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Bundesamt für Landestopografie swisstopo swisstopo
Landesgeologie

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Technical Review

2D seismic data light: Project Haute-Sorne

Table of Content

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1 Abstract

The raw (unprocessed) and processed 2D seismic data from Haute-Sorne (Canton Jura, Switzerland) recorded in 2023 has been reviewed. The review contains three parts: 1) Display of shot gathers and data integrity (textual and trace headers); 2) Quality Control of the seismic data using Kingdom Suite Software 2024 to check data integrity and geometry, and display data for data screening; 3) quality control using customized python scripts to screen the data for coherency and perform some statistics. The aim of this review is to ensure that the delivered seismic data meets minimum quality standards for subsequent interpretation. Key findings indicate that Line 02 exhibits significantly better quality than Line 01.

2 Overview

The geophysical reflection seismic survey was carried out between Glovelier and Bassecourt, municipality of Haute-Sorne (Switzerland) in July 2023 by GeoExpert AG on behalf of Geo-Energie Jura SA and contains two 2D seismic lines, here referred to as "light 2D seismic survey" to separate it from a large scale 2D seismic survey acquired in 2024.

The acquisition, processing and reporting of the light 2D data were conducted by GeoExpert AG. The acquisition and processing of light 2D seismic dataset was intended to enable Geo-Energie Jura SA to extract structural subsurface information for geothermal purposes.

Two intersecting seismic transects totaling about 3400 m were recorded near the planned site of the geothermal well at Haute-Sorne JU (Switzerland). Line 1 runs North-South (1564 m) and Line 2 East-West (1867 m). Apart from reflection seismic data, refractions were also recorded to perform an inversion and detect velocity inversions. The survey is expected to provide structural information of the subsurface approximately down to the base of the Mesozoic sedimentary sequence.

The main tasks of the survey were:

- Detecting layer discontinuities and delineating faults
- Mapping the geometry of the base Cenozoic and of the Mesozoic reflectors
- Providing a shallow velocity model that can be used for detecting karst or cavities (velocity inversion)

The following general information was extracted from the acquisition report (GeoExpert AG, see acquisition report for more details):

- Number of channels:	320
- Geophone pattern:	single geophones
- Source stations:	?
- Sensor spacing:	2 m
- Shot spacing:	6 m
- Source:	BISON EWG III accelerated weight dropper
- Num of drops per source point:	1 - 3
- Sampling:	0.5 ms
- Recording time:	2048 ms
- Geophone type:	10 Hz
- Coverage/fold.	50 (nominal)
- Field filters:	low cut at 4 Hz; high cut: anti-alias

Date of the survey: 24/07/2023 to 28/07/2023

3 Quality check of the data

The raw and processed data comes from GeoExpert AG. Final products are two 2D stacked seismic sections in segy format, in time and depth-domain as listed below:

- 23Haute-1_stackTime.sgy (22.4 MB)
- 23Haute-1_stackDepth.sgy (24.8 MB)
- 23Haute-1_stackTopo600m.sgy (24.8 MB)
- 23Haute-2_stackTime.sgy (26.6 MB)
- 23Haute-2_stackDepth.sgy (29.5 MB)
- 23Haute-2_stackTopo600m.sgy (29.5 MB)

3.1 General Procedure:

- **Import Raw and Processed Data:**
  - Check SEG-Y headers (text and trace headers) for accuracy and correctness
  - Load the 2D seismic lines into Kingdom Suite for quality control

- **Review performed data processing**
  - Review the processing report & evaluate the processing applied to the data

- **Display seismic lines in time- and depth-domain:**
  - Visually inspect data quality for continuity, amplitude consistency, and noise levels

3.2 Check of SEG-Y headers for correctness

The SEG-Y file information for raw data and processed data in time-domain and in depth-domain was checked.

TEXT HEADER

There is no textual header in the segy-files documenting the processing etc. applied to the data.

SUMMARY INFORMATION RAW DATA

D:\HauteSorne\2D light_HauteSorne\Raw_Edit\2-23Haute-1_edit3.sgy

SEG-Y File

Line 01	Line 02
ASCII Text Header Encoding Big Endian byte order # Traces : 73960 # Trace Samples : 3500 Sample Format : 5 : IEEE Float(32 bit) Sample Interval (uS) : 500 Time Length : 1749.5 --- Header First trace Last trace SP 101 624 CDP 202 1522 FFID 1001 1240	ASCII Text Header Encoding Big Endian byte order # Traces : 82240 # Trace Samples : 3600 Sample Format : 5 : IEEE Float(32 bit) Sample Interval (uS) : 500 Time Length : 1799.5 --- Header First trace Last trace SP 101 1003 CDP 202 2063 FFID 1001 1270

SUMMARY INFORMATION PROCESSED DATA

D:\HauteSorne\2D light_HauteSorne\Stack_Results\23Haute-Sorne_P-1

SEG-Y File

Time			**Depth**		
EBCDIC Text Header Encoding			EBCDIC Text Header Encoding		
Big Endian byte order			Big Endian byte order		
# Traces		: 1565	# Traces		: 1565
# Trace Samples		: 3600	# Trace Samples		: 4000
Sample Format		: 1	Sample Format		: 1
		: IBM Float (32 bit)			: IBM Float (32 bit)
Sample Interval (uS)		: 500	Sample Interval (uS)		: 1000
Time Length		: 1799.5	Time Length		: 3999
---			---		
Header	First trace	Last trace	Header	First trace	Last trace
SP	101	883	SP	101	883
CDP	1120534528	1146929152	CDP	1120534528	1146929152
FFID	1001	1194	FFID	1001	1194

The unusually high CDP numbers in the processed data (over 1 billion) appear non-standard and should be verified.

