PHASE 2 INITIAL BOREHOLE DRILLING AND TESTING AT IG BH04/05/06 IGNACE AREA

WP12 Data Report – Vertical Seismic Profiling for IG BH04

APM-REP-01332-0284 December 2022

Golder Associates Ltd.

NUCLEAR WASTE MANAGEMENT ORGANIZATION
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REPORT

PHASE 2 INITIAL BOREHOLE DRILLING AND TESTING AT IG BH04/05/06 IGNACE AREA

WP12 Data Report – Vertical Seismic Profiling for IG BH04

Submitted to:

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WP12 DATA REPORT
VERTICAL SEISMIC PROFILING FOR IG_BH04

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1.0 INTRODUCTION

The Phase 2 Initial Borehole Drilling and Testing at IG_BH04/05/06 project in the Ignace area of Ontario, is part of the Phase 2 Geoscientific Preliminary Field Investigations of the NWMO's Adaptive Phased Management (APM) Site Selection Phase.

This project involves testing of deep borehole IG_BH04 and the drilling and testing of deep boreholes IG_BH05 and IG_BH06 in the Ignace area within the identified Potential Repository Area (PRA). The work comprises a total of seven work packages and will be carried out by a team led by Golder Associates Ltd. (Golder) on behalf of the NWMO. The IG_BH04 program is described in the Borehole Characterization Plan (BCP) for IG_BH04 (Golder 2021a).

This data report describes the methodology, activities, and reporting for Work Package 12 (WP12): Vertical Seismic Profiling for IG_BH04. This report describes the methodology, calibration/verification, acquisition, processing, and interpretation of the Vertical Seismic Profiling data. Information from this work package will target and image potential sub-horizontal reflectors (e.g., fracture zones and thin lithological units over the study area) and sub-vertical reflectors around the borehole.

2.0 BACKGROUND INFORMATION

2.1 Geological Setting

The approximately 2.7-billion-year-old Revell batholith is located in the western part of the Wabigoon Sub-province of the Archean Superior Province. The batholith is roughly elliptical in shape trending northwest, is approximately 40 km in length, 15 km in width, and covers an area of approximately 455 km^2. Based on geophysical modelling, the batholith is approximately 2 km to 3 km thick through the center of the northern portion (SGL 2015). The batholith is surrounded by supracrustal rocks of the Raleigh Lake (to the north and east) and Bending Lake (to the southwest) greenstone belts (Figure 2).

IG_BH04 is located within an investigation area of approximately 19 km^2 in size, situated in the northern portion of the Revell batholith. Bedrock exposure in the area is generally very good due to minimal overburden, few water bodies, and relatively recent logging activities. Ground elevations generally range from 400 to 450 m above sea level. The ground surface broadly slopes towards the northwest as indicated by the flow direction of the main rivers in the area. Local water courses tend to flow to the southwest towards Mennin Lake (Figure 1).

Four main rock units are identified in the supracrustal rock group: mafic metavolcanic rocks, intermediate to felsic metavolcanic rocks, metasedimentary rocks, and mafic intrusive rocks (Figure 2). Sedimentation within the supracrustal rock assemblage was largely synvolcanic, although sediment deposition in the Bending Lake area may have continued past the volcanic period (Stone 2009; Stone 2010a; Stone 2010b). All supracrustal rocks are affected, to varying degrees, by penetrative brittle-ductile to ductile deformation under greenschist- to amphibolite-facies metamorphic conditions (Blackburn and Hinz 1996; Stone et al. 1998). In some locations, primary features, such as pillow basalt or bedding in sedimentary rocks are preserved, in other locations, primary relationships are completely masked by penetrative deformation. Uranium-lead (U-Pb) geochronological analysis of the supracrustal rocks produced ages that range between 2734.6 +/-1.1 Ma and 2725 +/-5 Ma (Stone et al. 2010). Three main suites of plutonic rock are recognized in the Revell batholith, including, from oldest to youngest: a Biotite Tonalite to Granodiorite suite, a Hornblende Tonalite to Granodiorite suite, and a Biotite Granite to Granodiorite suite (Figure 2) Plutonic rocks of the Biotite Tonalite to Granodiorite suite occur along the southwestern and northeastern margins of the Revell batholith. The principal type of rock within this suite is a white to grey, medium-grained, variably massive to foliated or weakly gneissic, biotite tonalite to granodiorite. One sample of foliated and medium-grained biotite tonalite produced a U-Pb age of 2734.2+/-0.8 Ma (Stone et al. 2010). The Hornblende Tonalite to Granodiorite suite occurs in two irregularly-shaped zones surrounding the central core of the Revell batholith. Rocks of the Hornblende Tonalite to Granodiorite suite range compositionally from tonalite through granodiorite to granite and also include significant proportions of quartz diorite and quartz monzodiorite. One sample of coarse-grained grey mesocratic hornblende tonalite produced a U-Pb age of 2732.3+/-0.8 Ma (Stone et al. 2010). Rocks of the Biotite Granite to Granodiorite suite underlie most of the northern, central and southern portions of the Revell batholith. Rocks of this suite are typically coarse-grained, massive to weakly foliated, and white to pink in colour. The Biotite Granite to Granodiorite suite ranges compositionally from granite through granodiorite to tonalite. A distinct potassium (K)-Feldspar Megacrystic Granite phase of the Biotite Granite to Granodiorite suite occurs as an oval-shaped body in the central portion of the Revell batholith (Figure 2). One sample of coarse-grained, pink, massive K-feldspar megacrystic biotite granite produced a U-Pb age of 2694.0+/-0.9 Ma (Stone et al. 2010).

The bedrock surrounding IG_BH04 is composed mainly of massive to weakly foliated felsic intrusive rocks that vary in composition between granodiorite and tonalite, and together form a relatively homogeneous intrusive complex. Bedrock identified as tonalite transitions gradationally into granodiorite and no distinct contact relationships between these two rock types are typically observed (SRK and Golder 2015; Golder and PGW 2017). Massive to weakly foliated granite is identified at the ground surface to the northwest of the feldspar-megacrystic granite. The granite is observed to intrude into the granodiorite-tonalite bedrock, indicating it is distinct from, and younger than, the intrusive complex (Golder and PGW 2017).

West-northwest trending mafic dykes interpreted from aeromagnetic data extend across the northern portion of the Revell batholith and into the surrounding greenstone belts. One mafic dyke occurrence, located to the northwest of IG_BH01, is approximately 15-20 m wide (Figure 2). All of these mafic dykes have a similar character and are interpreted to be part of the Wabigoon dyke swarm. One sample from the same Wabigoon swarm produced a U-Pb age of 1887+/-13 Ma (Stone et al. 2010), indicating that these mafic dykes are Proterozoic in age. It is assumed based on surface measurements that these mafic dykes are sub-vertical (Golder and PGW 2017).

Long, narrow valleys are located along the western and southern limits of the investigation area (Figure 1). These local valleys host creeks and small lakes that drain to the southwest and may represent the surface expression of structural features that extend into the bedrock. A broad valley is located along the eastern limits of the investigation area and hosts a more continuous, un-named water body that flows to the south. The linear and segmented nature of this waterbody's shorelines may also represent the surface expression of structural features that extend into the bedrock.

Regional observations from mapping have indicated that structural features are widely spaced (typical 30 to 500 cm spacing range) and dominantly comprised of sub-vertical joints with two dominant orientations, northeast and northwest trending (Golder and PGW 2017). Interpreted bedrock lineaments generally follow these same dominant orientations in the northern portion of the Revell batholith (Figure 2) (DesRoches et al. 2018). Minor sub-horizontal joints have been observed with minimal alteration, suggesting they are younger and perhaps related to glacial unloading. One mapped regional-scale fault, the Washeibemaga Lake fault, trends east and is located to the west of the Revell batholith (Figure 2). Ductile lineaments, also shown on Figure 2, follow the trend of foliation mapped in the surrounding greenstone belts. Additional details of the lithological units and structures found at surface within the investigation area are reported in Golder and PGW (2017).

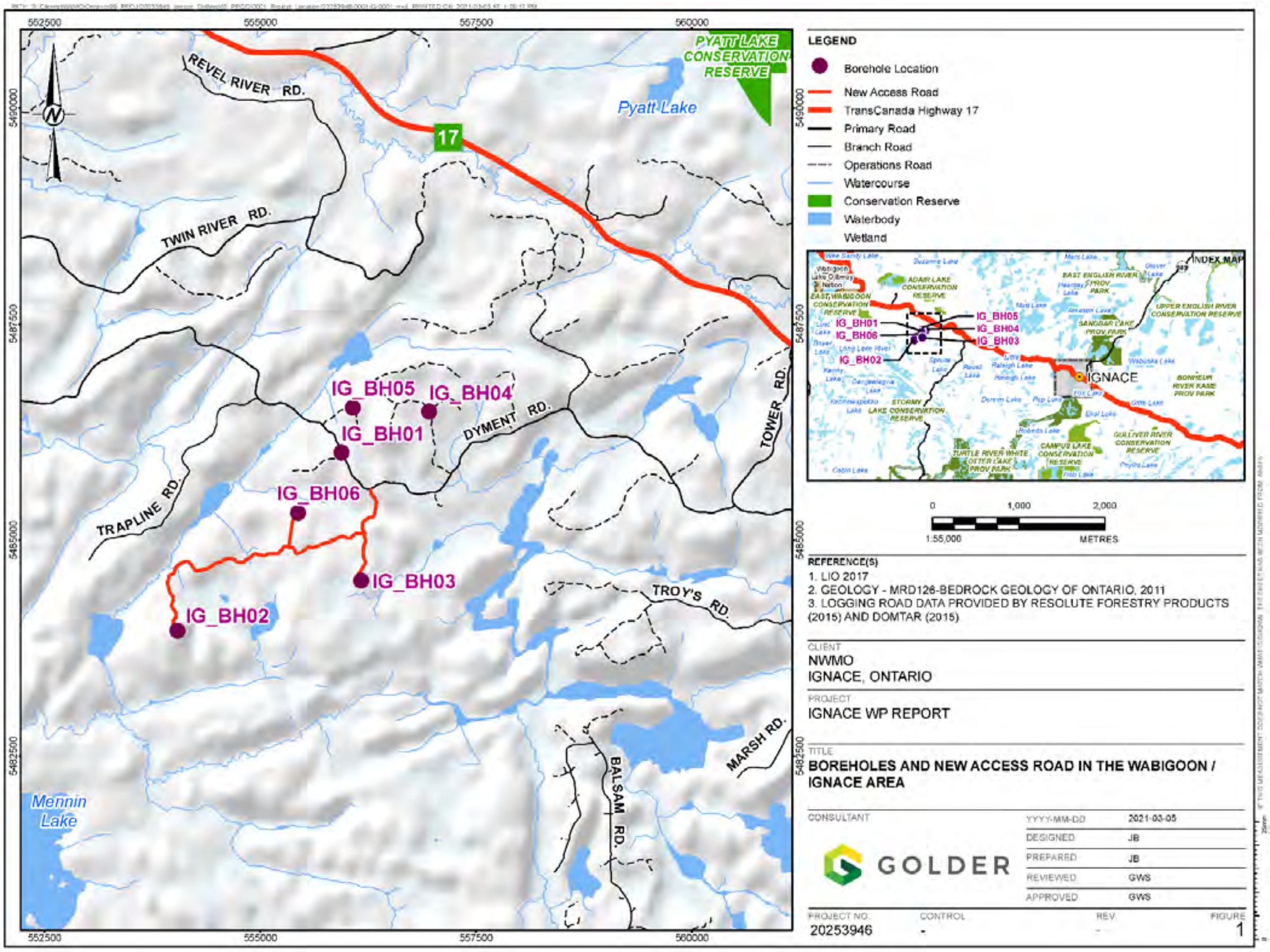


Figure 1: Location of IG_BH04 in relation to the Wabigoon / Ignace Area

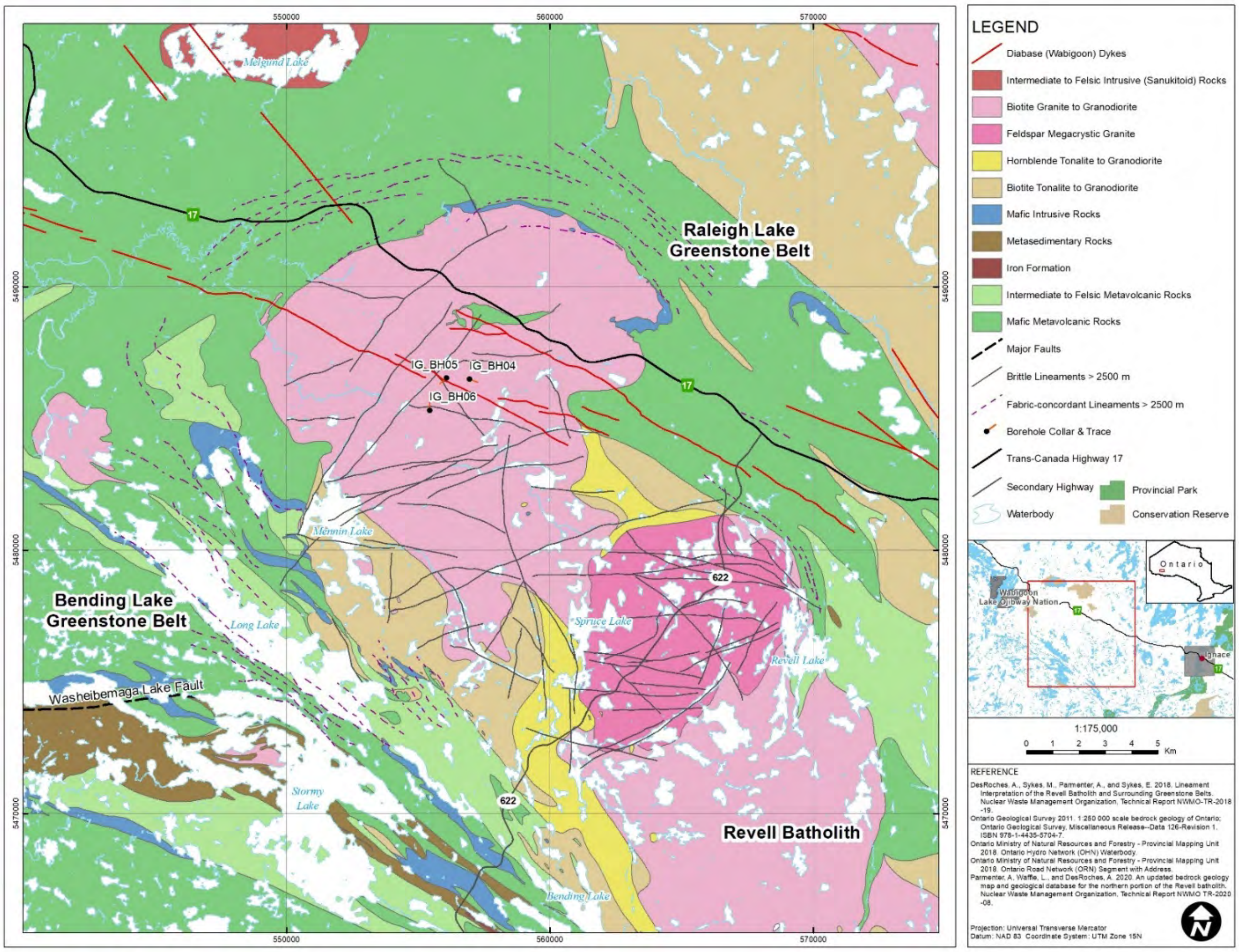


Figure 2: Geological setting and location of boreholes IG_BH04, IG_BH05, and IG_BH06 in the northern portion of the Revell batholith

3.0 VERTICAL SEISMIC PROFILING FROM BOREHOLE IG_BH04

This section reports the multi-offset multi-azimuth Vertical Seismic Profiling (VSP) survey performed by Vibrometric in borehole IG_BH04 at Ignace, Ontario, as well as the results obtained by processing and analyzing measured data. Data acquisition was done during July and August, 2021. The locations of the borehole and of the shot points used for the VSP measurements are shown in Figure 7 to Figure 9, as well as in Table 2 and Table 3.

The scope of the work presented here was to acquire, process, and interpret high-resolution vertical seismic profiles (VSP). This effort was designed to image potential reflectors (e.g. fracture zones and thin lithological units over the study area) with diverse dips from horizontal to vertical around the borehole. VSP results were correlated with available structural logs provided by the NWMO, as presented in Table 7.

The intended scope of the borehole and surface survey was to:

1) Collect 3D VSP data in one borehole to a maximum depth of ~1000 m;

2) Process seismic data by means of industry standard and proprietary seismic imaging techniques particularly adapted to hardrock; and

3) Interpret the main identified reflectors, i.e., position them in 3D, using all processed data and correlate them with the borehole lithological log (WP03) and lineaments identified in the vicinity of the borehole.

The VSP method provides a favorable geometry for mapping both steeply and gently dipping features that cut the borehole (Cosma et al. 2001b). Sub-vertical features not cutting the borehole can be mapped from surface to a depth of ½ to ¾ of the depth of the borehole. Sub-horizontal features can be mapped deep under the borehole, but with a lateral extent limited to ½ to ¾ of the mean shot point offset. In the case of the VSP borehole IG_BH04 at Ignace this means a maximum depth of about 500-750 m for the mapping of the sub-vertical and a maximum offset of about 550-1100 m (depending on the azimuth) for the sub-horizontal features.

Receivers located in the bedrock reduce the loss of the higher frequencies due to near-surface signal absorption. For this reason, VSP is often preferred to surface seismic profiling, especially at sites where hard bedrock is covered by soft overburden.

Since 2000, VSP surveys (Cosma et al. 2002a) have been carried out by Vibrometric with a time-distributed swept-impact source, the VIBSIST (Enescu and Cosma 1999; Cosma and Enescu 2001c), instead of explosives. With this source, the seismic signals are produced as rapid series of impacts, the impact intervals being monotonically increased to achieve a non-repeatable sequence. As the energy is built up from a large number of relatively low-power impacts, the high frequency components of the seismic signal are maintained.

Processing techniques developed over three decades (Cosma et al. 1994a, 1994b; Heikkinen et al. 1994, 1995), (Cosma and Enescu 2002b) were used, e.g., the determination of the orientation of the reflecting interfaces using several VSP profiles simultaneously. The limitations mentioned above regarding certain dip-position combinations can be overcome by acquiring VSP data in several holes and processing the data jointly.

The data processing comprises standard techniques, e.g., median and band-pass filters, as well as proprietary procedures, such as Image Point (IP) filtering techniques, aimed at enhancing the reflected wave fields and at separating events generated by reflectors with different orientations. With the Image Point transform, introduced by (Cosma 1990; Cosma and Heikkinen 1996), stacking is performed along curved time-depth paths corresponding to all possible reflector orientations. Due to this "physical" choice of the stacking paths, coherency across the profiles can effectively be used to enhance the weak reflections.

4.0 LOGISTICS

The field crew and equipment were mobilized from Toronto to the Ignace area in the middle of July 2021. The crew consisted of 3 – 4 Vibrometric personnel and 1 Golder personnel, at various times during the survey, with one geophysicist and one field engineer on site at all times. Figure 1 presents the location on the map of the survey site, situated approximately 40 km west of the Town of Ignace, Ontario.

The VSP acquisition work was carried out in borehole IG_BH04, instrumented with 3-components digital geophones, which recorded seismic signals generated by a VIBSIST-3000 source, activated at 30 shot points distributed on surface around the borehole, as shown on the map in Figure 8. Survey details are presented in Section 5.0.

4.1 Field Equipment and Operations

Vibrometric supplied all the field equipment required for data acquisition. Some supporting infrastructure onsite (e.g., tent over the borehole collar and work area around the borehole, acquisition room, electrical power supply, etc.) was provided by Golder. Trail access and standby trail clearing/towing capacity was provided by the NWMO.

The following list presents the field equipment used to carry out the VSP investigation:

- VIBSIST-3000 seismic source;
- RD-XYZH 3-component seismic receivers with 1,000 m of multi-pair geophysical cable on a winch powered by an electric motor;
- Dummy probe;
- Tripod to place over the borehole;
- Depth encoder to measure depth of receivers;
- Field computer for data acquisition;
- Radios for transmission of pilot trigger signal from source to acquisition computer;
- Radios for audio communication between acquisition shelter and seismic source;
- Wooden stakes to mark VSP shot locations; and
- GPS to measure the coordinates of the source locations (NAD83 UTM Zone 15N, CGVD2013 Datum).

VSP data acquisition was performed in one field session, as described below:

Table 1: Daily Activities during the VSP Survey in IG_BH04

Date	Day	Description of activity during the day
2021-07-19	Monday	Move equipment to site / Initial set up / Mark VSP shot points
2021-07-20	Tuesday	Complete set up / Dummy probe hole, clear to bottom
2021-07-21	Wednesday	Source calibration / Equipment testing at surface / All clear for deployment down hole / Stop work due to fire restrictions put in place for Northern ON / Order to demobilize

Table 1: Daily Activities during the VSP Survey in IG_BH04

Date	Day	Description of activity during the day
2021-07-22	Thursday	Pack equipment to be removed from site / Meeting to discuss modified scope of work (changed shot point locations) suitable to comply with new fire restrictions
2021-07-23	Friday	The survey can continue with the modified scope of work / Unpack equipment. Shot points S10, S11, S13, S25, S26 & S27 (Figure 4) will not be used. New shot points on the Eastern side are to be used instead / Equipment testing at surface.
2021-07-24	Saturday	Finalize setup and testing of equipment on surface / Place 12 units of RD24-XYZ in the borehole / Install radio communication tower and make first test records down hole, receivers remain placed for first layout / Mark and survey new shot points
2021-07-25	Sunday	VSP acquisition
2021-07-26	Monday	VSP acquisition
2021-07-27	Tuesday	VSP acquisition
2021-07-28	Wednesday	VSP acquisition
2021-07-29	Thursday	VSP acquisition
2021-07-30	Friday	VSP acquisition
2021-07-31	Saturday	VSP acquisition
2021-08-01	Sunday	Remove geophones from borehole / Pack all equipment / Demob

4.2 Equipment

One VIBSIST-3000 time-distributed seismic source was used on the surface. A 12-level, 3-component digital geophone receiver tool, the RD-XYZH, was used in the borehole. A PC-based acquisition program was used to record the seismic data. 3-component profiles were collected from 30 shot points. Each profile consisted of 15 receiver layouts with 12 receivers in each layout, spaced at 5m intervals between 80.15 m and 975.15 m depth.

4.2.1 The VIBSIST-3000 Seismic Source

The seismic source was the VIBSIST-3000, which is a multi-impact time-distributed seismic source based on the Swept Impact Seismic Technique (SIST), described in principle by Park et al. (1996) and technically elaborated and completed by Cosma and Enescu (2001).

The VIBSIST-3000 source uses a large-size hydraulic impact hammer, powered through a computer-controlled regulator that is mounted on an all-wheel drive/all-wheel steering 7-ton tool carrier, as shown in Figure 3. The seismic source can handle topography at a reasonable speed while providing high energy and a stable source signature. The hydraulic hammer is capable of delivering 2500 – 3250 J/impact at 400-800 impacts/minute. At each shot point, the VIBSIST-3000 source was activated three times for a period of 20 seconds each, with the impact frequency being varied to generate a swept impact sequence. Each sweep contains ~100 impacts. Based on data inspection in the field, the number of sweep repetitions was sufficient to obtain high-quality seismic signal for the desired investigation depth.

Figure 3: The VIBSIST-3000 seismic source used for the VSP survey in IG_BH04. New, thick rubber mat was used for the source, in order to avoid direct contact with outcrops (example from shot point V01 in the bottom).

The VIBSIST concept requires a pilot signal to be measured by a sensor placed on the source and this was conveyed by radio to the recording station and recorded together with the signals arriving from the receivers. The main role of the pilot signal is to record the actual time history and the energy of the impacts delivered to the ground by the source. High quality data were acquired from each shot location.

4.2.2 Downhole Seismic Receivers and Cable

A 3-component digital geophone chain was used for the VSP measurements. This is shown in Figure 4. The RD-XYZH consists of up to 24 3-component modules spaced at 5 m intervals. The signal digitizing is done down-hole, within each module. For logistic reasons, the survey was carried out with 12 levels. The frequency band is from 14 to 500 Hz. The units are equipped with side arms for clamping, activated by DC motors. The clamping control is independent for each unit.

Figure 4: Detail of the 3-component modules with clamping arms for the RD-XYZH geophone receiver system and picture of the receiver cable winch, together with the acquisition setup at borehole IG_BH04.

Survey Details

The VSP investigations were carried out in borehole IG_BH04. Three-component profiles were collected from 30 shot points spaced as evenly as possible around the borehole. Some of the shot points originally planned to be used were changed due to the terrain access issues and fire restrictions which precluded accessing some originally planned shot points with heavy equipment. The initial and actual survey layout are illustrated in Figure 5 and Figure 7, respectively. The green and orange place markers show the location of VSP sources for borehole IG_BH04 and the thick blue line shows the surface projection of the borehole. The field acquisition started on July 19, 2021, and was completed on August 1, 2021.

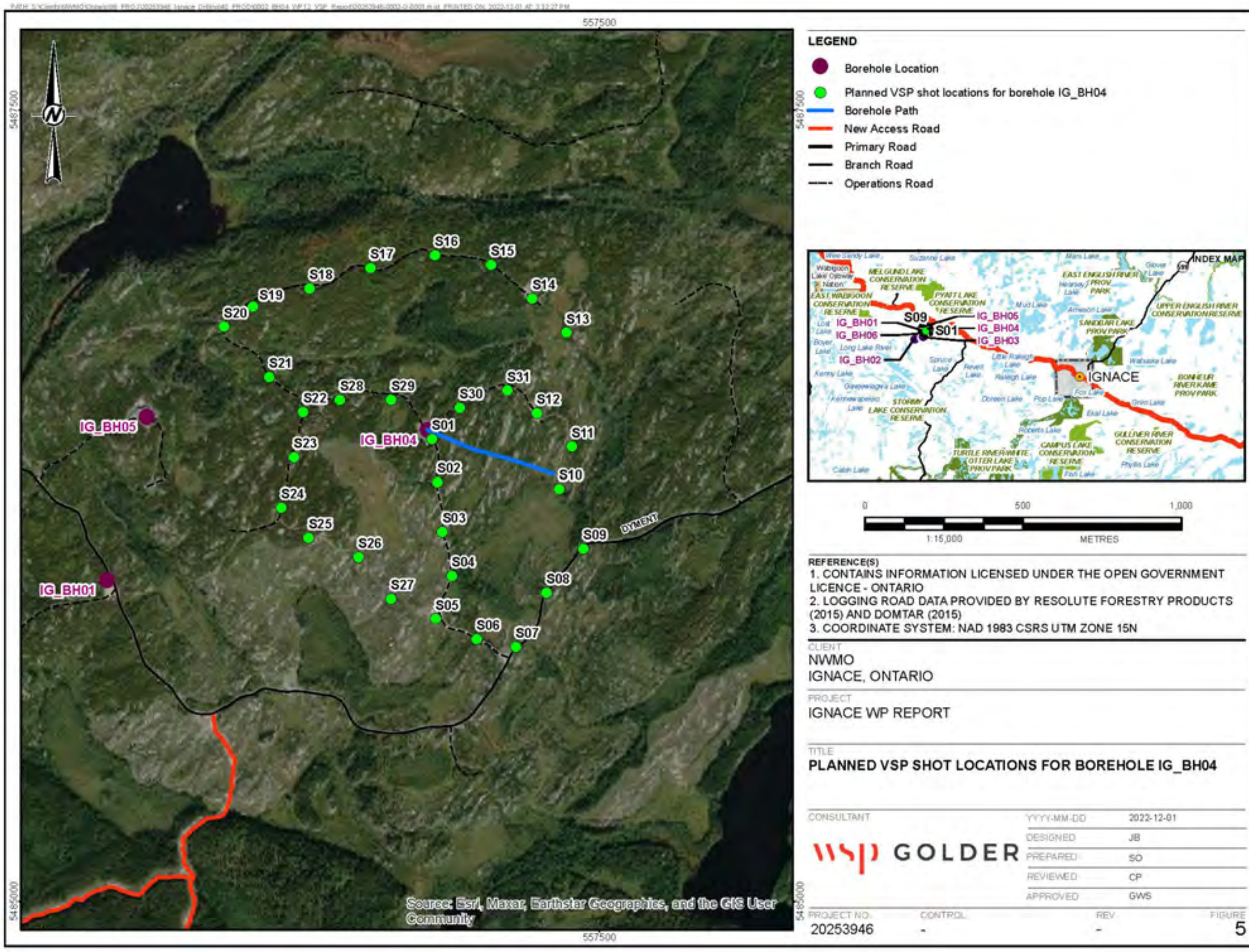


Figure 5: Location of borehole IG_BH04 and of the VSP shot points planned for data acquisition.

4.3 Borehole IG_BH04

Borehole IG_BH04 is inclined (dip -66° and azimuth 110°, approximately, see Figure 6) and the start and end positions of the borehole, in site coordinates, are given in Table 2. All coordinates shown in this report are reduced coordinates, obtained by subtracting 5480000 from the Northing and 550000 from the Easting coordinates, respectively. Top of the borehole is at Northing 6488.05 m, Easting 6957.25 m, and Elevation 443.46 masl. Casing was installed to a depth of 101 m down the hole. The installed casing is HWT surface casing, which has an outer diameter of 114.30 mm, and an inner diameter of 101.60 mm. The borehole was drilled HQ, resulting in a borehole diameter ranging from 98 to 108 mm. The caliper log along the borehole, together with some qualitative considerations used to guide the usage of receivers down-hole are also shown in Figure 6.

Table 2: The Coordinates of borehole IG_BH04. All coordinates shown in this report are reduced coordinates, obtained by subtracting 5480000 on the Northing and 550000 on the Easting coordinates, respectively.

Borehole used for the VSP Survey	Coordinates of the first receiver			Coordinates of the last receiver		
	Northing Y (m)	Easting X (m)	Elevation Z (m)	Northing Y (m)	Easting X (m)	Elevation Z (m)
IG_BH04	6477.32	6984.24	367.43	6353.39	7349.64	-447.83

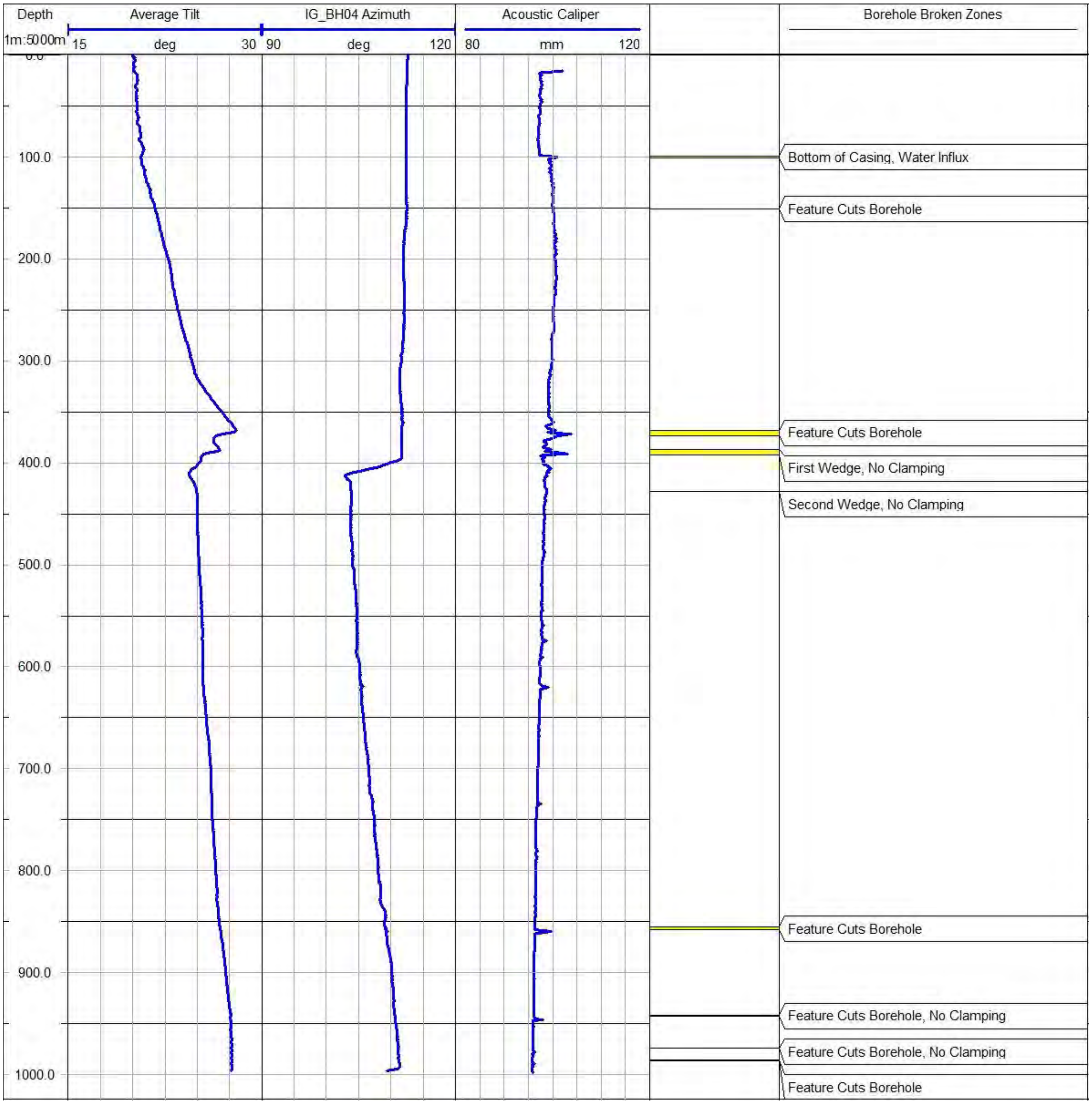


Figure 6: Orientation of borehole IG_BH04 with depth and Acoustic Caliper log together with a summary of zones where clamping of the geophones is to be avoided because of increased risk of instrument jam.

4.4 Survey Geometry

At each shot point, the VIBSIST-3000 source was activated for a period of 20 seconds, the impact frequency being varied from 3 Hz to 6 Hz to generate a swept impact sequence. Each sweep contained 95 to 100 impacts and was repeated three times. A pilot signal was measured by a sensor placed on the source plate and conveyed to the recording station by radio to be recorded on an additional channel, together with the signals arriving from the receivers.

The layout of the shot points is shown in Figure 7, Figure 8 and Figure 9 and their coordinates are given in Table 3. The zero-offset shot point (24 m away from the borehole top) is V14. The distances from the top of the borehole to shot points range from 24 to 1035 m. The distances from shot points to the first receiver in the borehole range from 94 to 1020 m. The distances from shot points to the deepest receivers in the borehole range from 902 to 1393 m.

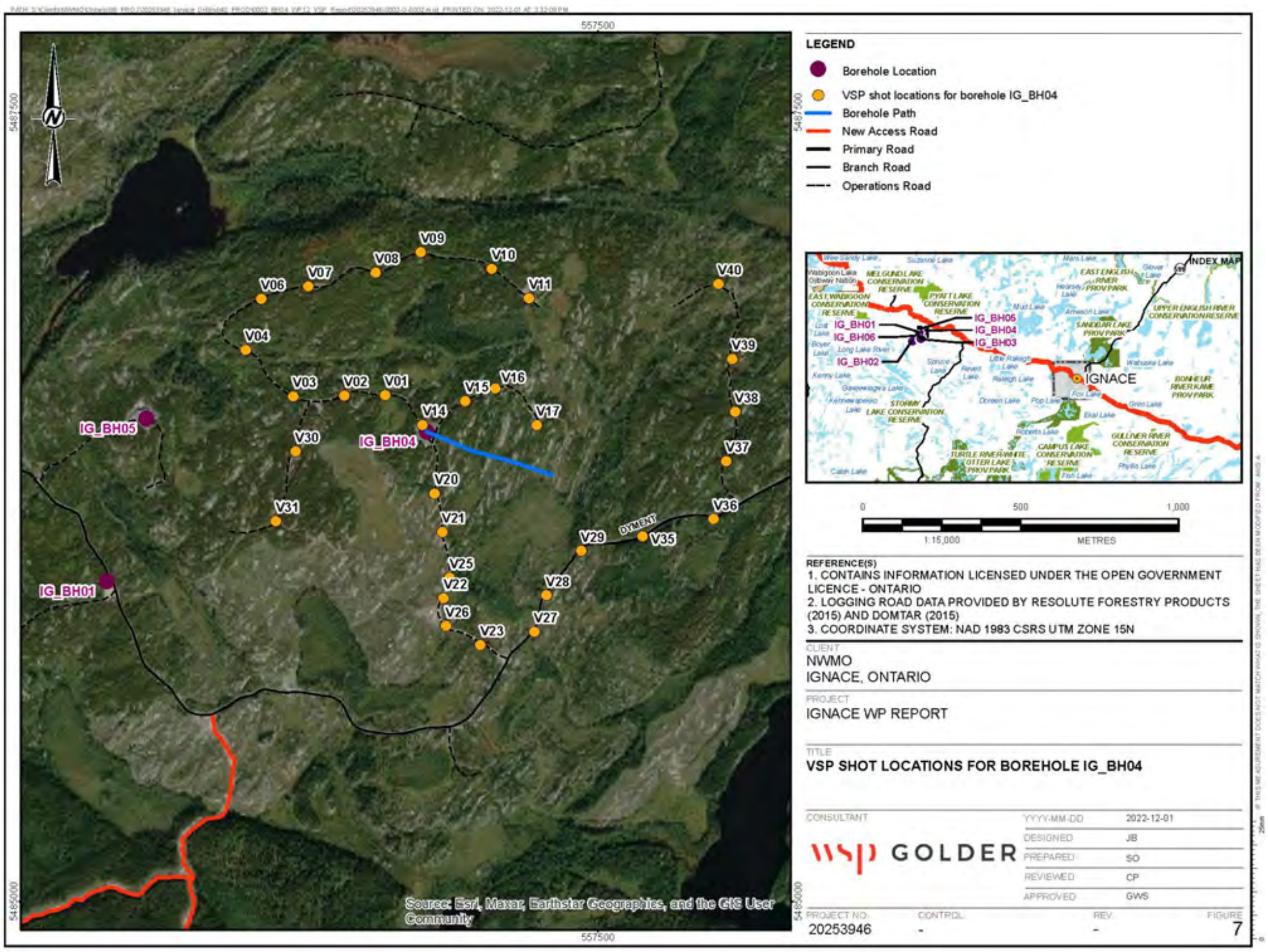


Figure 7: Location of borehole IG_BH04 and of the VSP shot points used for data acquisition

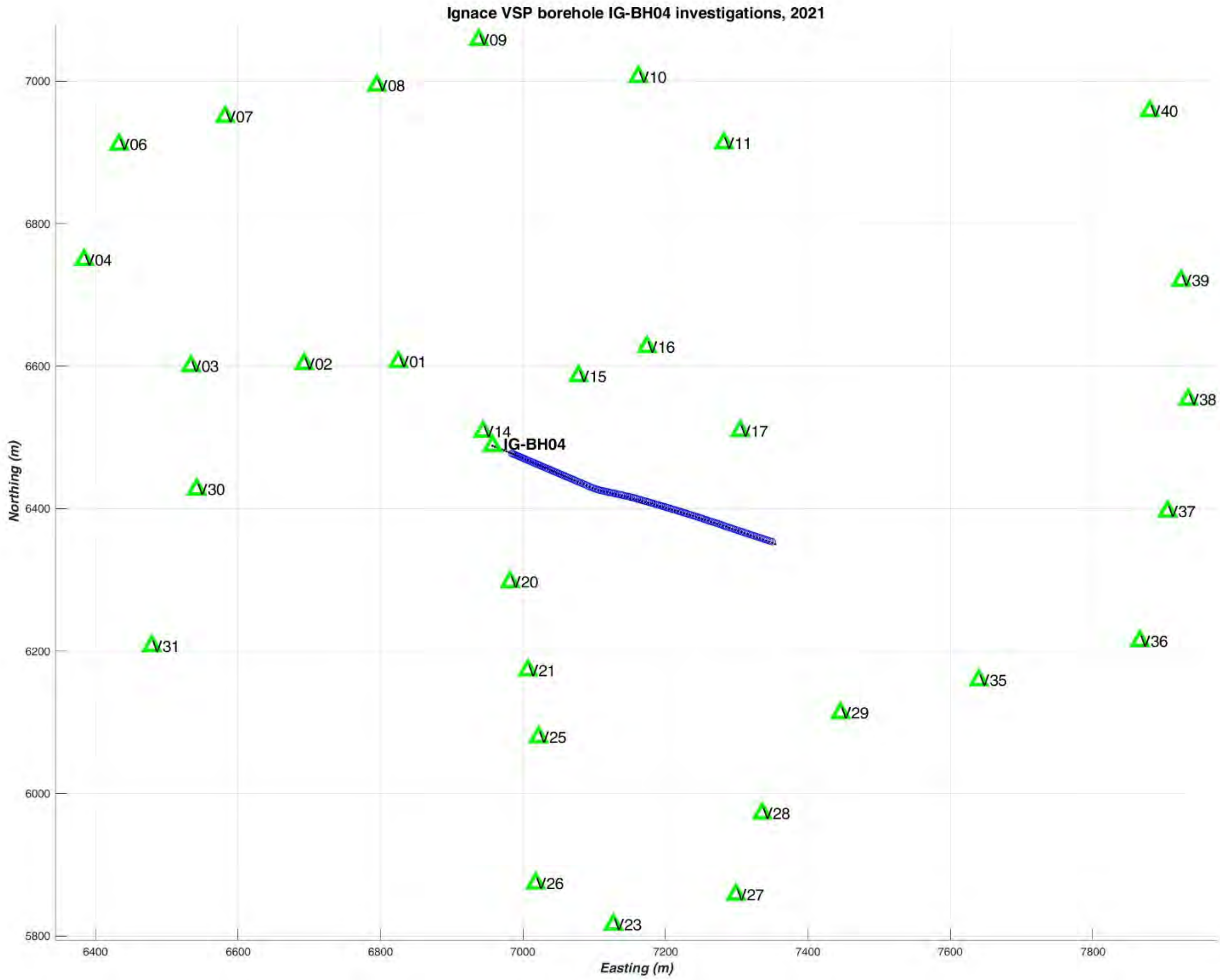


Figure 8: Top view of layout of the shot points used for the multi-offset VSP survey in borehole IG_BH04.

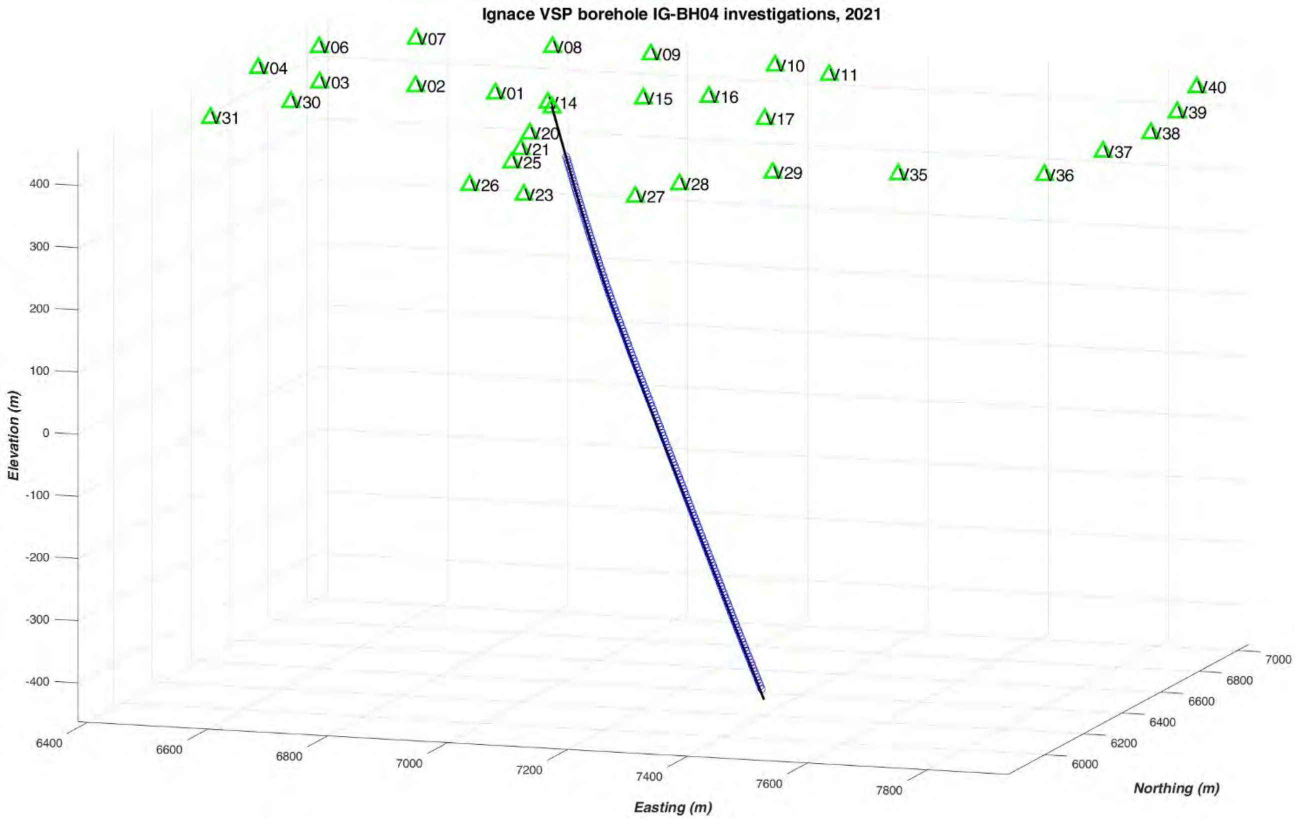


Figure 9: 3D view of layout of the shot points used for the multi-offset VSP survey in borehole IG_BH04. The location of the VSP receivers in borehole IG_BH04 are marked by blue circles.

Table 3: Reduced coordinates of the source positions for the VSP survey in IG_BH04. The zero-offset shot point (nearest to the borehole top) is printed bold.

Shot point	Northing (m)	Easting (m)	Elevation (m)	Distance from the shot point to the first receiver (m)	Distance from the shot point to the last receiver (m)
V01	6605.71	6825.11	439.39	216.88	1060.91
V02	6603.04	6692.71	443.79	326.31	1135.27
V03	6600.00	6533.82	442.00	472.57	1232.02
V04	6748.68	6383.82	432.18	662.02	1364.94
V06	6910.93	6432.82	441.21	705.24	1393.26
V07	6949.71	6581.96	455.71	626.95	1327.45
V08	6993.71	6794.93	446.75	555.97	1232.37
V09	7058.00	6938.00	432.46	586.09	1200.01
V10	7005.93	7162.00	435.29	561.84	1113.78
V11	6912.82	7282.04	442.00	532.95	1053.35
V14	**6508.43**	**6943.86**	**447.07**	**94.30**	**994.57**
V15	6585.68	7078.29	447.93	164.60	964.58

Table 3: Reduced coordinates of the source positions for the VSP survey in IG_BH04. The zero-offset shot point (nearest to the borehole top) is printed bold.

Shot point	Northing (m)	Easting (m)	Elevation (m)	Distance from the shot point to the first receiver (m)	Distance from the shot point to the last receiver (m)
V16	6627.00	7174.32	449.07	255.08	953.95
V17	6509.14	7305.25	440.11	330.39	902.47
V20	6296.71	6982.21	435.18	192.58	957.98
V21	6173.04	7007.11	431.82	311.93	961.27
V23	5816.04	7127.11	425.00	679.00	1048.90
V25	6079.21	7021.96	427.04	404.52	973.64
V26	5874.18	7017.96	425.04	607.00	1049.59
V27	5857.93	7298.89	423.71	697.02	1004.02
V28	5972.07	7336.00	426.79	618.57	954.45
V29	6113.11	7445.86	427.96	591.29	913.32
V30	6426.93	6542.18	439.89	450.97	1202.47
V31	6207.14	6479.00	448.29	578.65	1257.76
V35	6158.96	7640.07	428.36	731.45	942.96
V36	6214.18	7866.21	430.00	922.36	1027.93
V37	6396.00	7905.00	439.00	927.11	1047.24
V38	6553.00	7934.00	444.00	955.84	1084.75
V39	6720.00	7924.00	449.00	974.01	1126.32
V40	6958.00	7880.00	447.00	1019.69	1203.14

4.5 Work Procedure and Quality Control

The VSP measurements were conducted in increments of 60 m with 12-level geophone string at a nominal station interval of 5 m. The station interval was adjusted to 5.035 m to compensate for the actual cable elongation measured by comparing the reading of the depth encoder with preset cable markings. Measurements were done from 81.4 m to 983 m borehole depth from the top of the casing.

The data quality was controlled on screen immediately after acquiring a record. All shot-points were measured in one group, for which the geophone string was kept clamped to the borehole at the same depth. The last record of each day was repeated at the start of the next day to check the functioning of the clamping mechanism.

Daily Quality Control (DQC) Forms were filled out each day during the field program and submitted to NWMO with each daily field report. The DQC forms present each of the field checks and quality controls performed during the survey. They are provided for reference in Appendix A.

5.0 DATA PROCESSING

Reflecting interfaces associated with lithological contacts, faults or fracture zones can display strong to relatively weak seismic contrasts. Extensive processing is often needed to identify reflection events in the seismic profiles and to retrieve the information on the position of the reflectors.

The processing flow described below aims to suppress direct arrivals and improve the signal-to-noise ratio, so that the later events, e.g., reflections, become visible. As the reflection coefficients may be low, the reflectors cannot always be identified only by amplitude standout. Continuity and phase consistency throughout the profiles have been found to be sensitive indicators of the occurrence of reflections.

The processing flow used for the IG_BH04 VSP data is summarized below:

- Resampling from 1 ms to 500 μs
- Time stacking of the VIBSIST impact sequences
- Trace selection and sorting
- Adding the geometry information to the data files
- Data quality and frequency analysis
- Zero-phase band-pass filtering 20-240 Hz
- Component rotation: (X Y Z) to (R, T, Z)
- P- and S-wave arrival time picking and velocity computing
- Suppressing direct P- and S- wave arrivals
- Amplitude equalization
- Static corrections using tomographic reconstruction of velocities
- Spatial resampling to 2.5 m trace interval
- Image Point filtering and reflector enhancement
- Determining the positions of the reflectors multi-profile interactive interpretation.
- Migrating along the mean azimuths of the main interpreted reflectors

5.1 First Stage Processing of the VSP Data

5.1.1 Data Quality and Frequency Analysis

The data have been inspected for possible malfunctions of the measuring system, e.g., unusually high noise levels, possible errors in coordinates, time delays and trace order. The noise level was measured for reference at the beginning at each day. Noise higher noise than the reference level was noticed occasionally during activities of maintenance of site infrastructure, The measuring was paused for the duration of such operations. The depth of the geophone string in the borehole was verified by comparing the readings of the depth encoder with preset marks on the lead-in cable.

Following this, spectral analysis of the data has been done for all measured VSP profiles. Figure 10 displays the amplitude spectra for all three component profiles measured from shot point V01, which has a frequency response typical for the entire data group, although some shot points display lower frequency responses.

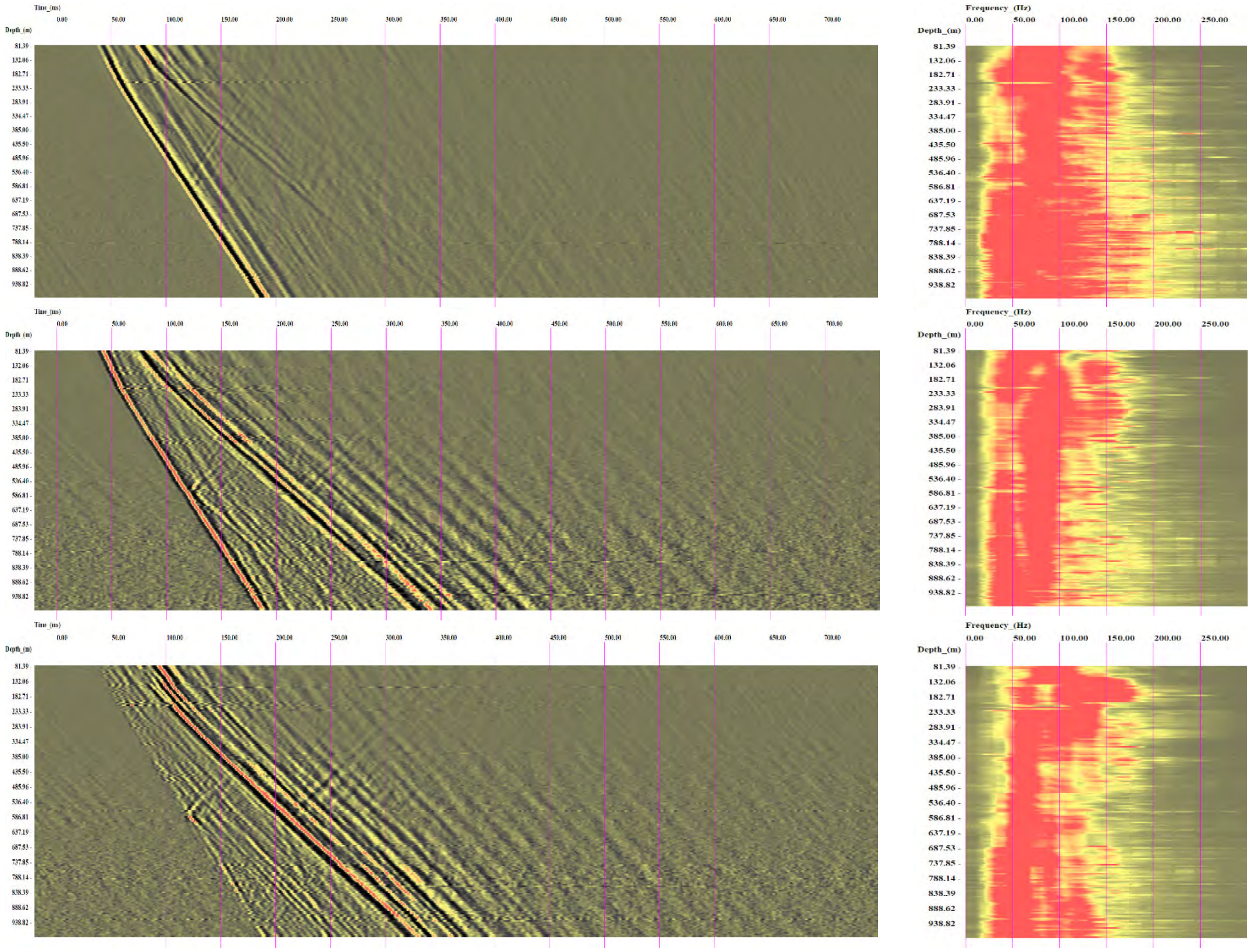


Figure 10: Spectra of the VSP data measured from IG_BH04 shot point V01 (right column). The vertical axis shows the depth along the borehole in metres. The horizontal axis shows time in ms (left) and the frequency in Hz (right). The useful seismic signal energy is contained in the 20 – 240 Hz band, as it appears in the right panel. The evaluation of the spectrum at this stage is meant to be overcovering. Shown are Z (top), R (middle), T (bottom) components, normalized to trace.

The raw VSP Profiles acquired for IG_BH04 are presented in Appendix B.

5.1.2 Preconditioning of the Data Profiles

The optimum frequency band of the P-waves was estimated to be 20 – 240 Hz (Figure 11). A zero-phase band-pass filter was used for filtering all data profiles.

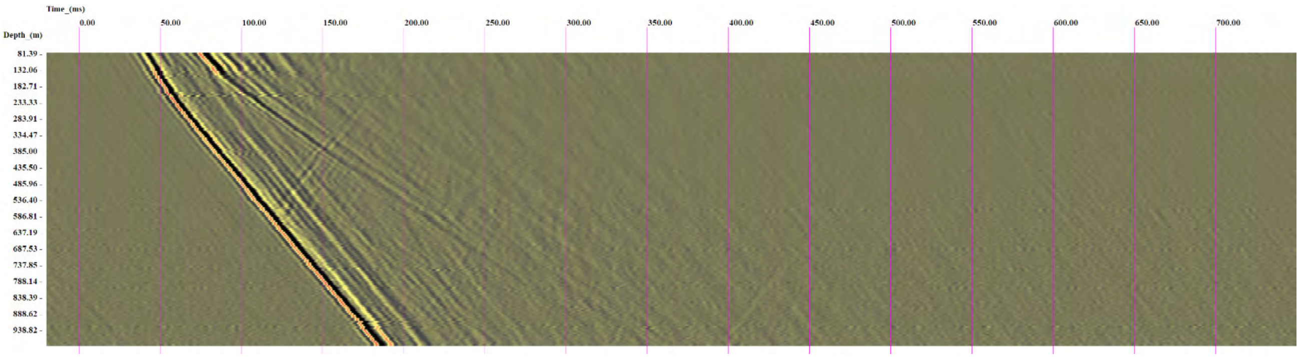


Figure 11: Band pass filtered axial component (Z) profile from shot point V01.

The processed VSP profiles are presented in Appendix C.

5.1.3 Rotation of Transverse Components

The orientation of the transverse components (X and Y) is not set or determined during the measurements and the down-hole probes can rotate while changing position.

The rotation of the horizontal components is done computationally, assuming that the direct P wave is polarized along the source-receiver line. The X-Y trace pair is rotated so that after rotation the X-component acquires the most of the P-wave energy and becomes the “Radial” – R-component, while the Y-component contains the minimum of the P-wave energy becomes the “Transversal” – T-component. The Z-component remains directed along the borehole and it becomes the “Axial” component. Figure 12 to Figure 14 present the rotated components recorded in borehole IG_BH04 from shot point V01. The rotated components from all shot points are displayed in Appendix C.

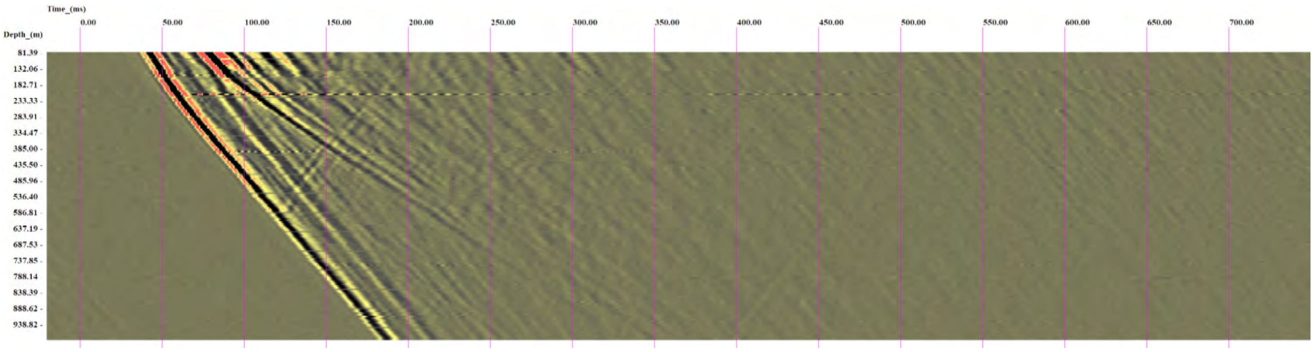


Figure 12: Axial (Z) VSP raw data profile, recorded in borehole IG_BH04, from shot V01. Profile normalized to value=100.

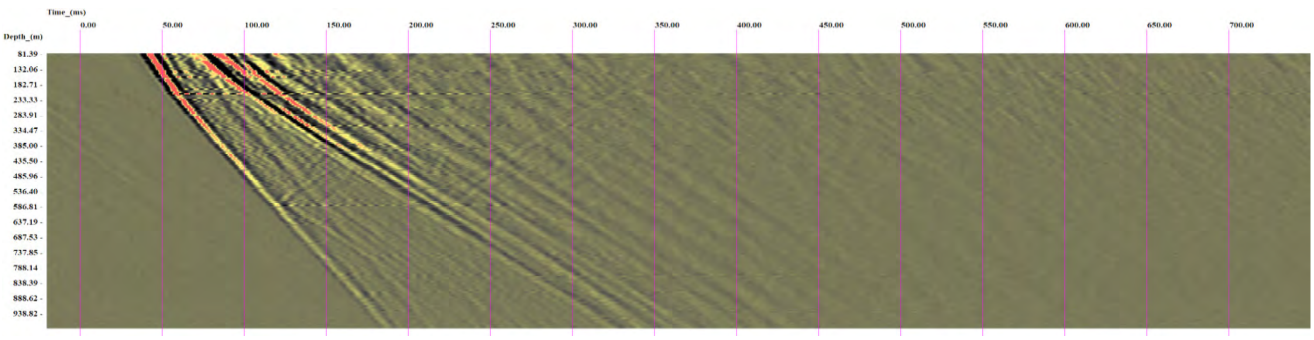


Figure 13: Rotated radial (R) VSP raw data profile, recorded in borehole IG_BH04, from shot V01. Profile normalized to value=100.

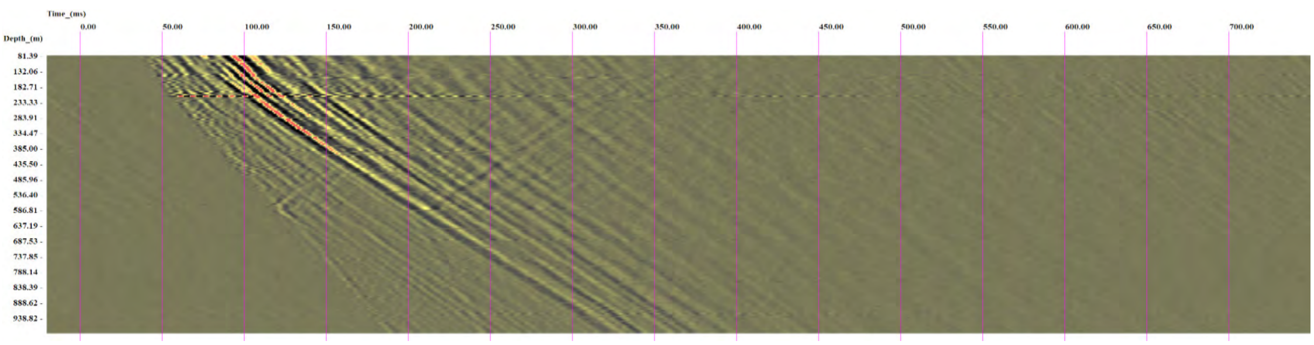


Figure 14: Rotated transversal (T) VSP raw data profile, recorded in borehole IG_BH04, from shot V01. Profile normalized to value=100.

5.1.4 Velocity Determinations

P and S wave first arrival times were picked for all shot gathers from rotated profiles, as the ones shown in Figure 12, Figure 13 and Figure 14. The smooth variation of the S-wave velocity vs. depth obtained by inverting all VSP data agrees well with the logging data. For the P-waves, there is a consistent offset towards slightly higher velocities when compared to results collected by sonic logging of the borehole (Figure 15). Potential reasons for this difference are macro vs. microscale measurements and that the sonic logging measures along unconfined rock along the borehole wall.

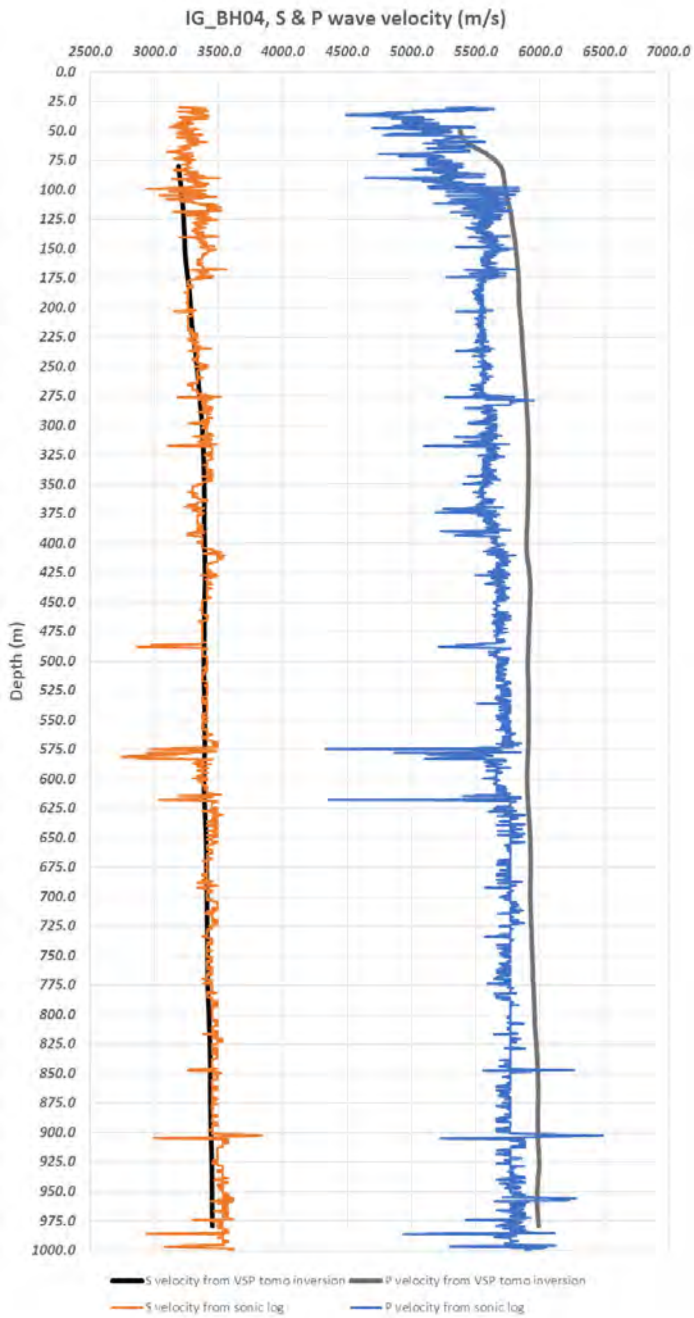


Figure 15: S- and P-wave velocity logs along borehole IG_BH04, derived from sonic logging and from tomographic inversion of VSP measured P & S waves first arrivals.

Tomographic reconstruction of the velocity field around the borehole was done using the picked first arrivals from all VSP shot points and the results are illustrated in Figure 16.

