Utah FORGE
PSS Tools Status Report

December 29, 2022

Prepared for:
University of Utah

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Summary

This report summarizes the data quality from the Utah FORGE borehole passive seismic sensors (PSS) tools at well sites 58-32 and 78B-32. Two level Avalon tools were installed on 09-28-2022 and 09-29-2022 by representatives from Avalon, Schlumberger, University of Utah, and ISTI. Each site contains two level geophones with three components each for a total of 12 seismic components in operation. At the time of installation, only one of the components was deemed marginally operating. This report details approximate timelines of data quality degradation.

To further complicate the situation, all remote sites lost AC power on Oct 23, 2022 at 01:16 am MDT. The DCP-2 and on-site PC are powered through the UPS and remained online via battery backup for about 3 hours and 21 minutes, after which the DCP-2 and PC powered off. AC mains site power resumed at about Oct 23, 2022 07:59am MDT. The DCP-2 is not able to resume power independently after power failure. The rest of the seismic acquisition system is fully functional, however the recordings are only digitizer noise.

Well	Seismic Station		Location Code	Description		Channel Code	Description
56-32	FBH1		01	Upper sonde		GH1	Z
58-32	FBH2		02	Lower Sonde		GH2	X
78B-32	FBH3					GH3	Y

Station Performance

Real-time Seismic Amplitude Measurement (RSAM)

RSAM is a rapid method to approximate the average waveform amplitude. The basic processing steps are as follows. In short, RSAM shows the 10 minute RMS amplitude.

1. Segment the waveforms into 600 second (10 minute) long windows.
2. Demean the data
3. Calculate the absolute values of the demeaned data.

4. Compute the mean average of these absolute demeaned data. This mean value is the RSAM value for that time window

RSAM figures are shown below for the Avalon geophones installed in 58-32 (FBH2) and 78B-32 (FBH3). Vertical axes are shown with log scaling to allow the wide range of values to be displayed.

RSAM for Well Pad 58-32 (FBH2)

2022-09-28T22:05:00	Acquisition begins. Wireline connected to DCP-2 and datalogger
2022-10-03T22:00	All components on lower sonde indicate sharp change in signal quality
2022-10-13T01:00	Y component on upper sonde shows large spike and degraded signal quality afterwards
2022-10-23	AC power was lost to station for a duration longer than the backup UPS was able to sustain power for DCP-2. Other station components resumed power and DCP-2 remained off until human intervention.

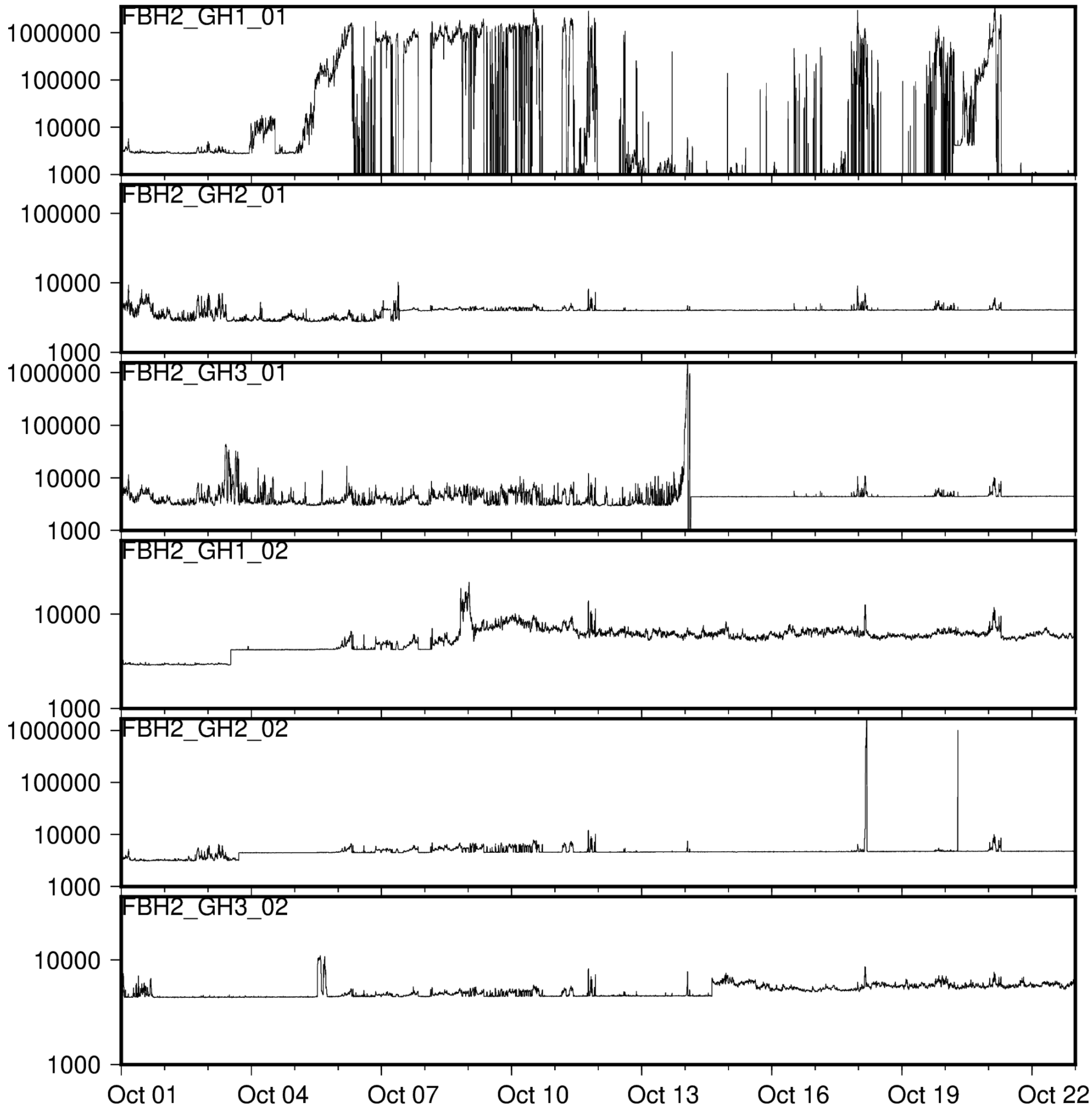


Figure 1. RSAM values at 58-32 (FBH2)*. Vertical axis is raw data counts on logarithmic scale to show wide range of values over the recording time.*

RSAM for Well Pad 78B-32 (FBH3)

2022-09-29T22:39:00	Acquisition begins. Wireline connected to DCP-2 and datalogger
2022-10-03T22:00	5 out of 6 components exhibit sharp change in signal quality

2022-10-12T05:00	Lower sonde appears to have lost response across all three components. Upper sonde seems unaffected.
2022-10-14T06:00	All components on both upper and lower sondes appear to have gradual increase in amplitudes
2022-10-23	AC power was lost to station for a duration longer than the backup UPS was able to sustain power for DCP-2. Other station components resumed power and DCP-2 remained off until human intervention.

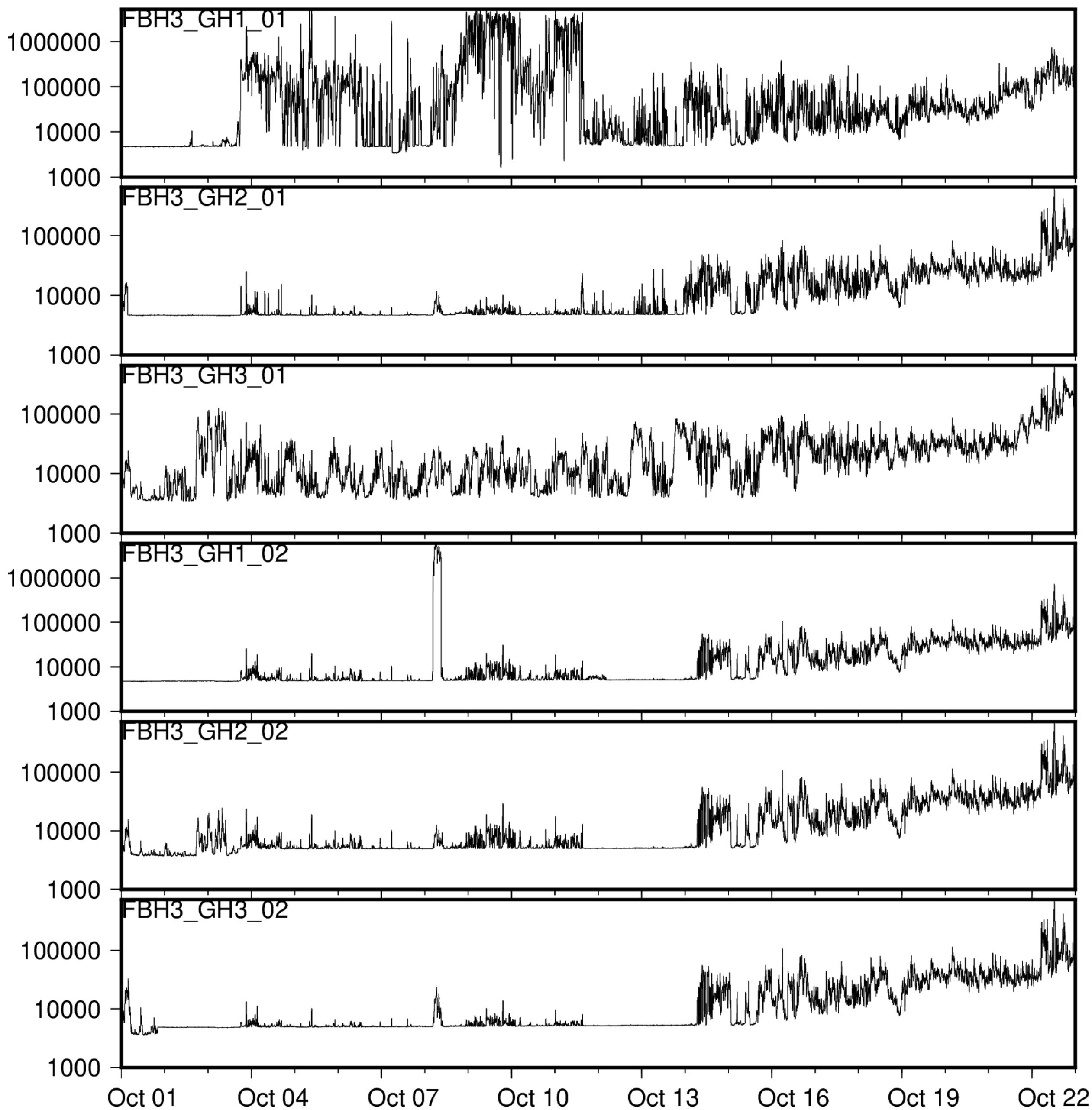


Figure 2. RSAM values at 78B-32 (FBH3)*. Vertical axis is raw data counts on logarithmic scale to show wide range of values over the recording time.*

Probabilistic Power Spectral Density Noise Analysis

Probabilistic power spectral density (PPSD) analysis is frequently used to assess functionality of a seismic sensor as well as the long term background noise levels at seismic stations (McNamara and Buland, 2004). Power spectral density (PSD) estimates are determined from hour-long continuous waveform segments. These PSDs are stacked to determine the probability that the seismic data exhibit this particular frequency-amplitude response over the entire recording period.

The figures below show PPSDs and the temporal variation of noise at a reference frequency of 200 Hz. There is redundancy in the presentation, however showing these attributes in different reference frames allows comparison among components of a single sensor, and among all components installed in a single borehole.

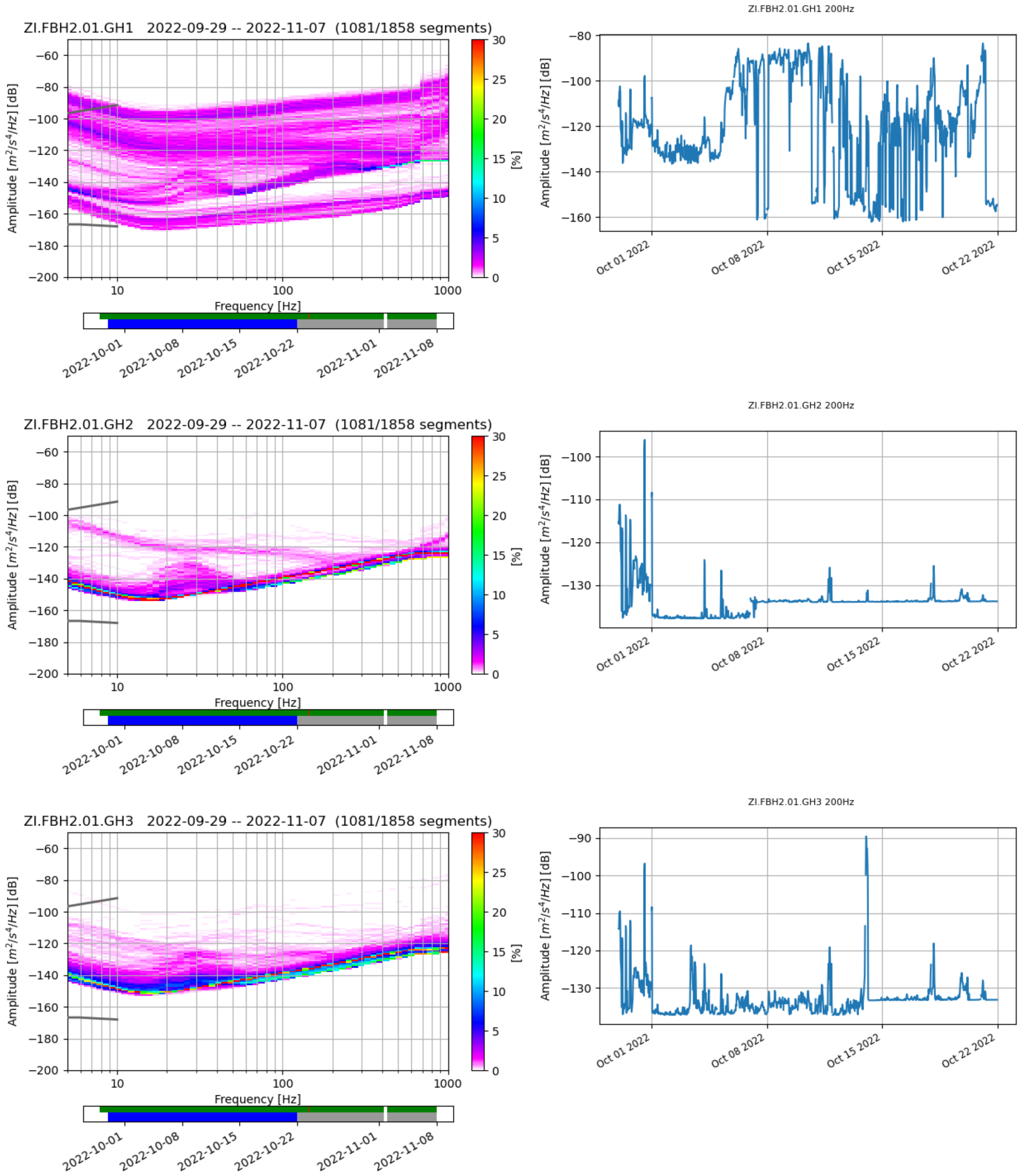


Figure 3. PPSD plots and Temporal noise values for 58-32 (FBH2), upper sonde (location code 01). *Left column shows PPSD; Right column shows temporal noise variation at 200 Hz. The blue line represents a cross section through the PPSD 2D histogram, sampling the noise value (in dB) at 200 Hz. Essentially this shows how the station noise level at a center frequency of 200 Hz varies over time. For example, the top row shows the performance of the vertical component of the upper sonde at 58-32 (FBH2). This component varies widely from -160 dB (likely a dead component) to -90 dB (likely very spiky data). The other components of this sonde are relatively stable. The components are ordered from top to bottom: Z, X, Y.*

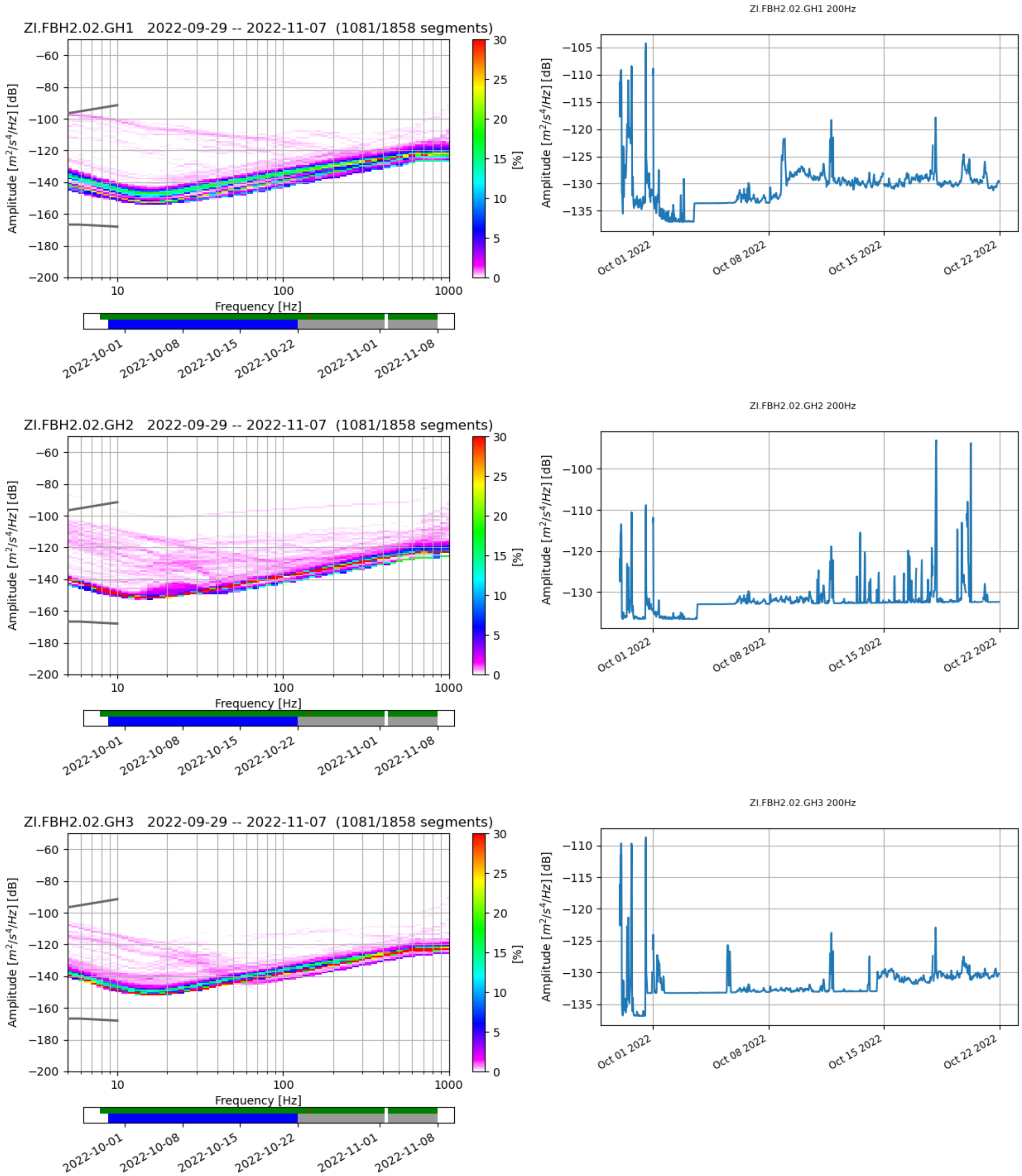


Figure 4. PPSD plots and Temporal noise values for 58-32 (FBH2), lower sonde (location code 02). *Left column shows PPSD; Right column shows temporal noise variation at 200 Hz. The blue line represents a cross section through the PPSD 2D histogram, sampling the noise value (in dB) at 200 Hz. Essentially this shows how the station noise level at a center frequency of 200 Hz varies over time. The other components of this sonde are relatively stable. The components are ordered from top to bottom: Z, X, Y.*