Processing documentation

There are four main steps in the processing sequence as described in the processing report by GeoExpert:

A Data verification and initial preparation
B Filtering and deconvolution
C Velocity analysis and stack
D Time-Depth conversion

For more details, consult the processing report of GeoExpert.

<u>**Missing information:**</u>

Static corrections (velocity field statics) are mentioned only in C and D. Refraction statics (if applied) and residual statics as distinct steps are not mentioned in the processing report.

There is no explicit mention of migration, either time or depth. For accurate imaging and fault delineation, at least **Post-Stack Time Migration (PSTM)** is generally standard in reflection workflows.

The report lacks **quantitative quality control metrics data** such as:

- Stacking fold maps
- Frequency spectra pre/post filtering
- S/N improvement plots
- Refraction residual errors after inversion

3.3 Display of seismic raw data (shot gathers)

The shot gather in Fig. 1 (one shot from line 01) shows clear first arrivals and strong coherent reflections, particularly near the center of the gather, indicating a good signal-to-noise ratio in that zone. Hyperbolic events are well-defined, especially in the central offset range, suggesting proper source-receiver geometry and good subsurface continuity. However, the far-offset traces display decreased amplitude and more noise, which could affect velocity analysis or stacking quality if not addressed during processing. Some trace regularity and low-frequency ground roll are present, especially at near offsets, which may require filtering during processing. Only a selection of shots for both lines was checked. Overall, the data quality appears good with some scope for noise attenuation and amplitude balancing.

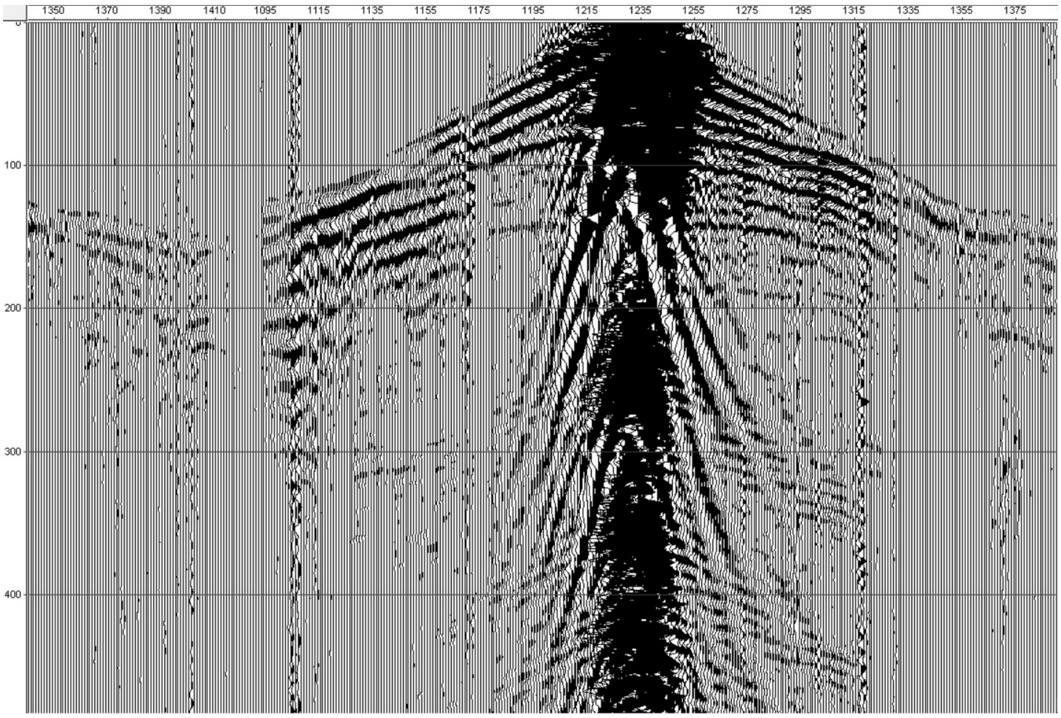

Fig. 1: Overview of a shot gather of line 01. A bandpass filter was applied with 10-20-100-130 Hz.

3.4 Import processed data into Kingdom Suite for Data Screening

Loading the data into Kingdom Suite requires assigning the correct byte numbers to CDP coordinates, including the scaling factor if any was used. For all coordinates, no scaling was used, implying that the accuracy of coordinates is limited to the dimension of meters (Fig. 2). Corresponding byte numbers are shown in Fig. 2.