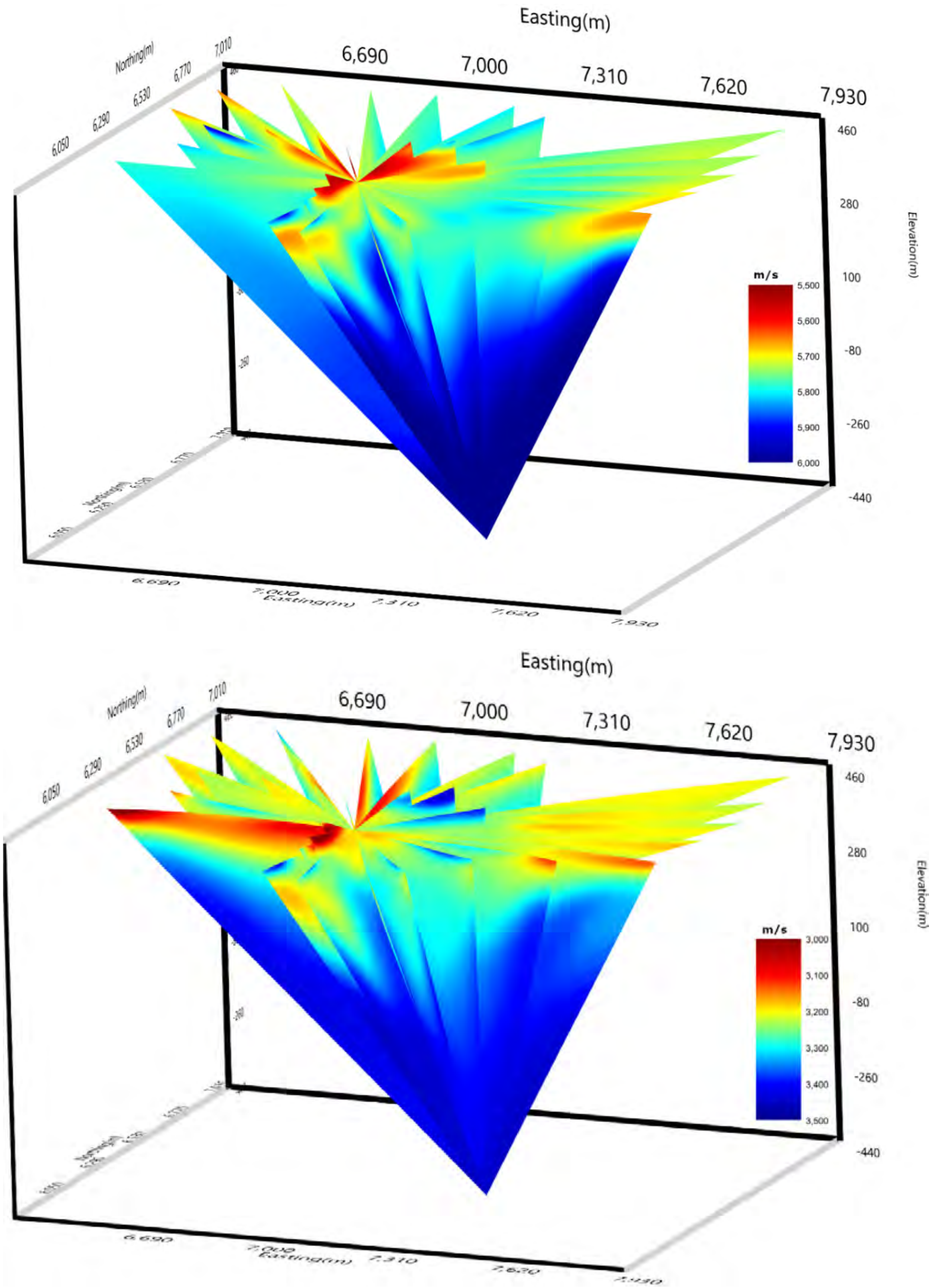
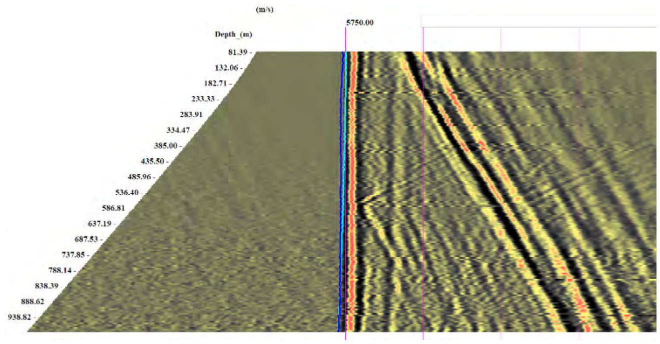
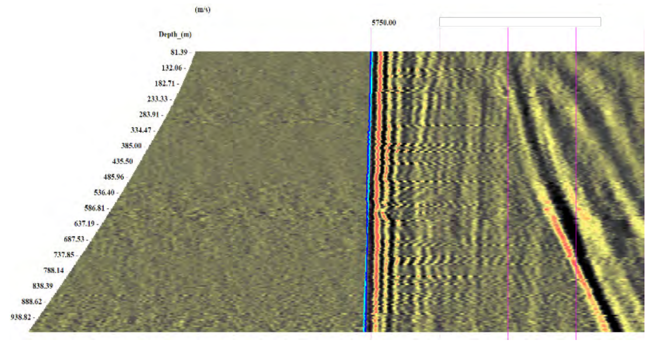


Figure 16: 3D view of the P-wave (top) and S-wave (bottom) velocity fields around the borehole, derived from tomographic inversion of VSP measured P & S first arrivals.

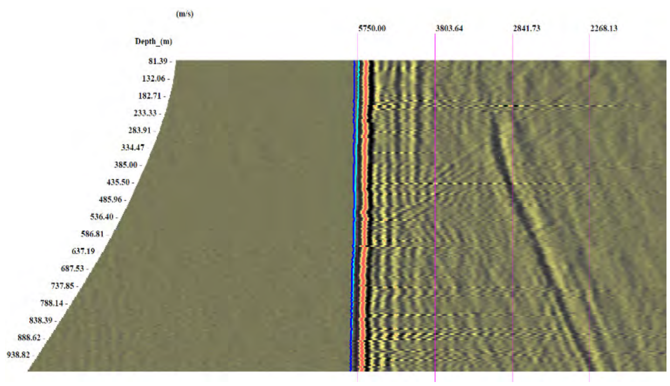
Figure 17 presents the picked arrival times on the R-component profiles from different shot points. By inspecting the reduced velocity plots for Vp=5750 m/s it appears that this velocity is appropriate for time-delay corrections amongst all VSP shot points and later removal of P wave direct arrivals.



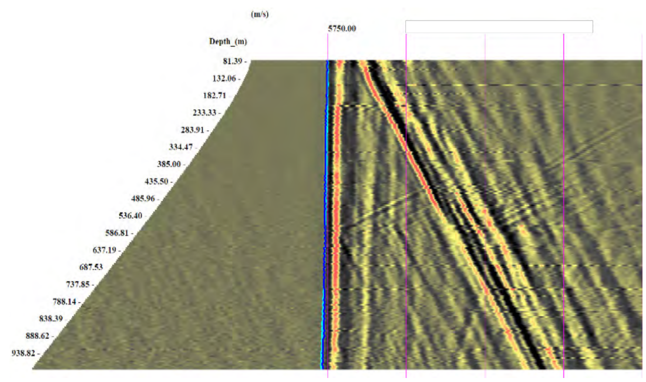
V01



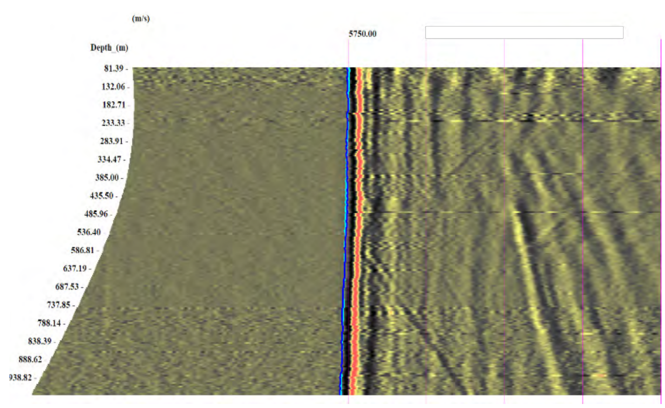
V07



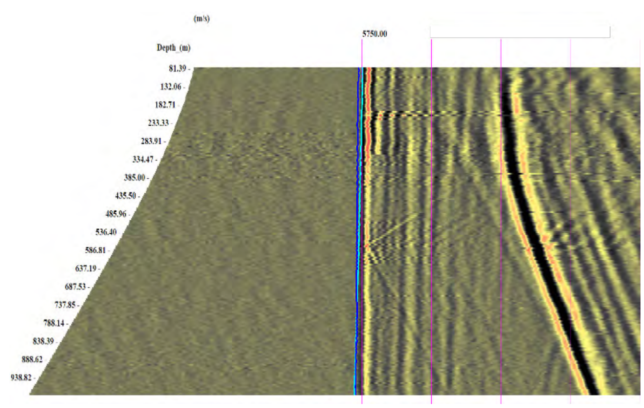
V10



V15



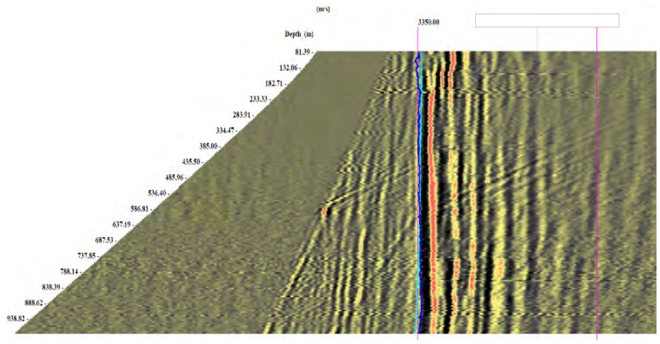
V23



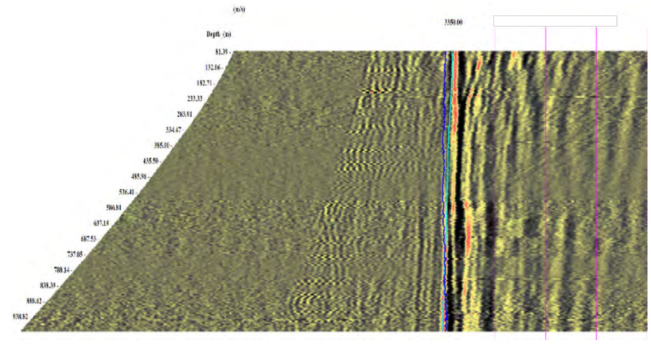
V31

Figure 17: Reduced velocity plots for profiles measured at different VSP shot points (V01, V07, V10, V15, V23 and V31). Vp=5750 m/s appears vertical. Picked P-wave arrival times are shown in blue and arrival times corresponding to the P-wave velocity derived by tomographic inversion are shown in light blue.

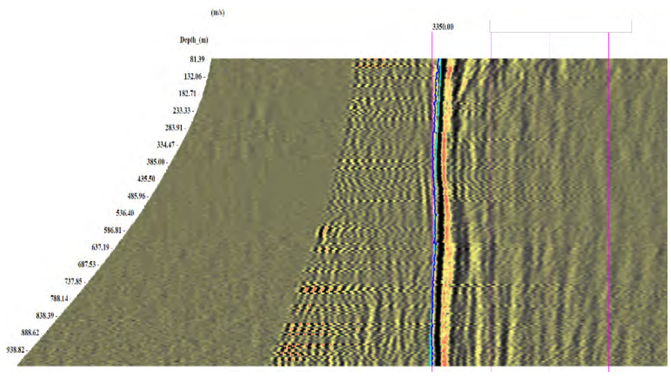
Figure 18 presents the picked arrival times on the T-component profiles from different shot points. By inspecting the reduced velocity plots for Vs=3350 m/s it appears that this velocity is appropriate for later removal of S-waves direct arrivals.



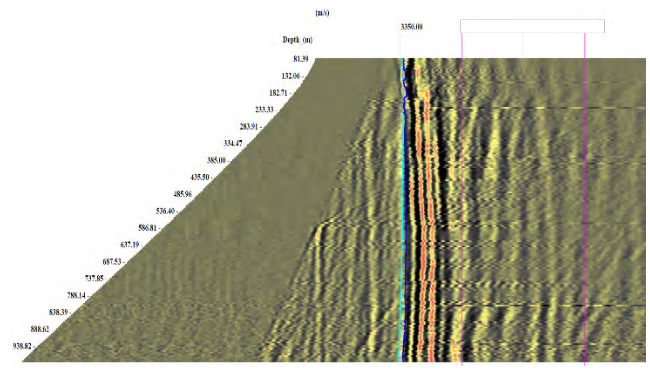
V01



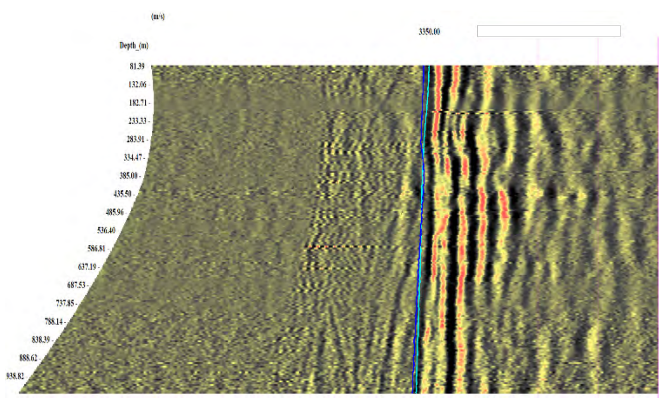
V07



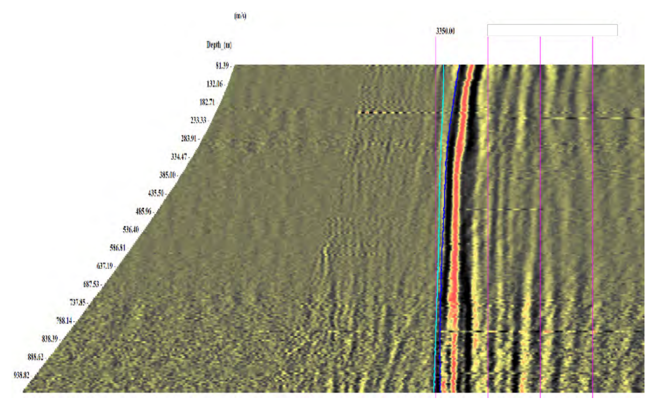
V10



V15



V23



V31

Figure 18: Reduced velocity plots for profiles measured at different VSP shot points (V01, V07, V10, V15, V23 and V31). Vs=3350 m/s appears vertical. Picked S-wave arrival times are shown in blue and arrival times corresponding to the S-wave velocity derived by tomographic inversion are shown in light blue.

5.1.5 Amplitude Compensation and Equalization

The signal levels were adjusted so that the average amplitudes of different traces and different parts of the same trace become comparable. Amplitude compensation (AGC) was performed to cancel the effects of geometrical spreading and attenuation and to reconstruct the original amplitude variations along the trace. With AGC, a variable gain operator is run along the records to increase the amplitude of later events assumed to have traveled along longer paths. The amplitude compensation for all three components was done with the same operator, so that the amplitude ratio among the components is conserved through the whole process. An inverse AGC operator is applied after median filtering, which restores the original amplitudes.

5.1.6 Suppression of Direct P-wave and S-waves and Static Corrections

The direct P-wave and S-wave wave fields were suppressed by means of variable slope 25-trace median filters applied along the P- and the S-first onset times, which corresponds to a +/- 60 m window along the borehole. Following several tests, this appeared to be the optimum filter length for a 50 Hz – 240 Hz frequency band. This band is used for median filter shaping and does not restrict the bandwidth of the data. The processing sequence is summarized in Table 4.

Table 4: Standard Processing Sequence for VSP Data

3-component AGC	Window 200 samples (100 ms)
Variable slope median	Slope: along picked S-wave arrivals Panel (traces) – 25 Window (samples) – 13
Band-pass filter	0-phase Butterworth Order of filter – 4 Low frequency limit (Hz) – 50 High frequency limit (Hz) – 240
Amplitude restore	Inverse AGC
3-component AGC	Window 200 samples (100 ms)
Variable slope median	Slope: along picked P-wave arrivals Panel (traces) – 25 Window (samples) – 13
Band-pass filter	0-phase Butterworth Order of filter – 4 Low frequency limit (Hz) – 50 High frequency limit (Hz) – 240
Amplitude restore	Inverse AGC
Time delay correction	Input times: picked P-wave arrivals Output times: modeled P-wave arrivals computed for constant velocity Vp=5750 m/s

Figure 19 to Figure 21 show the (Z R T) profiles where the direct P- and S-arrivals have been suppressed and static corrections applied, inferred by tomographic inversion (see Section 5.1.4), as described by the standard pre-processing sequence in Table 4.

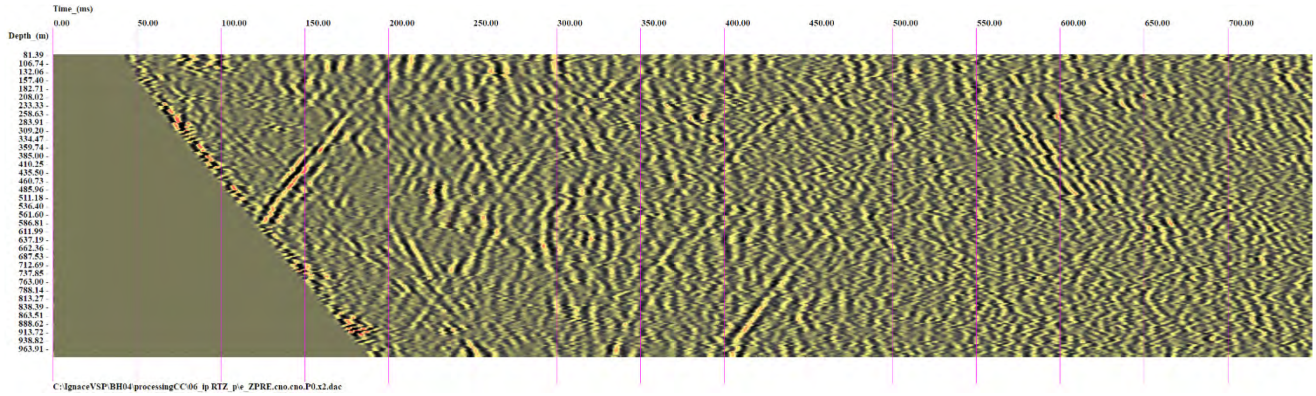


Figure 19: Profile (Z) shown in Figure 12, after removal of direct P- & S-wave fields and static corrections.

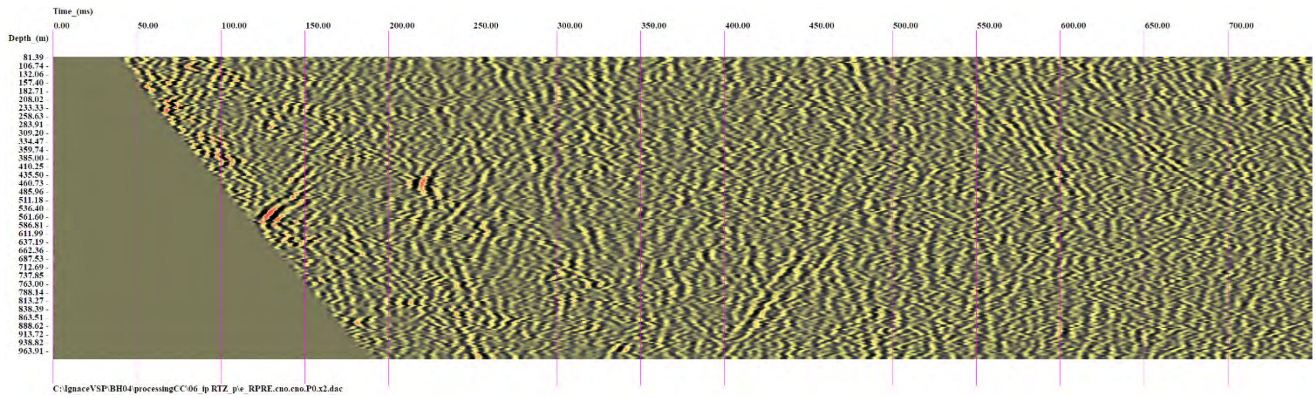


Figure 20: Profile (R) shown in Figure 13, after removal of direct P- & S-wave fields and static corrections.

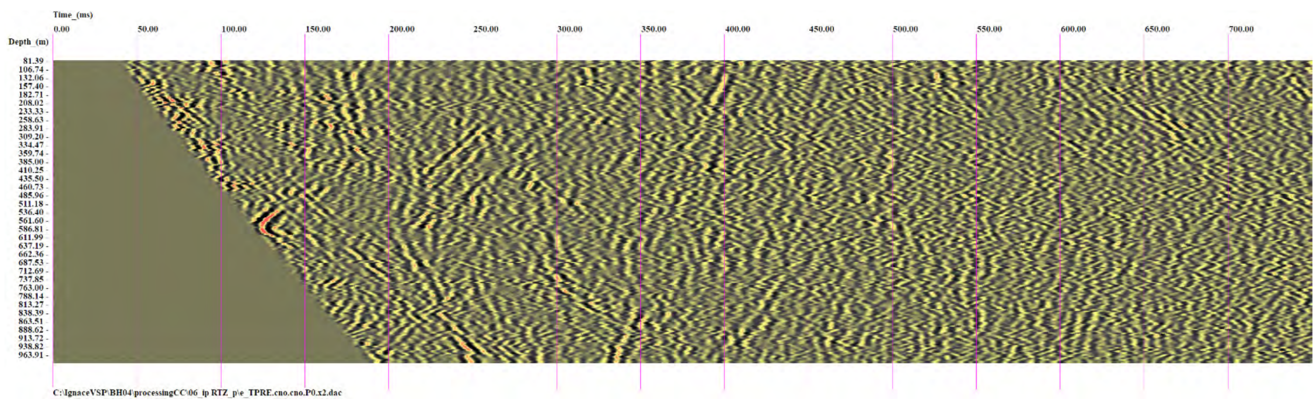


Figure 21: Profile (T) shown in Figure 14, after removal of direct P- & S-wave fields and static corrections.

5.2 Image Point Filtering and Reflector Enhancement in the Image Space for VSP Data

The second stage of the processing sequence focused on reflector enhancing by Image Point filtering. The procedure has been applied on data from all three components. Non-linear enhancement of reflected energy has also been used.

One of the properties of the Image Point transform and related filtering techniques is that, if the velocity field is correctly modeled, the coherent energy reflected by reflectors of any possible orientation adds in phase, producing well-defined maxima in the IP (Image Point) space (Cosma 1990; Cosma and Heikkinen 1996). This offers possibilities for advanced intricate processing, including polarization analysis, azimuth and dip filtering, as well as non-linear and neural network-based coherency-enhancement schemes.

Low energy, dipping P-wave reflectors are retrieved by IP-transform dip filtering and / or non-linear enhancement in the IP space, following the steps given in Table 5.

Table 5: Image Point Processing Sequence for VSP Data

A. Forward IP transform (see Appendix E for the definition of parameters)	Velocity (m/s) – 5750 Rho max (m) – 7000.00 Rho increment (m) – 5 Zita max (m) – 7000.00 Zita min (m) – 0.00 Zita increment (m) – 10
B. Inverse IP transform	Min cos slope – -0.1 Max cos slope – 1
C. Non-linear enhancement in IP space	
D. Inverse IP transform	Min cos slope – -1 Max cos slope – 1
E. Dip filtering in IP space	Dip min. – 30.00º Dip max. – 90.00º
F. Inverse IP transform	Min cos slope – -0.1 Max cos slope – 1

The stages of the filtering process are exemplified in Figure 22 to Figure 27.

Up to Step B in Table 5, no additional enhancement scheme is being applied. However, the intrinsic filtering due to the IP transform can easily be noticed; non-coherent noise being strongly suppressed, as well as coherent trends produced by wave fields traveling with other velocities than the P-wave velocity field specified in the transform input (see Section 5.1.4). Coherent S-wave events were therefore eliminated at this stage.

By further processing, with non-linear enhancement of continuous reflectors in the IP space, up to Step D in Table 5, the coherent P-wave reflected energy appears more clearly, as it can be seen in Figure 25 to Figure 27.

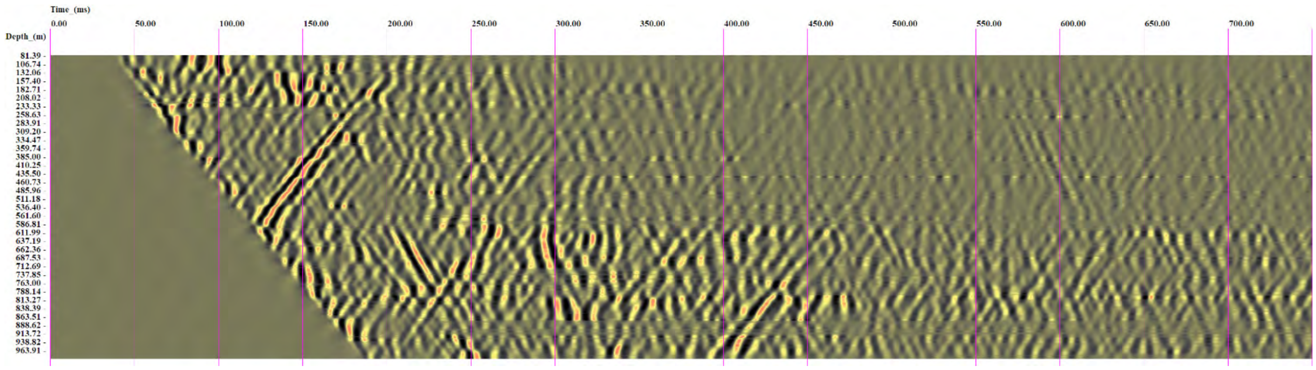


Figure 22: Profile (Z) in Figure 19, after filtering up to step B in Table 5. Normalized to trace.

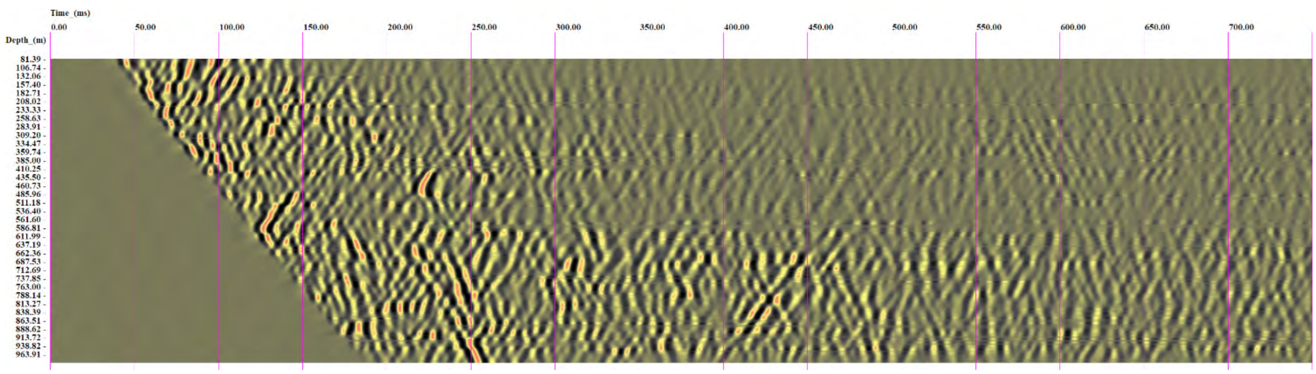


Figure 23: Profile (R) in Figure 20, after filtering up to step B in Table 5. Normalized to trace.

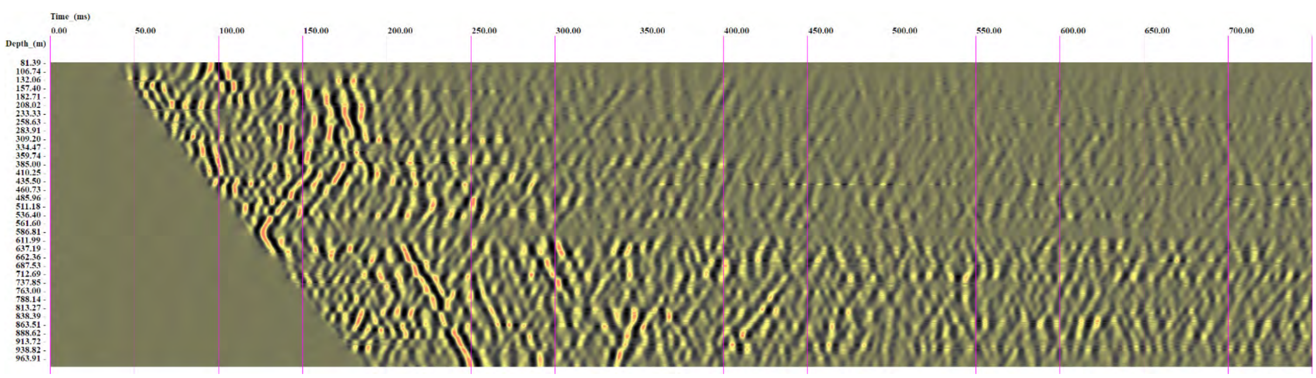


Figure 24: Profile (T) in Figure 21, after filtering up to step B in Table 5. Normalized to trace.

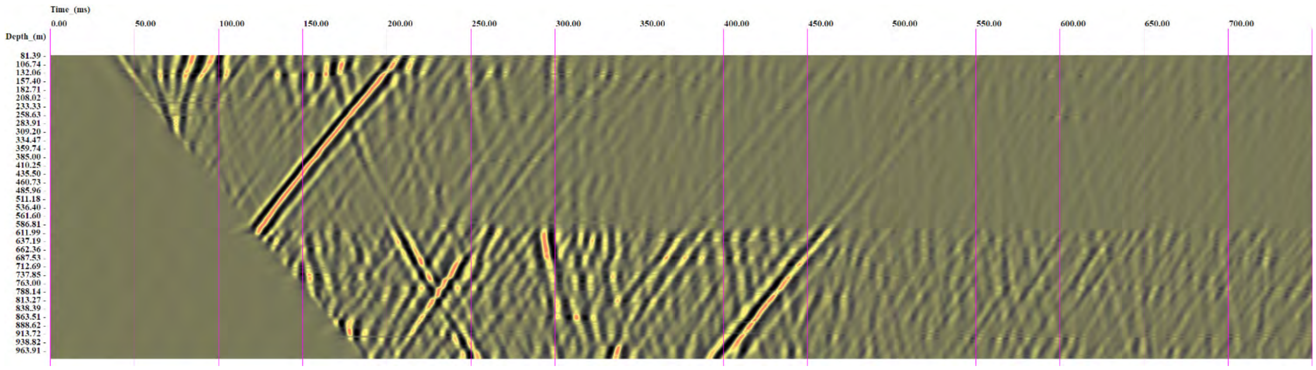


Figure 25: Profile (Z) in Figure 19, after filtering up to step D in Table 5. Normalized to trace.

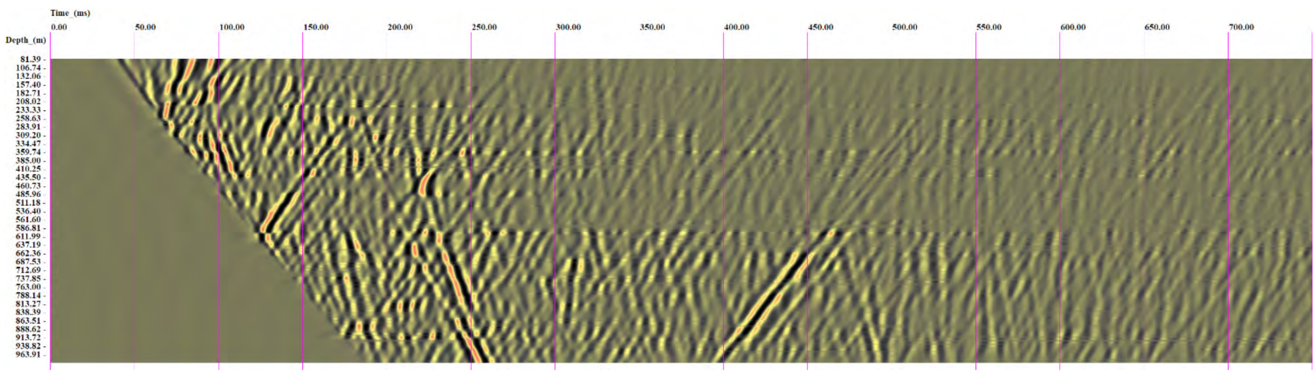


Figure 26: Profile (R) in Figure 20, after filtering up to step D in Table 5. Normalized to trace.

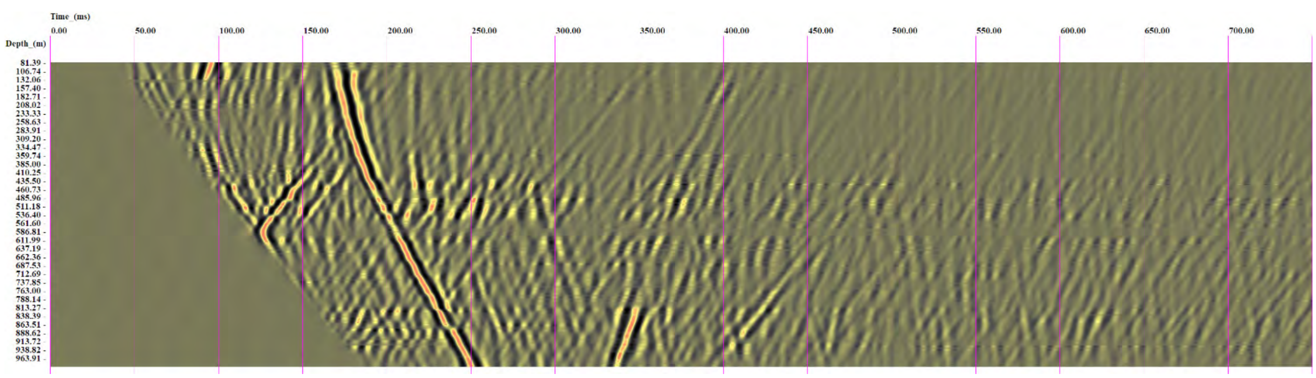


Figure 27: Profile (T) in Figure 21, after filtering up to step D in Table 5. Normalized to trace.

By further processing, with dip filtering in the IP space, up to Step E in Table 5, after inverse IP transform, the dip-filtered P-wave reflected energy of the higher dipping reflectors (Step F in Table 5) appears more clearly, as it can be seen in Figure 28 to Figure 30.

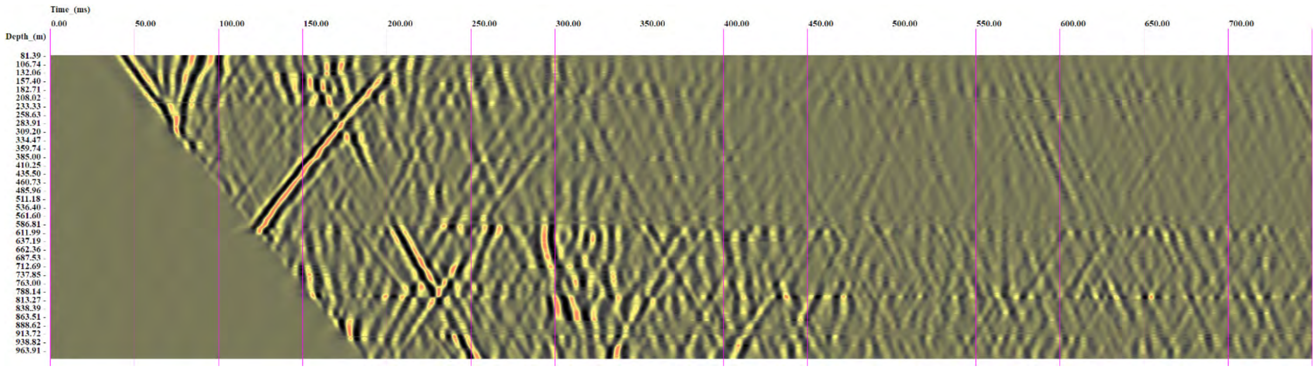


Figure 28: Profile (Z) in Figure 19, after filtering up to step F in Table 5. Normalized to trace.

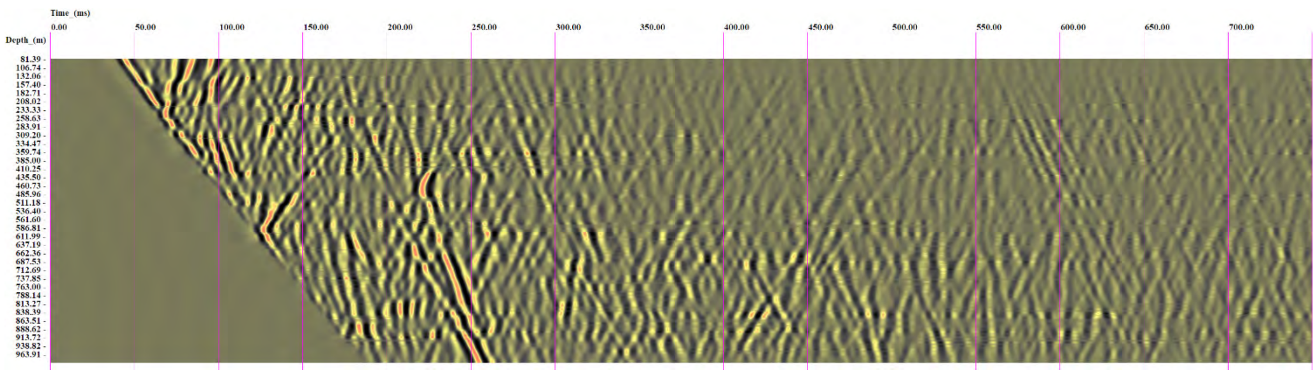


Figure 29: Profile (R) in Figure 20, after filtering up to step F in Table 5. Normalized to trace.

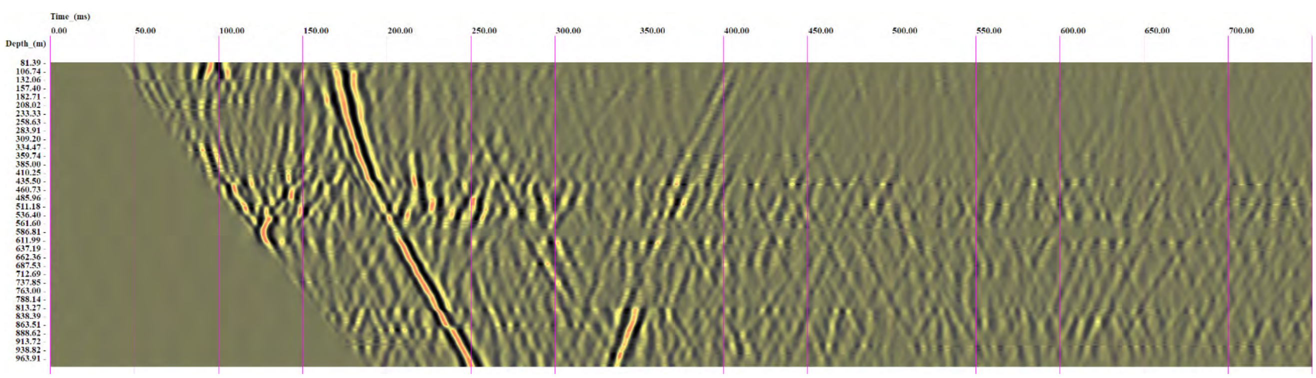


Figure 30: Profile (T) in Figure 21, after filtering up to step F in Table 5. Normalized to trace.

3D Image Point Cloud migration was performed on the data set, as discussed in further detail in Appendix D, however, was not used in the interpretation of the data.

6.0 DATA INTERPRETATION – 3D REFLECTORS LOCALIZATION AND 3D VSP MIGRATIONS

The interpretation phase consists, mainly, of computing the 3D locations and orientations of the reflectors, by using the coordinates of the shot points and the borehole and the velocity determined as part of the processing.

VSP shot gathers are 2D time-depth profiles and the image of a seismic reflector appears as a curved pattern of increased coherency. One approach to interpreting VSP profiles is to match hyperbolic travel time functions with coherent reflection events in the depth-time profiles. However, a full 3D target localization cannot be done from a single shot point because of the missing third dimension. Subsets of shot-gathers are processed together, and locations and orientations of the reflectors are computed by cross-fitting events observed in several profiles.

Reflector positions and orientations are computed from these and displayed in 3-D as reflection elements. An element extends between the computed reflection points corresponding to the given source and the first and the last receiver in the VSP array where the coherent hyperbolic pattern is observed. The width of the element is set approximately equal to the first Fresnel zone, given the position of the reflector relative to those and the dominant frequency of the event.

The results of the cross-fitting procedure are presented in Table 6 and illustrated in Figure 31 and Appendix F. The interpreted reflectors are marked with same-color lines on the processed profiles and labeled with reflector numbers, as presented on the first column in Table 6. All coordinates shown in this report are reduced coordinates, obtained by subtracting 5480000 on the Northing and 550000 on the Easting coordinates, respectively.

The geometrical estimates were obtained by cross fitting amongst all the VSP processed profiles from borehole IG_BH04 only.

6.1 Interpretation of Seismic Reflectors from VSP Data

6.1.1 Event Picking

In a VSP profile, backscattered wave fronts arriving from various regions of the investigated volume can appear at similar times and tend to crowd the records. The Image Point (IP) techniques have been the key to resolve and identify intermingling events. In hard rock settings, the amplitude of an event is not by itself relevant, the classification of the reliability and relevance of the events being based on their continuity within each profile and persistence from profile to profile. This applies to events corresponding to features with a lateral extent equal to or larger than the typical distance between adjacent shot points, which has been in this case ~100 m.

6.1.2 Determining the Azimuth

As mentioned above, resolving the site geometry by multi-offset multi-azimuth VSP relies on the simultaneous interactive fitting among several profiles corresponding to different shot points.

The azimuth estimate is obtained by comparing profiles from several shot points. Theoretically, seven shot points, forming non-collinear triplets, are needed to ensure that a plane reflector of unlimited extent does not fall in the blind zone of at least three profiles. Subgroups are formed from the total number of shots to probe various regions of the rock volume.

The first column in Table 6 is the event number, which is the same as the label of the reflector curves shown in the profiles displayed in Figure 31 and Appendix F. The width of the reflective elements shown in the 3-D plots of Figure 32 to Figure 35 is 100 m, which corresponds to +/- two mean wavelengths.

The second column is the distance from the top of the hole and the reflector intersection with the hole (or its extension). This parameter is relevant for interpretation only for the reflectors actually intersecting the borehole. For the others, it is only a mathematical way of describing the position of the reflector relative to the borehole axis.

The dips of the reflectors given in the third column and dip directions in the fourth column were determined interactively, in several steps, seeking the best reflector fit among all VSP profiles.

In each profile, reflectors are qualitatively classified in three categories. Major events, appearing as well defined and continuous, belong to the first category (Visibility mark = 2, thicker line). The weaker reflectors, visible but overridden by stronger events of other orientations belong to the second category (Visibility mark = 1, thinner line). If the position and orientation of an event are determined from other profiles but the event does not appear as visible in the current profile, it is categorized as a third class (Visibility mark = 0, dashed line). The mean of the marks obtained in all profiles is then computed for each reflector. Reflectors obtaining mean mark larger than 1.0 (the absolute maximum being 2.0) are classified as certain (class I). Reflectors with mean marks between 0.5 and 1.0 are classified as probable (class II). The weak seismic structures with mean marks lower than 0.5 are classified as possible (class III). The fifth column presents the confidence class, as defined above.

The 3D position and orientation of a planar reflector are fully determined by the coordinates of the foot of the perpendicular descended on the plane from a local origin, in this case the top of the borehole. This representation is attractive computationally because small variations of the X,Y,Z coordinates produce equally small variations of the corresponding hyperbolic time-depth functions in the time-depth data profiles, which helps the interactive fitting amongst several profiles. A certain variability of the fit is to be expected because of local deviations from planarity.

A maximum variability in the fit of +/- half wavelength on each side of the predicted travel time function is considered to represent the same reflector, This variability is then expressed as "Depth", "Dip" and "Dip Direction," which are more intuitive parameters than the X,Y,Z coordinates of the point defined above.

Columns 6 to 8 in Table 6 display the "Delta Depth", "Delta Dip" and "Delta Dip Direction" values estimated for each reflector.

Note that "Delta Depth" values are very large for sub-vertical reflectors, as the "Depth" of intersection between the reflector and the axis of the borehole varies considerably for small variations in Dip or Dip Direction of such a reflector.

Conversely, "Delta Dip Direction" values can be large for sub-horizontal reflectors.

Columns 9 to 11 in Table 6 give the coordinates of the crux point that, together with the coordinates of the Origin chosen for interpretation, fully characterizes the reflector element. For all seismic data interpreted here the top of borehole IG_BH04 was chosen as the origin for interactive interpretation (Northing 6488.05 m; Easting 6957.25 m and Elevation 443.46 masl). Having a common origin facilitates further integration of interpreted reflectors, among several profiles measured from other boreholes or from surface.

The last column in Table 6 lists the shot points where each reflector was identified.

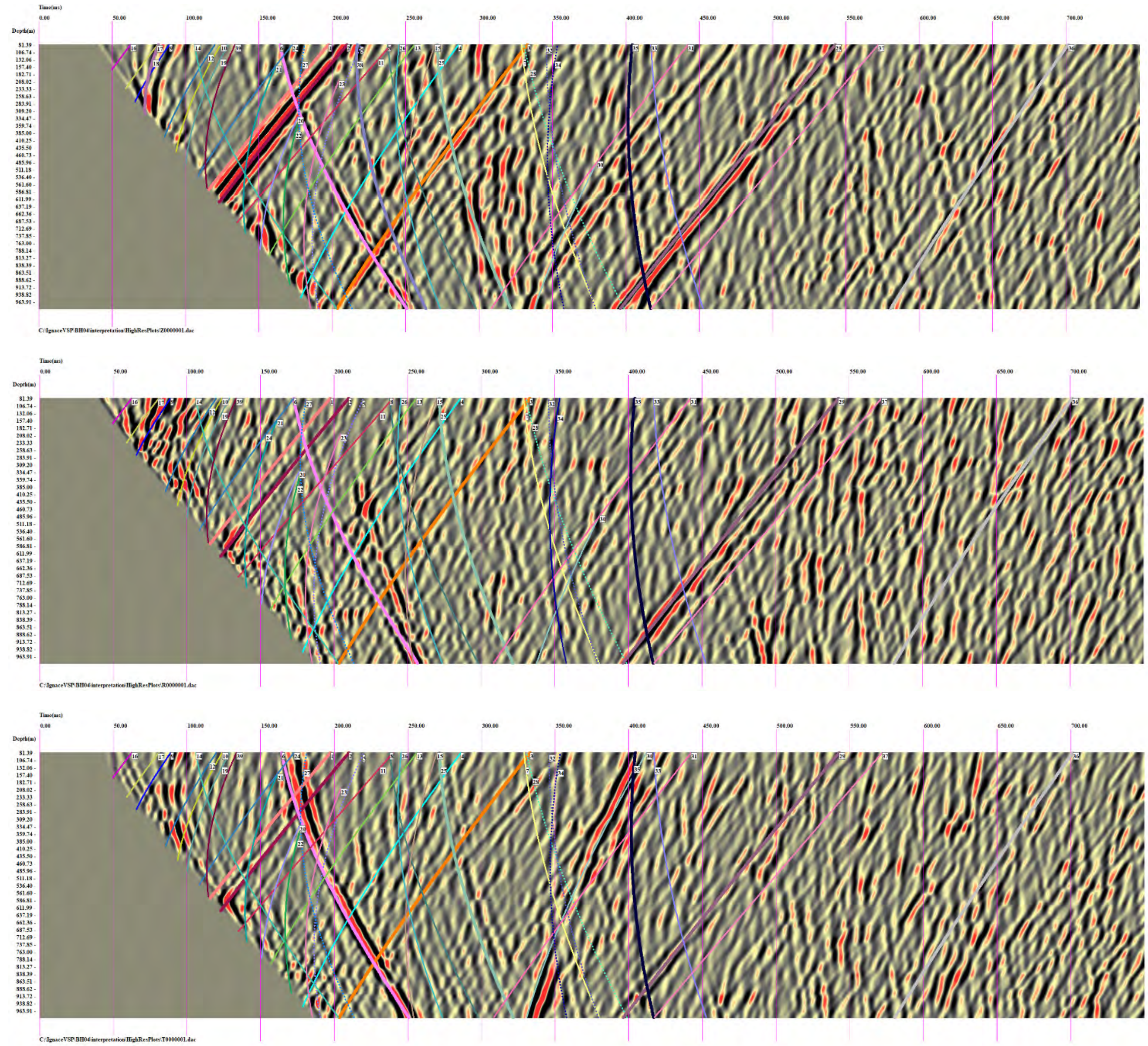


Figure 31: Axial (Z), Radial (R) and Transverse (T) components profiles from shot point V01, with interpreted reflectors.

6.2 Reflectors Interpreted from the IG_BH04 VSP Data

Table 6: Parameters of Reflector Interfaces Interpreted from the VSP Data Acquired in Borehole IG_BH04

Refl No.	Intersection Depth (m)	Dip (°)	Dip Dir (°)	Refl Class	Delta Depth (m)	Delta Dip (°)	Delta Dip Dir (°)	Northing Crux (m)	Easting Crux (m)	Elevation Crux (m)	Visible from shot point
1	581.00	38.00	315.00	I	6.16	0.29	1.81	6248.53	7196.77	9.90	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 20, 21, 25, 26, 27, 30, 31, 39, 40
2	623.60	39.36	316.29	I	6.24	0.19	3.01	6219.91	7213.59	-8.72	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 20, 21, 23, 25, 26, 27, 28, 30, 31, 35, 39, 40
3	1050.00	8.35	339.00	I	6.15	0.27	28.33	6354.85	7008.39	-528.87	1, 2, 3, 4, 6, 7, 8, 9, 10, 14, 15, 16, 17, 20, 21, 23, 25, 26, 27, 28, 29, 30, 31, 35, 36, 37, 38, 39, 40
4	950.00	12.00	15.00	I	7.48	0.41	6.93	6317.74	6911.62	-386.04	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 20, 21, 23, 25, 27, 28, 29, 30, 35, 36, 37, 38, 39
5	1030.00	59.50	226.00	II	10.54	0.44	0.79	6873.67	7356.57	116.47	3, 4, 6, 7, 8, 9, 10, 11, 15, 16, 17, 20, 21, 23, 25, 27, 28, 29, 35, 36
6	-7614.10	87.00	183.66	II	80.68	1.12	1.37	6972.34	6988.26	418.03	1, 2, 3, 4, 7, 11, 14, 15, 17, 20, 27, 29, 30
7	-28199.95	87.85	189.35	II	270.94	0.22	0.30	7483.33	7121.13	405.59	1, 2, 3, 4, 6, 7, 8, 9, 10, 14, 15, 17, 20, 23, 25, 26, 27, 29, 30, 31, 35
8	79238.70	82.51	183.82	I	8588.98	0.92	0.18	7168.99	7002.74	353.71	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 14, 15, 16, 20, 21, 23, 25, 26, 27, 28, 29, 30, 31, 35, 36
9	277.00	15.00	345.00	II	0.75	4.48	8.48	6422.87	6974.72	191.61	1, 2, 3, 4, 6, 7, 10, 11, 14, 15, 16, 17, 20, 21, 25, 31, 39, 40
10	450.00	14.00	42.00	I	10.36	1.10	8.67	6419.82	6895.81	75.21	1, 2, 4, 6, 7, 8, 9, 10, 14, 15, 16, 17, 20, 23, 25, 27, 28, 29, 30, 31, 35, 38, 39, 40

Table 6: Parameters of Reflector Interfaces Interpreted from the VSP Data Acquired in Borehole IG_BH04

Refl No.	Intersection Depth (m)	Dip (°)	Dip Dir (°)	Refl Class	Delta Depth (m)	Delta Dip (°)	Delta Dip Dir (°)	Northing Crux (m)	Easting Crux (m)	Elevation Crux (m)	Visible from shot point
11	694.00	33.00	305.00	I	5.88	0.18	2.03	6275.44	7260.88	-127.32	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 16, 17, 20, 21, 25, 27, 29, 30, 31, 35, 36, 37, 38, 39, 40
12	401.01	8.70	11.66	I	7.11	1.02	31.69	6434.12	6946.12	83.62	1, 2, 6, 7, 8, 9, 10, 11, 14, 15, 20, 21, 23, 26, 27, 28, 29, 30, 31, 35, 36, 37, 38, 39, 40
13	816.00	22.83	351.01	I	6.34	0.48	24.32	6202.74	7002.38	-242.73	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 20, 23, 25, 26, 27, 28, 29, 35, 36, 37, 38, 39, 40
14	3127.00	70.60	170.00	II	92.67	0.94	0.84	6781.16	6900.67	338.35	1, 2, 14, 15, 16, 17, 20, 21, 25, 26, 27, 28, 29, 30, 31, 36
15	1655.00	79.94	244.20	II	15.56	17.96	28.02	6810.95	7625.26	311.90	1, 3, 4, 6, 7, 8, 9, 10, 11, 15, 16, 17, 21, 23, 25, 26, 27, 29, 30, 31
16	170.00	57.91	307.36	III	6.97	4.63	1.56	6417.58	7049.55	370.64	1, 2, 3, 4, 6, 7, 11, 14, 15, 30, 31
17	235.01	57.46	310.56	III	7.07	4.09	6.50	6383.80	7079.06	341.17	1, 2, 3, 6, 8, 10, 11, 14, 15, 16, 30
18	320.00	65.44	246.52	II	10.64	2.73	2.03	6563.67	7131.30	356.72	1, 2, 3, 4, 6, 8, 14, 15, 20, 21, 23, 25, 26, 27
19	490.00	18.70	44.03	I	7.91	1.79	0.78	6397.15	6869.38	69.93	1, 2, 3, 4, 6, 7, 8, 9, 10, 14, 15, 16, 17, 20, 21, 25, 26, 27, 28, 29, 30, 31, 35, 36, 39
20	788.01	71.40	307.78	II	8.99	4.88	61.02	6183.08	7350.76	275.90	1, 2, 3, 4, 6, 7, 9, 10, 11, 14, 15, 16, 17, 20, 21, 25, 30, 31
21	728.91	77.51	311.16	II	10.76	3.58	70.63	6218.33	7265.81	352.71	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 16, 17, 20, 21, 25, 31
22	906.01	79.75	308.21	II	11.75	14.93	73.97	6183.13	7344.58	354.28	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 16, 17, 20, 30, 31

Table 6: Parameters of Reflector Interfaces Interpreted from the VSP Data Acquired in Borehole IG_BH04

Refl No.	Intersection Depth (m)	Dip (°)	Dip Dir (°)	Refl Class	Delta Depth (m)	Delta Dip (°)	Delta Dip Dir (°)	Northing Crux (m)	Easting Crux (m)	Elevation Crux (m)	Visible from shot point
23	989.00	80.55	296.16	I	11.80	8.01	63.52	6246.48	7449.14	352.29	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 20, 21, 25, 26
24	536.11	54.44	303.58	II	6.72	0.27	9.30	6281.39	7268.59	176.29	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 14, 15, 17, 21, 25, 30, 31
25	21052.83	79.00	180.30	II	392.53	0.04	0.02	7308.15	6961.54	284.05	1, 2, 3, 4, 6, 7, 8, 9, 11, 15, 16, 17, 20, 23, 25, 26, 27, 29, 30, 31, 36
26	3000.00	55.99	65.86	I	30.45	1.21	103.09	6236.27	6395.51	28.10	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 20, 21, 23, 25, 26, 27, 28, 29, 30, 31, 35, 36
27	1500.04	68.00	20.00	I	17.49	2.24	126.67	6054.89	6799.59	257.22	3, 4, 7, 8, 9, 10, 11, 14, 15, 16, 17, 20, 21, 25, 30, 35, 36, 37, 38, 39
28	-5699.97	85.00	161.64	III	18.88	0.59	145.52	7451.48	6637.43	354.65	2, 3, 7, 31
29	1640.00	18.00	330.00	I	5.98	0.03	4.55	6066.81	7200.45	-1053.54	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 20, 21, 23, 25, 26, 27, 28, 29, 30, 31, 35, 37, 38, 39
30	1715.85	58.01	341.03	I	8.42	1.40	111.14	5524.16	7288.67	-193.31	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 21, 23, 25, 27, 28, 29, 31, 36, 38, 39, 40
31	1400.00	14.00	352.83	I	6.20	0.47	0.67	6177.64	6996.32	-811.33	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 14, 16, 17, 20, 23, 25, 26, 27, 28, 29, 31, 35, 36, 37, 38, 39, 40
32	12591.38	61.13	129.07	II	119.95	8.94	43.08	7082.29	6225.21	-76.42	2, 3, 4, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 20, 23, 27, 28, 29, 30, 31, 36
33	76958.23	65.52	131.96	II	1825.36	9.52	40.21	7268.62	6089.08	-88.00	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 20, 23, 25, 26, 28, 31, 36
34	3850.01	60.90	46.28	II	26.23	0.86	126.94	5865.25	6306.03	-58.01	3, 4, 6, 7, 8, 9, 10, 11, 16, 17, 20, 25, 26, 27, 28, 29, 30, 31, 35, 36

Table 6: Parameters of Reflector Interfaces Interpreted from the VSP Data Acquired in Borehole IG_BH04

Refl No.	Intersection Depth (m)	Dip (°)	Dip Dir (°)	Refl Class	Delta Depth (m)	Delta Dip (°)	Delta Dip Dir (°)	Northing Crux (m)	Easting Crux (m)	Elevation Crux (m)	Visible from shot point
35	6596.46	67.42	44.23	I	21.11	0.64	128.89	5712.76	6202.44	-6.51	1, 3, 4, 6, 7, 8, 9, 10, 11, 15, 16, 17, 20, 23, 25, 26, 27, 29, 30, 31, 35, 36, 40
36	2447.56	34.87	359.19	I	6.62	0.01	83.37	5335.04	6973.58	-1211.49	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 20, 21, 23, 25, 26, 27, 28, 29, 30, 31, 35, 36, 37, 38, 39, 40
37	1668.45	22.40	291.32	I	5.76	0.48	0.17	6257.25	7548.73	-1096.90	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 20, 21, 23, 25, 26, 27, 28, 29, 30, 31, 35, 37, 38, 39, 40
38	4118.62	80.25	20.62	II	74.54	1.42	139.35	5957.13	6757.51	345.96	1, 2, 3, 6, 7, 8, 11, 14, 15, 16, 17, 20, 21, 28, 29, 30, 35, 36
39	575.00	78.39	313.62	II	10.98	1.55	67.25	6272.38	7183.53	379.25	1, 2, 3, 7, 8, 9, 10, 11, 14, 16, 17, 20, 21, 31
Crux origin = top of Hole IG_BH04					6488.05	6957.25	443.46				
Reflector Class				Coordinates translation: Northing +5480000 and Easting + 550000							
I	Strong										
II	Good										
III	Weak										

Figure 32 to Figure 34 show different views of all reflector elements interpreted from the seismic profiles measured in borehole IG_BH04. In these figures, the plot on the left displays the 3D reflector elements, while the plot on the right displays the interpreted reflector surfaces computed by 3D fitted interpolation through the elements corresponding to each reflector.

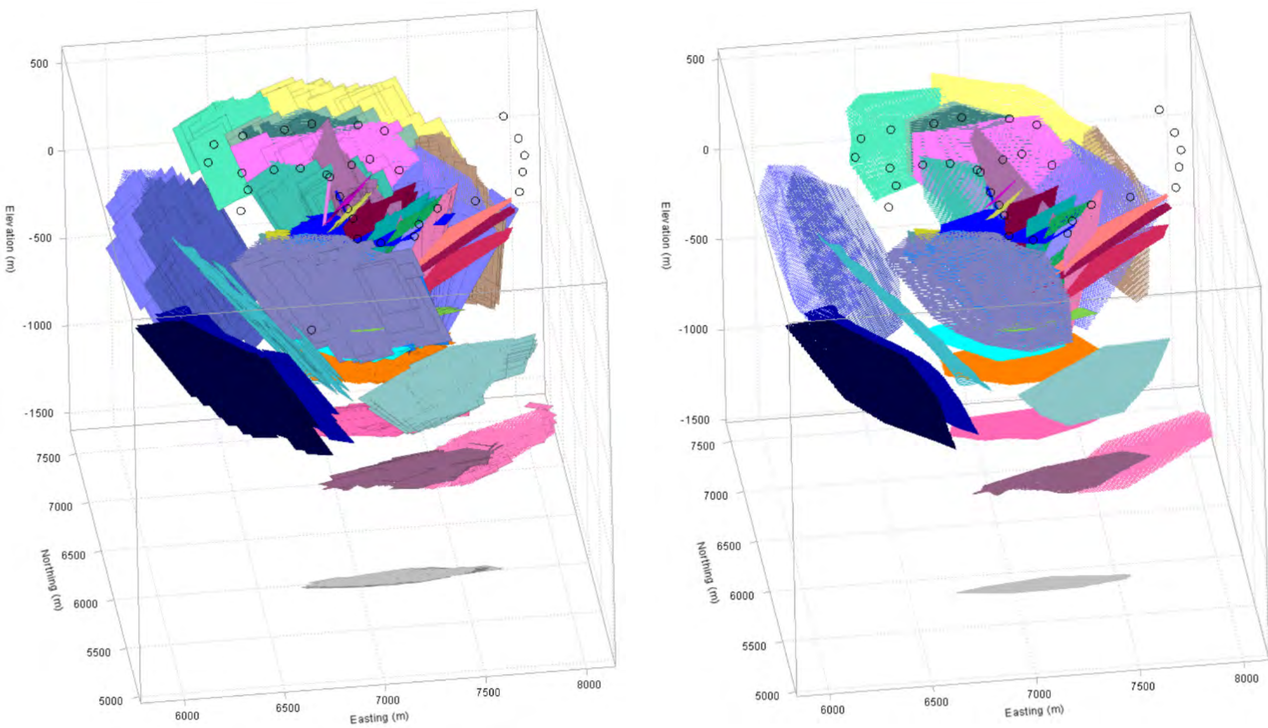


Figure 32: 3D view of all reflectors interpreted from all VSP data acquired from borehole IG_BH04.

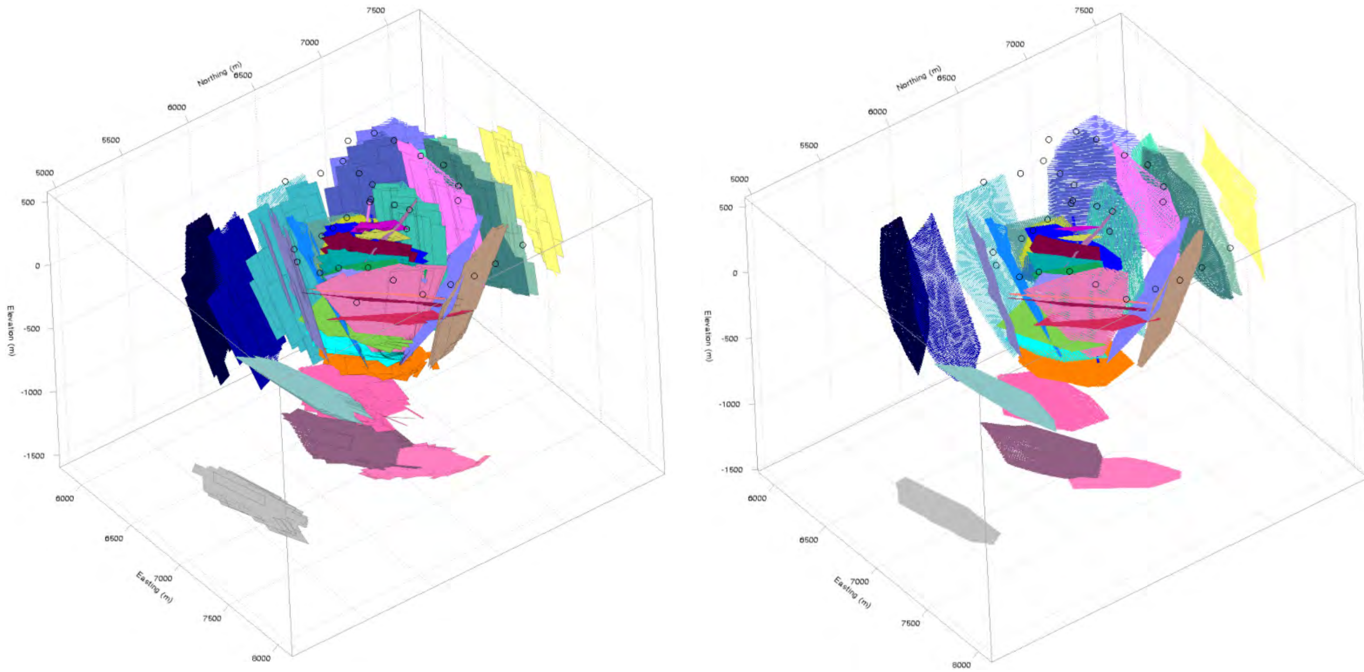


Figure 33: 3D view of all reflectors interpreted from all VSP data acquired from borehole IG_BH04.

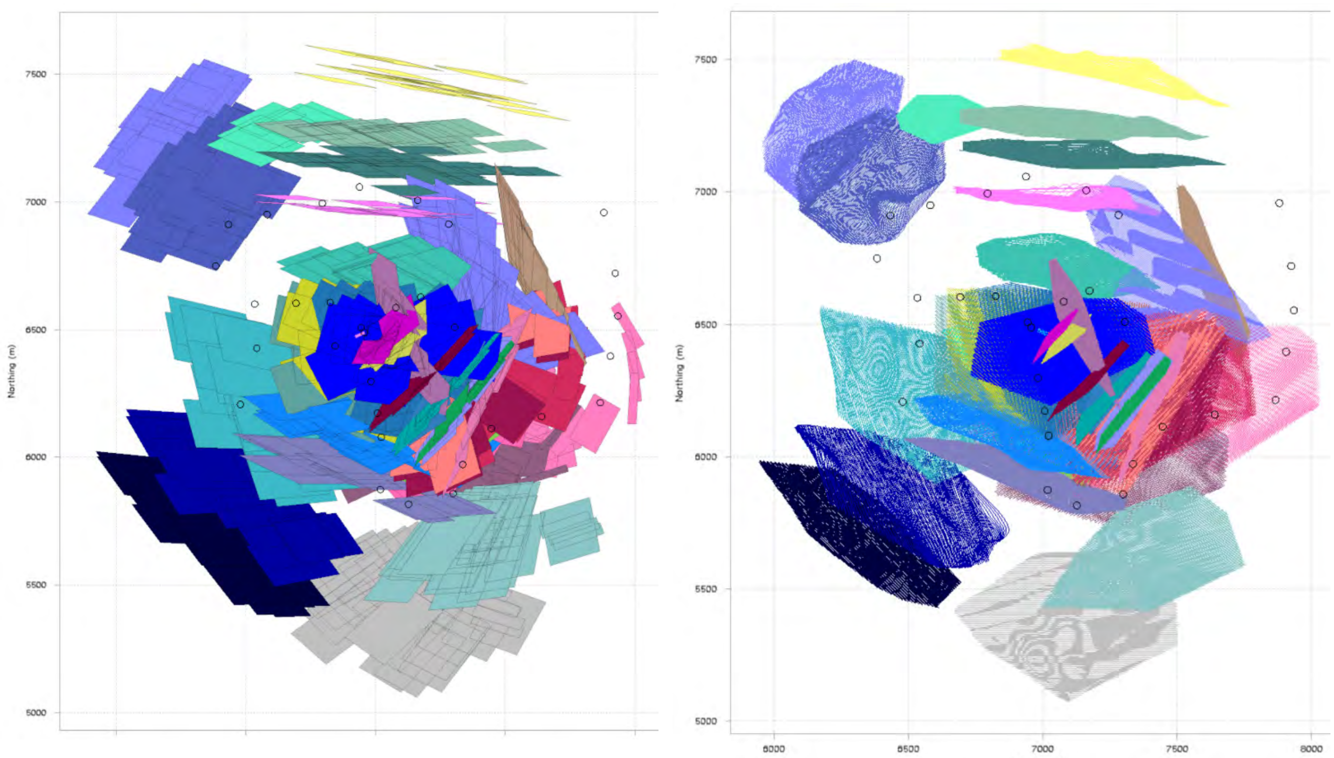


Figure 34: View from top of all reflector elements (left) and reflector surfaces (right) interpreted from all VSP data acquired from borehole IG_BH04.