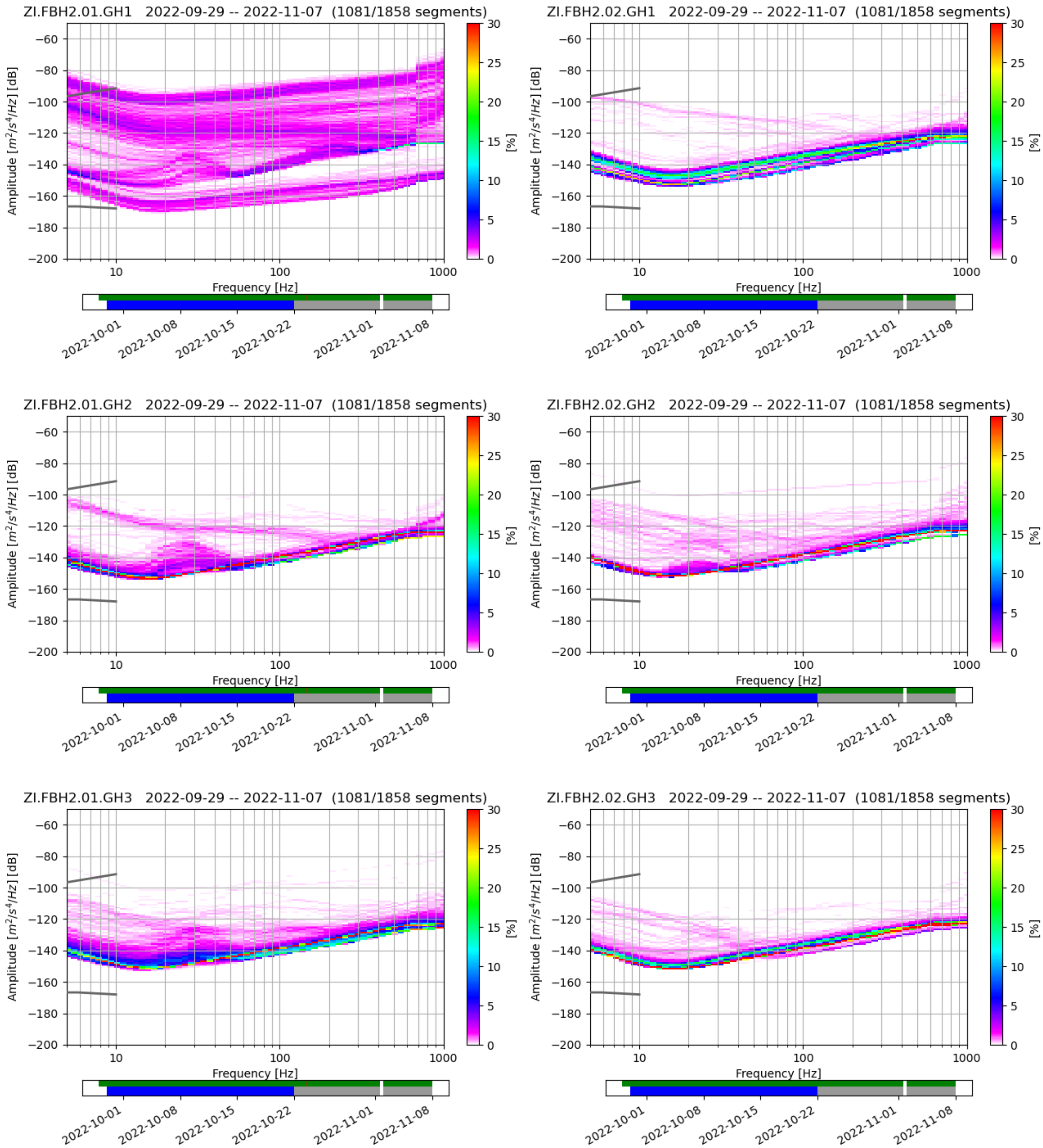


Figure 5. Probabilistic power spectral density analysis for 58-32 (FBH2)*. Left column shows upper sonde (location code 01); Right column shows lower sonde (location code 02). The components are ordered from top to bottom: Z, X, Y.*

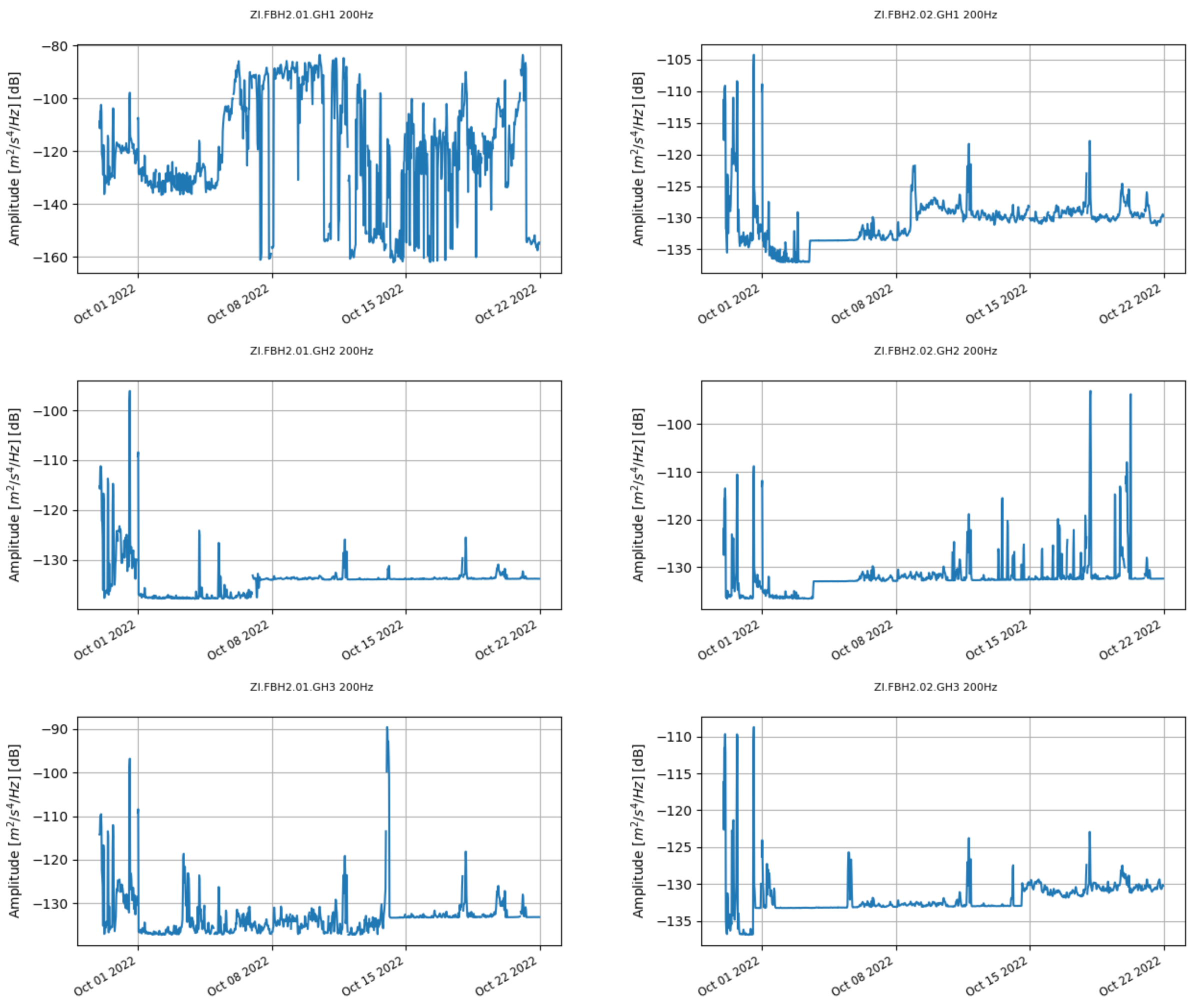


Figure 6. Temporal noise values for 58-32 (FBH2). *The blue line represents a cross section through the PPSD 2D histogram, sampling the noise value (in dB) at 200 Hz. Essentially this shows how the station noise level at a center frequency of 200 Hz varies over time. Left column shows upper sonde (location code 01); Right column shows lower sonde (location code 02). The components are ordered from top to bottom: Z, X, Y.*

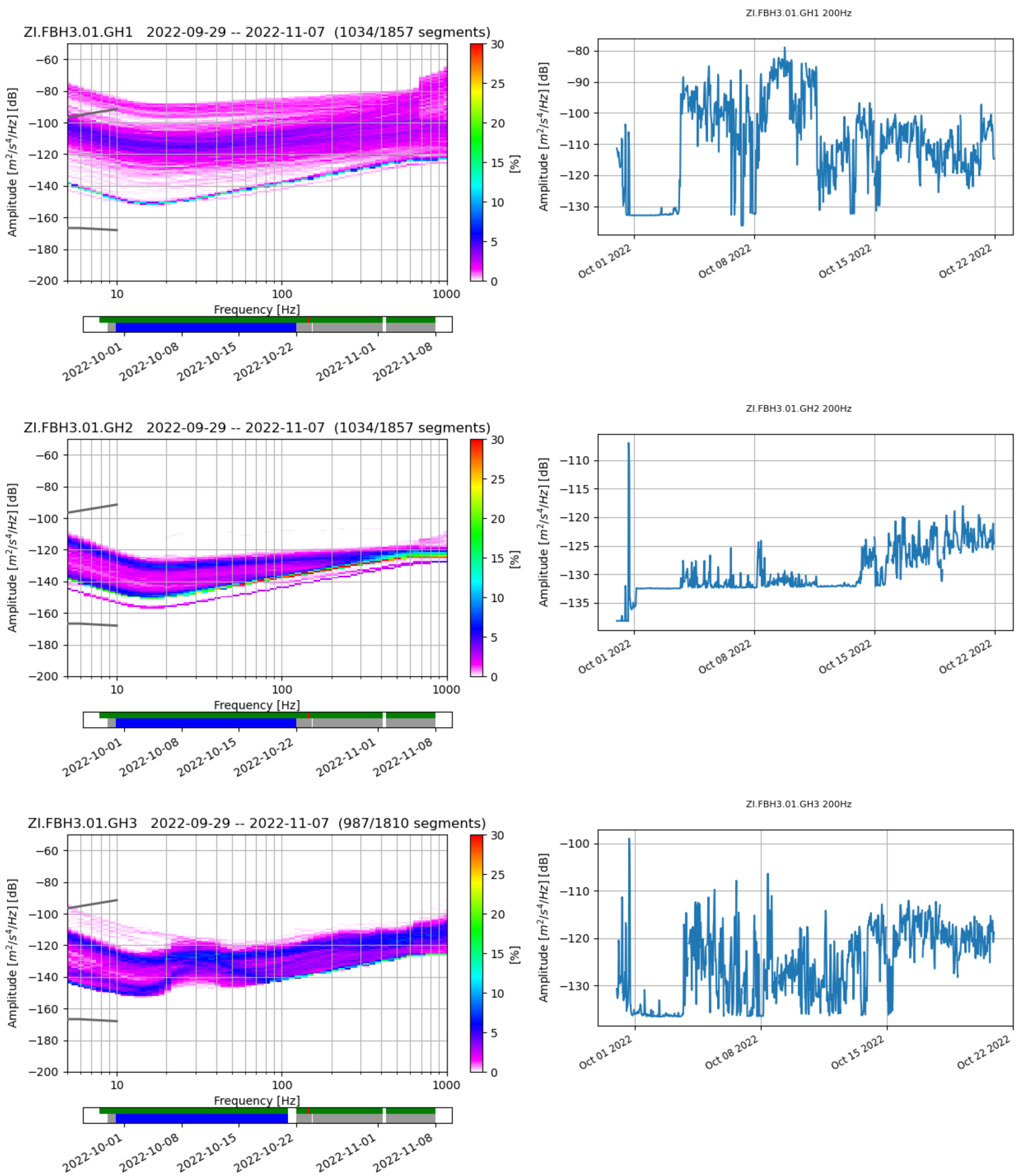


Figure 7. PPSD plots and Temporal noise values for 78B-32 (FBH3), upper sonde (location code 01). *Left column shows PPSD; Right column shows temporal noise variation at 200 Hz. The blue line represents a cross section through the PPSD 2D histogram, sampling the noise value (in dB) at 200 Hz. Essentially this shows how the station noise level at a center frequency of 200 Hz varies over time. Note all 3 components have concurrent noise level increases near 2022-10-14. The components are ordered from top to bottom: Z, X, Y.*

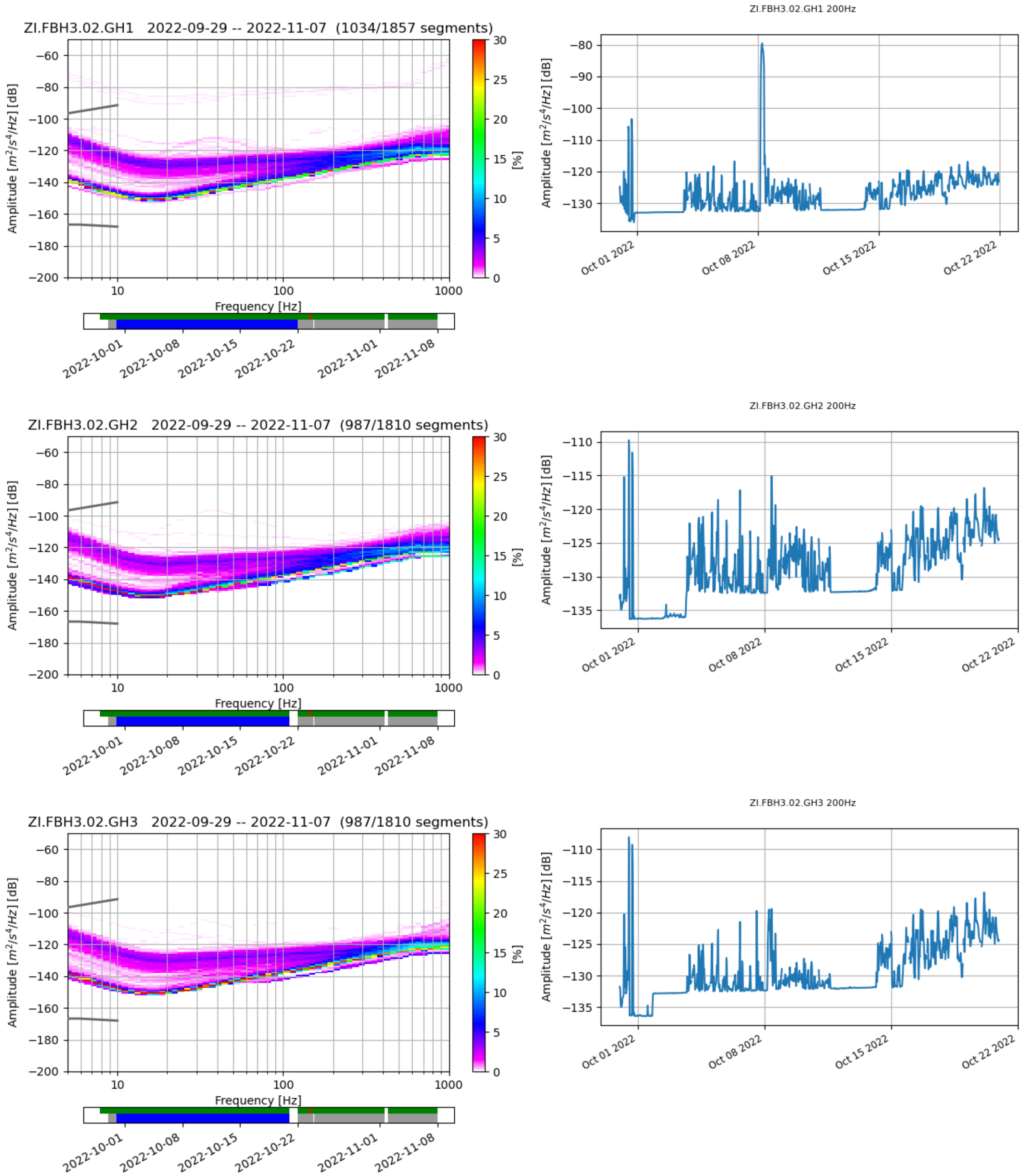


Figure 8. PPSD plots and Temporal noise values for 78B-32 (FBH3), lower sonde (location code 02). *Left column shows PPSD; Right column shows temporal noise variation at 200 Hz. The blue line represents a cross section through the PPSD 2D histogram, sampling the noise value (in dB) at 200 Hz. Essentially this shows how the station noise level at a center frequency of 200 Hz varies over time. Note all 3 components have concurrent noise level increases near 2022-10-14. The components are ordered from top to bottom: Z, X, Y.*