Trace#	FFID	SP	SRCX	SRCY	GRPX	GRPY	CDP-X	CDP-Y
1	1001	101	2583631	1241759	2583630	1241758	2583630	1241759
2	1001	101	2583631	1241759	2583631	1241760	2583631	1241760
3	1001	102	2583631	1241761	2583631	1241760	2583631	1241761
4	1001	102	2583631	1241761	2583631	1241762	2583631	1241762
5	1001	103	2583631	1241761	2583632	1241764	2583632	1241762
6	1001	103	2583632	1241764	2583632	1241763	2583632	1241763
7	1001	104	2583632	1241764	2583632	1241765	2583632	1241764
8	1001	104	2583632	1241764	2583633	1241767	2583632	1241765
9	1001	105	2583633	1241766	2583633	1241766	2583633	1241766
10	1001	105	2583633	1241766	2583633	1241768	2583633	1241767
11	1001	106	2583633	1241766	2583634	1241770	2583633	1241768
12	1001	106	2583634	1241769	2583634	1241769	2583634	1241769
13	1001	107	2583634	1241769	2583634	1241771	2583634	1241770
14	1001	107	2583634	1241769	2583635	1241773	2583634	1241771
15	1001	108	2583635	1241771	2583635	1241772	2583635	1241772
16	1001	108	2583635	1241771	2583635	1241774	2583635	1241773
17	1001	109	2583635	1241771	2583636	1241775	2583635	1241773
18	1001	109	2583635	1241774	2583636	1241775	2583636	1241774
19	1001	110	2583635	1241774	2583636	1241776	2583636	1241775
20	1001	110	2583635	1241774	2583637	1241778	2583636	1241776
21	1001	111	2583636	1241777	2583637	1241777	2583636	1241777
22	1001	111	2583636	1241777	2583637	1241779	2583637	1241778
23	1001	112	2583636	1241777	2583638	1241781	2583637	1241779
24	1001	112	2583637	1241780	2583637	1241780	2583637	1241780
25	1001	113	2583637	1241780	2583638	1241782	2583638	1241781
26	1001	113	2583637	1241780	2583639	1241784	2583638	1241782
27	1001	114	2583637	1241780	2583639	1241786	2583638	1241783
28	1001	114	2583638	1241783	2583639	1241785	2583638	1241784
29	1001	115	2583638	1241783	2583639	1241786	2583639	1241784
30	1001	115	2583639	1241785	2583639	1241785	2583639	1241785
31	1001	116	2583639	1241785	2583640	1241787	2583639	1241786
32	1001	116	2583639	1241785	2583640	1241789	2583640	1241787
33	1001	117	2583640	1241788	2583640	1241788	2583640	1241788
34	1001	117	2583640	1241788	2583640	1241790	2583640	1241789
35	1001	118	2583640	1241788	2583641	1241792	2583640	1241790
36	1001	118	2583641	1241790	2583641	1241791	2583641	1241791
37	1001	119	2583641	1241790	2583641	1241793	2583641	1241792
38	1001	119	2583641	1241790	2583642	1241794	2583641	1241792
39	1001	120	2583641	1241793	2583642	1241793	2583641	1241793

Fig. 2: Overview of coordinates used in segy trace header. There is no multiplier used for the coordinates, which may cause a loss of positioning precision.

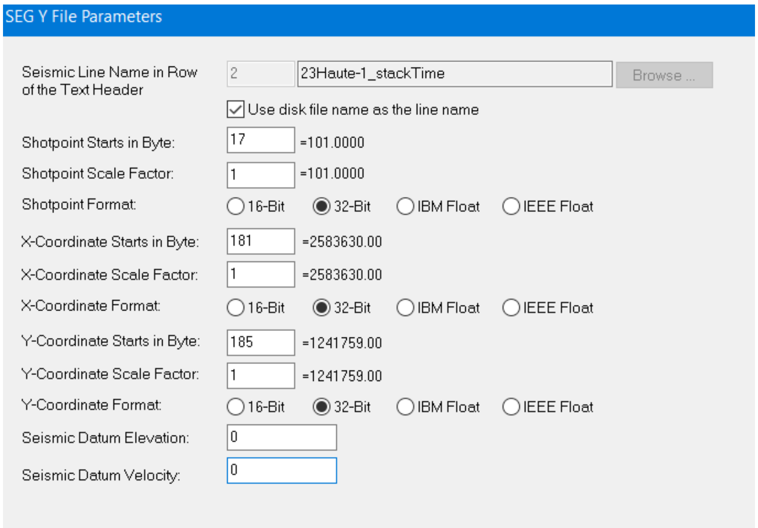

Fig. 3: Overview of loading the data into Kingdom Suite software. Right: overview of CDP coordinates and in-line and crossline numbers.

