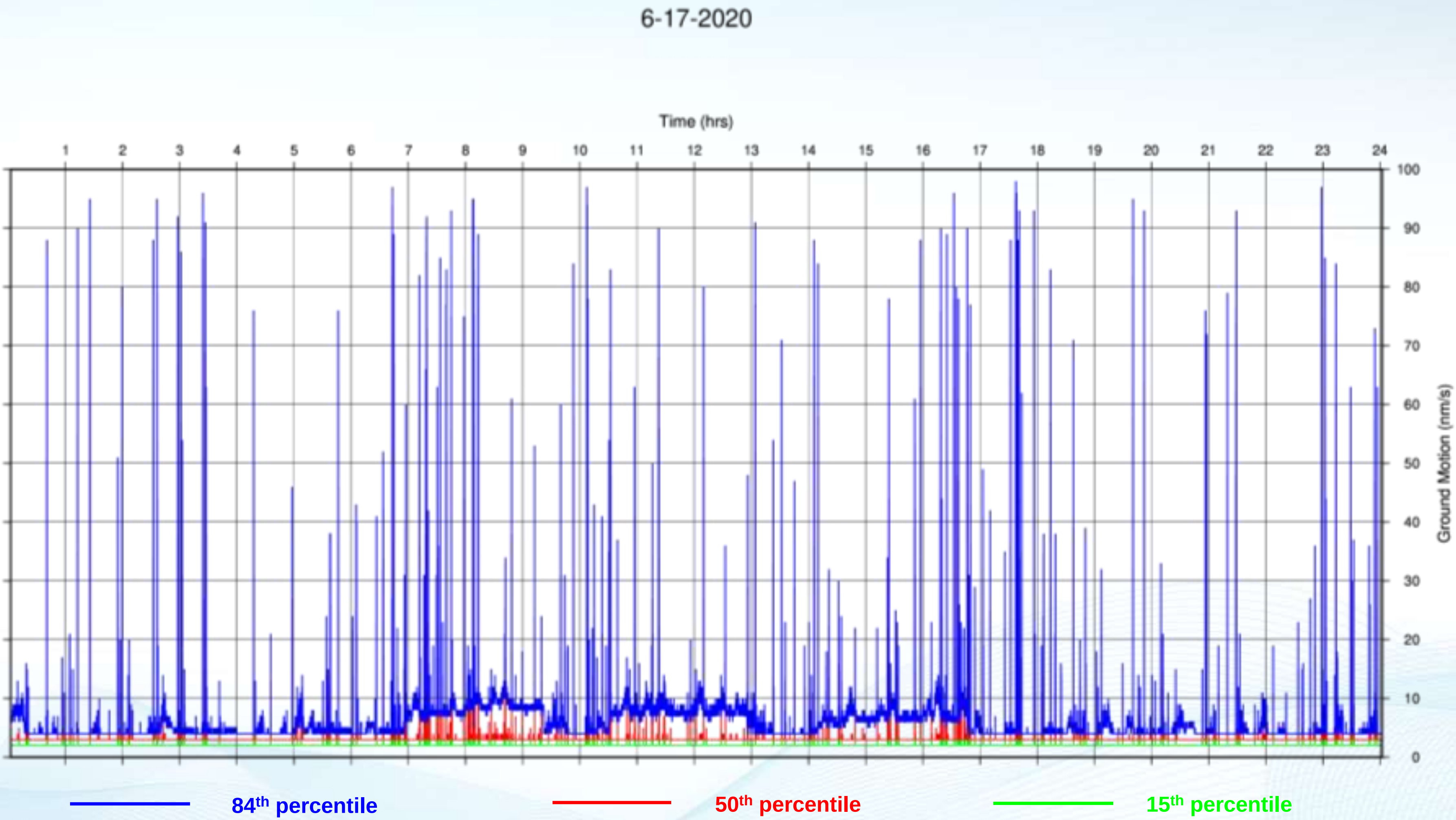


Tuesday, June 16, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

Noise Analysis – Day 169

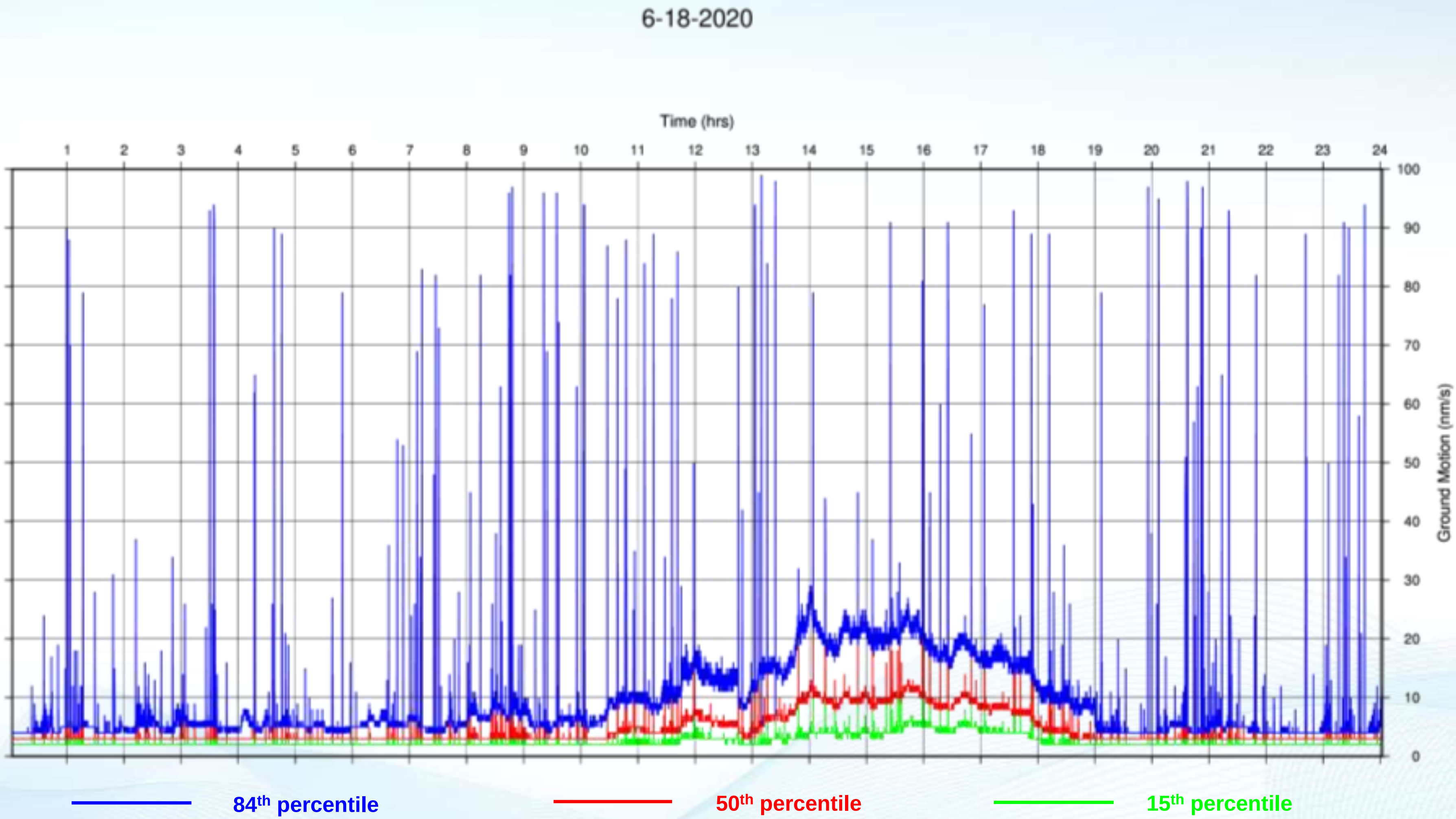


Wednesday, June 17, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

Noise Analysis – Day 170

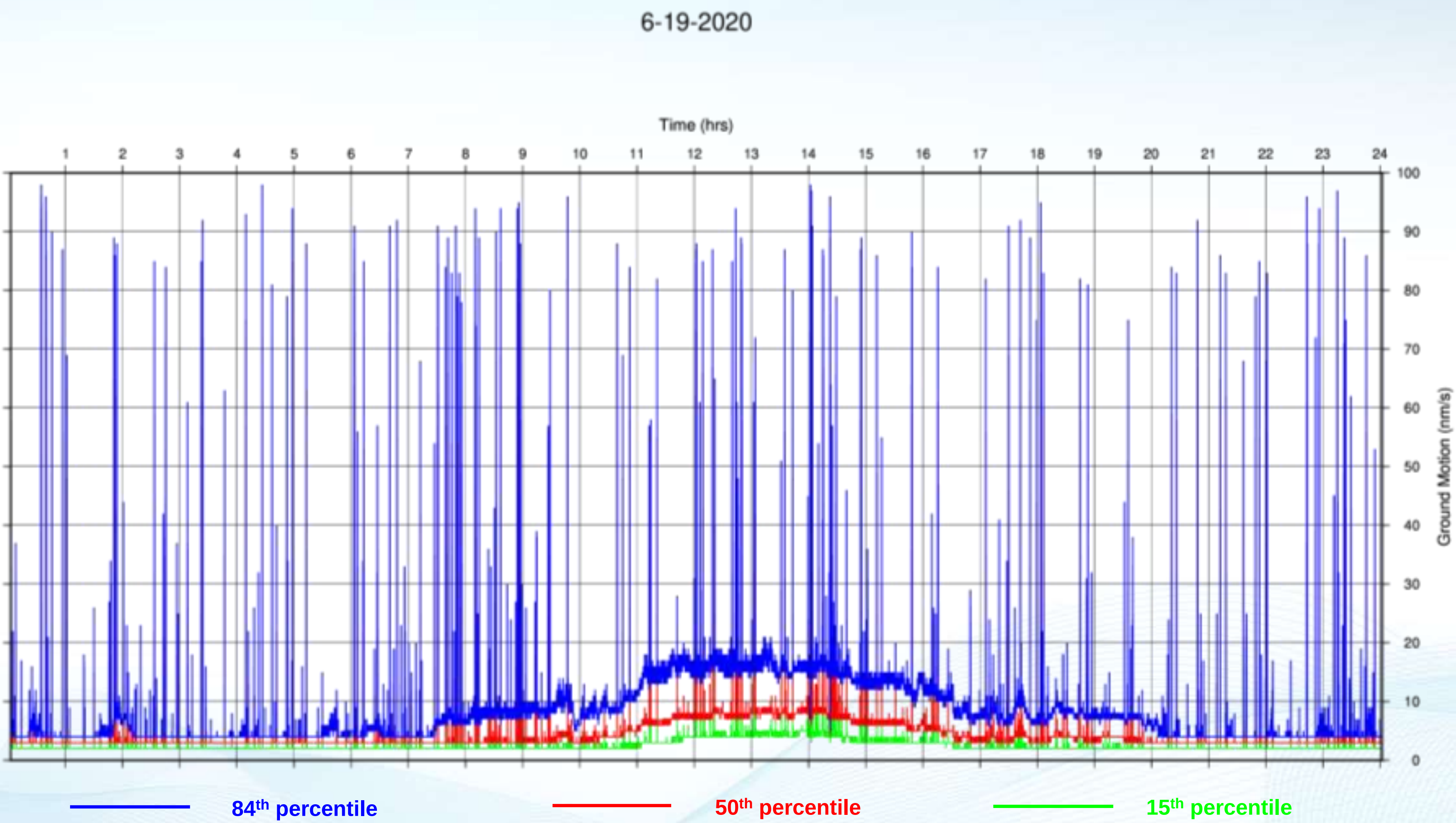


Thursday, June 18, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

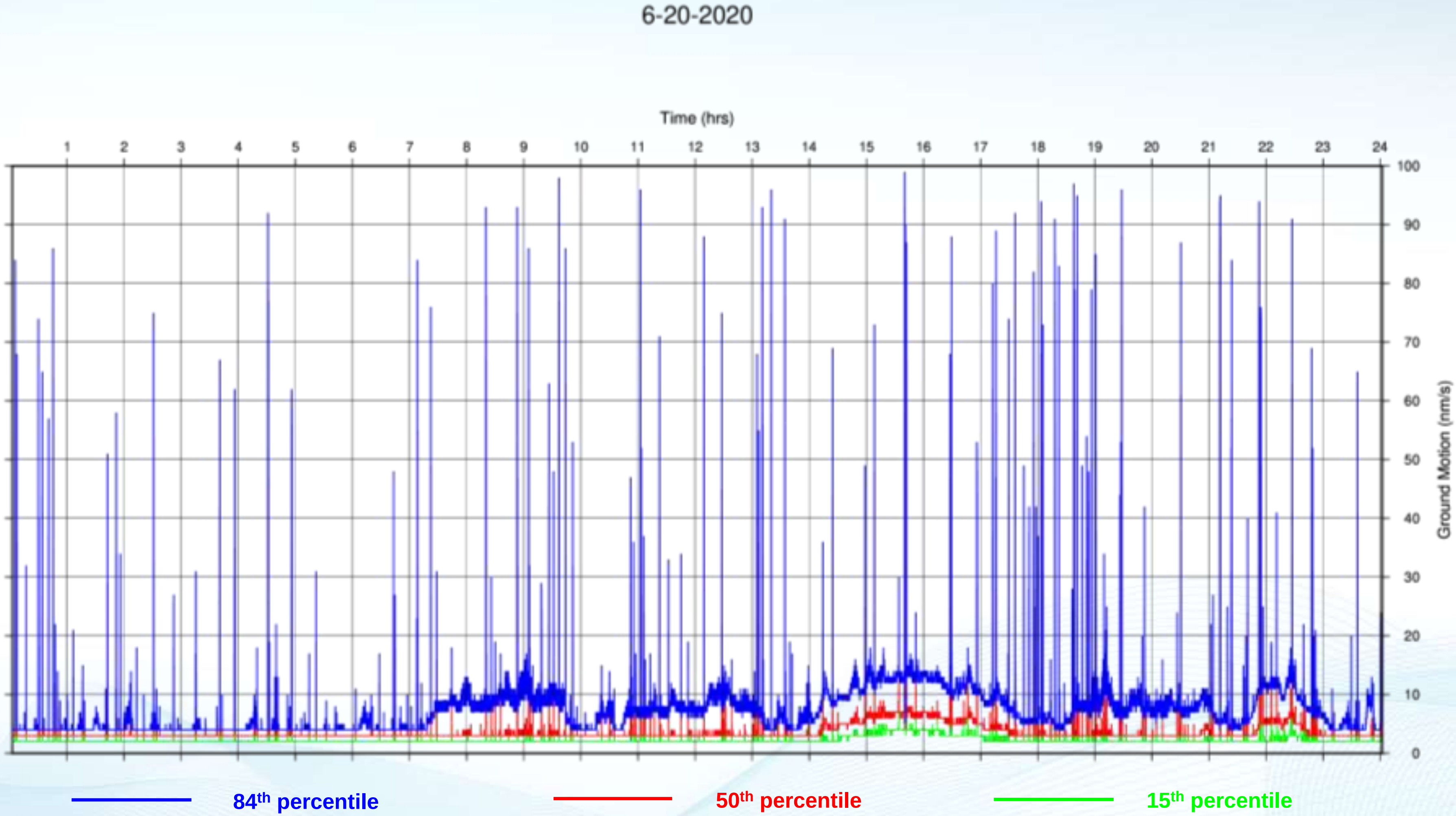
Noise Analysis – Day 171



Friday, June 19, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

Noise Analysis – Day 172

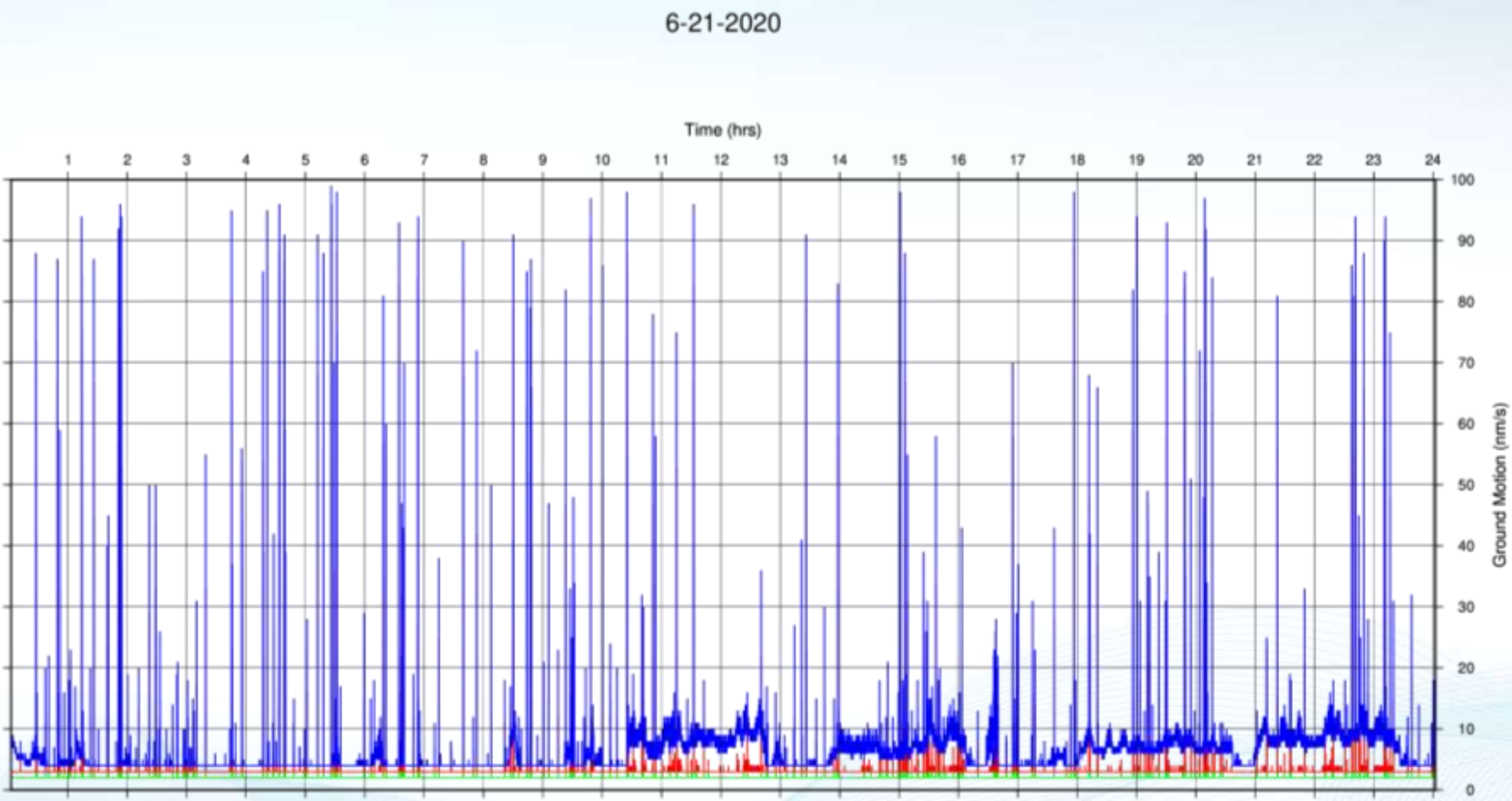


Saturday, June 20, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

Noise Analysis – Day 173



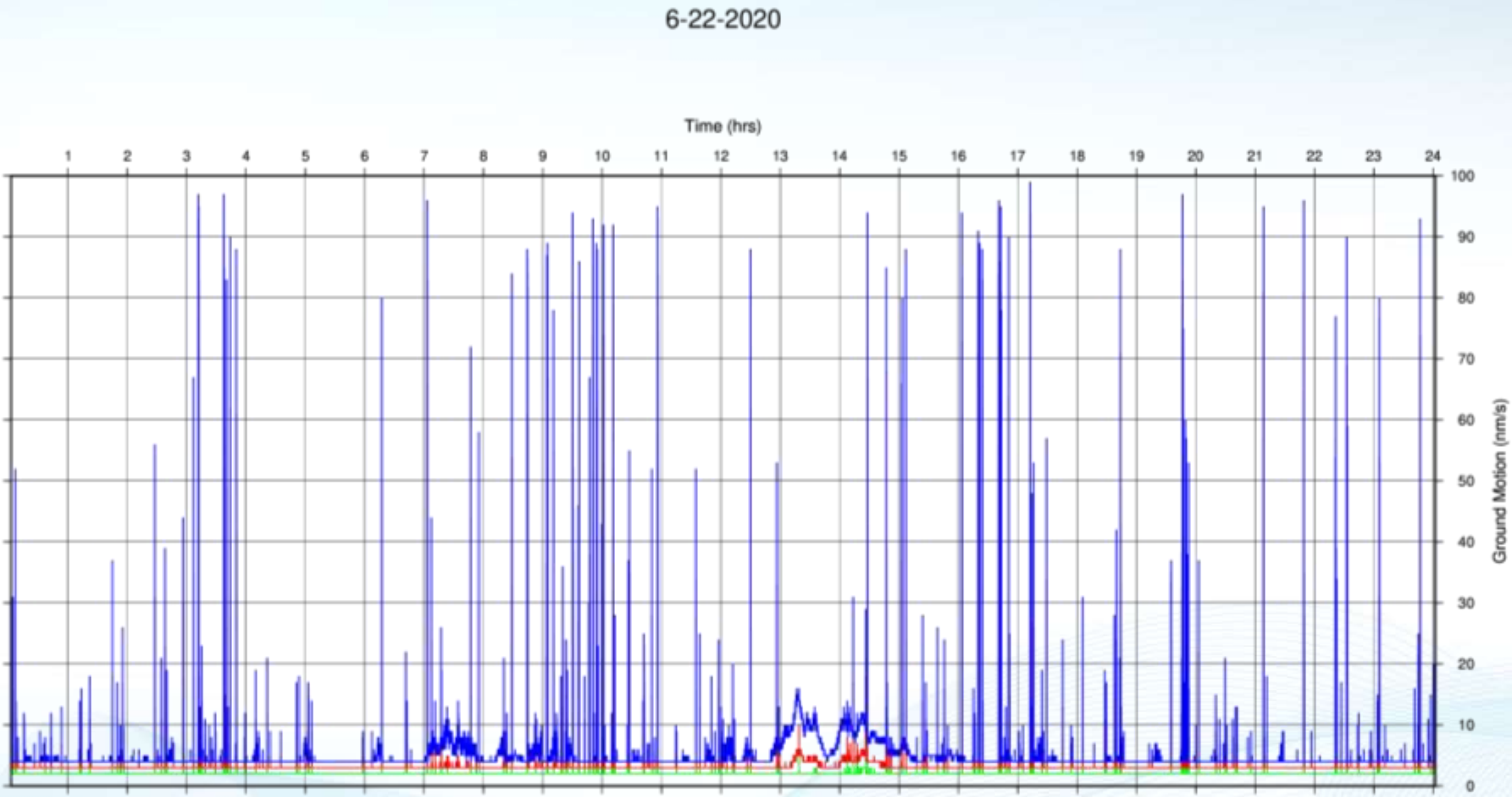
84th percentile **50th percentile** **15th percentile**