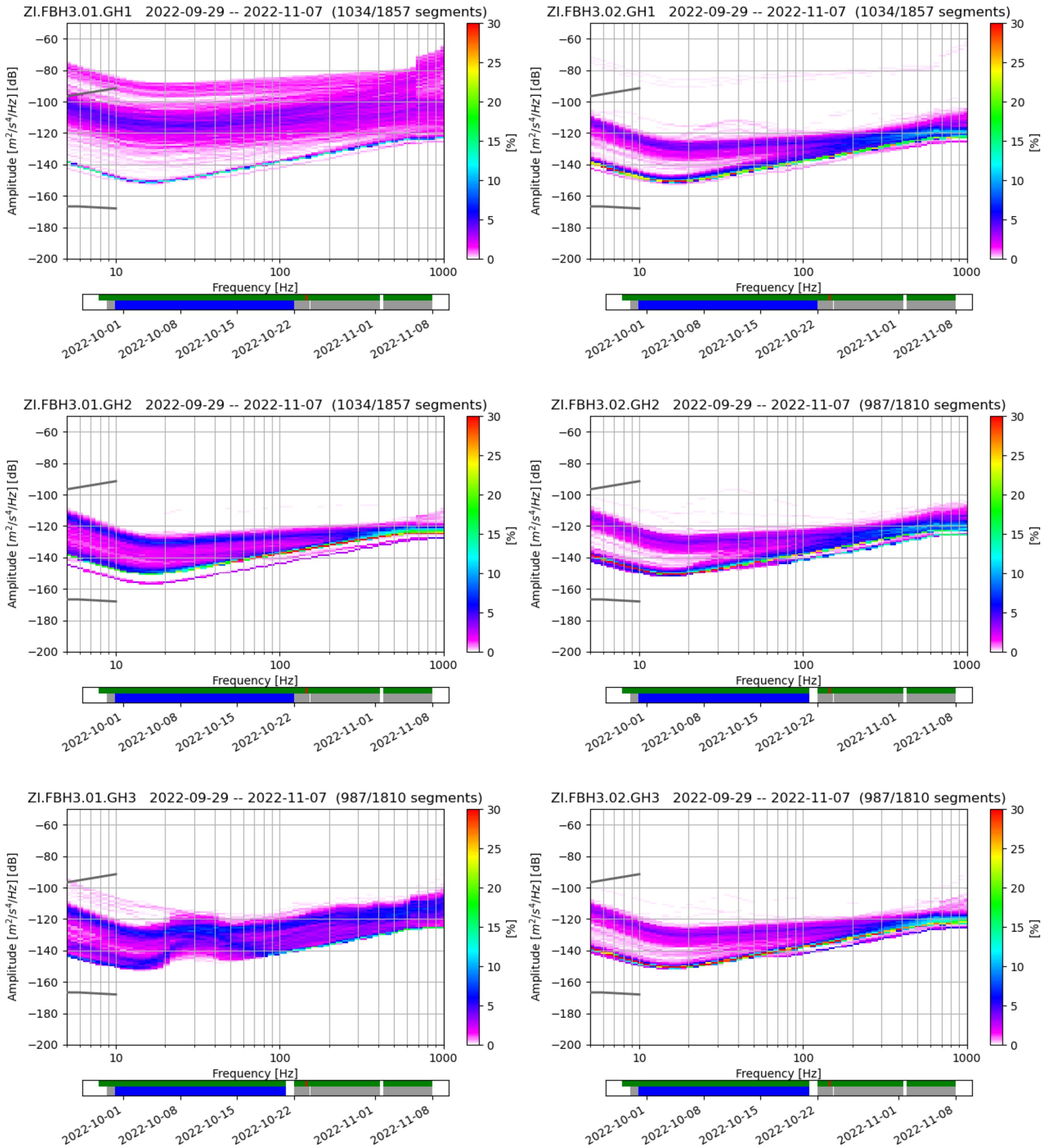


Figure 9. Probabilistic power spectral density analysis for 78B-32 (FBH3). *Left column shows upper sonde (location code 01); Right column shows lower sonde (location code 02). The components are ordered from top to bottom: Z, X, Y.*

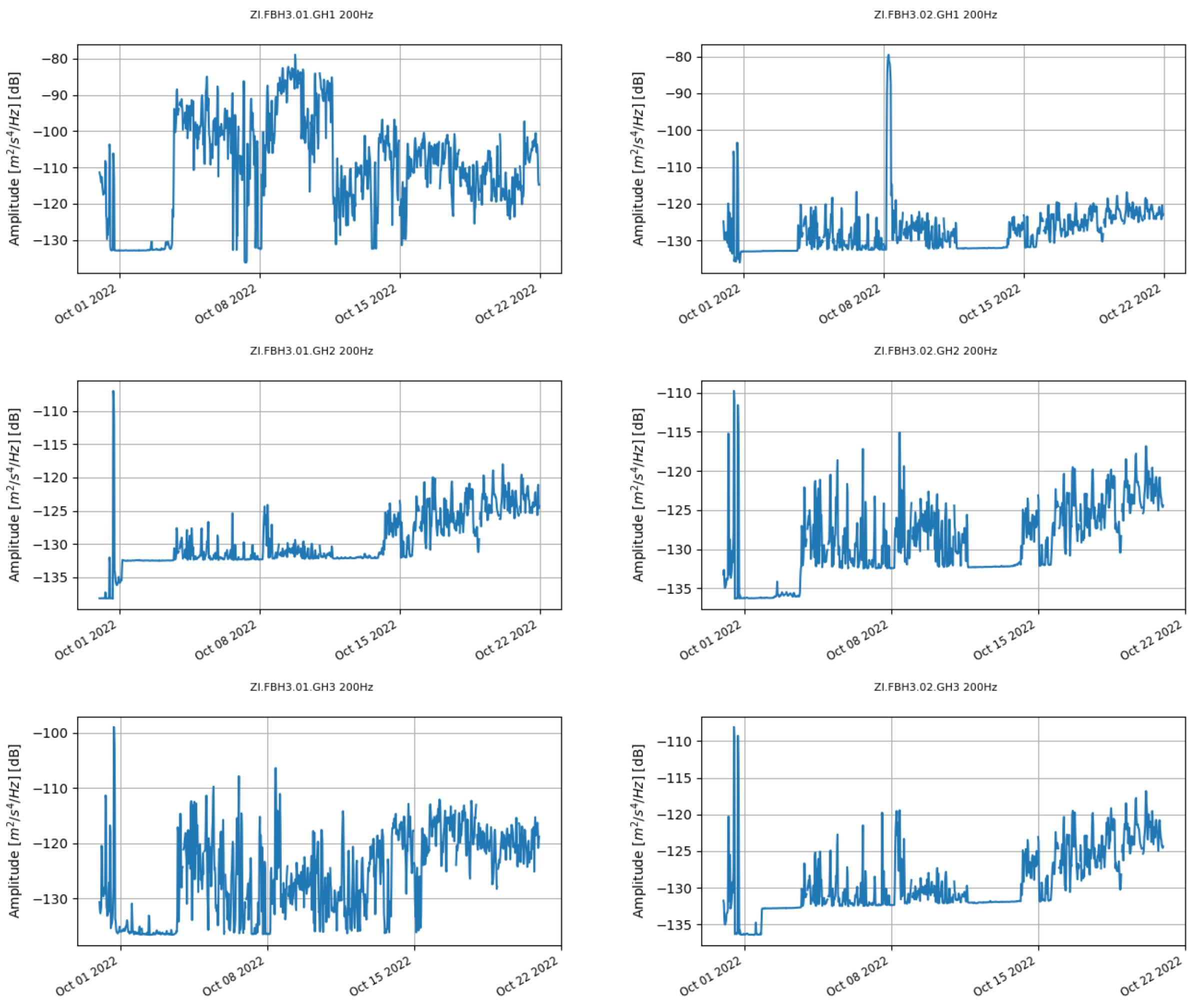


Figure 10. Temporal noise values for 78B-32 (FBH3). *The blue line represents a cross section through the PPSD 2D histogram, sampling the noise value (in dB) at 200 Hz. Essentially this shows how the station noise level at a center frequency of 200 Hz varies over time. Left column shows upper sonde (location code 01); Right column shows lower sonde (location code 02). The components are ordered from top to bottom: Z, X, Y. Note all 6 components have concurrent noise level increases near 2022-10-14.*

UU FORK Station Noise Levels

For reference, the PPSD noise analysis is shown for the University of Utah station FORK. These figures were obtained directly from IRIS:
(http://service.iris.edu/mustang/noise-pdf/docs/1/builder/)

The FORK station is approximately 200 m from 58-32 (FBH2) and 78B-32 (FBH3) with sensors installed in a shallow borehole configuration. The noteworthy comparison is that the FORK station shows very stable noise levels over long time periods, at about -120 dB at the 200 Hz reference frequency sampled at the other borehole stations.

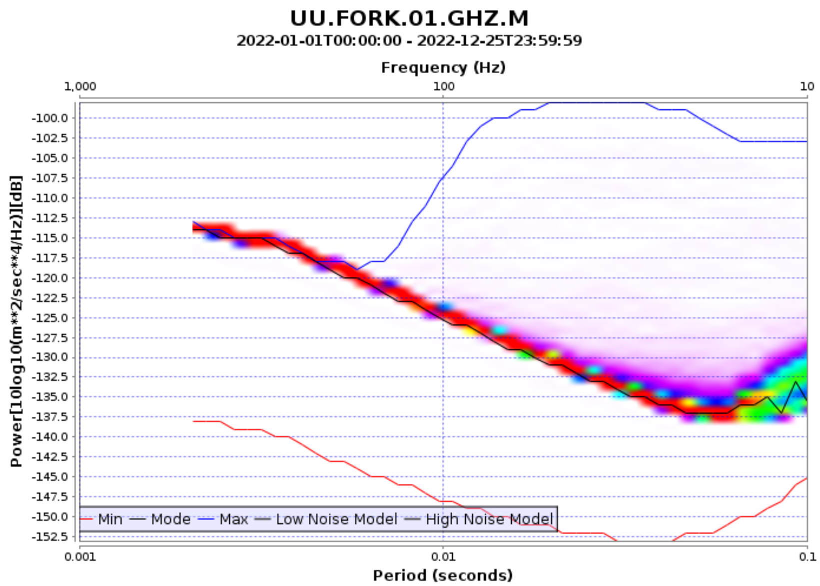


Figure 11. PPSD for UU.FORK *For comparison, shown is the PPSD plot for the vertical component at FORK for 2022.*

Waveforms and Noise Levels

Reviewing waveforms with other derived attributes is useful for assessing the health of the seismic sensors. Daily figures of waveforms, PPSD noise, RSAM, and temporal noise sampled at 200 Hz are provided separately.

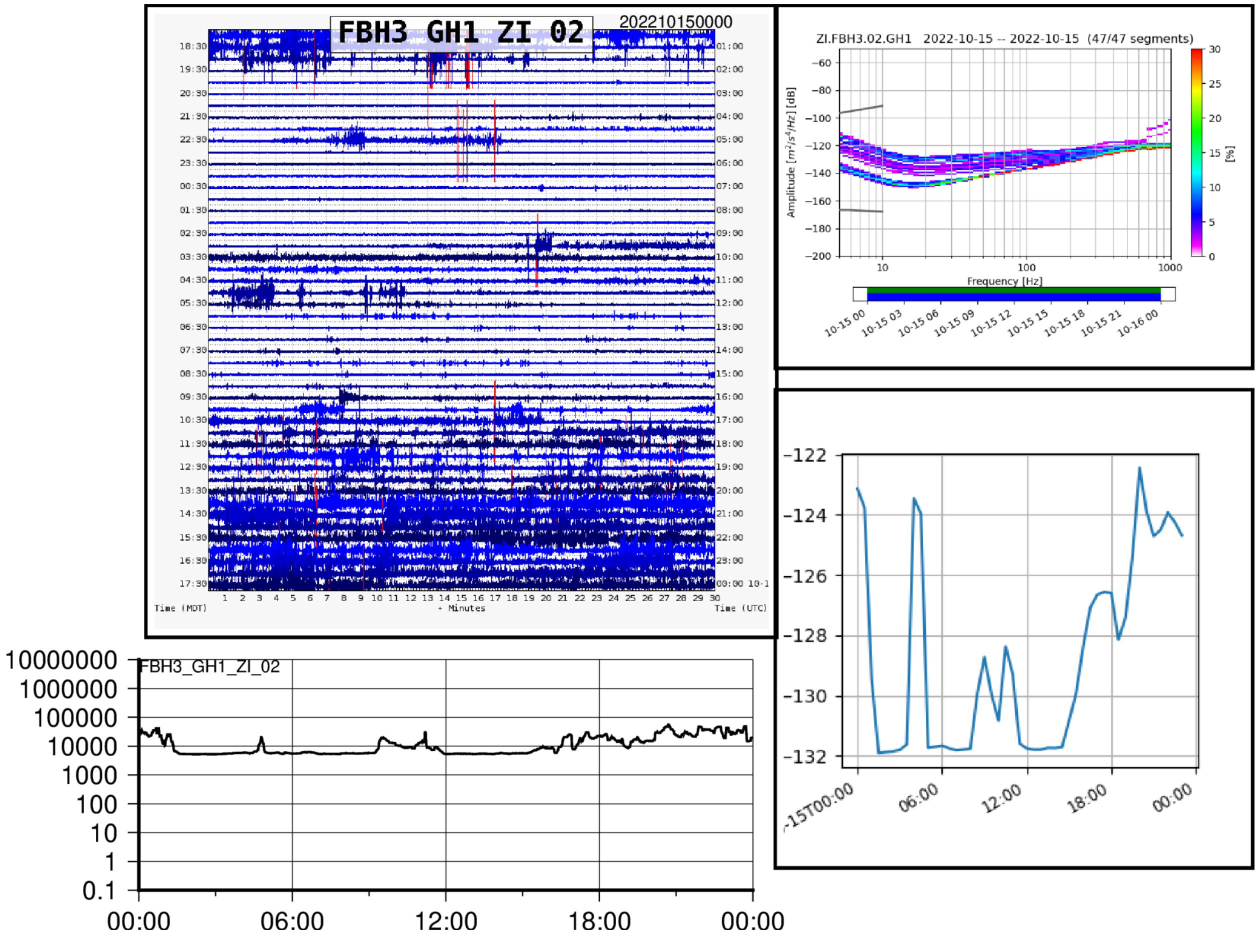


Figure 12. Combined waveforms and noise 78B-32, lower sonde, vertical component (FBH3_02_GH1).
Top Left: 24 hour helicorder record for the component indicated. Start time at upper right corner.
Top Right: PPSD analysis for the same 24 hour period. Note PPSD uses hour-long windows
Bottom Left: RSAM for the same 24 hour period. Note RSAM is RMS amplitude (raw counts) over 10 minute window
Bottom Right: Temporal PSD (noise) level sampled at 200 Hz. Units in dB

Power Failure

On Oct 23, 2022 at 01:16 am MDT, the FORGE site lost AC power for several hours. The onsite battery backup through the uninterruptible power supply (UPS) for the Avalon DCP-2 and local PC lasted for 3 hours and 21 minutes. After this time, AC power was no longer supplied to the DCP-2 and it was shut down. The DCP-2 does not automatically power back up after a power outage, thus the DCP-2 at 78B-32 and 58-32 remain off until human intervention is applied. The RSAM figure below shows average station amplitude over a 10 minute period for the vertical component of the upper sonde at 78B-32. Note the dramatic drop in amplitude on 10-23-2022 corresponding to the power failure and subsequent resuming of the rest of the station components absent of seismic data. The relatively flat amplitudes after 10-23-2022 represent digitizer noise without any input from seismic sensors.

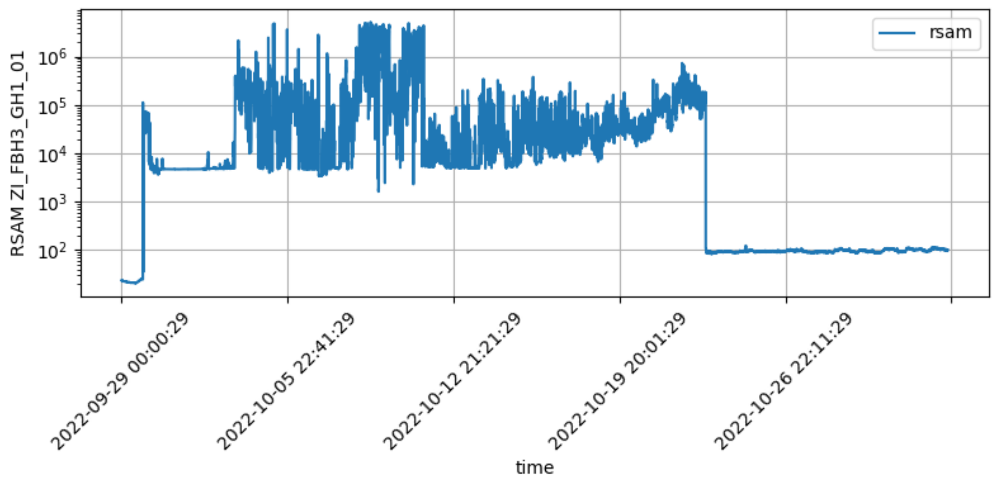


Figure 13. RSAM values at 78B-32 (FBH3). *RSAM on vertical component of upper sonde showing the drop of signal from the borehole geophones after the power failure and the DCP-2 did not automatically power back up.*

Seismic Data Processing

Automatic Detection and Processing

The automatic detection and location system found no automatic events since the Avalon tools were installed on September 29, 2022. The processing pipeline included the two-level analog strings at 58-32 (FBH2) and 78B-32 (FBH3), the UU.FORK seismometer, and UU.FOR2. Two detection methods were simultaneously operating on the continuous data streams: 1) a traditional STA/LTA detector and 2) a multi-frequency band detector (filter picker).