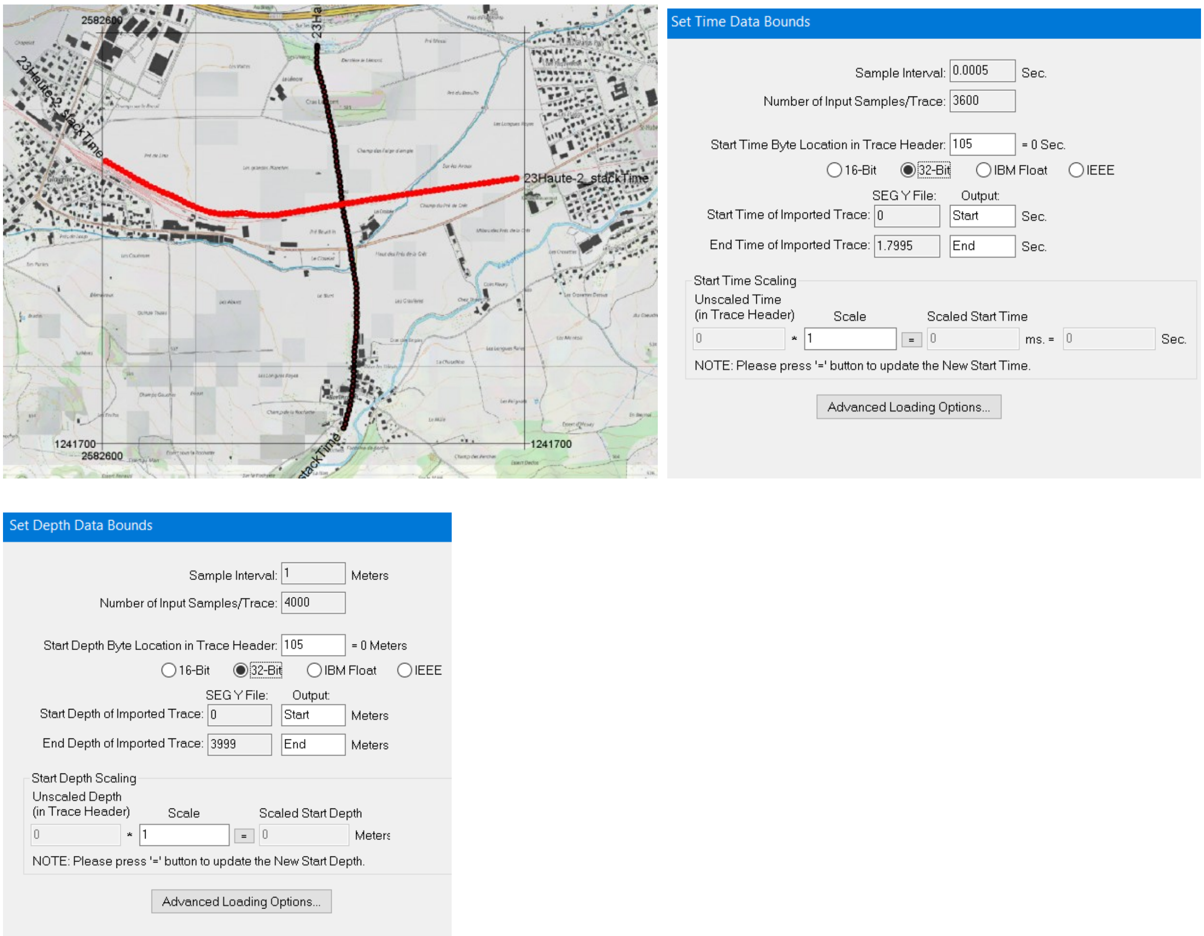

Fig. 4: Overview of loading data into Kingdom Suite software. Top left: Line overview, with every 10th shot symbol shown. Line 1 (black) and Line 2 (red) are shown. Top right: time data bounds and loading parameters. Bottom left: depth data bounds and loading parameters.

The data could be loaded correctly without any issues into the Kingdom Suite software. Used header information is shown in Figs. 3 and 4. All coordinates in the raw and processed data are not multiplied by a factor of 10 or 100. This indicates that the coordinate precision is limited to meters, instead of decimeters or centimeters. Coordinate precision to the nearest meter limits the ability to confidently tie data to surface features or well locations.

3.5 Display of processed 2D seismic lines

After project creation, the seismic lines (Figs. 5 and 6) were displayed. Both sections were checked for any display problems or offset traces. No systematic display error was found. Figure 7 shows the two lines without vertical exaggeration.