Sunday, June 21, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

Noise Analysis – Day 174

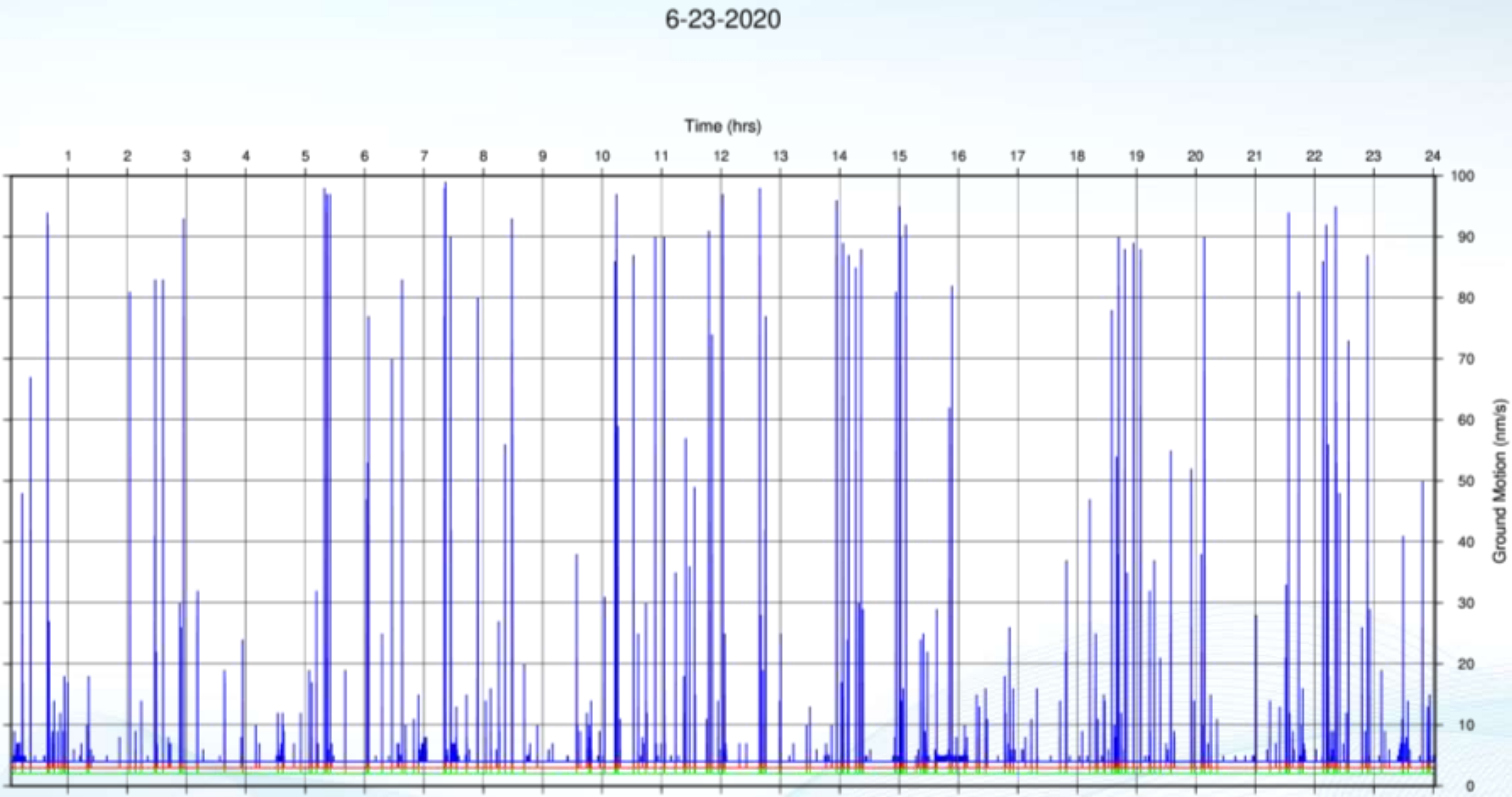


84th percentile **50th percentile** **15th percentile**

Monday, June 22, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

Noise Analysis – Day 175



84th percentile

50th percentile

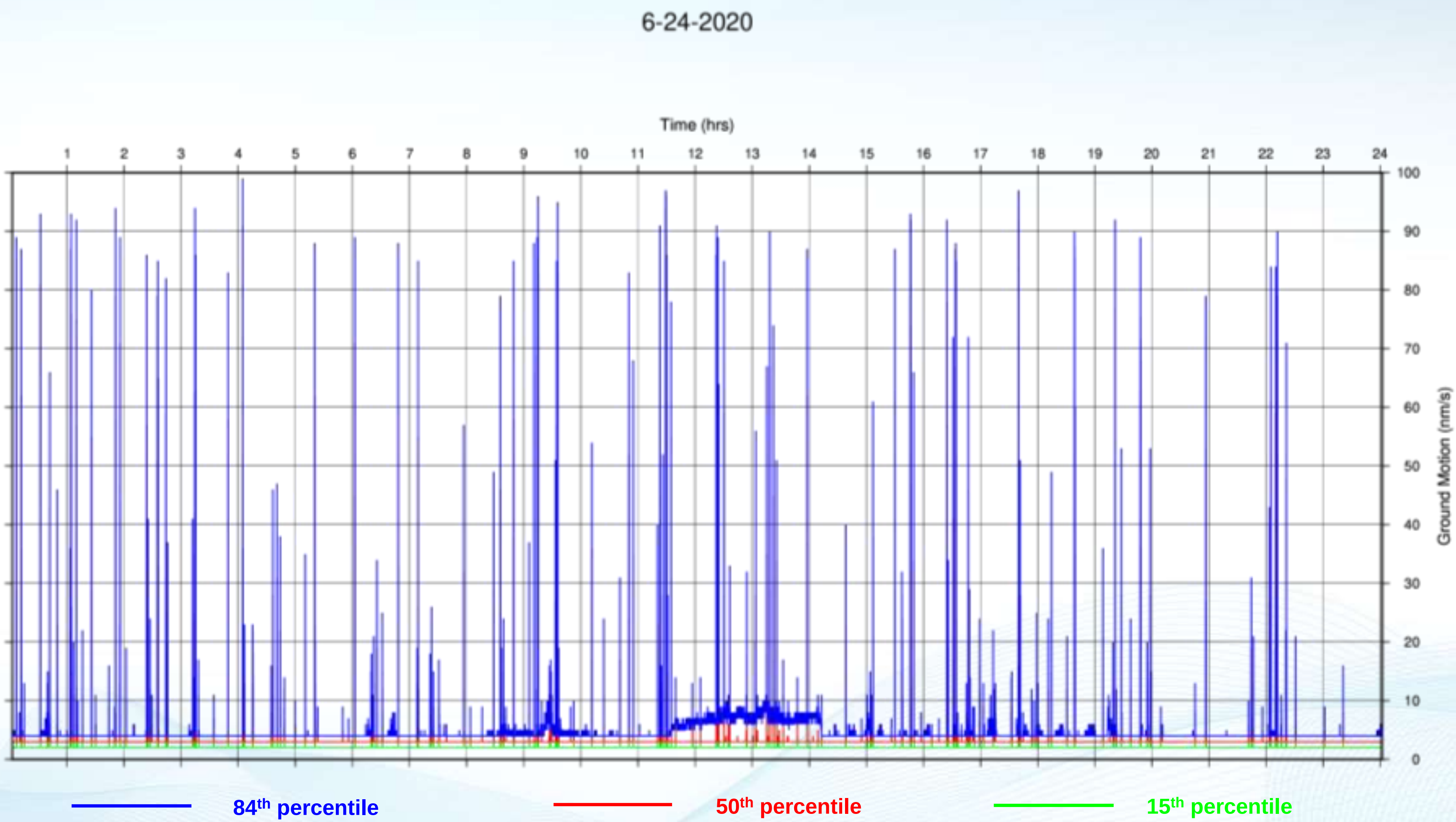
15th percentile

Tuesday, June 23, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

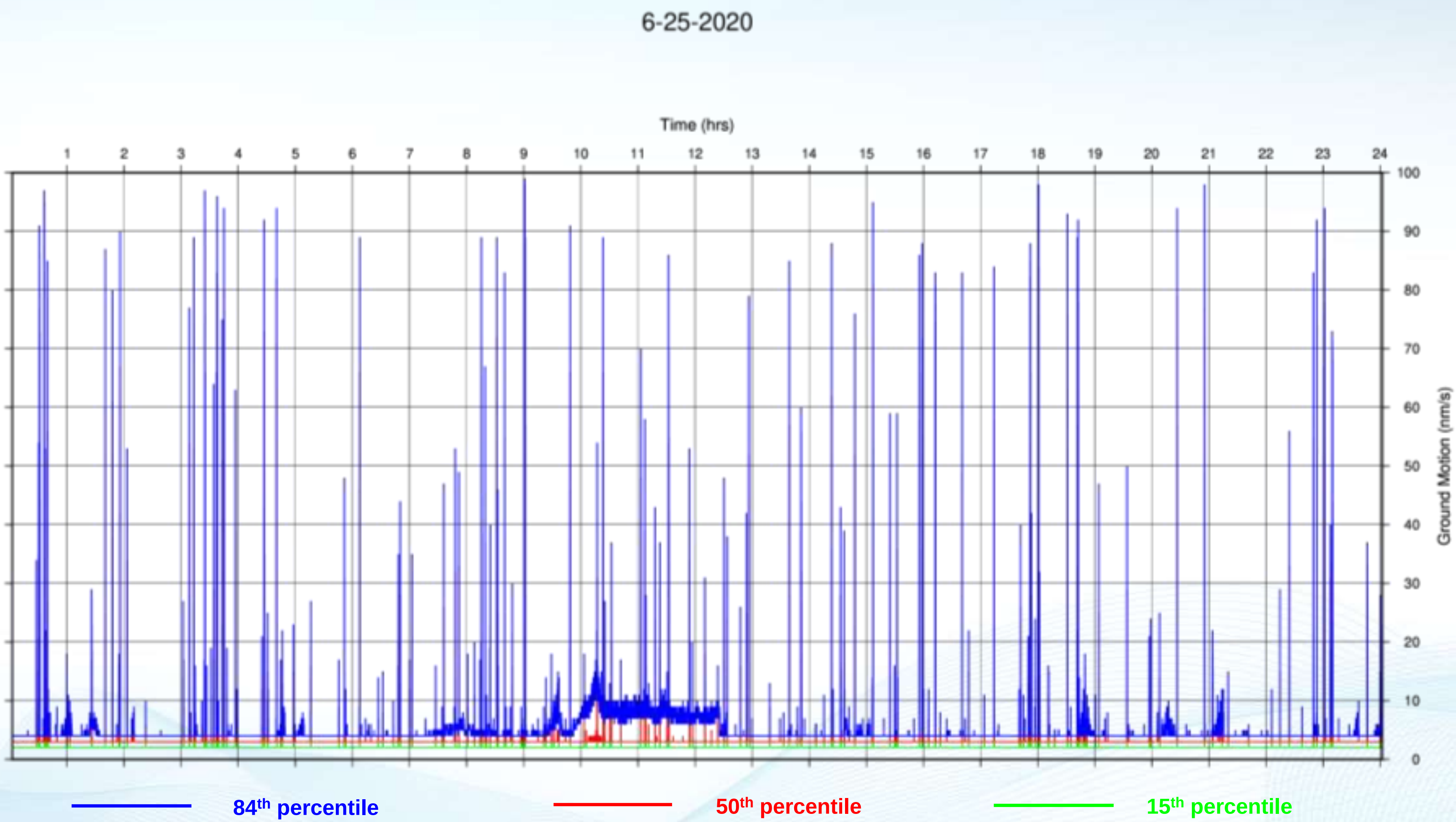
Noise Analysis – Day 176



Wednesday, June 24, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

Noise Analysis – Day 177

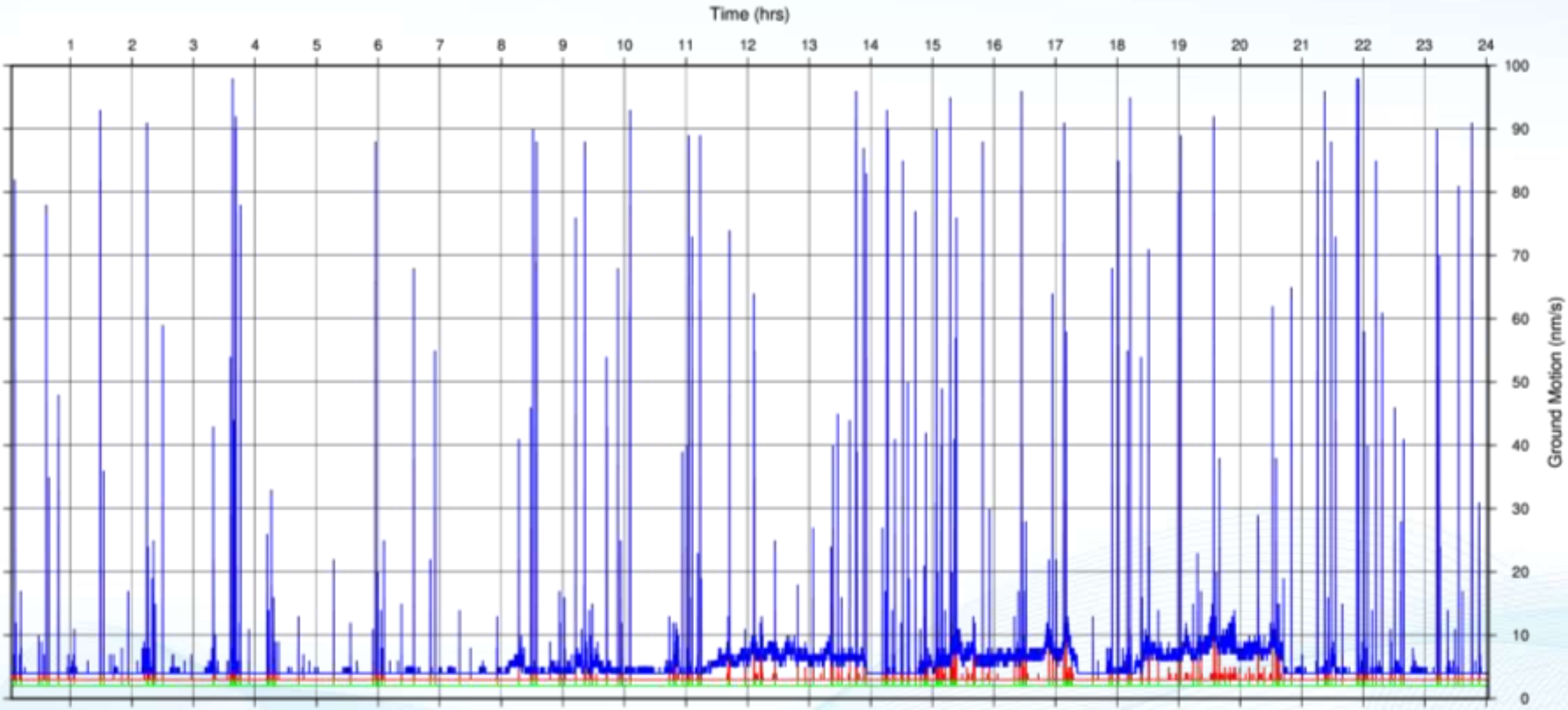