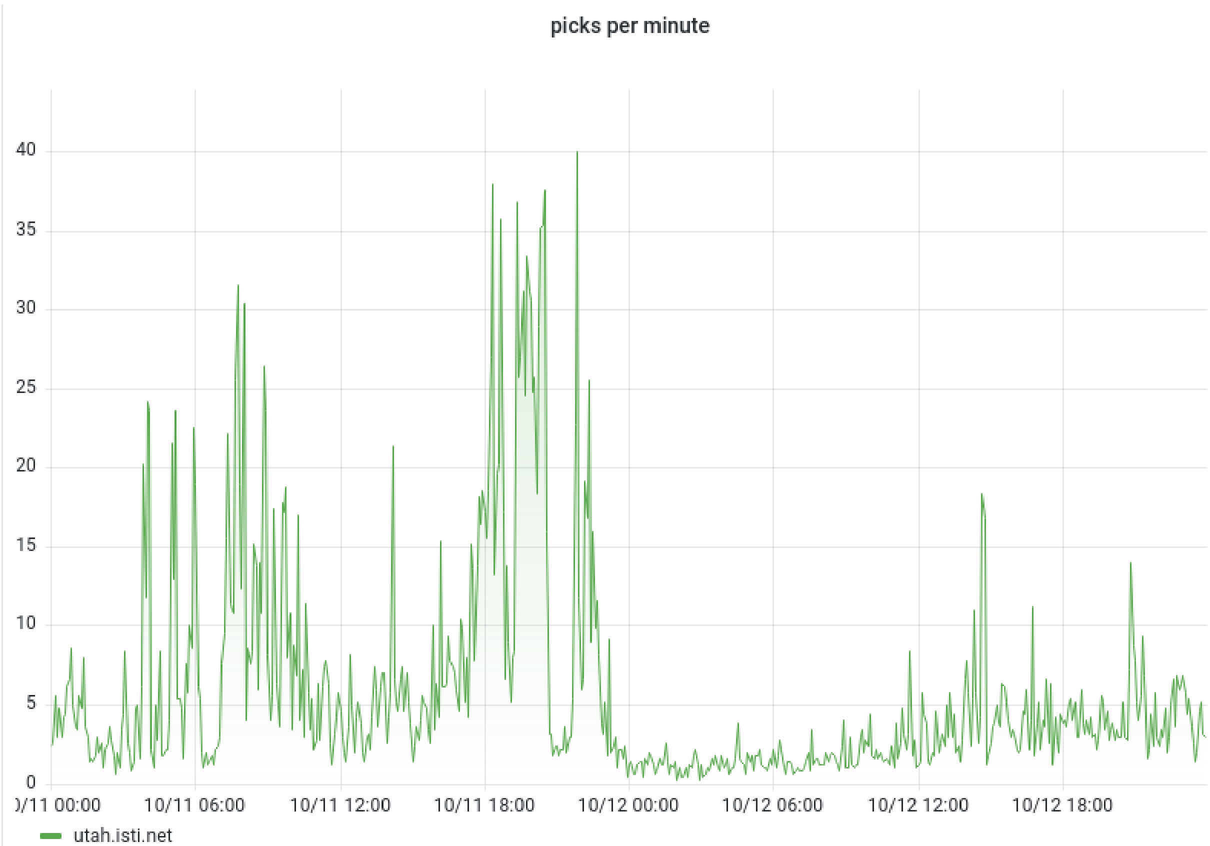


Figure 14. Detections (Picks) per minute. *The automatic processing system outputs picks that are passed to the event associator. In the time range shown here, the number of picks during a noisy (instrument glitches) time period decreased quickly near 10/12/2022 00:00. Shown are the number of picks per minute across all components included in the processing stream.*

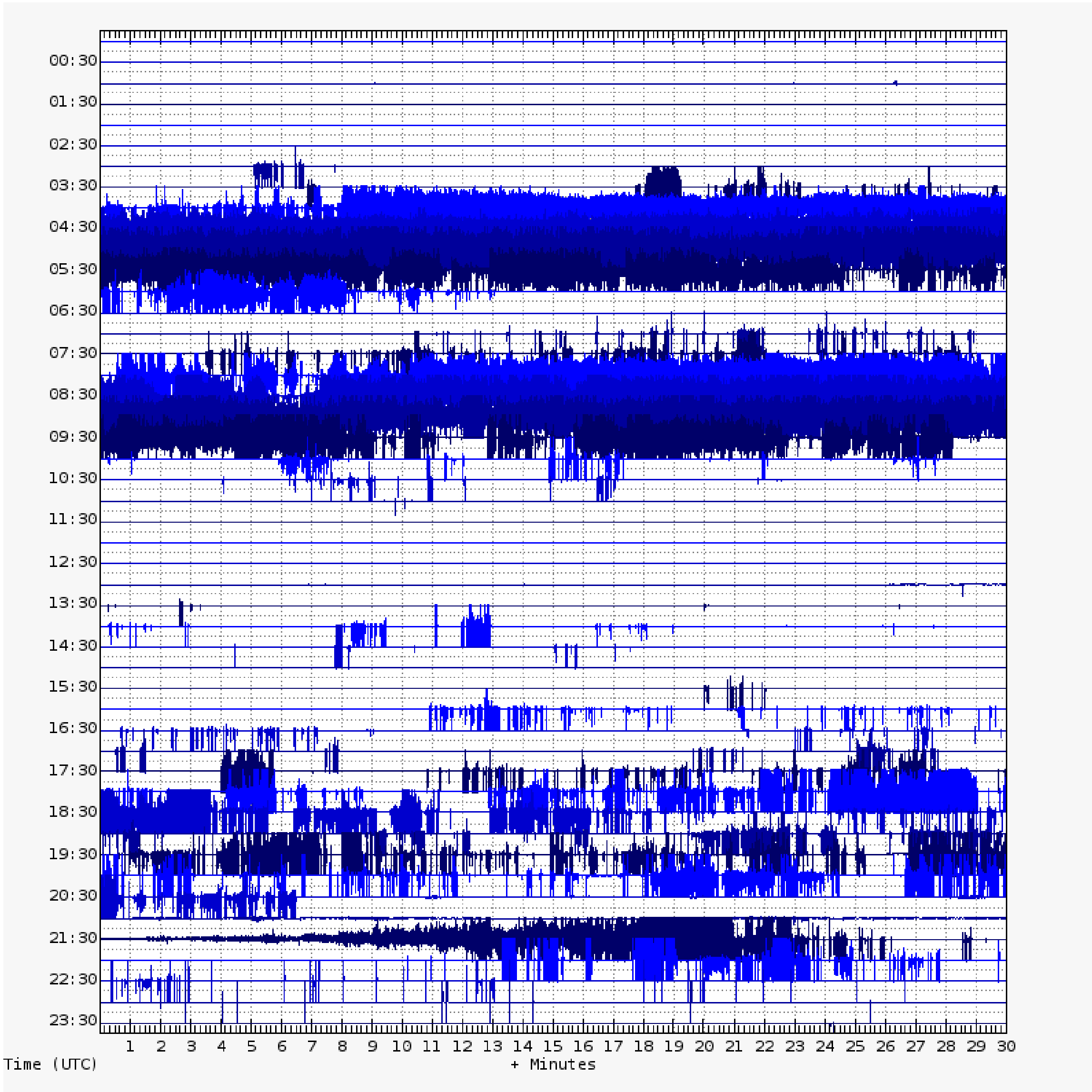


Figure 15. Helicorder record for 58-32, upper sonde, vertical component (FBH2_01_GH1) *Shown is 24 hours of data from 2022-10-11:00:00 to 2022-10-12:00:00, corresponding to portion of the time period shown in the previous figure of picks per minute. The noisy data contribute to excessive false picks in the processing system.*

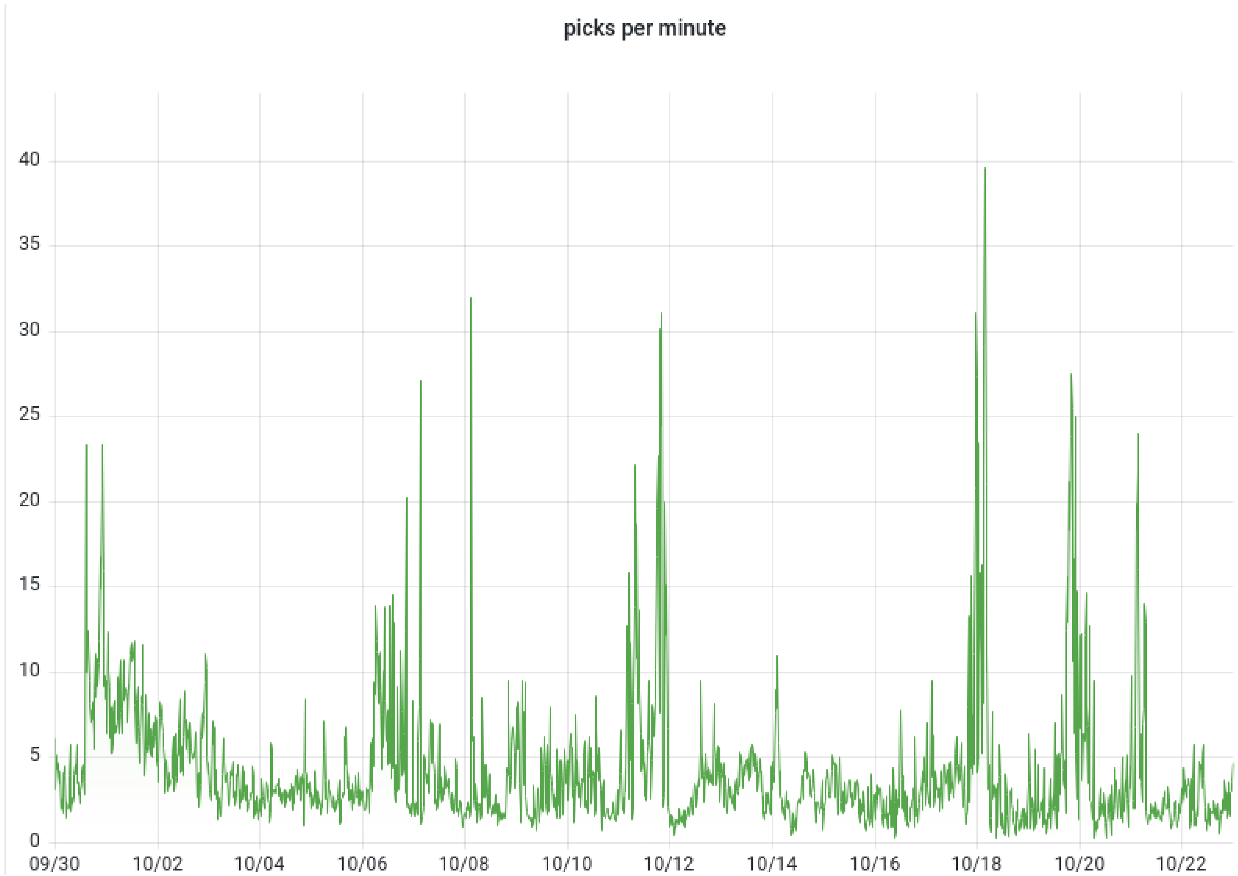


Figure 16. Detections (Picks) per minute. *The number of picks per minute for the entire time range (9/30/2022 - 10/23/2022). Shown are the number of picks per minute across all components included in the processing stream.*

Observations of Local Seismic Events

The University of Utah regional seismic network located 35 seismic events in the region surrounding FORGE from 10-01-2022 to 11-02-2022. Waveforms are shown below for events prior to 10-23-2022, when the AC power failure caused the Avalon DCP-2 to lose power and become unavailable to power the downhole sondes.

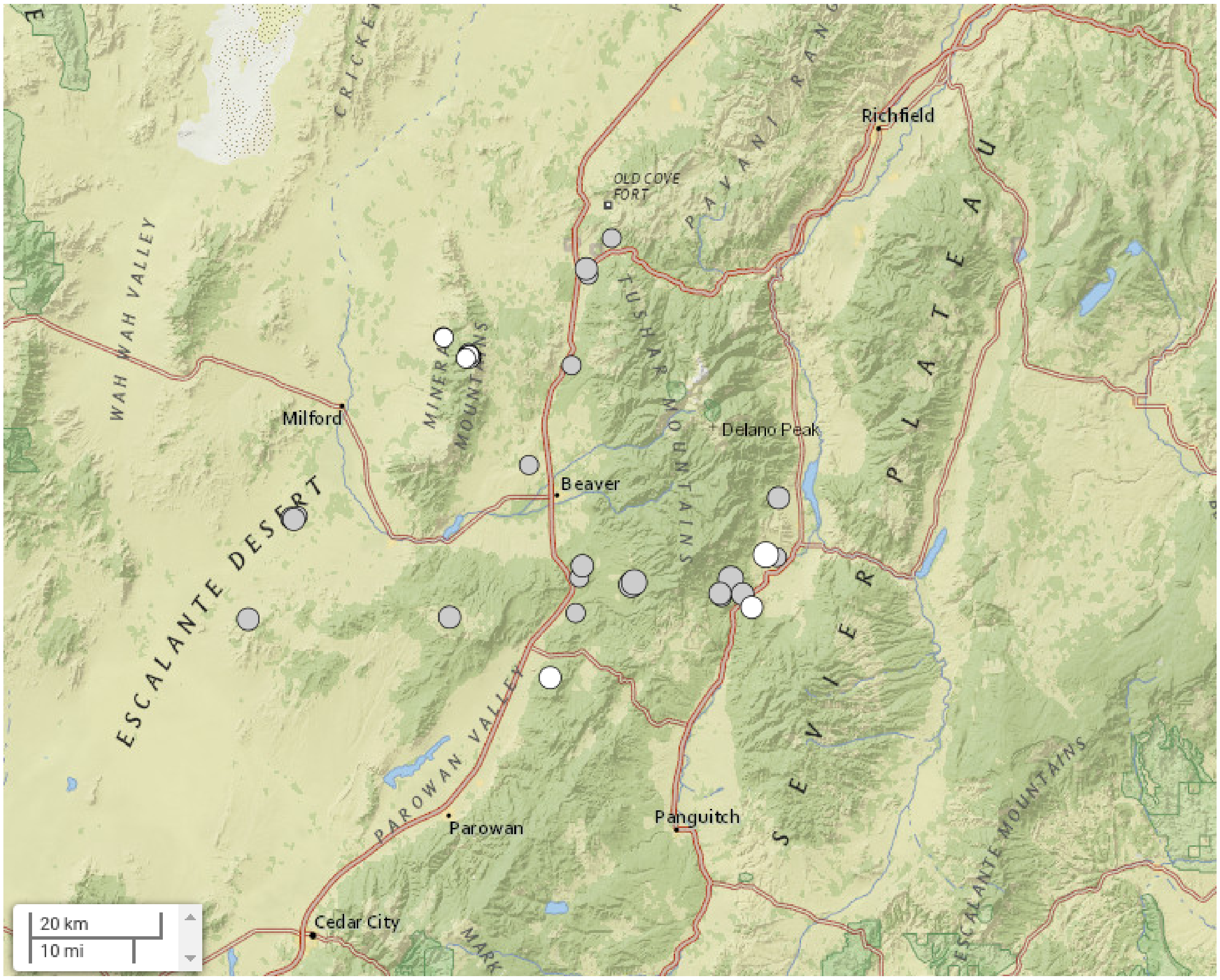
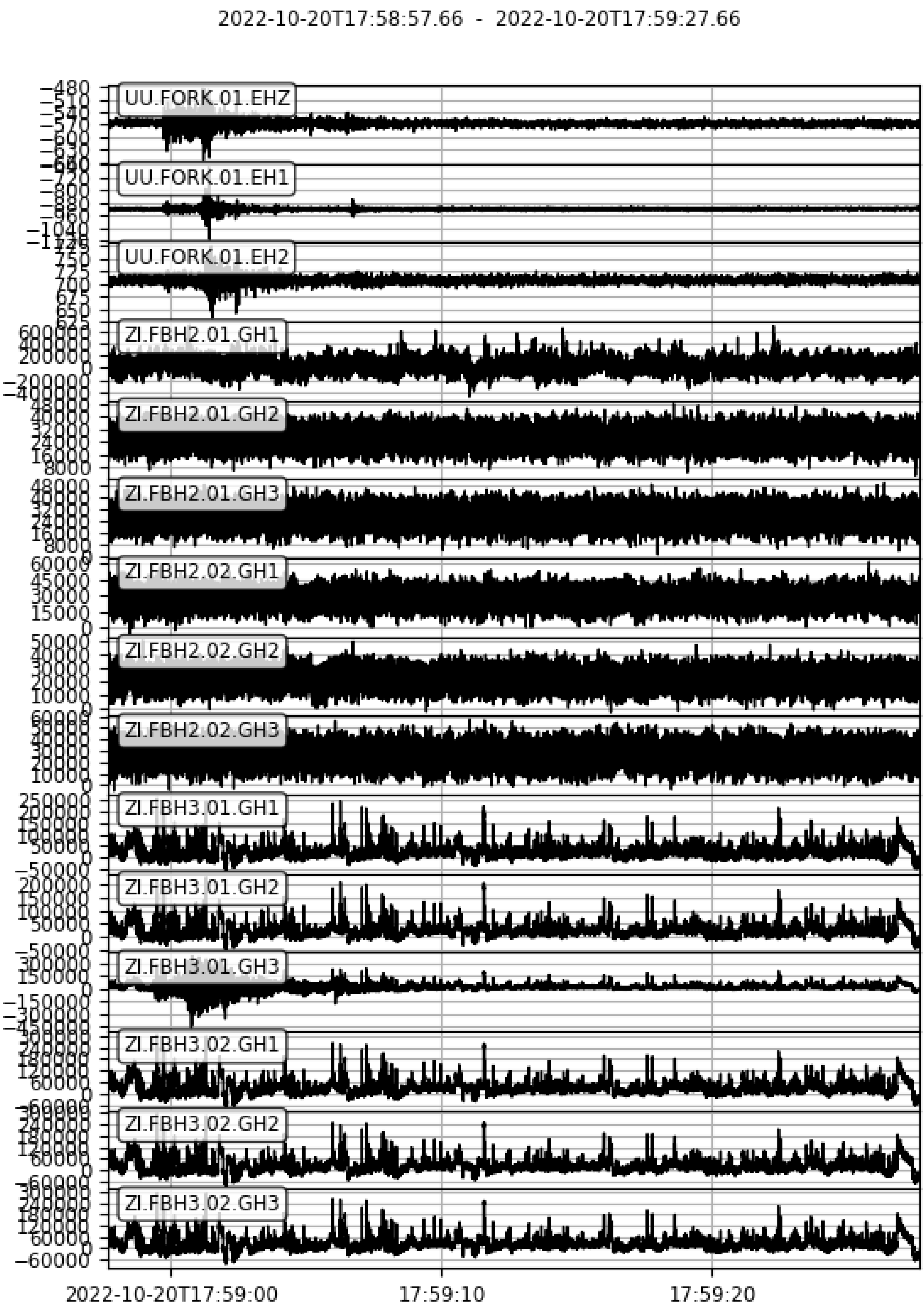
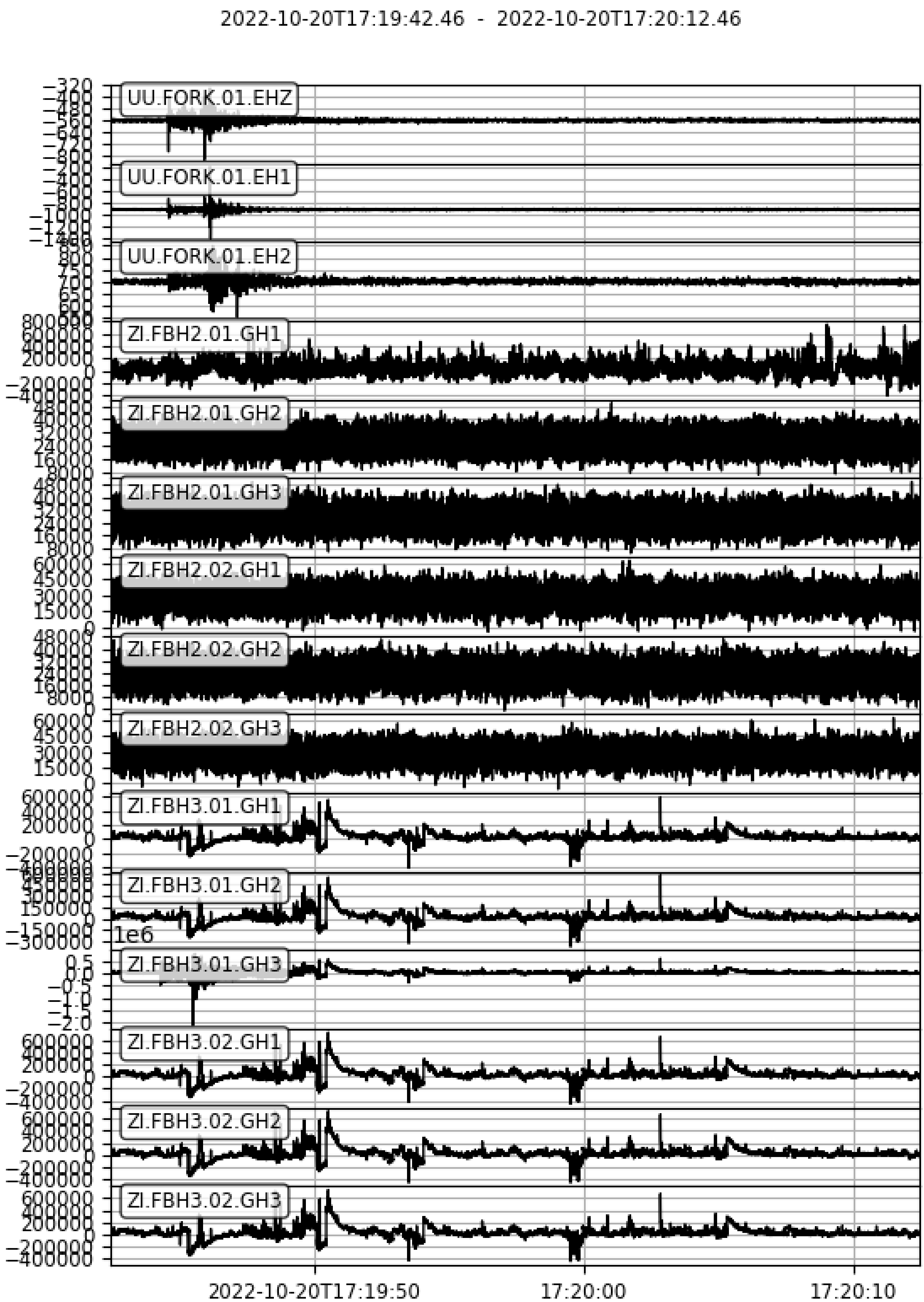
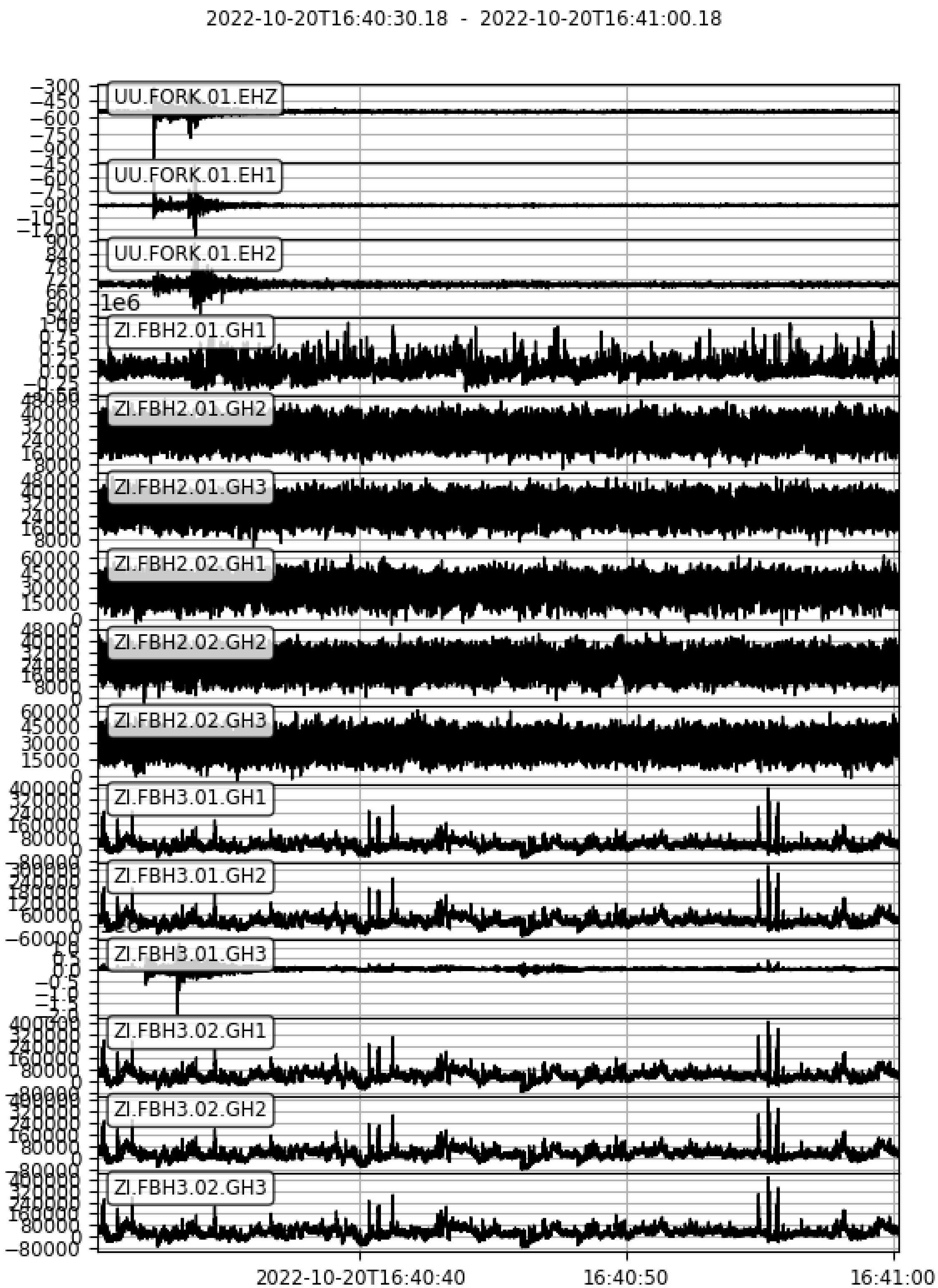