South North

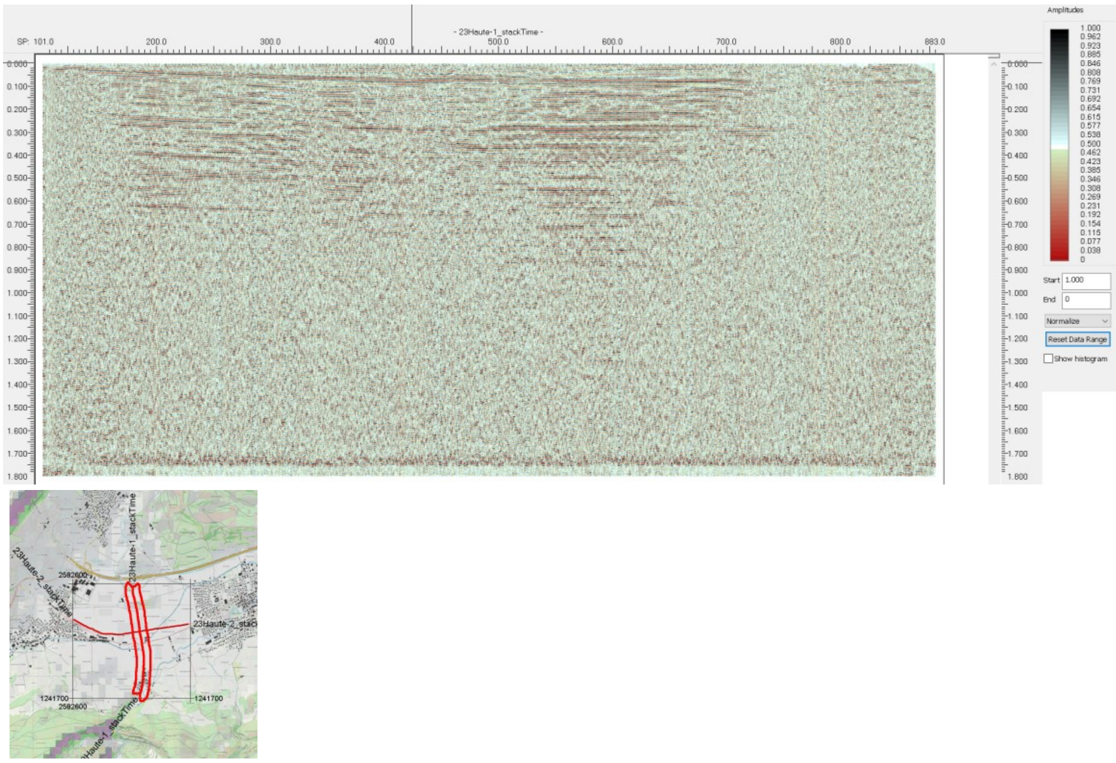

Fig. 5, top: North-South seismic section (Line 01) in time-domain. The image is horizontally stretched for illustration purposes. Bottom: Location of shown seismic section (red rectangle).

West East

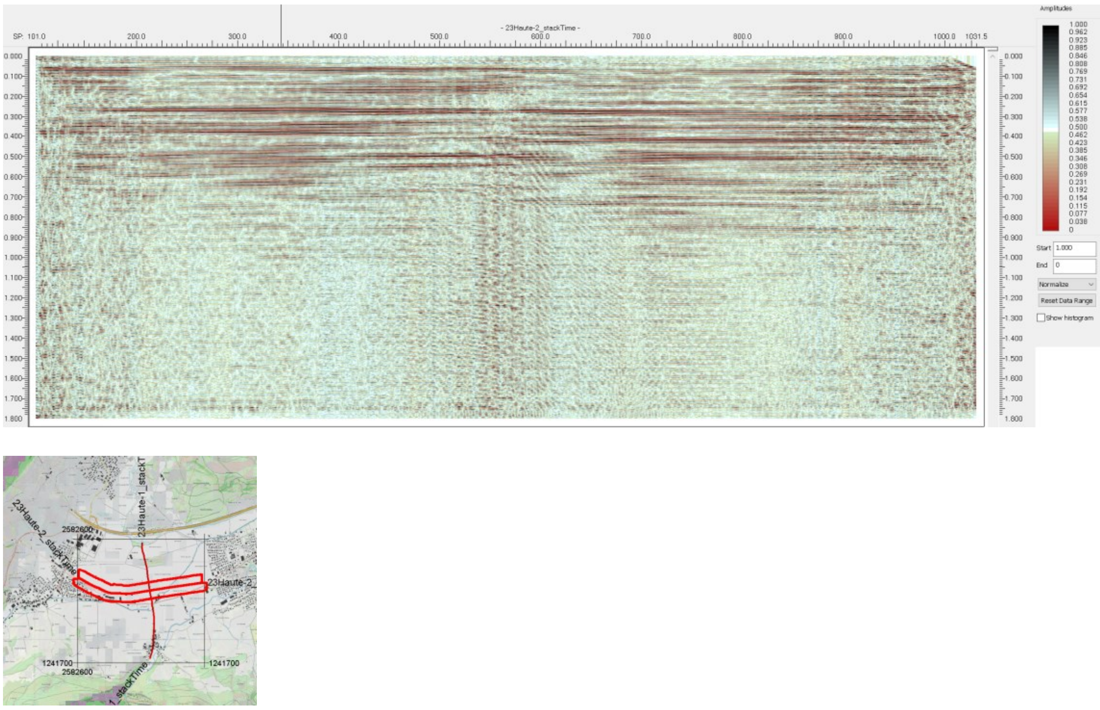

Fig. 6, top: East-West seismic section (Line 02) in time-domain. The image is horizontally stretched for illustration purposes. Bottom: Location of shown seismic section (red rectangle).