Thursday, June 25, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

Noise Analysis – Day 178

6-26-2020



84th percentile

50th percentile

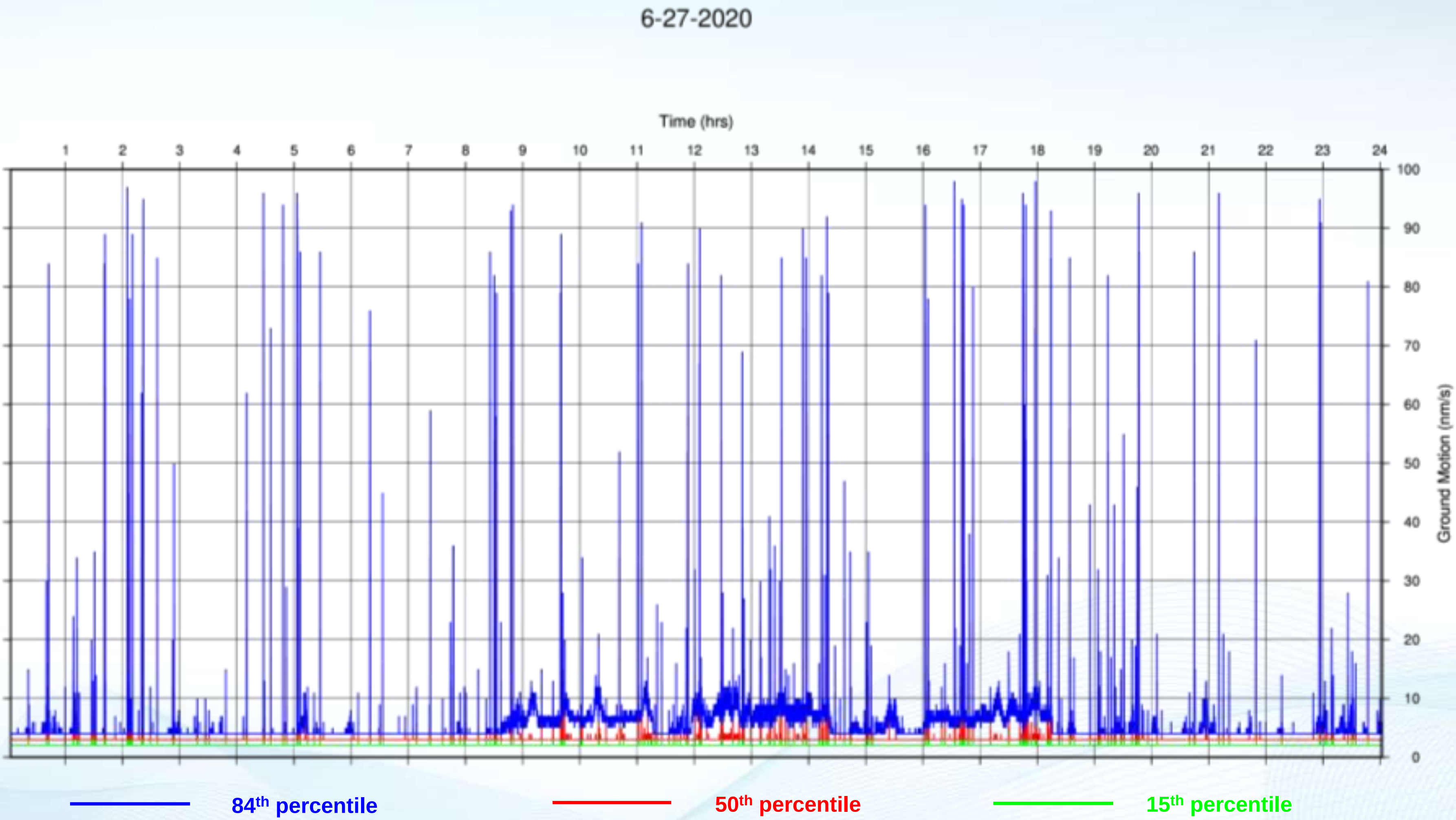
15th percentile

Friday, June 26, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

Noise Analysis – Day 179

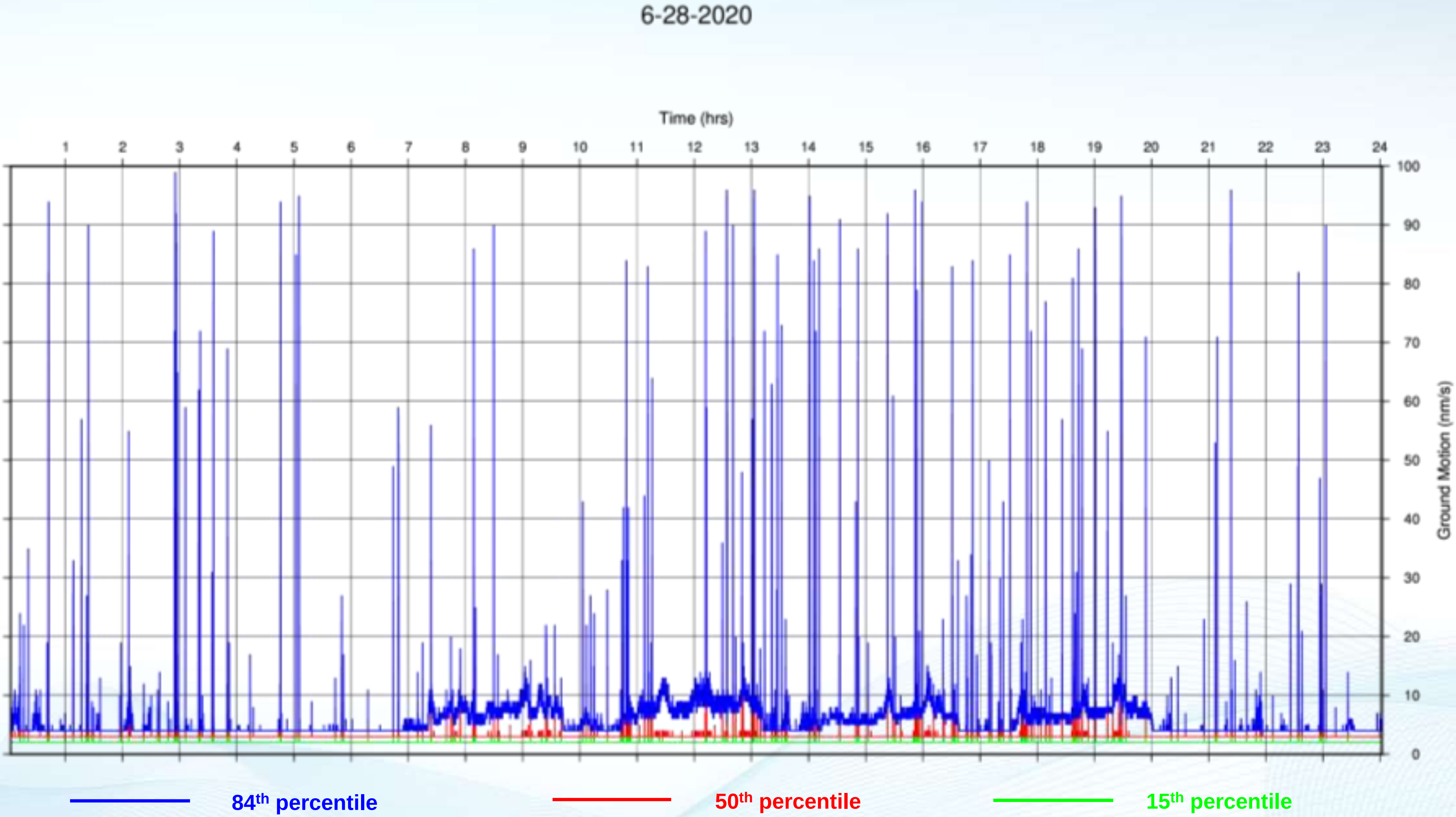


Saturday, June 27, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

Noise Analysis – Day 180

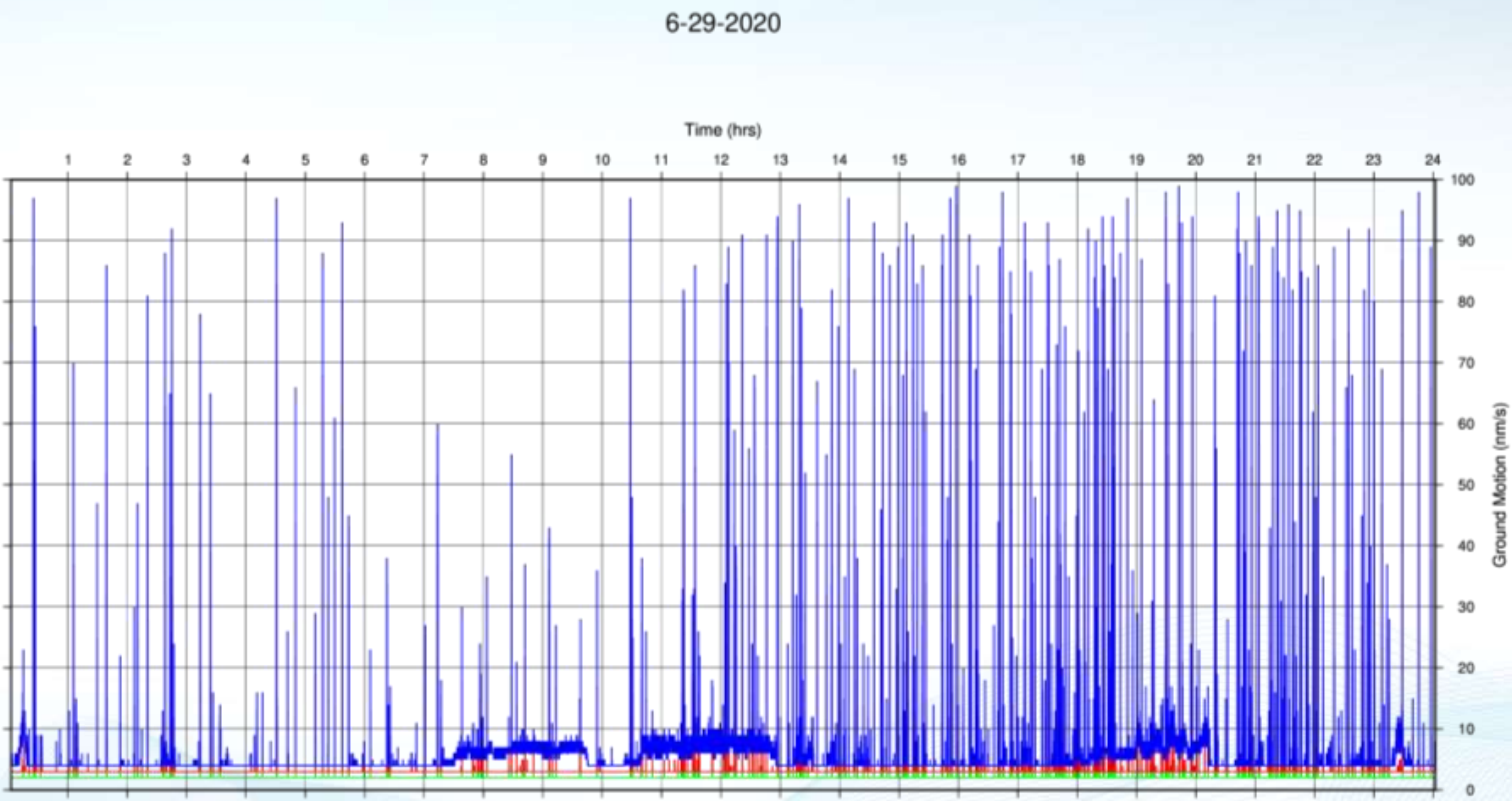


Sunday, June 28, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

Noise Analysis – Day 181



84th percentile

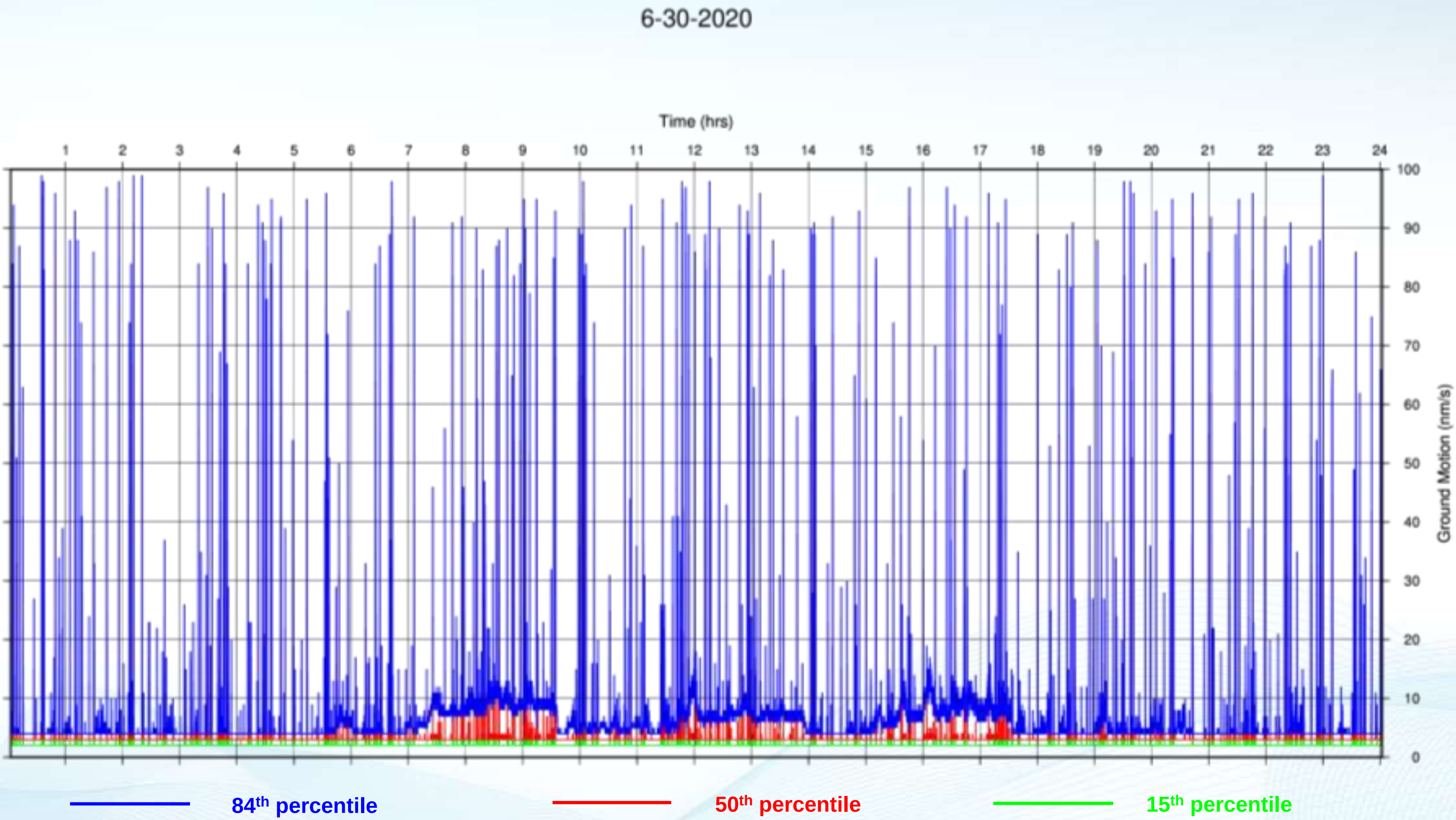
50th percentile

15th percentile