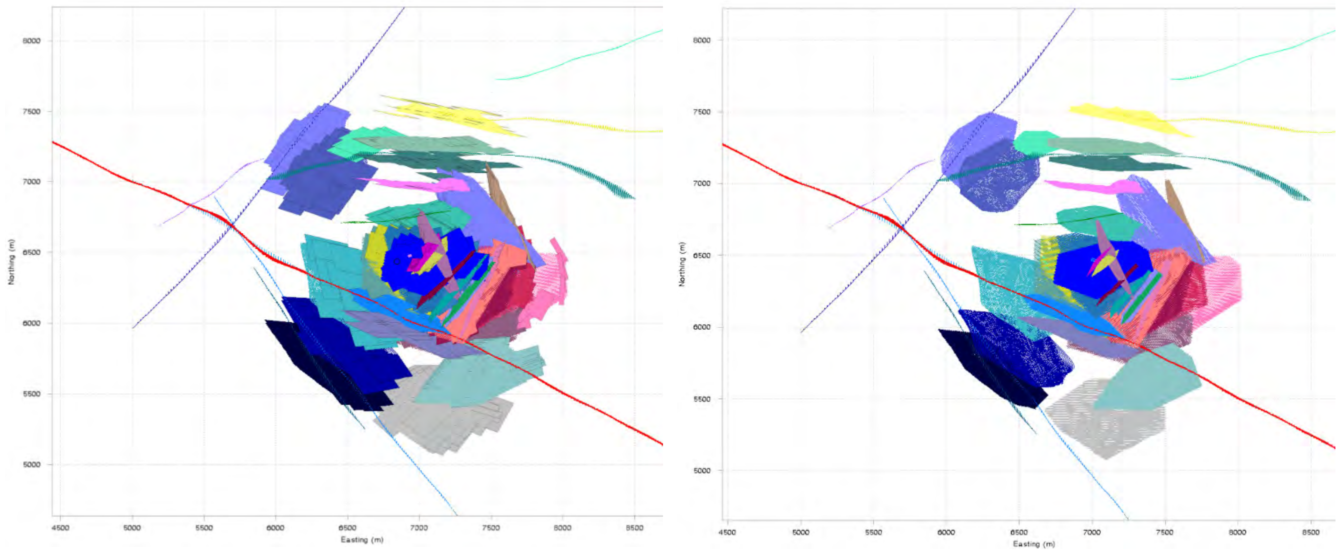


Figure 35: View from top of main site features (dykes and lineaments interpreted from surface are shown in magenta; provided by NWMO) together with all reflector elements (left) and reflector surfaces (right) interpreted from all VSP data acquired from borehole IG_BH04.

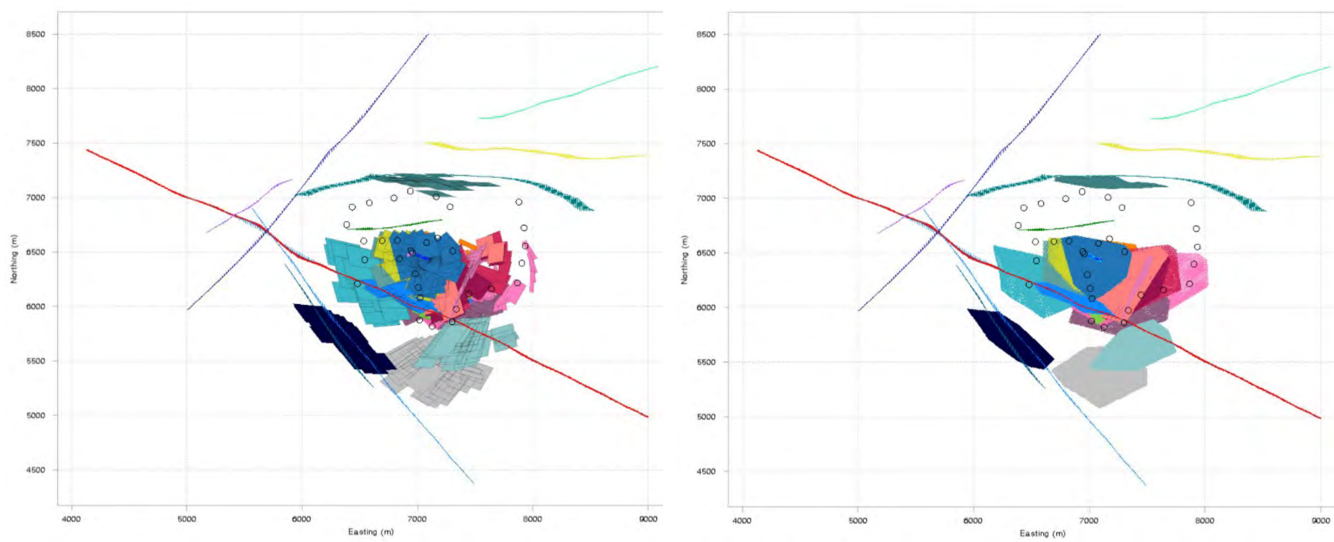


Figure 36: View from top of main site features (dykes and lineaments interpreted from surface are shown in magenta; provided by NWMO) together with reflector elements (left) and reflector surfaces (right) interpreted as strong reflectors (Class I) from all VSP data acquired from borehole IG_BH04.

Figure 37 illustrates the orientation distribution of the interpreted reflectors.

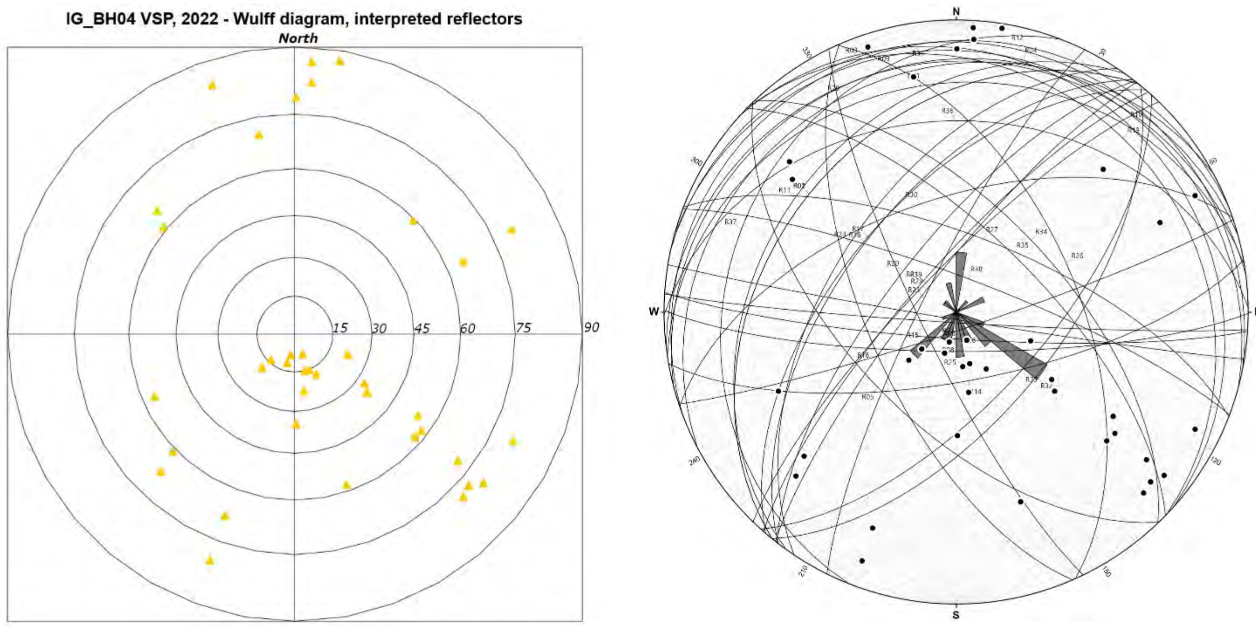


Figure 37: Left: Stereographic projection (Wulff diagram) of all reflectors interpreted from the VSP data measured in borehole IG_BH04 and Right: Rose diagram and Circular histogram.

Table 7: Reflector Interfaces Interpreted to Intersect Borehole IG_BH04

Refl No.	Intersection Depth (m)	Dip (°)	Dip Dir (°)	Refl Class	Comments (with reference to the lithology log of borehole IG_BH04, WP03)
1	581.00	38.00	315.00	I	Strong Vp & Vs variation, 570-582 m
2	623.60	39.36	316.29	I	Large Vp & Vs variation, 616-620 m amphibolite
4	950.00	12.00	15.00	I	Weak Vp & Vs variation, 943-945 m amphibolite, foliated, dyke; 963m amphibolite dyke, foliated
9	277.00	15.00	345.00	II	276.5 m lithological change
10	450.00	14.00	42.00	I	
11	694.00	33.00	305.00	I	Small Vs variation
12	401.01	8.70	11.66	I	~396 m mild Vp & large Vs variation
13	816.00	22.83	351.01	I	
16	170.00	57.91	307.36	III	Small Vp & Vs variation, lithological contact
17	235.01	57.46	310.56	III	Small Vp & Vs variation
18	320.00	65.44	246.52	II	Mild Vp & large Vs variation, lithological contact
19	490.00	18.70	44.03	I	Large Vp & Vs variation, 488-492 m intrusive dyke, quartzolite into tonalite
20	788.01	71.40	307.78	II	Thin dyke intrusion
21	728.91	77.51	311.16	II	
22	906.01	79.75	308.21	II	Amphibolite dyke, strong anomaly; 905-906.5 m amphibolite dyke
23	989.00	80.55	296.16	I	Strong Vp & Vs variation, 963m, 977-978m, 988-989.6m amphibolite dykes, foliated

Table 7: Reflector Interfaces Interpreted to Intersect Borehole IG_BH04

Refl No.	Intersection Depth (m)	Dip (°)	Dip Dir (°)	Refl Class	Comments (with reference to the lithology log of borehole IG_BH04, WP03)
24	536.11	54.44	303.58	II	
39	575.00	78.39	313.62	II	Strong Vp & Vs variation, 575-576m amphibolite dyke intrusion

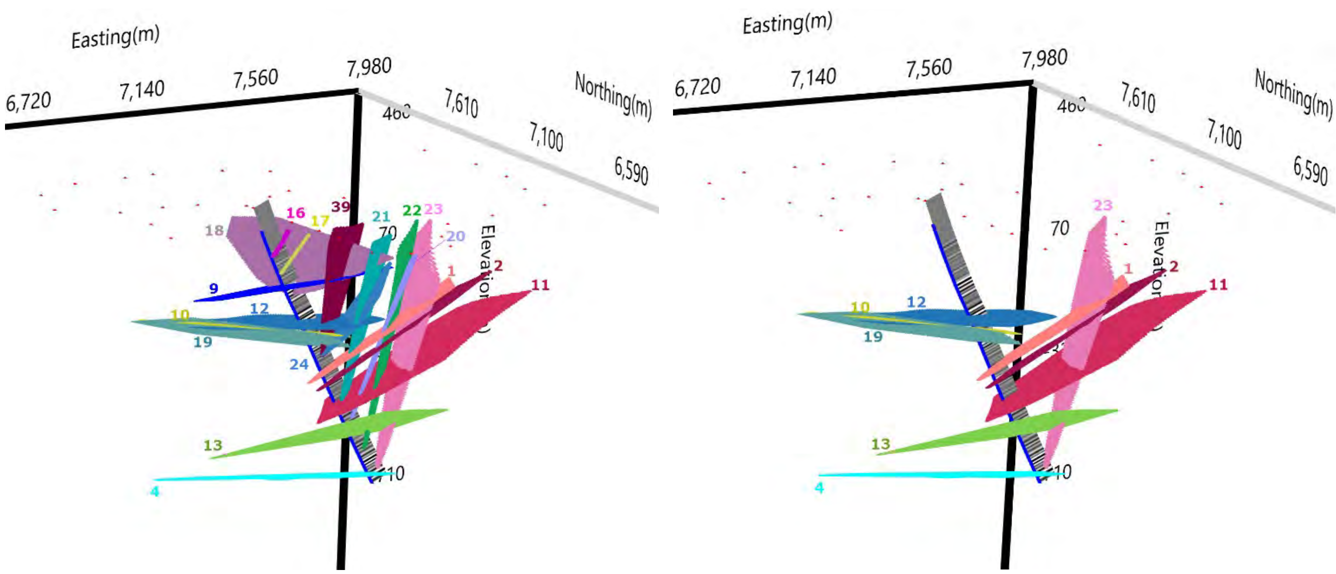


Figure 38: Left: 3D view of reflector surfaces interpreted from all VSP data acquired from borehole IG_BH04 and described in Table 7. Right: similar with the plot on the left, but showing only Class I reflectors.

The synthetic seismogram (see also Figure 45 and Figure 46) is illustrated in gray. Table 8, below, presents the reflector interfaces interpreted as sub-vertical features that may be associated with lineaments mapped from surface. The lineaments numbers provided in Table 8 are defined and presented in DesRoches et al. (2021). The sub-vertical features are also shown in Appendix G.

Table 8: Reflector interfaces interpreted as sub-vertical features that may be associated with lineaments mapped from surface, as shown in Figure 35.

Refl No.	Intersection Depth (m)	Dip (°)	Dip Dir (°)	Refl Class	Comments (with reference to the lineaments, as provided by NWMO)
7	-28199.95	87.85	189.35	II	Possibly associated with lineament IFZ016
8	79238.70	82.51	183.82	I	Possibly associated with lineament IFZ019
14	3127.00	70.60	170.00	II	Possibly associated with lineament IFZ036
25	21052.83	79.00	180.30	II	Possibly associated with lineament IFZ019
27	1500.04	68.00	20.00	I	Possibly associated with lineament DYKE01
28	-5699.97	85.00	161.64	III	Possibly associated with lineament IFZ018
33	76958.23	65.52	131.96	II	Possibly associated with lineament IFZ004
34	3850.01	60.90	46.28	II	Possibly associated with lineament IFZ012
35	6596.46	67.42	44.23	I	Possibly associated with lineament IFZ030
38	4118.62	80.25	20.62	II	Possibly associated with lineament DYKE01

6.3 Physical Properties Derived from the VSP Data

P- and S-wave sonic logs and density logs were reported for borehole IG_BH04 by Golder in NWMO Report APM-REP-01332-0356. These are shown in Figure 39.

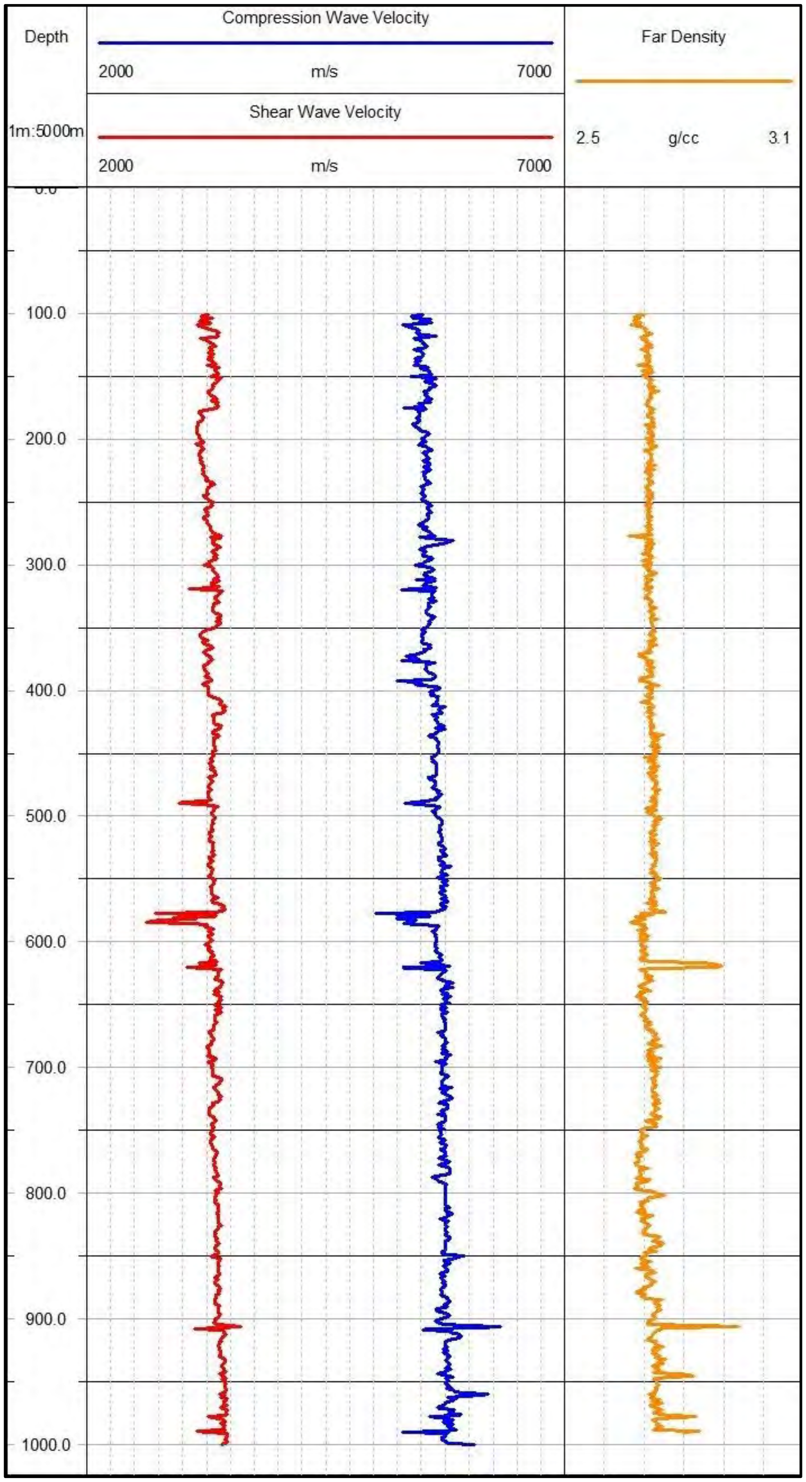


Figure 39: Borehole Seismic Velocity and Density Logs for IG_BH04.

The Shear and Young moduli, as well as the Poisson ratio logs from the measured borehole logs are shown in Figure 40.

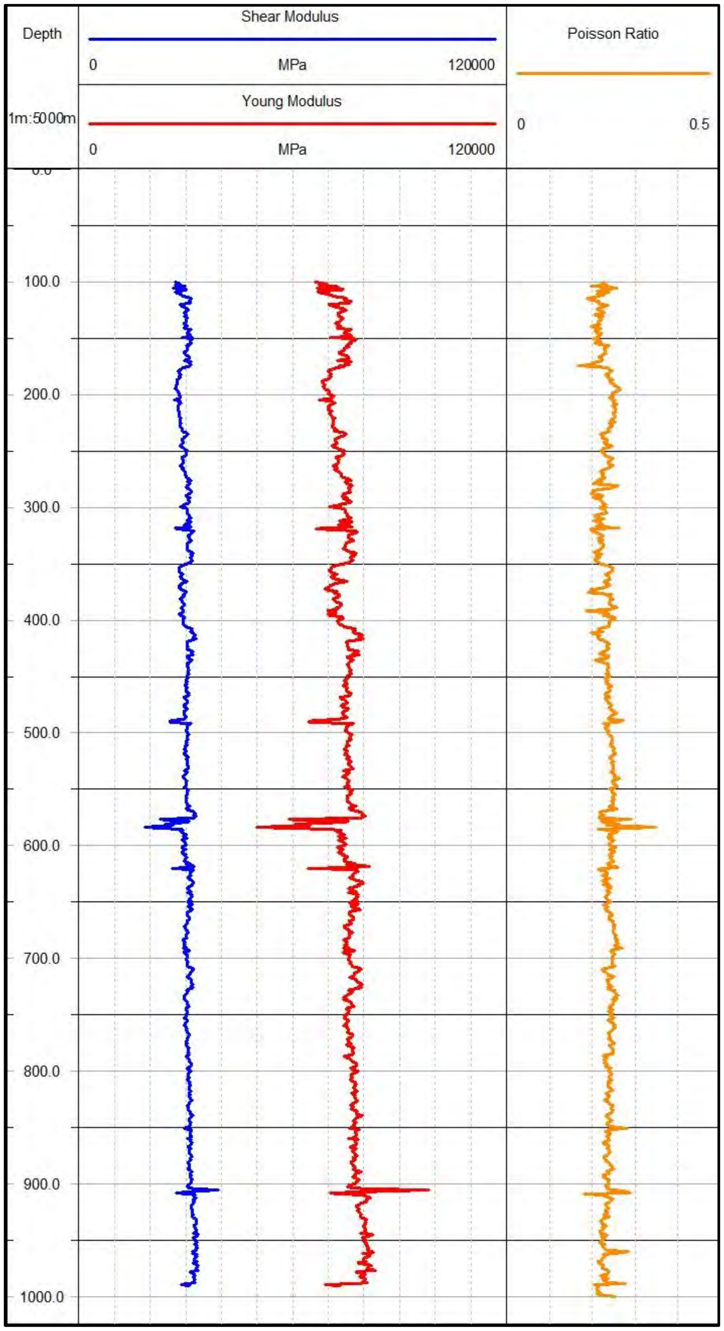


Figure 40: Borehole Shear and Young moduli as well as the Poisson ratio logs for IG_BH04.

Shear and Young moduli, as well as the Poisson ratio 3D distributions around the borehole were also computed from the 3D P- and S-wave velocity distributions, together with the density logs along the borehole.

The below formula was used to calculate the Poisson's Ratio log, according to the formula (ALT 2011):

$$Poisson's\ Ratio = \frac{\frac{1}{2}\left(\frac{dts}{dtc}\right)^2 - 1}{\left(\frac{dts}{dtc}\right)^2 - 1}$$

where:

$$dtc = Compression\ Wave\ Slowness\ \ (\mu s/sm)$$

$$dts = Shear\ Wave\ Slowness\ (\mu s/sm)$$

The calculated Poisson's Ratio was then used in conjunction with the Shear Modulus to generate the Young's Modulus, according to the formula:

$$Young's\ Modulus\ (MPa) = 2 \times \mu \times (1 + \nu)$$

where:

$$\mu = Shear\ Modulus\ (MPa)$$

$$\nu = Poisson's\ Ratio$$

The Bulk Modulus was calculated according to the formula:

$$Bulk\ Modulus\ (MPa) = \rho_b \times \left(\frac{1}{dtc^2} - \frac{4}{3 \times dts^2}\right)$$

where:

$$\rho_b = Bulk\ Density\ (g/cc)$$

Using the Near Density log in conjunction with the Shear Wave slowness log, the Shear Modulus was calculated according to the relationship (ALT 2011):

$$Shear\ Modulus\ (MPa) = \frac{\rho_b}{dts^2}$$

The 3D Shear modulus, Young modulus, and Poisson ratio distributions are shown in Figure 41, Figure 42 and Figure 43.

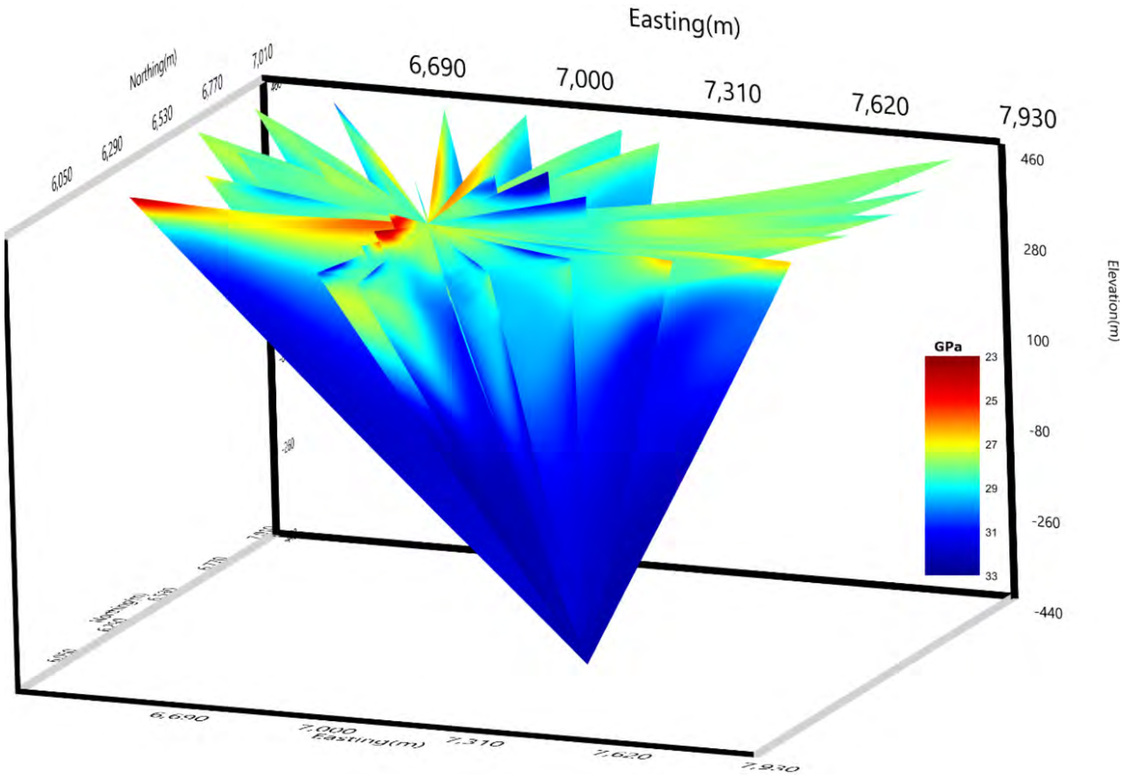


Figure 41: 3D Shear modulus distribution around borehole IG_BH04.

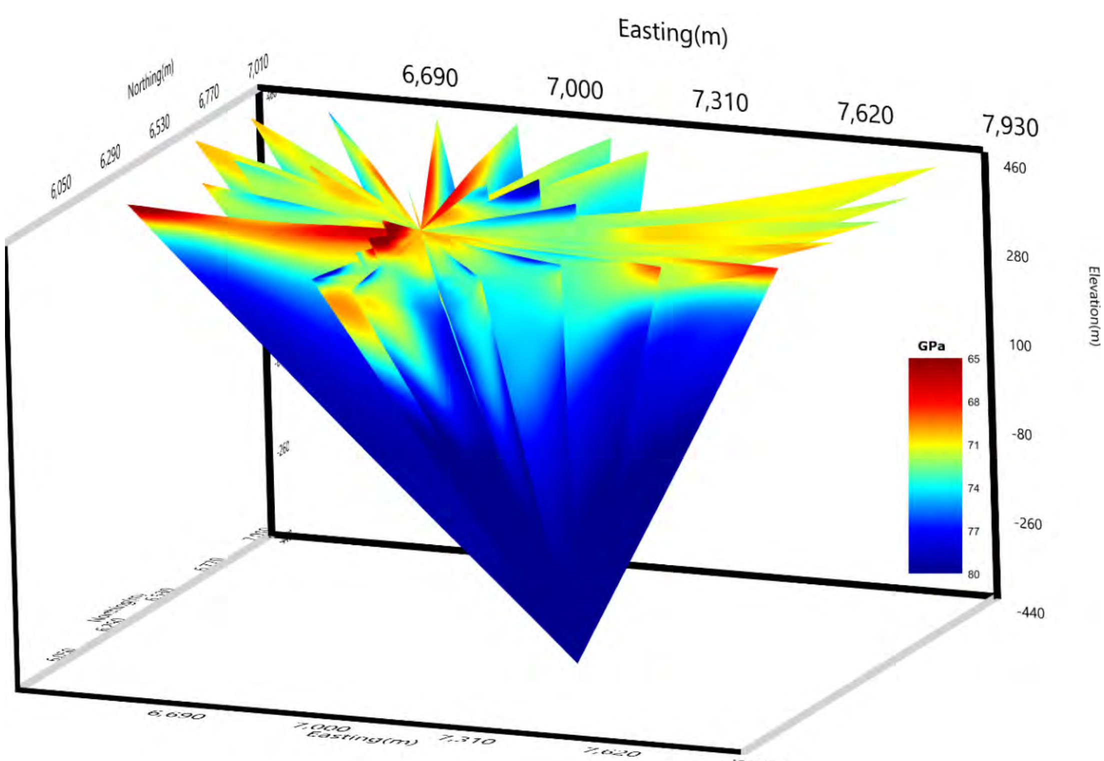


Figure 42: 3D Young modulus distribution around borehole IG_BH04.

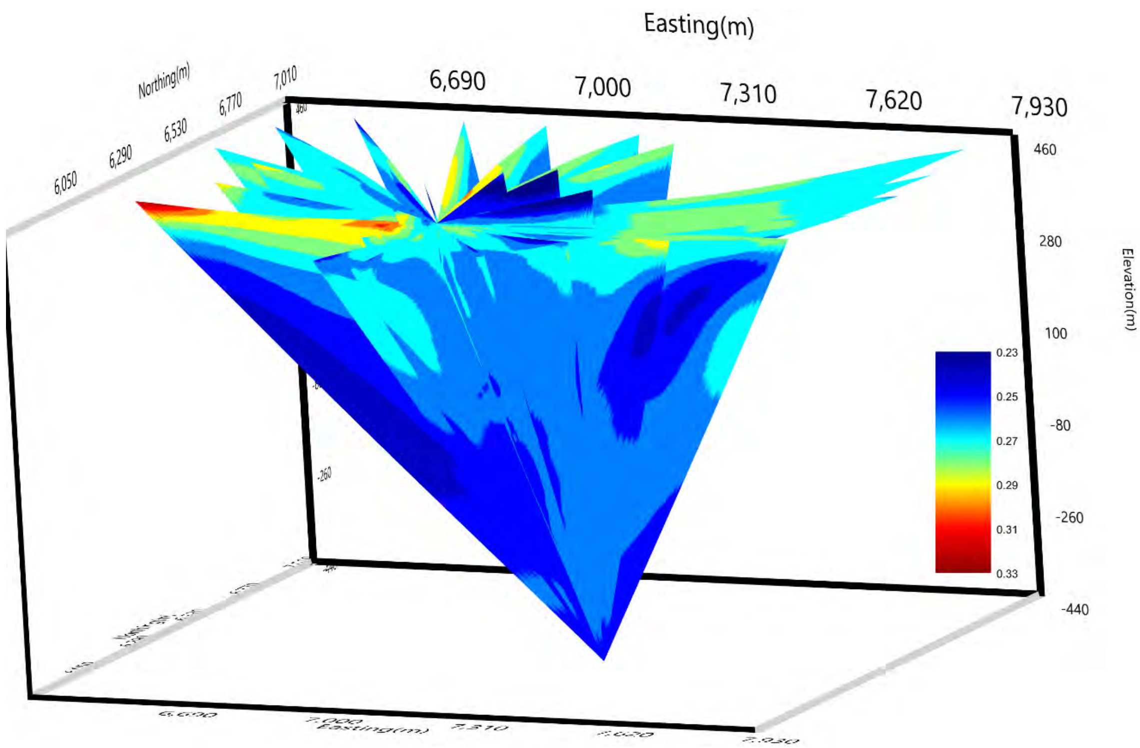


Figure 43: 3D Poisson ratio distribution around borehole IG_BH04.

6.4 Borehole Synthetics

A reflectivity log along the borehole was calculated from the logs shown in Figure 39 and it is shown in Figure 44, together with the reflectivity log used for generation of synthetics. For the later, the upper 100 m of the borehole reflectivity log was dismissed (highly attenuated) as it was measured in the casing.

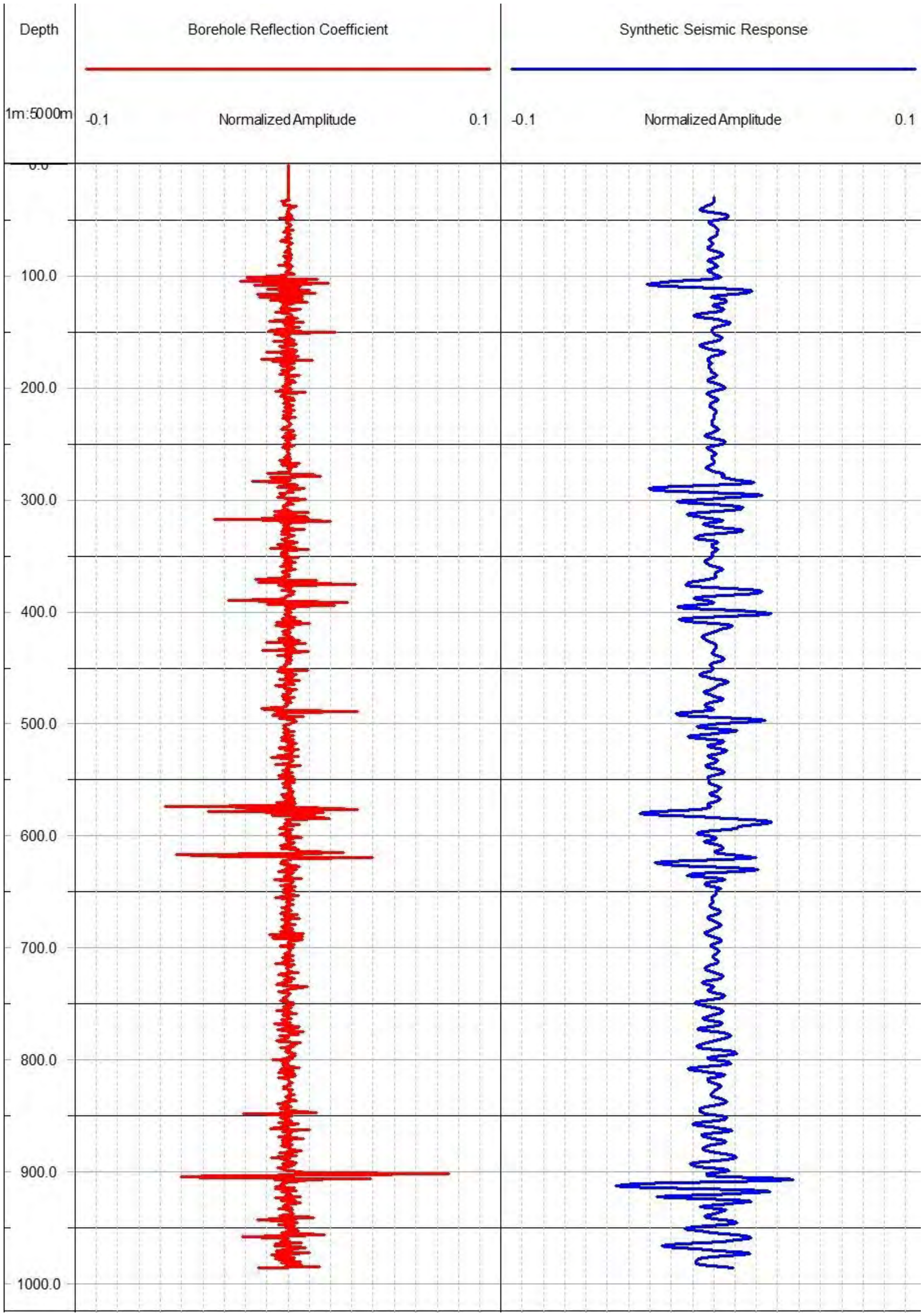


Figure 44: Borehole reflectivity log (left - red) used to calculate the synthetic seismic response along the borehole (right – blue), computed using the wavelet shown in Figure 45.

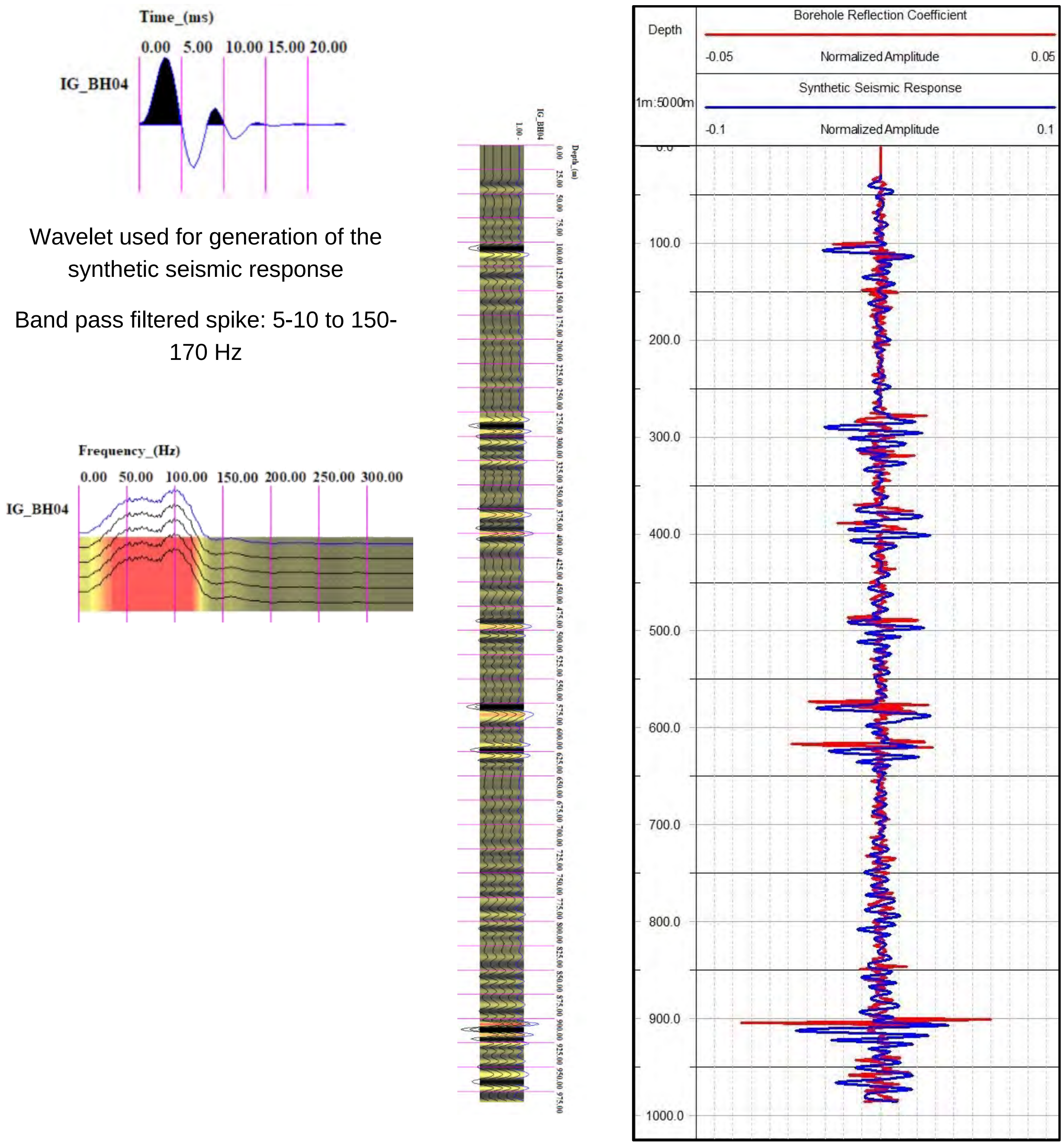


Figure 45: Wavelet used for generation of the synthetic seismic response along IG_BH04 together with its frequency spectra (left). The synthetic seismic response (middle) and the reflectivity log used for generation of synthetics (right). The blue curve in the plot on the right represents the synthetic seismic response along the borehole.

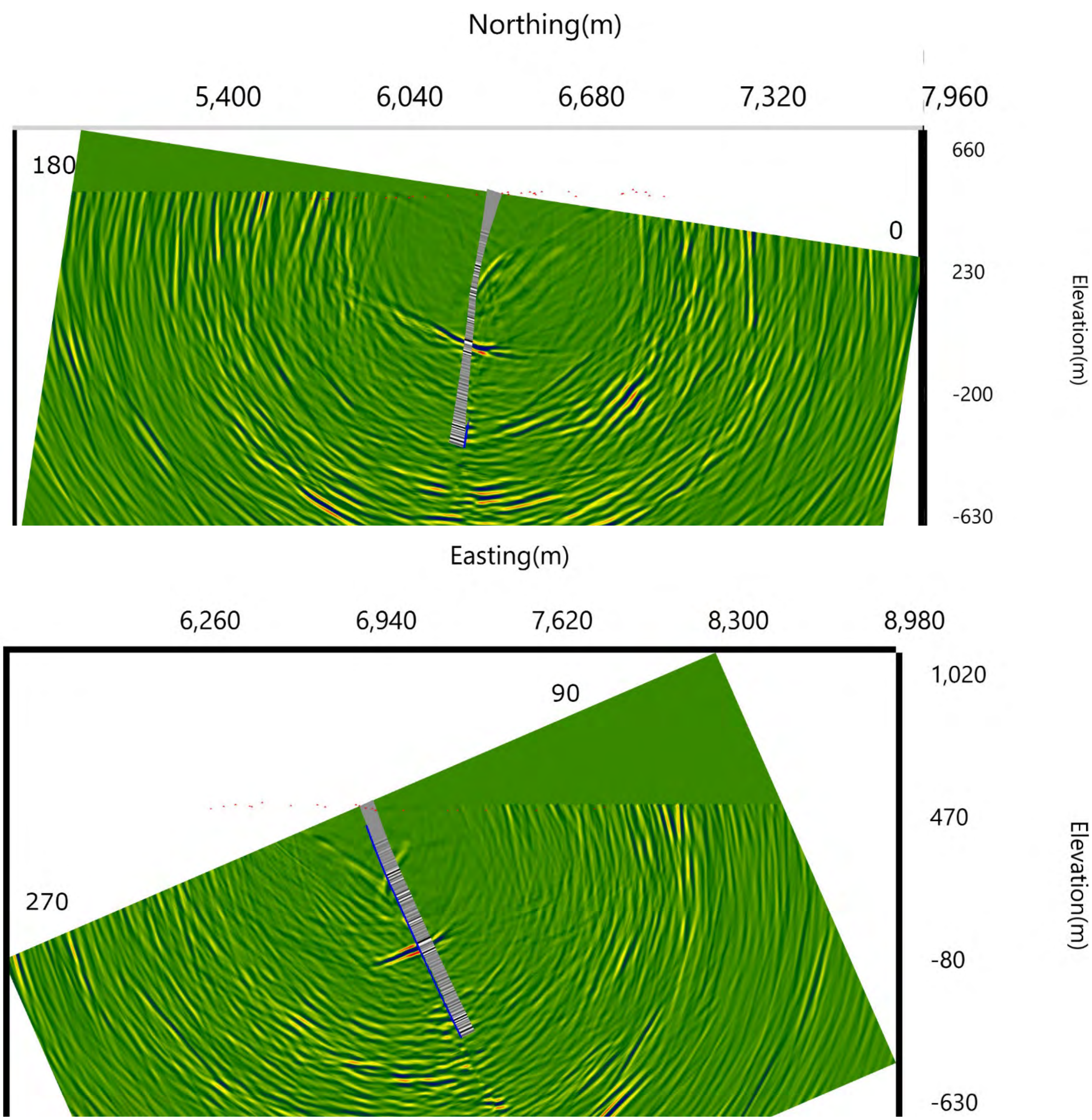


Figure 46: Synthetic seismogram (gray, same as shown in the middle column of Figure 45) and 3D IP migrations – Top: South-North sections and Bottom: West-East sections.

7.0 DISCUSSION

To map rock discontinuities by seismics, at least one dense array of measuring points is needed. For the IG_BH04 VSP survey, the dense array has been a line of 3-component geophone receivers spread in the borehole at 5-m intervals (see Section 4.2.2). With the dominant P-wave velocity slightly less than 6000 m/s (see Figure 15), and the frequency of the data being high cut at 240 Hz (see Figure 10), the theoretical minimum wavelength $\lambda = V/f$ was 25 m. The geophone interval was therefore less than one fifth of the wavelength, sufficiently dense to prevent artifacts from being generated throughout the processing sequence described in Section 5.0. Phase-consistent events, appearing in the individual shot gathers must therefore be identified and treated in as real seismic events, even when concentrations of crisscrossing coherent patterns may appear as noise.

The interpretation of the IG_BH04 VSP data resulted in a geometrical model of seismically significant rock discontinuities. Seismic reflectors with positions and orientations consistent with the current structural data for the site were identified. No attempt has been made at this time to infer the nature or texture of these features. Common rock discontinuities that these seismic features could represent are lithological contacts, dykes, faults and fracture zones.

The visibility of a lithological contact depends primarily on the impedance contrast between the adjacent units and possibly also on the alteration zone that may line the contact. Lithological contacts with an acoustic impedance contrast of more than 5-10% appear generally as outstanding continuous events and are relatively easy to recognize.

Faults, fracture zones and dykes are essentially two-dimensional features, with transverse dimensions much smaller than their transverse extent, The net acoustic impedance contrast is the combined effect of the closer and the further interface. The double, opposite transition of impedance and the variability of texture within the feature make the amplitude of the reflected wave field largely variable. Consequently, the visibility of faults, fracture zones and dykes as seismic reflectors is also largely variable, not only from feature to feature, but even from a region to another of the same feature. It is therefore to be expected that certain features have not equally high visibility in all shot gathers.

The implication is that the interpretation of seismic data from hard rock must rely primarily on phase and amplitude consistency rather than on amplitude magnitude. To follow the continuity of events across traces in the same profile and across profiles and thus make the interpretation possible, even illumination coverage and diversity of view angles are instrumental. An evenly spaced set of sources locations on the ground surface has initially been considered, the distance between two adjacent sources being approximately 200 m (see Figure 5). Larger distances between adjacent shots occurred in the actual layout, caused by accessibility limitations in the SW and NE sides of the survey area (see Figure 7). These gaps were, however, filled in the interpretation stage (see Section 6.0), by the images produced by other shots. Integrated processing and interpretation of multi-borehole VSP is bound to provide improved coverage and a more accurate non-ambiguous 3D target localization even with imperfect distributions of shots on surface.

7.1 How Accurately Can the Seismic Features be Mapped in 3D?

The IG_BH04 VSP survey produced indications of various site structures aligned with lineaments mapped in the area covered by the VSP survey and/or matching geological log in borehole IG_BH04. Other seismic features of similar extent and possibly similar relevance complete the geometrical model derived by VSP in borehole IG_BH-04.

Characterizing these targets is a complex task, as besides merely detecting them (which has been done), one needs to compute their positions in space. This is definitely more than testing hypotheses regarding the existence of a given feature, with a given orientation, in a given region of the site volume. The following discussion attempts to show the complexity of the problem and produce guidelines for solving it.

On a locally planar reflector, the reflection points are distributed along a straight segment limited by the reflection points corresponding to the first and the last receiver in the receiver line. With offset sources, reflectors with equal dips but different azimuths are not covered symmetrically around the borehole. Figure 47 shows a volumetric reconstruction obtained from one shot point when the reflector dip is 60° and the dip direction is undetermined. The region between the source and the receivers and about two wavelengths around the borehole, appears as a blind zone, as reflections do not occur with the source and the receivers on opposite sides of a reflecting plane. The outer boundary of the coverage volume is determined by the investigation distance, which in the present case is about 1.5 km.

The imaging volume is quite complicated and is different for different dips. The ideal targets for VSP are features dipping 30º – 75º relative to the mean direction of the receiver array, i.e. to the borehole in the VSP case. Generally speaking, gently dipping reflectors are imaged close to the borehole and under it, while steeply dipping reflectors are imaged laterally, at depths smaller or comparable with the borehole depth.

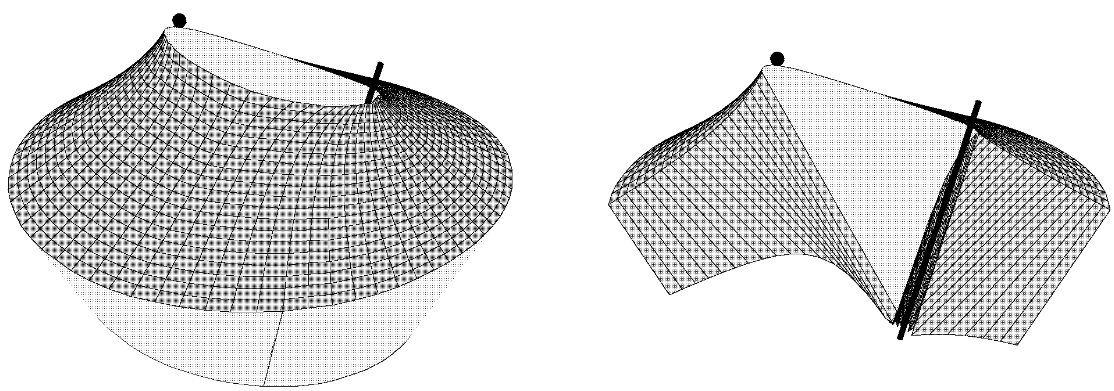


Figure 47: The volume covered from one shot point when the dip is fixed to 60°. Cut view of the coverage volume. The light grey region between the shot point and the receiver array depicts the blind zone (Cosma 2000).

Figure 48 illustrates how a site can be covered by 10 offsets, evenly distributed around the borehole top. One can note that some regions remain uncovered even with 10 shot points.

Whatever the spread of shot points, the actual mapping coverage of the VSP layout converges towards the borehole as depth increases. It is therefore preferable to perform measurements in more boreholes, to cover a larger area at depth.

To resolve this problem, VSP surveys are normally conducted in several boreholes, with each subsequent survey partly overlapping with the previous ones but also contributing with new information, from other regions of the site, until a quasi-complete and iteratively validated coverage is obtained.

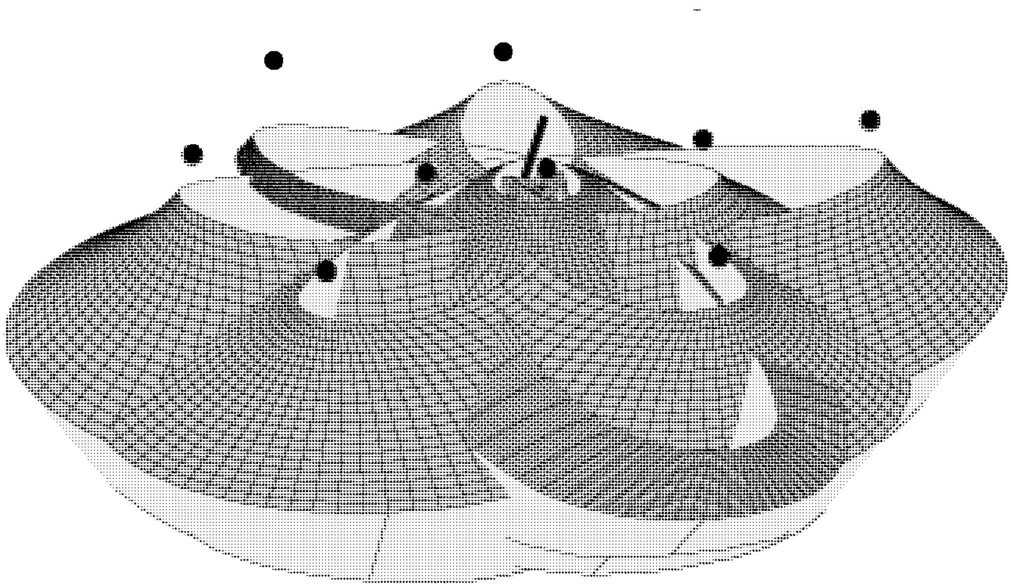


Figure 48: Volume covered from 10 shot points. The dip θ is 60° (Cosma 2000).

7.2 Recommendations for Further Analysis of the IG_BH04 VSP Data

Looking at the example of interpreted shot gathers from Figure 31 can be misleading on at least two counts. Firstly, the number of interpreted events is strikingly large. Secondly, the correspondence between the lines representing the computed time functions and the coherent patterns underneath is not crystal clear in all cases. One must note that although only one-shot profile is shown as an example, the time functions for events were inferred from several profiles and components (see also Appendix F). This explains the occasional slight misfit, as the theoretical extrapolation as a planar mathematical object of a reflector interpreted and confirmed in one profile does not necessarily fit exactly when ported to a different profile and extrapolation over large distances can produce fit variations. This issue is solved locally, by analyzing subsets of close by shot profiles.

This brings forward the question of the actual resolution of a coherent event fitting a time function. Indeed, +/- ¼ cycle at 200 Hz and 6000 m/s corresponds to ~ +/- 10 m. However, a velocity of 5750 m/s instead of 6000 m/s, over a distance of 1000 m, which is possible in the near surface part of the bedrock, would generate a positioning error of ~40 m.

Likewise, a variation of 1º of the dip or strike of a distant reflector can lead to a predicted intersection depth with the borehole offset by tens or even hundreds of meters, depending of its dip with respect to the borehole. In conclusion, a more reliable way to evaluate the seismic results is by analyzing the reflector elements and surfaces generated by joining them with the site geological and structural model.

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APPENDIX A

Daily Quality Control Forms

WP12 Data Quality Confirmation (DQC) Form			
Document No.: 20253946-4120-210724	Original Date: *24 July 2021*	Developed By: *Nicoleta Enescu*	GOLDER MEMBER OF WSP
Revision No.: *R1*	Revision Date: *31 July 2021*	Authorized By: *Christopher Phillips*	

TO:	Mostafa Khorshidi	**Date:**	*July 24, 2021*
	Maria Sánchez-Rico Castejón	**Work Package:**	WP12 – VSP Profiling
	Sarah Hirschorn		
CC:	George Schneider		
		Distributed By:	Email

Record Number: 20253946-4120-210724

IGBH_04, IGNACE, ONTARIO

Acquisition depth interval: n/a

Staff: Jon Crawford, Nicoleta, Cristian

Start time: 4:00pm Finish time: 4:30pm

Shot location(s): Pre-production testing

Prepared by: Jonathan Crawford

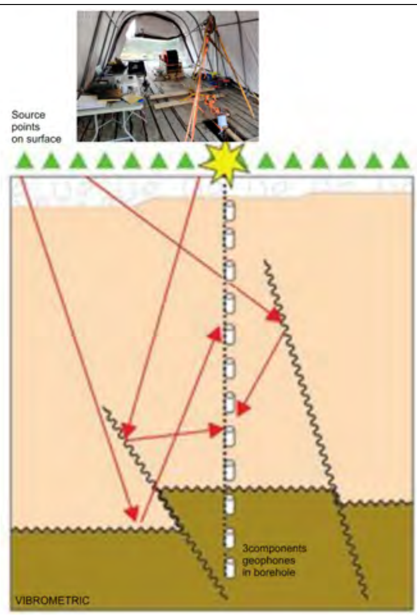
Verified by: Nicoleta Enescu

Usage notes:

- Complete one form per field day
- Office forms will be complete as processing packages/tasks are completed and will include supporting documentation
- Complete all header information (above)
- Delete unused tables (below) and fully populate those that remain
- Form is divided into A through O tables and field and processing tasks

FIELD

A	**Winch and Depth Counter**
Calibrated by measuring and marking the cable every 25 m (with depth labels every 50m) before insertion in the borehole. Verifying these distances using the depth counter. Discrepancies are adjusted by changing the depth value on the depth counter to match the cable mark.	
Results	At 49.95m the depth counter read 51.55m.
Settings applied	Factor was changed from 0.2860 to 0.2771. Depth counter now reads 49.95m. Will be verified again when geophones are lowered to 100m

B	**Tool Assembly**
Schematic	
Results of pre-shipping checks. Refer to relevant document.	All good.

E	**Equipment Calibration/Function Checklist**	**OK**	**Maintenance**

E Equipment Calibration/Function Checklist	OK	Maintenance
Geophones		
Geophone used (RD or R):		
Testing at ground surface performed before insertion in the borehole:		
Level of electrical disturbance	_X_	
Water tightness	_X_	
Operation of side arm clamp	_X_	
Verification of noise level and real seismic signal in each component	_X_	
Winch Motor and transmission Controller Brake Ground anchors	X	
Cable Borehole collar level mark Overnight clamp	X	
Depth counter	X	
Radio check	X	
Acquisition computer		
Computer	_X_	
Acquisition Software	_X_	
Data Analysis Software	_X_	
Power source	X	
Access vehicle	X	
Geophones calibration certificate verification:		
Technical ID	_X_	
Signature	_X_	
Date	_X_	
Validity period	_X_	
Location	_X_	

E Equipment Calibration/Function Checklist	OK	Maintenance
Depth counter calibration certificate verification: Technical ID Signature Date Validity period Location	 __ __ __ __ __	

F Decontamination	
Verification of equipment decontamination before insertion into borehole	Yes

G Dummy Probe Run	
Done before insertion of geophones into borehole	Yes (done on Tuesday, July 20th)
Impact of metal wedge on instrument deployment	No impact

H Geophone Testing in Borehole	
Clamping location verified	Yes
Level of electrical disturbance	None
Operation of the side arm clamp	Good
Verification of noise in each component	Good file: test_geophone_noise.dlc
Verification of real seismic signal in each component	Good file: test_signal_verification.dlc

I Shot	
Confirmation of shot point ID with receiver staff	n/a
Data acquisition sampling rate confirmed at 1 ms	n/a

J Field Data – Review and Verification			
Data File	**Shot ID**	**Depths of receivers in borehole**	**Comment/Verified** (fitness for use)
n/a			

K Field Issues	
Observed damage (note here as-needed additional detail on Daily Report items)	*corrective action (e.g. repair, component replacement)*

L File Control					
Data File	**DateTime**	**Depth Range**	**Staff**	**Software**	**Parameters/Settings**

WP12 Data Quality Confirmation (DQC) Form			GOLDER MEMBER OF WSP
Document No.: 20253946-4120-210724	Original Date: *24 July 2021*	Developed By: *Nicoleta Enescu*	
Revision No.: *R1*	Revision Date: *31 July 2021*	Authorized By: *Christopher Phillips*	

Vibrometric Seismic Source Checklist

Engine Off Checks	OK	Maintenance
Leaks – Fuel, Hydraulic Oil, Engine Oil or Radiator Coolant	✓	
Tires – Condition and Pressure	✓	34 PSI
Hydraulic Hoses, Mast Chains, Cables and Stops – Check Visually	✓	
Safety Warnings – Attached (Refer to Parts Manual for Location)	✓	
Battery – Check Water/Electrolyte Level and Charge	✓	MAINTANCE FREE
Hydraulic Fluid Level – Check Level	✓	
Engine Oil Level – Dipstick	✓	
Transmission Fluid Level – Dipstick	✓	
Radiator Coolant – Check Level	✓	
Operator's Manual – In Container	?	
Nameplate – Attached and Information Matches Model, Serial Number and Attachments	✓	
Seat Belt – Functioning Smoothly	✓	
Hood Latch – Adjusted and Securely Fastened	✓	
Brake Fluid – Check Level		
Seismic Vibrator Check Screws, Cables, Hoses	✓	
Fuel level	✓	
Lights check	✓	
Engine On Checks	OK	Maintenance
Accelerator or Direction Control Pedal – Functioning Smoothly	✓	
Service Brake – Functioning Smoothly	✓	
Parking Brake – Functioning Smoothly	✓	
Steering Operation – Functioning Smoothly	✓	
Drive Control – Forward/Reverse – Functioning Smoothly	✓	
Arm Tilt Control – Forward and Back – Functioning Smoothly	✓	
Hoist (Seismic Source) and Lowering Control – Functioning Smoothly	✓	
Testing the sweep – Operation		@ A LATER TIME
Horn and Lights – Functioning	✓	
Cab (if equipped) – Heater, Defroster, Wipers – Functioning	✓	
Gauges: Ammeter, Engine Oil Pressure, Hour Meter, Fuel Level, Temperature, Instrument Monitors – Functioning	✓	FUEL LEVEL AND TEMP GAUGE NOT ACCURATE
Controller check | Trigger sensor on impact plate check		@ A LATER TIME
Impact plate check | Radio check		@ A LATER TIME
Source type VIBSIST 3000		

OPERATOR: BOB TAYLOR. [signature]

DATE: July 24/21

PROCESSING

M Processing: *n/a*		
Depth adjustment (if any)		
Processing parameters (e.g. workflow and filters)		
Senior Review	*Name*	*Date / Time*
Comments on data quality		

N Interpretation: *n/a*		
Integration of VSP features with geophysical logs (synthetic seismogram parameters)		
Senior Review	*Name*	*Date / Time*
Comments on data quality		

O Sign-Off		
Prepared	*Name* *Jon Crawford*	*Date* *July 25, 2021*
Reviewed	*Name* *Nicoleta Enescu*	*Date* *July 25, 2021*
Reviewed	*Name*	*Date*
Approved	*Name* *Christopher Phillips*	*Date* *July 25, 2021*

WP12 Data Quality Confirmation (DQC) Form			
Document No.: 20253946-4120-210725	Original Date: *25 July 2021*	Developed By: *Nicoleta Enescu*	
Revision No.: *R1*	Revision Date: *31 July 2021*	Authorized By: *Christopher Phillips*	

TO:	Mostafa Khorshidi	**Date:**	*July 25, 2021*
	Maria Sánchez-Rico Castejón	**Work Package:**	WP12 – VSP Profiling
	Sarah Hirschorn		
CC:	George Schneider		
		Distributed By:	Email

Record Number: 20253946-4120-210725

IGBH_04, IGNACE, ONTARIO

Acquisition depth interval: 5m

Staff: Cristian Vasile

Start time: 9:45am **Finish time: 5:00pm**

Shot location(s): All 30 shot locations for level at 70m, 17/30 shots at level 130m

Prepared by: Nicoleta Enescu

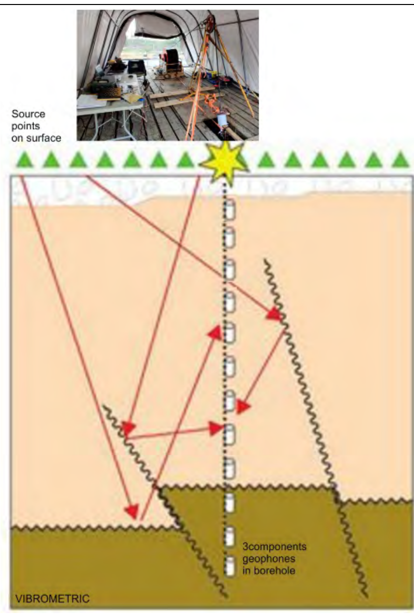
Verified by: Jonathan Crawford

Usage notes:

- Complete one form per field day
- Office forms will be complete as processing packages/tasks are completed and will include supporting documentation
- Complete all header information (above)
- Delete unused tables (below) and fully populate those that remain
- Form is divided into A through O tables and field and processing tasks

FIELD

A	Winch and Depth Counter
Calibrated by measuring and marking the cable every 25 m (with depth labels every 50m) before insertion in the borehole. Verifying these distances using the depth counter. Discrepancies are adjusted by changing the depth value on the depth counter to match the cable mark.	
Results	At 49.95m the depth counter read 51.55m.
Settings applied	Factor was changed from 0.2860 to 0.2771. Depth counter now reads 49.95m. Calibration was verified at 100m

B	Tool Assembly
Schematic	
Results of pre-shipping checks. Refer to relevant document.	All good.