Figure 17. *Map of 35 seismic events detected and located by the UU regional seismic network between 10-01-2022 and 11-02-2022. Seismic event symbols (circles) are scaled by magnitude.*

In the following figures, waveforms from the UU.FORK sensor are also plotted for reference.


2022-10-20T17:58:57.66 - 2022-10-20T17:59:27.66
UU.FORK.01.EHZ
UU.FORK.01.EH1
UU.FORK.01.EH2
ZI.FBH2.01.GH1
ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
ZI.FBH3.01.GH3
ZI.FBH3.02.GH1
ZI.FBH3.02.GH2
ZI.FBH3.02.GH3
2022-10-20T17:59:00
17:59:10
17:59:20


2022-10-20T17:19:42.46 - 2022-10-20T17:20:12.46
UU.FORK.01.EHZ
UU.FORK.01.EH1
UU.FORK.01.EH2
ZI.FBH2.01.GH1
ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
1e6
ZI.FBH3.01.GH3
ZI.FBH3.02.GH1
ZI.FBH3.02.GH2
ZI.FBH3.02.GH3
2022-10-20T17:19:50
17:20:00
17:20:10


2022-10-20T16:40:30.18 - 2022-10-20T16:41:00.18
UU.FORK.01.EHZ
UU.FORK.01.EH1
UU.FORK.01.EH2
ZI.FBH2.01.GH1
ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
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ZI.FBH3.02.GH1
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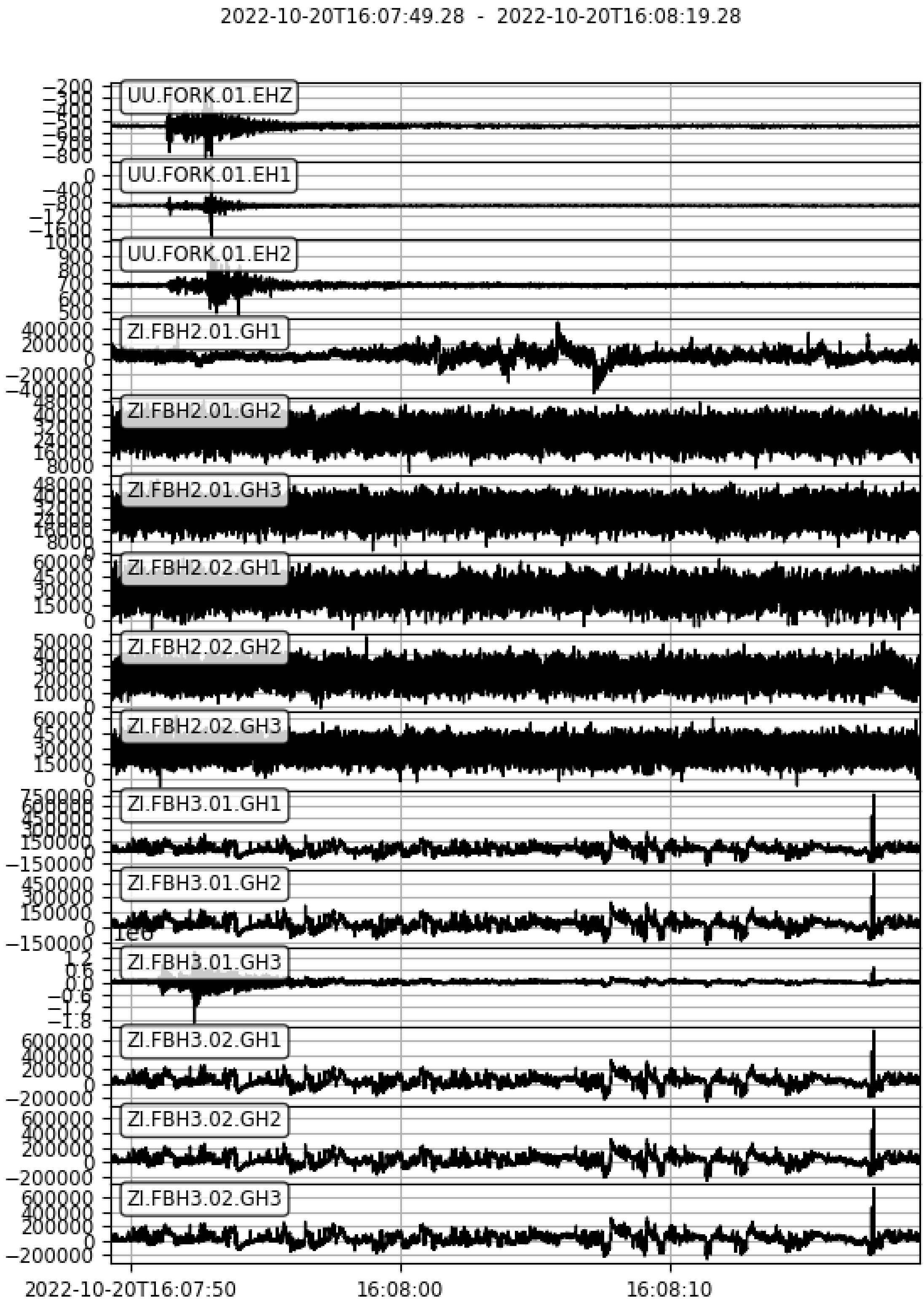
16:41:00


2022-10-20T16:07:49.28 - 2022-10-20T16:08:19.28
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UU.FORK.01.EH2
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ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
1e6
ZI.FBH3.01.GH3
ZI.FBH3.02.GH1
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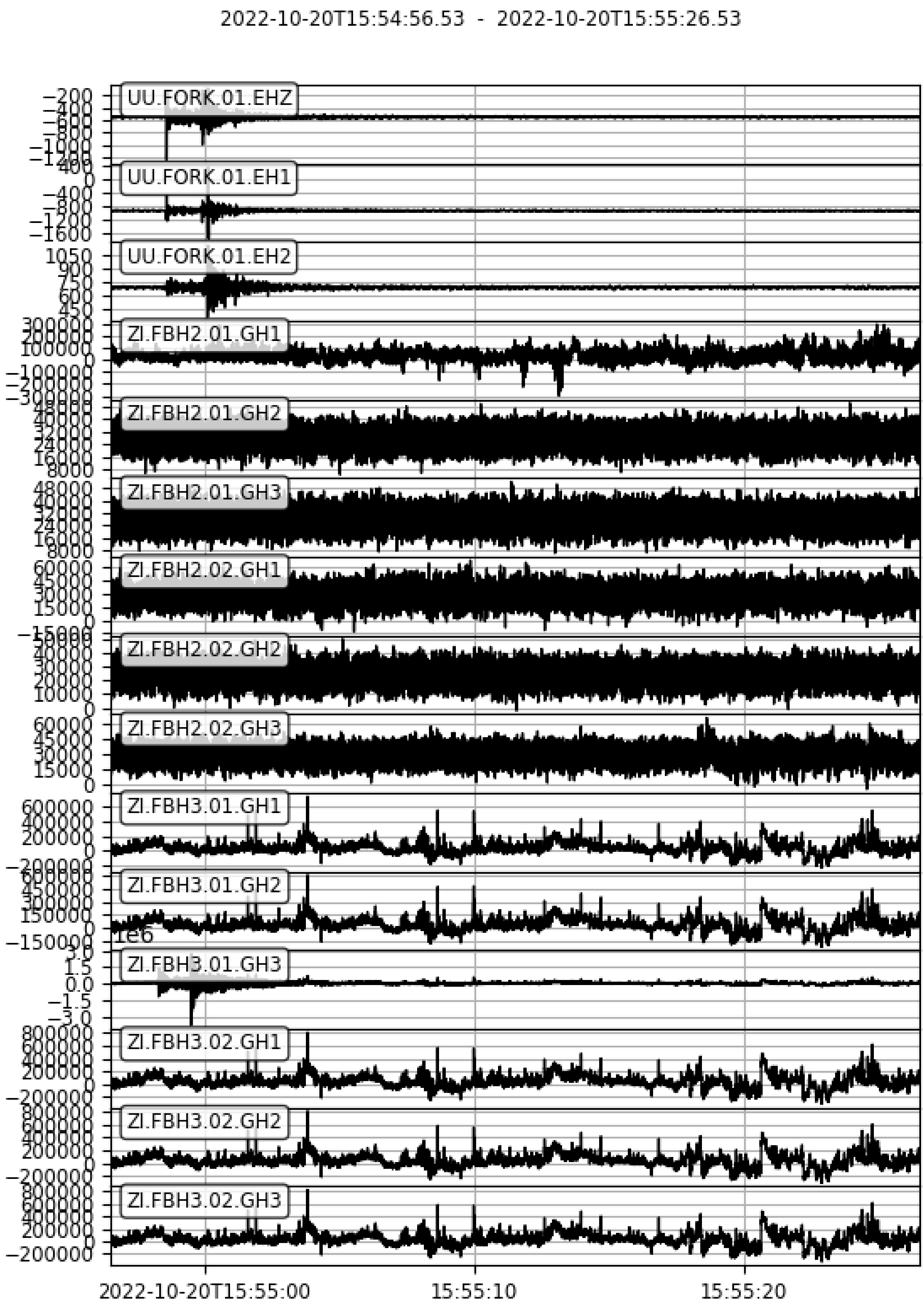
ZI.FBH3.02.GH3
2022-10-20T16:07:50
16:08:00
16:08:10



2022-10-20T15:54:56.53 - 2022-10-20T15:55:26.53
UU.FORK.01.EHZ
UU.FORK.01.EH1
UU.FORK.01.EH2
ZI.FBH2.01.GH1
ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
ZI.FBH3.01.GH3
ZI.FBH3.02.GH1
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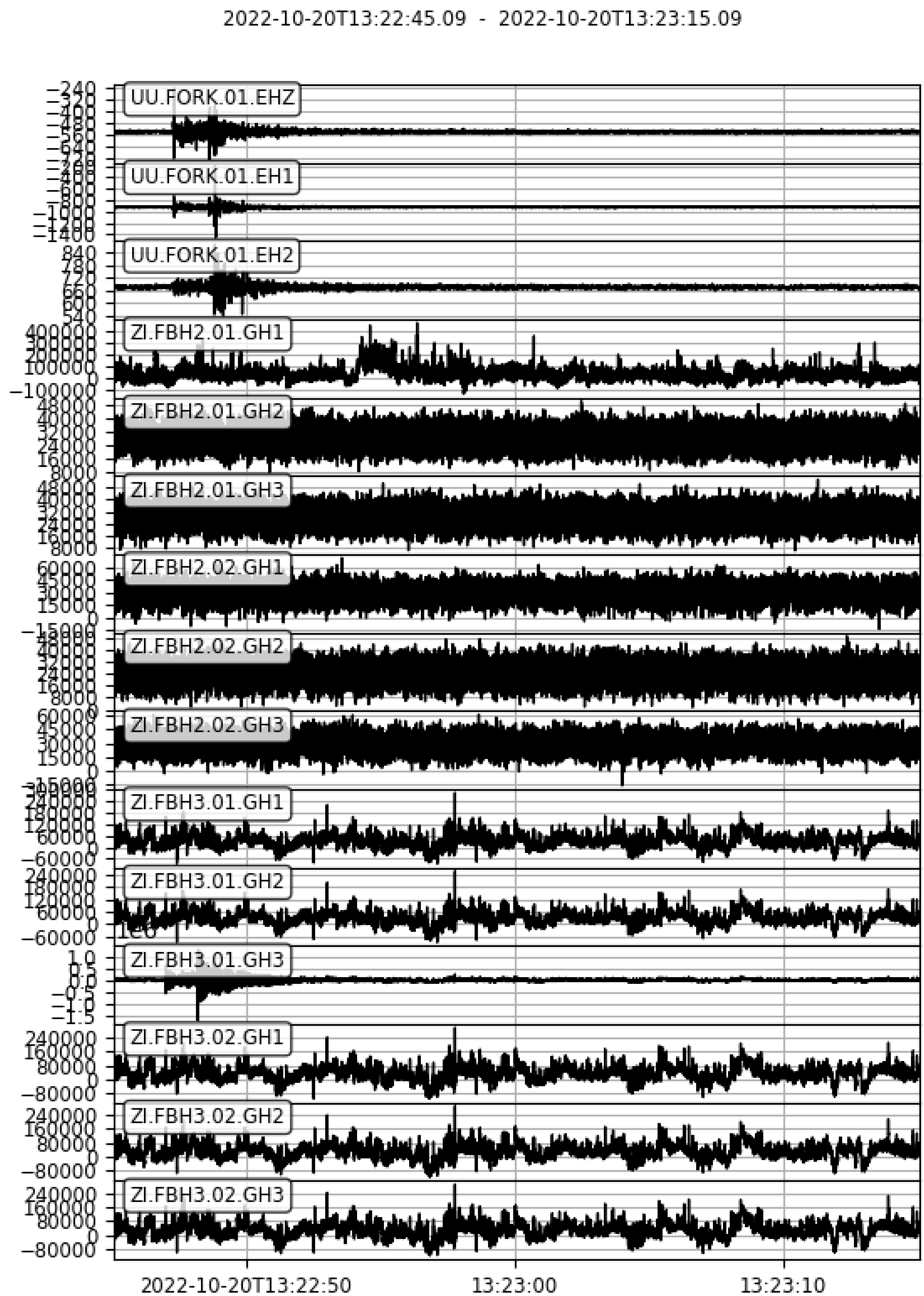
15:55:10
15:55:20