Monday, June 29, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

Noise Analysis – Day 182

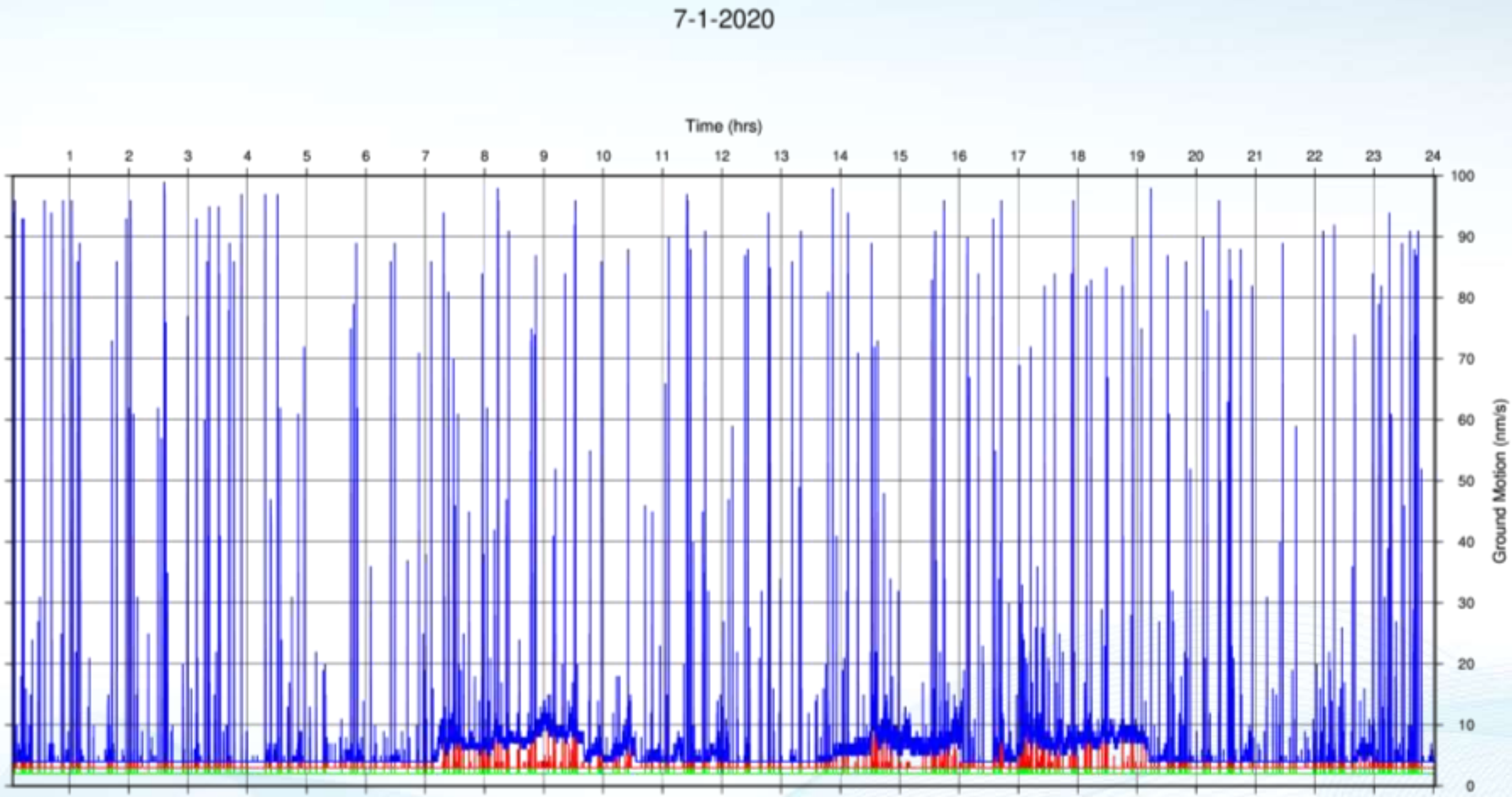


Tuesday, June 30, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

Noise Analysis – Day 183



84th percentile

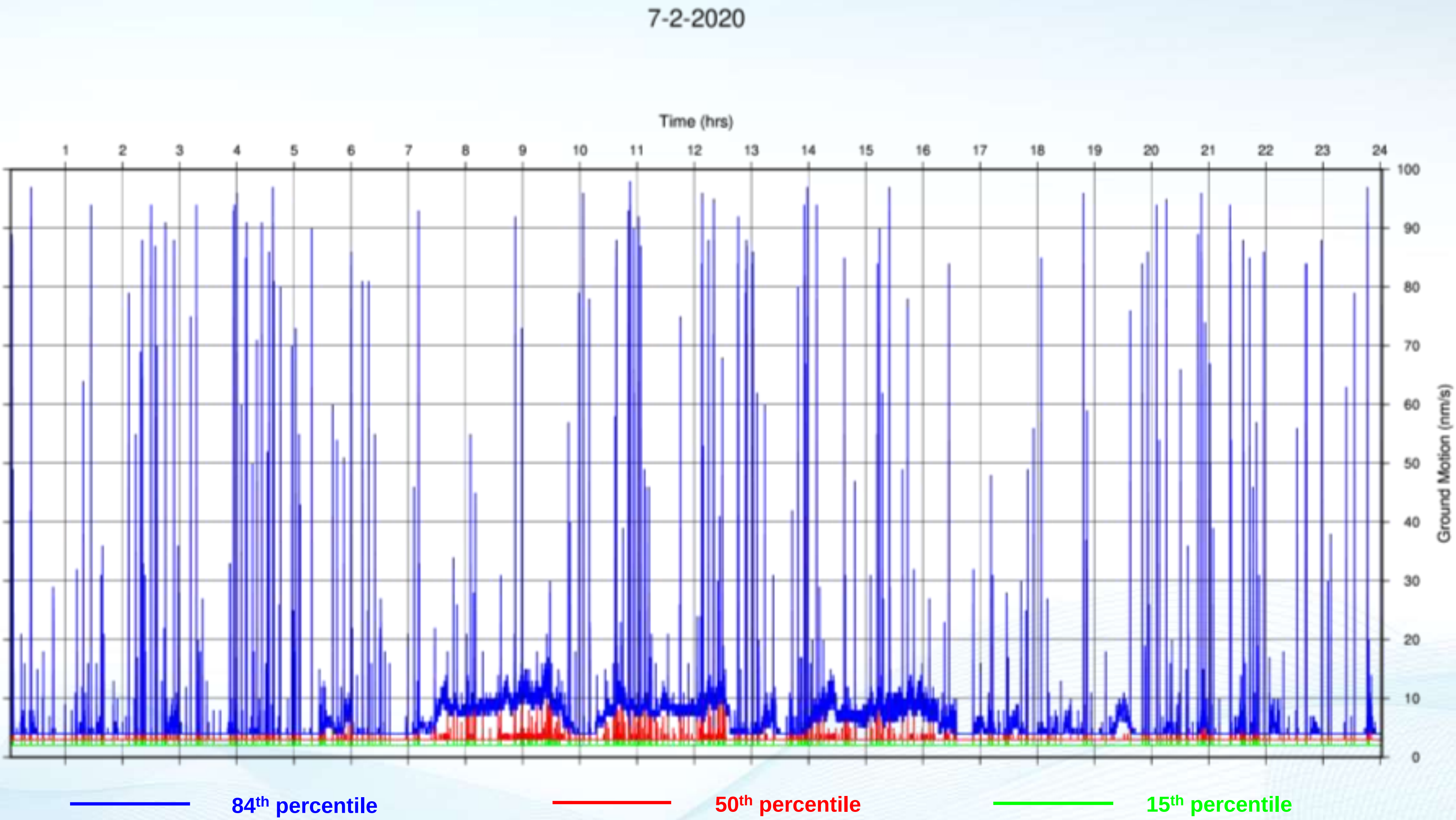
50th percentile

15th percentile

Wednesday, July 1, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

Noise Analysis – Day 184

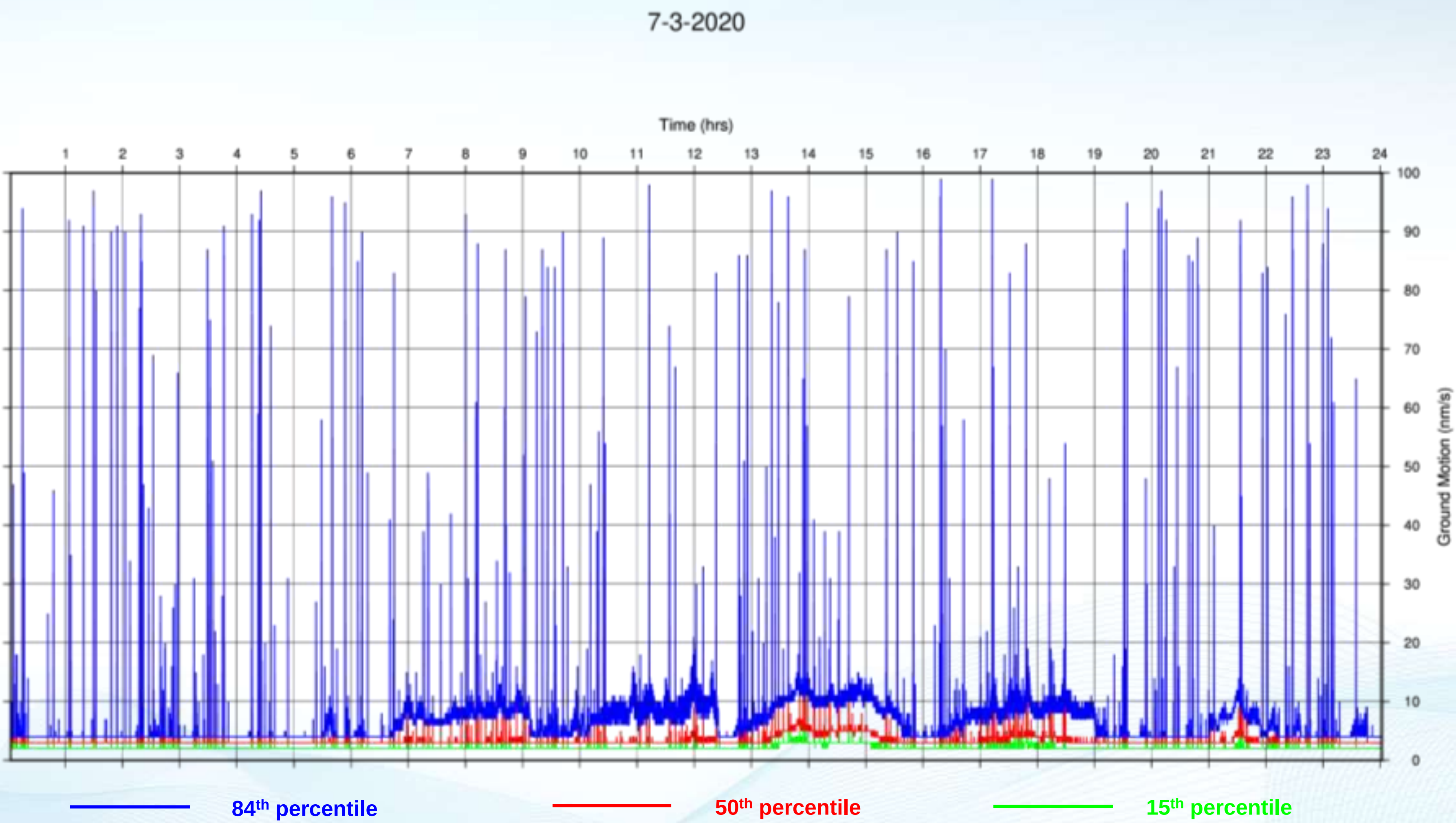


Thursday, July 2, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

Noise Analysis – Day 185

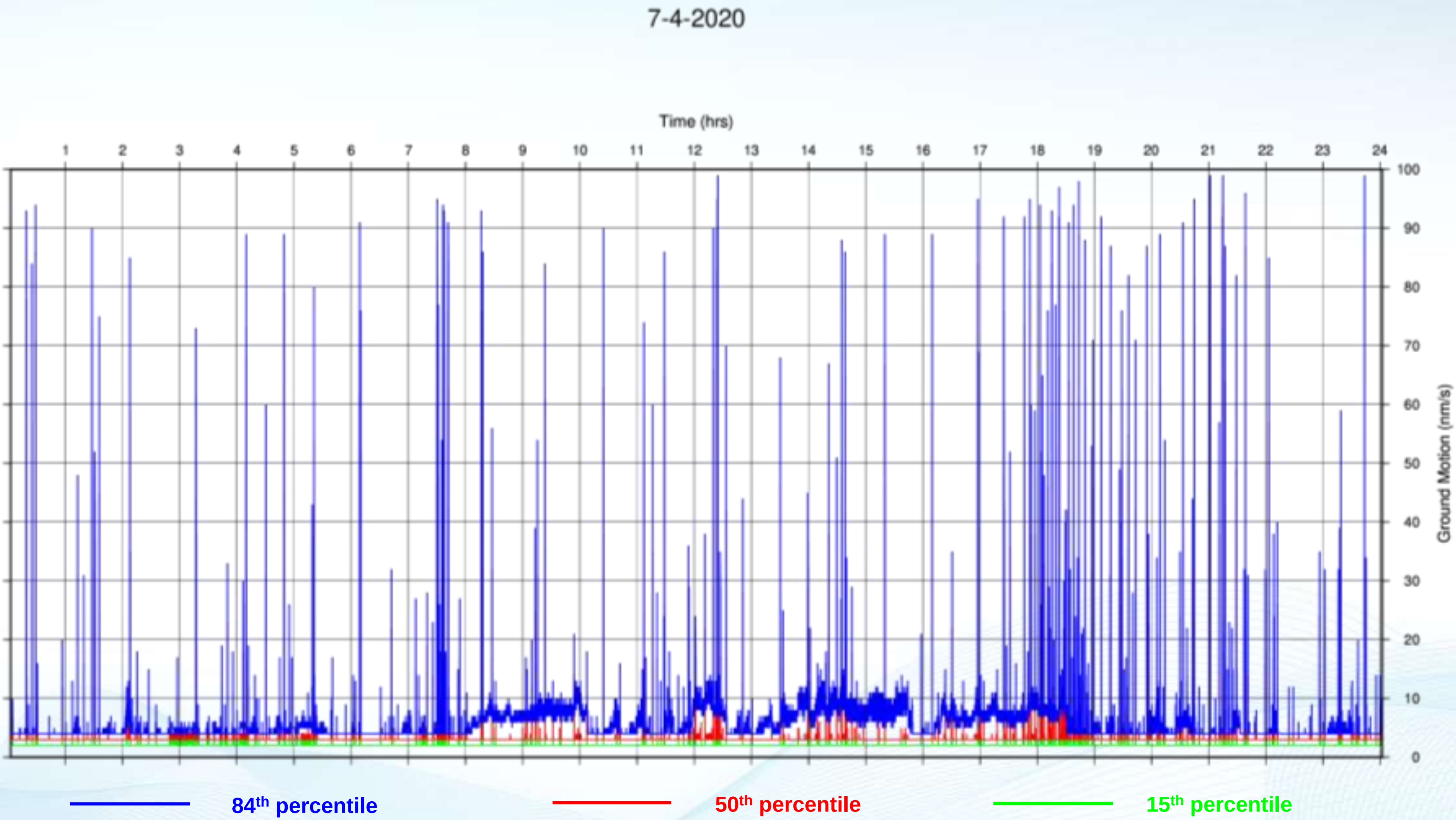


Friday, July 3, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

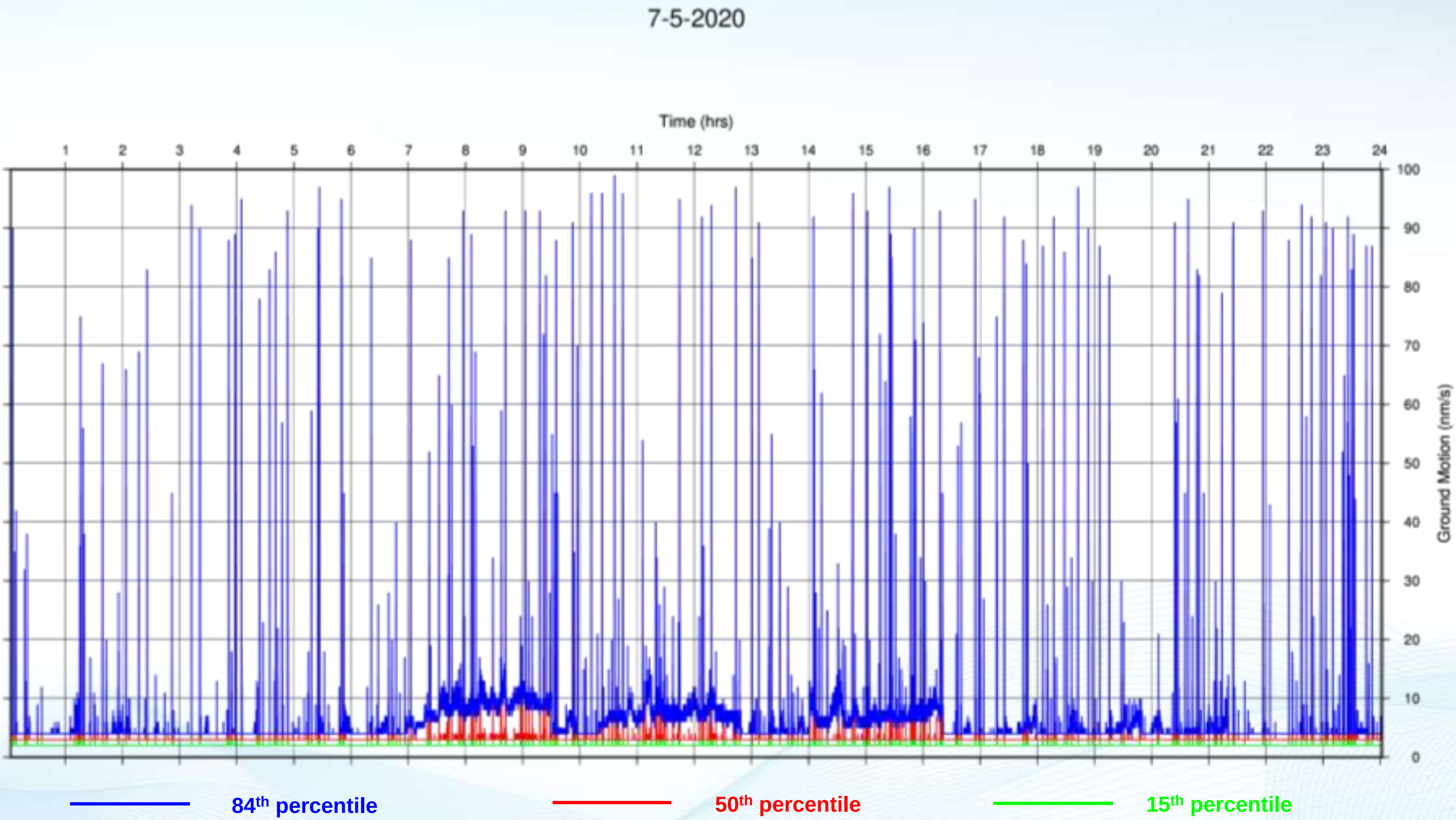