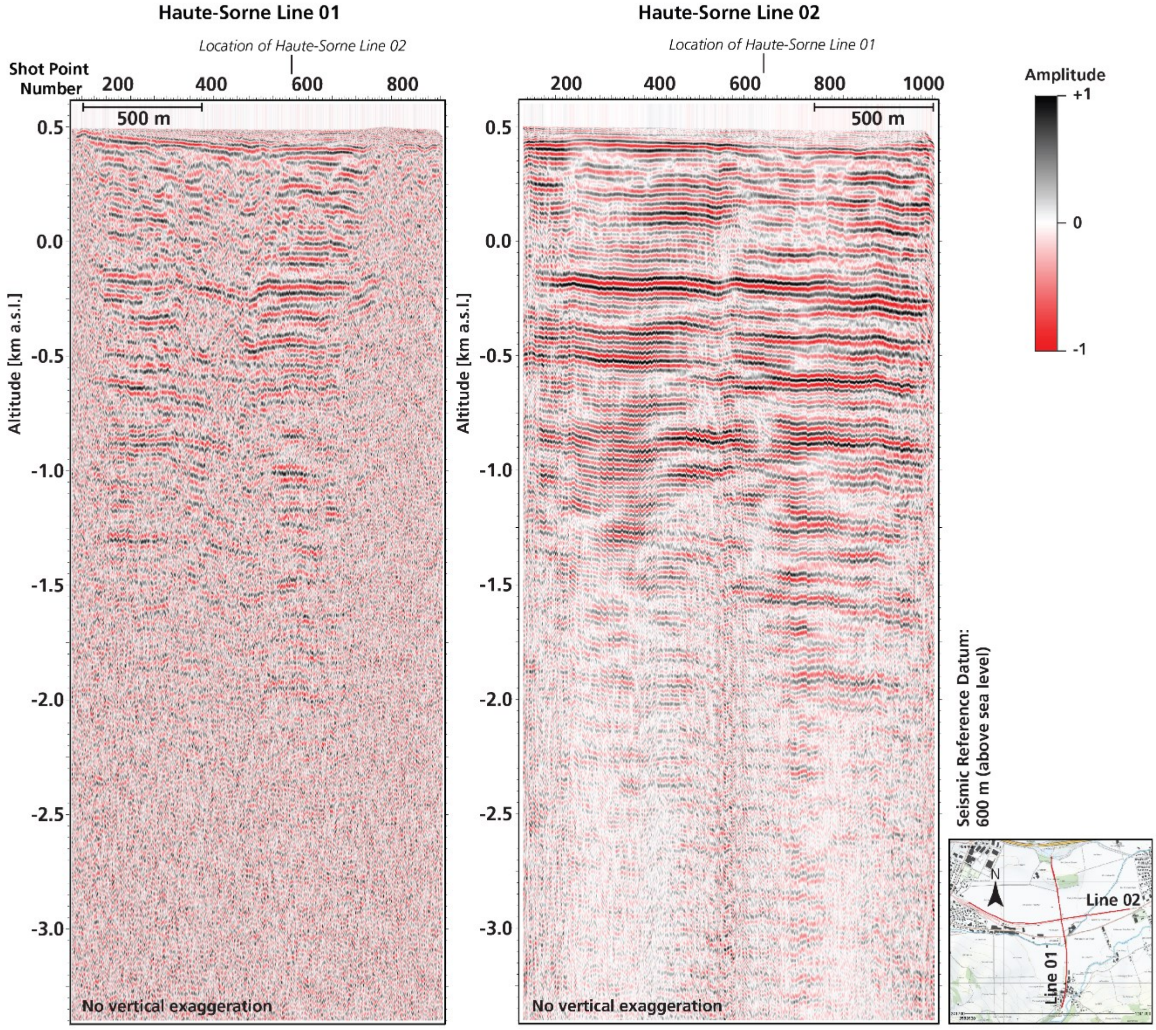

Fig. 7: Overview of both seismic lines with reference datum applied in depth-domain. Images show no vertical exaggeration. The vertical axis shows altitude in kilometers above sea level. Line 1 is 1564 m long. Line 2 is 1867 m long.

4 Spectral Analysis and Statistics

Spectral analysis was performed for both seismic lines (01 and 02) in time-domain. The following analyses were performed using dedicated python scripts:

1. RMS Amplitude per Trace:
This shows the root-mean-square energy of each trace. Uniform RMS suggests stable acquisition and preprocessing, while spikes or dips can indicate noisy or dead traces, gain problems, or processing artifacts. A gradual decay over distance can reflect geometric spreading or absorption.

2. Average Frequency Spectrum:
This plot reveals the dominant frequency content of the dataset. A broad, bell-shaped spectrum peaking around 20–60 Hz is typical for shallow to intermediate-depth reflection data. Sharp roll-offs or irregular patterns can signal issues with filtering or frequency loss.

3. Signal-to-Noise Ratio (S/N) per Trace:
This metric compares energy in a defined signal window (e.g. 0.05–0.5 s) to a noise window (e.g. 1–1.5 s). Higher S/N ratios (e.g. >10 dB) generally indicate good data quality. Low or erratic S/N might point to environmental noise, poor coupling, or near-surface issues.

Quality Control Summary

Line 01 – North–South Line – Figure 8

- **RMS Amplitude:** The overall RMS amplitude remains relatively stable through the central part of the line, with pronounced spikes at both ends, indicating acquisition or processing edge effects. However, the amplitude levels are generally lower compared to Line 02.
- **Frequency Spectrum:** The energy is concentrated between ~10 Hz and ~120 Hz, peaking near 40–50 Hz. While the spectrum looks balanced, it suggests moderate bandwidth suitable for resolving intermediate structural features.
- **S/N Ratio:** The signal-to-noise (S/N) ratio is consistently low across the entire line, fluctuating around 0 dB, with negative values at both ends. This implies that noise levels are nearly equivalent to the signal energy, especially in the near-surface or low-amplitude zones. The line is overall **noisy**, and data quality is **marginal** without further noise suppression or muting.

Given the overall low S/N ratio (<0 dB) across Line 01, its interpretability is limited without further noise reduction processing. Use with caution in structural interpretation.