E Equipment Calibration/Function Checklist	OK	Maintenance
Geophones		
Geophone used (RD or R):		
Testing at ground surface performed before insertion in the borehole:		
Level of electrical disturbance	_X_	
Water tightness	_X_	
Operation of side arm clamp	_X_	
Verification of noise level and real seismic signal in each component	_X_	

E Equipment Calibration/Function Checklist	OK	Maintenance
Winch Motor and transmission Controller Brake Ground anchors	X	
Cable Borehole collar level mark Overnight clamp	X	
Depth counter	X	
Radio check	X	
Acquisition computer Computer Acquisition Software Data Analysis Software	_X_ _X_ _X_	
Power source	X	
Access vehicle	X	
Geophones calibration certificate verification: Technical ID Signature Date Validity period Location	_X_ _X_ _X_ _X_ _X_	
Depth counter calibration certificate verification: Technical ID Signature Date Validity period Location	__ __ __ __ __	

H Geophone Testing in Borehole	
Clamping location verified	Yes
Level of electrical disturbance	None
Operation of the side arm clamp	Good
Verification of noise in each component	Good file: test_geophone_noise.dlc
Verification of real seismic signal in each component	Good file: test_signal_verification.dlc

I Shot	
Confirmation of shot point ID with receiver staff	yes
Data acquisition sampling rate confirmed at 1 ms	yes

J Field Data - Review and Verification

Zero Mark of receivers	Shot ID	File Name	Comments/Verified
70	V14	V_BH4_0070__33_00002	All files verified during acquisition
		V_BH4_0070__33_00003	
		V_BH4_0070__33_00004	
70	V01	V_BH4_0070__33_00005	
		V_BH4_0070__33_00006	
		V_BH4_0070__33_00007	
70	V02	V_BH4_0070__33_00008	
		V_BH4_0070__33_00009	
		V_BH4_0070__33_00010	
70	V03	V_BH4_0070__33_00011	
		V_BH4_0070__33_00012	
		V_BH4_0070__33_00013	
70	V04	V_BH4_0070__33_00014	
		V_BH4_0070__33_00015	
		V_BH4_0070__33_00016	
70	V06	V_BH4_0070__33_00017	
		V_BH4_0070__33_00018	
		V_BH4_0070__33_00019	
70	V07	V_BH4_0070__33_00020	
		V_BH4_0070__33_00021	
		V_BH4_0070__33_00022	
70	V08	V_BH4_0070__33_00023	
		V_BH4_0070__33_00024	
		V_BH4_0070__33_00025	
70	V09	V_BH4_0070__33_00026	
		V_BH4_0070__33_00027	
		V_BH4_0070__33_00028	
70	V10	V_BH4_0070__33_00029	
		V_BH4_0070__33_00030	
		V_BH4_0070__33_00031	
70	V11	V_BH4_0070__33_00032	

		V_BH4_0070__33_00033	
		V_BH4_0070__33_00034	
70	V30	V_BH4_0070__33_00035	
		V_BH4_0070__33_00036	
		V_BH4_0070__33_00037	
70	V31	V_BH4_0070__33_00038	
		V_BH4_0070__33_00039	
		V_BH4_0070__33_00040	
70	V15	V_BH4_0070__33_00041	
		V_BH4_0070__33_00042	
		V_BH4_0070__33_00043	
70	V16	V_BH4_0070__33_00044	
		V_BH4_0070__33_00045	
		V_BH4_0070__33_00046	
70	V17	V_BH4_0070__33_00047	
		V_BH4_0070__33_00048	
		V_BH4_0070__33_00049	
70	V20	V_BH4_0070__33_00050	
		V_BH4_0070__33_00051	
		V_BH4_0070__33_00052	
70	V21	V_BH4_0070__33_00053	
		V_BH4_0070__33_00054	
		V_BH4_0070__33_00055	
70	V25	V_BH4_0070__33_00056	
		V_BH4_0070__33_00057	
		V_BH4_0070__33_00058	
70	V26	V_BH4_0070__33_00062	
		V_BH4_0070__33_00063	
		V_BH4_0070__33_00064	
70	V23	V_BH4_0070__33_00065	
		V_BH4_0070__33_00066	
		V_BH4_0070__33_00067	
70	V27	V_BH4_0070__33_00068	
		V_BH4_0070__33_00069	
		V_BH4_0070__33_00070	
70	V28	V_BH4_0070__33_00071	
		V_BH4_0070__33_00072	
		V_BH4_0070__33_00073	
70	V29	V_BH4_0070__33_00074	

		V_BH4_0070__33_00075	
		V_BH4_0070__33_00076	
70	E01	V_BH4_0070__33_00077	
		V_BH4_0070__33_00078	
		V_BH4_0070__33_00079	
70	E02	V_BH4_0070__33_00080	
		V_BH4_0070__33_00081	
		V_BH4_0070__33_00082	
70	E03	V_BH4_0070__33_00083	
		V_BH4_0070__33_00084	
		V_BH4_0070__33_00085	
70	E04	V_BH4_0070__33_00086	
		V_BH4_0070__33_00087	
		V_BH4_0070__33_00088	
70	E05	V_BH4_0070__33_00089	
		V_BH4_0070__33_00090	
		V_BH4_0070__33_00091	
70	E06	V_BH4_0070__33_00092	
		V_BH4_0070__33_00093	
		V_BH4_0070__33_00094	
130	E06	V_BH4_0070__33_00095	
		V_BH4_0070__33_00096	
		V_BH4_0070__33_00097	
130	E05	V_BH4_0070__33_00098	
		V_BH4_0070__33_00099	
		V_BH4_0070__33_00100	
130	E04	V_BH4_0070__33_00101	
		V_BH4_0070__33_00102	
		V_BH4_0070__33_00103	
130	E03	V_BH4_0070__33_00104	
		V_BH4_0070__33_00105	
		V_BH4_0070__33_00106	
130	E02	V_BH4_0070__33_00107	
		V_BH4_0070__33_00108	
		V_BH4_0070__33_00109	
130	E01	V_BH4_0070__33_00110	
		V_BH4_0070__33_00111	
		V_BH4_0070__33_00112	

130	V29	V_BH4_0070__33_00113	
		V_BH4_0070__33_00114	
		V_BH4_0070__33_00115	
130	V28	V_BH4_0070__33_00116	
		V_BH4_0070__33_00117	
		V_BH4_0070__33_00118	
130	V23	V_BH4_0070__33_00119	
		V_BH4_0070__33_00120	
		V_BH4_0070__33_00121	
130	V26	V_BH4_0070__33_00122	
		V_BH4_0070__33_00123	
		V_BH4_0070__33_00124	
130	V25	V_BH4_0070__33_00128	
		V_BH4_0070__33_00129	
		V_BH4_0070__33_00130	
130	V21	V_BH4_0070__33_00131	
		V_BH4_0070__33_00132	
		V_BH4_0070__33_00133	
130	V20	V_BH4_0070__33_00134	
		V_BH4_0070__33_00135	
		V_BH4_0070__33_00136	
130	V15	V_BH4_0070__33_00137	
		V_BH4_0070__33_00138	
		V_BH4_0070__33_00139	
130	V16	V_BH4_0070__33_00140	
		V_BH4_0070__33_00141	
		V_BH4_0070__33_00142	
130	V17	V_BH4_0070__33_00143	
		V_BH4_0070__33_00144	
		V_BH4_0070__33_00145	

K Field Issues

Observed damage (note here as-needed additional detail on Daily Report items)	*corrective action (e.g. repair, component replacement)*

L File Control

L File Control					
Data File	**DateTime**	**Depth Range**	**Staff**	**Software**	**Parameters/Settings**
V_BH4_0070__33_00002		80.7-135.7m	Cristian Vasile for all	VIPS5.11	
V_BH4_0070__33_00003					
V_BH4_0070__33_00004					
V_BH4_0070__33_00005					
V_BH4_0070__33_00006					
V_BH4_0070__33_00007					
V_BH4_0070__33_00008					
V_BH4_0070__33_00009					
V_BH4_0070__33_00010					
V_BH4_0070__33_00011					
V_BH4_0070__33_00012					
V_BH4_0070__33_00013					
V_BH4_0070__33_00014					
V_BH4_0070__33_00015					
V_BH4_0070__33_00016					
V_BH4_0070__33_00017					
V_BH4_0070__33_00018					
V_BH4_0070__33_00019					
V_BH4_0070__33_00020					
V_BH4_0070__33_00021					
V_BH4_0070__33_00022					
V_BH4_0070__33_00023					
V_BH4_0070__33_00024					
V_BH4_0070__33_00025					
V_BH4_0070__33_00026					
V_BH4_0070__33_00027					
V_BH4_0070__33_00028					
V_BH4_0070__33_00029					
V_BH4_0070__33_00030					
V_BH4_0070__33_00031					

L	**File Control**				
V_BH4_0070__33_00032					
V_BH4_0070__33_00033					
V_BH4_0070__33_00034					
V_BH4_0070__33_00035					
V_BH4_0070__33_00036					
V_BH4_0070__33_00037					
V_BH4_0070__33_00038					
V_BH4_0070__33_00039					
V_BH4_0070__33_00040					
V_BH4_0070__33_00041					
V_BH4_0070__33_00042					
V_BH4_0070__33_00043					
V_BH4_0070__33_00044					
V_BH4_0070__33_00045					
V_BH4_0070__33_00046					
V_BH4_0070__33_00047					
V_BH4_0070__33_00048					
V_BH4_0070__33_00049					
V_BH4_0070__33_00050					
V_BH4_0070__33_00051					
V_BH4_0070__33_00052					
V_BH4_0070__33_00053					
V_BH4_0070__33_00054					
V_BH4_0070__33_00055					
V_BH4_0070__33_00056					
V_BH4_0070__33_00057					
V_BH4_0070__33_00058					
V_BH4_0070__33_00062					
V_BH4_0070__33_00063					
V_BH4_0070__33_00064					
V_BH4_0070__33_00065					
V_BH4_0070__33_00066					

L	**File Control**				
V_BH4_0070__33_00067					
V_BH4_0070__33_00068					
V_BH4_0070__33_00069					
V_BH4_0070__33_00070					
V_BH4_0070__33_00071					
V_BH4_0070__33_00072					
V_BH4_0070__33_00073					
V_BH4_0070__33_00074					
V_BH4_0070__33_00075					
V_BH4_0070__33_00076					
V_BH4_0070__33_00077					
V_BH4_0070__33_00078					
V_BH4_0070__33_00079					
V_BH4_0070__33_00080					
V_BH4_0070__33_00081					
V_BH4_0070__33_00082					
V_BH4_0070__33_00083					
V_BH4_0070__33_00084					
V_BH4_0070__33_00085					
V_BH4_0070__33_00086					
V_BH4_0070__33_00087					
V_BH4_0070__33_00088					
V_BH4_0070__33_00089					
V_BH4_0070__33_00090					
V_BH4_0070__33_00091					
V_BH4_0070__33_00092					
V_BH4_0070__33_00093					
V_BH4_0070__33_00094					
V_BH4_0070__33_00095		140.7-195.7			
V_BH4_0070__33_00096					
V_BH4_0070__33_00097					

L File Control					
V_BH4_0070__33_00098					
V_BH4_0070__33_00099					
V_BH4_0070__33_00100					
V_BH4_0070__33_00101					
V_BH4_0070__33_00102					
V_BH4_0070__33_00103					
V_BH4_0070__33_00104					
V_BH4_0070__33_00105					
V_BH4_0070__33_00106					
V_BH4_0070__33_00107					
V_BH4_0070__33_00108					
V_BH4_0070__33_00109					
V_BH4_0070__33_00110					
V_BH4_0070__33_00111					
V_BH4_0070__33_00112					
V_BH4_0070__33_00113					
V_BH4_0070__33_00114					
V_BH4_0070__33_00115					
V_BH4_0070__33_00116					
V_BH4_0070__33_00117					
V_BH4_0070__33_00118					
V_BH4_0070__33_00119					
V_BH4_0070__33_00120					
V_BH4_0070__33_00121					
V_BH4_0070__33_00122					
V_BH4_0070__33_00123					
V_BH4_0070__33_00124					
V_BH4_0070__33_00128					
V_BH4_0070__33_00129					
V_BH4_0070__33_00130					
V_BH4_0070__33_00131					
V_BH4_0070__33_00132					

L	**File Control**				
V_BH4_0070__33_00133					
V_BH4_0070__33_00134					
V_BH4_0070__33_00135					
V_BH4_0070__33_00136					
V_BH4_0070__33_00137					
V_BH4_0070__33_00138					
V_BH4_0070__33_00139					
V_BH4_0070__33_00140					
V_BH4_0070__33_00141					
V_BH4_0070__33_00142					
V_BH4_0070__33_00143					
V_BH4_0070__33_00144					
V_BH4_0070__33_00145					

O	**Sign-Off**	
Prepared	*Name* *Jon Crawford*	*Date* *July 25, 2021*
Reviewed	*Name* *Nicoleta Enescu*	*Date* *July 25, 2021*
Reviewed	*Name*	*Date*
Approved	*Name* *Christopher Phillips*	*Date* *July 25, 2021*

VIBROMETRIC

Vibrometric Seismic Source Checklist

NWMO

Engine Off Checks	OK	Maintenance
Leaks – Fuel, Hydraulic Oil, Engine Oil or Radiator Coolant	✓	
Tires – Condition and Pressure	✓	
Hydraulic Hoses, Mast Chains, Cables and Stops – Check Visually	✓	
Safety Warnings – Attached (Refer to Parts Manual for Location)	✓	
Battery – Check Water/Electrolyte Level and Charge	✓	
Hydraulic Fluid Level – Check Level	✓	
Engine Oil Level – Dipstick	✓	
Transmission Fluid Level – Dipstick	✓	
Radiator Coolant – Check Level	✓	
Operator's Manual – In Container		
Nameplate – Attached and Information Matches Model, Serial Number and Attachments	✓	
Seat Belt – Functioning Smoothly	✓	
Hood Latch – Adjusted and Securely Fastened	✓	
Brake Fluid – Check Level		
Seismic Vibrator Check Screws, Cables, Hoses		
Fuel level	✓	
Lights check	✓	
Engine On Checks	OK	Maintenance
Accelerator or Direction Control Pedal – Functioning Smoothly	✓	
Service Brake – Functioning Smoothly	✓	
Parking Brake – Functioning Smoothly	✓	
Steering Operation – Functioning Smoothly	✓	
Drive Control – Forward/Reverse – Functioning Smoothly	✓	
Arm Tilt Control – Forward and Back – Functioning Smoothly	✓	
Hoist (Seismic Source) and Lowering Control – Functioning Smoothly	✓	
Testing the sweep – Operation		
Horn and Lights – Functioning	✓	
Cab (if equipped) – Heater, Defroster, Wipers – Functioning	✓	
Gauges: Ammeter, Engine Oil Pressure, Hour Meter, Fuel Level, Temperature, Instrument Monitors – Functioning	✓	FUEL AND TEMP GAUGE NOT ACCURATE
Controller check | Trigger sensor on impact plate check		
Impact plate check | Radio check		
Source type VIBSIST 3000 ENGINE HOURS		6368 HRS

OPERATOR: BOB TAYLOR [signature]

DATE: July 25/21

WP12 Data Quality Confirmation (DQC) Form		
Document No.: 20253946-4120-210726	Original Date: *26 July 2021*	Developed By: *Nicoleta Enescu*
Revision No.: *R1*	Revision Date: *31 July 2021*	Authorized By: *Christopher Phillips*

GOLDER
MEMBER OF WSP

TO:	Mostafa Khorshidi	**Date:**	*July 26, 2021*
	Maria Sánchez-Rico Castejón	**Work Package:**	WP12 – VSP Profiling
	Sarah Hirschorn		
CC:	George Schneider		
		Distributed By:	Email

Record Number: 20253946-4120-210726

IGBH_04, IGNACE, ONTARIO

Acquisition depth interval: 5m

Staff: Cristian Vasile

Start time: 8:45am **Finish time: 5:00pm**

Shot location(s): 13/30 shot locations for level at 130m, all 30 shot locations for 190m, 23/30 shots at level 250m (66 total shots locations)

Prepared by: Nicoleta Enescu

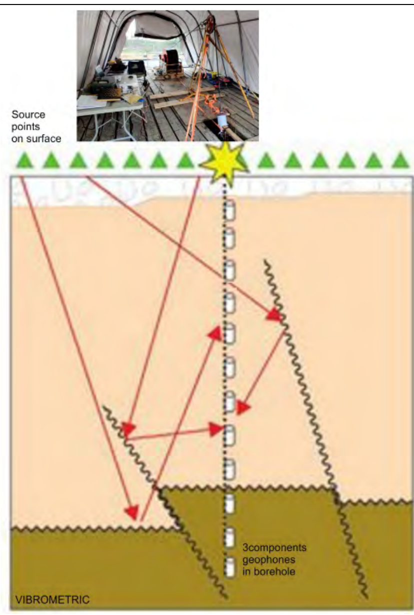
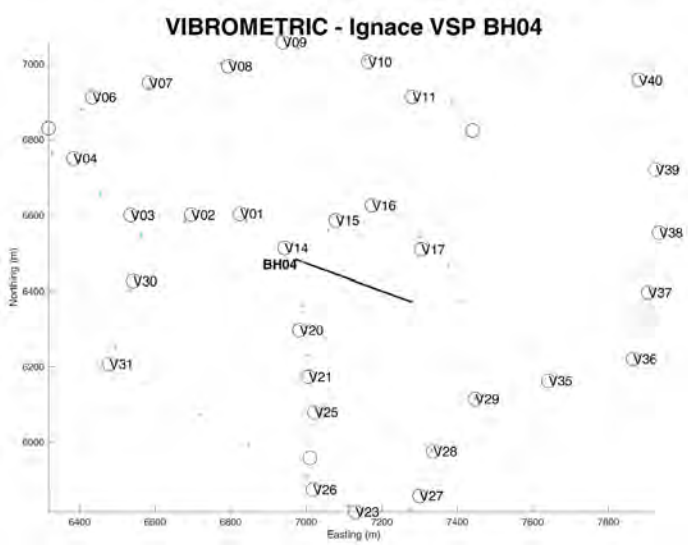
Verified by: Jonathan Crawford

Usage notes:

- Complete one form per field day
- Office forms will be complete as processing packages/tasks are completed and will include supporting documentation
- Complete all header information (above)
- Delete unused tables (below) and fully populate those that remain
- Form is divided into A through O tables and field and processing tasks

FIELD

A Winch and Depth Counter	
Calibrated by measuring and marking the cable every 25 m (with depth labels every 50m) before insertion in the borehole. Verifying these distances using the depth counter. Discrepancies are adjusted by changing the depth value on the depth counter to match the cable mark.	
Results	
Settings applied	Factor was 0.2771. Calibration was verified at 190m – Depth counter reading 190.05m Calibration was verified at 250m – Depth counter reading 250.03m

B Tool Assembly	
Schematic	 
Results of pre-shipping checks. Refer to relevant document.	All good.

E Equipment Calibration/Function Checklist	OK	Maintenance

E Equipment Calibration/Function Checklist	OK	Maintenance
Geophones Geophone used (RD or R): Testing at ground surface performed before insertion in the borehole: Level of electrical disturbance Water tightness Operation of side arm clamp Verification of noise level and real seismic signal in each component	 _X_ _X_ _X_ _X_	
Winch Motor and transmission Controller Brake Ground anchors	X	
Cable Borehole collar level mark Overnight clamp	X	
Depth counter	X	
Radio check	X	
Acquisition computer Computer Acquisition Software Data Analysis Software	 _X_ _X_ _X_	
Power source	X	
Access vehicle	X	
Geophones calibration certificate verification: Technical ID Signature Date Validity period Location	 _X_ _X_ _X_ _X_ _X_	
Depth counter calibration certificate verification: Technical ID Signature Date Validity period Location	 __ __ __ __ __	

H Geophone Testing in Borehole	
Clamping location verified	Yes
Level of electrical disturbance	None
Operation of the side arm clamp	Good
Verification of noise in each component	Good
Verification of real seismic signal in each component	Good file

I Shot	
Confirmation of shot point ID with receiver staff	yes
Data acquisition sampling rate confirmed at 1 ms	yes

J Field Data - Review and Verification

Zero Mark of receivers	Shot ID	File Name	Comments/Verified
			All files verified during acquisition
130	V14	V_BH4_0130__21_00147	
		V_BH4_0130__21_00148	
		V_BH4_0130__21_00149	
130	V01	V_BH4_0130__21_00150	
		V_BH4_0130__21_00151	
		V_BH4_0130__21_00152	
130	V02	V_BH4_0130__21_00153	
		V_BH4_0130__21_00154	
		V_BH4_0130__21_00155	
130	V30	V_BH4_0130__21_00156	
		V_BH4_0130__21_00157	
		V_BH4_0130__21_00158	
130	V31	V_BH4_0130__21_00159	

		V_BH4_0130__21_00160	
		V_BH4_0130__21_00161	
130	V03	V_BH4_0130__21_00162	
		V_BH4_0130__21_00163	
		V_BH4_0130__21_00164	
130	V04	V_BH4_0130__21_00165	
		V_BH4_0130__21_00166	
		V_BH4_0130__21_00167	
130	V06	V_BH4_0130__21_00168	
		V_BH4_0130__21_00169	
		V_BH4_0130__21_00170	
130	V07	V_BH4_0130__21_00171	
		V_BH4_0130__21_00172	
		V_BH4_0130__21_00173	
130	V08	V_BH4_0130__21_00174	
		V_BH4_0130__21_00175	
		V_BH4_0130__21_00176	
130	V09	V_BH4_0130__21_00177	
		V_BH4_0130__21_00178	
		V_BH4_0130__21_00179	
130	V10	V_BH4_0130__21_00180	
		V_BH4_0130__21_00181	

		V_BH4_0130__21_00182	
130	V11	V_BH4_0130__21_00183	
		V_BH4_0130__21_00184	
		V_BH4_0130__21_00185	
190	V11	V_BH4_0190__21_00186	
		V_BH4_0190__21_00187	
		V_BH4_0190__21_00188	
190	V10	V_BH4_0190__21_00189	
		V_BH4_0190__21_00190	
		V_BH4_0190__21_00191	
190	V09	V_BH4_0190__21_00192	
		V_BH4_0190__21_00193	
		V_BH4_0190__21_00194	
190	V08	V_BH4_0190__21_00195	
		V_BH4_0190__21_00196	
		V_BH4_0190__21_00197	
190	V07	V_BH4_0190__21_00198	
		V_BH4_0190__21_00199	
		V_BH4_0190__21_00200	
190	V06	V_BH4_0190__21_00201	Noise from toilet cleaning machine
		V_BH4_0190__21_00202	Noise from toilet cleaning machine
		V_BH4_0190__21_00203	Noise from toilet cleaning machine

190	V04	V_BH4_0190__21_00204	Noise from toilet cleaning machine
		V_BH4_0190__21_00205	Noise from toilet cleaning machine
		V_BH4_0190__21_00206	Noise from toilet cleaning machine
190	V03	V_BH4_0190__21_00207	Noise from toilet cleaning machine
		V_BH4_0190__21_00208	Noise from toilet cleaning machine
		V_BH4_0190__21_00209	Noise from toilet cleaning machine
190	V30	V_BH4_0190__21_00210	Noise from toilet cleaning machine
		V_BH4_0190__21_00211	Noise from toilet cleaning machine
		V_BH4_0190__21_00212	Noise from toilet cleaning machine
190	V31	V_BH4_0190__21_00213	Noise from toilet cleaning machine
		V_BH4_0190__21_00214	Noise from toilet cleaning machine
		V_BH4_0190__21_00215	Noise from toilet cleaning machine
190	V02	V_BH4_0190__21_00216	Noise from toilet cleaning machine
		V_BH4_0190__21_00217	Noise from toilet cleaning machine
		V_BH4_0190__21_00218	
190	V01	V_BH4_0190__21_00219	
		V_BH4_0190__21_00220	
		V_BH4_0190__21_00221	
190	V14	V_BH4_0190__21_00222	
		V_BH4_0190__21_00223	
		V_BH4_0190__21_00224	
190	V15	V_BH4_0190__21_00225	

		V_BH4_0190__21_00226	
		V_BH4_0190__21_00227	
190	V16	V_BH4_0190__21_00228	
		V_BH4_0190__21_00229	
		V_BH4_0190__21_00230	
190	V17	V_BH4_0190__21_00231	
		V_BH4_0190__21_00232	
		V_BH4_0190__21_00233	
190	V20	V_BH4_0190__21_00234	
		V_BH4_0190__21_00235	
		V_BH4_0190__21_00236	
190	V21	V_BH4_0190__21_00237	
		V_BH4_0190__21_00238	
		V_BH4_0190__21_00239	
190	V25	V_BH4_0190__21_00240	
		V_BH4_0190__21_00241	
		V_BH4_0190__21_00242	
190	V26	V_BH4_0190__21_00243	
		V_BH4_0190__21_00244	
		V_BH4_0190__21_00245	
190	V23	V_BH4_0190__21_00246	
		V_BH4_0190__21_00247	

		V_BH4_0190__21_00248	
190	V27	V_BH4_0190__21_00249	
		V_BH4_0190__21_00250	
		V_BH4_0190__21_00251	
190	V28	V_BH4_0190__21_00252	
		V_BH4_0190__21_00253	
		V_BH4_0190__21_00254	
190	V29	V_BH4_0190__21_00255	
		V_BH4_0190__21_00256	
		V_BH4_0190__21_00257	
190	V35	V_BH4_0190__21_00258	
		V_BH4_0190__21_00259	
		V_BH4_0190__21_00260	
190	V36	V_BH4_0190__21_00261	
		V_BH4_0190__21_00262	
		V_BH4_0190__21_00263	
190	V37	V_BH4_0190__21_00264	
		V_BH4_0190__21_00265	
		V_BH4_0190__21_00266	
190	V38	V_BH4_0190__21_00267	
		V_BH4_0190__21_00268	
		V_BH4_0190__21_00269	

190	V39	V_BH4_0190__21_00270	
		V_BH4_0190__21_00271	
		V_BH4_0190__21_00272	
190	V40	V_BH4_0190__21_00273	
		V_BH4_0190__21_00274	
		V_BH4_0190__21_00275	
250	V40	V_BH4_0250__21_00276	
		V_BH4_0250__21_00277	
		V_BH4_0250__21_00278	
250	V39	V_BH4_0250__21_00279	
		V_BH4_0250__21_00280	
		V_BH4_0250__21_00281	
250	V38	V_BH4_0250__21_00282	
		V_BH4_0250__21_00283	
		V_BH4_0250__21_00284	
250	V37	V_BH4_0250__21_00285	
		V_BH4_0250__21_00286	
		V_BH4_0250__21_00287	
250	V36	V_BH4_0250__21_00288	
		V_BH4_0250__21_00289	
		V_BH4_0250__21_00290	

250	V35	V_BH4_0250__21_00291	
		V_BH4_0250__21_00292	
		V_BH4_0250__21_00293	
250	V29	V_BH4_0250__21_00294	
		V_BH4_0250__21_00295	
		V_BH4_0250__21_00296	
250	V28	V_BH4_0250__21_00297	
		V_BH4_0250__21_00298	
		V_BH4_0250__21_00299	
250	V27	V_BH4_0250__21_00300	
		V_BH4_0250__21_00301	
		V_BH4_0250__21_00302	
250	V23	V_BH4_0250__21_00303	
		V_BH4_0250__21_00304	
		V_BH4_0250__21_00305	
250	V26	V_BH4_0250__21_00306	
		V_BH4_0250__21_00307	
		V_BH4_0250__21_00308	
250	V25	V_BH4_0250__21_00309	
		V_BH4_0250__21_00310	
		V_BH4_0250__21_00311	
250	V21	V_BH4_0250__21_00312	

		V_BH4_0250__21_00313	
		V_BH4_0250__21_00314	
250	V20	V_BH4_0250__21_00315	
		V_BH4_0250__21_00316	
		V_BH4_0250__21_00317	
250	V15	V_BH4_0250__21_00318	
		V_BH4_0250__21_00319	
		V_BH4_0250__21_00320	
250	V16	V_BH4_0250__21_00321	
		V_BH4_0250__21_00322	
		V_BH4_0250__21_00323	
250	V17	V_BH4_0250__21_00324	
		V_BH4_0250__21_00325	
		V_BH4_0250__21_00326	
250	V14	V_BH4_0250__21_00327	
		V_BH4_0250__21_00328	
		V_BH4_0250__21_00329	
250	V01	V_BH4_0250__21_00330	
		V_BH4_0250__21_00331	
		V_BH4_0250__21_00332	
250	V02	V_BH4_0250__21_00333	
		V_BH4_0250__21_00334	

		V_BH4_0250__21_00335	
250	V30	V_BH4_0250__21_00336	
		V_BH4_0250__21_00337	
		V_BH4_0250__21_00338	
250	V31	V_BH4_0250__21_00339	
		V_BH4_0250__21_00340	
		V_BH4_0250__21_00341	
250	V03	V_BH4_0250__21_00342	
		V_BH4_0250__21_00343	
		V_BH4_0250__21_00344	
250	V04	V_BH4_0250__21_00345	
		V_BH4_0250__21_00346	
		V_BH4_0250__21_00347	

K **Field Issues**		
Observed damage (note here as-needed additional detail on Daily Report items)		*corrective action (e.g. repair, component replacement)*

L **File Control**					
Data File	**DateTime**	**Depth Range**	**Staff**	**Software**	**Parameters/Settings**
			Cristian Vasile for all	VIPS5.11	1ms sample rate. 3 records of 20 seconds each
V_BH4_0130__21_00147		140.7 – 195.7			
V_BH4_0130__21_00148					

L File Control					
V_BH4_0130__21_00149					
V_BH4_0130__21_00150					
V_BH4_0130__21_00151					
V_BH4_0130__21_00152					
V_BH4_0130__21_00153					
V_BH4_0130__21_00154					
V_BH4_0130__21_00155					
V_BH4_0130__21_00156					
V_BH4_0130__21_00157					
V_BH4_0130__21_00158					
V_BH4_0130__21_00159					
V_BH4_0130__21_00160					
V_BH4_0130__21_00161					
V_BH4_0130__21_00162					
V_BH4_0130__21_00163					
V_BH4_0130__21_00164					
V_BH4_0130__21_00165					
V_BH4_0130__21_00166					
V_BH4_0130__21_00167					
V_BH4_0130__21_00168					
V_BH4_0130__21_00169					
V_BH4_0130__21_00170					

L File Control					
V_BH4_0130__21_00171					
V_BH4_0130__21_00172					
V_BH4_0130__21_00173					
V_BH4_0130__21_00174					
V_BH4_0130__21_00175					
V_BH4_0130__21_00176					
V_BH4_0130__21_00177					
V_BH4_0130__21_00178					
V_BH4_0130__21_00179					
V_BH4_0130__21_00180					
V_BH4_0130__21_00181					
V_BH4_0130__21_00182					
V_BH4_0130__21_00183					
V_BH4_0130__21_00184					
V_BH4_0130__21_00185					
V_BH4_0190__21_00186		200.7 – 255.7			
V_BH4_0190__21_00187					
V_BH4_0190__21_00188					
V_BH4_0190__21_00189					
V_BH4_0190__21_00190					
V_BH4_0190__21_00191					
V_BH4_0190__21_00192					

L File Control					
V_BH4_0190__21_00193					
V_BH4_0190__21_00194					
V_BH4_0190__21_00195					
V_BH4_0190__21_00196					
V_BH4_0190__21_00197					
V_BH4_0190__21_00198					
V_BH4_0190__21_00199					
V_BH4_0190__21_00200					
V_BH4_0190__21_00201					
V_BH4_0190__21_00202					
V_BH4_0190__21_00203					
V_BH4_0190__21_00204					
V_BH4_0190__21_00205					
V_BH4_0190__21_00206					
V_BH4_0190__21_00207					
V_BH4_0190__21_00208					
V_BH4_0190__21_00209					
V_BH4_0190__21_00210					
V_BH4_0190__21_00211					
V_BH4_0190__21_00212					
V_BH4_0190__21_00213					
V_BH4_0190__21_00214					

L File Control					
V_BH4_0190__21_00215					
V_BH4_0190__21_00216					
V_BH4_0190__21_00217					
V_BH4_0190__21_00218					
V_BH4_0190__21_00219					
V_BH4_0190__21_00220					
V_BH4_0190__21_00221					
V_BH4_0190__21_00222					
V_BH4_0190__21_00223					
V_BH4_0190__21_00224					
V_BH4_0190__21_00225					
V_BH4_0190__21_00226					
V_BH4_0190__21_00227					
V_BH4_0190__21_00228					
V_BH4_0190__21_00229					
V_BH4_0190__21_00230					
V_BH4_0190__21_00231					
V_BH4_0190__21_00232					
V_BH4_0190__21_00233					
V_BH4_0130__21_00234					
V_BH4_0130__21_00235					
V_BH4_0130__21_00236					

L	**File Control**				
V_BH4_0130__21_00237					
V_BH4_0130__21_00238					
V_BH4_0130__21_00239					
V_BH4_0130__21_00240					
V_BH4_0130__21_00241					
V_BH4_0130__21_00242					
V_BH4_0130__21_00243					
V_BH4_0130__21_00244					
V_BH4_0130__21_00245					
V_BH4_0130__21_00246					
V_BH4_0130__21_00247					
V_BH4_0130__21_00248					
V_BH4_0130__21_00249					
V_BH4_0130__21_00250					
V_BH4_0130__21_00251					
V_BH4_0130__21_00252					
V_BH4_0130__21_00253					
V_BH4_0130__21_00254					
V_BH4_0130__21_00255					
V_BH4_0130__21_00256					
V_BH4_0130__21_00257					
V_BH4_0130__21_00258					

L File Control					
V_BH4_0130__21_00259					
V_BH4_0130__21_00260					
V_BH4_0130__21_00261					
V_BH4_0130__21_00262					
V_BH4_0130__21_00263					
V_BH4_0130__21_00264					
V_BH4_0130__21_00265					
V_BH4_0130__21_00266					
V_BH4_0130__21_00267					
V_BH4_0130__21_00268					
V_BH4_0130__21_00269					
V_BH4_0130__21_00270					
V_BH4_0130__21_00271					
V_BH4_0130__21_00272					
V_BH4_0130__21_00273					
V_BH4_0130__21_00274					
V_BH4_0130__21_00275					
V_BH4_0250__21_00276		260.7 – 315.7			
V_BH4_0250__21_00277					
V_BH4_0250__21_00278					
V_BH4_0250__21_00279					
V_BH4_0250__21_00280					

L **File Control**					
V_BH4_0250__21_00281					
V_BH4_0250__21_00282					
V_BH4_0250__21_00283					
V_BH4_0250__21_00284					
V_BH4_0250__21_00285					
V_BH4_0250__21_00286					
V_BH4_0250__21_00287					
V_BH4_0250__21_00288					
V_BH4_0250__21_00289					
V_BH4_0250__21_00290					
V_BH4_0250__21_00291					
V_BH4_0250__21_00292					
V_BH4_0250__21_00293					
V_BH4_0250__21_00294					
V_BH4_0250__21_00295					
V_BH4_0250__21_00296					
V_BH4_0250__21_00297					
V_BH4_0250__21_00298					
V_BH4_0250__21_00299					
V_BH4_0250__21_00300					
V_BH4_0250__21_00301					
V_BH4_0250__21_00302					

L File Control					
V_BH4_0250__21_00303					
V_BH4_0250__21_00304					
V_BH4_0250__21_00305					
V_BH4_0250__21_00306					
V_BH4_0250__21_00307					
V_BH4_0250__21_00308					
V_BH4_0250__21_00309					
V_BH4_0250__21_00310					
V_BH4_0250__21_00311					
V_BH4_0250__21_00312					
V_BH4_0250__21_00313					
V_BH4_0250__21_00314					
V_BH4_0250__21_00315					
V_BH4_0250__21_00316					
V_BH4_0250__21_00317					
V_BH4_0250__21_00318					
V_BH4_0250__21_00319					
V_BH4_0250__21_00320					
V_BH4_0250__21_00321					
V_BH4_0250__21_00322					
V_BH4_0250__21_00323					
V_BH4_0250__21_00324					

L **File Control**					
V_BH4_0250__21_00325					
V_BH4_0250__21_00326					
V_BH4_0250__21_00327					
V_BH4_0250__21_00328					
V_BH4_0250__21_00329					
V_BH4_0250__21_00330					
V_BH4_0250__21_00331					
V_BH4_0250__21_00332					
V_BH4_0250__21_00333					
V_BH4_0250__21_00334					
V_BH4_0250__21_00335					
V_BH4_0250__21_00336					
V_BH4_0250__21_00337					
V_BH4_0250__21_00338					
V_BH4_0250__21_00339					
V_BH4_0250__21_00340					
V_BH4_0250__21_00341					
V_BH4_0250__21_00342					
V_BH4_0250__21_00343					
V_BH4_0250__21_00344					
V_BH4_0250__21_00345					
V_BH4_0250__21_00346					

WP12 Data Quality Confirmation (DQC) Form			GOLDER MEMBER OF WSP
Document No.: 20253946-4120-210726	Original Date: *26 July 2021*	Developed By: *Nicoleta Enescu*	
Revision No.: *R1*	Revision Date: *31 July 2021*	Authorized By: *Christopher Phillips*	

L **File Control**					
V_BH4_0250__21_00347					

VIBROMETRIC

DATE: July 26/21

Vibrometric Seismic Source Checklist

Engine Off Checks	OK	Maintenance
Leaks – Fuel, Hydraulic Oil, Engine Oil or Radiator Coolant	√	
Tires – Condition and Pressure	√	
Hydraulic Hoses, Mast Chains, Cables and Stops – Check Visually	√	
Safety Warnings – Attached (Refer to Parts Manual for Location)	√	
Battery – Check Water/Electrolyte Level and Charge	√	
Hydraulic Fluid Level – Check Level	√	
Engine Oil Level – Dipstick	√	
Transmission Fluid Level – Dipstick	√	
Radiator Coolant – Check Level	√	
Operator's Manual – In Container		
Nameplate – Attached and Information Matches Model, Serial Number and Attachments	√	
Seat Belt – Functioning Smoothly	√	
Hood Latch – Adjusted and Securely Fastened	√	
Brake Fluid – Check Level		
Seismic Vibrator Check Screws, Cables, Hoses	√	
Fuel level	√	
Lights check	√	
Engine On Checks	OK	Maintenance
Accelerator or Direction Control Pedal – Functioning Smoothly	√	
Service Brake – Functioning Smoothly	√	
Parking Brake – Functioning Smoothly	√	
Steering Operation – Functioning Smoothly	√	
Drive Control – Forward/Reverse – Functioning Smoothly	√	
Arm Tilt Control – Forward and Back – Functioning Smoothly	√	
Hoist (Seismic Source) and Lowering Control – Functioning Smoothly	√	
Testing the sweep – Operation	√	
Horn and Lights – Functioning	√	
Cab (if equipped) – Heater, Defroster, Wipers – Functioning	√	
Gauges: Ammeter, Engine Oil Pressure, Hour Meter, Fuel Level, Temperature, Instrument Monitors – Functioning	√	FUEL AND TEMP GAUGE NOT ACCURATE
Controller check | Trigger sensor on impact plate check	√	
Impact plate check | Radio check	√	
Source type VIBSIST 3000 ENGINE HOURS		6375 HRS

OPERATOR: ROBERT TAYLOR

R. Taylor

O Sign-Off		
Prepared	*Name* *Nicoleta Enescu*	*Date* *July 26, 2021*
Reviewed	*Name* *Jon Crawford*	*Date* *July 26, 2021*
Reviewed	*Name*	*Date*
Approved	*Name* *Christopher Phillips*	*Date* *July 26, 2021*

WP12 Data Quality Confirmation (DQC) Form			
Document No.: 20253946-4120-210727	Original Date: *27 July 2021*	Developed By: *Nicoleta Enescu*	GOLDER MEMBER OF WSP
Revision No.: *R1*	Revision Date: *31 July 2021*	Authorized By: *Christopher Phillips*	

TO:	Mostafa Khorshidi	**Date:**	*July 27, 2021*
	Maria Sánchez-Rico Castejón	**Work Package:**	WP12 – VSP Profiling
	Sarah Hirschorn		
CC:	George Schneider		
		Distributed By:	Email

Record Number: 20253946-4120-210726

IGBH_04, IGNACE, ONTARIO

Acquisition depth interval: 5m

Staff: Cristian Vasile & Sorin Dobrovicescu

Start time: 8:15am **Finish time: 4:45pm**

Shot location(s): 7/30 shot locations for level at 250m, all 26 shot locations for 310m and 370m. 17/26 shots at level 43m (76 total shots locations)

Prepared by: Nicoleta Enescu

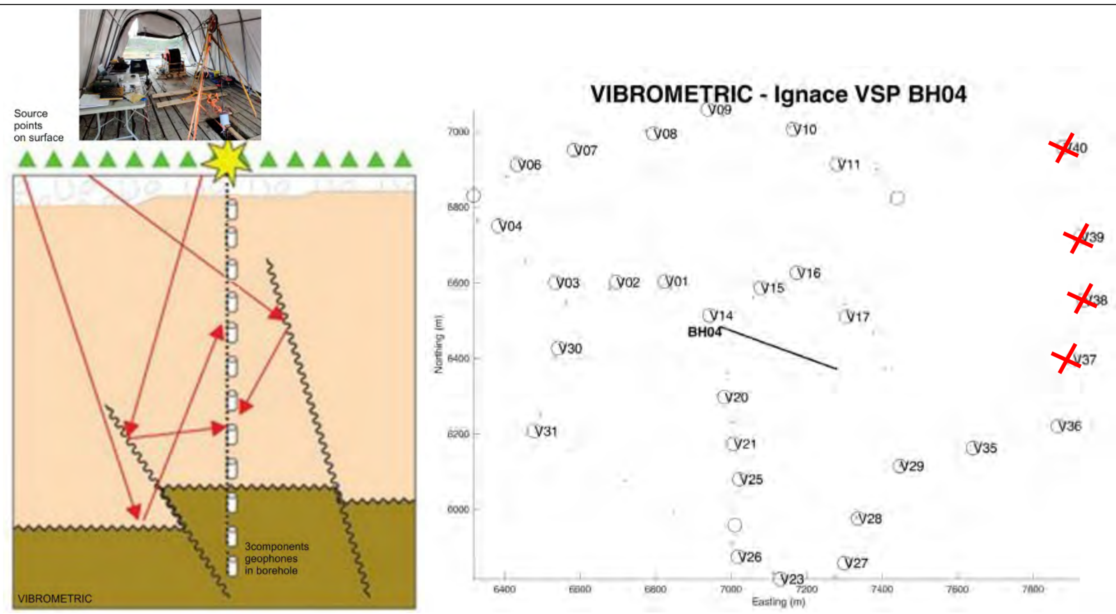
Verified by: Jonathan Crawford

Usage notes:

- Complete one form per field day
- Office forms will be complete as processing packages/tasks are completed and will include supporting documentation
- Complete all header information (above)
- Delete unused tables (below) and fully populate those that remain
- Form is divided into A through O tables and field and processing tasks

FIELD

A	Winch and Depth Counter
Calibrated by measuring and marking the cable every 25 m (with depth labels every 50m) before insertion in the borehole. Verifying these distances using the depth counter. Discrepancies are adjusted by changing the depth value on the depth counter to match the cable mark.	
Results	
Settings applied	Factor was 0.2771. Calibration was verified at 310m – Depth counter reading 310.03m Calibration was verified at 370m – Depth counter reading 370.09m Calibration was verified at 430m – Depth counter reading 430.03m

B	Tool Assembly
Schematic	
Results of pre-shipping checks. Refer to relevant document.	All good.

E	Equipment Calibration/Function Checklist	OK	Maintenance

E Equipment Calibration/Function Checklist	OK	Maintenance
Geophones Geophone used (RD or R): Testing at ground surface performed before insertion in the borehole: Level of electrical disturbance Water tightness Operation of side arm clamp Verification of noise level and real seismic signal in each component	 _X_ _X_ _X_ _X_	
Winch Motor and transmission Controller Brake Ground anchors	X	
Cable Borehole collar level mark Overnight clamp	X	
Depth counter	X	
Radio check	X	
Acquisition computer Computer Acquisition Software Data Analysis Software	_X_ _X_ _X_	
Power source	X	
Access vehicle	X	
Geophones calibration certificate verification: Technical ID Signature Date Validity period Location	 _X_ _X_ _X_ _X_ _X_	
Depth counter calibration certificate verification: Technical ID Signature Date Validity period Location	 __ __ __ __ __	

H	Geophone Testing in Borehole
Clamping location verified	Yes
Level of electrical disturbance	None
Operation of the side arm clamp	Good
Verification of noise in each component	Good
Verification of real seismic signal in each component	Good

I	Shot
Confirmation of shot point ID with receiver staff	yes
Data acquisition sampling rate confirmed at 1 ms	yes

J Field Data - Review and Verification

Zero Mark of receivers	Shot ID	File Name	Comments/Verified
			All files verified during acquisition
250	V04	V_BH4_0250__21_00348	
		V_BH4_0250__21_00349	
		V_BH4_0250__21_00350	
250	V06	V_BH4_0250__21_00351	
		V_BH4_0250__21_00352	
		V_BH4_0250__21_00353	
250	V07	V_BH4_0250__21_00354	
		V_BH4_0250__21_00355	
		V_BH4_0250__21_00356	
250	V08	V_BH4_0250__21_00357	
		V_BH4_0250__21_00358	
		V_BH4_0250__21_00359	
250	V09	V_BH4_0250__21_00360	
		V_BH4_0250__21_00361	

		V_BH4_0250__21_00362	
250	V10	V_BH4_0250__21_00363	
		V_BH4_0250__21_00364	
		V_BH4_0250__21_00365	
250	V11	V_BH4_0250__21_00366	
		V_BH4_0250__21_00367	
		V_BH4_0250__21_00368	
310	V11	V_BH4_0310__21_00369	
		V_BH4_0310__21_00370	
		V_BH4_0310__21_00371	
310	V10	V_BH4_0310__21_00372	
		V_BH4_0310__21_00373	
		V_BH4_0310__21_00374	
310	V09	V_BH4_0310__21_00375	
		V_BH4_0310__21_00376	
		V_BH4_0310__21_00377	
310	V08	V_BH4_0310__21_00378	
		V_BH4_0310__21_00379	
		V_BH4_0310__21_00380	
310	V07	V_BH4_0310__21_00381	
		V_BH4_0310__21_00382	
		V_BH4_0310__21_00383	
310	V06	V_BH4_0310__21_00384	

		V_BH4_0310__21_00385	
		V_BH4_0310__21_00386	
310	V04	V_BH4_0310__21_00387	
		V_BH4_0310__21_00388	
		V_BH4_0310__21_00389	
310	V03	V_BH4_0310__21_00390	
		V_BH4_0310__21_00391	
		V_BH4_0310__21_00392	
310	V30	V_BH4_0310__21_00393	
		V_BH4_0310__21_00394	
		V_BH4_0310__21_00395	
310	V31	V_BH4_0310__21_00396	
		V_BH4_0310__21_00397	
		V_BH4_0310__21_00398	
310	V02	V_BH4_0310__21_00399	
		V_BH4_0310__21_00400	
		V_BH4_0310__21_00401	
310	V01	V_BH4_0310__21_00402	
		V_BH4_0310__21_00403	
		V_BH4_0310__21_00404	
310	V14	V_BH4_0310__21_00405	
		V_BH4_0310__21_00406	
		V_BH4_0310__21_00407	

310	V15	V_BH4_0310__21_00408	
		V_BH4_0310__21_00409	
		V_BH4_0310__21_00410	
310	V16	V_BH4_0310__21_00411	
		V_BH4_0310__21_00412	
		V_BH4_0310__21_00413	
310	V17	V_BH4_0310__21_00414	
		V_BH4_0310__21_00415	
		V_BH4_0310__21_00416	
310	V20	V_BH4_0310__21_00417	
		V_BH4_0310__21_00418	
		V_BH4_0310__21_00419	
310	V21	V_BH4_0310__21_00420	
		V_BH4_0310__21_00421	
		V_BH4_0310__21_00422	
310	V25	V_BH4_0310__21_00423	
		V_BH4_0310__21_00424	
		V_BH4_0310__21_00425	
310	V26	V_BH4_0310__21_00426	
		V_BH4_0310__21_00427	
		V_BH4_0310__21_00428	
310	V23	V_BH4_0310__21_00429	
		V_BH4_0310__21_00430	

		V_BH4_0310__21_00431	
310	V27	V_BH4_0310__21_00432	
		V_BH4_0310__21_00433	
		V_BH4_0310__21_00434	
310	V28	V_BH4_0310__21_00435	
		V_BH4_0310__21_00436	
		V_BH4_0310__21_00437	
310	V29	V_BH4_0310__21_00438	
		V_BH4_0310__21_00439	
		V_BH4_0310__21_00440	
310	V35	V_BH4_0310__21_00441	
		V_BH4_0310__21_00442	
		V_BH4_0310__21_00443	
310	V36	V_BH4_0310__21_00444	
		V_BH4_0310__21_00445	
		V_BH4_0310__21_00446	
370	V36	V_BH4_0370__21_00447	
		V_BH4_0370__21_00448	
		V_BH4_0370__21_00449	
370	V35	V_BH4_0370__21_00450	
		V_BH4_0370__21_00451	
		V_BH4_0370__21_00452	
370	V29	V_BH4_0370__21_00453	

		V_BH4_0370__21_00454	
		V_BH4_0370__21_00455	
370	V28	V_BH4_0370__21_00456	
		V_BH4_0370__21_00457	
		V_BH4_0370__21_00458	
370	V27	V_BH4_0370__21_00459	
		V_BH4_0370__21_00460	
		V_BH4_0370__21_00461	
370	V23	V_BH4_0370__21_00462	
		V_BH4_0370__21_00463	
		V_BH4_0370__21_00464	
370	V26	V_BH4_0370__21_00465	
		V_BH4_0370__21_00466	
		V_BH4_0370__21_00467	
370	V25	V_BH4_0370__21_00468	
		V_BH4_0370__21_00469	
		V_BH4_0370__21_00470	
370	V21	V_BH4_0370__21_00471	
		V_BH4_0370__21_00472	
		V_BH4_0370__21_00473	
370	V20	V_BH4_0370__21_00474	
		V_BH4_0370__21_00475	
		V_BH4_0370__21_00476	

370	V15	V_BH4_0370__21_00477	
		V_BH4_0370__21_00478	
		V_BH4_0370__21_00479	
370	V16	V_BH4_0370__21_00480	
		V_BH4_0370__21_00481	
		V_BH4_0370__21_00482	
370	V17	V_BH4_0370__21_00483	
		V_BH4_0370__21_00484	
		V_BH4_0370__21_00485	
370	V14	V_BH4_0370__21_00486	
		V_BH4_0370__21_00487	
		V_BH4_0370__21_00488	
370	V01	V_BH4_0370__21_00489	
		V_BH4_0370__21_00490	
		V_BH4_0370__21_00491	
370	V02	V_BH4_0370__21_00492	
		V_BH4_0370__21_00493	
		V_BH4_0370__21_00494	
370	V30	V_BH4_0370__21_00495	
		V_BH4_0370__21_00496	
		V_BH4_0370__21_00497	
370	V31	V_BH4_0370__21_00498	
		V_BH4_0370__21_00499	

		V_BH4_0370__21_00500	
370	V03	V_BH4_0370__21_00501	
		V_BH4_0370__21_00502	
		V_BH4_0370__21_00503	
370	V04	V_BH4_0370__21_00504	
		V_BH4_0370__21_00505	
		V_BH4_0370__21_00506	
370	V06	V_BH4_0370__21_00507	
		V_BH4_0370__21_00508	
		V_BH4_0370__21_00509	
370	V07	V_BH4_0370__21_00510	
		V_BH4_0370__21_00511	
		V_BH4_0370__21_00512	
370	V08	V_BH4_0370__21_00513	
		V_BH4_0370__21_00514	
		V_BH4_0370__21_00515	
370	V09	V_BH4_0370__21_00516	
		V_BH4_0370__21_00517	
		V_BH4_0370__21_00518	
370	V10	V_BH4_0370__21_00519	
		V_BH4_0370__21_00520	
		V_BH4_0370__21_00521	
370	V11	V_BH4_0370__21_00522	

		V_BH4_0370__21_00523	
		V_BH4_0370__21_00524	
430	V11	V_BH4_0430__21_00525	
		V_BH4_0430__21_00526	
		V_BH4_0430__21_00527	
430	V10	V_BH4_0430__21_00528	
		V_BH4_0430__21_00529	
		V_BH4_0430__21_00530	
430	V09	V_BH4_0430__21_00531	
		V_BH4_0430__21_00532	
		V_BH4_0430__21_00533	
430	V08	V_BH4_0430__21_00534	
		V_BH4_0430__21_00535	
		V_BH4_0430__21_00536	
430	V07	V_BH4_0430__21_00537	
		V_BH4_0430__21_00538	
		V_BH4_0430__21_00539	
430	V06	V_BH4_0430__21_00540	
		V_BH4_0430__21_00541	
		V_BH4_0430__21_00542	
430	V04	V_BH4_0430__21_00543	
		V_BH4_0430__21_00544	
		V_BH4_0430__21_00545	

430	V03	V_BH4_0430__21_00546	
		V_BH4_0430__21_00547	
		V_BH4_0430__21_00548	
430	V30	V_BH4_0430__21_00549	
		V_BH4_0430__21_00550	
		V_BH4_0430__21_00551	
430	V31	V_BH4_0430__21_00552	
		V_BH4_0430__21_00553	
		V_BH4_0430__21_00554	
430	V02	V_BH4_0430__21_00555	
		V_BH4_0430__21_00556	
		V_BH4_0430__21_00557	
430	V01	V_BH4_0430__21_00558	
		V_BH4_0430__21_00559	
		V_BH4_0430__21_00560	
430	V14	V_BH4_0430__21_00561	
		V_BH4_0430__21_00562	
		V_BH4_0430__21_00563	
430	V15	V_BH4_0430__21_00564	
		V_BH4_0430__21_00565	
		V_BH4_0430__21_00566	
430	V16	V_BH4_0430__21_00567	
		V_BH4_0430__21_00568	

		V_BH4_0430__21_00569	
430	V17	V_BH4_0430__21_00570	
		V_BH4_0430__21_00571	
		V_BH4_0430__21_00572	
430	V20	V_BH4_0430__21_00573	
		V_BH4_0430__21_00574	
		V_BH4_0430__21_00575	

K Field Issues

Observed damage (note here as-needed additional detail on Daily Report items)		*corrective action (e.g. repair, component replacement)*

L File Control

Data File	DateTime	Depth Range	Staff	Software	Parameters/Settings
			Cristian Vasile & Sorin Dobrovicescu	VIPS5.11	1ms sample rate. 3 records of 20 seconds each
V_BH4_0250__21_00348		260.7 – 315.7	Cristian		
V_BH4_0250__21_00349			Cristian		
V_BH4_0250__21_00350			Cristian		
V_BH4_0250__21_00351			Cristian		
V_BH4_0250__21_00352			Cristian		
V_BH4_0250__21_00353			Cristian		
V_BH4_0250__21_00354			Cristian		
V_BH4_0250__21_00355			Cristian		
V_BH4_0250__21_00356			Cristian		

L File Control					
V_BH4_0250__21_00357			Cristian		
V_BH4_0250__21_00358			Cristian		
V_BH4_0250__21_00359			Cristian		
V_BH4_0250__21_00360			Cristian		
V_BH4_0250__21_00361			Cristian		
V_BH4_0250__21_00362			Cristian		
V_BH4_0250__21_00363			Cristian		
V_BH4_0250__21_00364			Cristian		
V_BH4_0250__21_00365			Cristian		
V_BH4_0310__21_00366			Cristian		
V_BH4_0310__21_00367			Cristian		
V_BH4_0310__21_00368			Cristian		
V_BH4_0310__21_00369		320.7 – 375.7	Cristian		
V_BH4_0310__21_00370			Cristian		
V_BH4_0310__21_00371			Cristian		
V_BH4_0310__21_00372			Cristian		
V_BH4_0310__21_00373			Cristian		
V_BH4_0310__21_00374			Cristian		
V_BH4_0310__21_00375			Cristian		
V_BH4_0310__21_00376			Cristian		
V_BH4_0310__21_00377			Cristian		
V_BH4_0310__21_00378			Cristian		

L	**File Control**				
V_BH4_0310__21_00379			Cristian		
V_BH4_0310__21_00380			Cristian		
V_BH4_0310__21_00381			Cristian		
V_BH4_0310__21_00382			Cristian		
V_BH4_0310__21_00383			Cristian		
V_BH4_0310__21_00384			Cristian		
V_BH4_0310__21_00385			Cristian		
V_BH4_0310__21_00386			Cristian		
V_BH4_0310__21_00387			Cristian		
V_BH4_0310__21_00388			Cristian		
V_BH4_0310__21_00389			Cristian		
V_BH4_0310__21_00390			Cristian		
V_BH4_0310__21_00391			Cristian		
V_BH4_0310__21_00392			Cristian		
V_BH4_0310__21_00393			Cristian		
V_BH4_0310__21_00394			Cristian		
V_BH4_0310__21_00395			Cristian		
V_BH4_0310__21_00396			Cristian		
V_BH4_0310__21_00397			Cristian		
V_BH4_0310__21_00398			Cristian		
V_BH4_0310__21_00399			Sorin		
V_BH4_0310__21_00400			Sorin		

L	File Control				
V_BH4_0310__21_00401			Sorin		
V_BH4_0310__21_00402			Sorin		
V_BH4_0310__21_00403			Sorin		
V_BH4_0310__21_00404			Sorin		
V_BH4_0310__21_00405			Sorin		
V_BH4_0310__21_00406			Sorin		
V_BH4_0310__21_00407			Sorin		
V_BH4_0310__21_00408			Sorin		
V_BH4_0310__21_00409			Sorin		
V_BH4_0310__21_00410			Sorin		
V_BH4_0310__21_00411			Sorin		
V_BH4_0310__21_00412			Sorin		
V_BH4_0310__21_00413			Sorin		
V_BH4_0310__21_00414			Sorin		
V_BH4_0310__21_00415			Sorin		
V_BH4_0310__21_00416			Sorin		
V_BH4_0310__21_00417			Sorin		
V_BH4_0310__21_00418			Sorin		
V_BH4_0310__21_00419			Sorin		
V_BH4_0310__21_00420			Sorin		
V_BH4_0310__21_00421			Sorin		
V_BH4_0310__21_00422			Sorin		

L File Control					
V_BH4_0310__21_00423			Sorin		
V_BH4_0310__21_00424			Sorin		
V_BH4_0310__21_00425			Sorin		
V_BH4_0310__21_00426			Sorin		
V_BH4_0310__21_00427			Sorin		
V_BH4_0310__21_00428			Sorin		
V_BH4_0310__21_00429			Sorin		
V_BH4_0310__21_00430			Sorin		
V_BH4_0310__21_00431			Sorin		
V_BH4_0310__21_00432			Sorin		
V_BH4_0310__21_00433			Sorin		
V_BH4_0310__21_00434			Sorin		
V_BH4_0310__21_00435			Sorin		
V_BH4_0310__21_00436			Sorin		
V_BH4_0310__21_00437			Sorin		
V_BH4_0310__21_00438			Cristian		
V_BH4_0310__21_00439			Cristian		
V_BH4_0310__21_00440			Cristian		
V_BH4_0310__21_00441			Cristian		
V_BH4_0310__21_00442			Cristian		
V_BH4_0310__21_00443			Cristian		
V_BH4_0310__21_00444			Cristian		
V_BH4_0310__21_00445			Cristian		

L	File Control				
V_BH4_0310__21_00446			Cristian		
V_BH4_0370__21_00447		380.7 – 435.7	Sorin		
V_BH4_0370__21_00448			Sorin		
V_BH4_0370__21_00449			Sorin		
V_BH4_0370__21_00450			Sorin		
V_BH4_0370__21_00451			Sorin		
V_BH4_0370__21_00452			Sorin		
V_BH4_0370__21_00453			Sorin		
V_BH4_0370__21_00454			Sorin		
V_BH4_0370__21_00455			Sorin		
V_BH4_0370__21_00456			Sorin		
V_BH4_0370__21_00457			Sorin		
V_BH4_0370__21_00458			Sorin		
V_BH4_0370__21_00459			Sorin		
V_BH4_0370__21_00460			Sorin		
V_BH4_0370__21_00461			Sorin		
V_BH4_0370__21_00462			Sorin		
V_BH4_0370__21_00463			Sorin		
V_BH4_0370__21_00464			Sorin		
V_BH4_0370__21_00465			Sorin		
V_BH4_0370__21_00466			Sorin		
V_BH4_0370__21_00467			Sorin		

L	File Control				
V_BH4_0370__21_00468			Sorin		
V_BH4_0370__21_00469			Sorin		
V_BH4_0370__21_00470			Sorin		
V_BH4_0370__21_00471			Sorin		
V_BH4_0370__21_00472			Sorin		
V_BH4_0370__21_00473			Sorin		
V_BH4_0370__21_00474			Sorin		
V_BH4_0370__21_00475			Sorin		
V_BH4_0370__21_00476			Sorin		
V_BH4_0370__21_00477			Sorin		
V_BH4_0370__21_00478			Sorin		
V_BH4_0370__21_00479			Sorin		
V_BH4_0370__21_00480			Sorin		
V_BH4_0370__21_00481			Sorin		
V_BH4_0370__21_00482			Sorin		
V_BH4_0370__21_00483			Sorin		
V_BH4_0370__21_00484			Sorin		
V_BH4_0370__21_00485			Sorin		
V_BH4_0370__21_00486			Cristian		
V_BH4_0370__21_00487			Cristian		
V_BH4_0370__21_00488			Cristian		
V_BH4_0370__21_00489			Cristian		

L	**File Control**				
V_BH4_0370__21_00490			Cristian		
V_BH4_0370__21_00491			Cristian		
V_BH4_0370__21_00492			Cristian		
V_BH4_0370__21_00493			Cristian		
V_BH4_0370__21_00494			Cristian		
V_BH4_0370__21_00495			Cristian		
V_BH4_0370__21_00496			Cristian		
V_BH4_0370__21_00497			Cristian		
V_BH4_0370__21_00498			Cristian		
V_BH4_0370__21_00499			Cristian		
V_BH4_0370__21_00500			Cristian		
V_BH4_0370__21_00501			Cristian		
V_BH4_0370__21_00502			Cristian		
V_BH4_0370__21_00503			Cristian		
V_BH4_0370__21_00504			Cristian		
V_BH4_0370__21_00505			Cristian		
V_BH4_0370__21_00506			Cristian		
V_BH4_0370__21_00507			Cristian		
V_BH4_0370__21_00508			Cristian		
V_BH4_0370__21_00509			Cristian		
V_BH4_0370__21_00510			Cristian		
V_BH4_0370__21_00511			Cristian		

L File Control					
V_BH4_0370__21_00512			Cristian		
V_BH4_0370__21_00513			Cristian		
V_BH4_0370__21_00514			Cristian		
V_BH4_0370__21_00515			Cristian		
V_BH4_0370__21_00516			Cristian		
V_BH4_0370__21_00517			Cristian		
V_BH4_0370__21_00518			Cristian		
V_BH4_0370__21_00519			Cristian		
V_BH4_0370__21_00520			Cristian		
V_BH4_0370__21_00521			Cristian		
V_BH4_0370__21_00522			Cristian		
V_BH4_0370__21_00523			Cristian		
V_BH4_0370__21_00524			Cristian		
V_BH4_0430__21_00525		440.7 – 495.7	Cristian		
V_BH4_0430__21_00526			Cristian		
V_BH4_0430__21_00527			Cristian		
V_BH4_0430__21_00528			Cristian		
V_BH4_0430__21_00529			Cristian		
V_BH4_0430__21_00530			Cristian		
V_BH4_0430__21_00531			Cristian		
V_BH4_0430__21_00532			Cristian		
V_BH4_0430__21_00533			Cristian		

L	**File Control**				
V_BH4_0430__21_00534			Cristian		
V_BH4_0430__21_00535			Cristian		
V_BH4_0430__21_00536			Cristian		
V_BH4_0430__21_00537			Cristian		
V_BH4_0430__21_00538			Cristian		
V_BH4_0430__21_00539			Cristian		
V_BH4_0430__21_00540			Cristian		
V_BH4_0430__21_00541			Cristian		
V_BH4_0430__21_00542			Cristian		
V_BH4_0430__21_00543			Cristian		
V_BH4_0430__21_00544			Cristian		
V_BH4_0430__21_00545			Cristian		
V_BH4_0430__21_00546			Cristian		
V_BH4_0430__21_00547			Cristian		
V_BH4_0430__21_00548			Cristian		
V_BH4_0430__21_00549			Cristian		
V_BH4_0430__21_00550			Cristian		
V_BH4_0430__21_00551			Cristian		
V_BH4_0430__21_00552			Cristian		
V_BH4_0430__21_00553			Cristian		
V_BH4_0430__21_00554			Cristian		
V_BH4_0430__21_00555			Cristian		

L File Control					
V_BH4_0430__21_00556			Cristian		
V_BH4_0430__21_00557			Cristian		
V_BH4_0430__21_00558			Cristian		
V_BH4_0430__21_00559			Cristian		
V_BH4_0430__21_00560			Cristian		
V_BH4_0430__21_00561			Cristian		
V_BH4_0430__21_00562			Cristian		
V_BH4_0430__21_00563			Cristian		
V_BH4_0430__21_00564			Cristian		
V_BH4_0430__21_00565			Cristian		
V_BH4_0430__21_00566			Cristian		
V_BH4_0430__21_00567			Cristian		
V_BH4_0430__21_00568			Cristian		
V_BH4_0430__21_00569			Cristian		
V_BH4_0430__21_00570			Cristian		
V_BH4_0430__21_00571			Cristian		
V_BH4_0430__21_00572			Cristian		
V_BH4_0430__21_00573			Cristian		
V_BH4_0430__21_00574			Cristian		
V_BH4_0430__21_00575			Cristian		

WP12 Data Quality Confirmation (DQC) Form		
Document No.: 20253946-4120-210727	Original Date: *27 July 2021*	Developed By: *Nicoleta Enescu*
Revision No.: *R1*	Revision Date: *31 July 2021*	Authorized By: *Christopher Phillips*

GOLDER
MEMBER OF WSP

VIBROMETRIC

NWMO **Vibrometric Seismic Source Checklist** DATE: July 27/21

Engine Off Checks	OK	Maintenance
Leaks – Fuel, Hydraulic Oil, Engine Oil or Radiator Coolant	✓	
Tires – Condition and Pressure	✓	
Hydraulic Hoses, Mast Chains, Cables and Stops – Check Visually	✓	
Safety Warnings – Attached (Refer to Parts Manual for Location)	✓	
Battery – Check Water/Electrolyte Level and Charge	✓	
Hydraulic Fluid Level – Check Level	✓	
Engine Oil Level – Dipstick	✓	
Transmission Fluid Level – Dipstick	✓	
Radiator Coolant – Check Level	✓	
Operator's Manual – In Container		
Nameplate – Attached and Information Matches Model, Serial Number and Attachments	✓	
Seat Belt – Functioning Smoothly	✓	
Hood Latch – Adjusted and Securely Fastened	✓	
Brake Fluid – Check Level		
Seismic Vibrator Check Screws, Cables, Hoses	✓	
Fuel level	✓	
Lights check	✓	
Engine On Checks	OK	Maintenance
Accelerator or Direction Control Pedal – Functioning Smoothly	✓	
Service Brake – Functioning Smoothly	✓	
Parking Brake – Functioning Smoothly	✓	
Steering Operation – Functioning Smoothly	✓	
Drive Control – Forward/Reverse – Functioning Smoothly	✓	
Arm Tilt Control – Forward and Back – Functioning Smoothly	✓	
Hoist (Seismic Source) and Lowering Control – Functioning Smoothly	✓	
Testing the sweep – Operation	✓	
Horn and Lights – Functioning	✓	
Cab (if equipped) – Heater, Defroster, Wipers – Functioning	✓	
Gauges: Ammeter, Engine Oil Pressure, Hour Meter, Fuel Level, Temperature, Instrument Monitors – Functioning	✓	FUEL AND ~~[illegible]~~ ENGINE TEMP NOT ACCURATE
Controller check | Trigger sensor on impact plate check	✓	
Impact plate check | Radio check	✓	
Source type VIBSIST 3000 ENGINE HRS		6383 HRS

OPERATOR: BOB TAYLOR
R. Tayl

O Sign-Off		
Prepared	*Name* *Nicoleta Enescu*	*Date* *July 27, 2021*

Reviewed	*Name* *Jon Crawford*	*Date* *July 27, 2021*
Reviewed	*Name*	*Date*
Approved	*Name* *Christopher Phillips*	*Date* *July 27, 2021*

<table>
<tr><td colspan="3">WP12 Data Quality Confirmation (DQC) Form</td><td rowspan="3">GOLDER MEMBER OF WSP</td></tr>
<tr><td>Document No.:
20253946-4120-210728</td><td>Original Date:
28 July 2021</td><td>Developed By:
Nicoleta Enescu</td></tr>
<tr><td>Revision No.:
R1</td><td>Revision Date:
31 July 2021</td><td>Authorized By:
Christopher Phillips</td></tr>
</table>

TO:	Mostafa Khorshidi	**Date:**	*July 28, 2021*
	Maria Sánchez-Rico Castejón	**Work Package:**	WP12 – VSP Profiling
	Sarah Hirschorn		
CC:	George Schneider		
		Distributed By:	Email

Record Number: 20253946-4120-210728

IGBH_04, IGNACE, ONTARIO

Acquisition depth interval: 5m

Staff: Cristian Vasile & Sorin Dobrovicescu

Start time: 8:00am **Finish time: 4:45pm**

Shot location(s): 10/26 shot locations for level at 430m (V20 repeated), all 26 shot locations for 490m and 550m. 10/26 shots at level 610m (71 total shots locations)

Prepared by: Nicoleta Enescu

Verified by: Jonathan Crawford

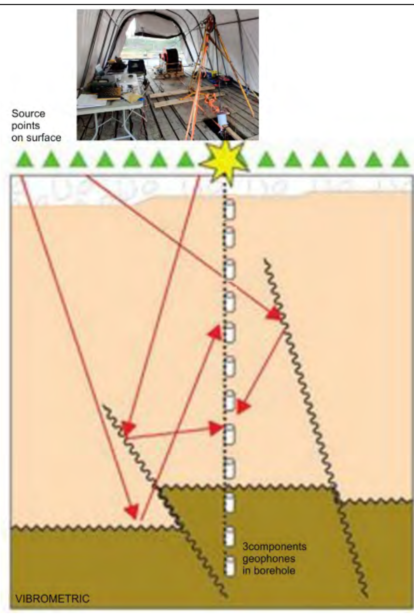
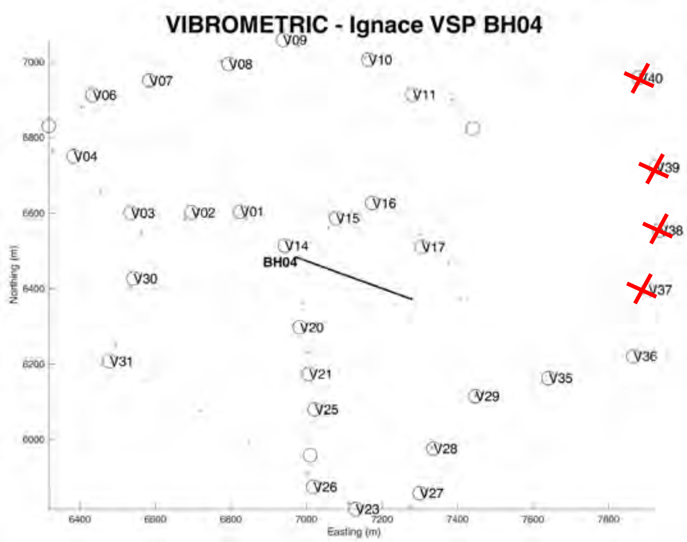
Usage notes:

- Complete one form per field day
- Office forms will be complete as processing packages/tasks are completed and will include supporting documentation
- Complete all header information (above)
- Delete unused tables (below) and fully populate those that remain
- Form is divided into A through O tables and field and processing tasks

WP12 Data Quality Confirmation (DQC) Form		
Document No.: 20253946-4120-210728	Original Date: *28 July 2021*	Developed By: *Nicoleta Enescu*
Revision No.: *R1*	Revision Date: *31 July 2021*	Authorized By: *Christopher Phillips*

FIELD

A Winch and Depth Counter	
Calibrated by measuring and marking the cable every 25 m (with depth labels every 50m) before insertion in the borehole. Verifying these distances using the depth counter. Discrepancies are adjusted by changing the depth value on the depth counter to match the cable mark.	
Results	
Settings applied	Factor was 0.2771. Calibration was verified at 490m – Depth counter reading 490.00m Calibration was verified at 550m – Depth counter reading 449.94m Calibration was verified at 610m – Depth counter reading 609.95m

B Tool Assembly	
Schematic	 
Results of pre-shipping checks. Refer to relevant document.	All good.