Noise Analysis – Day 186



Saturday, July 4, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

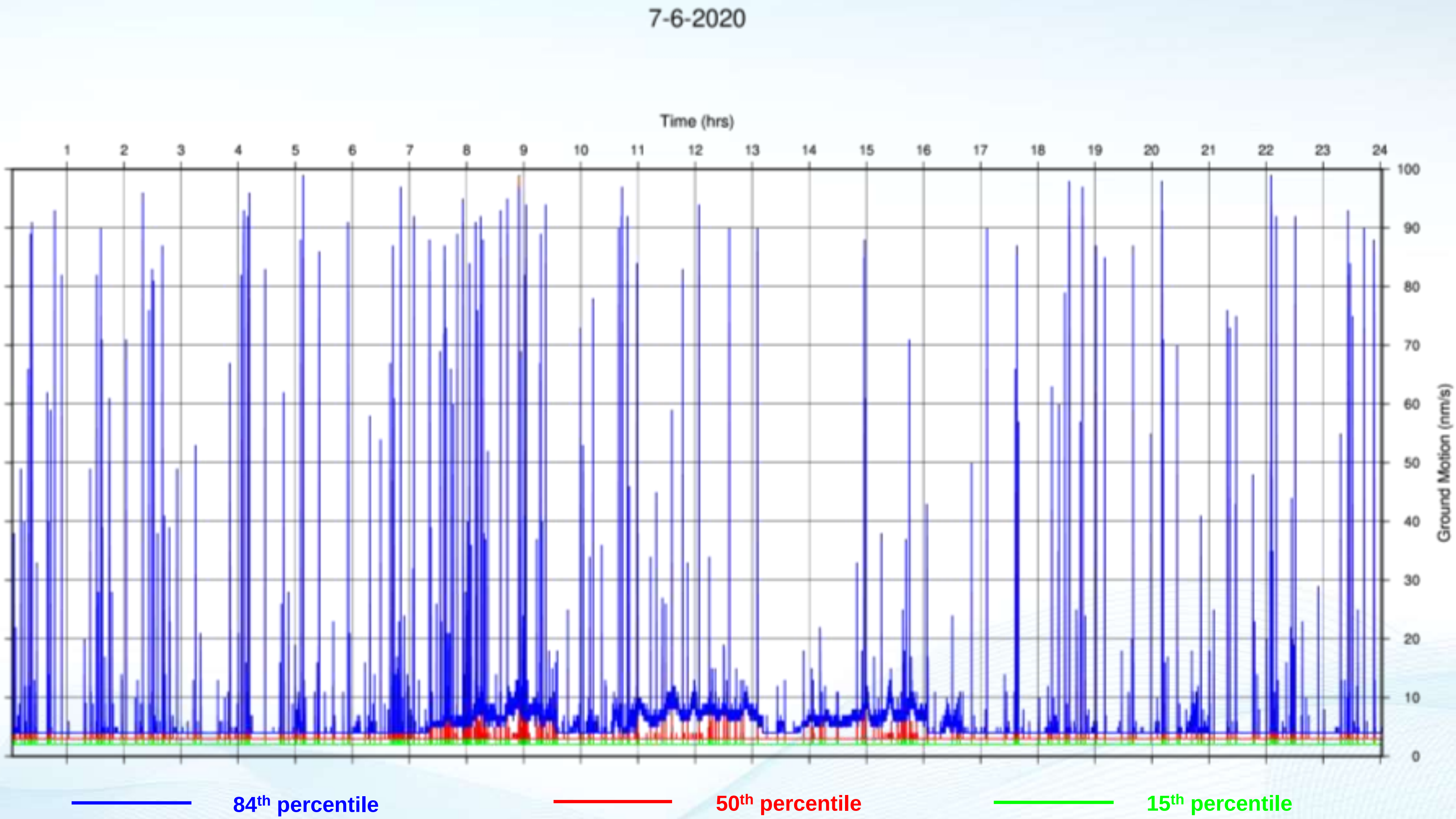
Noise Analysis – Day 187



Sunday, July 5, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

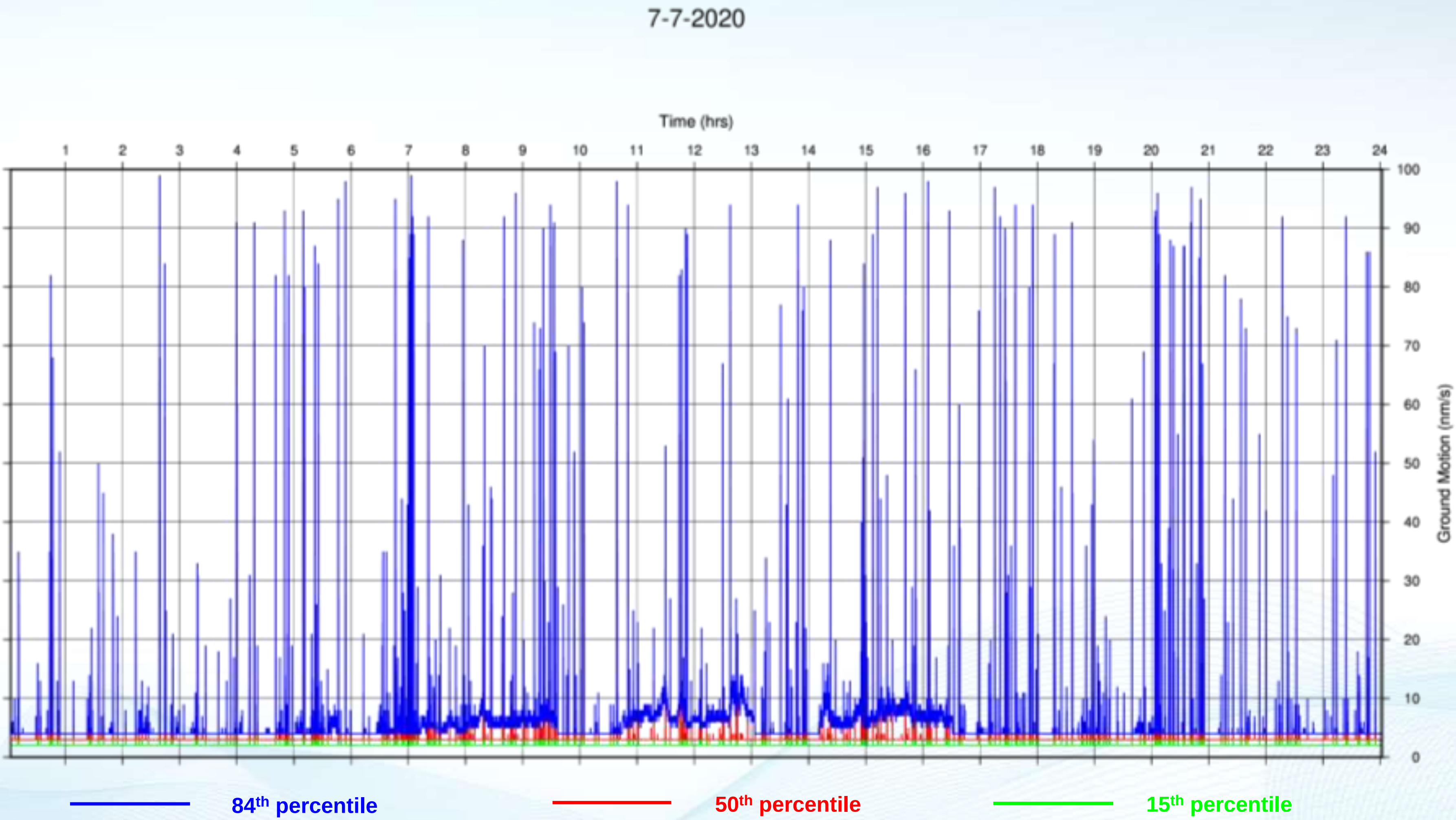
Noise Analysis – Day 188



Monday, July 6, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

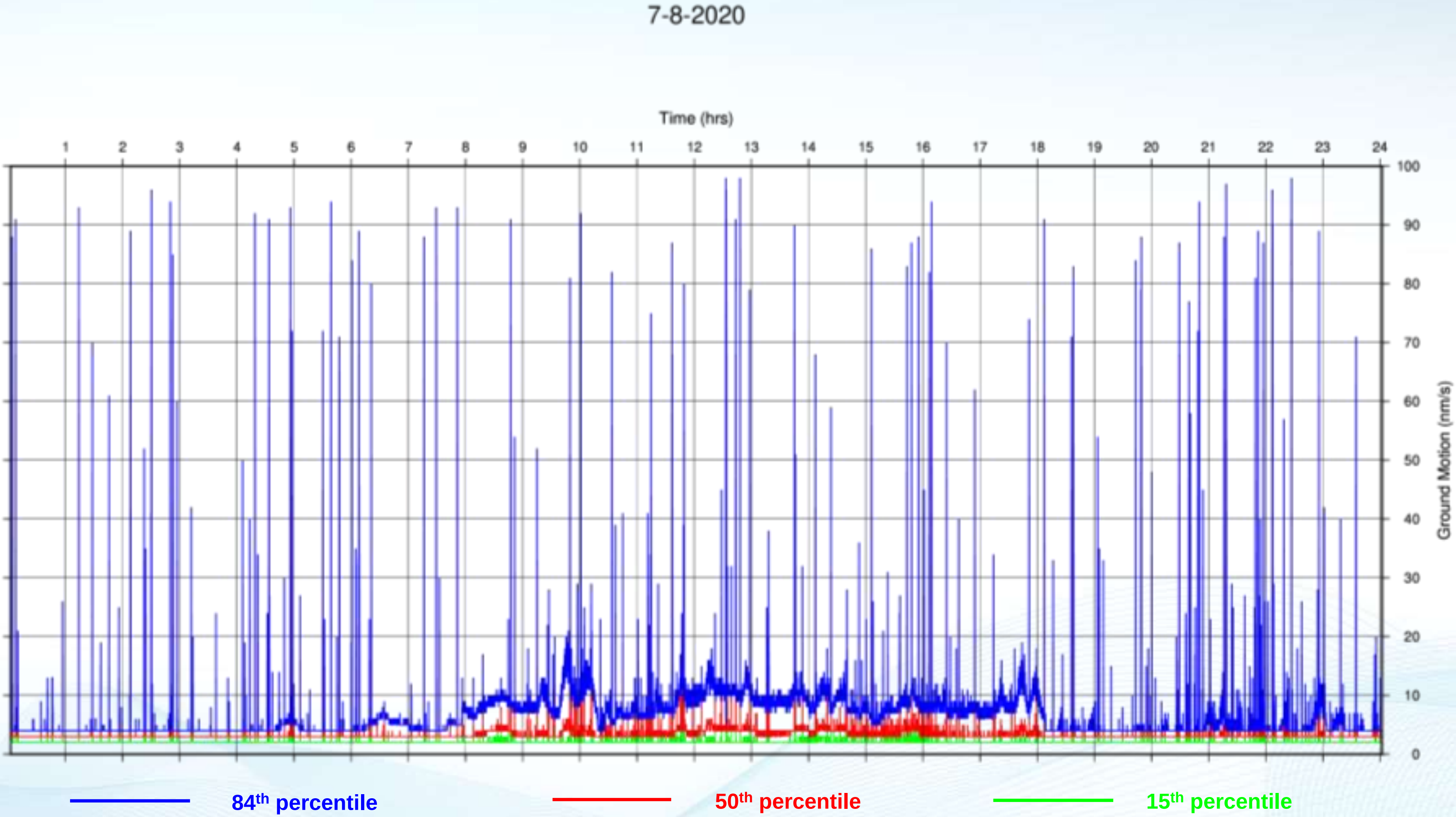
Noise Analysis – Day 189



Tuesday, July 7, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

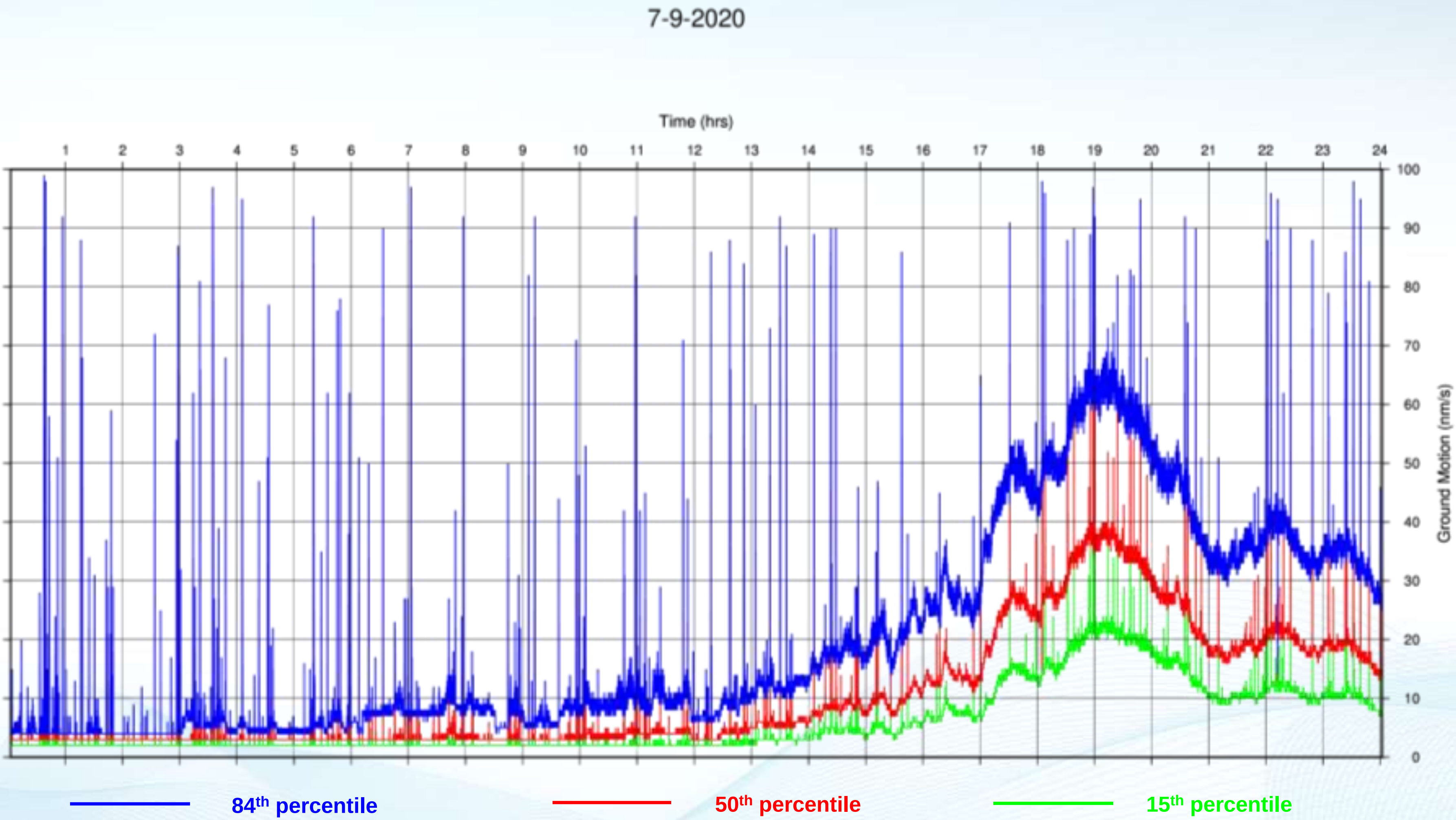
Noise Analysis – Day 190



Wednesday, July 8, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