2022-10-20T13:22:45.09 - 2022-10-20T13:23:15.09
UU.FORK.01.EHZ
UU.FORK.01.EH1
UU.FORK.01.EH2
ZI.FBH2.01.GH1
ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
ZI.FBH3.01.GH3
ZI.FBH3.02.GH1
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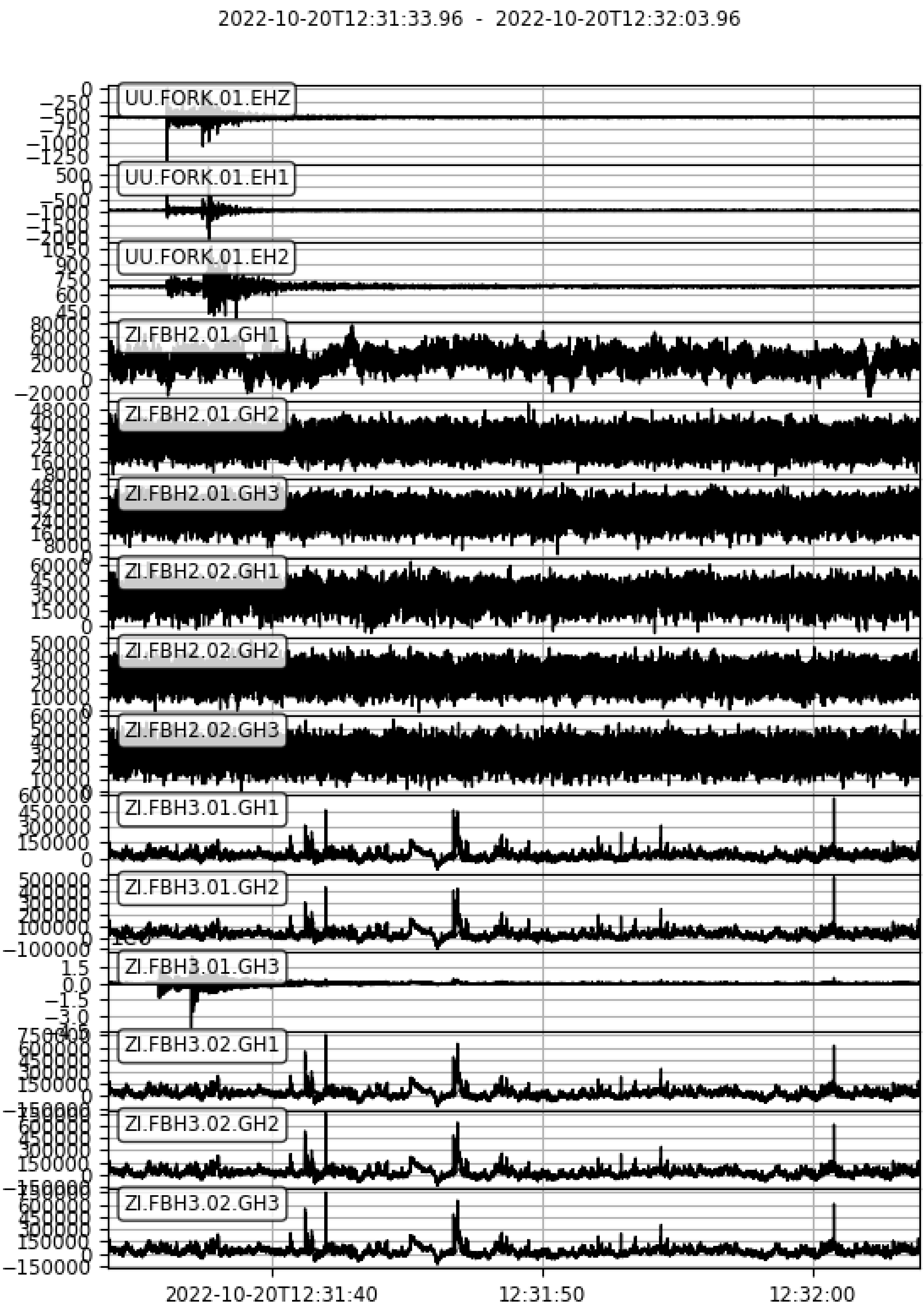
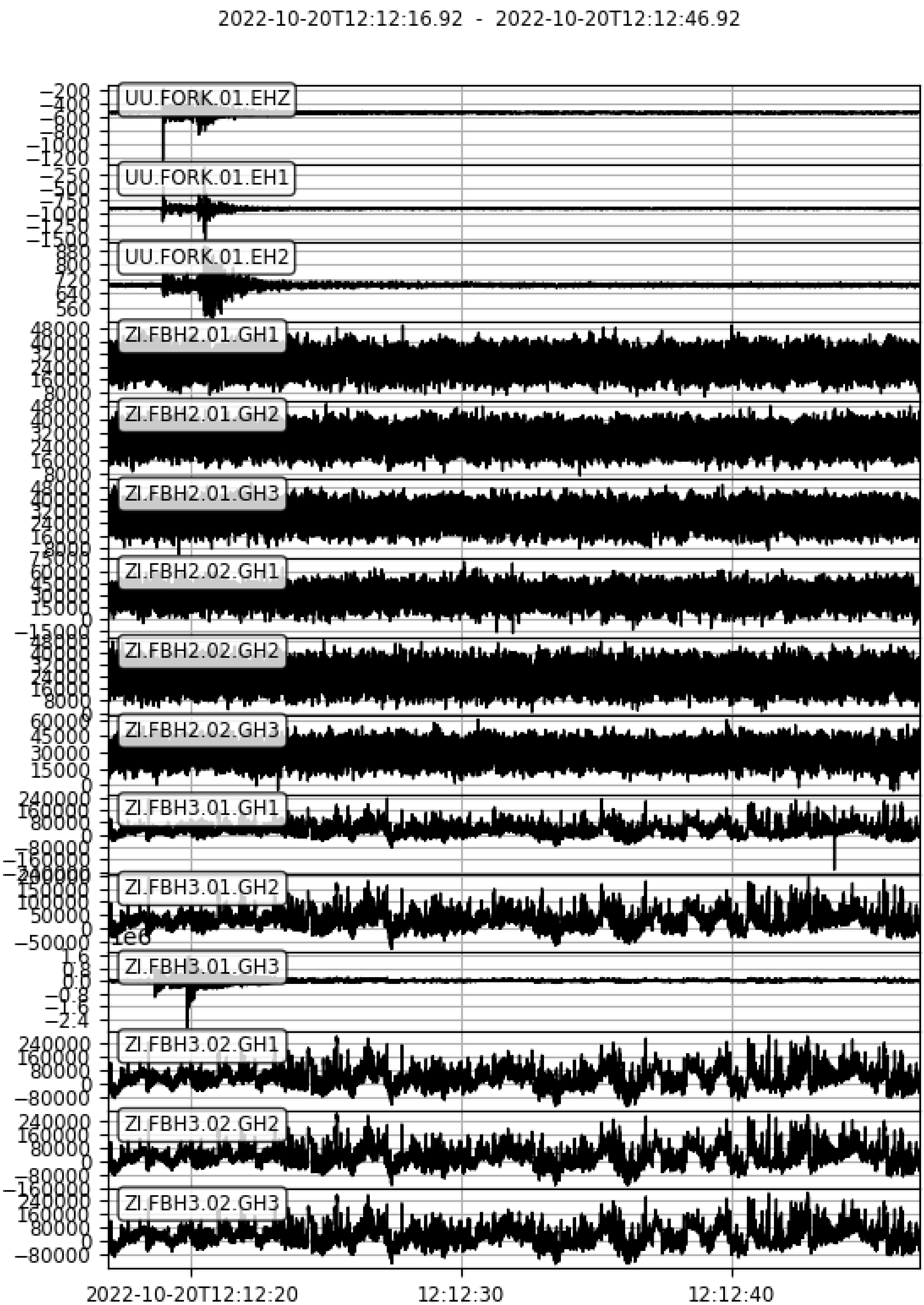
13:23:00
13:23:10


2022-10-20T12:31:33.96 - 2022-10-20T12:32:03.96
UU.FORK.01.EHZ
UU.FORK.01.EH1
UU.FORK.01.EH2
ZI.FBH2.01.GH1
ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
ZI.FBH3.01.GH3
ZI.FBH3.02.GH1
ZI.FBH3.02.GH2
ZI.FBH3.02.GH3
2022-10-20T12:31:40
12:31:50
12:32:00



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UU.FORK.01.EH2
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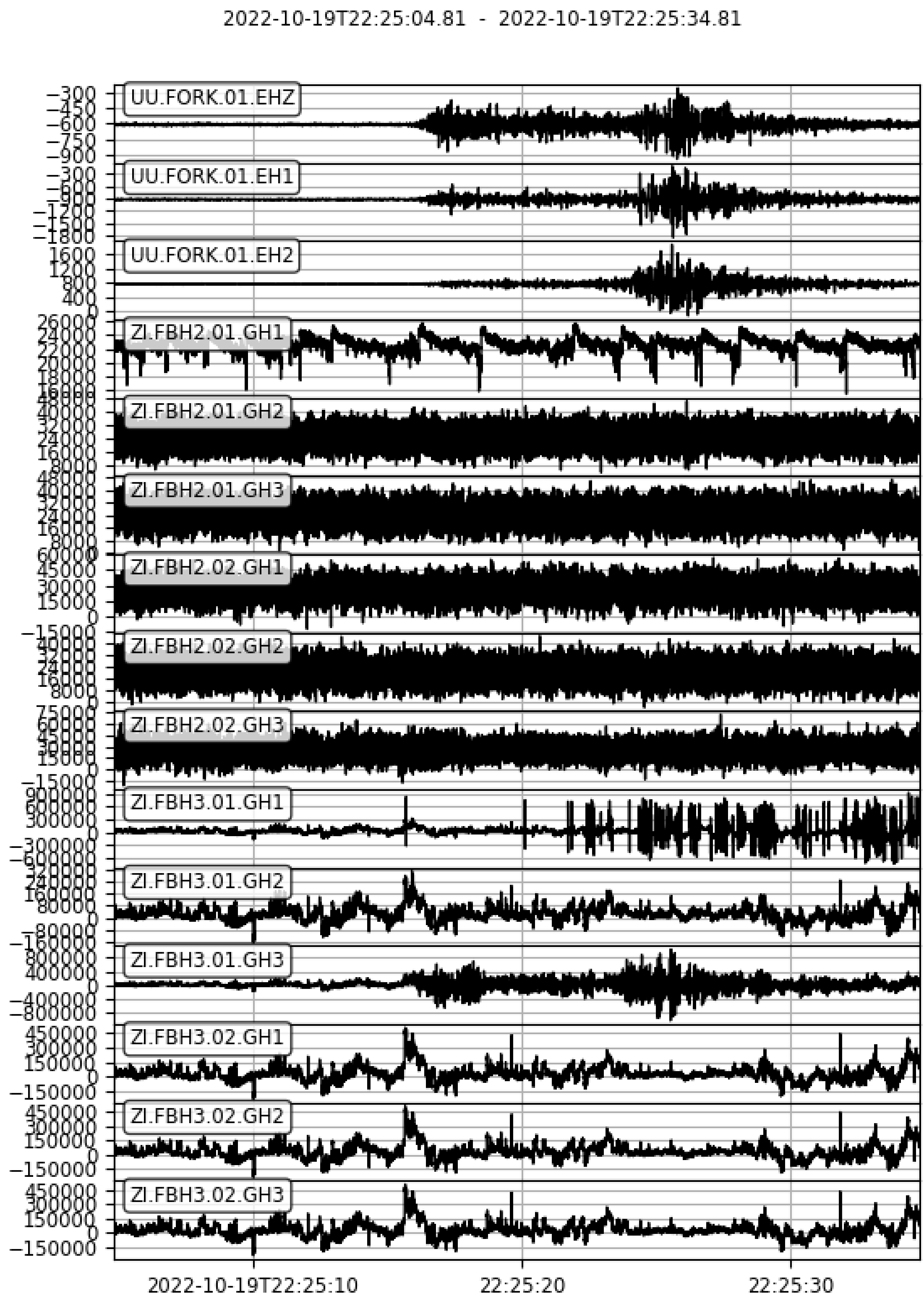
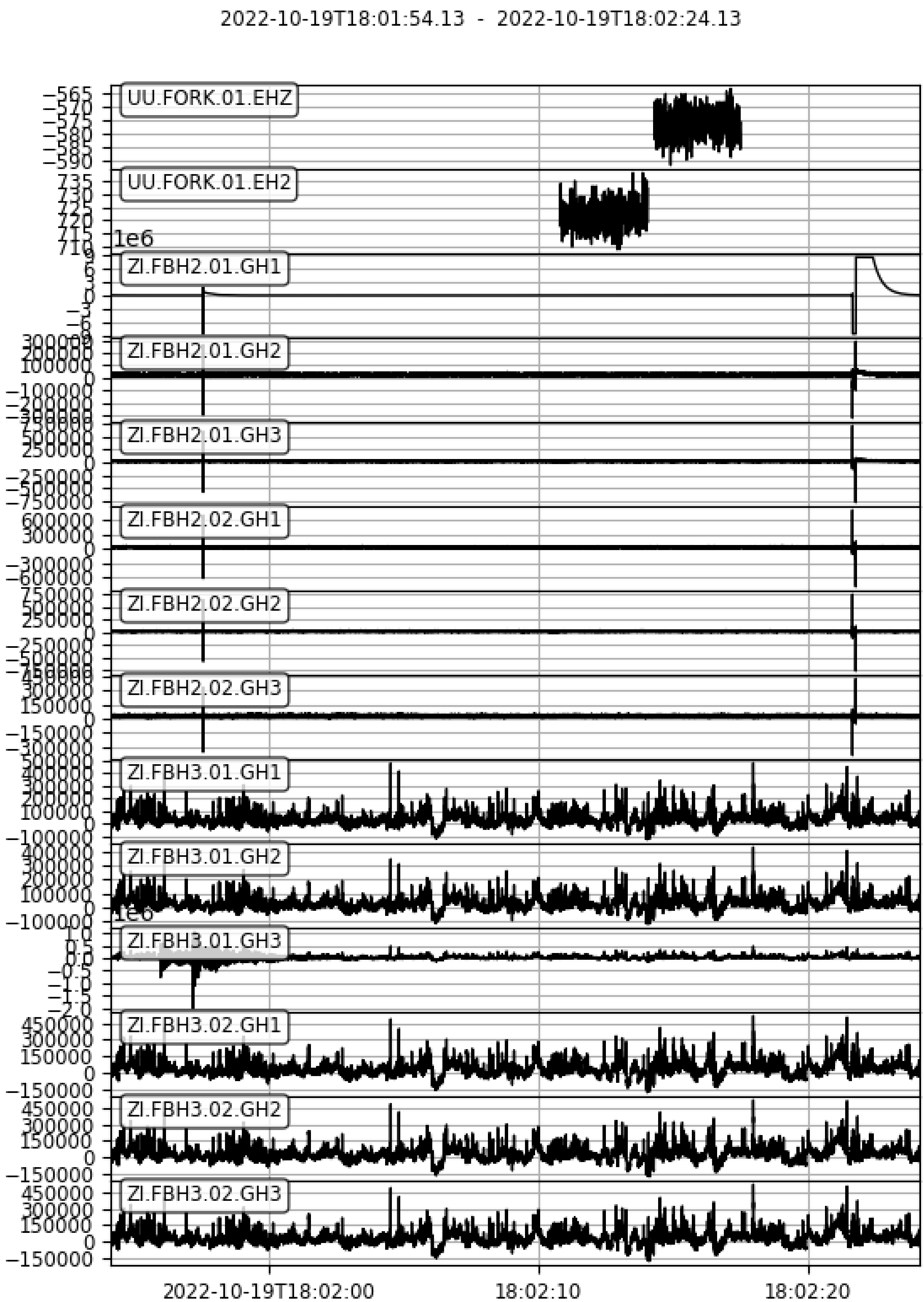
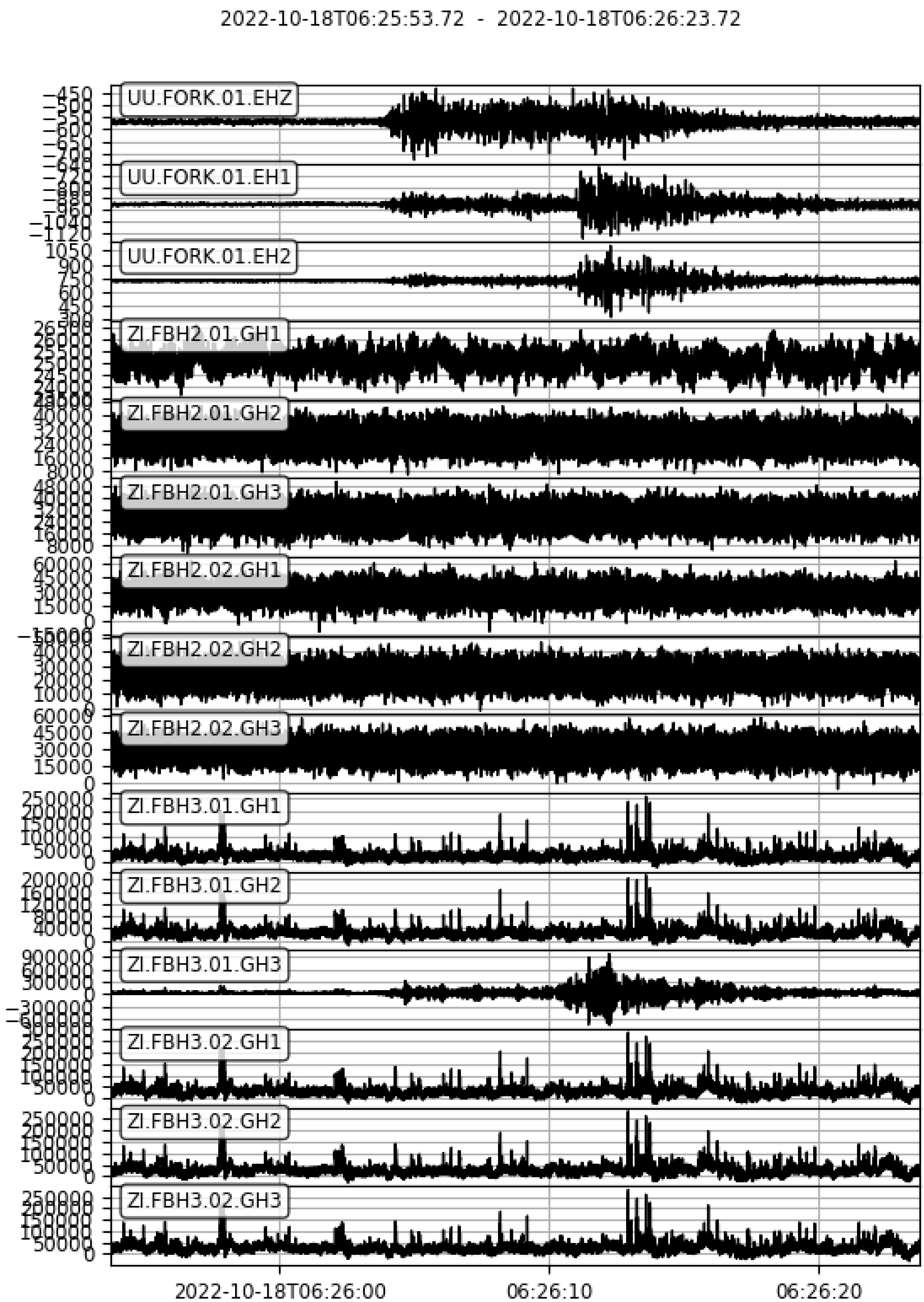
ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
ZI.FBH3.01.GH3
ZI.FBH3.02.GH1
ZI.FBH3.02.GH2
ZI.FBH3.02.GH3
1e6
2022-10-20T12:12:20
12:12:30
12:12:40



2022-10-19T22:25:04.81 - 2022-10-19T22:25:34.81
UU.FORK.01.EHZ
UU.FORK.01.EH1
UU.FORK.01.EH2
ZI.FBH2.01.GH1
ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
ZI.FBH3.01.GH3
ZI.FBH3.02.GH1
ZI.FBH3.02.GH2
ZI.FBH3.02.GH3
2022-10-19T22:25:10
22:25:20
22:25:30