Line 02 – East–West Line – Figure 9

- **RMS Amplitude:** The RMS amplitude plot shows much stronger and more coherent energy across the central portion of the line, with a smoother variation and predictable increase toward the flanks. This indicates stronger reflections and better signal fidelity.
- **Frequency Spectrum:** Energy is concentrated below ~120 Hz, with clear peaks suggesting strong signal presence, albeit with minor harmonic influence. This may reflect coherent noise (e.g., ground roll or cultural noise) that should be verified.
- **S/N Ratio:** The S/N ratio varies between approximately **0 to +12 dB**, peaking around trace 700–900. This is a clear indication of higher signal fidelity, especially in the central parts of the line. Edge effects are again visible, but the data is much cleaner overall.

Line 02 exhibits sufficient quality for integration into structural mapping workflows with minimal additional processing.

The two 2D seismic lines present notably different quality characteristics. **Line 02** is clearly the better dataset, with high RMS amplitudes, strong frequency content, and an S/N ratio that consistently exceeds +6 dB in the central part. This line is suitable for structural interpretation with minimal additional processing.

Line 01, in contrast, shows **substantially lower signal-to-noise characteristics**, with S/N values often near or below 0 dB. While reflection events may still be interpretable, the high noise level suggests the need for further preprocessing (e.g., noise attenuation, trace editing, or adaptive muting) before confident interpretation is possible.

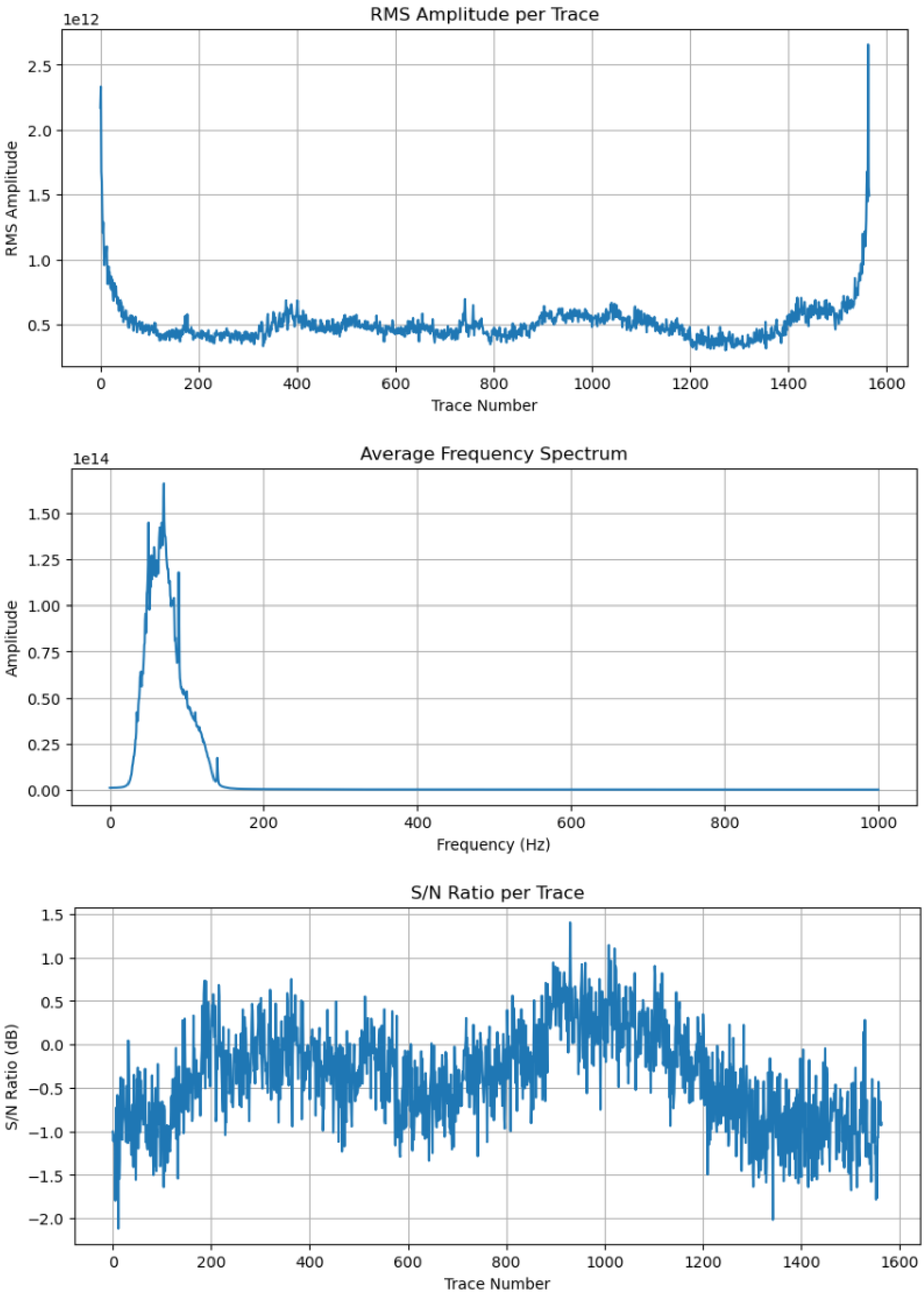

Fig. 8: RMS amplitude (top), frequency spectrum (middle) and S/N ratio (bottom) for seismic line 01 (North-South).