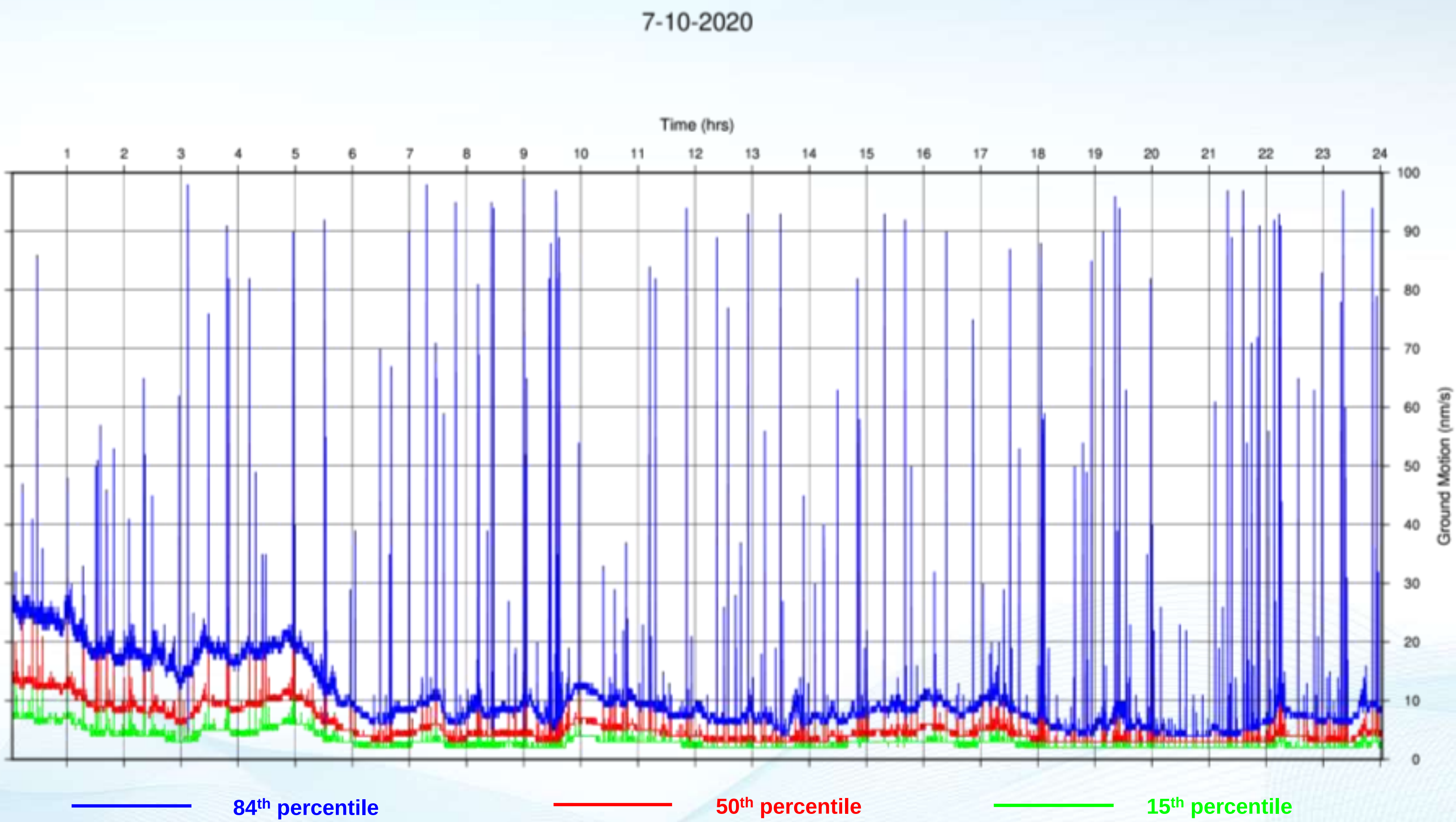
Noise Analysis – Day 191



Thursday, July 9, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

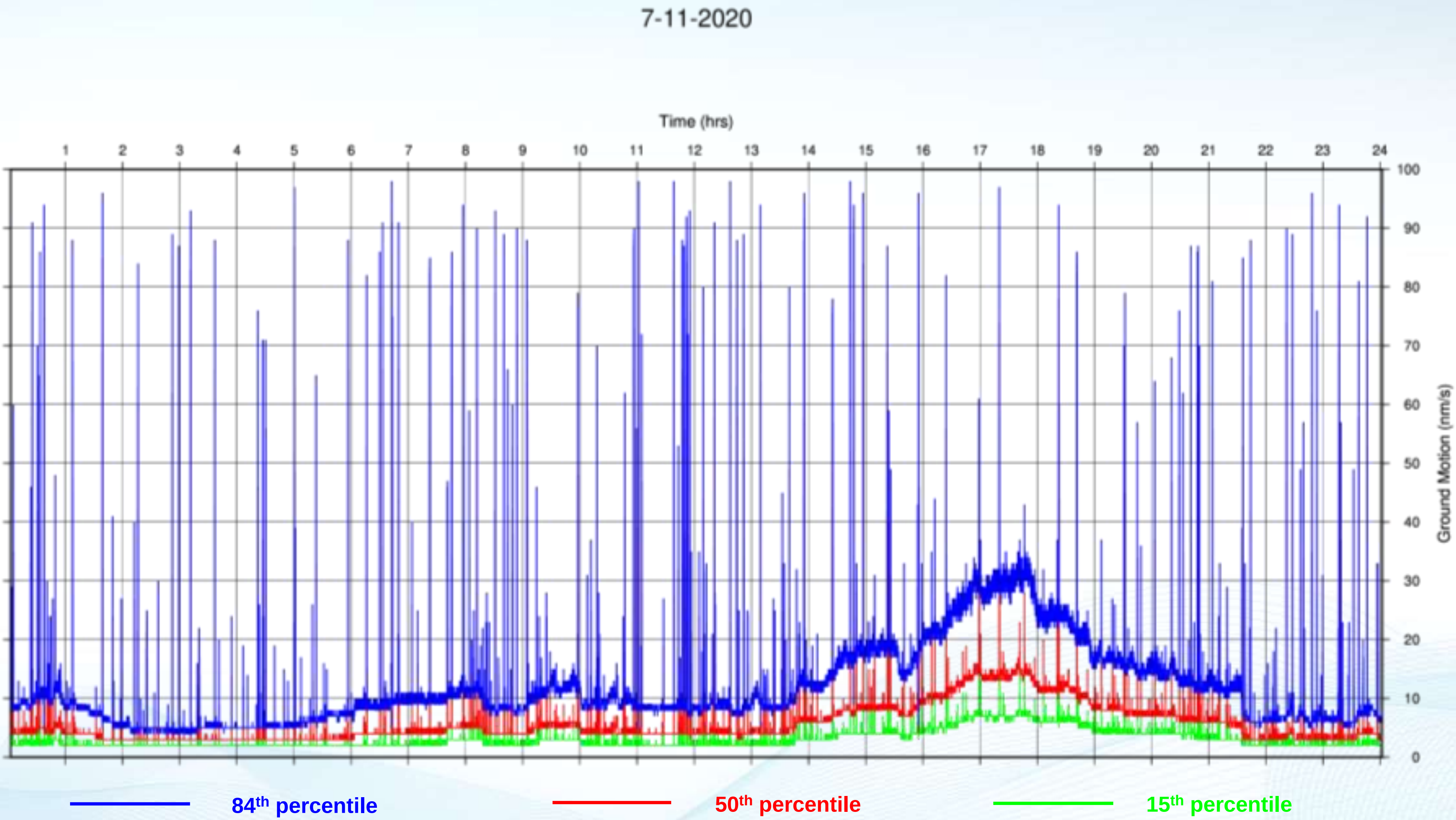
Noise Analysis – Day 192



Friday, July 10, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

Noise Analysis – Day 193

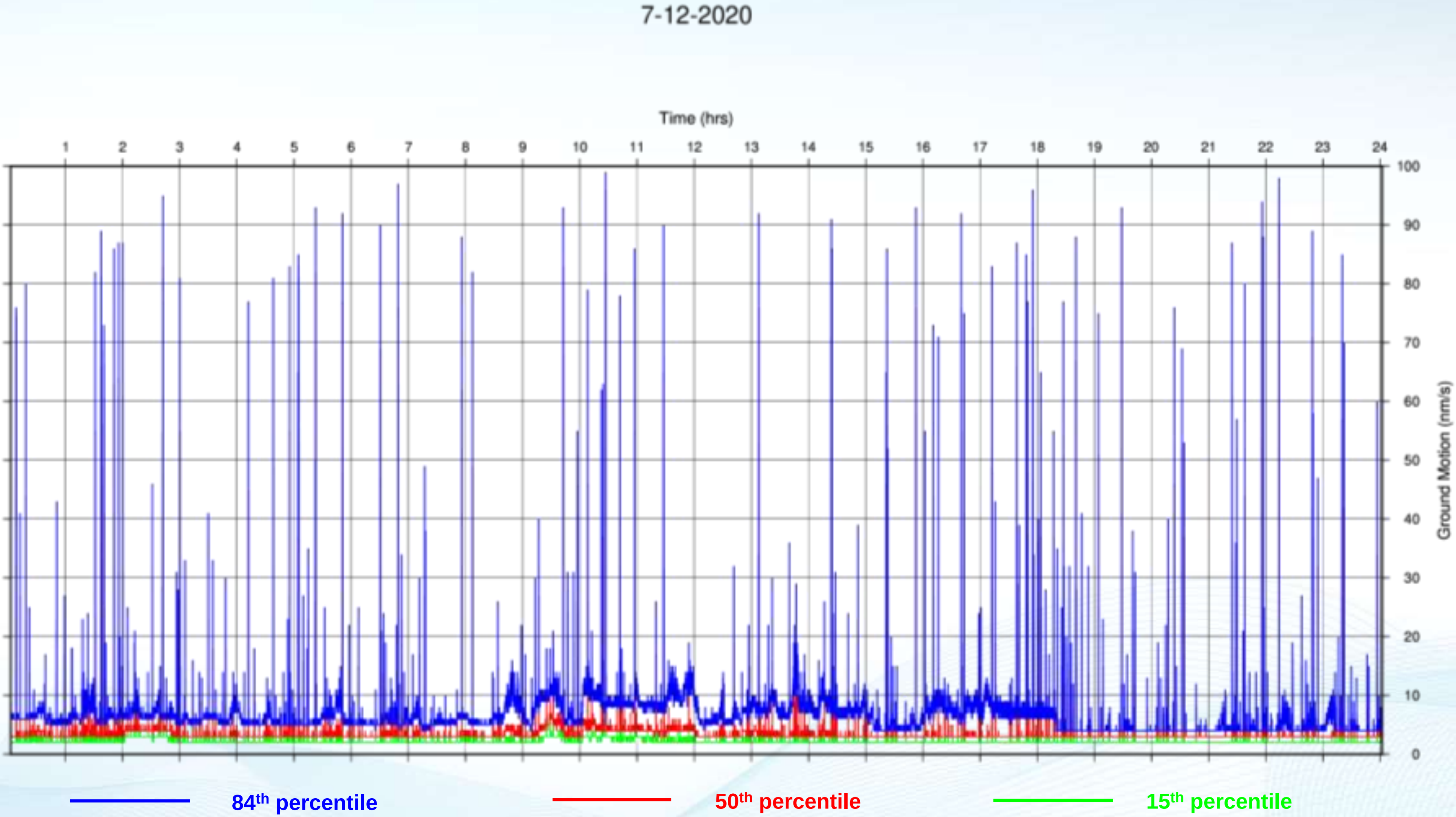


Saturday, July 11, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

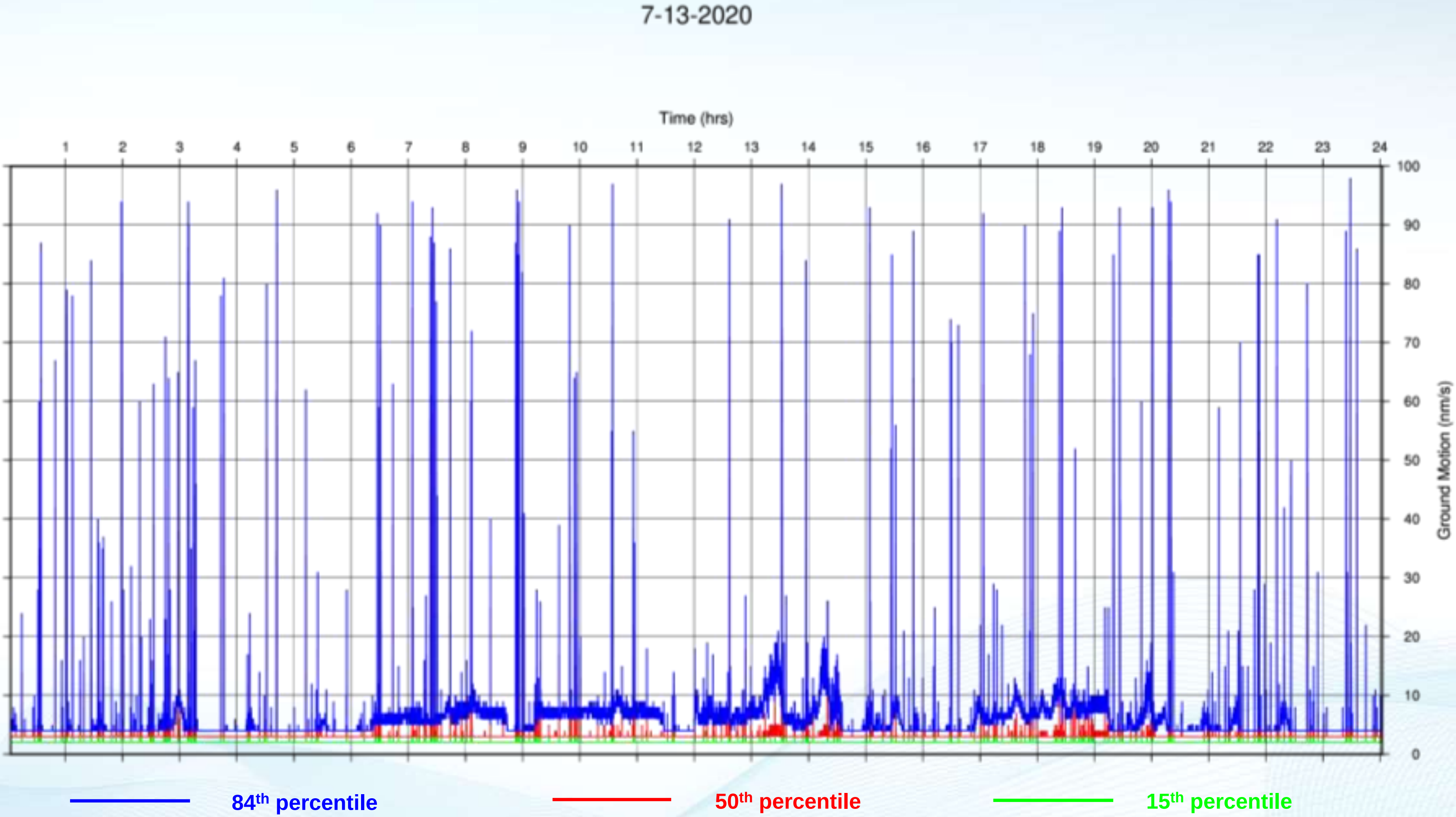
Noise Analysis – Day 194



Sunday, July 12, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

Noise Analysis – Day 195

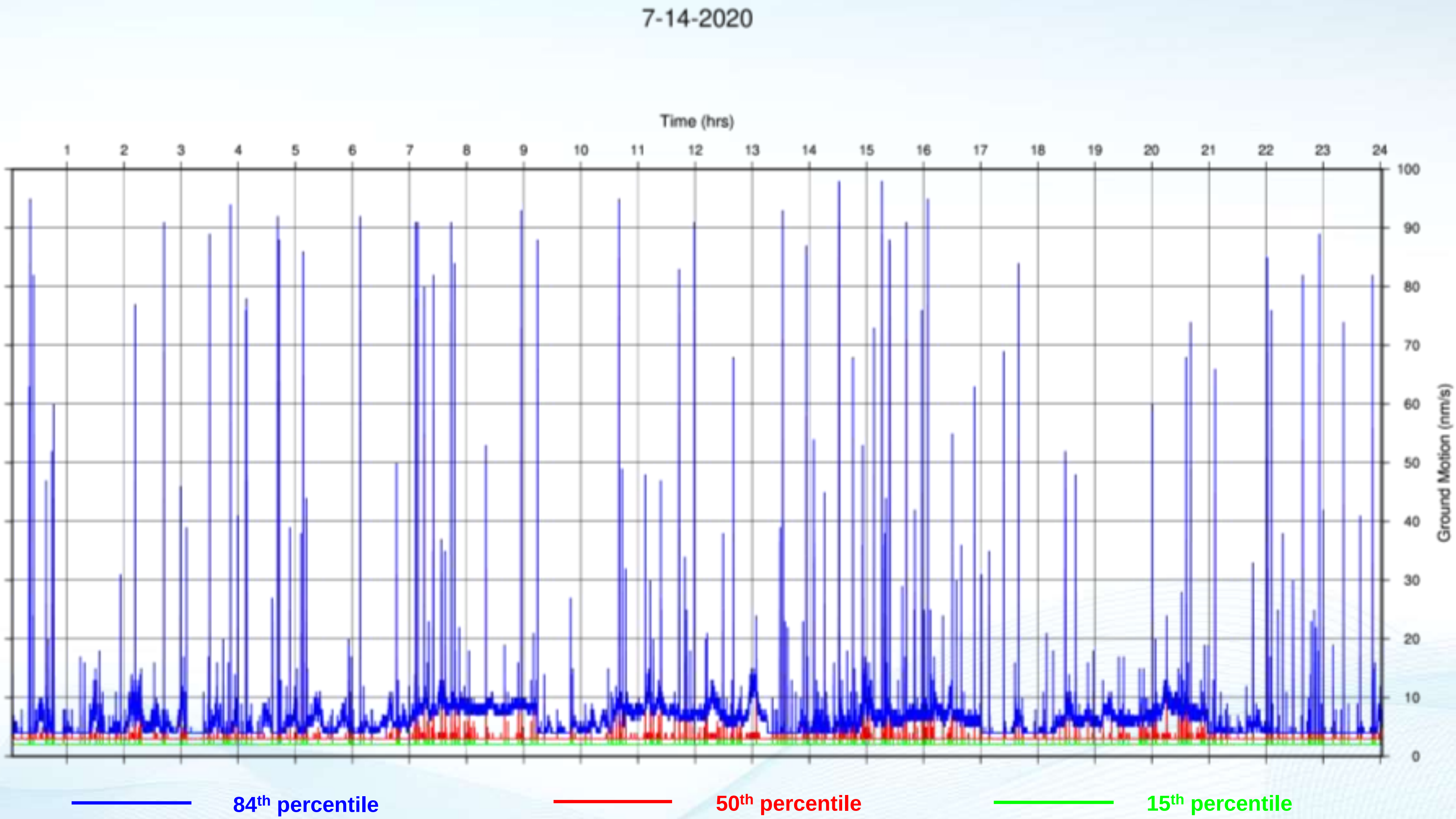


Monday, July 13, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