2022-10-19T18:01:54.13 - 2022-10-19T18:02:24.13
UU.FORK.01.EHZ
UU.FORK.01.EH2
ZI.FBH2.01.GH1
ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
ZI.FBH3.01.GH3
ZI.FBH3.02.GH1
ZI.FBH3.02.GH2
ZI.FBH3.02.GH3
2022-10-19T18:02:00
18:02:10
18:02:20


2022-10-18T06:25:53.72 - 2022-10-18T06:26:23.72
UU.FORK.01.EHZ
UU.FORK.01.EH1
UU.FORK.01.EH2
ZI.FBH2.01.GH1
ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
ZI.FBH3.01.GH3
ZI.FBH3.02.GH1
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ZI.FBH3.02.GH3
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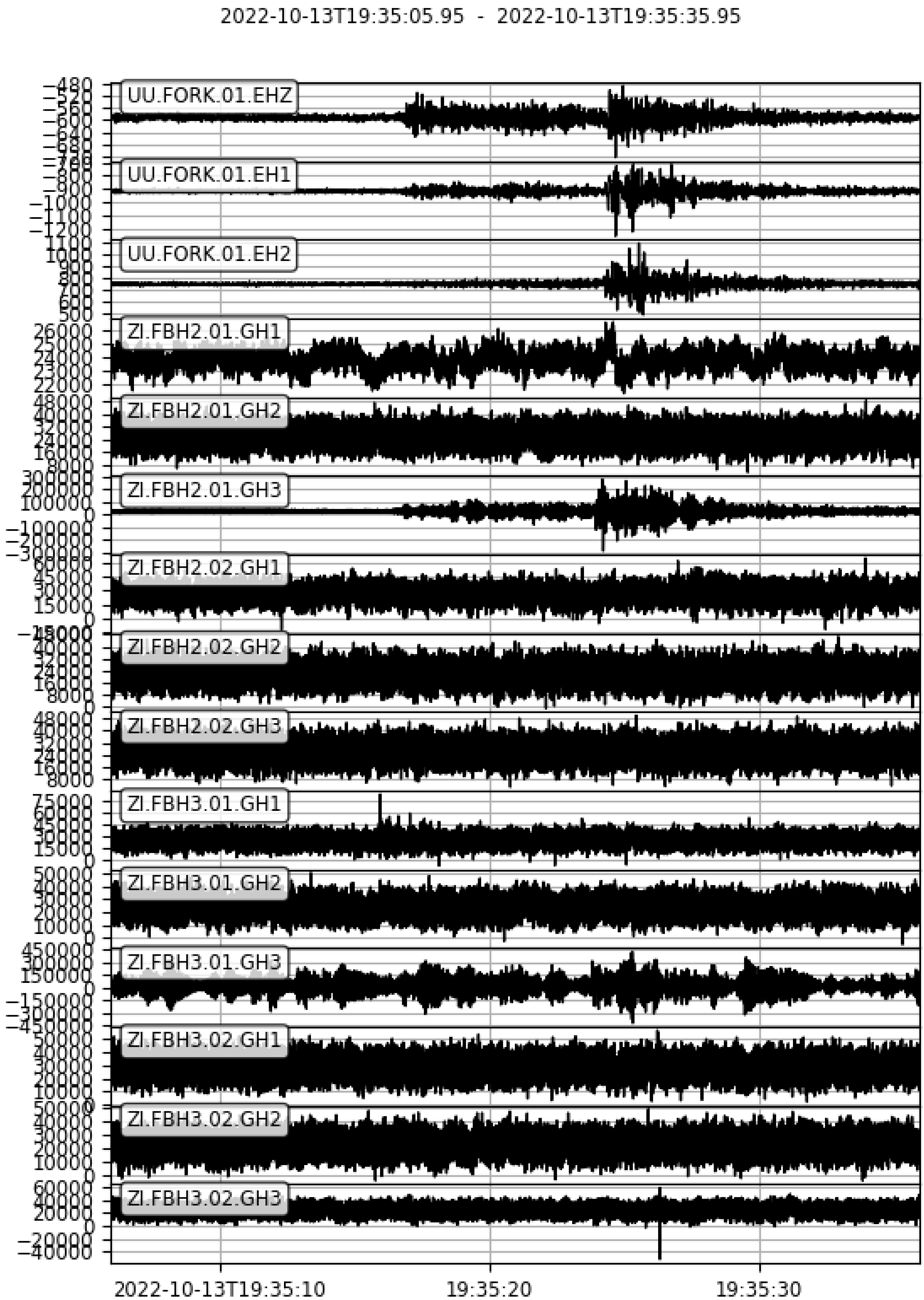
06:26:10
06:26:20


2022-10-13T19:35:05.95 - 2022-10-13T19:35:35.95
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UU.FORK.01.EH2
ZI.FBH2.01.GH1
ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
ZI.FBH3.01.GH3
ZI.FBH3.02.GH1
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ZI.FBH3.02.GH3
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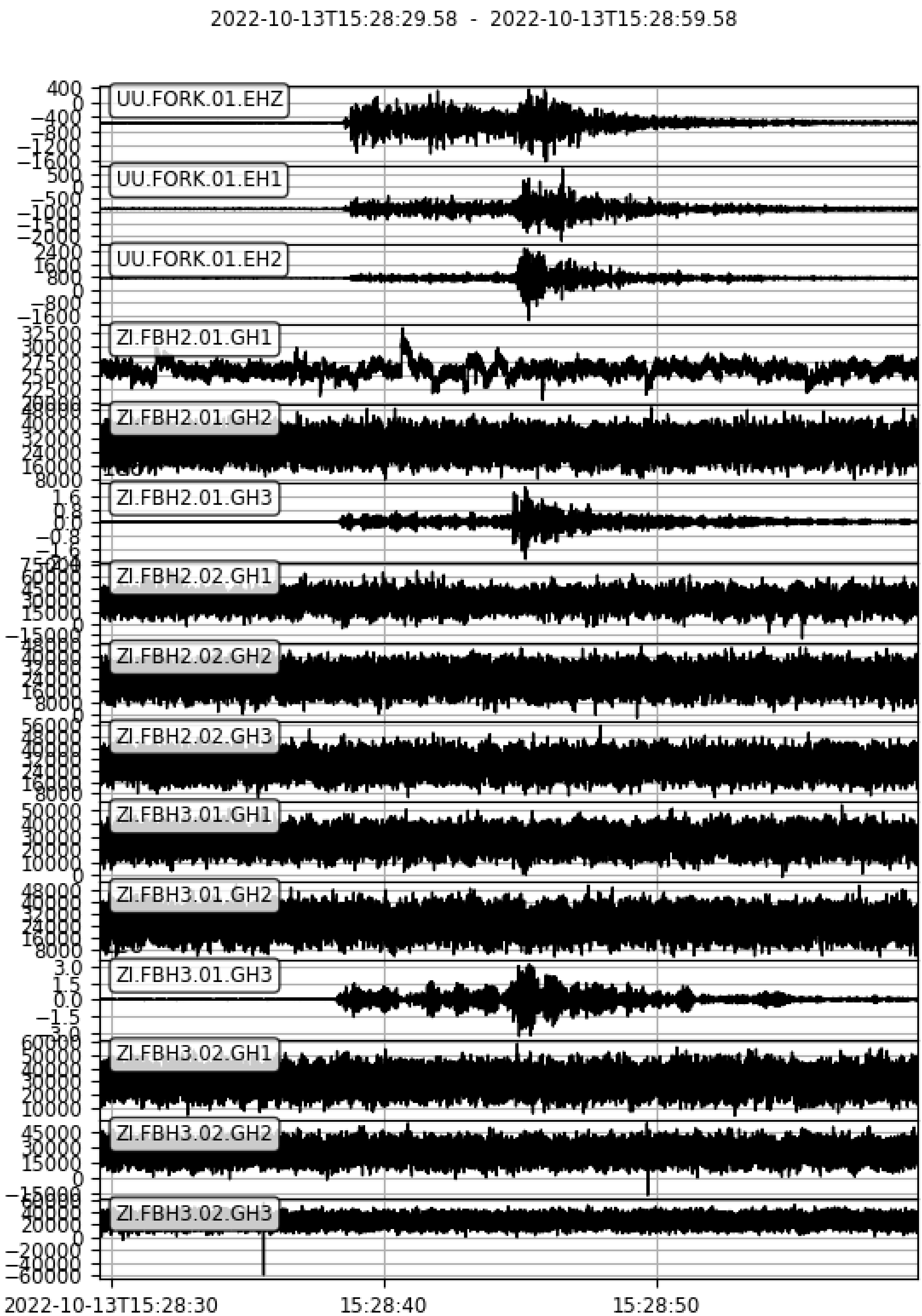
19:35:20
19:35:30


2022-10-13T15:28:29.58 - 2022-10-13T15:28:59.58
UU.FORK.01.EHZ
UU.FORK.01.EH1
UU.FORK.01.EH2
ZI.FBH2.01.GH1
ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
ZI.FBH3.01.GH3
ZI.FBH3.02.GH1
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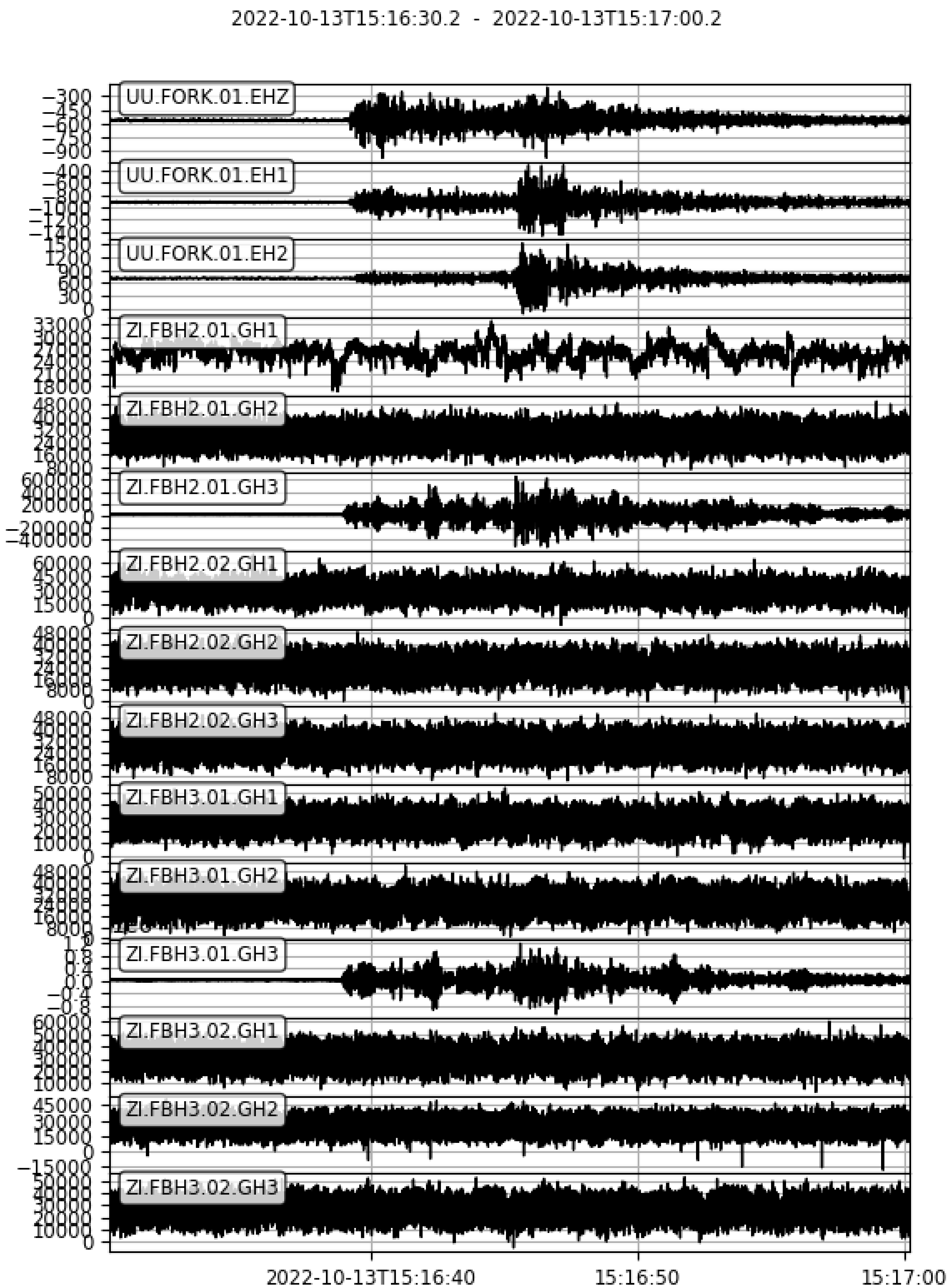
ZI.FBH3.02.GH3
2022-10-13T15:28:30
15:28:40
15:28:50