E Equipment Calibration/Function Checklist	OK	Maintenance

E Equipment Calibration/Function Checklist	OK	Maintenance
Geophones Geophone used (RD or R): Testing at ground surface performed before insertion in the borehole: Level of electrical disturbance Water tightness Operation of side arm clamp Verification of noise level and real seismic signal in each component	 _X_ _X_ _X_ _X_	
Winch Motor and transmission Controller Brake Ground anchors	X	
Cable Borehole collar level mark Overnight clamp	X	
Depth counter	X	
Radio check	X	
Acquisition computer Computer Acquisition Software Data Analysis Software	_X_ _X_ _X_	
Power source	X	
Access vehicle	X	
Geophones calibration certificate verification: Technical ID Signature Date Validity period Location	 _X_ _X_ _X_ _X_ _X_	
Depth counter calibration certificate verification: Technical ID Signature Date Validity period Location	 __ __ __ __ __	

H	**Geophone Testing in Borehole**
Clamping location verified	Yes
Level of electrical disturbance	None
Operation of the side arm clamp	Good
Verification of noise in each component	Good
Verification of real seismic signal in each component	Good

I	**Shot**
Confirmation of shot point ID with receiver staff	yes
Data acquisition sampling rate confirmed at 1 ms	yes

J Field Data - Review and Verification

Zero Mark of receivers	Shot ID	File Name	Comments/Verified
			All files verified during acquisition
430	V20	V_BH4_0430__21_00576	
		V_BH4_0430__21_00577	
		V_BH4_0430__21_00578	
430	V21	V_BH4_0430__21_00579	
		V_BH4_0430__21_00580	
		V_BH4_0430__21_00581	
430	V25	V_BH4_0430__21_00582	
		V_BH4_0430__21_00583	
		V_BH4_0430__21_00584	
430	V26	V_BH4_0430__21_00585	
		V_BH4_0430__21_00586	
		V_BH4_0430__21_00587	
430	V23	V_BH4_0430__21_00588	
		V_BH4_0430__21_00589	

		V_BH4_0430__21_00590	
430	V27	V_BH4_0430__21_00591	
		V_BH4_0430__21_00592	
		V_BH4_0430__21_00593	
430	V28	V_BH4_0430__21_00594	
		V_BH4_0430__21_00595	
		V_BH4_0430__21_00596	
430	V29	V_BH4_0430__21_00597	
		V_BH4_0430__21_00598	
		V_BH4_0430__21_00599	
430	V35	V_BH4_0430__21_00600	
		V_BH4_0430__21_00601	
		V_BH4_0430__21_00602	
430	V36	V_BH4_0430__21_00603	
		V_BH4_0430__21_00604	
		V_BH4_0430__21_00605	
490	V36	V_BH4_0490__21_00606	
		V_BH4_0490__21_00607	
		V_BH4_0490__21_00608	
490	V35	V_BH4_0490__21_00609	
		V_BH4_0490__21_00610	
		V_BH4_0490__21_00611	
490	V29	V_BH4_0490__21_00612	

		V_BH4_0490__21_00613	
		V_BH4_0490__21_00614	
490	V28	V_BH4_0490__21_00615	
		V_BH4_0490__21_00616	
		V_BH4_0490__21_00617	
490	V27	V_BH4_0490__21_00618	
		V_BH4_0490__21_00619	
		V_BH4_0490__21_00620	
490	V23	V_BH4_0490__21_00621	
		V_BH4_0490__21_00622	
		V_BH4_0490__21_00623	
490	V26	V_BH4_0490__21_00624	
		V_BH4_0490__21_00625	
		V_BH4_0490__21_00626	
490	V25	V_BH4_0490__21_00627	
		V_BH4_0490__21_00628	
		V_BH4_0490__21_00629	
490	V21	V_BH4_0490__21_00630	
		V_BH4_0490__21_00631	
		V_BH4_0490__21_00632	
490	V20	V_BH4_0490__21_00633	
		V_BH4_0490__21_00634	
		V_BH4_0490__21_00635	

490	V15	V_BH4_0490__21_00636	
		V_BH4_0490__21_00637	
		V_BH4_0490__21_00638	
490	V16	V_BH4_0490__21_00639	
		V_BH4_0490__21_00640	
		V_BH4_0490__21_00641	
490	V17	V_BH4_0490__21_00642	
		V_BH4_0490__21_00643	
		V_BH4_0490__21_00644	
490	V14	V_BH4_0490__21_00645	
		V_BH4_0490__21_00646	
		V_BH4_0490__21_00647	
490	V01	V_BH4_0490__21_00648	
		V_BH4_0490__21_00649	
		V_BH4_0490__21_00650	
490	V02	V_BH4_0490__21_00651	
		V_BH4_0490__21_00652	
		V_BH4_0490__21_00653	
490	V30	V_BH4_0490__21_00654	
		V_BH4_0490__21_00655	
		V_BH4_0490__21_00656	
490	V31	V_BH4_0490__21_00657	
		V_BH4_0490__21_00658	

		V_BH4_0490__21_00659	
490	V03	V_BH4_0490__21_00660	
		V_BH4_0490__21_00661	
		V_BH4_0490__21_00662	
490	V04	V_BH4_0490__21_00663	
		V_BH4_0490__21_00664	
		V_BH4_0490__21_00665	
490	V06	V_BH4_0490__21_00666	
		V_BH4_0490__21_00667	
		V_BH4_0490__21_00668	
490	V07	V_BH4_0490__21_00669	
		V_BH4_0490__21_00670	
		V_BH4_0490__21_00671	
490	V08	V_BH4_0490__21_00672	
		V_BH4_0490__21_00673	
		V_BH4_0490__21_00674	
490	V09	V_BH4_0490__21_00675	
		V_BH4_0490__21_00676	
		V_BH4_0490__21_00677	
490	V10	V_BH4_0490__21_00678	
		V_BH4_0490__21_00679	
		V_BH4_0490__21_00680	
490	V11	V_BH4_0490__21_00681	

		V_BH4_0490__21_00682	
		V_BH4_0490__21_00683	
550	V11	V_BH4_0550__21_00684	
		V_BH4_0550__21_00685	
		V_BH4_0550__21_00686	
550	V10	V_BH4_0550__21_00687	
		V_BH4_0550__21_00688	
		V_BH4_0550__21_00689	
550	V09	V_BH4_0550__21_00690	
		V_BH4_0550__21_00691	
		V_BH4_0550__21_00692	
550	V08	V_BH4_0550__21_00693	
		V_BH4_0550__21_00694	
		V_BH4_0550__21_00695	
550	V07	V_BH4_0550__21_00696	
		V_BH4_0550__21_00697	
		V_BH4_0550__21_00698	
550	V06	V_BH4_0550__21_00699	
		V_BH4_0550__21_00700	
		V_BH4_0550__21_00701	
550	V04	V_BH4_0550__21_00702	
		V_BH4_0550__21_00703	
		V_BH4_0550__21_00704	

550	V03	V_BH4_0550__21_00705	
		V_BH4_0550__21_00706	
		V_BH4_0550__21_00707	
550	V30	V_BH4_0550__21_00708	
		V_BH4_0550__21_00709	
		V_BH4_0550__21_00710	
550	V31	V_BH4_0550__21_00711	
		V_BH4_0550__21_00712	
		V_BH4_0550__21_00713	
550	V02	V_BH4_0550__21_00714	
		V_BH4_0550__21_00715	
		V_BH4_0550__21_00716	
550	V01	V_BH4_0550__21_00717	
		V_BH4_0550__21_00718	
		V_BH4_0550__21_00719	
550	V14	V_BH4_0550__21_00720	
		V_BH4_0550__21_00721	
		V_BH4_0550__21_00722	
550	V15	V_BH4_0550__21_00723	
		V_BH4_0550__21_00724	
		V_BH4_0550__21_00725	
550	V16	V_BH4_0550__21_00726	
		V_BH4_0550__21_00727	

		V_BH4_0550__21_00728	
550	V17	V_BH4_0550__21_00729	
		V_BH4_0550__21_00730	
		V_BH4_0550__21_00731	
550	V20	V_BH4_0550__21_00732	
		V_BH4_0550__21_00733	
		V_BH4_0550__21_00734	
550	V21	V_BH4_0550__21_00735	
		V_BH4_0550__21_00736	
		V_BH4_0550__21_00737	
550	V25	V_BH4_0550__21_00738	
		V_BH4_0550__21_00739	
		V_BH4_0550__21_00740	
550	V26	V_BH4_0550__21_00741	
		V_BH4_0550__21_00742	
		V_BH4_0550__21_00743	
550	V23	V_BH4_0550__21_00744	
		V_BH4_0550__21_00745	
		V_BH4_0550__21_00746	
550	V27	V_BH4_0550__21_00747	
		V_BH4_0550__21_00748	
		V_BH4_0550__21_00749	
550	V28	V_BH4_0550__21_00750	

		V_BH4_0550__21_00751	
		V_BH4_0550__21_00752	
550	V29	V_BH4_0550__21_00753	
		V_BH4_0550__21_00754	
		V_BH4_0550__21_00755	
550	V35	V_BH4_0550__21_00756	
		V_BH4_0550__21_00757	
		V_BH4_0550__21_00758	
550	V36	V_BH4_0550__21_00759	
		V_BH4_0550__21_00760	
		V_BH4_0550__21_00761	
610	V36	V_BH4_0610__21_00762	
		V_BH4_0610__21_00763	
		V_BH4_0610__21_00764	
610	V35	V_BH4_0610__21_00765	
		V_BH4_0610__21_00766	
		V_BH4_0610__21_00767	
610	V29	V_BH4_0610__21_00768	
		V_BH4_0610__21_00769	
		V_BH4_0610__21_00770	
610	V28	V_BH4_0610__21_00771	
		V_BH4_0610__21_00772	
		V_BH4_0610__21_00773	

610	V27	V_BH4_0610__21_00774	
		V_BH4_0610__21_00775	
		V_BH4_0610__21_00776	
610	V23	V_BH4_0610__21_00777	
		V_BH4_0610__21_00778	
		V_BH4_0610__21_00779	
610	V26	V_BH4_0610__21_00780	
		V_BH4_0610__21_00781	
		V_BH4_0610__21_00782	
610	V25	V_BH4_0610__21_00783	
		V_BH4_0610__21_00784	
		V_BH4_0610__21_00785	
610	V21	V_BH4_0610__21_00786	
		V_BH4_0610__21_00787	
		V_BH4_0610__21_00788	
610	V20	V_BH4_0610__21_00789	
		V_BH4_0610__21_00790	
		V_BH4_0610__21_00791	

K Field Issues		
Observed damage (note here as-needed additional detail on Daily Report items)		*corrective action (e.g. repair, component replacement)*

L File Control					
Data File	**DateTime**	**Depth Range**	**Staff**	**Software**	**Parameters/Settings**
			Cristian Vasile	VIPS5.11	1ms sample rate. 3 records of 20 seconds each
V_BH4_0430__21_00576		440.7 – 495.7			
V_BH4_0430__21_00577					
V_BH4_0430__21_00578					
V_BH4_0430__21_00579					
V_BH4_0430__21_00580					
V_BH4_0430__21_00581					
V_BH4_0430__21_00582					
V_BH4_0430__21_00583					
V_BH4_0430__21_00584					
V_BH4_0430__21_00585					
V_BH4_0430__21_00586					
V_BH4_0430__21_00587					
V_BH4_0430__21_00588					
V_BH4_0430__21_00589					
V_BH4_0430__21_00590					
V_BH4_0430__21_00591					
V_BH4_0430__21_00592					
V_BH4_0430__21_00593					
V_BH4_0430__21_00594					

L File Control					
V_BH4_0430__21_00595					
V_BH4_0430__21_00596					
V_BH4_0430__21_00597					
V_BH4_0430__21_00598					
V_BH4_0430__21_00599					
V_BH4_0430__21_00600					
V_BH4_0430__21_00601					
V_BH4_0430__21_00602					
V_BH4_0430__21_00603					
V_BH4_0430__21_00604					
V_BH4_0430__21_00605					
V_BH4_0490__21_00606		500.7 – 555.7			
V_BH4_0490__21_00607					
V_BH4_0490__21_00608					
V_BH4_0490__21_00609					
V_BH4_0490__21_00610					
V_BH4_0490__21_00611					
V_BH4_0490__21_00612					
V_BH4_0490__21_00613					
V_BH4_0490__21_00614					
V_BH4_0490__21_00615					
V_BH4_0490__21_00616					

L	**File Control**				
V_BH4_0490__21_00617					
V_BH4_0490__21_00618					
V_BH4_0490__21_00619					
V_BH4_0490__21_00620					
V_BH4_0490__21_00621					
V_BH4_0490__21_00622					
V_BH4_0490__21_00623					
V_BH4_0490__21_00624					
V_BH4_0490__21_00625					
V_BH4_0490__21_00626					
V_BH4_0490__21_00627					
V_BH4_0490__21_00628					
V_BH4_0490__21_00629					
V_BH4_0490__21_00630					
V_BH4_0490__21_00631					
V_BH4_0490__21_00632					
V_BH4_0490__21_00633					
V_BH4_0490__21_00634					
V_BH4_0490__21_00635					
V_BH4_0490__21_00636					
V_BH4_0490__21_00637					
V_BH4_0490__21_00638					

L File Control					
V_BH4_0490__21_00639					
V_BH4_0490__21_00640					
V_BH4_0490__21_00641					
V_BH4_0490__21_00642					
V_BH4_0490__21_00643					
V_BH4_0490__21_00644					
V_BH4_0490__21_00645					
V_BH4_0490__21_00646					
V_BH4_0490__21_00647					
V_BH4_0490__21_00648					
V_BH4_0490__21_00649					
V_BH4_0490__21_00650					
V_BH4_0490__21_00651					
V_BH4_0490__21_00652					
V_BH4_0490__21_00653					
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V_BH4_0490__21_00659					
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L	File Control				
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V_BH4_0490__21_00662					
V_BH4_0490__21_00663					
V_BH4_0490__21_00664					
V_BH4_0490__21_00665					
V_BH4_0490__21_00666					
V_BH4_0490__21_00667					
V_BH4_0490__21_00668					
V_BH4_0490__21_00669					
V_BH4_0490__21_00670					
V_BH4_0490__21_00671					
V_BH4_0490__21_00672					
V_BH4_0490__21_00673					
V_BH4_0490__21_00674					
V_BH4_0490__21_00675					
V_BH4_0490__21_00676					
V_BH4_0490__21_00677					
V_BH4_0490__21_00678					
V_BH4_0490__21_00679					
V_BH4_0490__21_00680					
V_BH4_0490__21_00681					
V_BH4_0490__21_00682					

L File Control					
V_BH4_0490__21_00683					
V_BH4_0550__21_00684		560.7 – 615.7			
V_BH4_0550__21_00685					
V_BH4_0550__21_00686					
V_BH4_0550__21_00687					
V_BH4_0550__21_00688					
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V_BH4_0550__21_00692					
V_BH4_0550__21_00693					
V_BH4_0550__21_00694					
V_BH4_0550__21_00695					
V_BH4_0550__21_00696					
V_BH4_0550__21_00697					
V_BH4_0550__21_00698					
V_BH4_0550__21_00699					
V_BH4_0550__21_00700					
V_BH4_0550__21_00701					
V_BH4_0550__21_00702					
V_BH4_0550__21_00703					
V_BH4_0550__21_00704					

L File Control					
V_BH4_0550__21_00705					
V_BH4_0550__21_00706					
V_BH4_0550__21_00707					
V_BH4_0550__21_00708					
V_BH4_0550__21_00709					
V_BH4_0550__21_00710					
V_BH4_0550__21_00711					
V_BH4_0550__21_00712					
V_BH4_0550__21_00713					
V_BH4_0550__21_00714					
V_BH4_0550__21_00715					
V_BH4_0550__21_00716					
V_BH4_0550__21_00717					
V_BH4_0550__21_00718					
V_BH4_0550__21_00719					
V_BH4_0550__21_00720					
V_BH4_0550__21_00721					
V_BH4_0550__21_00722					
V_BH4_0550__21_00723					
V_BH4_0550__21_00724					
V_BH4_0550__21_00725					
V_BH4_0550__21_00726					

L	**File Control**				
V_BH4_0550__21_00727					
V_BH4_0550__21_00728					
V_BH4_0550__21_00729					
V_BH4_0550__21_00730					
V_BH4_0550__21_00731					
V_BH4_0550__21_00732					
V_BH4_0550__21_00733					
V_BH4_0550__21_00734					
V_BH4_0550__21_00735					
V_BH4_0550__21_00736					
V_BH4_0550__21_00737					
V_BH4_0550__21_00738					
V_BH4_0550__21_00739					
V_BH4_0550__21_00740					
V_BH4_0550__21_00741					
V_BH4_0550__21_00742					
V_BH4_0550__21_00743					
V_BH4_0550__21_00744					
V_BH4_0550__21_00745					
V_BH4_0550__21_00746					
V_BH4_0550__21_00747					
V_BH4_0550__21_00748					

L File Control

V_BH4_0550__21_00749					
V_BH4_0550__21_00750					
V_BH4_0550__21_00751					
V_BH4_0550__21_00752					
V_BH4_0550__21_00753					
V_BH4_0550__21_00754					
V_BH4_0550__21_00755					
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V_BH4_0550__21_00757					
V_BH4_0550__21_00758					
V_BH4_0550__21_00759					
V_BH4_0550__21_00760					
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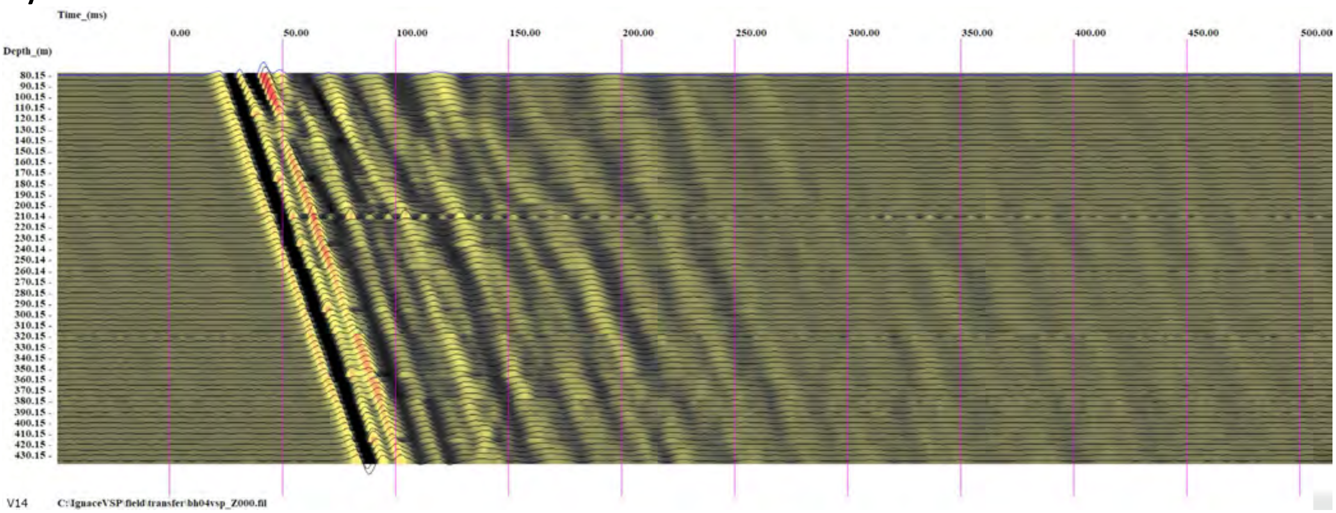
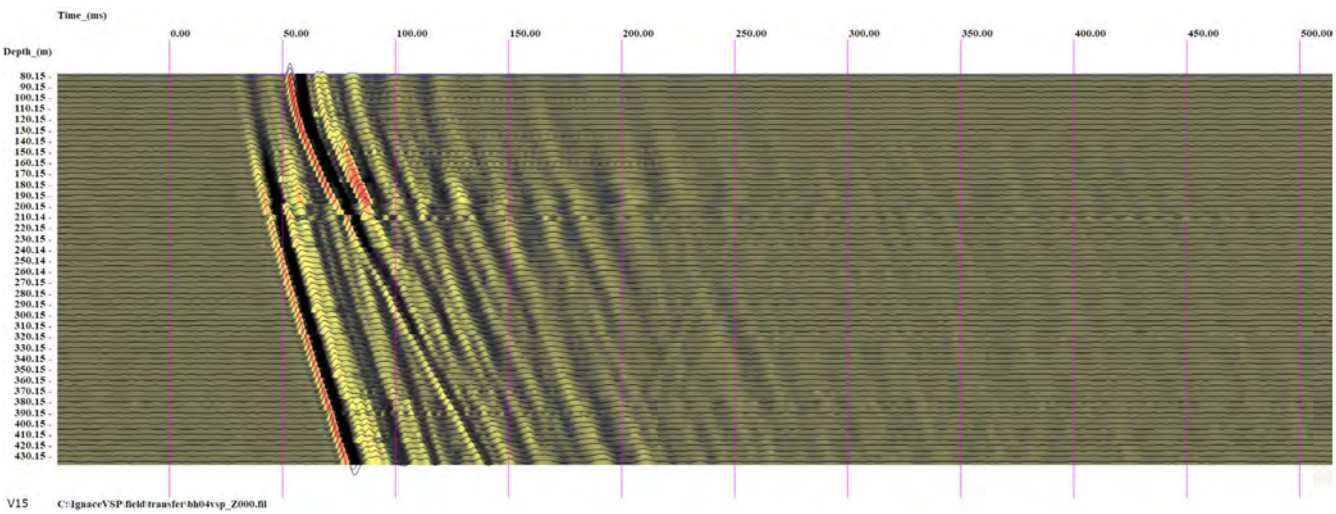
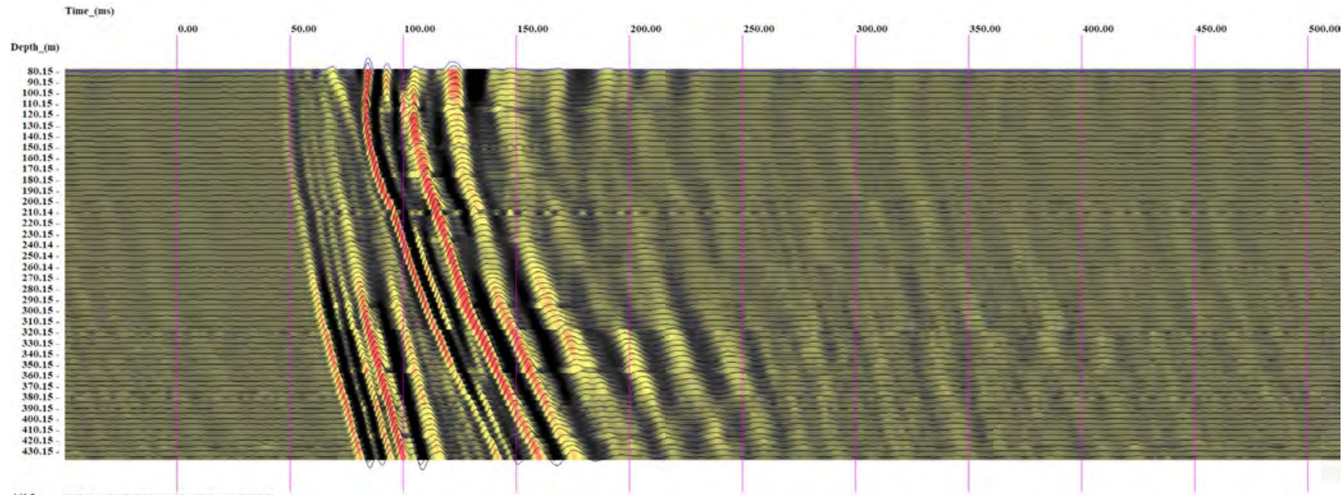
V_BH4_0610__21_00767					
V_BH4_0610__21_00768					
V_BH4_0610__21_00769					
V_BH4_0610__21_00770					

L File Control					
V_BH4_0610__21_00771					
V_BH4_0610__21_00772					
V_BH4_0610__21_00773					
V_BH4_0610__21_00774					
V_BH4_0610__21_00775					
V_BH4_0610__21_00776					
V_BH4_0610__21_00777					
V_BH4_0610__21_00778					
V_BH4_0610__21_00779					
V_BH4_0610__21_00780					
V_BH4_0610__21_00781					
V_BH4_0610__21_00782					
V_BH4_0610__21_00783					
V_BH4_0610__21_00784					
V_BH4_0610__21_00785					
V_BH4_0610__21_00786					
V_BH4_0610__21_00787					
V_BH4_0610__21_00788					
V_BH4_0610__21_00789					
V_BH4_0610__21_00790					
V_BH4_0610__21_00791					

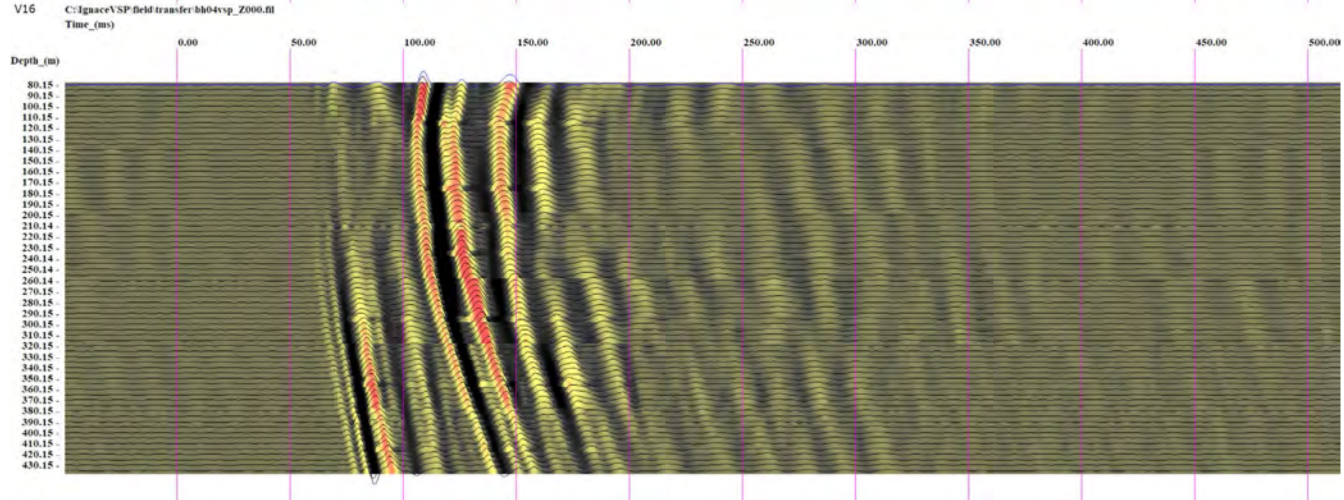
Example of raw data axial component profiles recorded from shot points V14, V15, V16 & V17 and receiver layouts 1 to 6.







V16 C:\IgnaceVSP\field\transfer\bh04vsp_Z000.fil



V17 C:\IgnaceVSP\field\transfer\bh04vsp_Z000.fil

VIBROMETRIC

NWMO

Vibrometric Seismic Source Checklist DATES July 28/21

Engine Off Checks	OK	Maintenance
Leaks – Fuel, Hydraulic Oil, Engine Oil or Radiator Coolant	✓	
Tires – Condition and Pressure	✓	
Hydraulic Hoses, Mast Chains, Cables and Stops – Check Visually	✓	
Safety Warnings – Attached (Refer to Parts Manual for Location)	✓	
Battery – Check Water/Electrolyte Level and Charge	✓	
Hydraulic Fluid Level – Check Level	✓	
Engine Oil Level – Dipstick	✓	
Transmission Fluid Level – Dipstick	✓	
Radiator Coolant – Check Level	✓	
Operator's Manual – In Container		
Nameplate – Attached and Information Matches Model, Serial Number and Attachments	✓	
Seat Belt – Functioning Smoothly	✓	
Hood Latch – Adjusted and Securely Fastened	✓	
Brake Fluid – Check Level	✓	
Seismic Vibrator Check Screws, Cables, Hoses	✓	
Fuel level	✓	
Lights check	✓	

Engine On Checks	OK	Maintenance
Accelerator or Direction Control Pedal – Functioning Smoothly	✓	
Service Brake – Functioning Smoothly	✓	
Parking Brake – Functioning Smoothly	✓	
Steering Operation – Functioning Smoothly	✓	
Drive Control – Forward/Reverse – Functioning Smoothly	✓	
Arm Tilt Control – Forward and Back – Functioning Smoothly	✓	
Hoist (Seismic Source) and Lowering Control – Functioning Smoothly	✓	
Testing the sweep – Operation	✓	
Horn and Lights – Functioning	✓	
Cab (if equipped) – Heater, Defroster, Wipers – Functioning	✓	
Gauges: Ammeter, Engine Oil Pressure, Hour Meter, Fuel Level, Temperature, Instrument Monitors – Functioning	✓	FUEL AND ENGINE TEMP NOT ACCURATE
Controller check | Trigger sensor on impact plate check	✓	
Impact plate check | Radio check	✓	
Source type VIBSIST 3000 ENGINE HRS		6390 HRS

O Sign-Off		
Prepared	*Name* *Nicoleta Enescu*	*Date* *July 28, 2021*
Reviewed	*Name* *Jon Crawford*	*Date* *July 28, 2021*
Reviewed	*Name*	*Date*
Approved	*Name* *Christopher Phillips*	*Date* *July 28, 2021*

WP12 Data Quality Confirmation (DQC) Form			
Document No.: 20253946-4120-210729	Original Date: *29 July 2021*	Developed By: *Nicoleta Enescu*	
Revision No.: *R0*	Revision Date: *N/A*	Authorized By: *Christopher Phillips*	

TO:	Mostafa Khorshidi	**Date:**	*July 28, 2021*
	Maria Sánchez-Rico Castejón	**Work Package:**	WP12 – VSP Profiling
	Sarah Hirschorn		
CC:	George Schneider		
		Distributed By:	Email

Record Number: 20253946-4120-210729

IGBH_04, IGNACE, ONTARIO

Acquisition depth interval: 5m

Staff: Cristian Vasile

Start time: 8:00am **Finish time: 4:30pm**

Shot location(s): 17/26 shot locations (V20 was repeated, from yesterday) for level at 610m, all 26 shot locations for 670m. 14/26 shots at level 730m (57 total shots locations)

Prepared by: Nicoleta Enescu

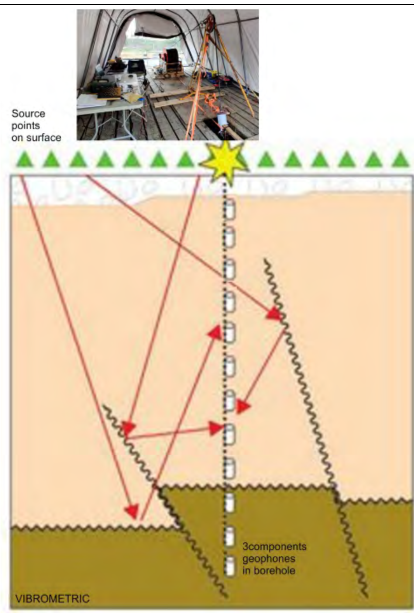
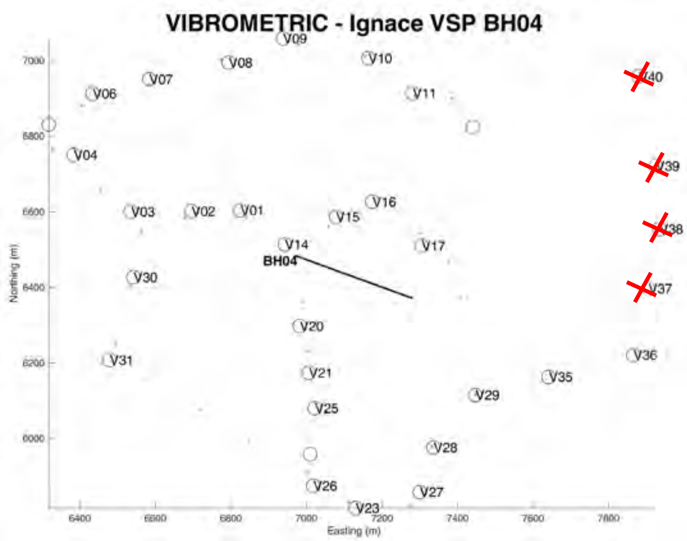
Verified by: Jonathan Crawford

Usage notes:

- Complete one form per field day
- Office forms will be complete as processing packages/tasks are completed and will include supporting documentation
- Complete all header information (above)
- Delete unused tables (below) and fully populate those that remain
- Form is divided into A through O tables and field and processing tasks

FIELD

A	Winch and Depth Counter
Calibrated by measuring and marking the cable every 25 m (with depth labels every 50m) before insertion in the borehole. Verifying these distances using the depth counter. Discrepancies are adjusted by changing the depth value on the depth counter to match the cable mark.	
Results	
Settings applied	Factor was 0.2771. Calibration was verified at 670m – Depth counter reading 669.95m Calibration was verified at 730m – Depth counter reading 730.07m

B	Tool Assembly
Schematic	
Results of pre-shipping checks. Refer to relevant document.	All good.

E	Equipment Calibration/Function Checklist	OK	Maintenance
Geophones			
	Geophone used (RD or R):	RD	
	Testing at ground surface performed before insertion in the borehole:		
	Level of electrical disturbance	_X_	
	Water tightness	_X_	
	Operation of side arm clamp	_X_	
	Verification of noise level and real seismic signal in each component	_X_	

A	Winch and Depth Counter	
Winch Motor and transmission Controller Brake Ground anchors	X	
Cable Borehole collar level mark Overnight clamp	X	
Depth counter	X	
Radio check	X	
Acquisition computer Computer Acquisition Software Data Analysis Software	_X_ _X_ _X_	
Power source	X	
Access vehicle	X	
Geophones calibration certificate verification: Technical ID Signature Date Validity period Location	_X_ _X_ _X_ _X_ _X_	
Depth counter calibration certificate verification: Technical ID Signature Date Validity period Location	__ __ __ __ __	

H	Geophone Testing in Borehole
Clamping location verified	Yes
Level of electrical disturbance	None
Operation of the side arm clamp	Good
Verification of noise in each component	Good
Verification of real seismic signal in each component	Good

I Shot	
Confirmation of shot point ID with receiver staff	yes
Data acquisition sampling rate confirmed at 1 ms	yes

J Field Data - Review and Verification

Zero Mark of receivers	Shot ID	File Name	Comments/Verified
			All files verified during acquisition
610	V20	V_BH4_0610__21_00792	
		V_BH4_0610__21_00793	
		V_BH4_0610__21_00794	
610	V15	V_BH4_0610__21_00795	
		V_BH4_0610__21_00796	
		V_BH4_0610__21_00797	
610	V16	V_BH4_0610__21_00798	
		V_BH4_0610__21_00799	
		V_BH4_0610__21_00800	
610	V17	V_BH4_0610__21_00801	
		V_BH4_0610__21_00802	
		V_BH4_0610__21_00803	
610	V14	V_BH4_0610__21_00804	
		V_BH4_0610__21_00805	
		V_BH4_0610__21_00806	
610	V01	V_BH4_0610__21_00807	
		V_BH4_0610__21_00808	
		V_BH4_0610__21_00809	

610	V02	V_BH4_0610__21_00810	
		V_BH4_0610__21_00811	
		V_BH4_0610__21_00812	
610	V30	V_BH4_0610__21_00813	
		V_BH4_0610__21_00814	
		V_BH4_0610__21_00815	
610	V31	V_BH4_0610__21_00816	
		V_BH4_0610__21_00817	
		V_BH4_0610__21_00818	
610	V03	V_BH4_0610__21_00819	
		V_BH4_0610__21_00820	
		V_BH4_0610__21_00821	
610	V04	V_BH4_0610__21_00822	
		V_BH4_0610__21_00823	
		V_BH4_0610__21_00824	
610	V06	V_BH4_0610__21_00825	
		V_BH4_0610__21_00826	
		V_BH4_0610__21_00827	
610	V07	V_BH4_0610__21_00828	
		V_BH4_0610__21_00829	
		V_BH4_0610__21_00830	
610	V08	V_BH4_0610__21_00831	
		V_BH4_0610__21_00832	

		V_BH4_0610__21_00833	
610	V09	V_BH4_0610__21_00834	
		V_BH4_0610__21_00835	
		V_BH4_0610__21_00836	
610	V10	V_BH4_0610__21_00837	
		V_BH4_0610__21_00838	
		V_BH4_0610__21_00839	
610	V11	V_BH4_0610__21_00840	
		V_BH4_0610__21_00841	
		V_BH4_0610__21_00842	
670	V11	V_BH4_0670__21_00843	
		V_BH4_0670__21_00844	
		V_BH4_0670__21_00845	
670	V10	V_BH4_0670__21_00846	
		V_BH4_0670__21_00847	
		V_BH4_0670__21_00848	
670	V09	V_BH4_0670__21_00849	
		V_BH4_0670__21_00850	
		V_BH4_0670__21_00851	
670	V08	V_BH4_0670__21_00852	
		V_BH4_0670__21_00853	
		V_BH4_0670__21_00854	
670	V07	V_BH4_0670__21_00855	

		V_BH4_0670__21_00856	
		V_BH4_0670__21_00857	
670	V06	V_BH4_0670__21_00858	
		V_BH4_0670__21_00859	
		V_BH4_0670__21_00860	
670	V04	V_BH4_0670__21_00861	
		V_BH4_0670__21_00862	
		V_BH4_0670__21_00863	
670	V03	V_BH4_0670__21_00864	
		V_BH4_0670__21_00865	
		V_BH4_0670__21_00866	
670	V30	V_BH4_0670__21_00867	
		V_BH4_0670__21_00868	
		V_BH4_0670__21_00869	
670	V31	V_BH4_0670__21_00870	
		V_BH4_0670__21_00871	
		V_BH4_0670__21_00872	
670	V02	V_BH4_0670__21_00873	
		V_BH4_0670__21_00874	
		V_BH4_0670__21_00875	
670	V01	V_BH4_0670__21_00876	
		V_BH4_0670__21_00877	
		V_BH4_0670__21_00878	

670	V14	V_BH4_0670__21_00879	
		V_BH4_0670__21_00880	
		V_BH4_0670__21_00881	
670	V15	V_BH4_0670__21_00882	
		V_BH4_0670__21_00883	
		V_BH4_0670__21_00884	
670	V16	V_BH4_0670__21_00885	
		V_BH4_0670__21_00886	
		V_BH4_0670__21_00887	
670	V17	V_BH4_0670__21_00888	
		V_BH4_0670__21_00889	
		V_BH4_0670__21_00890	
670	V20	V_BH4_0670__21_00891	
		V_BH4_0670__21_00892	
		V_BH4_0670__21_00893	
670	V21	V_BH4_0670__21_00894	
		V_BH4_0670__21_00895	
		V_BH4_0670__21_00896	
670	V25	V_BH4_0670__21_00897	
		V_BH4_0670__21_00898	
		V_BH4_0670__21_00899	
670	V26	V_BH4_0670__21_00900	
		V_BH4_0670__21_00901	

		V_BH4_0670__21_00902	
670	V23	V_BH4_0670__21_00903	
		V_BH4_0670__21_00904	
		V_BH4_0670__21_00905	
670	V27	V_BH4_0670__21_00906	
		V_BH4_0670__21_00907	
		V_BH4_0670__21_00908	
670	V28	V_BH4_0670__21_00909	
		V_BH4_0670__21_00910	
		V_BH4_0670__21_00911	
670	V29	V_BH4_0670__21_00912	
		V_BH4_0670__21_00913	
		V_BH4_0670__21_00914	
670	V35	V_BH4_0670__21_00915	
		V_BH4_0670__21_00916	
		V_BH4_0670__21_00917	
670	V36	V_BH4_0670__21_00918	
		V_BH4_0670__21_00919	
		V_BH4_0670__21_00920	
730	V36	V_BH4_0730__21_00921	
		V_BH4_0730__21_00922	
		V_BH4_0730__21_00923	
730	V35	V_BH4_0730__21_00924	

		V_BH4_0730__21_00925	
		V_BH4_0730__21_00926	
730	V29	V_BH4_0730__21_00927	
		V_BH4_0730__21_00928	
		V_BH4_0730__21_00929	
730	V28	V_BH4_0730__21_00930	
		V_BH4_0730__21_00931	
		V_BH4_0730__21_00932	
730	V27	V_BH4_0730__21_00933	
		V_BH4_0730__21_00934	
		V_BH4_0730__21_00935	
730	V23	V_BH4_0730__21_00936	
		V_BH4_0730__21_00937	
		V_BH4_0730__21_00938	
730	V26	V_BH4_0730__21_00939	
		V_BH4_0730__21_00940	
		V_BH4_0730__21_00941	
730	V25	V_BH4_0730__21_00942	
		V_BH4_0730__21_00943	
		V_BH4_0730__21_00944	
730	V21	V_BH4_0730__21_00945	
		V_BH4_0730__21_00946	
		V_BH4_0730__21_00947	

730	V20	V_BH4_0730__21_00948	
		V_BH4_0730__21_00949	
		V_BH4_0730__21_00950	
730	V15	V_BH4_0730__21_00951	
		V_BH4_0730__21_00952	
		V_BH4_0730__21_00953	
730	V16	V_BH4_0730__21_00954	
		V_BH4_0730__21_00955	
		V_BH4_0730__21_00956	
730	V17	V_BH4_0730__21_00957	
		V_BH4_0730__21_00958	
		V_BH4_0730__21_00959	
730	V14	V_BH4_0730__21_00960	
		V_BH4_0730__21_00961	
		V_BH4_0730__21_00962	

K Field Issues		
Observed damage (note here as-needed additional detail on Daily Report items)		*corrective action (e.g. repair, component replacement)*

L File Control					
Data File	**DateTime**	**Depth Range**	**Staff**	**Software**	**Parameters/Settings**
			Cristian Vasile	VIPS5.11	1ms sample rate. 3 records of 20 seconds each

L File Control					
V_BH4_0610__21_00792		620.7 – 675.7			
V_BH4_0610__21_00793					
V_BH4_0610__21_00794					
V_BH4_0610__21_00795					
V_BH4_0610__21_00796					
V_BH4_0610__21_00797					
V_BH4_0610__21_00798					
V_BH4_0610__21_00799					
V_BH4_0610__21_00800					
V_BH4_0610__21_00801					
V_BH4_0610__21_00802					
V_BH4_0610__21_00803					
V_BH4_0610__21_00804					
V_BH4_0610__21_00805					
V_BH4_0610__21_00806					
V_BH4_0610__21_00807					
V_BH4_0610__21_00808					
V_BH4_0610__21_00809					
V_BH4_0610__21_00810					
V_BH4_0610__21_00811					
V_BH4_0610__21_00812					
V_BH4_0610__21_00813					

L File Control					
V_BH4_0610__21_00814					
V_BH4_0610__21_00815					
V_BH4_0610__21_00816					
V_BH4_0610__21_00817					
V_BH4_0610__21_00818					
V_BH4_0610__21_00819					
V_BH4_0610__21_00820					
V_BH4_0610__21_00821					
V_BH4_0610__21_00822					
V_BH4_0610__21_00823					
V_BH4_0610__21_00824					
V_BH4_0610__21_00825					
V_BH4_0610__21_00826					
V_BH4_0610__21_00827					
V_BH4_0610__21_00828					
V_BH4_0610__21_00829					
V_BH4_0610__21_00830					
V_BH4_0610__21_00831					
V_BH4_0610__21_00832					
V_BH4_0610__21_00833					
V_BH4_0610__21_00834					
V_BH4_0610__21_00835					

L	**File Control**				
V_BH4_0610__21_00836					
V_BH4_0610__21_00837					
V_BH4_0610__21_00838					
V_BH4_0610__21_00839					
V_BH4_0610__21_00840					
V_BH4_0610__21_00841					
V_BH4_0610__21_00842					
V_BH4_0670__21_00843		680.7 – 735.7			
V_BH4_0670__21_00844					
V_BH4_0670__21_00845					
V_BH4_0670__21_00846					
V_BH4_0670__21_00847					
V_BH4_0670__21_00848					
V_BH4_0670__21_00849					
V_BH4_0670__21_00850					
V_BH4_0670__21_00851					
V_BH4_0670__21_00852					
V_BH4_0670__21_00853					
V_BH4_0670__21_00854					
V_BH4_0670__21_00855					
V_BH4_0670__21_00856					
V_BH4_0670__21_00857					

L File Control					
V_BH4_0670__21_00858					
V_BH4_0670__21_00859					
V_BH4_0670__21_00860					
V_BH4_0670__21_00861					
V_BH4_0670__21_00862					
V_BH4_0670__21_00863					
V_BH4_0670__21_00864					
V_BH4_0670__21_00865					
V_BH4_0670__21_00866					
V_BH4_0670__21_00867					
V_BH4_0670__21_00868					
V_BH4_0670__21_00869					
V_BH4_0670__21_00870					
V_BH4_0670__21_00871					
V_BH4_0670__21_00872					
V_BH4_0670__21_00873					
V_BH4_0670__21_00874					
V_BH4_0670__21_00875					
V_BH4_0670__21_00876					
V_BH4_0670__21_00877					
V_BH4_0670__21_00878					
V_BH4_0670__21_00879					

L	File Control				
V_BH4_0670__21_00880					
V_BH4_0670__21_00881					
V_BH4_0670__21_00882					
V_BH4_0670__21_00883					
V_BH4_0670__21_00884					
V_BH4_0670__21_00885					
V_BH4_0670__21_00886					
V_BH4_0670__21_00887					
V_BH4_0670__21_00888					
V_BH4_0670__21_00889					
V_BH4_0670__21_00890					
V_BH4_0670__21_00891					
V_BH4_0670__21_00892					
V_BH4_0670__21_00893					
V_BH4_0670__21_00894					
V_BH4_0670__21_00895					
V_BH4_0670__21_00896					
V_BH4_0670__21_00897					
V_BH4_0670__21_00898					
V_BH4_0670__21_00899					
V_BH4_0670__21_00900					
V_BH4_0670__21_00901					

L	File Control				
V_BH4_0670__21_00902					
V_BH4_0670__21_00903					
V_BH4_0670__21_00904					
V_BH4_0670__21_00905					
V_BH4_0670__21_00906					
V_BH4_0670__21_00907					
V_BH4_0670__21_00908					
V_BH4_0670__21_00909					
V_BH4_0670__21_00910					
V_BH4_0670__21_00911					
V_BH4_0670__21_00912					
V_BH4_0670__21_00913					
V_BH4_0670__21_00914					
V_BH4_0670__21_00915					
V_BH4_0670__21_00916					
V_BH4_0670__21_00917					
V_BH4_0670__21_00918					
V_BH4_0670__21_00919					
V_BH4_0670__21_00920					
V_BH4_0730__21_00921		740.7 – 795.7			
V_BH4_0730__21_00922					
V_BH4_0730__21_00923					

L	**File Control**				
V_BH4_0730__21_00924					
V_BH4_0730__21_00925					
V_BH4_0730__21_00926					
V_BH4_0730__21_00927					
V_BH4_0730__21_00928					
V_BH4_0730__21_00929					
V_BH4_0730__21_00930					
V_BH4_0730__21_00931					
V_BH4_0730__21_00932					
V_BH4_0730__21_00933					
V_BH4_0730__21_00934					
V_BH4_0730__21_00935					
V_BH4_0730__21_00936					
V_BH4_0730__21_00937					
V_BH4_0730__21_00938					
V_BH4_0730__21_00939					
V_BH4_0730__21_00940					
V_BH4_0730__21_00941					
V_BH4_0730__21_00942					
V_BH4_0730__21_00943					
V_BH4_0730__21_00944					
V_BH4_0730__21_00945					

L	**File Control**				
V_BH4_0730__21_00946					
V_BH4_0730__21_00947					
V_BH4_0730__21_00948					
V_BH4_0730__21_00949					
V_BH4_0730__21_00950					
V_BH4_0730__21_00951					
V_BH4_0730__21_00952					
V_BH4_0730__21_00953					
V_BH4_0730__21_00954					
V_BH4_0730__21_00955					
V_BH4_0730__21_00956					
V_BH4_0730__21_00957					
V_BH4_0730__21_00958					
V_BH4_0730__21_00959					
V_BH4_0730__21_00960					
V_BH4_0730__21_00961					
V_BH4_0730__21_00962					

VIBROMETRIC

Vibrometric Seismic Source Checklist

Engine Off Checks	OK	Maintenance
Leaks – Fuel, Hydraulic Oil, Engine Oil or Radiator Coolant	✓	
Tires – Condition and Pressure	✓	
Hydraulic Hoses, Mast Chains, Cables and Stops – Check Visually	✓	
Safety Warnings – Attached (Refer to Parts Manual for Location)	✓	
Battery – Check Water/Electrolyte Level and Charge	✓	
Hydraulic Fluid Level – Check Level	✓	
Engine Oil Level – Dipstick	✓	
Transmission Fluid Level – Dipstick	✓	
Radiator Coolant – Check Level	✓	
Operator's Manual – In Container		
Nameplate – Attached and Information Matches Model, Serial Number and Attachments	✓	
Seat Belt – Functioning Smoothly	✓	
Hood Latch – Adjusted and Securely Fastened	✓	
Brake Fluid – Check Level	✓	
Seismic Vibrator Check Screws, Cables, Hoses	✓	
Fuel level	✓	
Lights check	✓	
Engine On Checks	OK	Maintenance
Accelerator or Direction Control Pedal – Functioning Smoothly	✓	
Service Brake – Functioning Smoothly	✓	
Parking Brake – Functioning Smoothly	✓	
Steering Operation – Functioning Smoothly	✓	
Drive Control – Forward/Reverse – Functioning Smoothly	✓	
Arm Tilt Control – Forward and Back – Functioning Smoothly	✓	
Hoist (Seismic Source) and Lowering Control – Functioning Smoothly	✓	
Testing the sweep – Operation	✓	
Horn and Lights – Functioning	✓	
Cab (if equipped) – Heater, Defroster, Wipers – Functioning	✓	
Gauges: Ammeter, Engine Oil Pressure, Hour Meter, Fuel Level, Temperature, Instrument Monitors – Functioning	✓	FUEL AND ENGINE TEMP GAUGE NOT ACCURATE
Controller check | Trigger sensor on impact plate check	✓	
Impact plate check | Radio check	✓	
Source type VIB SIST 3000 ENGINE HOURS		6398 HRS

OPERATOR: BOB TAYLOR.

R. Tayl

*Printed or electronic copies of this document, other than the original found on the **Canadian QMS SharePoint Site,** are uncontrolled.*

O Sign-Off		
Prepared	*Name* *Nicoleta Enescu*	*Date* *July 29, 2021*
Reviewed	*Name* *Jon Crawford*	*Date* *July 29, 2021*
Reviewed	*Name*	*Date*
Approved	*Name* *Christopher Phillips*	*Date* *July 29, 2021*

WP12 Data Quality Confirmation (DQC) Form			
Document No.: 20253946-4120-210730	Original Date: *30 July 2021*	Developed By: *Nicoleta Enescu*	
Revision No.: *R0*	Revision Date: *N/A*	Authorized By: *Christopher Phillips*	

TO:	Mostafa Khorshidi	**Date:**	*July 30, 2021*
	Maria Sánchez-Rico Castejón	**Work Package:**	WP12 – VSP Profiling
	Sarah Hirschorn		
CC:	George Schneider		
		Distributed By:	Email

Record Number: 20253946-4120-210730

IGBH_04, IGNACE, ONTARIO

Acquisition depth interval: 5m

Staff: Cristian Vasile

Start time: 8:00am **Finish time: 3:30pm**

Shot location(s): 13/26 shot locations (V14 was repeated, from yesterday) for level at 730m, all 26 shot locations for 790m, all 26 shot locations for 850m.

Prepared by: Nicoleta Enescu

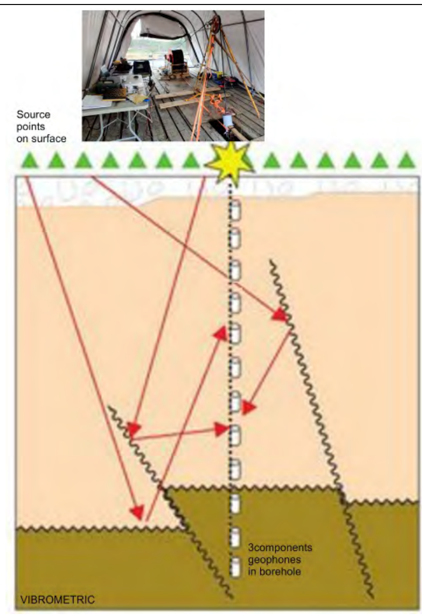
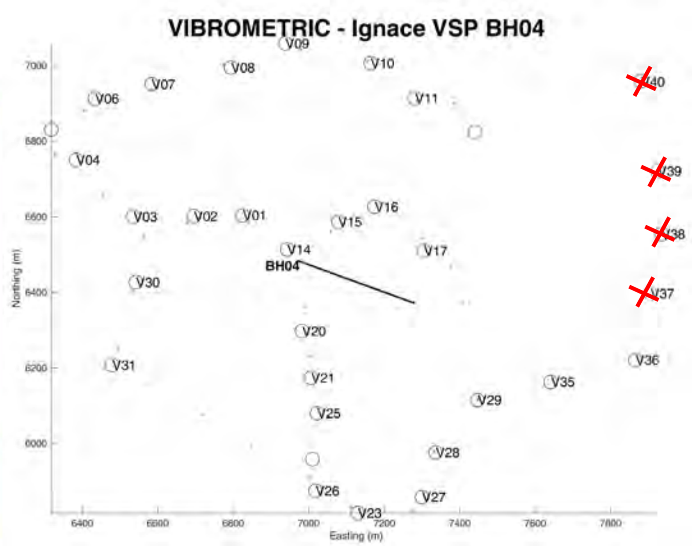
Verified by: Jonathan Crawford

Usage notes:

- Complete one form per field day
- Office forms will be complete as processing packages/tasks are completed and will include supporting documentation
- Complete all header information (above)
- Delete unused tables (below) and fully populate those that remain
- Form is divided into A through O tables and field and processing tasks

FIELD

A	Winch and Depth Counter
Calibrated by measuring and marking the cable every 25 m (with depth labels every 50m) before insertion in the borehole. Verifying these distances using the depth counter. Discrepancies are adjusted by changing the depth value on the depth counter to match the cable mark.	
Results	
Settings applied	Factor was 0.2771. Calibration was verified at 750m – Depth counter reading 749.83m, Real depth = 790.05m (for level 790m). Real depth = 849.95m (for level 850m)

B	Tool Assembly
Schematic	 

Results of pre-shipping checks. Refer to relevant document.	All good.