Noise Analysis – Day 196

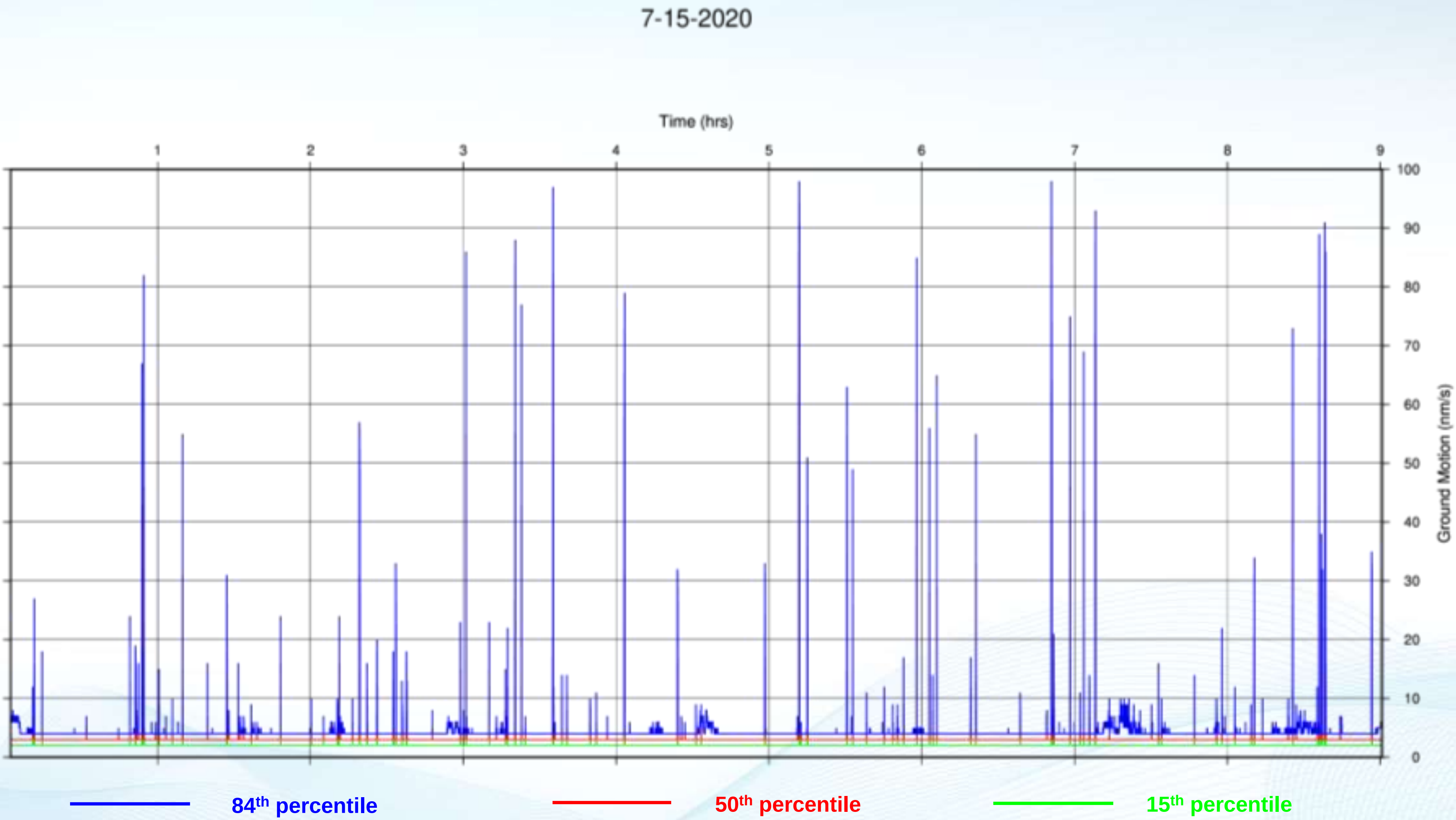


Tuesday, July 14, 2020
24 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

MicroSeismic

Noise Analysis – Day 197



Wednesday, July 15, 2020
9 hours of data

- Spikes in the plot are caused by high magnitude fault activity.

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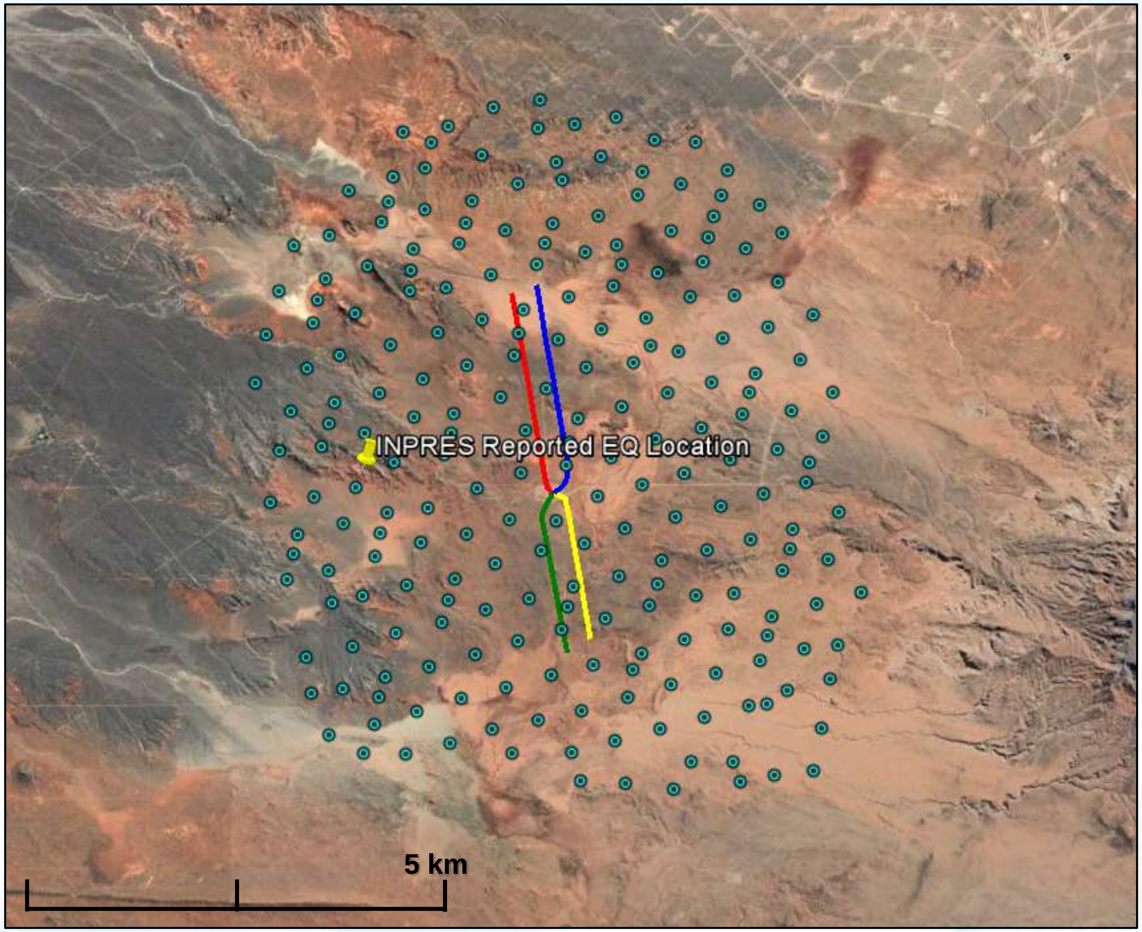
Earthquakes

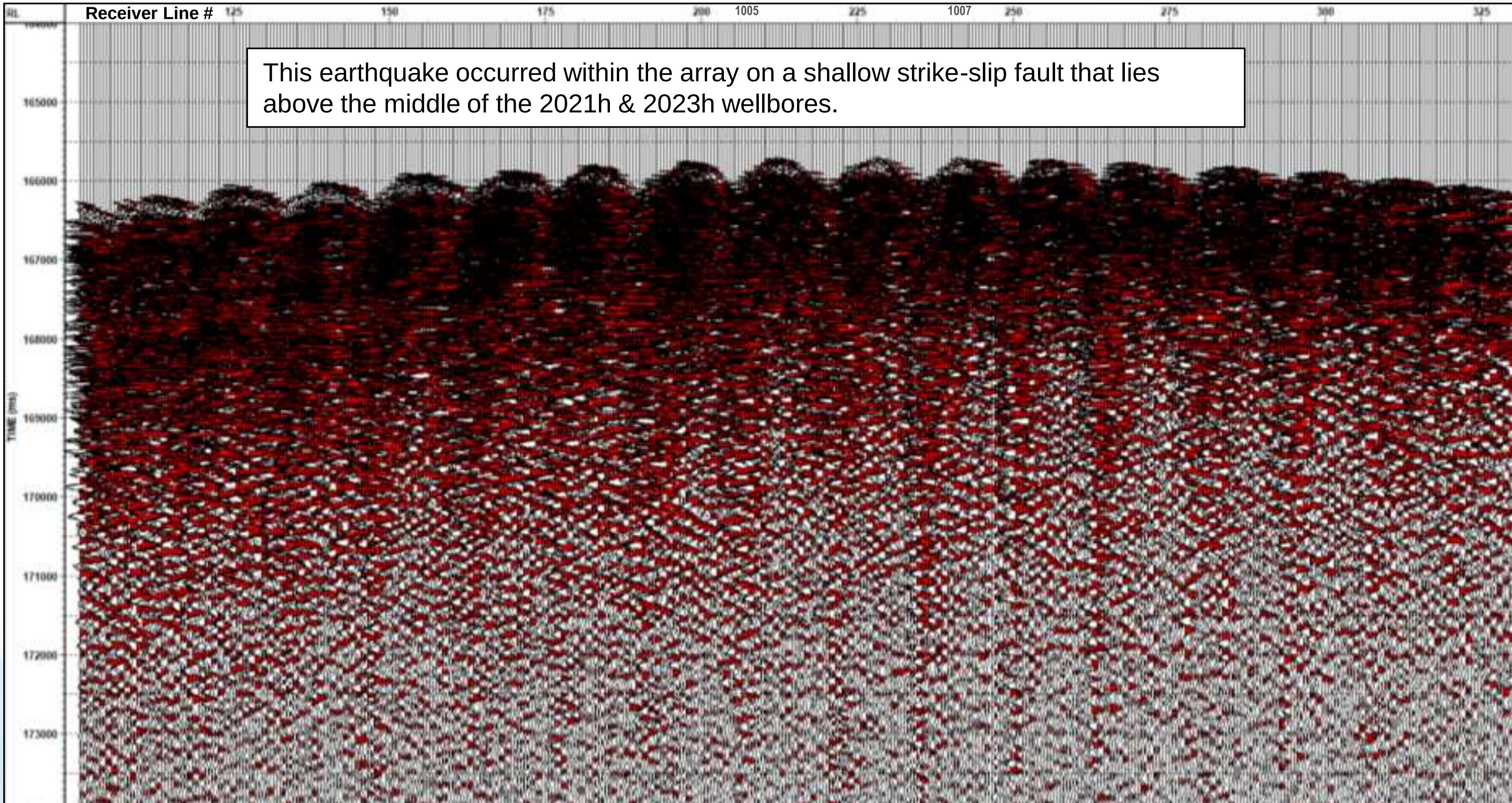
Earthquakes Reported by INPRES



- A 3.3 local magnitude (ML) earthquake was reported on July 6th, 2020 at 22:04:45 local time.
- The image to the left shows the surface array and the reported location of the earthquake recorded by the array.