2022-10-13T15:16:30.2 - 2022-10-13T15:17:00.2
UU.FORK.01.EHZ
UU.FORK.01.EH1
UU.FORK.01.EH2
ZI.FBH2.01.GH1
ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
ZI.FBH3.01.GH3
ZI.FBH3.02.GH1
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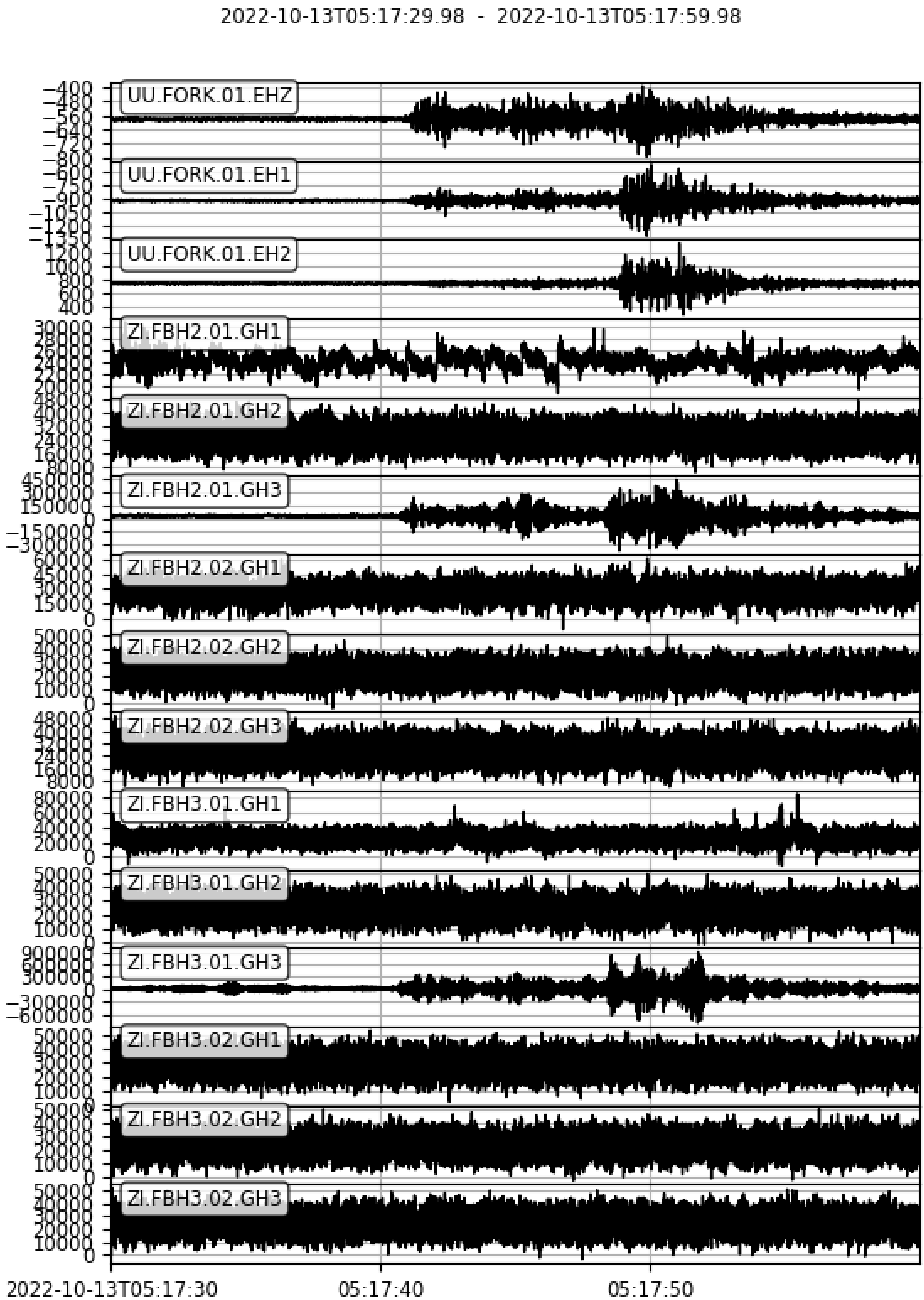
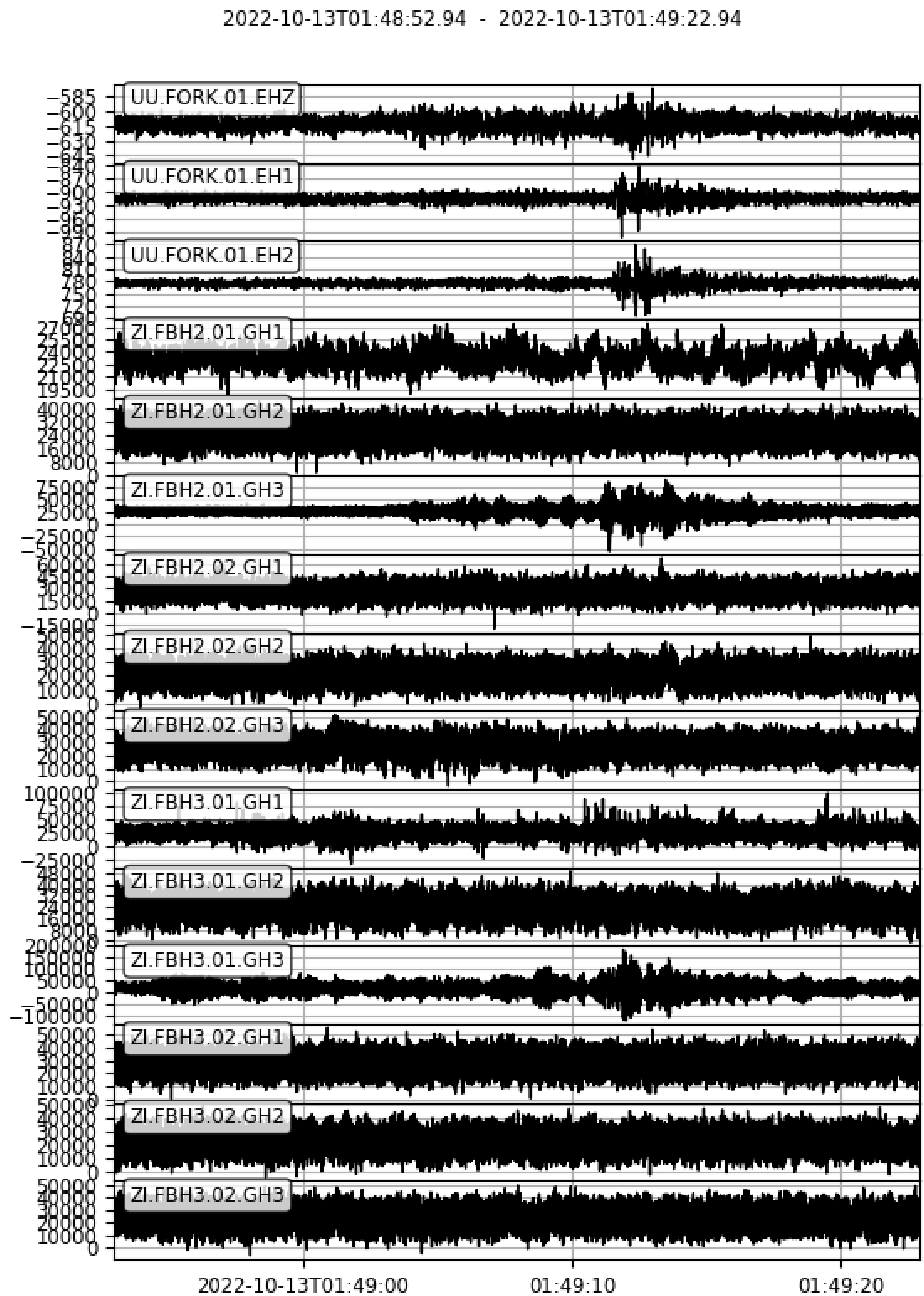
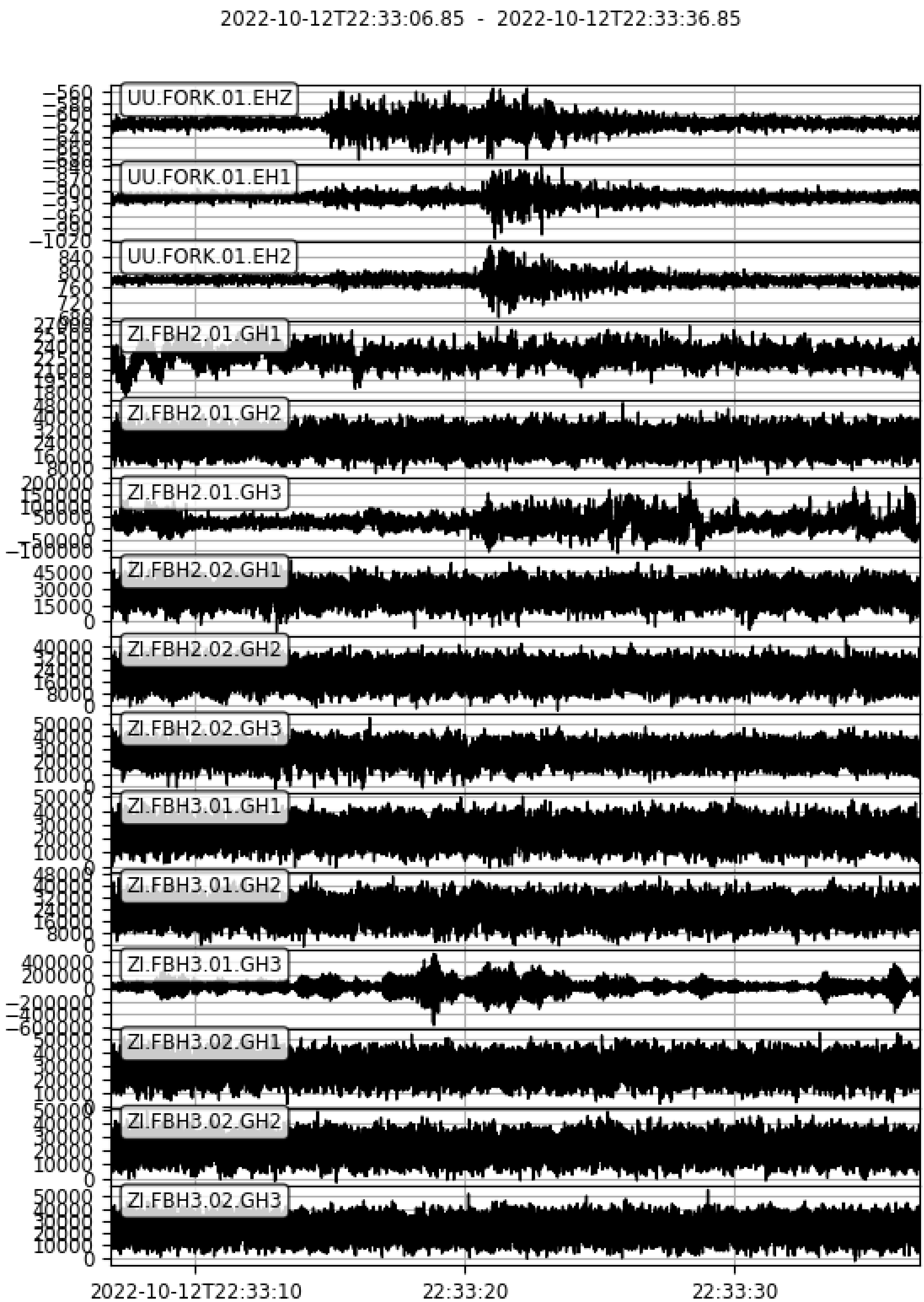
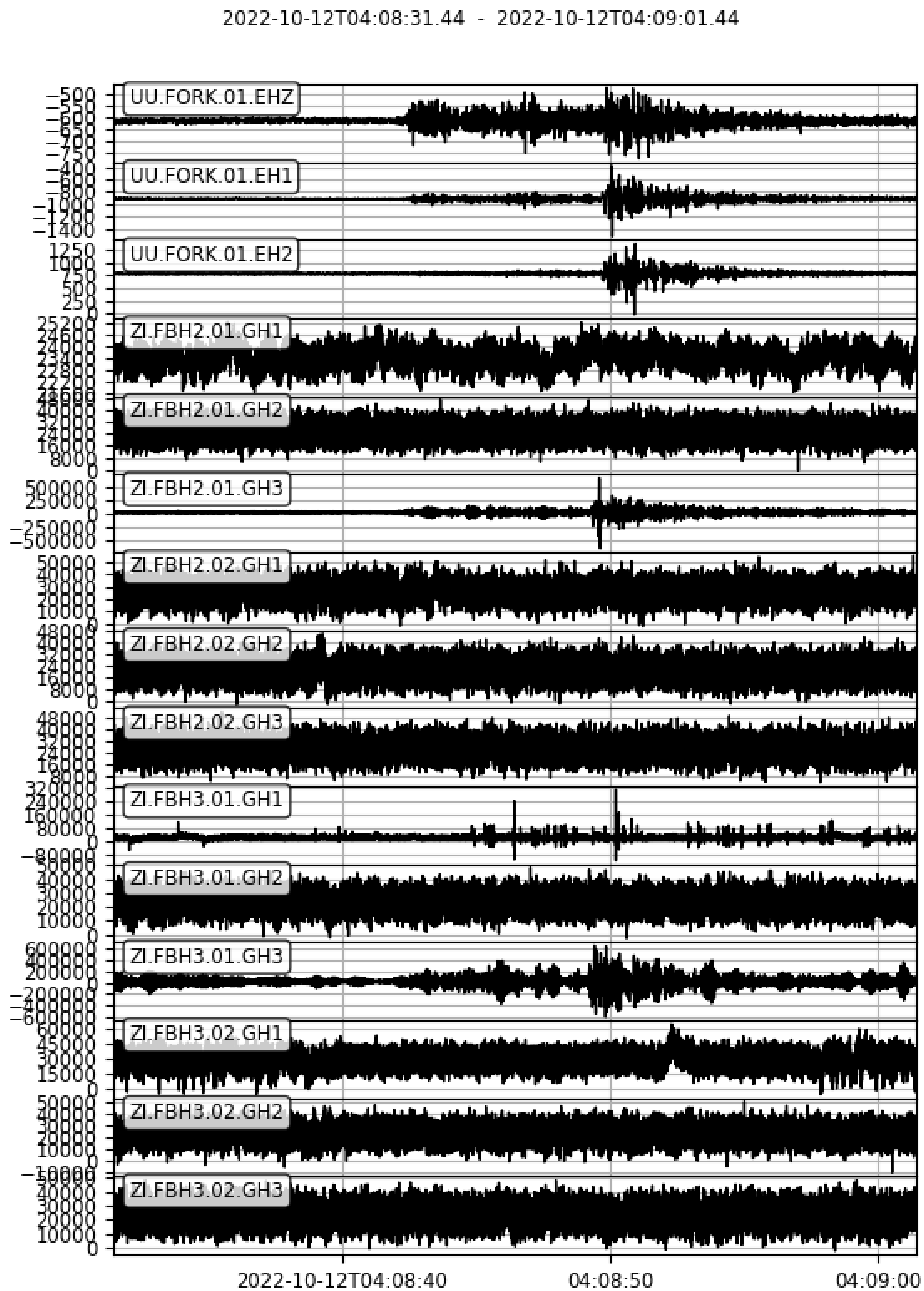
15:17:00


2022-10-13T05:17:29.98 - 2022-10-13T05:17:59.98
UU.FORK.01.EHZ
UU.FORK.01.EH1
UU.FORK.01.EH2
ZI.FBH2.01.GH1
ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
ZI.FBH3.01.GH3
ZI.FBH3.02.GH1
ZI.FBH3.02.GH2
ZI.FBH3.02.GH3
2022-10-13T05:17:30
05:17:40
05:17:50


2022-10-13T01:48:52.94 - 2022-10-13T01:49:22.94
UU.FORK.01.EHZ
UU.FORK.01.EH1
UU.FORK.01.EH2
ZI.FBH2.01.GH1
ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
ZI.FBH3.01.GH3
ZI.FBH3.02.GH1
ZI.FBH3.02.GH2
ZI.FBH3.02.GH3
2022-10-13T01:49:00
01:49:10
01:49:20


2022-10-12T22:33:06.85 - 2022-10-12T22:33:36.85
UU.FORK.01.EHZ
UU.FORK.01.EH1
UU.FORK.01.EH2
ZI.FBH2.01.GH1
ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
ZI.FBH3.01.GH3
ZI.FBH3.02.GH1
ZI.FBH3.02.GH2
ZI.FBH3.02.GH3
2022-10-12T22:33:10
22:33:20
22:33:30


2022-10-12T04:08:31.44 - 2022-10-12T04:09:01.44
UU.FORK.01.EHZ
UU.FORK.01.EH1
UU.FORK.01.EH2
ZI.FBH2.01.GH1
ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
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ZI.FBH3.02.GH1
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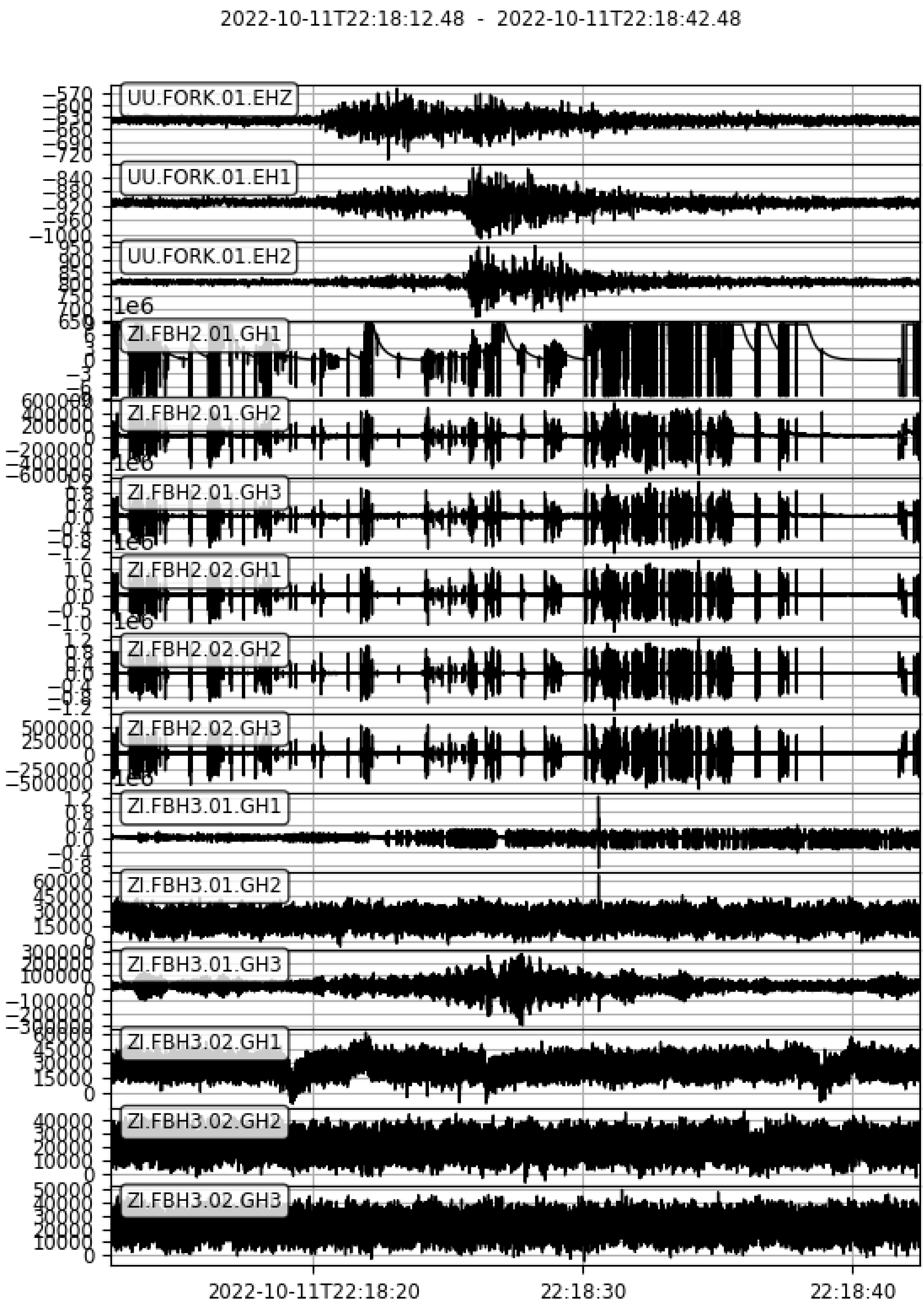
ZI.FBH3.02.GH3
2022-10-12T04:08:40
04:08:50
04:09:00


2022-10-11T22:18:12.48 - 2022-10-11T22:18:42.48
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UU.FORK.01.EH2
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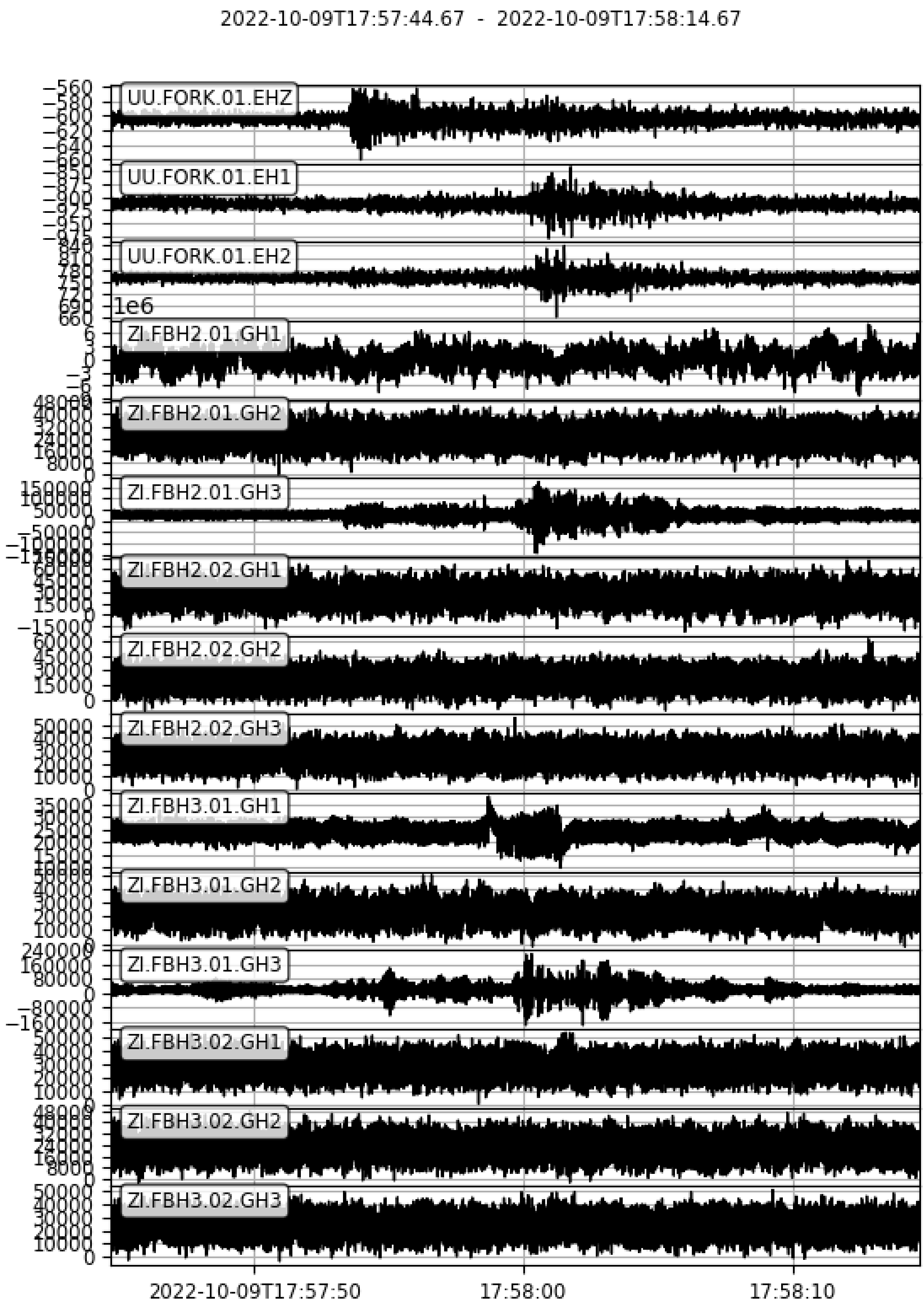
ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
ZI.FBH3.01.GH3
ZI.FBH3.02.GH1
ZI.FBH3.02.GH2
ZI.FBH3.02.GH3
2022-10-11T22:18:20
22:18:30
22:18:40


2022-10-09T17:57:44.67 - 2022-10-09T17:58:14.67
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UU.FORK.01.EH2
1e6
ZI.FBH2.01.GH1
ZI.FBH2.01.GH2
ZI.FBH2.01.GH3
ZI.FBH2.02.GH1
ZI.FBH2.02.GH2
ZI.FBH2.02.GH3
ZI.FBH3.01.GH1
ZI.FBH3.01.GH2
ZI.FBH3.01.GH3
ZI.FBH3.02.GH1
ZI.FBH3.02.GH2
ZI.FBH3.02.GH3
2022-10-09T17:57:50
17:58:00
17:58:10

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