E	Equipment Calibration/Function Checklist	OK	Maintenance

WP12 Data Quality Confirmation (DQC) Form			
Document No.: 20253946-4120-210730	Original Date: *30 July 2021*	Developed By: *Nicoleta Enescu*	GOLDER MEMBER OF WSP
Revision No.: *R0*	Revision Date: *N/A*	Authorized By: *Christopher Phillips*	

A	**Winch and Depth Counter**		
Geophones Geophone used (RD or R): Testing at ground surface performed before insertion in the borehole: Level of electrical disturbance Water tightness Operation of side arm clamp Verification of noise level and real seismic signal in each component		RD _X_ _X_ _X_ _X_	
Winch Motor and transmission Controller Brake Ground anchors		X	
Cable Borehole collar level mark Overnight clamp		X	
Depth counter		X	
Radio check		X	
Acquisition computer Computer Acquisition Software Data Analysis Software		_X_ _X_ _X_	
Power source		X	
Access vehicle		X	
Geophones calibration certificate verification: Technical ID Signature Date Validity period Location		_X_ _X_ _X_ _X_ _X_	
Depth counter calibration certificate verification: Technical ID Signature Date Validity period Location		__ __ __ __ __	

H	**Geophone Testing in Borehole**
Clamping location verified	Yes

WP12 Data Quality Confirmation (DQC) Form			
Document No.: 20253946-4120-210730	Original Date: *30 July 2021*	Developed By: *Nicoleta Enescu*	
Revision No.: *R0*	Revision Date: *N/A*	Authorized By: *Christopher Phillips*	

A Winch and Depth Counter	
Level of electrical disturbance	None
Operation of the side arm clamp	Good
Verification of noise in each component	Good
Verification of real seismic signal in each component	Good

I Shot	
Confirmation of shot point ID with receiver staff	yes
Data acquisition sampling rate confirmed at 1 ms	yes

J Field Data - Review and Verification

Zero Mark of receivers	Shot ID	File Name	Comments/Verified
			All files verified during acquisition
730	V14	V_BH4_0730__21_00963	
		V_BH4_0730__21_00964	
		V_BH4_0730__21_00965	
730	V01	V_BH4_0730__21_00966	
		V_BH4_0730__21_00967	
		V_BH4_0730__21_00968	
730	V02	V_BH4_0730__21_00969	
		V_BH4_0730__21_00970	
		V_BH4_0730__21_00971	
730	V30	V_BH4_0730__21_00972	
		V_BH4_0730__21_00973	
		V_BH4_0730__21_00974	
730	V31	V_BH4_0730__21_00975	
		V_BH4_0730__21_00976	
		V_BH4_0730__21_00977	

730	V03	V_BH4_0730__21_00978	
		V_BH4_0730__21_00979	
		V_BH4_0730__21_00980	
730	V04	V_BH4_0730__21_00981	
		V_BH4_0730__21_00982	
		V_BH4_0730__21_00983	
730	V06	V_BH4_0730__21_00984	
		V_BH4_0730__21_00985	
		V_BH4_0730__21_00986	
730	V07	V_BH4_0730__21_00987	
		V_BH4_0730__21_00988	
		V_BH4_0730__21_00989	
730	V08	V_BH4_0730__21_00990	
		V_BH4_0730__21_00991	
		V_BH4_0730__21_00992	
730	V09	V_BH4_0730__21_00993	
		V_BH4_0730__21_00994	
		V_BH4_0730__21_00995	
730	V10	V_BH4_0730__21_00996	
		V_BH4_0730__21_00997	
		V_BH4_0730__21_00998	
730	V11	V_BH4_0730__21_00999	
		V_BH4_0730__21_01000	

		V_BH4_0730__21_01001	
790	V11	V_BH4_0790__21_01002	
		V_BH4_0790__21_01003	
		V_BH4_0790__21_01004	
790	V10	V_BH4_0790__21_01005	
		V_BH4_0790__21_01006	
		V_BH4_0790__21_01007	
790	V09	V_BH4_0790__21_01008	
		V_BH4_0790__21_01009	
		V_BH4_0790__21_01010	
790	V08	V_BH4_0790__21_01011	
		V_BH4_0790__21_01012	
		V_BH4_0790__21_01013	
790	V07	V_BH4_0790__21_01014	
		V_BH4_0790__21_01015	
		V_BH4_0790__21_01016	
790	V06	V_BH4_0790__21_01017	
		V_BH4_0790__21_01018	
		V_BH4_0790__21_01019	
790	V04	V_BH4_0790__21_01020	
		V_BH4_0790__21_01021	
		V_BH4_0790__21_01022	
790	V03	V_BH4_0790__21_01023	

		V_BH4_0790__21_01024	
		V_BH4_0790__21_01025	
790	V30	V_BH4_0790__21_01026	
		V_BH4_0790__21_01027	
		V_BH4_0790__21_01028	
790	V31	V_BH4_0790__21_01029	
		V_BH4_0790__21_01030	
		V_BH4_0790__21_01031	
790	V02	V_BH4_0790__21_01032	
		V_BH4_0790__21_01033	
		V_BH4_0790__21_01034	
790	V01	V_BH4_0790__21_01035	
		V_BH4_0790__21_01036	
		V_BH4_0790__21_01037	
790	V14	V_BH4_0790__21_01038	
		V_BH4_0790__21_01039	
		V_BH4_0790__21_01040	
790	V15	V_BH4_0790__21_01041	
		V_BH4_0790__21_01042	
		V_BH4_0790__21_01043	
790	V16	V_BH4_0790__21_01044	
		V_BH4_0790__21_01045	
		V_BH4_0790__21_01046	

790	V17	V_BH4_0790__21_01047	
		V_BH4_0790__21_01048	
		V_BH4_0790__21_01049	
790	V20	V_BH4_0790__21_01050	
		V_BH4_0790__21_01051	
		V_BH4_0790__21_01052	
790	V21	V_BH4_0790__21_01053	
		V_BH4_0790__21_01054	
		V_BH4_0790__21_01055	
790	V25	V_BH4_0790__21_01056	
		V_BH4_0790__21_01057	
		V_BH4_0790__21_01058	
790	V26	V_BH4_0790__21_01059	
		V_BH4_0790__21_01060	
		V_BH4_0790__21_01061	
790	V23	V_BH4_0790__21_01062	
		V_BH4_0790__21_01063	
		V_BH4_0790__21_01064	
790	V27	V_BH4_0790__21_01065	
		V_BH4_0790__21_01066	
		V_BH4_0790__21_01067	
790	V28	V_BH4_0790__21_01068	
		V_BH4_0790__21_01069	

		V_BH4_0790__21_01070	
790	V29	V_BH4_0790__21_01071	
		V_BH4_0790__21_01072	
		V_BH4_0790__21_01073	
790	V35	V_BH4_0790__21_01074	
		V_BH4_0790__21_01075	
		V_BH4_0790__21_01076	
790	V36	V_BH4_0790__21_01077	
		V_BH4_0790__21_01078	
		V_BH4_0790__21_01079	
850	V36	V_BH4_0850__21_01080	
		V_BH4_0850__21_01081	
		V_BH4_0850__21_01082	
850	V35	V_BH4_0850__21_01083	
		V_BH4_0850__21_01084	
		V_BH4_0850__21_01085	
850	V29	V_BH4_0850__21_01086	
		V_BH4_0850__21_01087	
		V_BH4_0850__21_01088	
850	V28	V_BH4_0850__21_01089	
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		V_BH4_0850__21_01091	
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850	V23	V_BH4_0850__21_01095	
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		V_BH4_0850__21_01097	
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		V_BH4_0850__21_01100	
850	V25	V_BH4_0850__21_01101	
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850	V21	V_BH4_0850__21_01104	
		V_BH4_0850__21_01105	
		V_BH4_0850__21_01106	
850	V20	V_BH4_0850__21_01107	
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		V_BH4_0850__21_01109	
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		V_BH4_0850__21_01112	
850	V16	V_BH4_0850__21_01113	
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		V_BH4_0850__21_01115	

850	V17	V_BH4_0850__21_01116	
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		V_BH4_0850__21_01118	
850	V14	V_BH4_0850__21_01119	
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850	V02	V_BH4_0850__21_01125	
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		V_BH4_0850__21_01127	
850	V30	V_BH4_0850__21_01128	
		V_BH4_0850__21_01129	
		V_BH4_0850__21_01130	
850	V31	V_BH4_0850__21_01131	
		V_BH4_0850__21_01132	
		V_BH4_0850__21_01133	
850	V03	V_BH4_0850__21_01134	
		V_BH4_0850__21_01135	
		V_BH4_0850__21_01136	
850	V04	V_BH4_0850__21_01137	
		V_BH4_0850__21_01138	

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850	V06	V_BH4_0850__21_01140	
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		V_BH4_0850__21_01142	
850	V07	V_BH4_0850__21_01143	
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		V_BH4_0850__21_01145	
850	V08	V_BH4_0850__21_01146	
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		V_BH4_0850__21_01148	
850	V09	V_BH4_0850__21_01149	
		V_BH4_0850__21_01150	
		V_BH4_0850__21_01151	
850	V10	V_BH4_0850__21_01152	
		V_BH4_0850__21_01153	
		V_BH4_0850__21_01154	
850	V11	V_BH4_0850__21_01155	
		V_BH4_0850__21_01156	
		V_BH4_0850__21_01157	

K Field Issues

Observed damage (note here as-needed additional detail on Daily Report items)		*corrective action (e.g. repair, component replacement)*

L File Control					
Data File	**DateTime**	**Depth Range**	**Staff**	**Software**	**Parameters/Settings**
			Cristian Vasile	VIPS5.11	1ms sample rate. 3 records of 20 seconds each
V_BH4_0730__21_00963		740.7 – 795.7			
V_BH4_0730__21_00964					
V_BH4_0730__21_00965					
V_BH4_0730__21_00966					
V_BH4_0730__21_00967					
V_BH4_0730__21_00968					
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L File Control					
V_BH4_0730__21_00982					
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V_BH4_0730__21_00998					
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V_BH4_0730__21_01001					
V_BH4_0790__21_01002					
V_BH4_0790__21_01003					

L File Control					
V_BH4_0790__21_01004					
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V_BH4_0790__21_01006					
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V_BH4_0790__21_01008					
V_BH4_0790__21_01009					
V_BH4_0790__21_01010					
V_BH4_0790__21_01011					
V_BH4_0790__21_01012					
V_BH4_0790__21_01013					
V_BH4_0790__21_01014		680.7 – 735.7			
V_BH4_0790__21_01015					
V_BH4_0790__21_01016					
V_BH4_0790__21_01017					
V_BH4_0790__21_01018					
V_BH4_0790__21_01019					
V_BH4_0790__21_01020					
V_BH4_0790__21_01021					
V_BH4_0790__21_01022					
V_BH4_0790__21_01023					
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V_BH4_0790__21_01025					

L	**File Control**				
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L File Control					
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L File Control					
V_BH4_0850__21_01092		740.7 – 795.7			
V_BH4_0850__21_01093					
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L **File Control**					
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L **File Control**					
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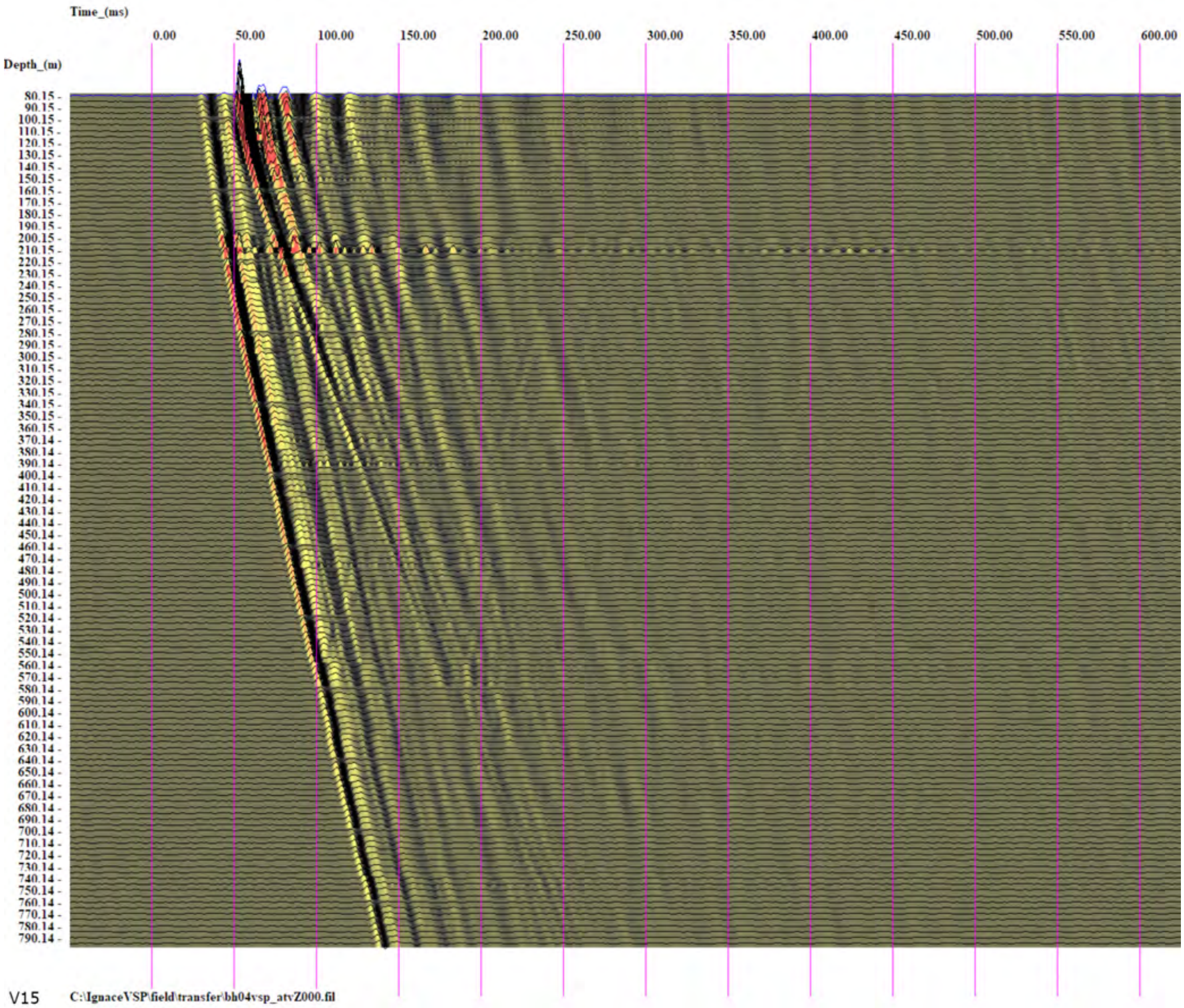
V_BH4_0850__21_01157					



Time_(ms)
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50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
500.00
550.00
600.00
Depth_(m)
80.15
90.15
100.15
110.15
120.15
130.15
140.15
150.15
160.15
170.15
180.15
190.15
200.15
210.15
220.15
230.15
240.15
250.15
260.15
270.15
280.15
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360.15
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380.14
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410.14
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460.14
470.14
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750.14
760.14
770.14
780.14
790.14
C:\IgnaceVSP\field\transfer\bh04vsp_atvZ000.fil

V15

VIBROMETRIC

NWMO

Vibrometric Seismic Source Checklist

DATE: July 30/21

Engine Off Checks	OK	Maintenance
Leaks – Fuel, Hydraulic Oil, Engine Oil or Radiator Coolant	✓	
Tires – Condition and Pressure	✓	
Hydraulic Hoses, Mast Chains, Cables and Stops – Check Visually	✓	
Safety Warnings – Attached (Refer to Parts Manual for Location)	✓	
Battery – Check Water/Electrolyte Level and Charge	✓	
Hydraulic Fluid Level – Check Level	✓	
Engine Oil Level – Dipstick	✓	
Transmission Fluid Level – Dipstick	✓	
Radiator Coolant – Check Level	✓	
Operator's Manual – In Container		
Nameplate – Attached and Information Matches Model, Serial Number and Attachments	✓	
Seat Belt – Functioning Smoothly	✓	
Hood Latch – Adjusted and Securely Fastened	✓	
Brake Fluid – Check Level	✓	
Seismic Vibrator Check Screws, Cables, Hoses	✓	
Fuel level	✓	
Lights check	✓	
Engine On Checks	OK	Maintenance
Accelerator or Direction Control Pedal – Functioning Smoothly	✓	
Service Brake – Functioning Smoothly	✓	
Parking Brake – Functioning Smoothly	✓	
Steering Operation – Functioning Smoothly	✓	
Drive Control – Forward/Reverse – Functioning Smoothly	✓	
Arm Tilt Control – Forward and Back – Functioning Smoothly	✓	
Hoist (Seismic Source) and Lowering Control – Functioning Smoothly	✓	
Testing the sweep – Operation	✓	
Horn and Lights – Functioning	✓	
Cab (if equipped) – Heater, Defroster, Wipers – Functioning	✓	
Gauges: Ammeter, Engine Oil Pressure, Hour Meter, Fuel Level, Temperature, Instrument Monitors – Functioning	✓	FUEL AND ENGINE TEMP NOT ACCURATE.
Controller check | Trigger sensor on impact plate check	✓	
Impact plate check | Radio check	✓	
Source type VIBSIST 3000 ENGINE HOURS		6405 HRS

OPERATOR: ROBERT TAYLOR

R Taylor

O Sign-Off		
Prepared	*Name* *Nicoleta Enescu*	*Date* *July 30, 2021*
Reviewed	*Name* *Jon Crawford*	*Date* *July 30, 2021*
Reviewed	*Name*	*Date*
Approved	*Name* *Christopher Phillips*	*Date* *July 30, 2021*

TO:	Mostafa Khorshidi	**Date:**	*July 31, 2021*
	Maria Sánchez-Rico Castejón	**Work Package:**	WP12 – VSP Profiling
	Sarah Hirschorn		
CC:	George Schneider		
		Distributed By:	Email

Record Number: 20253946-4120-210731

IGBH_04, IGNACE, ONTARIO

Acquisition depth interval: 5m

Staff: Cristian Vasile

Start time: 8:00am **Finish time: 5:00pm**

Shot location(s): 26 shot locations for 910m. Check shots V20 at level 670m and level 350m. V6, V10, V27, V28, and V31 at level 130m

Prepared by: Nicoleta Enescu

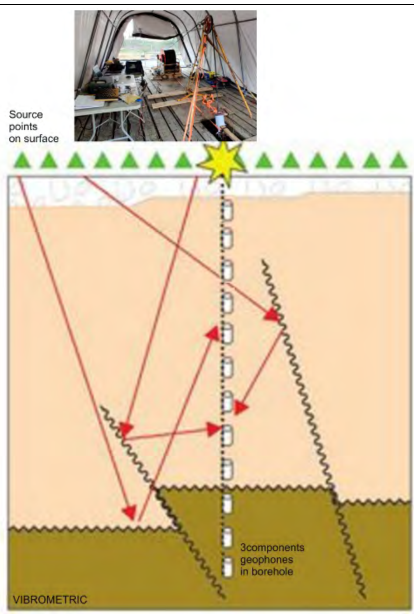
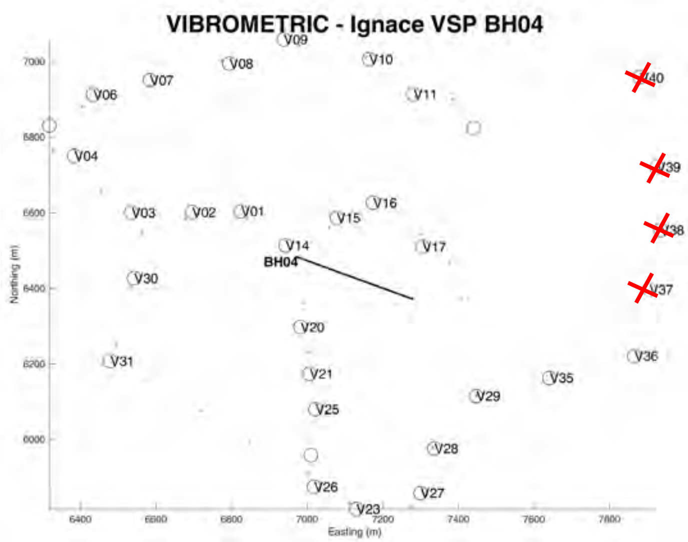
Verified by: Jonathan Crawford

Usage notes:

- Complete one form per field day
- Office forms will be complete as processing packages/tasks are completed and will include supporting documentation
- Complete all header information (above)
- Delete unused tables (below) and fully populate those that remain
- Form is divided into A through O tables and field and processing tasks

FIELD

A	**Winch and Depth Counter**
Calibrated by measuring and marking the cable every 25 m (with depth labels every 50m) before insertion in the borehole. Verifying these distances using the depth counter. Discrepancies are adjusted by changing the depth value on the depth counter to match the cable mark.	
Results	
Settings applied	Factor was 0.2771. Calibration was verified at 900m – Depth counter reading 899.85m,

B	**Tool Assembly**
Schematic	 
Results of pre-shipping checks. Refer to relevant document.	All good.

E	**Equipment Calibration/Function Checklist**	**OK**	**Maintenance**
Geophones			
	Geophone used (RD or R):	RD	
	Testing at ground surface performed before insertion in the borehole:		
	Level of electrical disturbance	_X_	
	Water tightness	_X_	
	Operation of side arm clamp	_X_	
	Verification of noise level and real seismic signal in each component	_X_	

A	**Winch and Depth Counter**	
Winch Motor and transmission Controller Brake Ground anchors	X	
Cable Borehole collar level mark Overnight clamp	X	
Depth counter	X	
Radio check	X	
Acquisition computer Computer Acquisition Software Data Analysis Software	_X_ _X_ _X_	
Power source	X	
Access vehicle	X	
Geophones calibration certificate verification: Technical ID Signature Date Validity period Location	_X_ _X_ _X_ _X_ _X_	
Depth counter calibration certificate verification: Technical ID Signature Date Validity period Location	__ __ __ __ __	

H	**Geophone Testing in Borehole**
Clamping location verified	Yes
Level of electrical disturbance	None
Operation of the side arm clamp	Good
Verification of noise in each component	Good
Verification of real seismic signal in each component	Good

I	**Shot**
Confirmation of shot point ID with receiver staff	yes

A	Winch and Depth Counter
Data acquisition sampling rate confirmed at 1 ms	yes

J Field Data - Review and Verification

Zero Mark of receivers	Shot ID	File Name	Comments/Verified
			All files verified during acquisition
910	V11	V_BH4_0910__21_01162	
		V_BH4_0910__21_01163	
		V_BH4_0910__21_01164	
910	V10	V_BH4_0910__21_01165	
		V_BH4_0910__21_01166	
		V_BH4_0910__21_01167	
910	V09	V_BH4_0910__21_01168	
		V_BH4_0910__21_01169	
		V_BH4_0910__21_01170	
910	V08	V_BH4_0910__21_01171	
		V_BH4_0910__21_01172	
		V_BH4_0910__21_01173	
910	V07	V_BH4_0910__21_01174	
		V_BH4_0910__21_01175	
		V_BH4_0910__21_01176	
910	V06	V_BH4_0910__21_01177	
		V_BH4_0910__21_01178	
		V_BH4_0910__21_01179	
910	V04	V_BH4_0910__21_01180	

		V_BH4_0910__21_01181	
		V_BH4_0910__21_01182	
910	V03	V_BH4_0910__21_01183	
		V_BH4_0910__21_01184	
		V_BH4_0910__21_01185	
910	V30	V_BH4_0910__21_01186	
		V_BH4_0910__21_01187	
		V_BH4_0910__21_01188	
910	V31	V_BH4_0910__21_01189	
		V_BH4_0910__21_01190	
		V_BH4_0910__21_01191	
910	V02	V_BH4_0910__21_01192	
		V_BH4_0910__21_01193	
		V_BH4_0910__21_01194	
910	V01	V_BH4_0910__21_01195	
		V_BH4_0910__21_01196	
		V_BH4_0910__21_01197	
910	V14	V_BH4_0910__21_01198	
		V_BH4_0910__21_01199	
		V_BH4_0910__21_01200	
910	V15	V_BH4_0910__21_01201	
		V_BH4_0910__21_01202	
		V_BH4_0910__21_01203	

910	V16	V_BH4_0910__21_01204	
		V_BH4_0910__21_01205	
		V_BH4_0910__21_01206	
910	V17	V_BH4_0910__21_01207	
		V_BH4_0910__21_01208	
		V_BH4_0910__21_01209	
910	V20	V_BH4_0910__21_01210	
		V_BH4_0910__21_01211	
		V_BH4_0910__21_01212	
910	V21	V_BH4_0910__21_01213	
		V_BH4_0910__21_01214	
		V_BH4_0910__21_01215	
910	V25	V_BH4_0910__21_01216	
		V_BH4_0910__21_01217	
		V_BH4_0910__21_01218	
910	V26	V_BH4_0910__21_01219	
		V_BH4_0910__21_01220	
		V_BH4_0910__21_01221	
910	V23	V_BH4_0910__21_01222	
		V_BH4_0910__21_01223	
		V_BH4_0910__21_01224	
910	V27	V_BH4_0910__21_01225	
		V_BH4_0910__21_01226	

		V_BH4_0910__21_01227	
910	V28	V_BH4_0910__21_01228	
		V_BH4_0910__21_01229	
		V_BH4_0910__21_01230	
910	V29	V_BH4_0910__21_01231	
		V_BH4_0910__21_01232	
		V_BH4_0910__21_01233	
910	V35	V_BH4_0910__21_01234	
		V_BH4_0910__21_01235	
		V_BH4_0910__21_01236	
910	V36	V_BH4_0910__21_01237	
		V_BH4_0910__21_01238	
		V_BH4_0910__21_01239	
670	V20	V_BH4_0670__21_01240	
		V_BH4_0670__21_01241	
		V_BH4_0670__21_01242	
370	V20	V_BH4_0370__21_01243	
		V_BH4_0370__21_01244	
		V_BH4_0370__21_01245	
130	V10	V_BH4_0130__21_01247	
		V_BH4_0130__21_01248	
		V_BH4_0130__21_01249	
		V_BH4_0130__21_01250	

130	V06	V_BH4_0130__21_01251	
		V_BH4_0130__21_01252	
		V_BH4_0130__21_01253	
130	V31	V_BH4_0130__21_01254	
		V_BH4_0130__21_01255	
		V_BH4_0130__21_01256	
130	V27	V_BH4_0130__21_01257	
		V_BH4_0130__21_01258	
		V_BH4_0130__21_01259	
130	V28	V_BH4_0130__21_01260	
		V_BH4_0130__21_01261	
		V_BH4_0130__21_01262	
		V_BH4_0130__21_01263	

K Field Issues		
Observed damage (note here as-needed additional detail on Daily Report items)		*corrective action (e.g. repair, component replacement)*

L File Control					
Data File	**DateTime**	**Depth Range**	**Staff**	**Software**	**Parameters/Settings**
			Cristian Vasile	VIPS5.11	1ms sample rate. 3 records of 20 seconds each
V_BH4_0910__21_01162		920.7 – 975.7			
V_BH4_0910__21_01163					

L **File Control**					
V_BH4_0910__21_01164		680.7 – 735.7			
V_BH4_0910__21_01165					
V_BH4_0910__21_01166					
V_BH4_0910__21_01167					
V_BH4_0910__21_01168					
V_BH4_0910__21_01169					
V_BH4_0910__21_01170					
V_BH4_0910__21_01171					
V_BH4_0910__21_01172					
V_BH4_0910__21_01173					
V_BH4_0910__21_01174					
V_BH4_0910__21_01175					
V_BH4_0910__21_01176					
V_BH4_0910__21_01177					
V_BH4_0910__21_01178					
V_BH4_0910__21_01179					
V_BH4_0910__21_01180					
V_BH4_0910__21_01181					
V_BH4_0910__21_01182					
V_BH4_0910__21_01183					
V_BH4_0910__21_01184					
V_BH4_0910__21_01185					

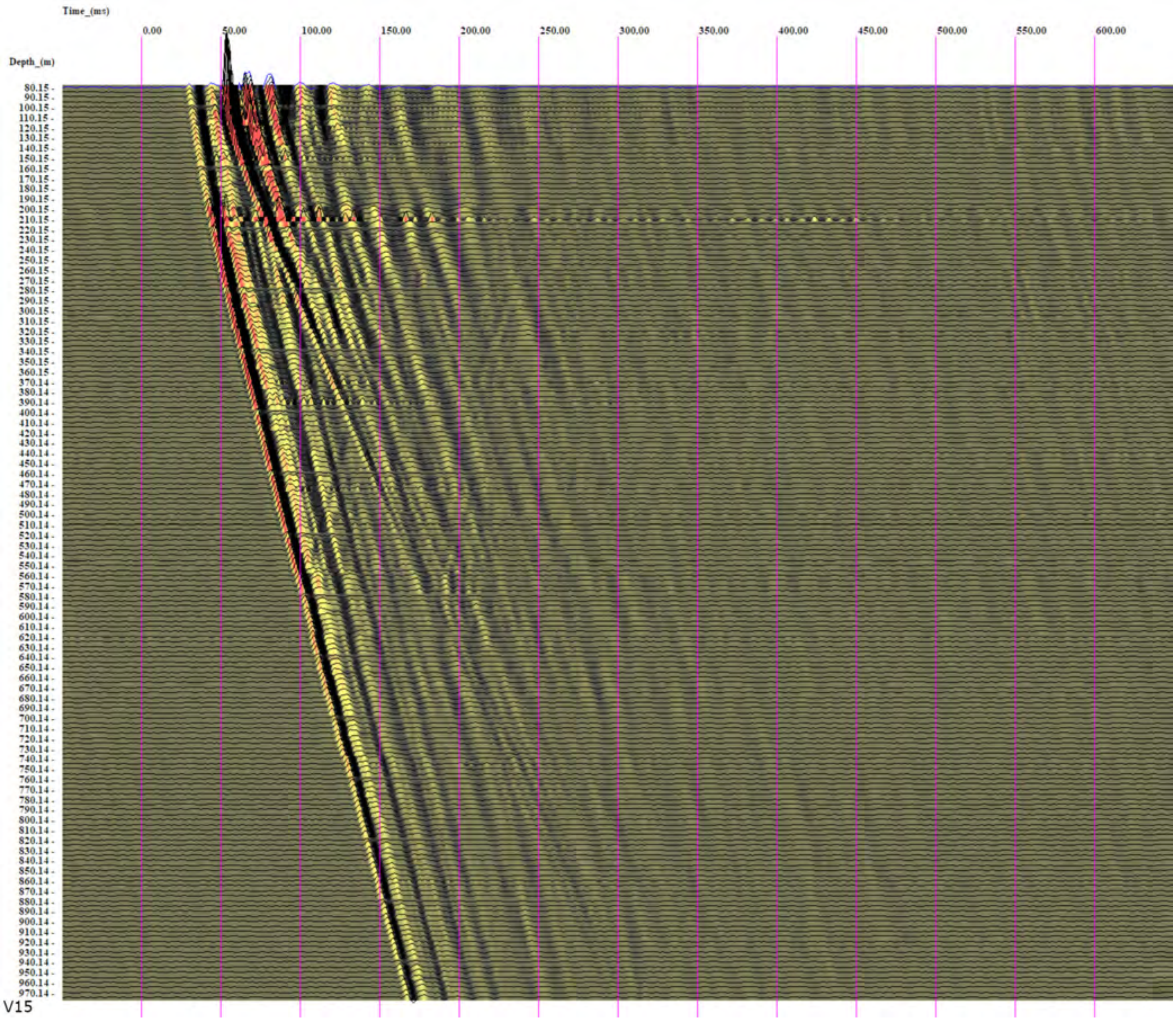
L File Control					
V_BH4_0910__21_01186					
V_BH4_0910__21_01187					
V_BH4_0910__21_01188					
V_BH4_0910__21_01189					
V_BH4_0910__21_01190					
V_BH4_0910__21_01191					
V_BH4_0910__21_01192					
V_BH4_0910__21_01193					
V_BH4_0910__21_01194					
V_BH4_0910__21_01195					
V_BH4_0910__21_01196					
V_BH4_0910__21_01197					
V_BH4_0910__21_01198					
V_BH4_0910__21_01199					
V_BH4_0910__21_01200					
V_BH4_0910__21_01201					
V_BH4_0910__21_01202					
V_BH4_0910__21_01203					
V_BH4_0910__21_01204					
V_BH4_0910__21_01205					
V_BH4_0910__21_01206					
V_BH4_0910__21_01207					

L File Control					
V_BH4_0910__21_01208					
V_BH4_0910__21_01209					
V_BH4_0910__21_01210					
V_BH4_0910__21_01211					
V_BH4_0910__21_01212					
V_BH4_0910__21_01213					
V_BH4_0910__21_01214					
V_BH4_0910__21_01215					
V_BH4_0910__21_01216					
V_BH4_0910__21_01217					
V_BH4_0910__21_01218					
V_BH4_0910__21_01219					
V_BH4_0910__21_01220					
V_BH4_0910__21_01221					
V_BH4_0910__21_01222					
V_BH4_0910__21_01223					
V_BH4_0910__21_01224					
V_BH4_0910__21_01225					
V_BH4_0910__21_01226					
V_BH4_0910__21_01227					
V_BH4_0910__21_01228					
V_BH4_0910__21_01229					

L File Control

V_BH4_0910__21_01230					
V_BH4_0910__21_01231					
V_BH4_0910__21_01232					
V_BH4_0910__21_01233					
V_BH4_0910__21_01234					
V_BH4_0910__21_01235					
V_BH4_0910__21_01236					
V_BH4_0910__21_01237					
V_BH4_0910__21_01238					
V_BH4_0910__21_01239					
V_BH4_0670__21_01240		680.7 – 735.7			
V_BH4_0670__21_01241					
V_BH4_0670__21_01242					
V_BH4_0370__21_01243		380.7 – 435.7			
V_BH4_0370__21_01244					
V_BH4_0370__21_01245					
V_BH4_0370__21_01246					
V_BH4_0130__21_01247		140.7 – 195.7			
V_BH4_0130__21_01248					
V_BH4_0130__21_01249					
V_BH4_0130__21_01250					
V_BH4_0130__21_01251					

L **File Control**					
V_BH4_0130__21_01252					
V_BH4_0130__21_01253					
V_BH4_0130__21_01254					
V_BH4_0130__21_01255					
V_BH4_0130__21_01256					
V_BH4_0130__21_01257					
V_BH4_0130__21_01258					
V_BH4_0130__21_01259					
V_BH4_0130__21_01260					
V_BH4_0130__21_01261					
V_BH4_0130__21_01262					
V_BH4_0130__21_01263					



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100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
500.00
550.00
600.00
Depth_(m)
80.15
90.15
100.15
110.15
120.15
130.15
140.15
150.15
160.15
170.15
180.15
190.15
200.15
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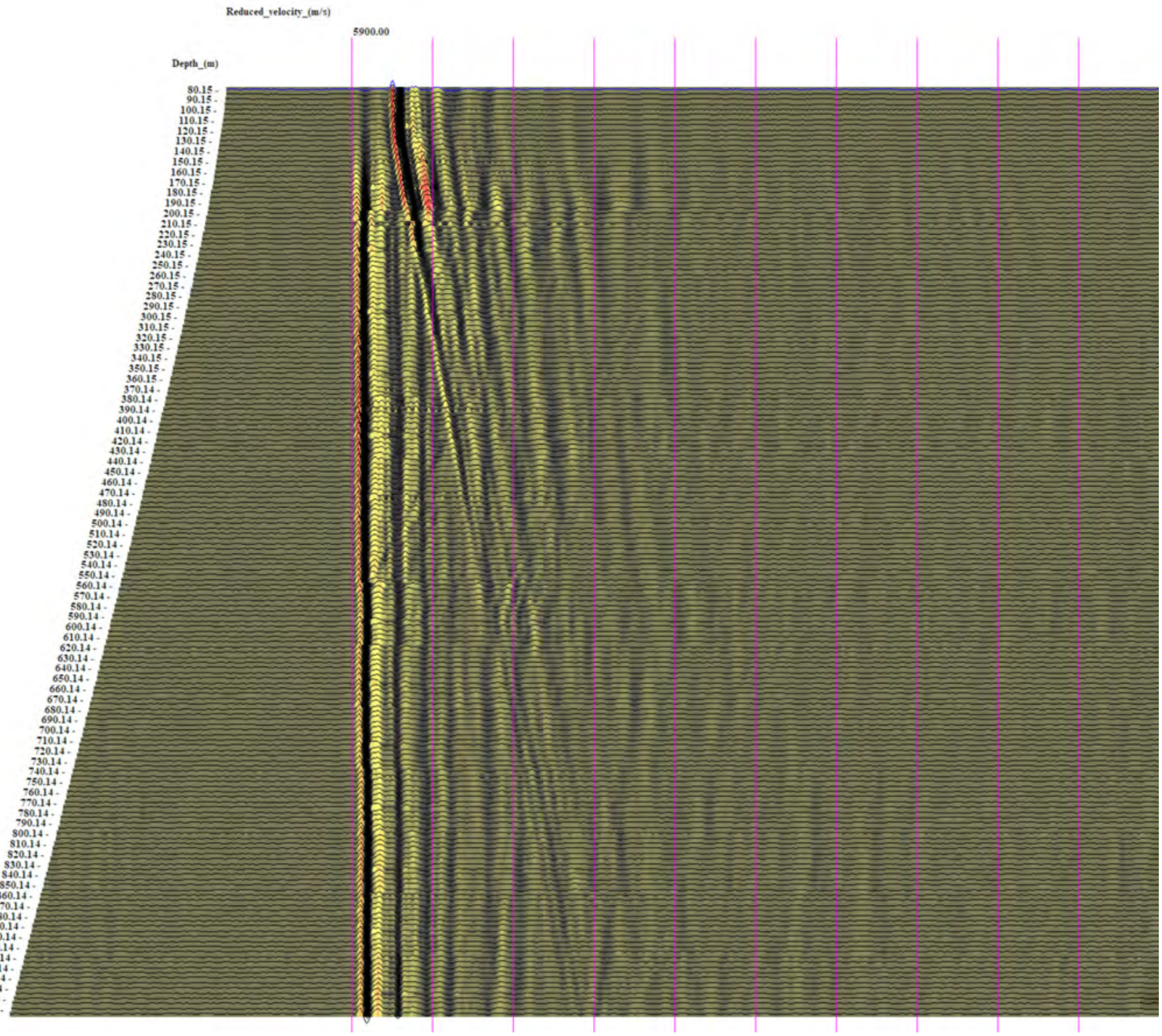
970.14

V15



Reduced_velocity_(m/s)
5900.00
Depth_(m)
80.15
90.15
100.15
110.15
120.15
130.15
140.15
150.15
160.15
170.15
180.15
190.15
200.15
210.15
220.15
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860.14
870.14
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920.14
930.14
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950.14
960.14
970.14

V15

WP12 Data Quality Confirmation (DQC) Form		
Document No.: 20253946-4120-210731	Original Date: *31 July 2021*	Developed By: *Nicoleta Enescu*
Revision No.: *R0*	Revision Date: *N/A*	Authorized By: *Christopher Phillips*

NWMO

Vibrometric Seismic Source Checklist

DATE: July 31/21

Engine Off Checks	OK	Maintenance
Leaks – Fuel, Hydraulic Oil, Engine Oil or Radiator Coolant	✓	
Tires – Condition and Pressure	✓	
Hydraulic Hoses, Mast Chains, Cables and Stops – Check Visually	✓	
Safety Warnings – Attached (Refer to Parts Manual for Location)	✓	
Battery – Check Water/Electrolyte Level and Charge	✓	
Hydraulic Fluid Level – Check Level	✓	
Engine Oil Level – Dipstick	✓	
Transmission Fluid Level – Dipstick	✓	
Radiator Coolant – Check Level	✓	
Operator's Manual – In Container		
Nameplate – Attached and Information Matches Model, Serial Number and Attachments	✓	
Seat Belt – Functioning Smoothly	✓	
Hood Latch – Adjusted and Securely Fastened	✓	
Brake Fluid – Check Level	✓	
Seismic Vibrator Check Screws, Cables, Hoses	✓	
Fuel level	✓	
Lights check	✓	
Engine On Checks	OK	Maintenance
Accelerator or Direction Control Pedal – Functioning Smoothly	✓	
Service Brake – Functioning Smoothly	✓	
Parking Brake – Functioning Smoothly	✓	
Steering Operation – Functioning Smoothly	✓	
Drive Control – Forward/Reverse – Functioning Smoothly	✓	
Arm Tilt Control – Forward and Back – Functioning Smoothly	✓	
Hoist (Seismic Source) and Lowering Control – Functioning Smoothly	✓	
Testing the sweep – Operation	✓	
Horn and Lights – Functioning	✓	
Cab (if equipped) – Heater, Defroster, Wipers – Functioning	✓	
Gauges: Ammeter, Engine Oil Pressure, Hour Meter, Fuel Level, Temperature, Instrument Monitors – Functioning	✓	FUEL AND ENGINE TEMP NOT ACCURATE
Controller check | Trigger sensor on impact plate check	✓	
Impact plate check | Radio check	✓	
Source type VIBSIST 3000 ENGINE HOURS		6412 HRS

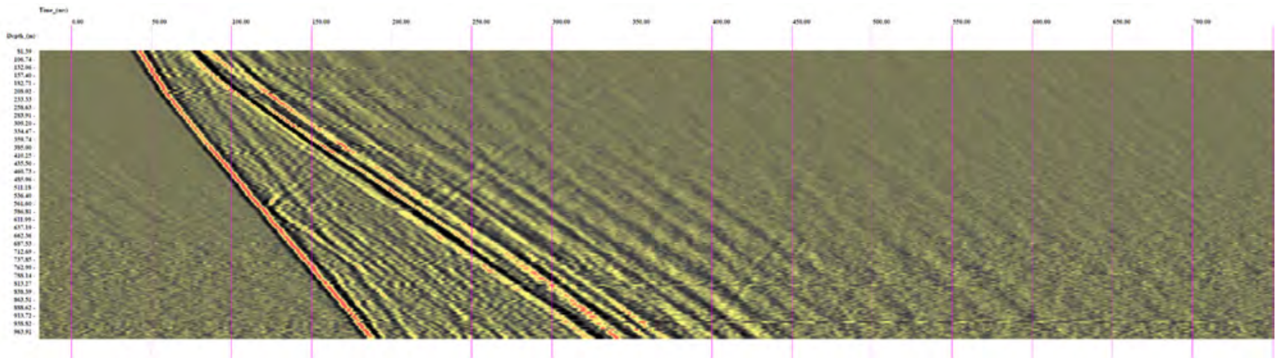
OPERATOR: BOB TAYLOR

R. Taylor

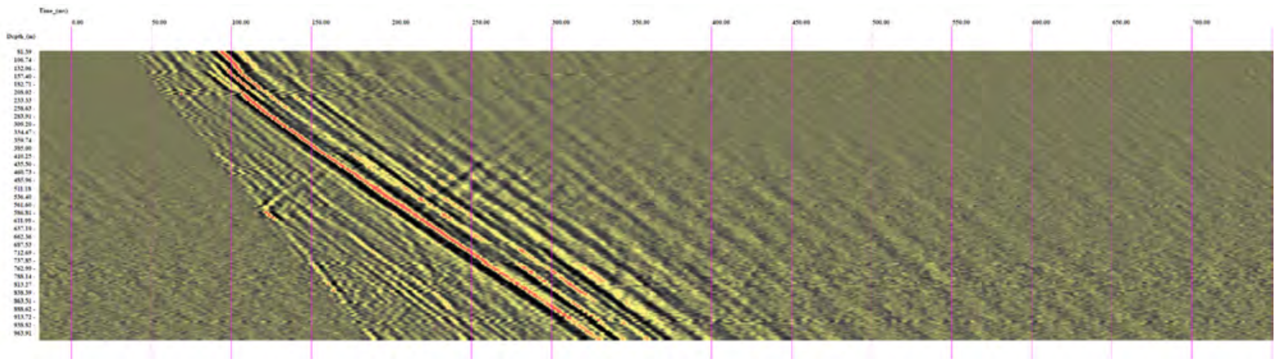
O	**Sign-Off**	
Prepared	*Name* *Nicoleta Enescu*	*Date* *July 31, 2021*
Reviewed	*Name* *Jon Crawford*	*Date* *July 31, 2021*
Reviewed	*Name*	*Date*
Approved	*Name* *Christopher Phillips*	*Date* *July 31, 2021*

APPENDIX B

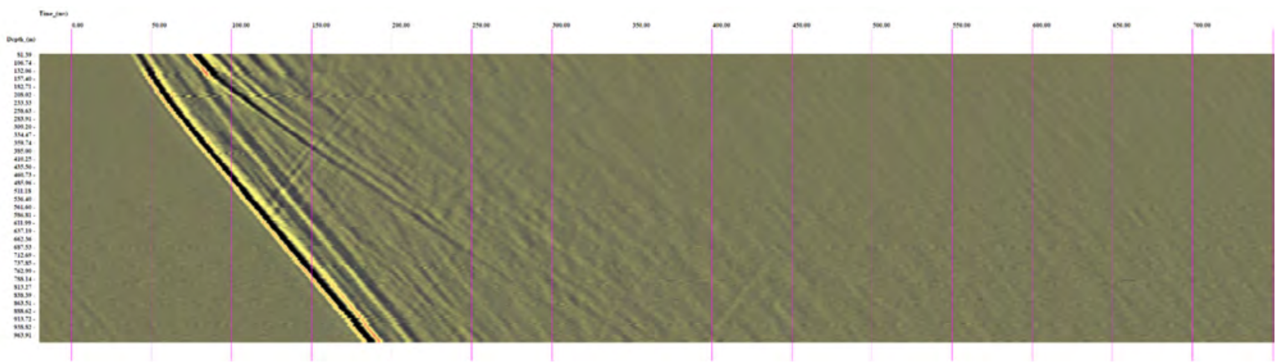
Raw VSP Profiles Acquired from Borehole IG_BH04