Raw Data – Earthquake

7/06/2020 22:05:03.168 local (GPS corrected time) Raw data – 10 second window – Event at ~165.7 seconds



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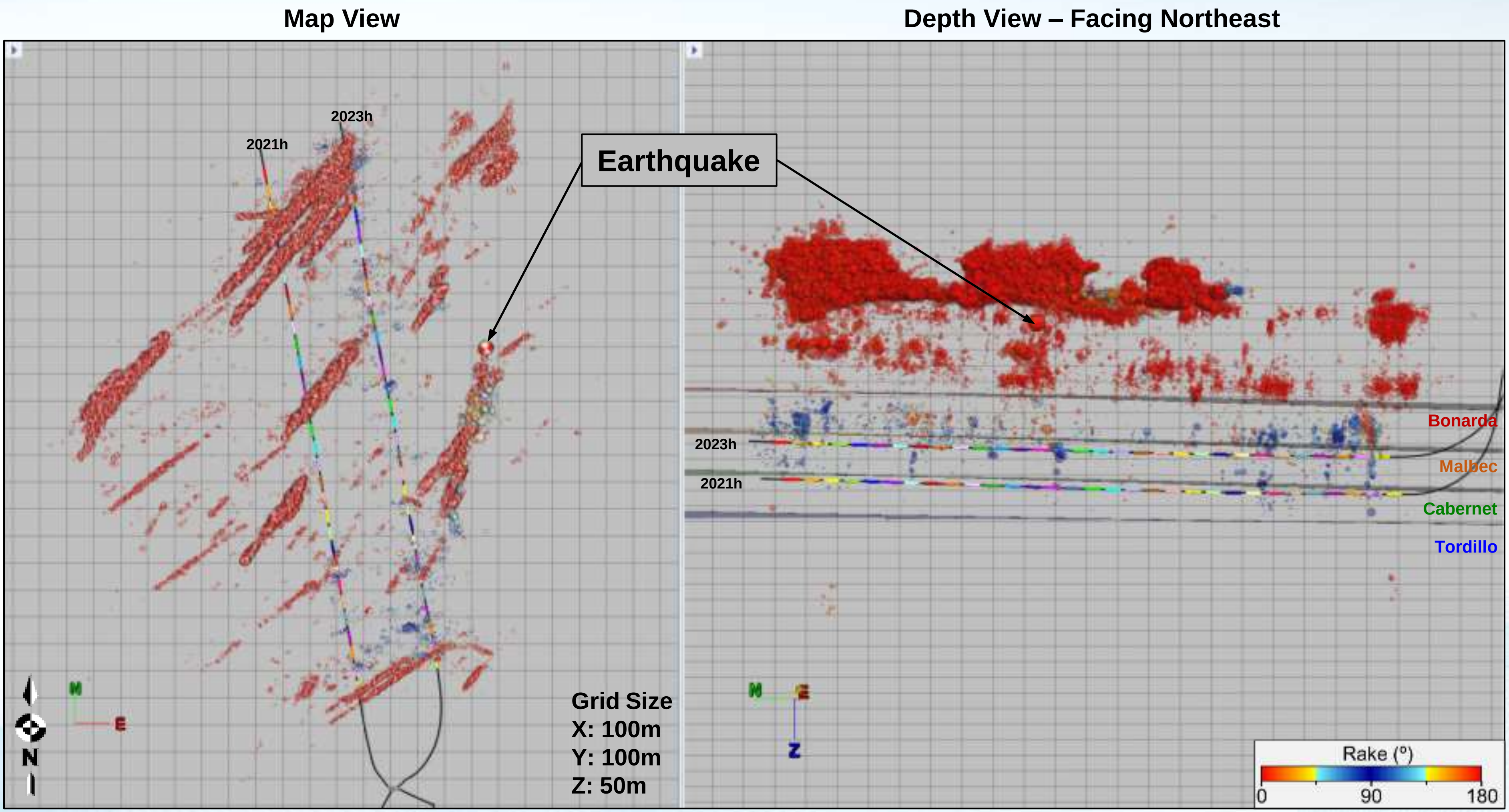
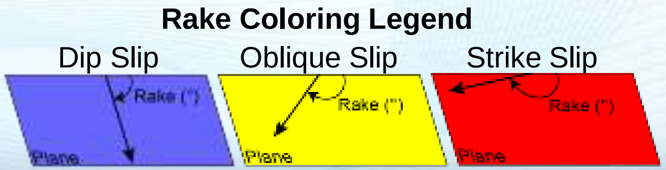
Earthquake Location



Events are styled by source mechanism, colored by rake, and sized by magnitude.
All events except for the reported earthquake are shown semi-transparent.



Additional Analysis

b Value

b Values: Earthquake Seismology

- Gutenberg and Richter established relationship between magnitude and the total number of earthquakes (GR law):

$$\log_{10} N = a - bM \qquad \text{or} \qquad N = 10^{a-bM}$$

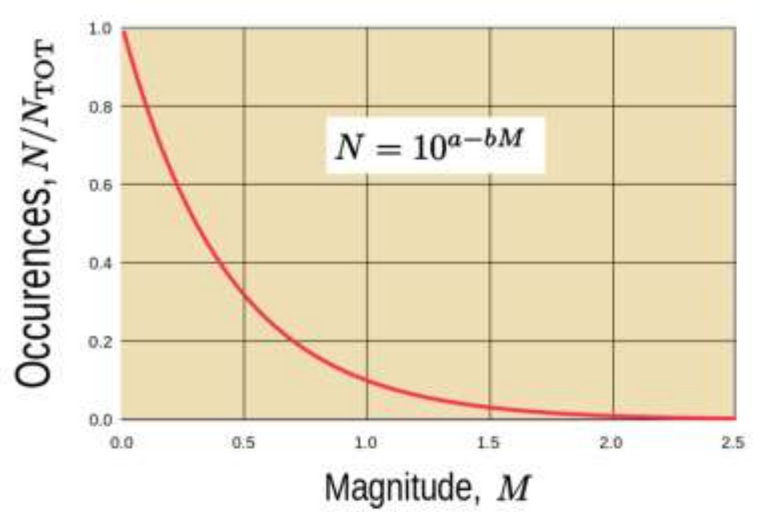
- N is number of events with magnitude ≥ M
- a and b are constants
- The a-value indicates total seismicity rate and GR law can be expressed in terms of total number of events:

$$N = N_{TOT}10^{-bM} \qquad \text{where} \qquad N_{TOT} = 10^{a}$$

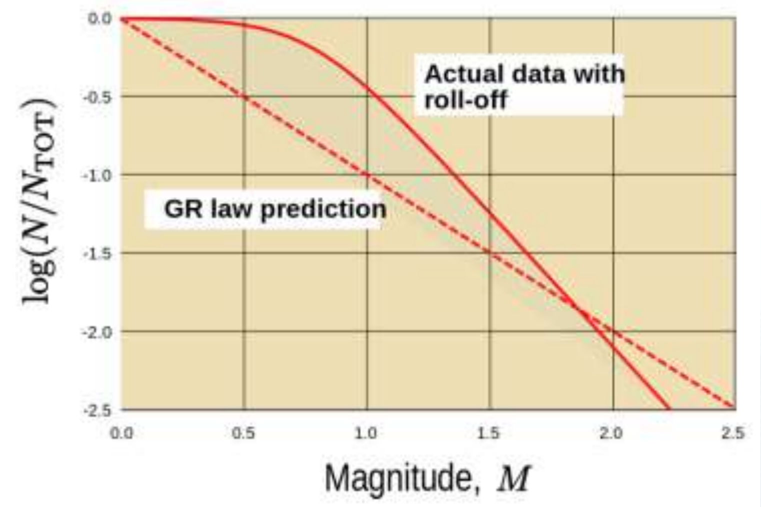
- In general:
  - b values for tectonic seismicity are ~1
  - b values for induced seismicity are ~2

b Values: Earthquake Seismology

GR law for b=1

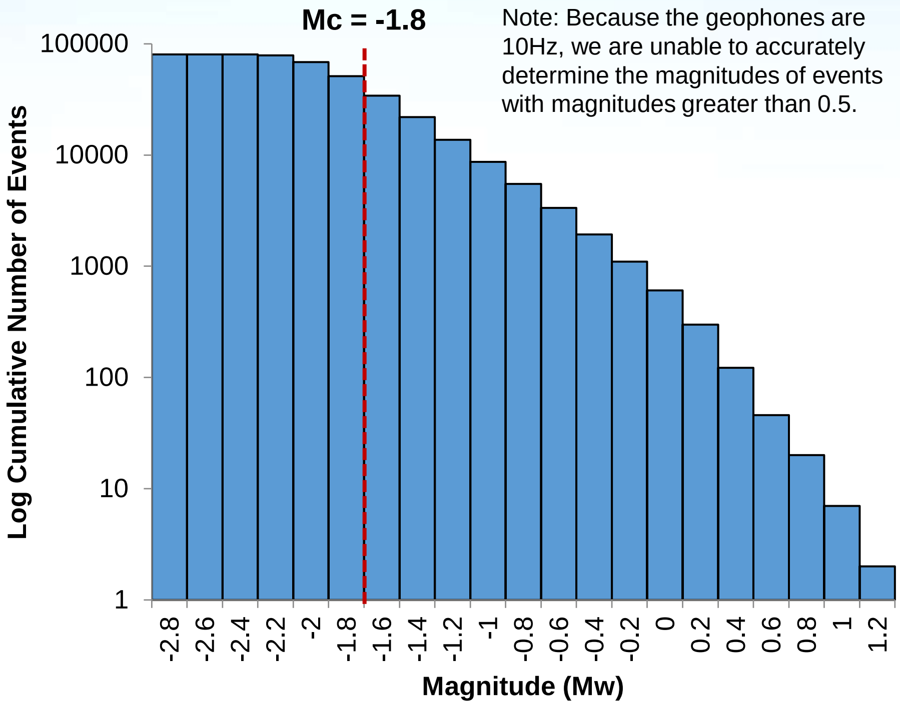


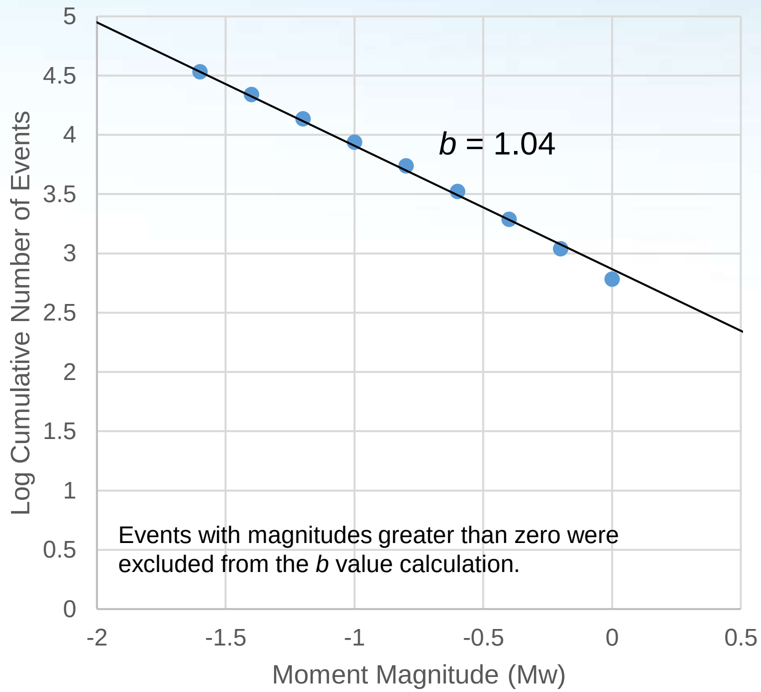
Roll-off compared to ideal GR law with b=1



- For actual earthquake catalogs, b values tend to decrease for smaller magnitude events as less are detected at lower magnitudes.
- The magnitude of completeness (Mc) is the lowest magnitude at which 100% of the events are detected.
- After all events with magnitudes less than Mc have been removed, the b-value can be determined.

b Value Analysis – Fault Events





- Maximum-likelihood estimation (Utsu, 1965):

$$b = \log_{10} e \,/(Mav - Mmin)$$

- A *b*-value of ~1 suggests that the events are related to the stimulation of pre-existing faults or features.

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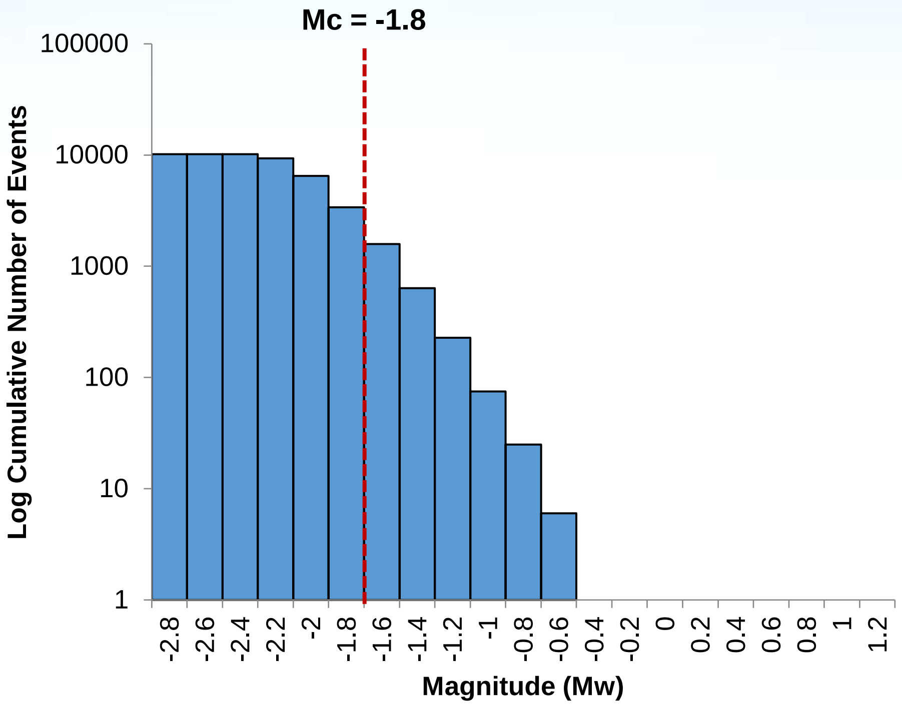
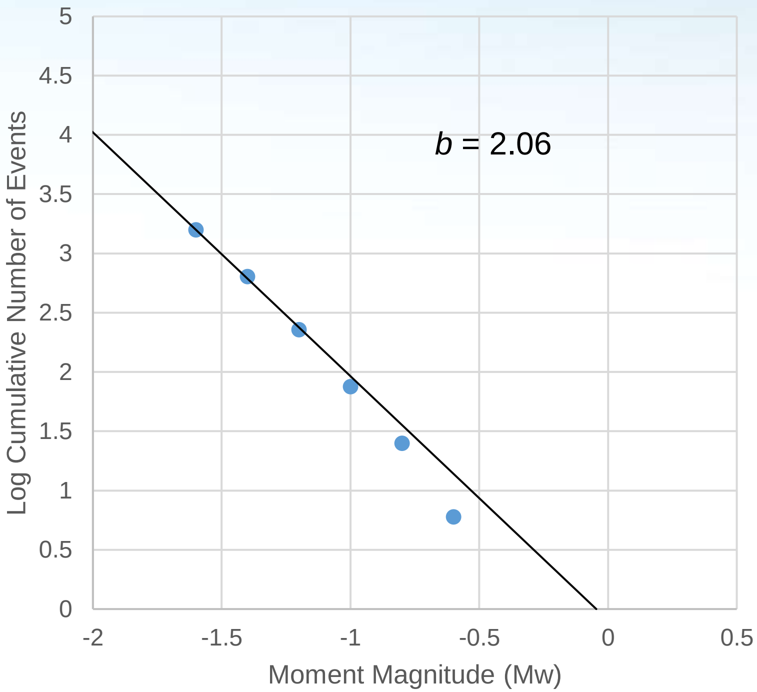
b Value Analysis – Reservoir Events





- Maximum-likelihood estimation (Utsu, 1965):

  $$b = \log_{10} e \,/(Mav - Mmin)$$

- A *b*-value of ~2 suggests that the events are related to hydraulic fracturing.

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Appendix II: Stage by Stage Results

See separate power point

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