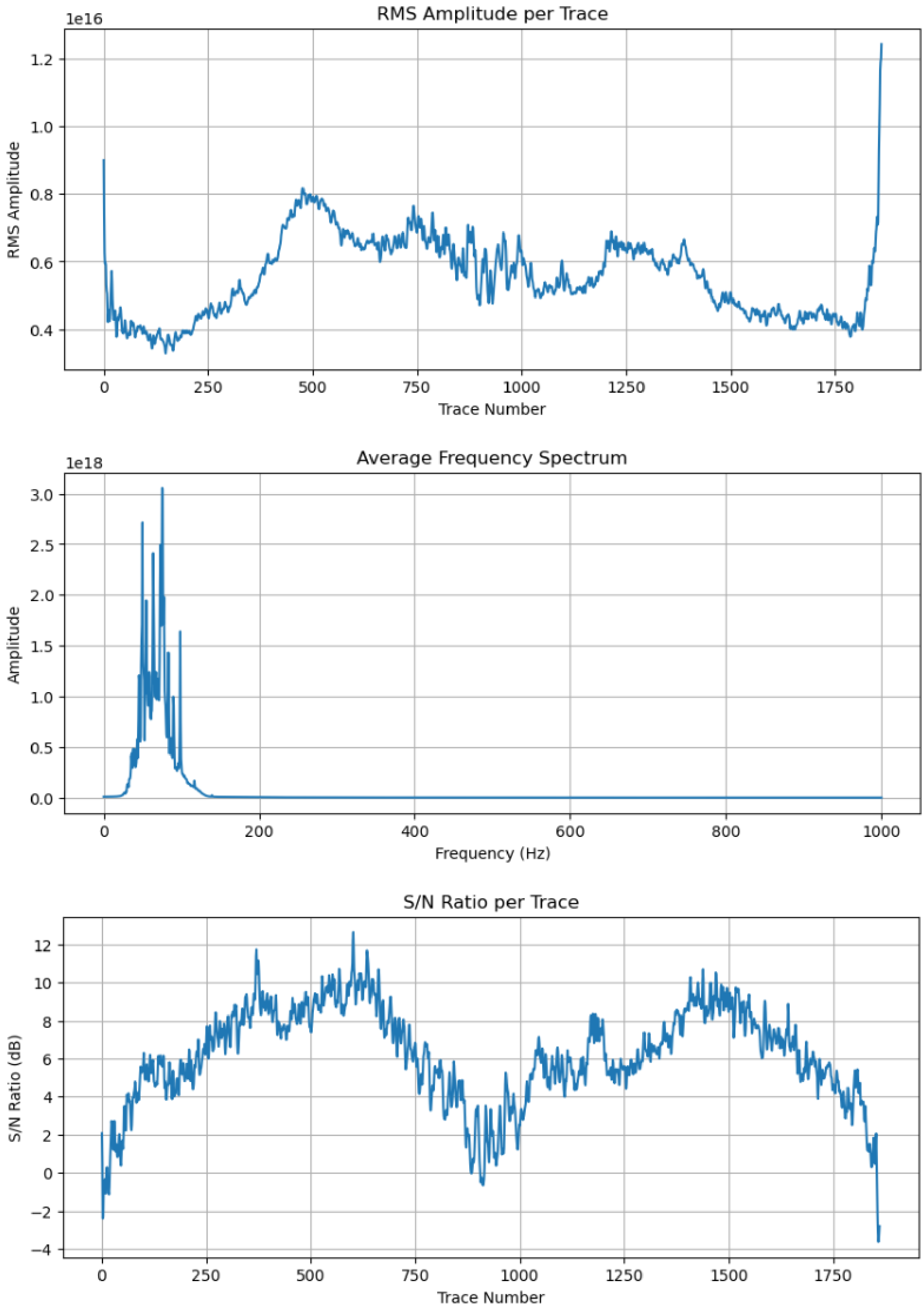

Fig. 9: RMS amplitude (top), frequency spectrum (middle) and S/N ratio (bottom) for seismic line 02 (East-West).

5 Conclusion

The delivered seismic data is in a compatible format and can be loaded into standard interpretation software without issue. However, the processing documentation is incomplete: there is no reference to the application of refraction or residual statics, and no indication of time or depth migration. For accurate structural imaging—especially in areas with faulting—post-stack time migration (PSTM) is typically considered a minimum standard and should be applied.

From a data quality perspective, both seismic lines are generally interpretable. The QC metrics confirm that Line 02 (East–West) exhibits significantly higher data quality than Line 01 (North–South). RMS amplitudes are stronger and more coherent, frequency content is broader, and S/N ratios reach up to 12 dB, suggesting that the signal dominates over background noise. Line 02 is suitable for structural interpretation. Line 01, by contrast, is affected by consistently low signal-to-noise ratios and lower amplitude levels, particularly toward the edges. The data is usable but would benefit from additional processing—especially noise attenuation and muting—before being integrated into interpretation workflows.

Both lines are formally interpretable, but confidence in structural picks and horizon continuity will be significantly higher in Line 02.

The segy-files lack textual header information and coordinates have limited precision to the meter scale.

While both datasets fulfill basic criteria for seismic interpretation, a reprocessing phase focused on noise suppression, muting, and migration could substantially improve interpretability—particularly for Line 01. More complete metadata would increase the reliability of subsequent interpretation workflows.

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