Radial component

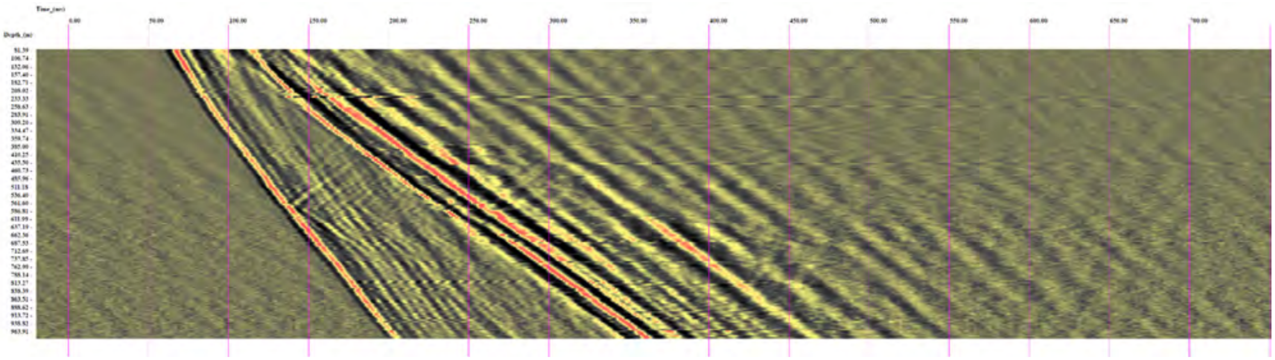


Transversal component

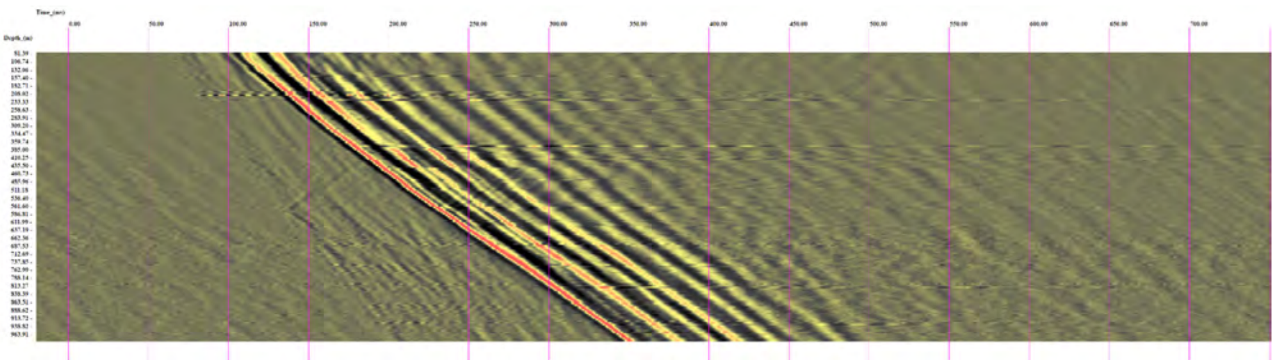


Axial component

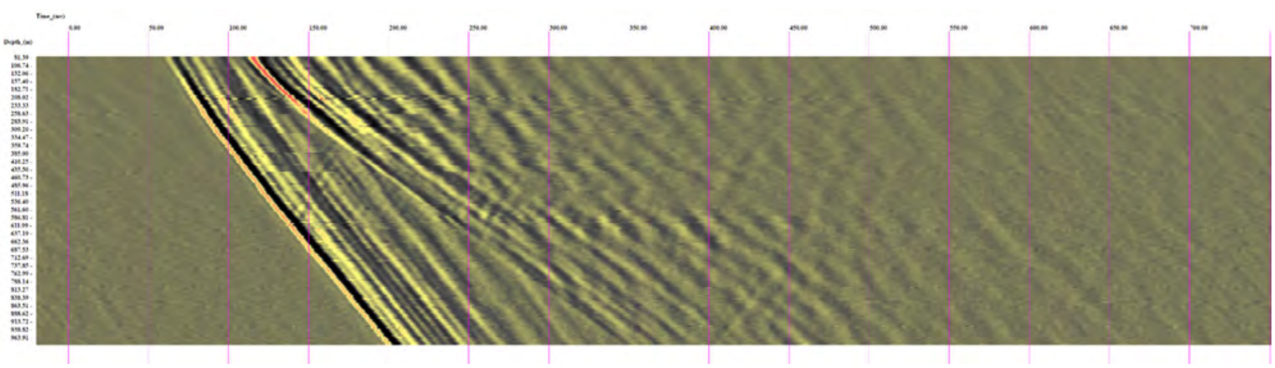
Figure 1. IG_BH04 VSP, Shot V01



Radial component

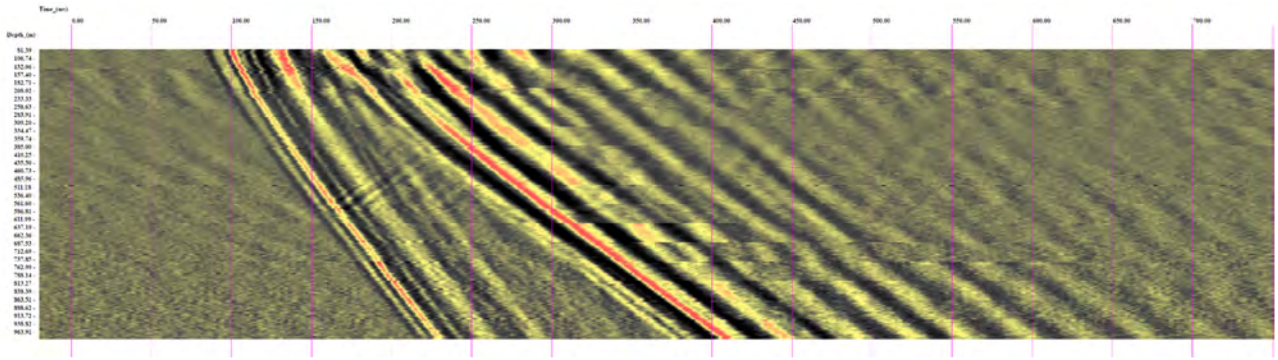


Transversal component

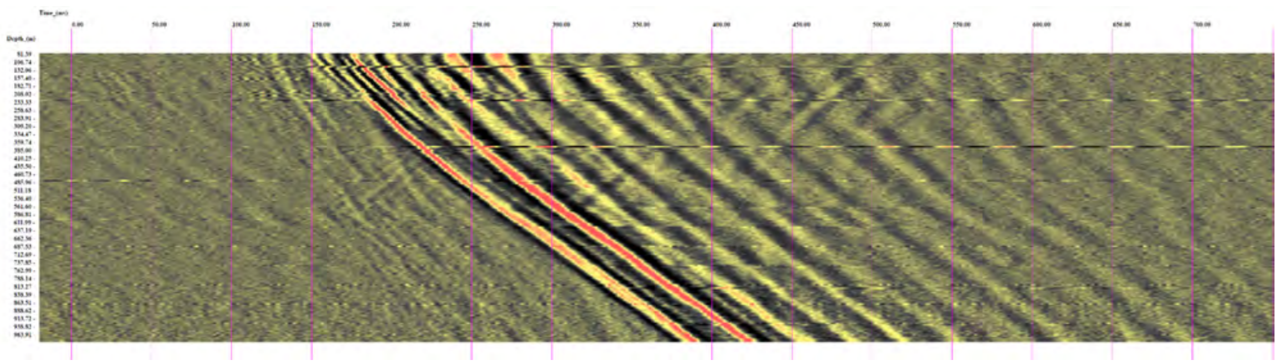


Axial component

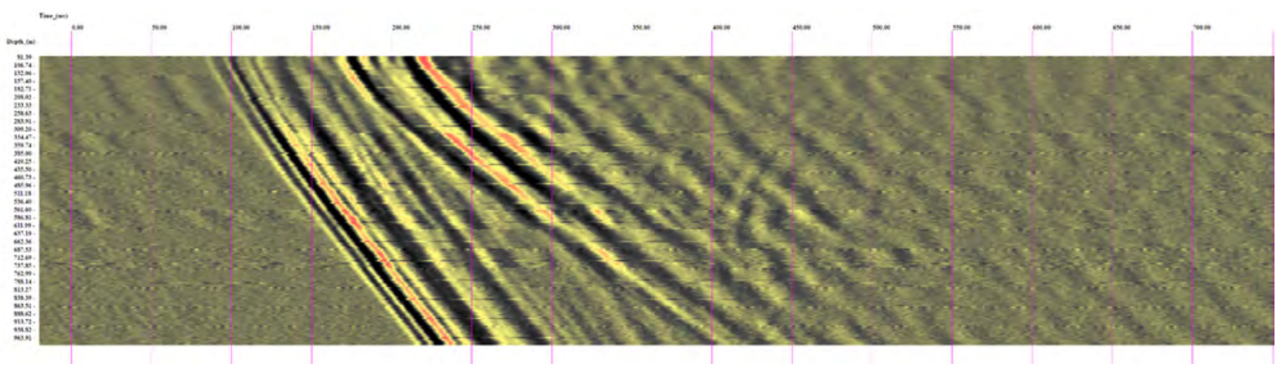
Figure 2. IG_BH04 VSP, Shot V02



Radial component

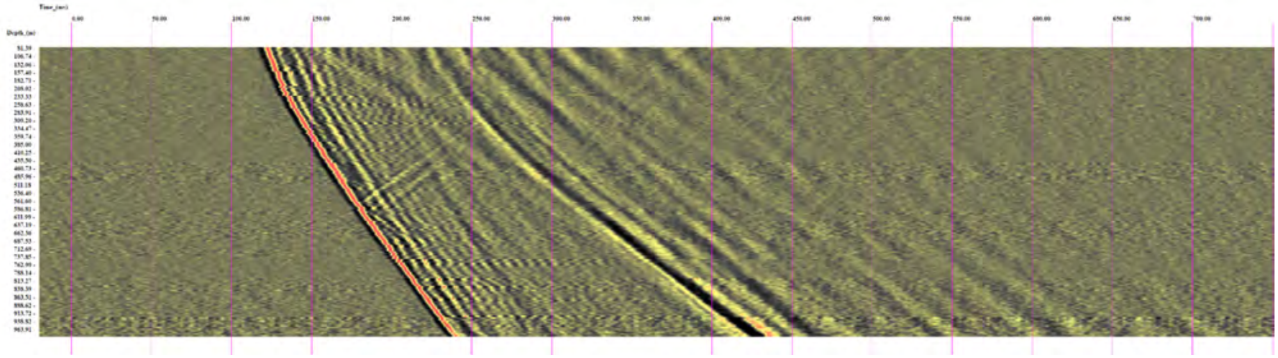


Transversal component

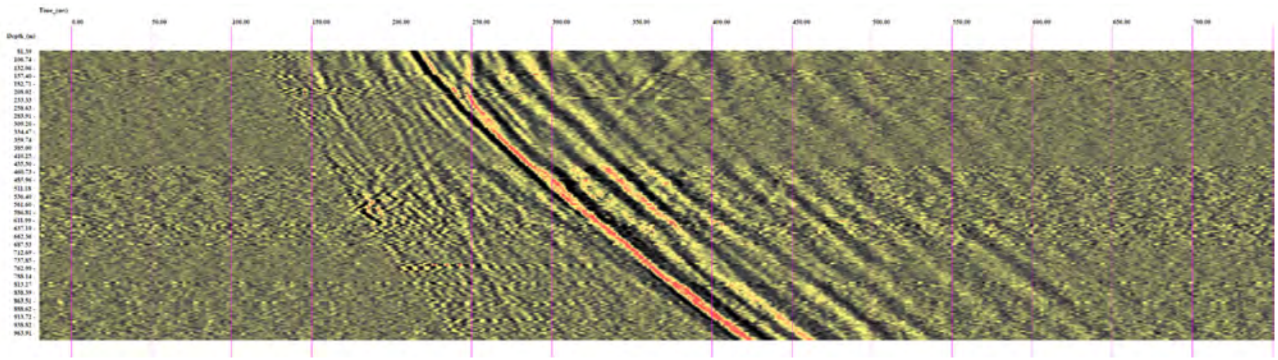


Axial component

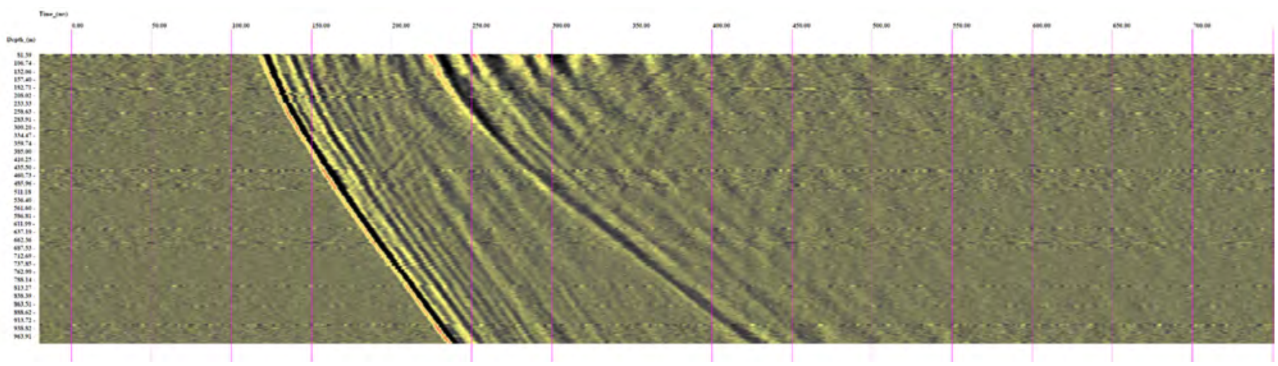
Figure 3. IG_BH04 VSP, Shot V03



Radial component

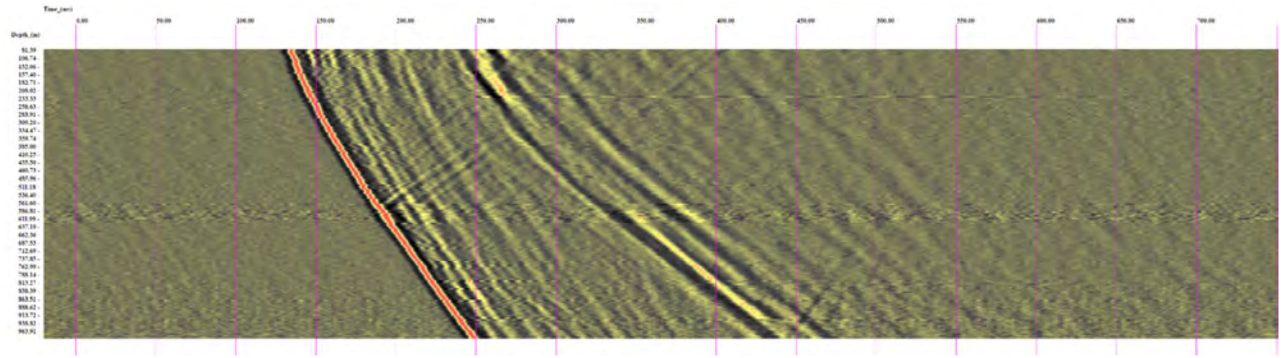


Transversal component

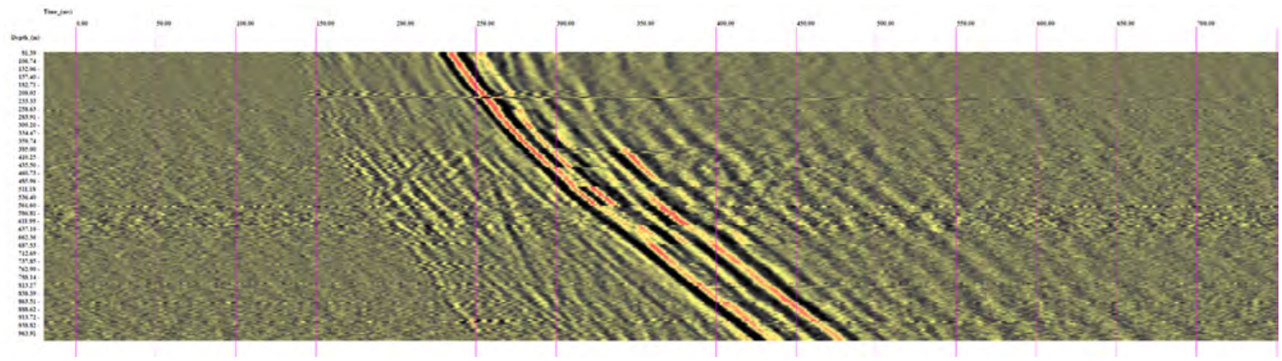


Axial component

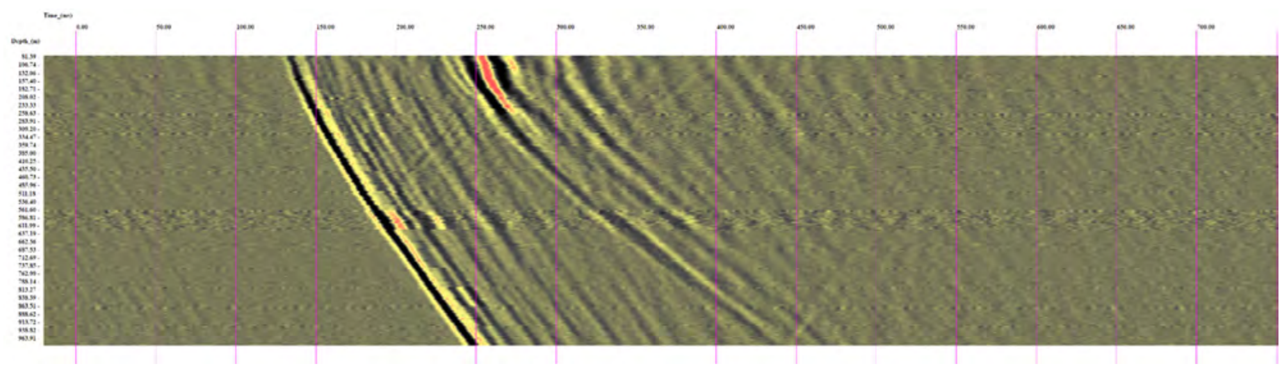
Figure 4. IG_BH04 VSP, Shot V04



Radial component

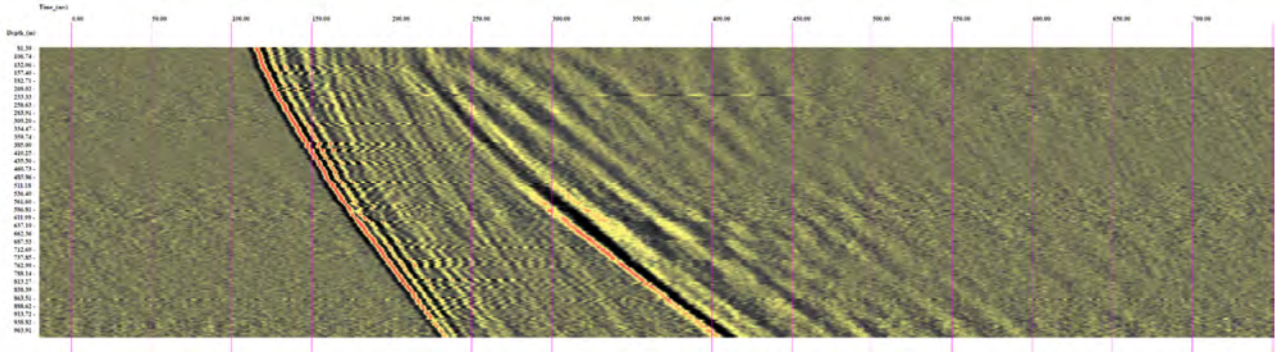


Transversal component

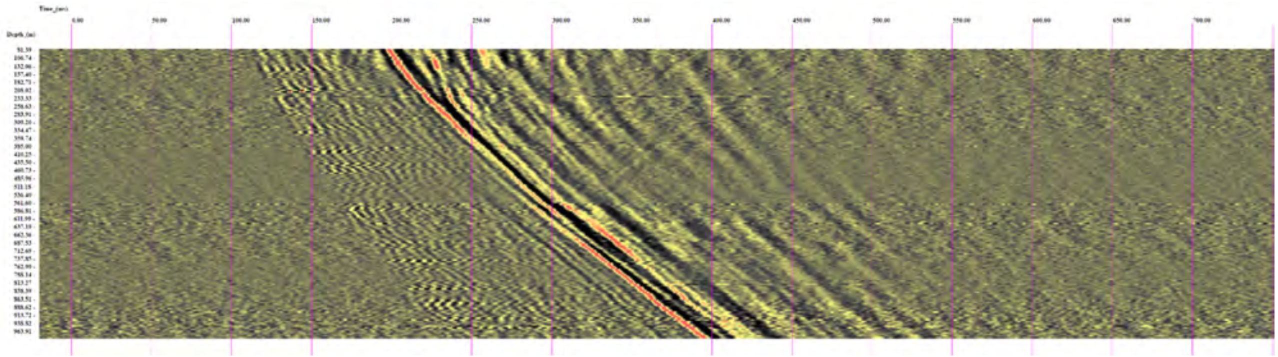


Axial component

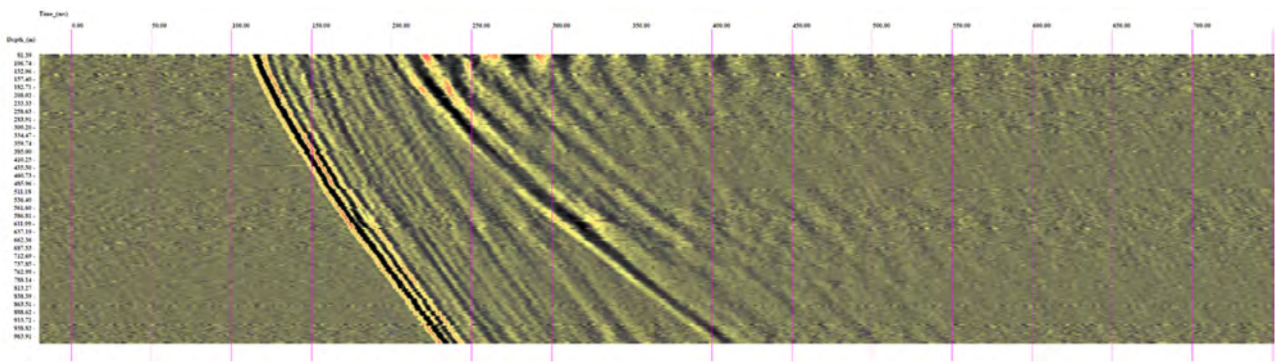
Figure 5. IG_BH04 VSP, Shot V06



Radial component

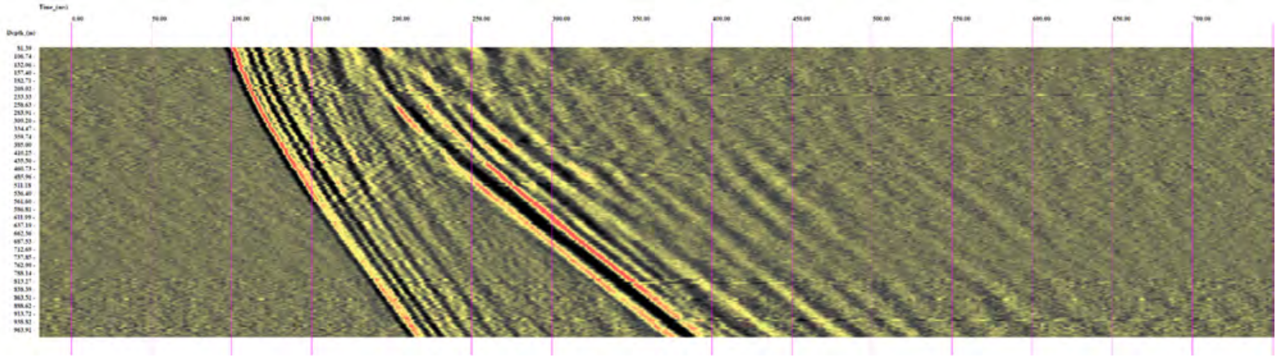


Transversal component

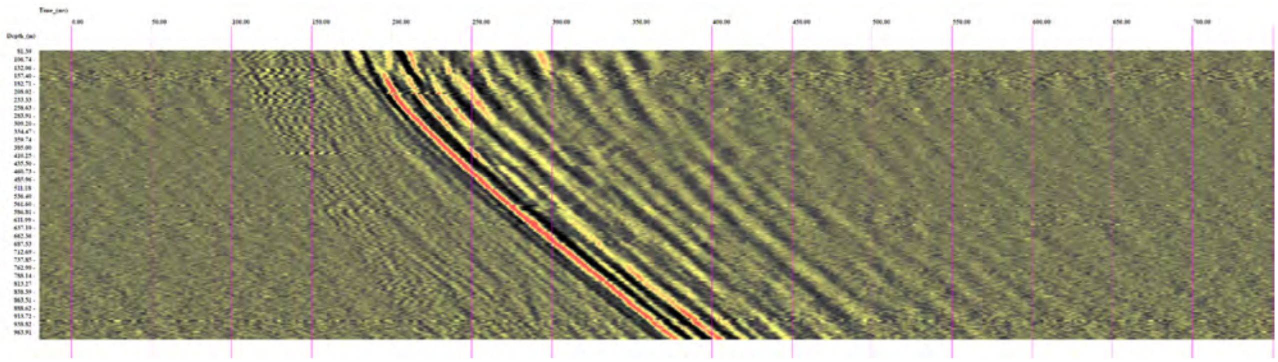


Axial component

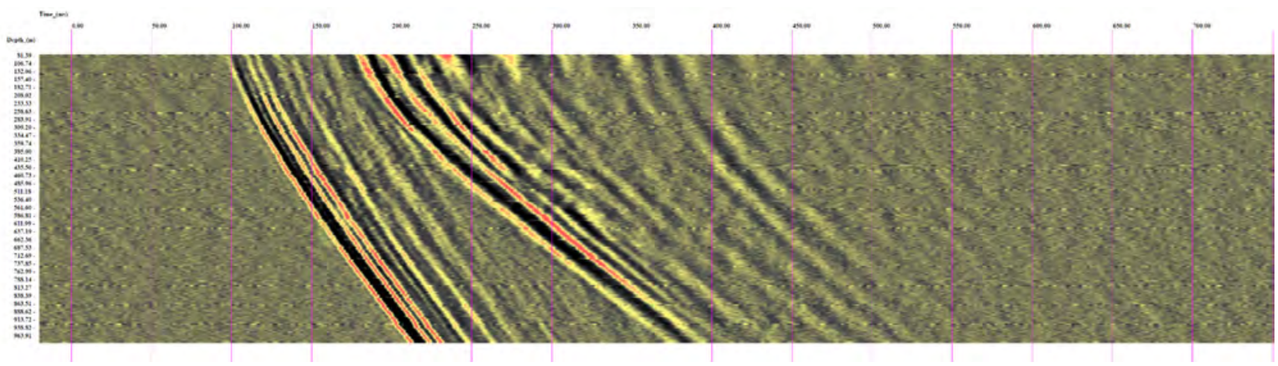
Figure 6. IG_BH04 VSP, Shot V07



Radial component

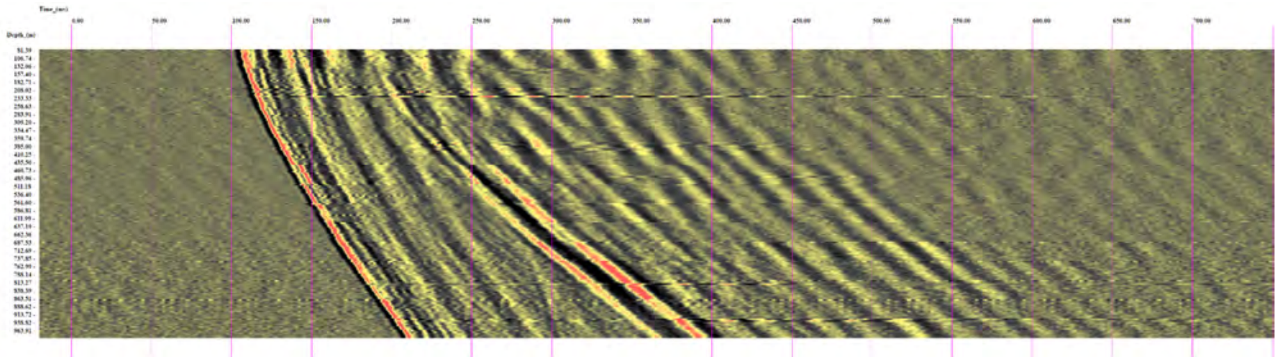


Transversal component

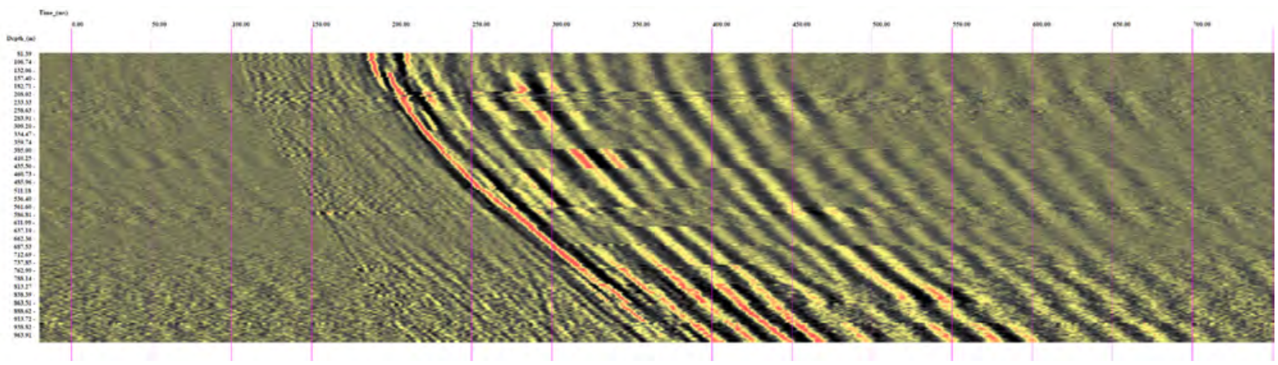


Axial component

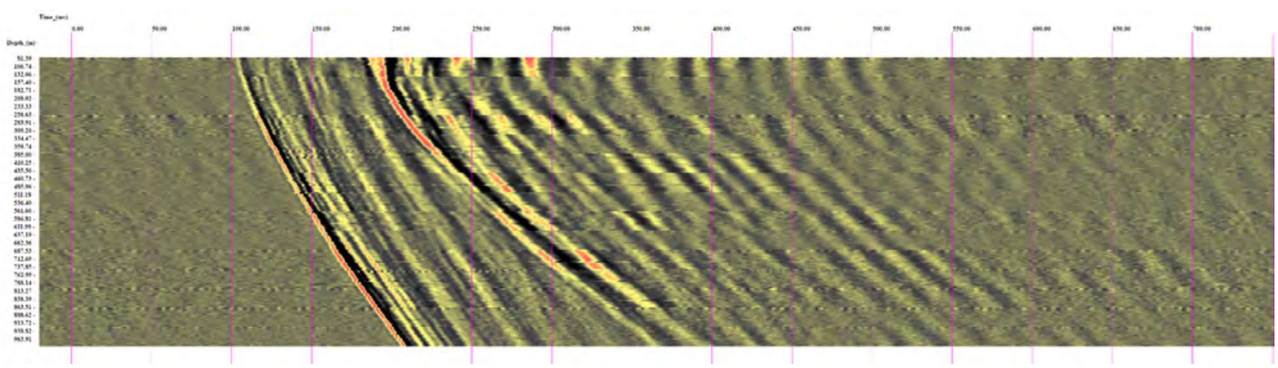
Figure 7. IG_BH04 VSP, Shot V08



Radial component

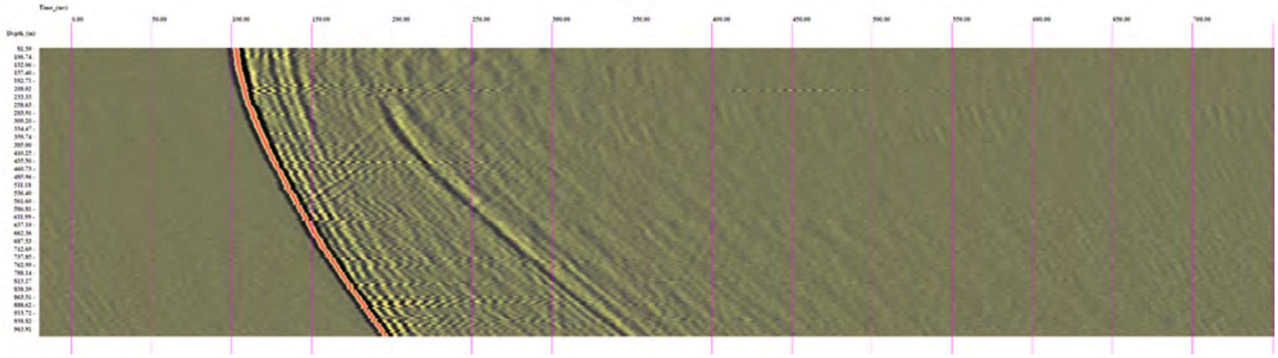


Transversal component

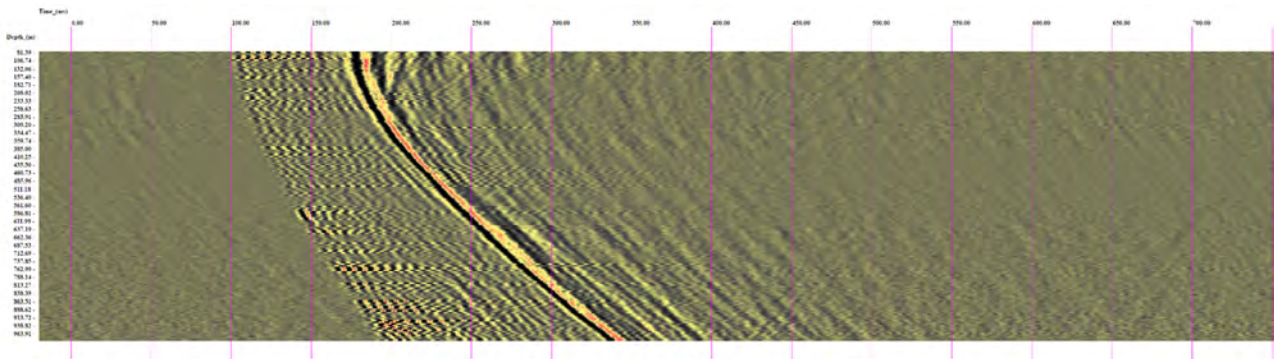


Axial component

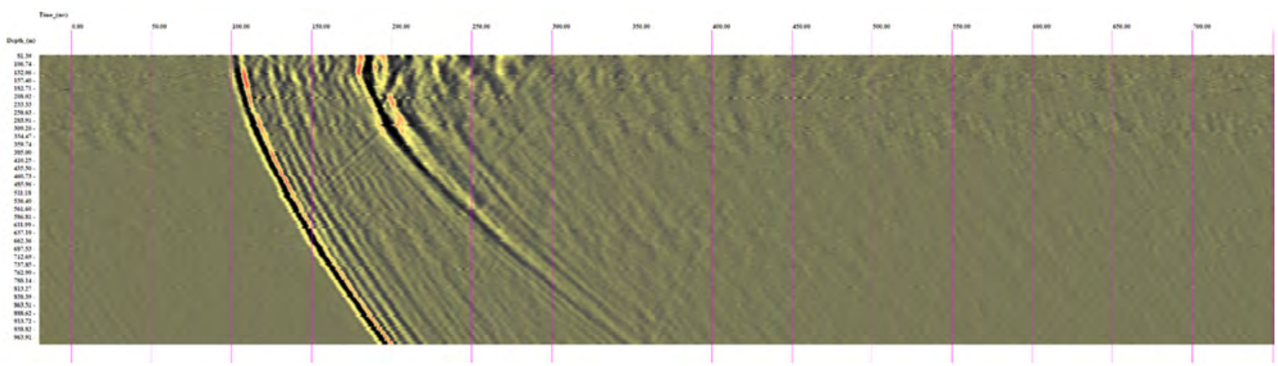
Figure 8. IG_BH04 VSP, Shot V09



Radial component

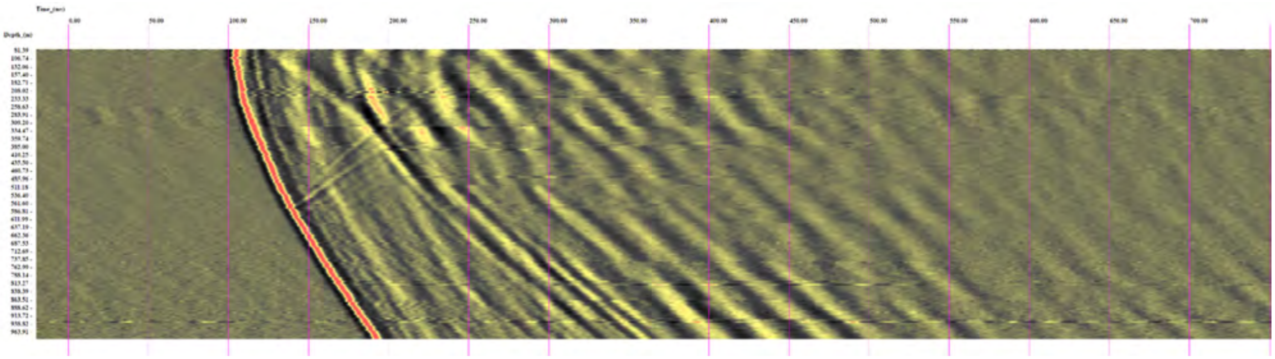


Transversal component

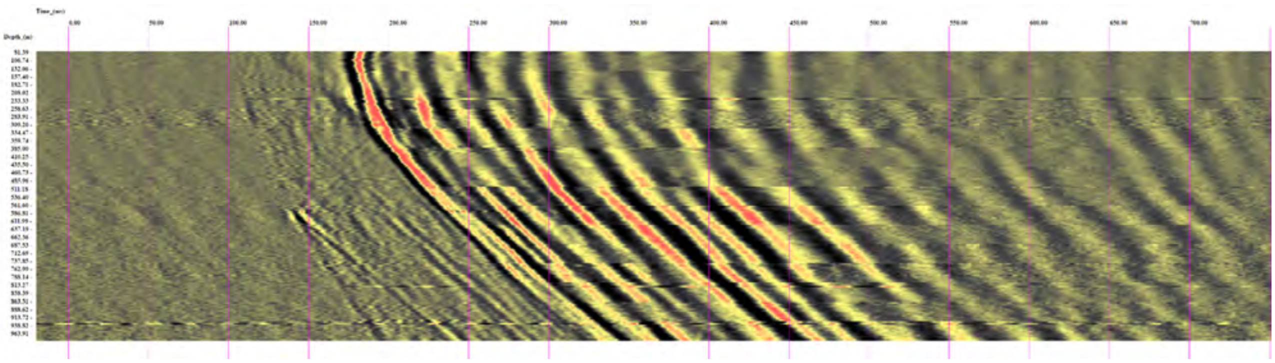


Axial component

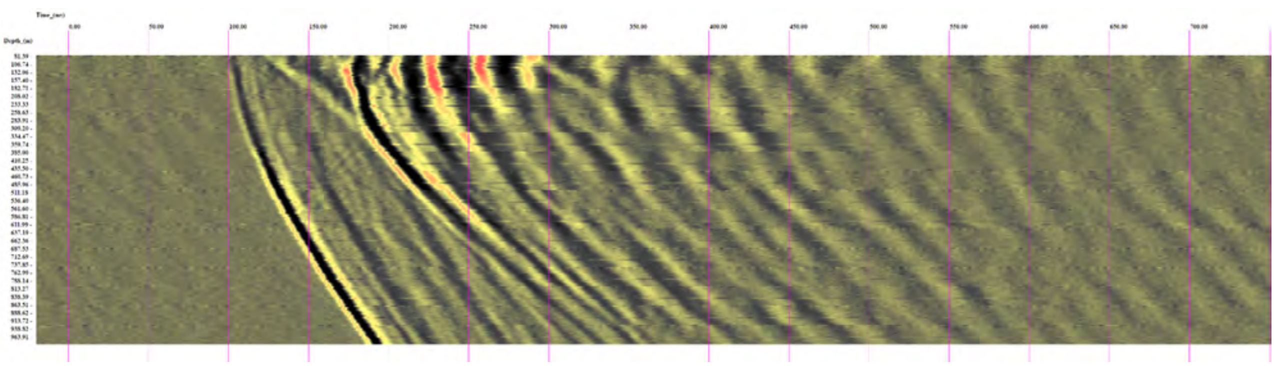
Figure 9. IG_BH04 VSP, Shot V10



Radial component

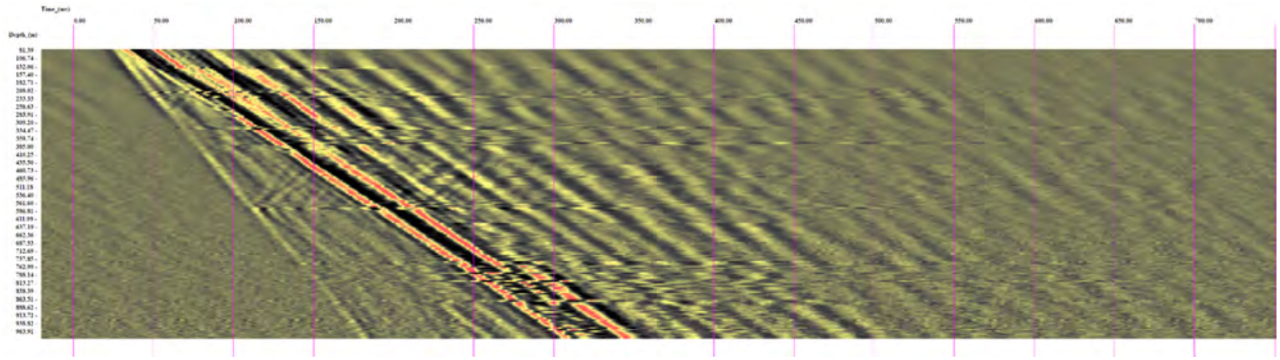


Transversal component

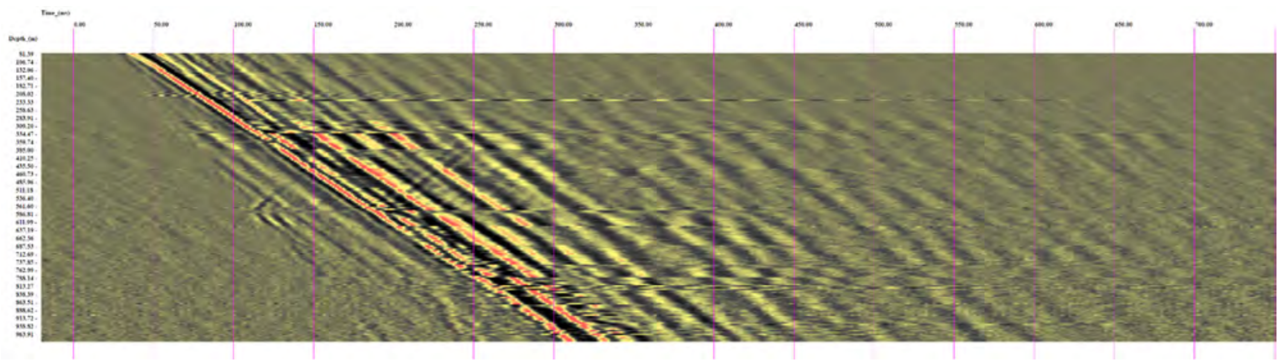


Axial component

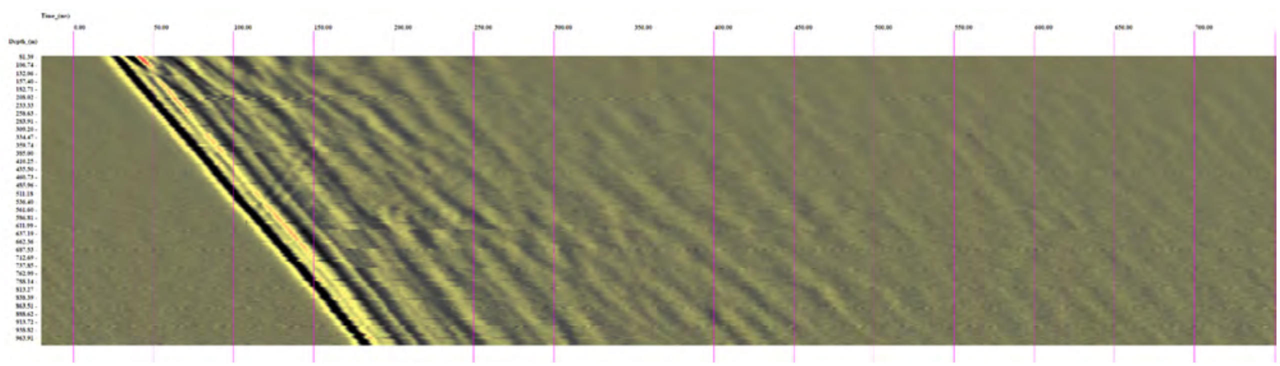
Figure 10. IG_BH04 VSP, Shot V11



Radial component

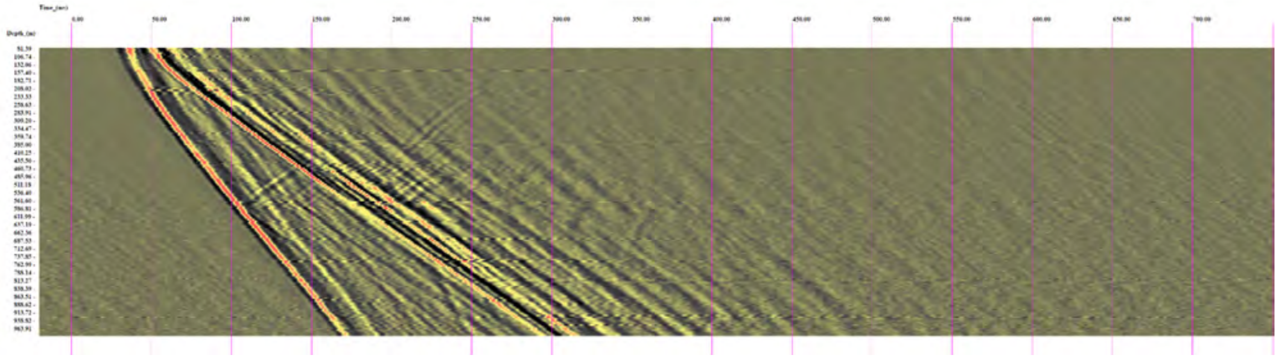


Transversal component

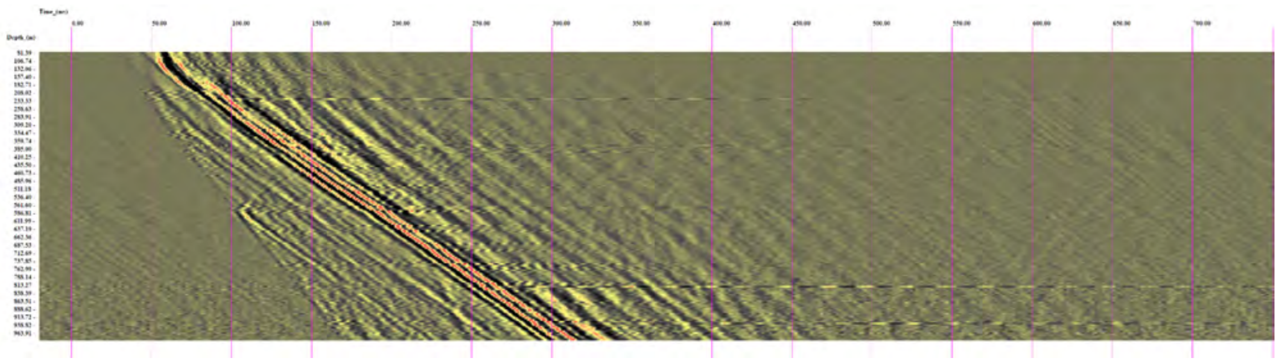


Axial component

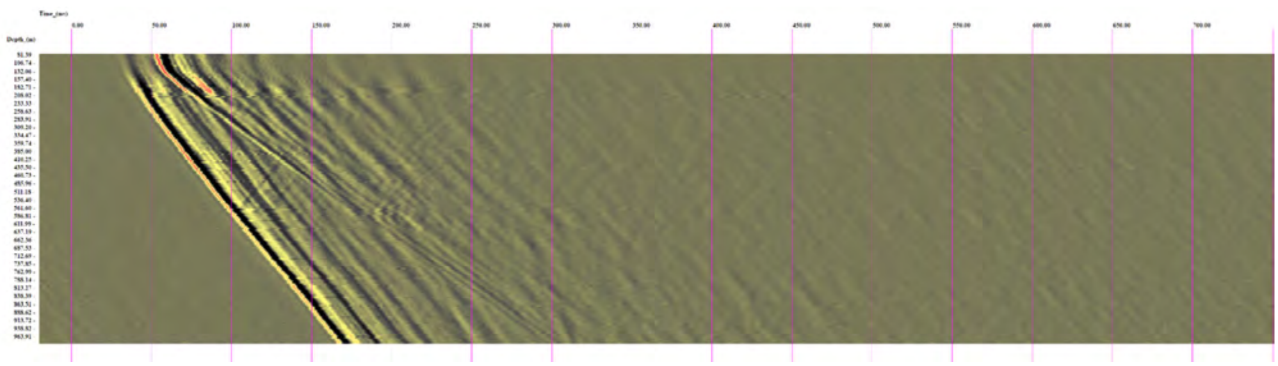
Figure 11. IG_BH04 VSP, Shot V14



Radial component

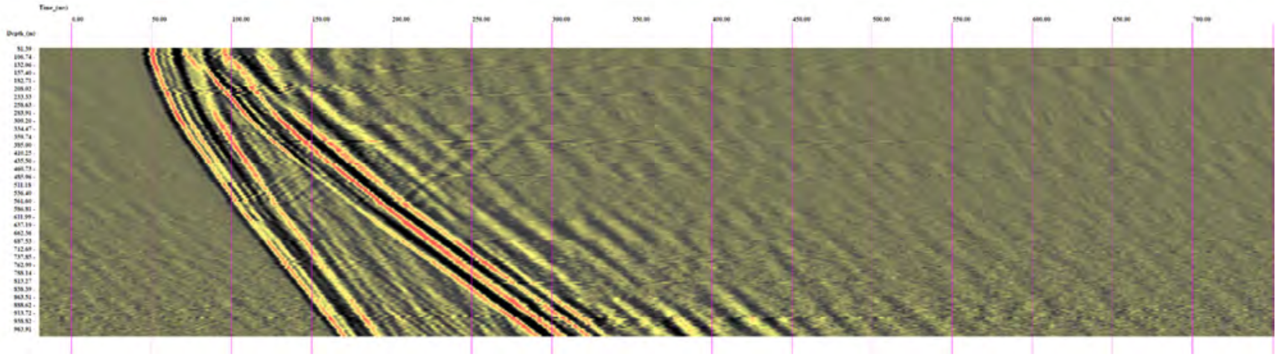


Transversal component

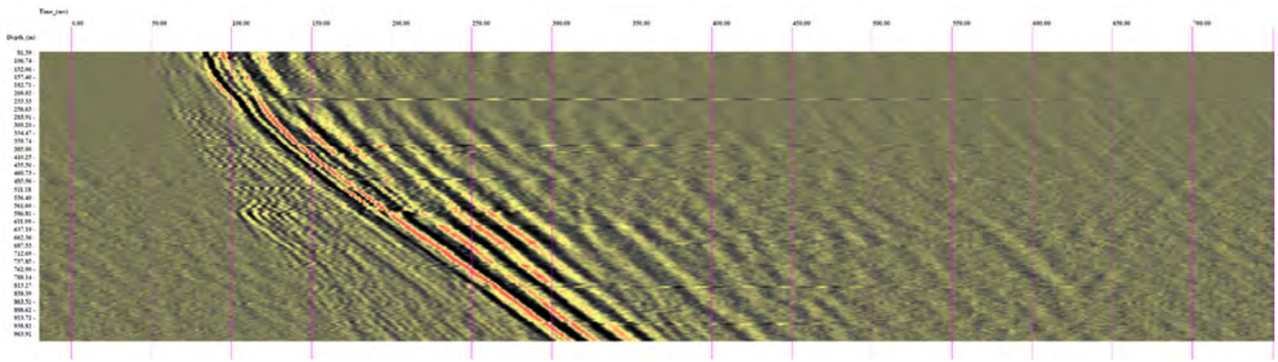


Axial component

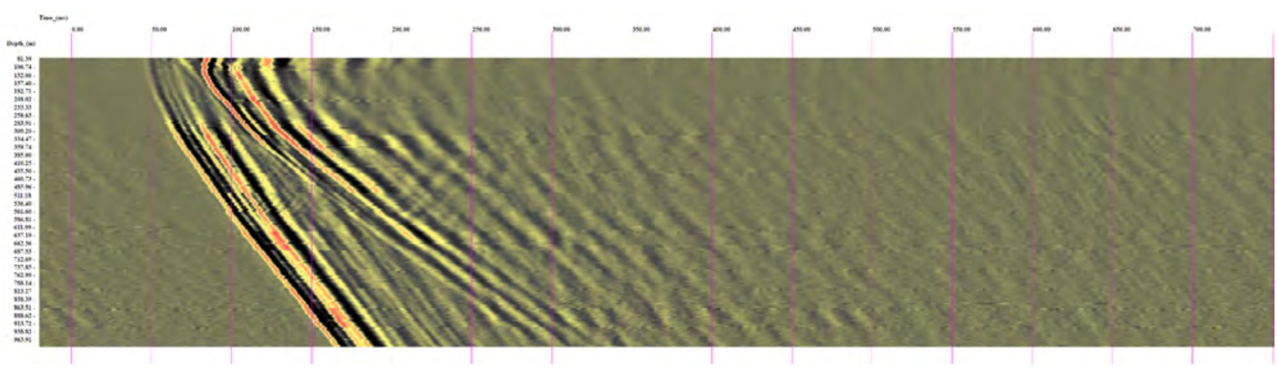
Figure 12. IG_BH04 VSP, Shot V15



Radial component

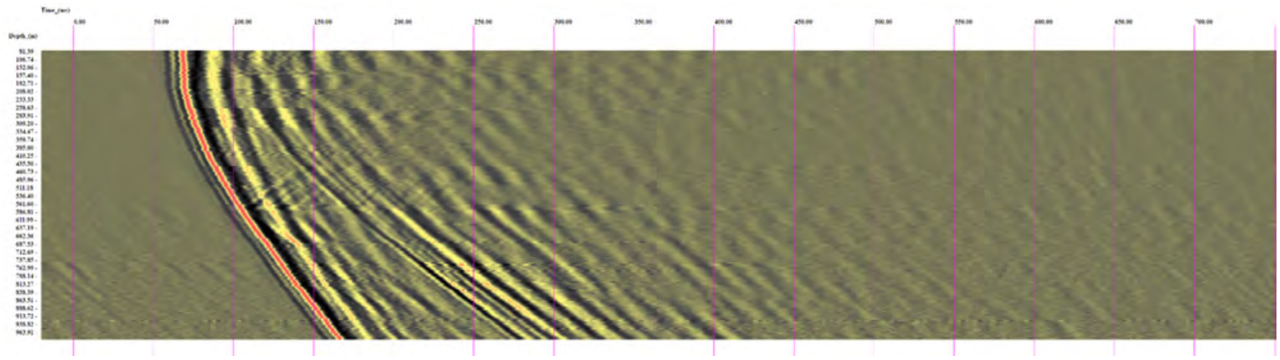


Transversal component

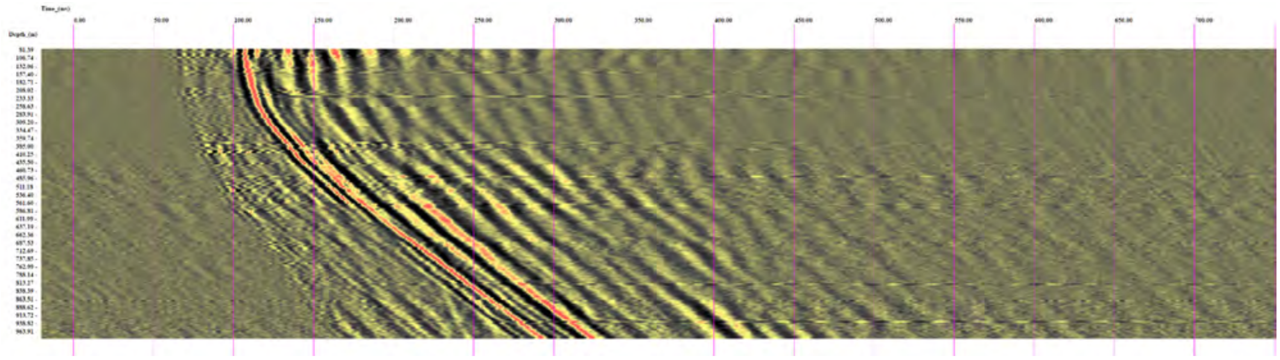


Axial component

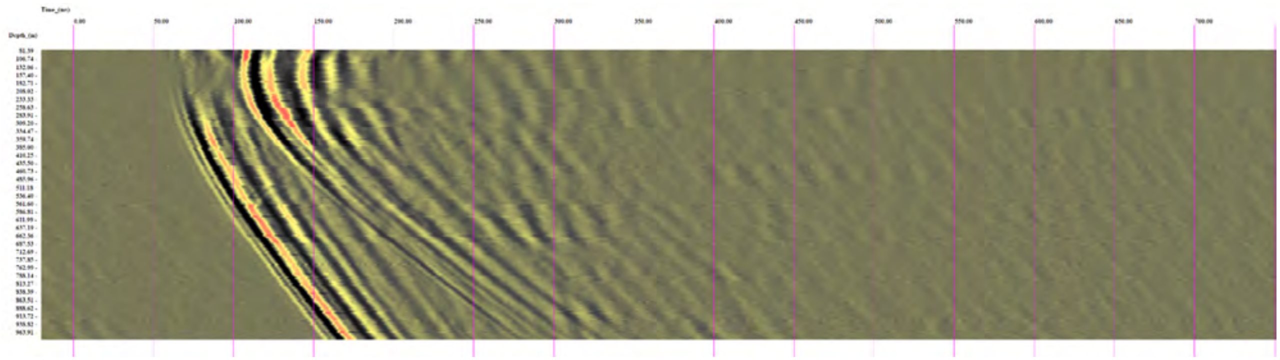
Figure 13. IG_BH04 VSP, Shot V16



Radial component

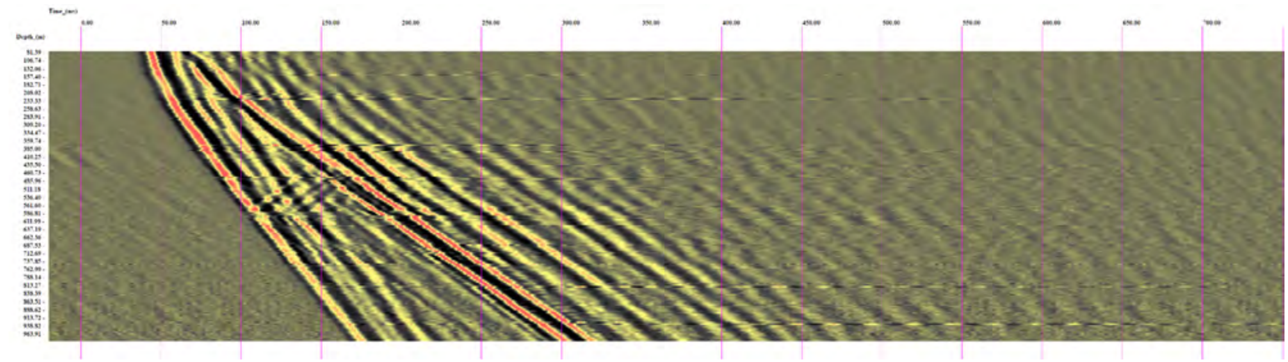


Transversal component

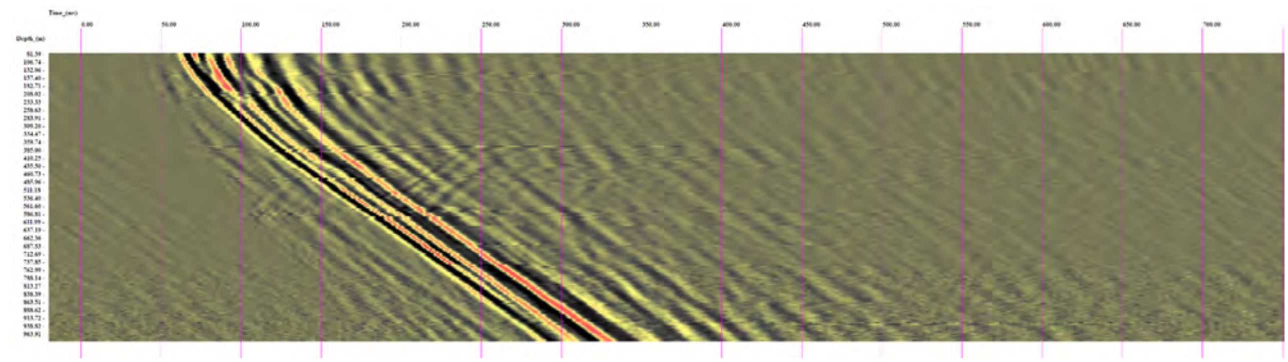


Axial component

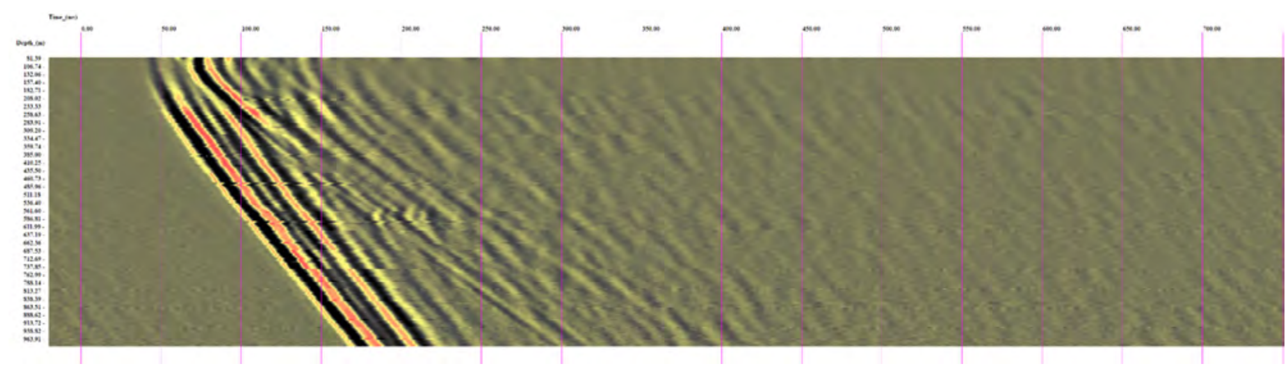
Figure 14. IG_BH04 VSP, Shot V17



Radial component

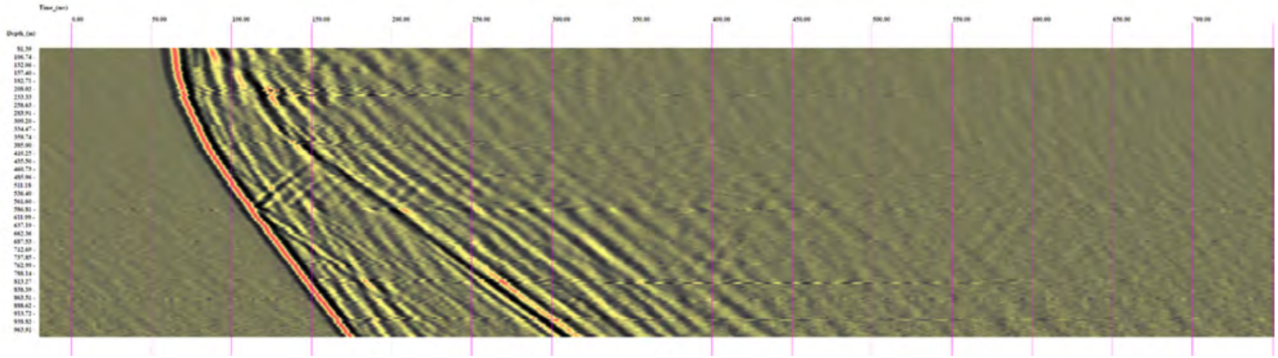


Transversal component

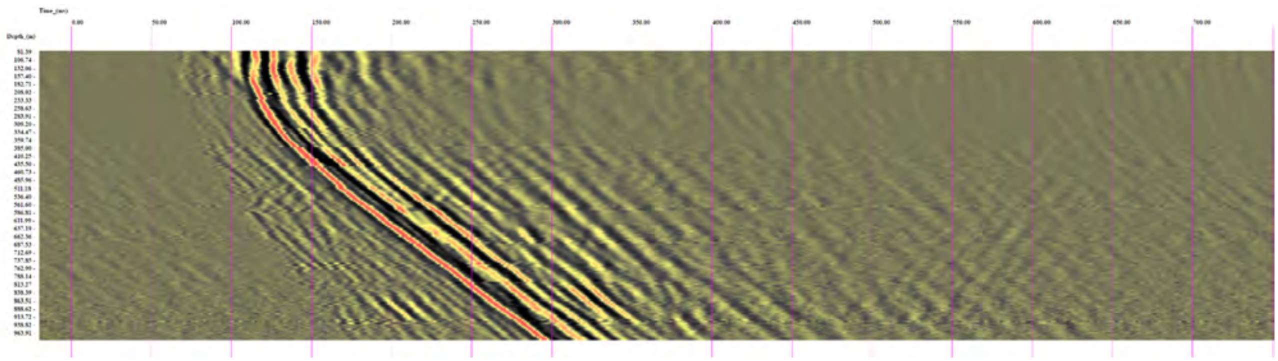


Axial component

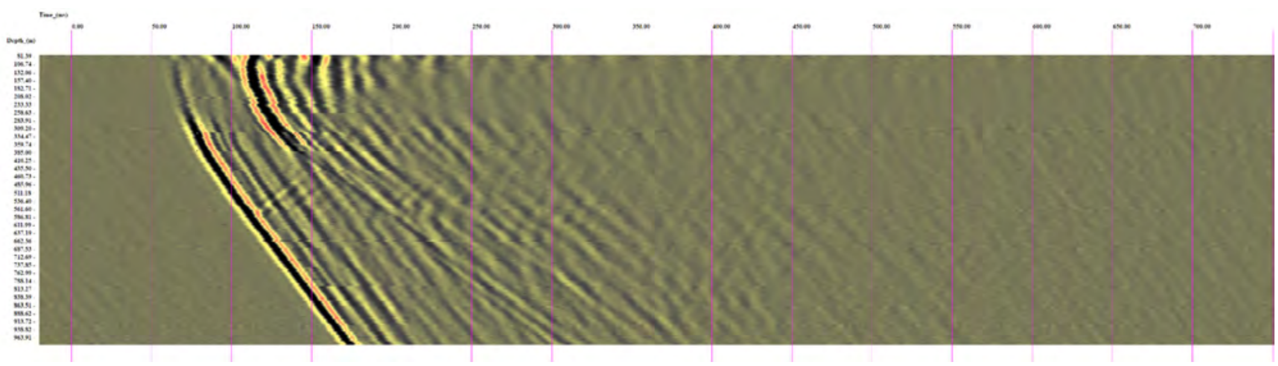
Figure 15. IG_BH04 VSP, Shot V20



Radial component

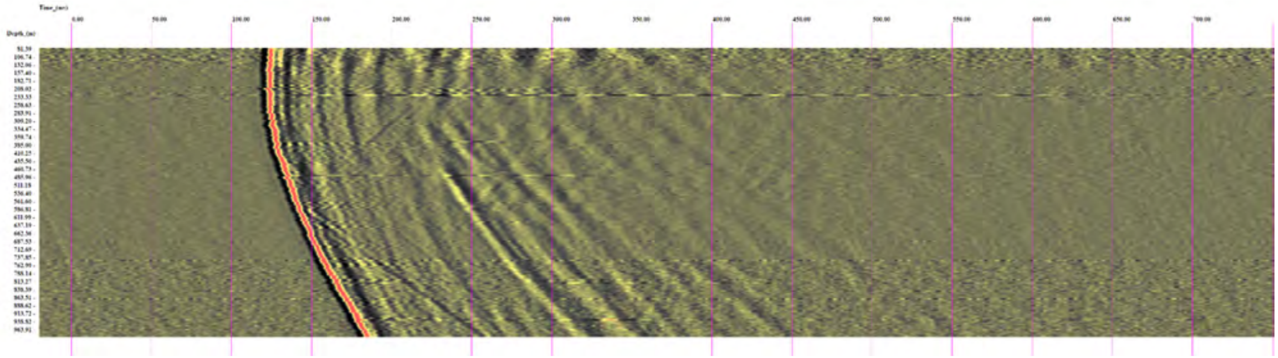


Transversal component

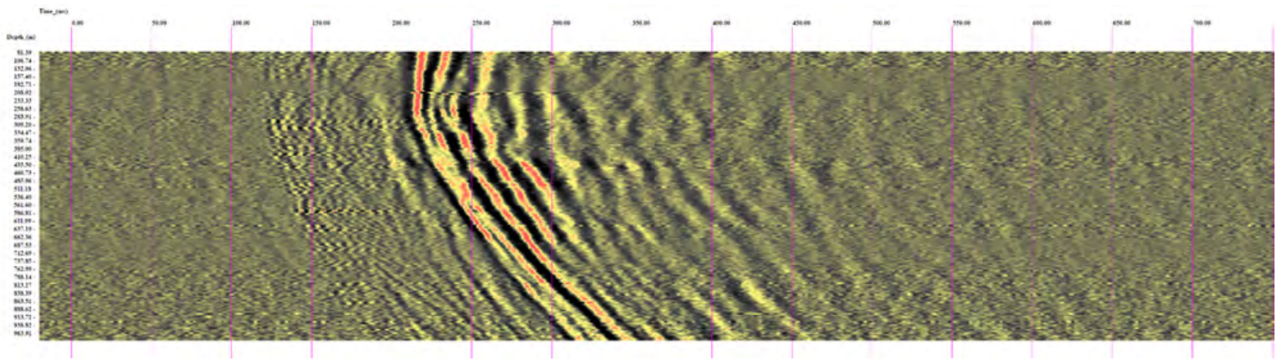


Axial component

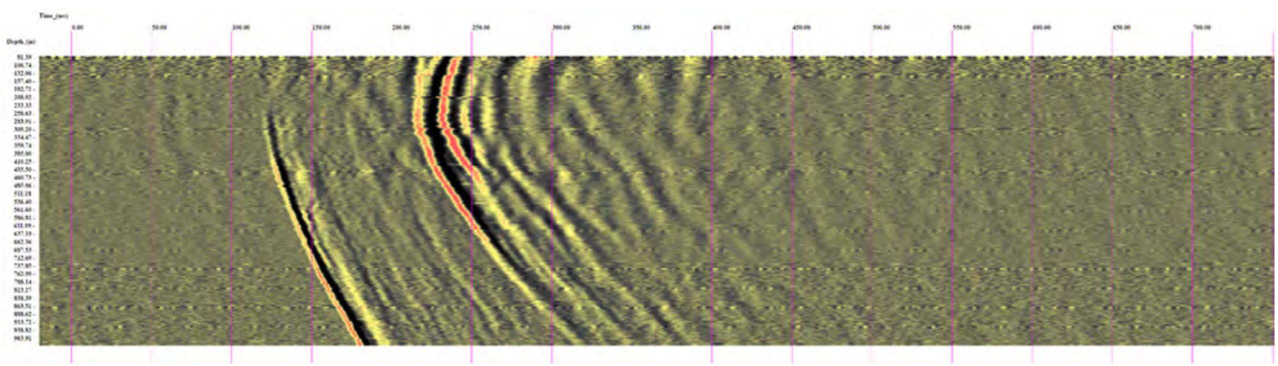
Figure 16. IG_BH04 VSP, Shot V21



Radial component

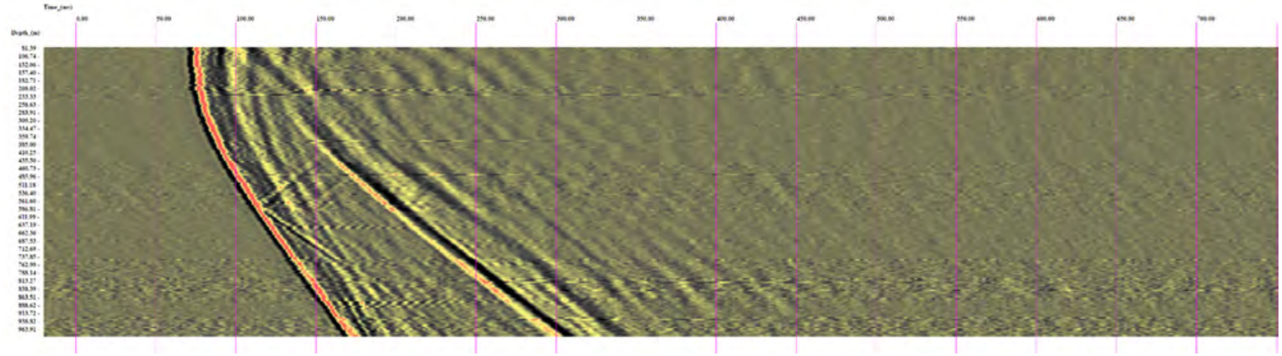


Transversal component

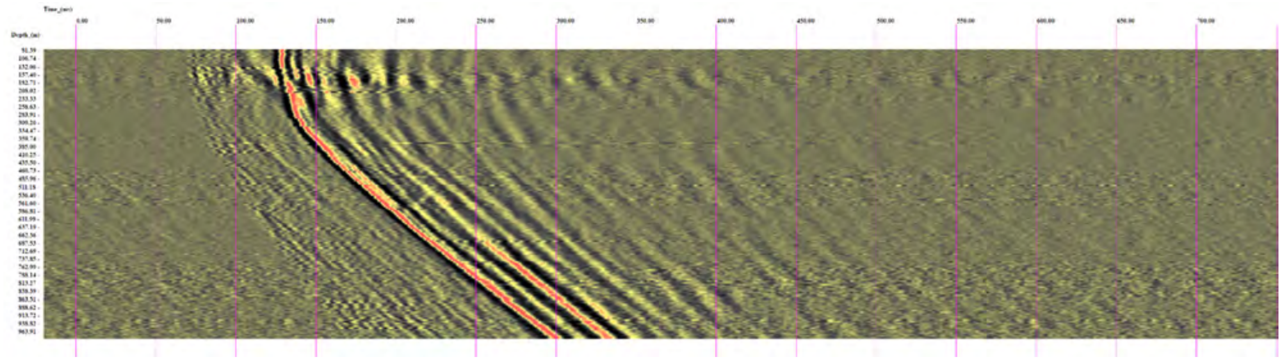


Axial component

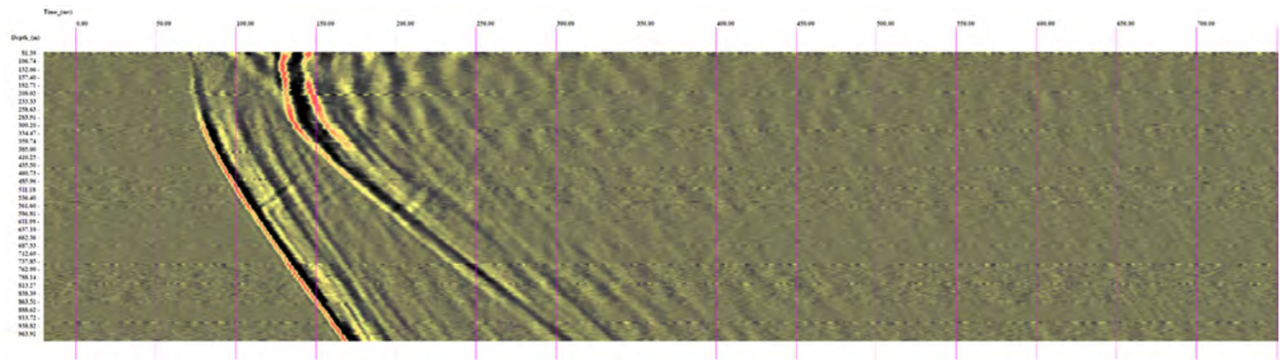
Figure 17. IG_BH04 VSP, Shot V23



Radial component

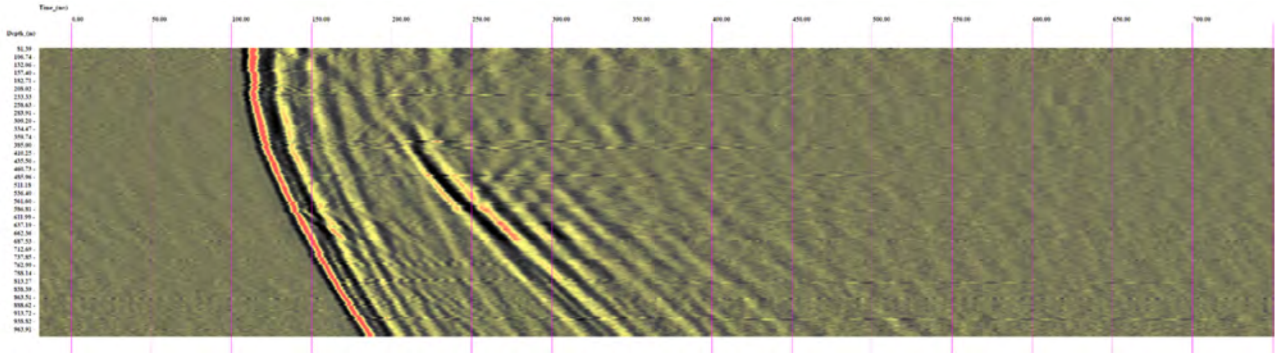


Transversal component

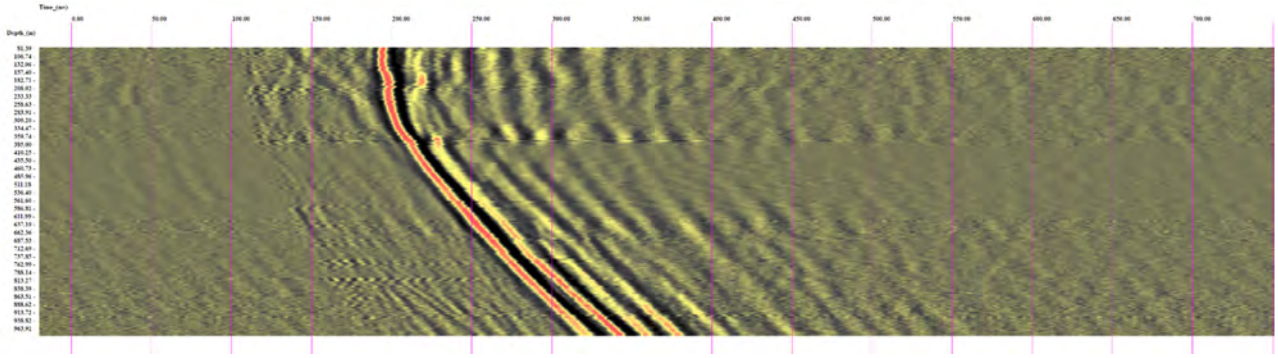


Axial component

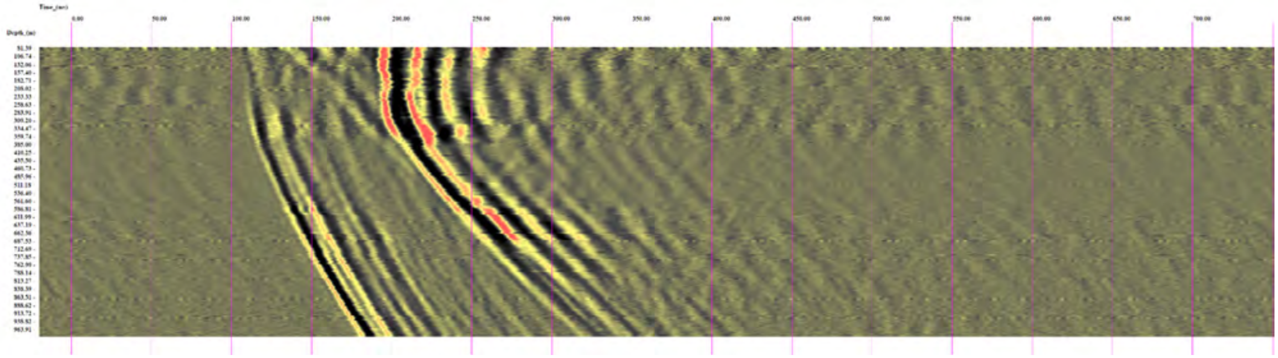
Figure 18. IG_BH04 VSP, Shot V25



Radial component

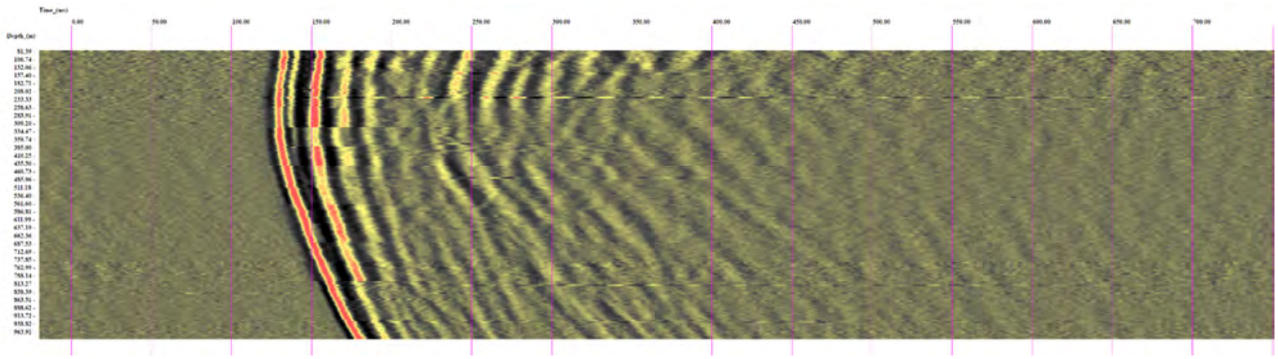


Transversal component

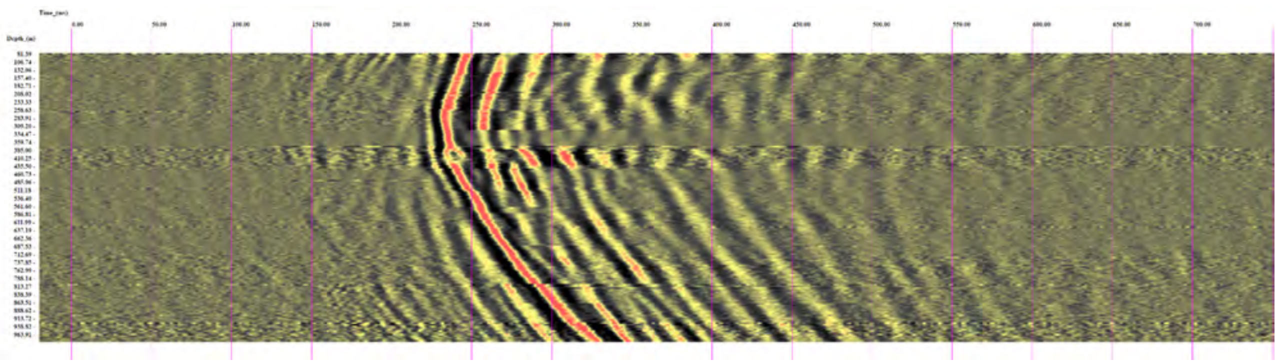


Axial component

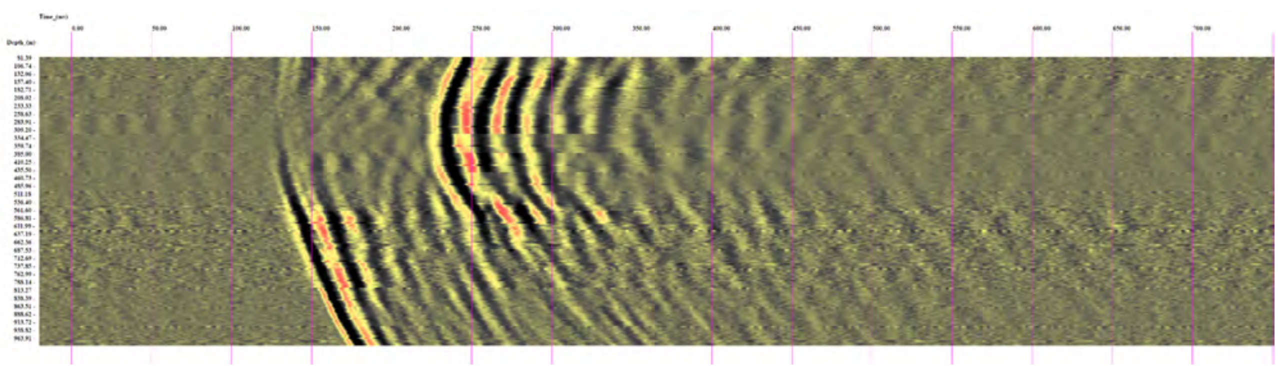
Figure 19. IG_BH04 VSP, Shot V26



Radial component

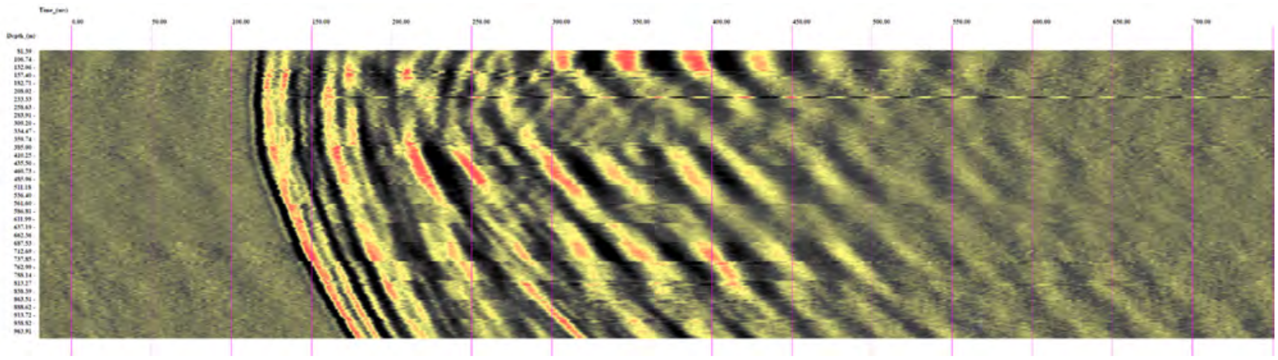


Transversal component

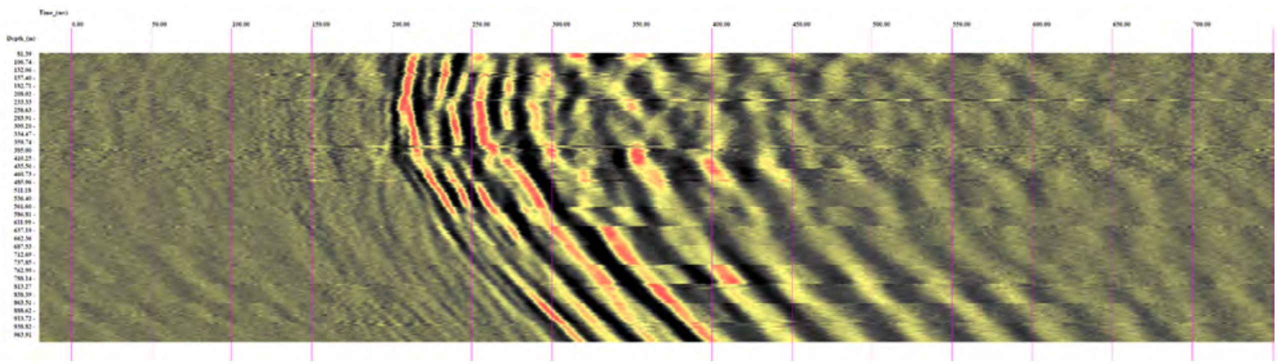


Axial component

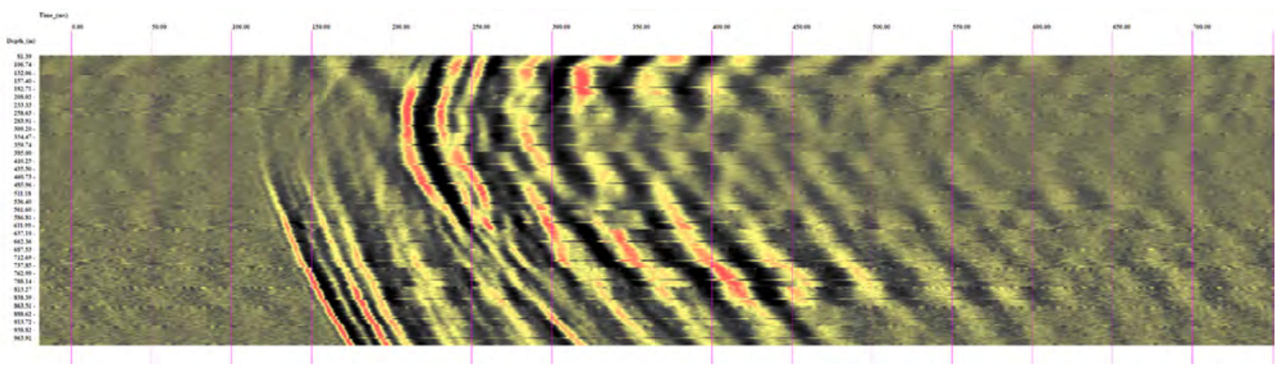
Figure 20. IG_BH04 VSP, Shot V27



Radial component

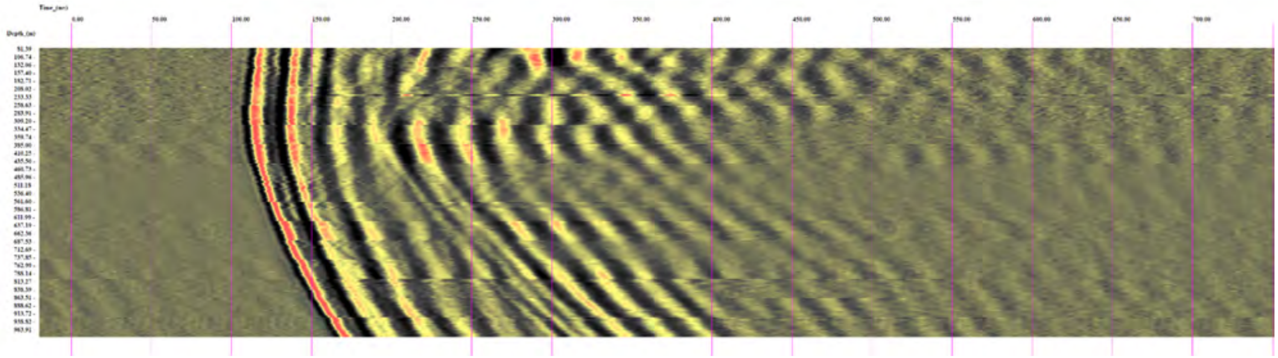


Transversal component

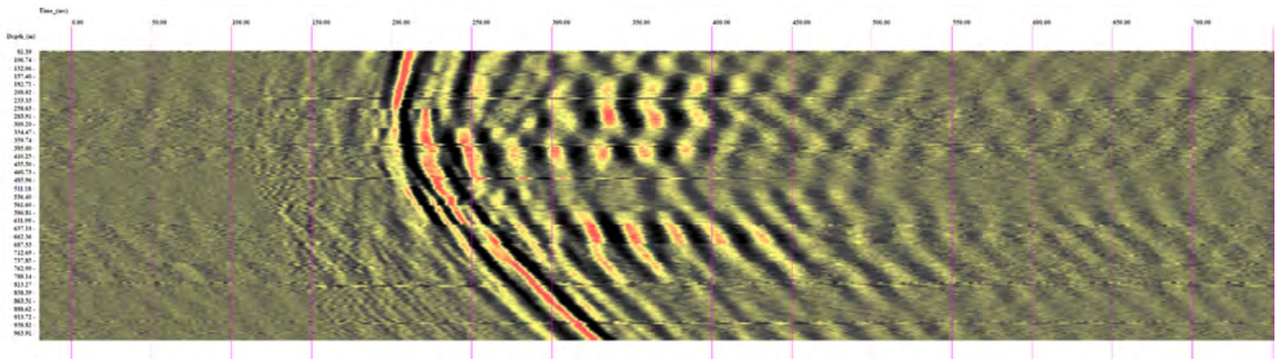


Axial component

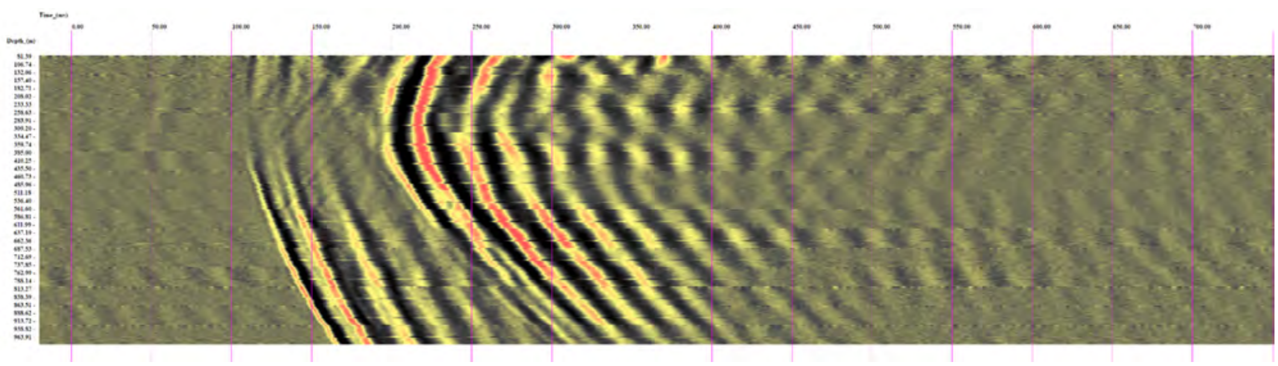
Figure 21. IG_BH04 VSP, Shot V28



Radial component

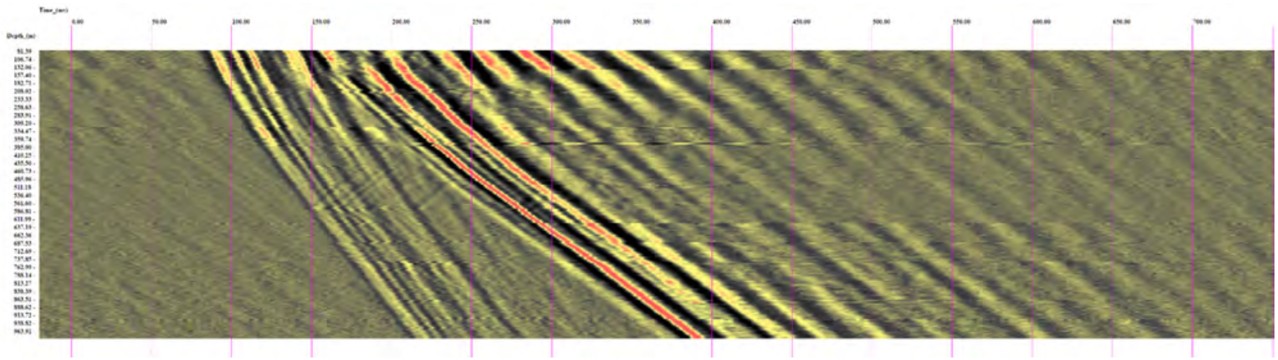


Transversal component

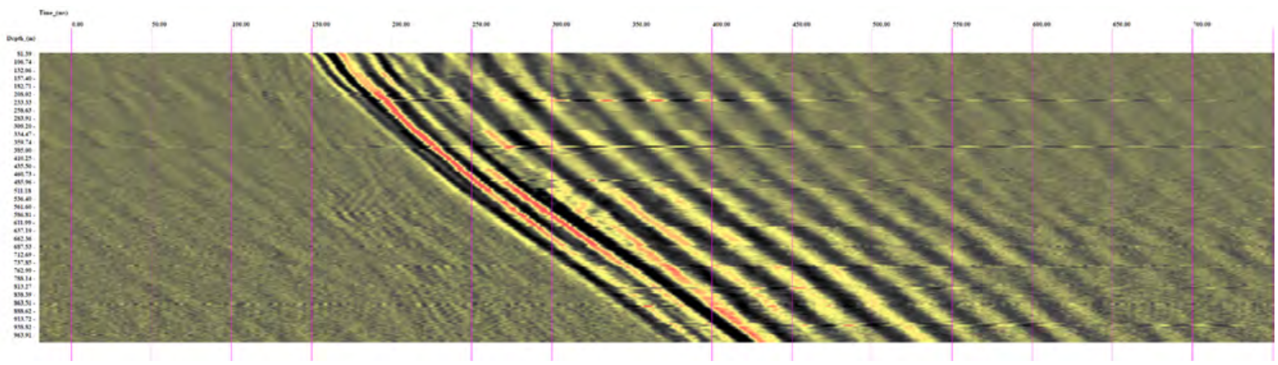


Axial component

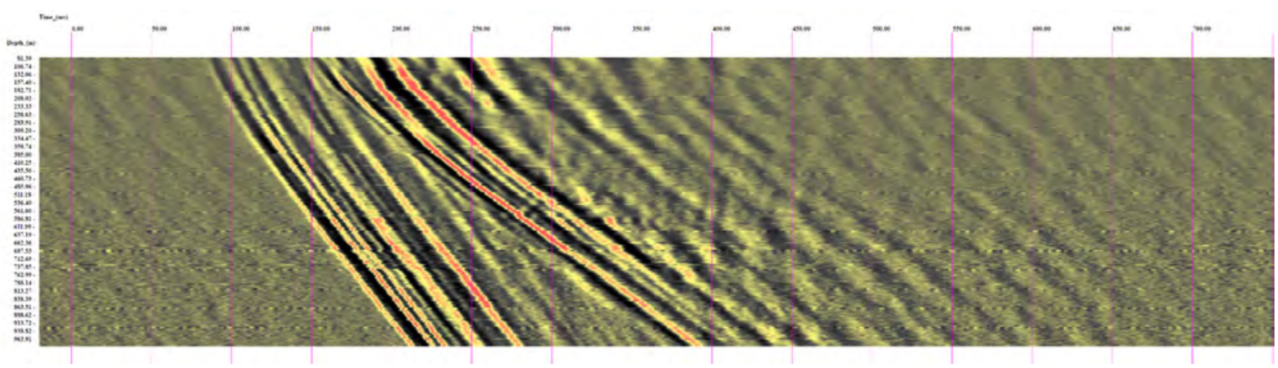
Figure 22. IG_BH04 VSP, Shot V29



Radial component

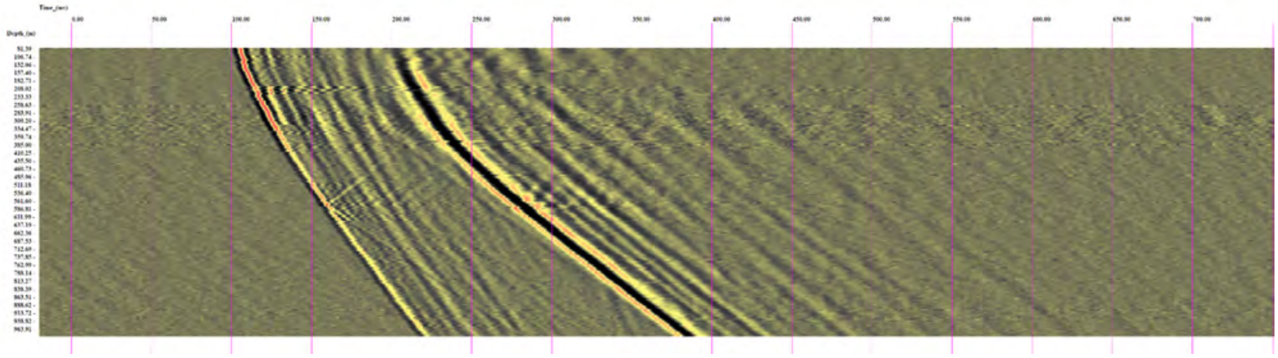


Transversal component

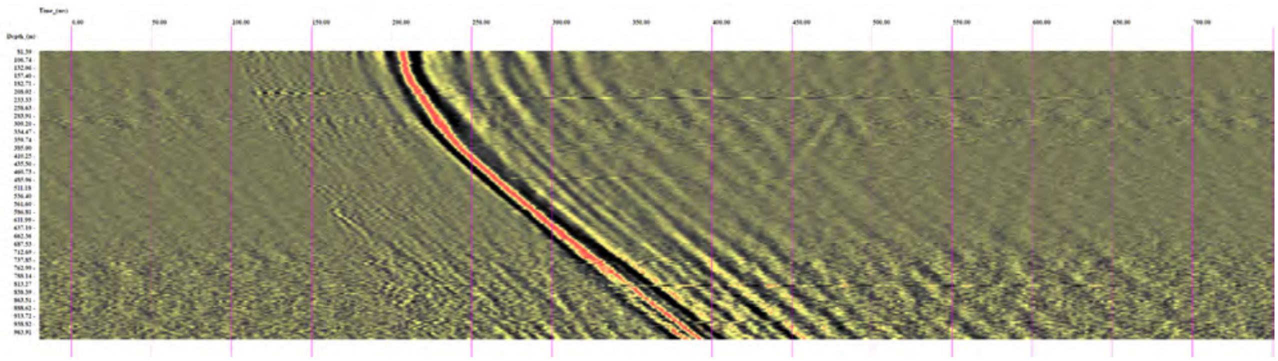


Axial component

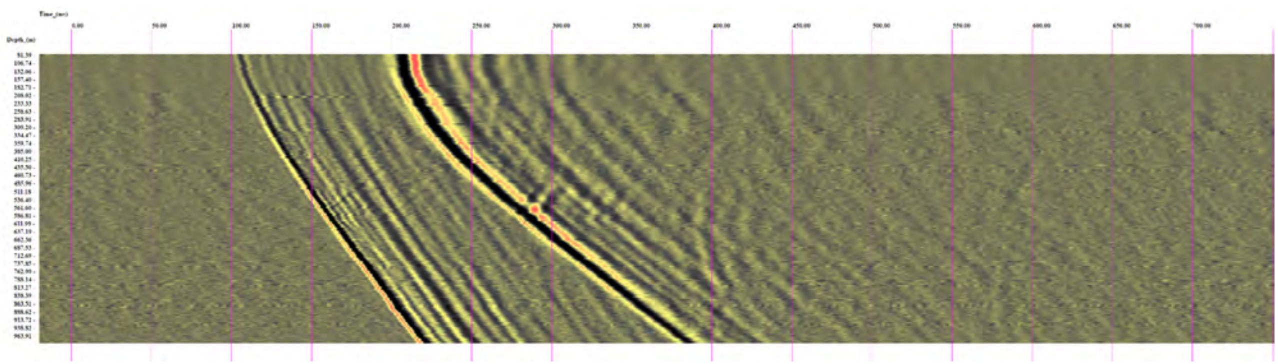
Figure 23. IG_BH04 VSP, Shot V30



Radial component

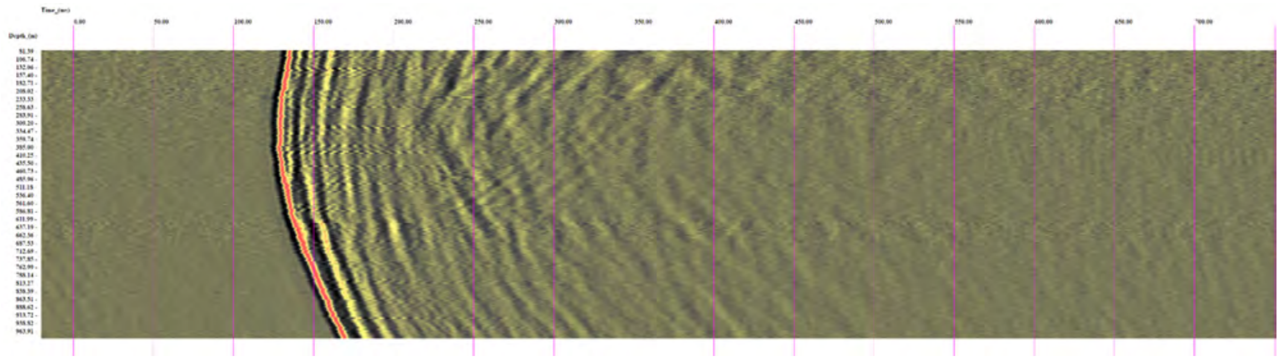


Transversal component

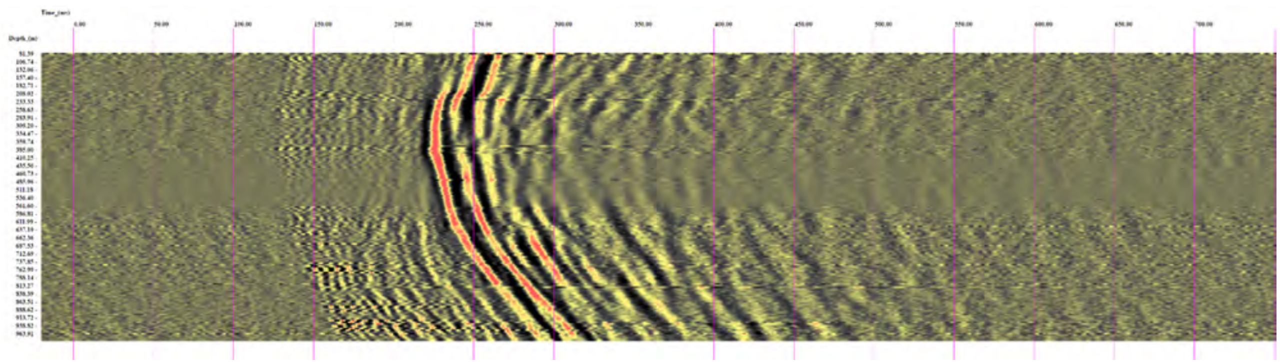


Axial component

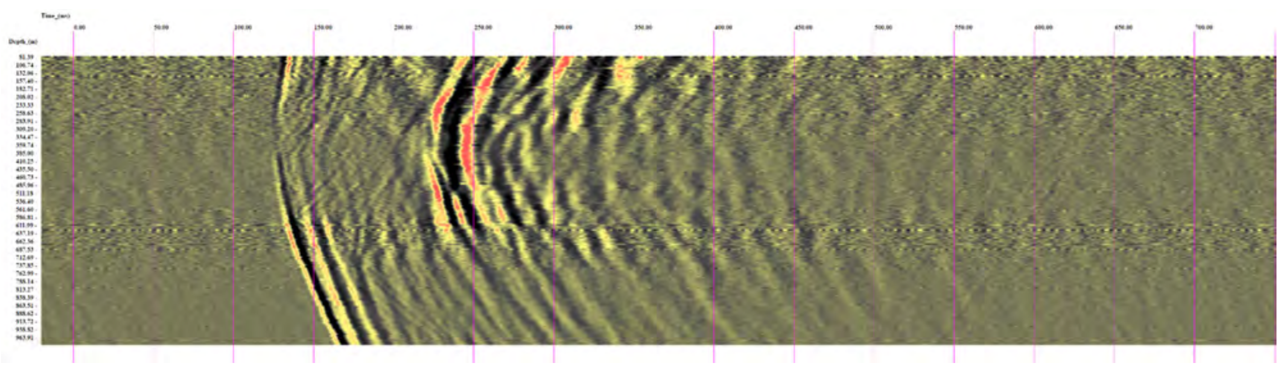
Figure 24. IG_BH04 VSP, Shot V31



Radial component

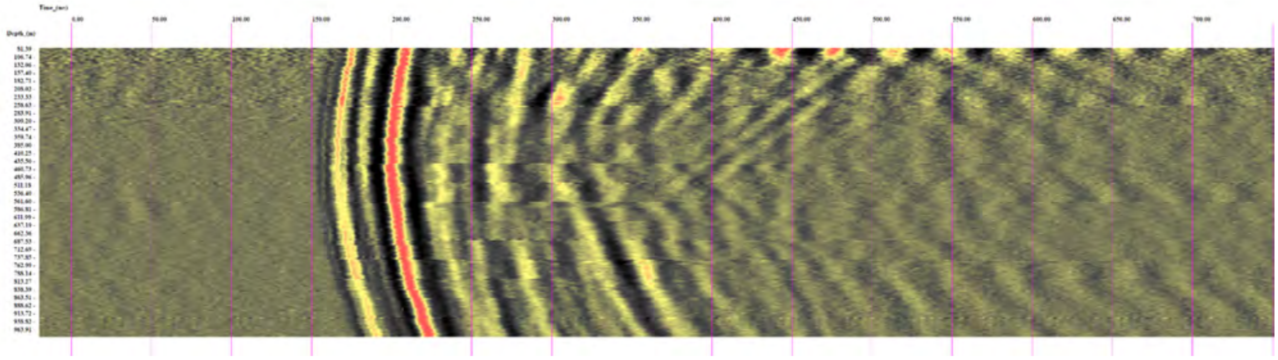


Transversal component

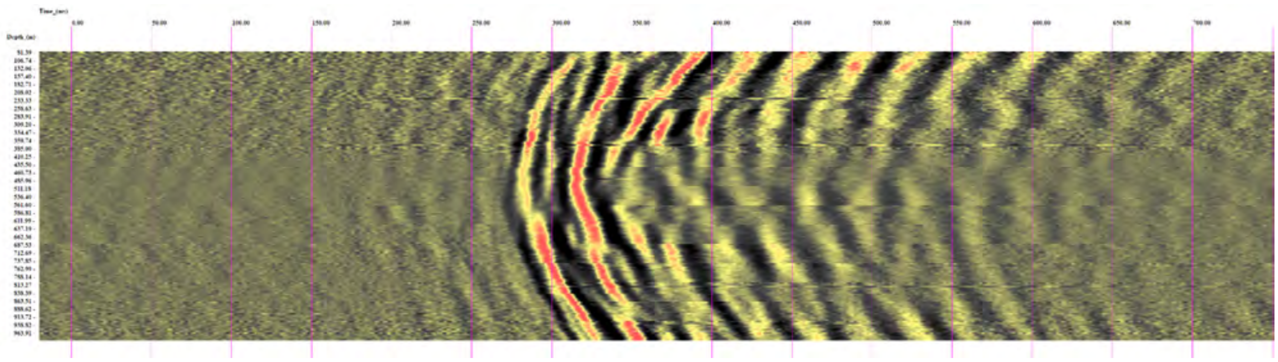


Axial component

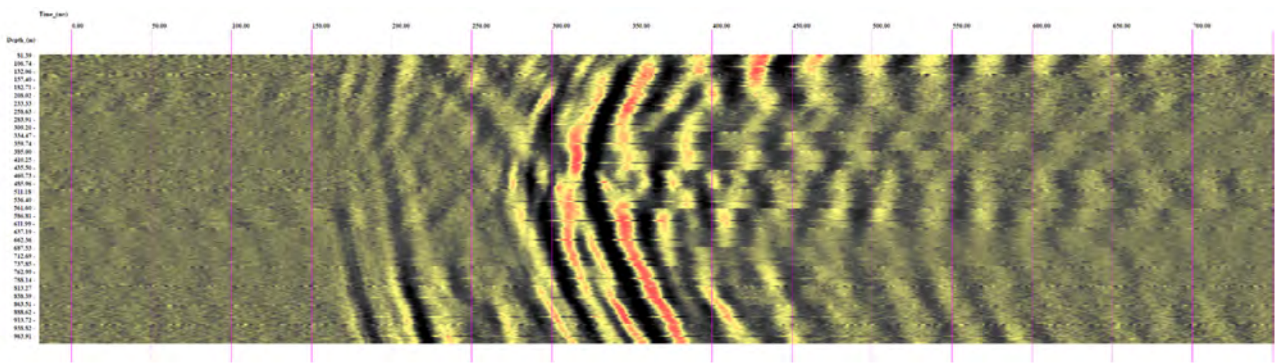
Figure 25. IG_BH04 VSP, Shot V35



Radial component

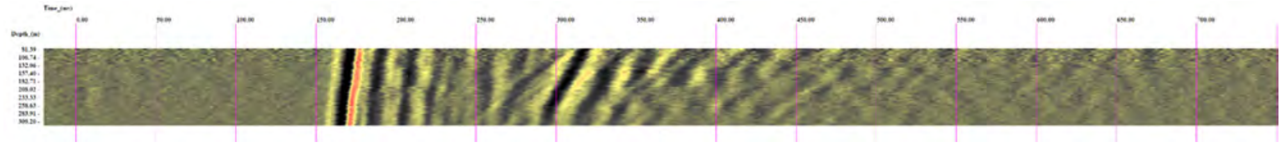


Transversal component

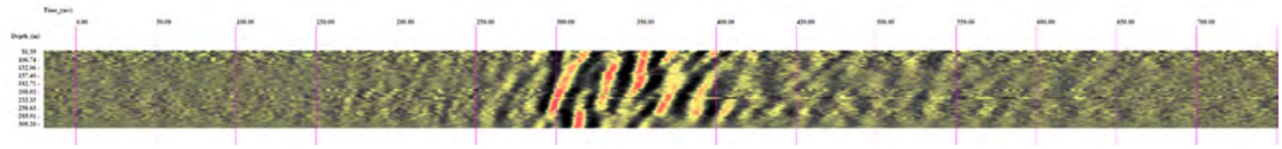


Axial component

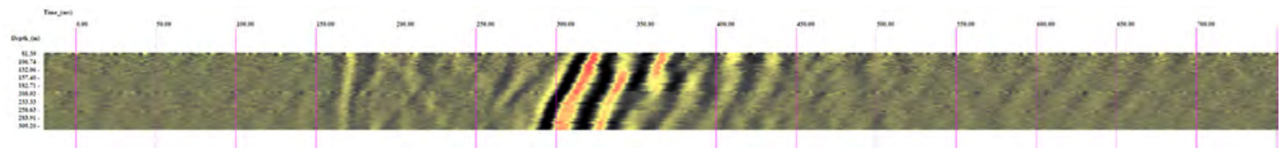
Figure 26. IG_BH04 VSP, Shot V36



Radial component

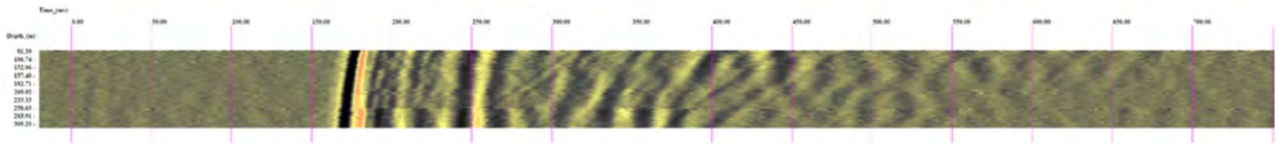


Transversal component

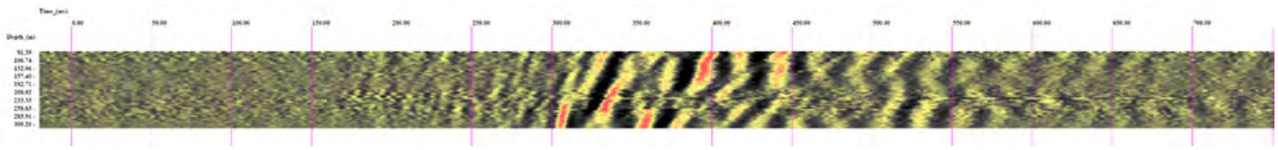


Axial component

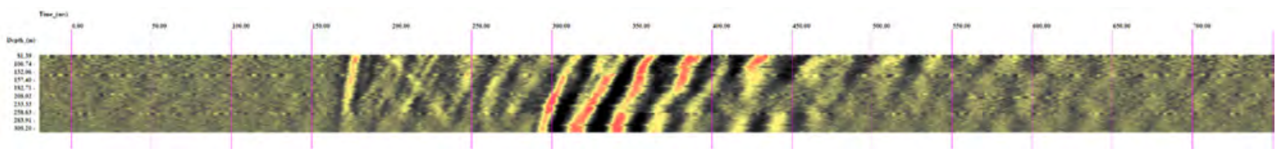
Figure 27. IG_BH04 VSP, Shot V37



Radial component

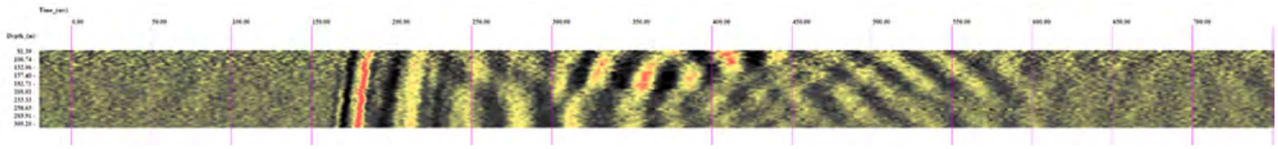


Transversal component

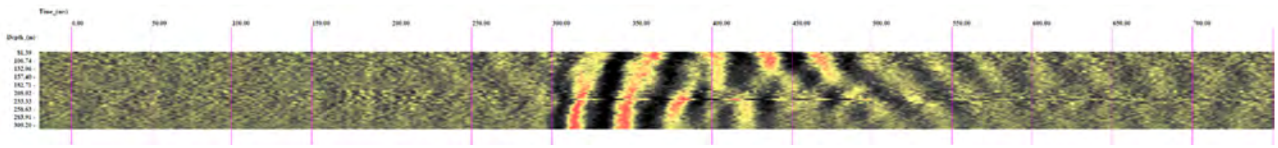


Axial component

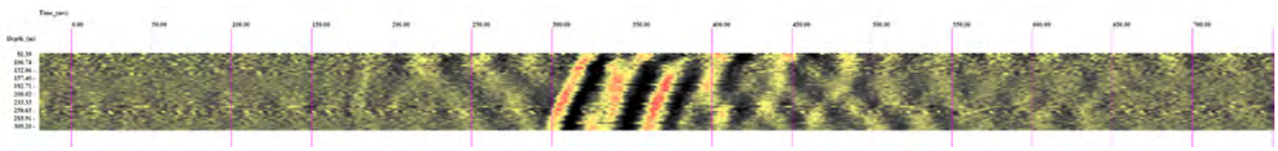
Figure 28. IG_BH04 VSP, Shot V38



Radial component

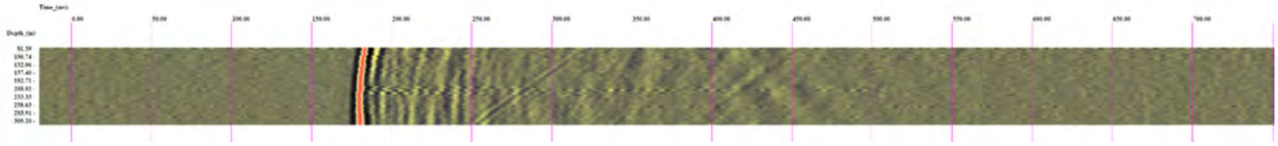


Transversal component

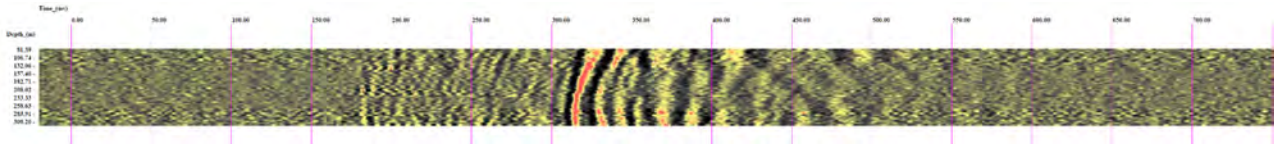


Axial component

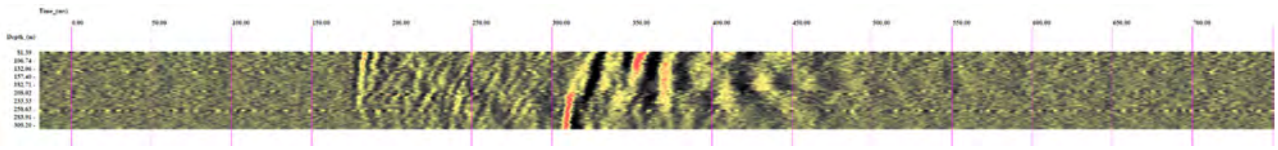
Figure 29. IG_BH04 VSP, Shot V39



Radial component



Transversal component

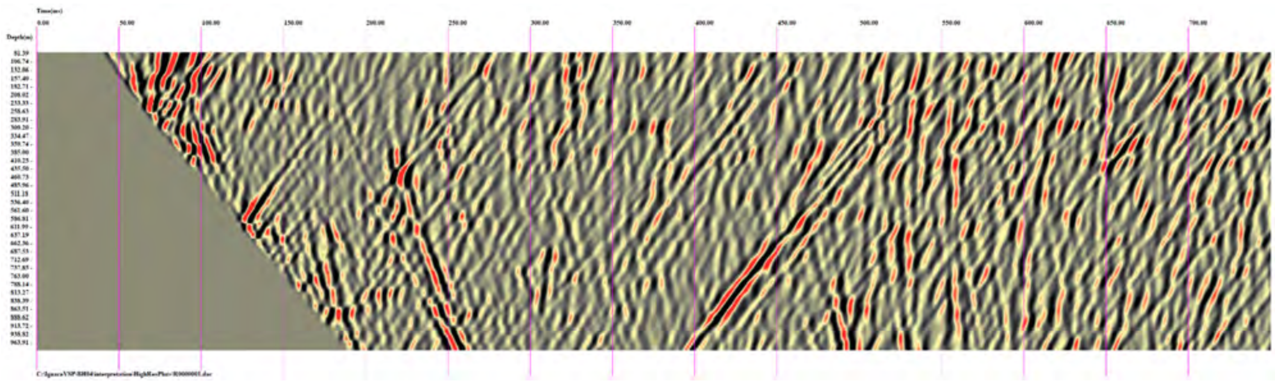


Axial component

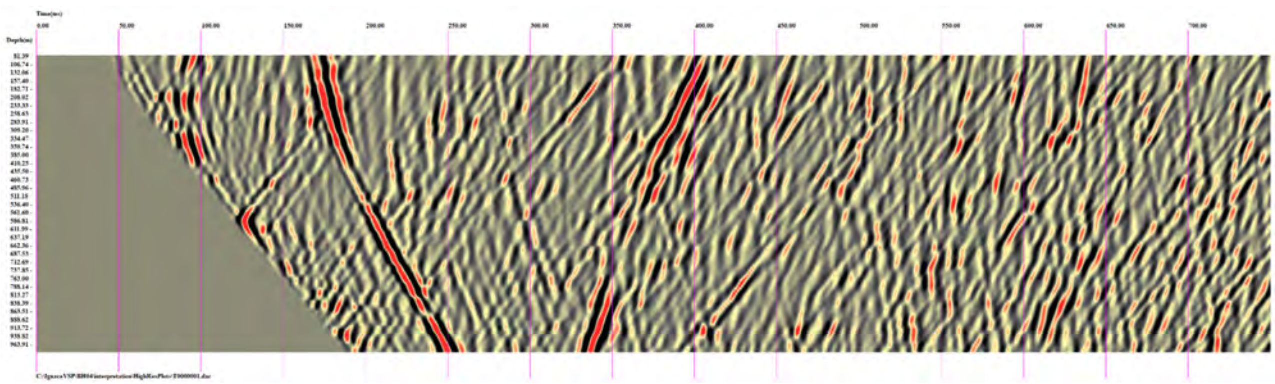
Figure 30. IG_BH04 VSP, Shot V40

APPENDIX C

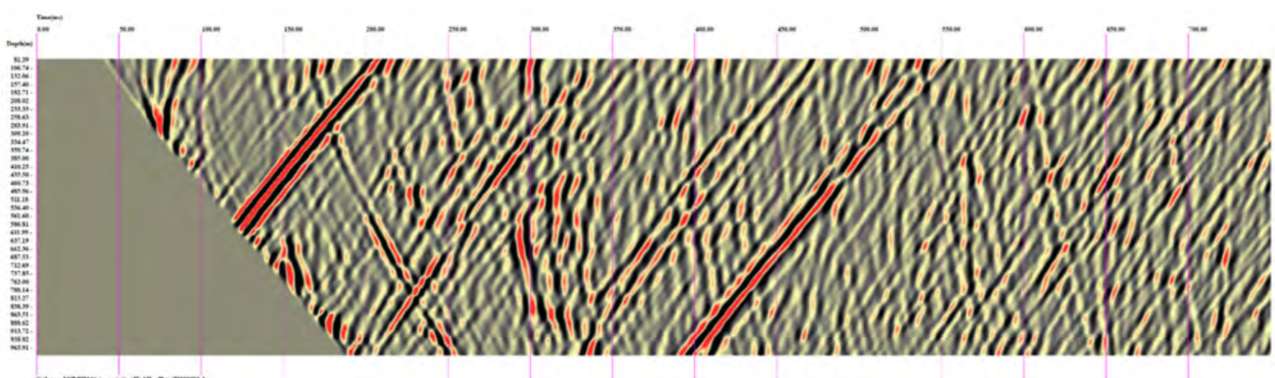
Processed VSP Profiles from Borehole IG_BH04



Radial component

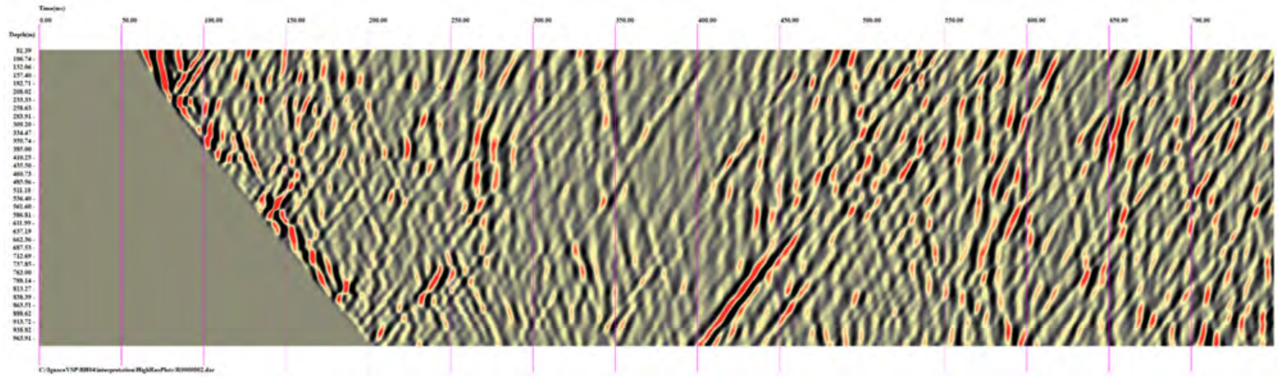


Transversal component

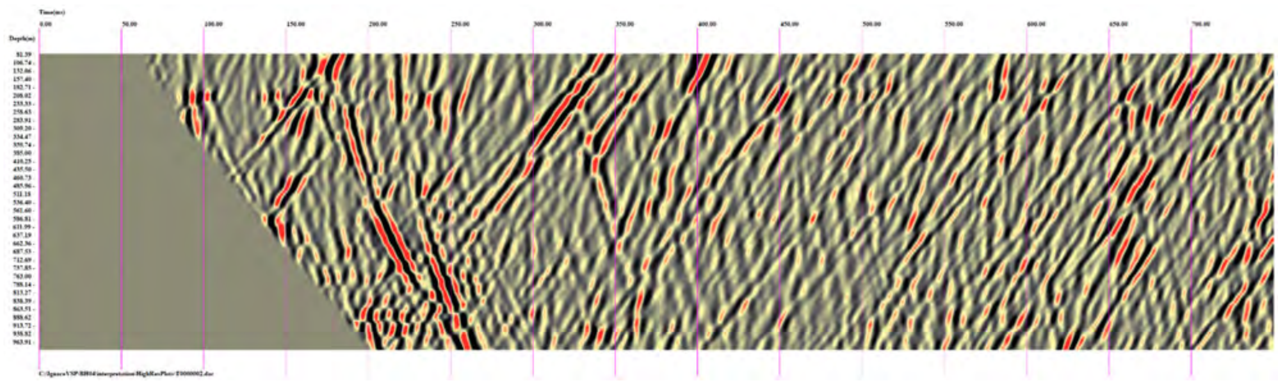


Axial component

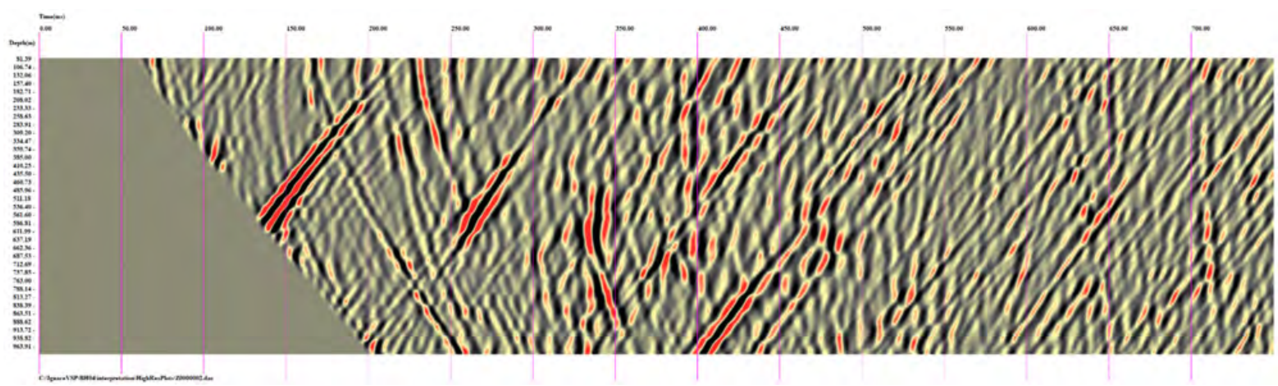
Figure 1. IG_BH04 VSP, Shot V01



Radial component

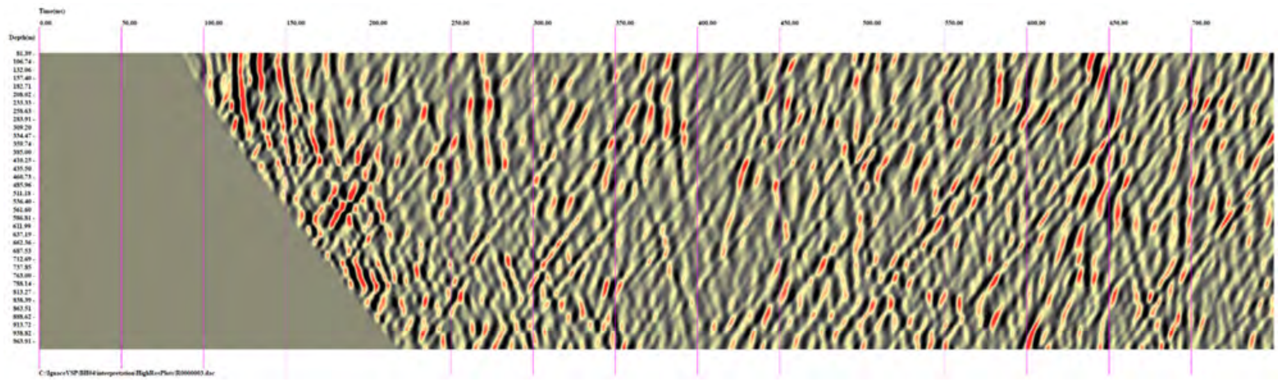


Transversal component

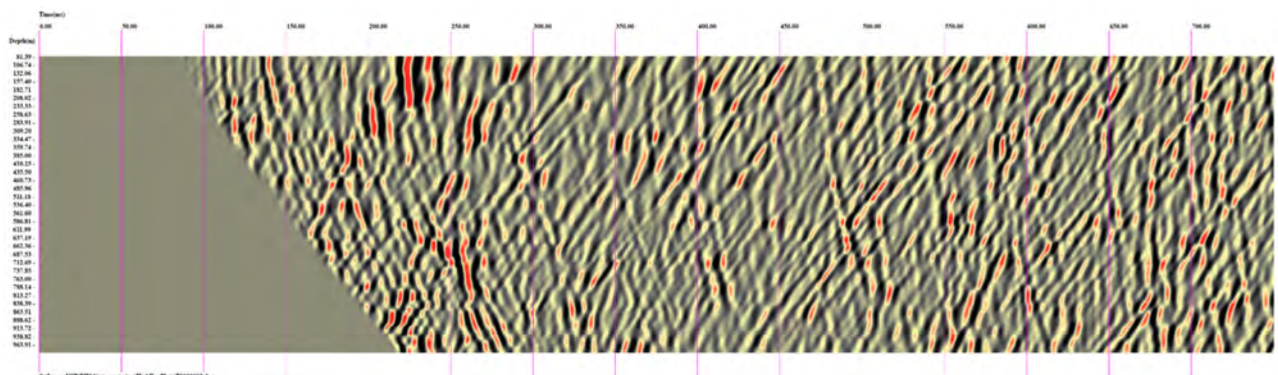


Axial component

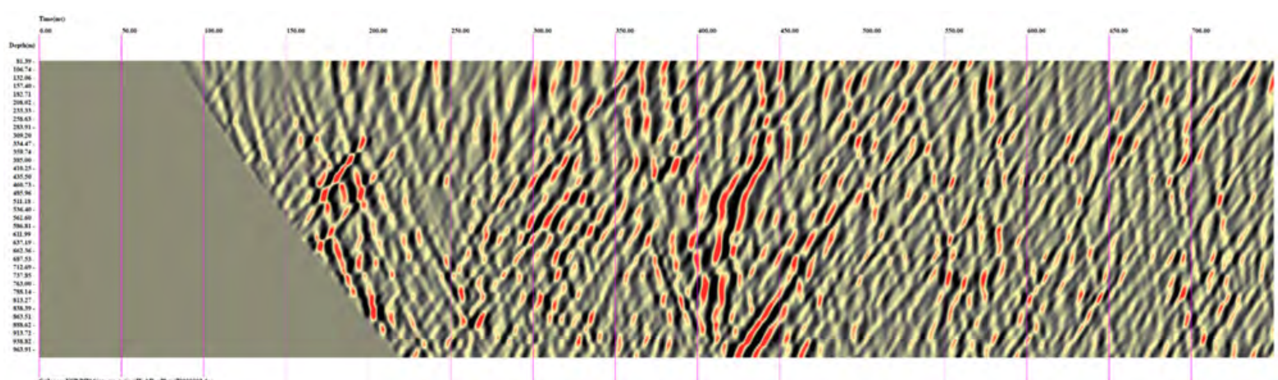
Figure 2. IG_BH04 VSP, Shot V02



Radial component

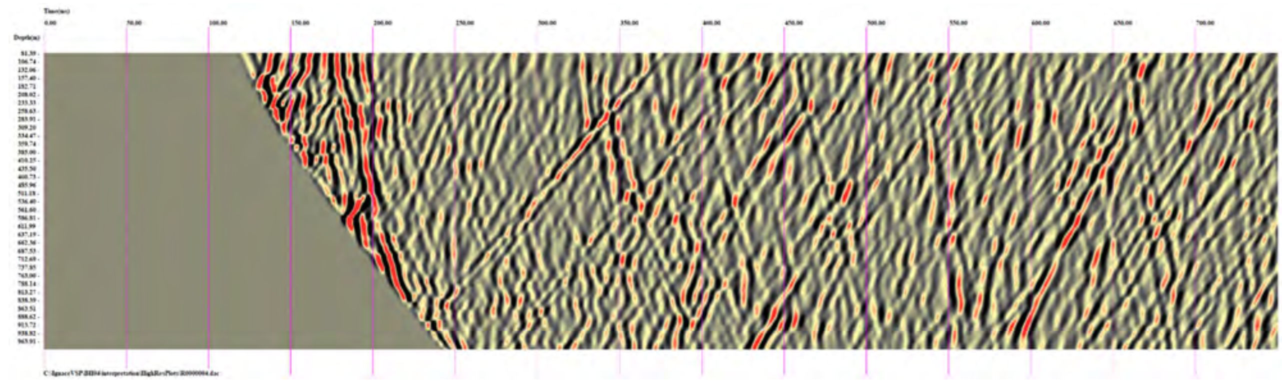


Transversal component

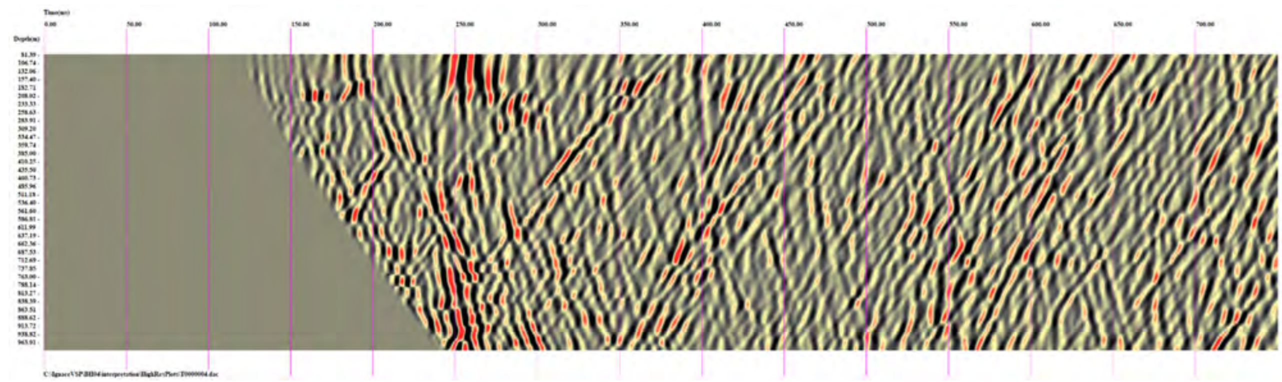


Axial component

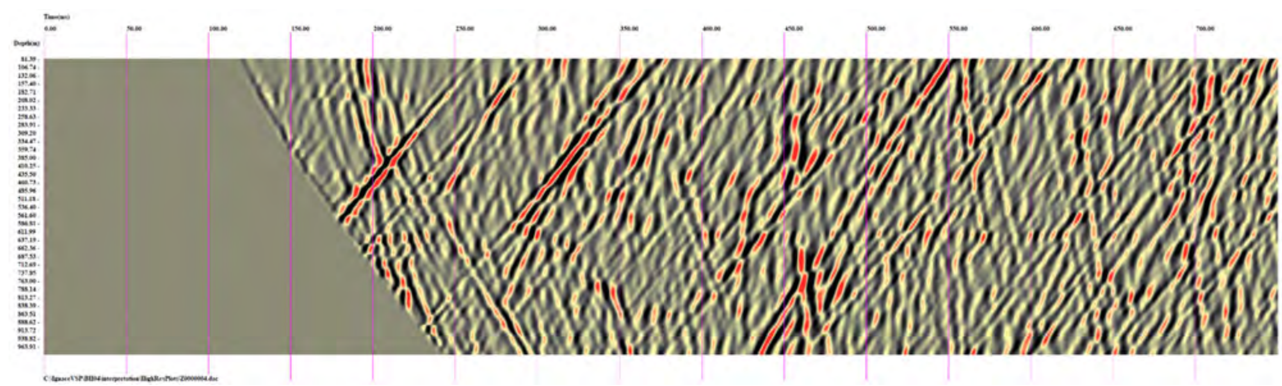
Figure 3. IG_BH04 VSP, Shot V03



Radial component

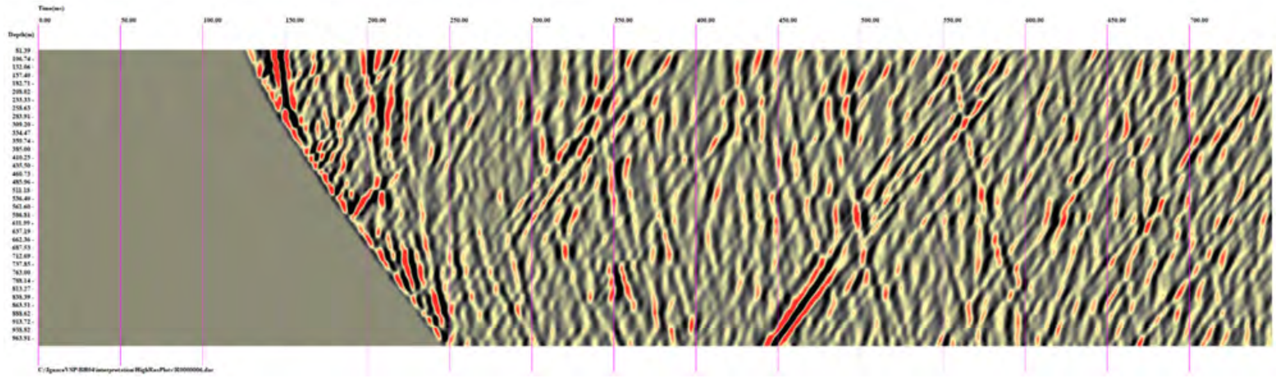


Transversal component

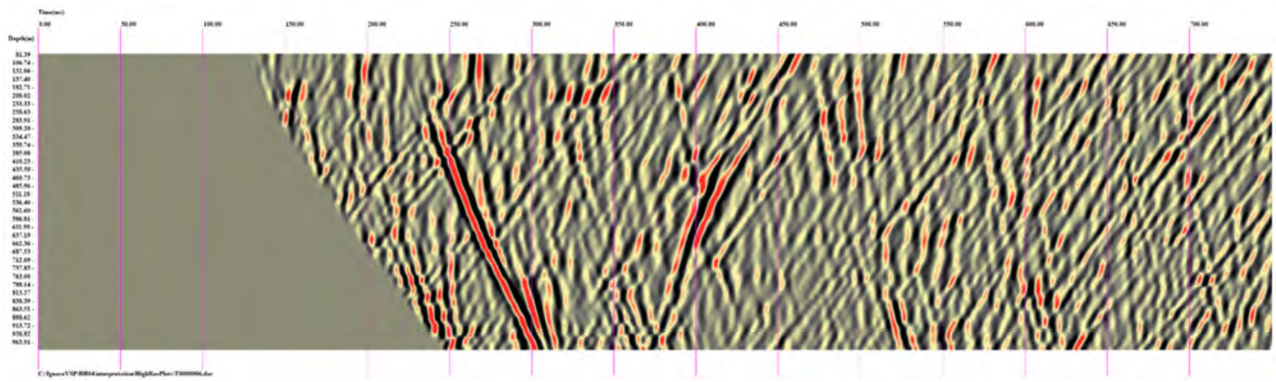


Axial component

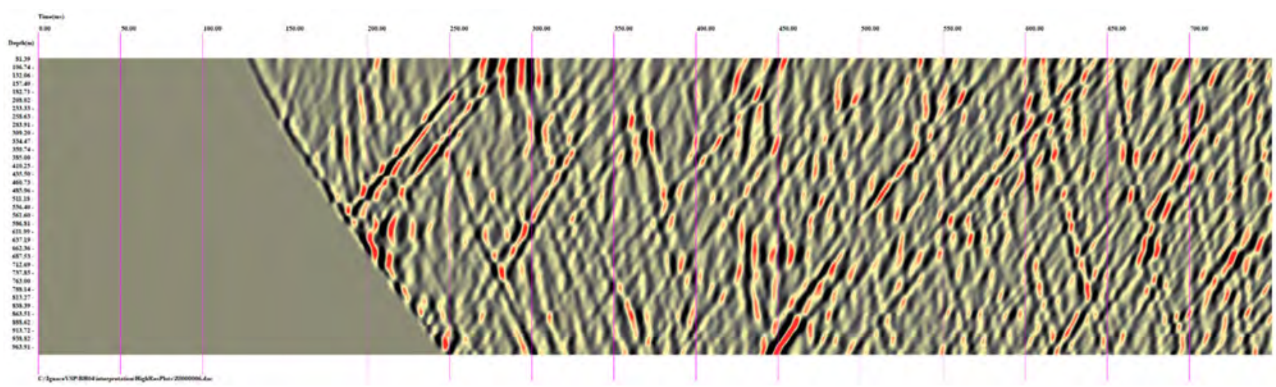
Figure 4. IG_BH04 VSP, Shot V04



Radial component

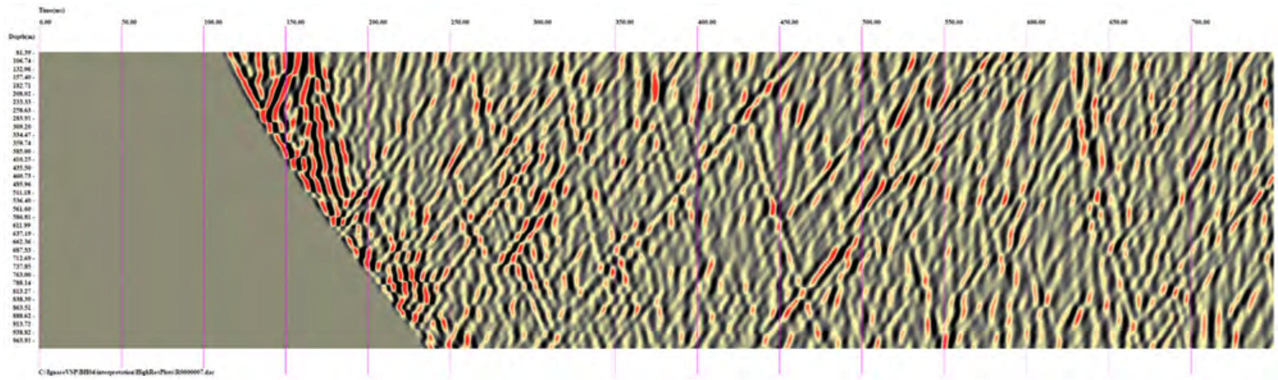


Transversal component

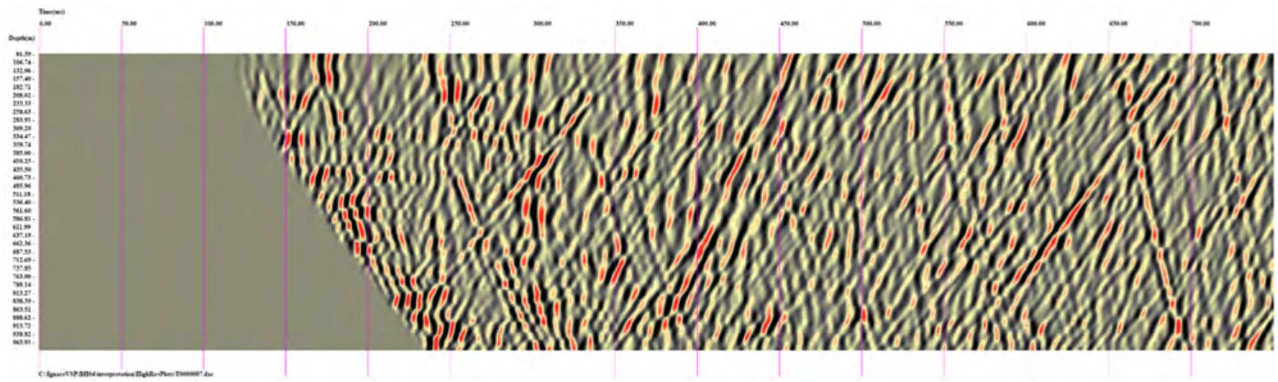


Axial component

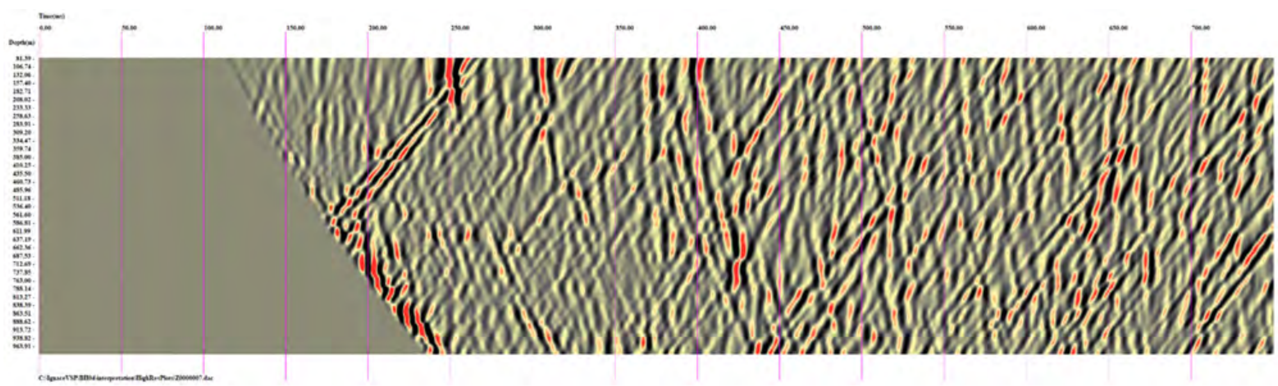
Figure 5. IG_BH04 VSP, Shot V06



Radial component

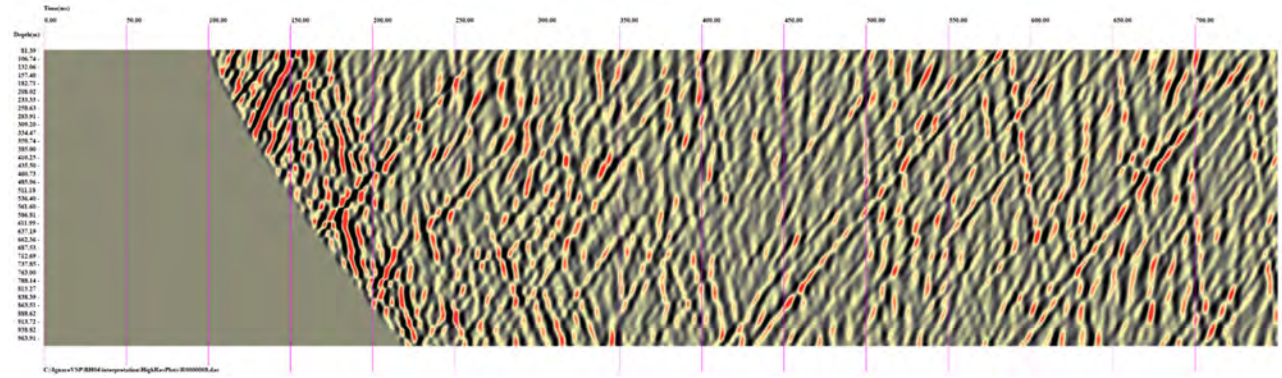


Transversal component

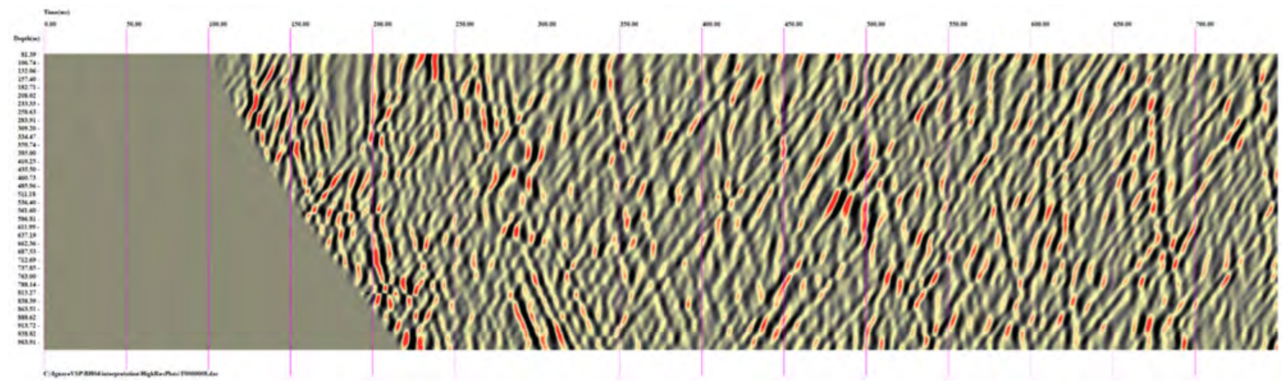


Axial component

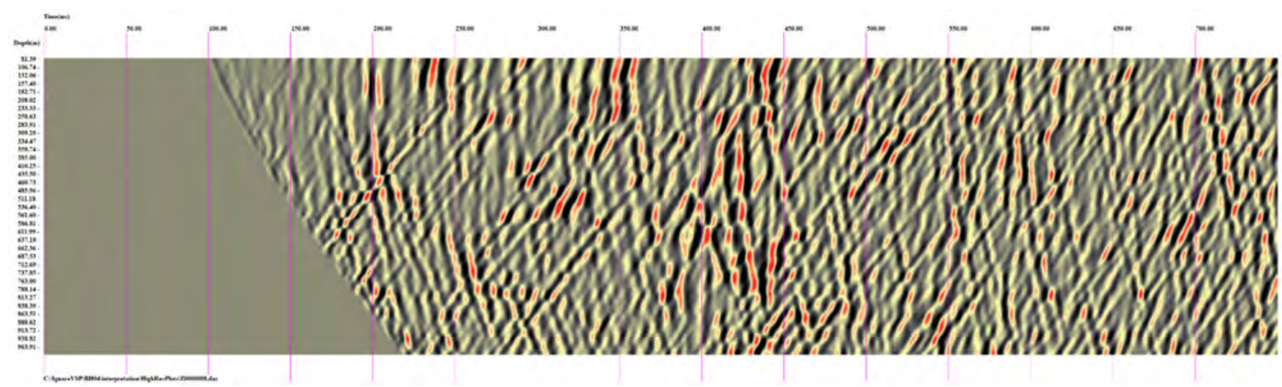
Figure 6. IG_BH04 VSP, Shot V07



Radial component

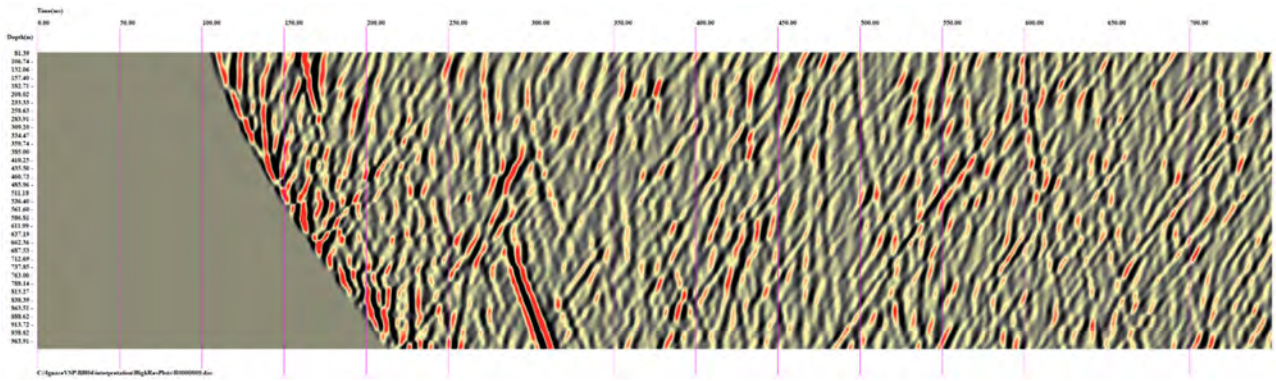


Transversal component

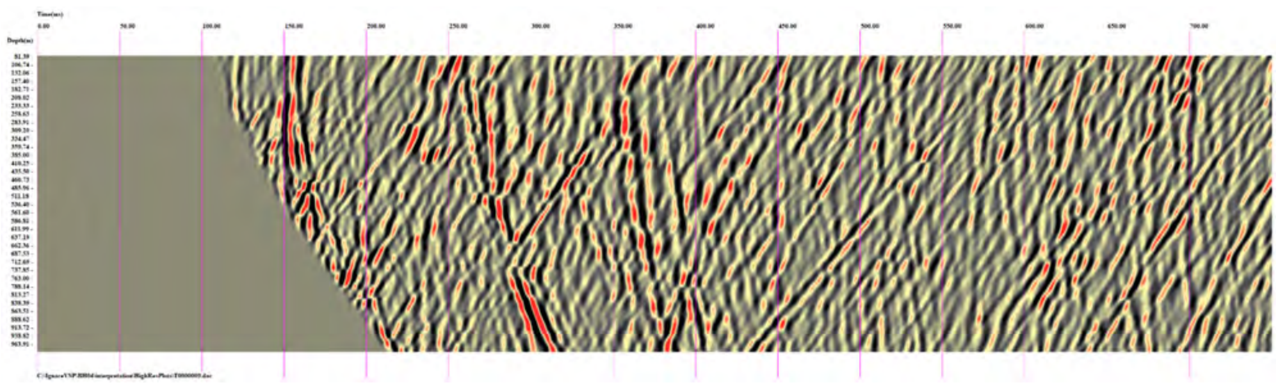


Axial component

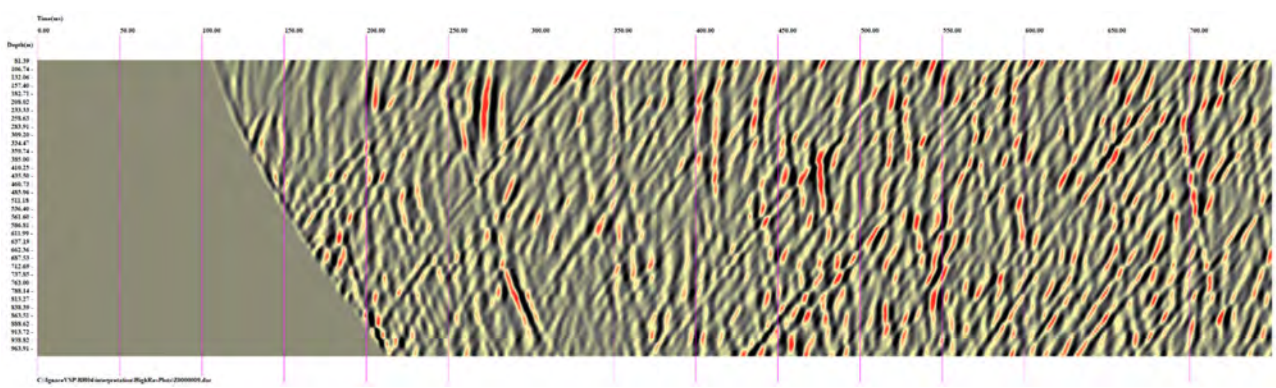
Figure 7. IG_BH04 VSP, Shot V08



Radial component

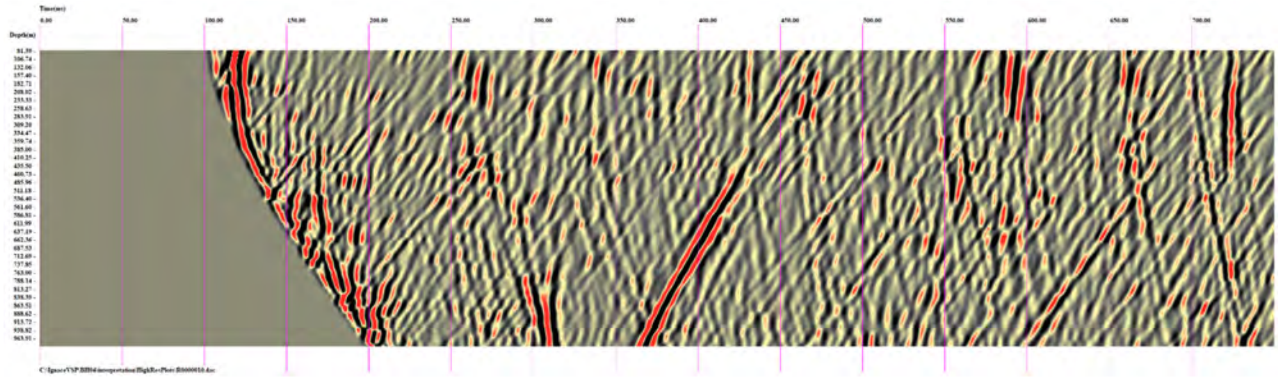


Transversal component

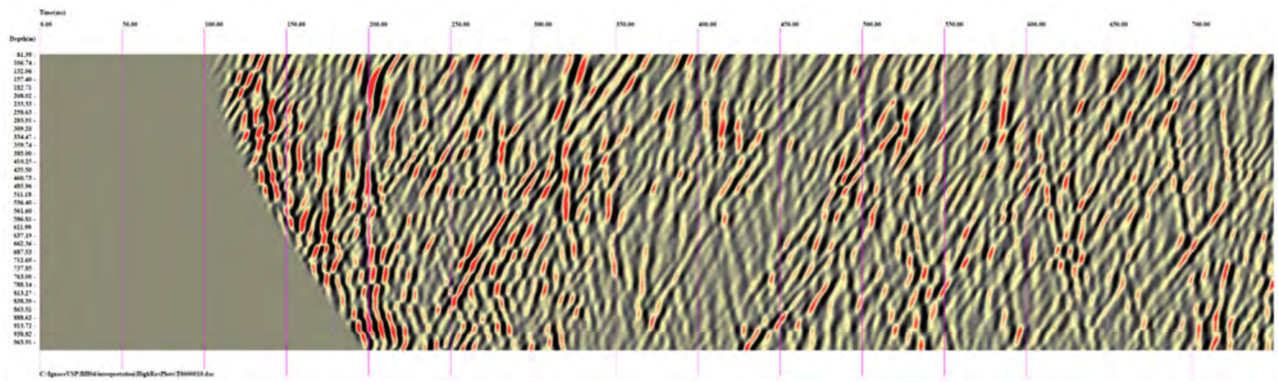


Axial component

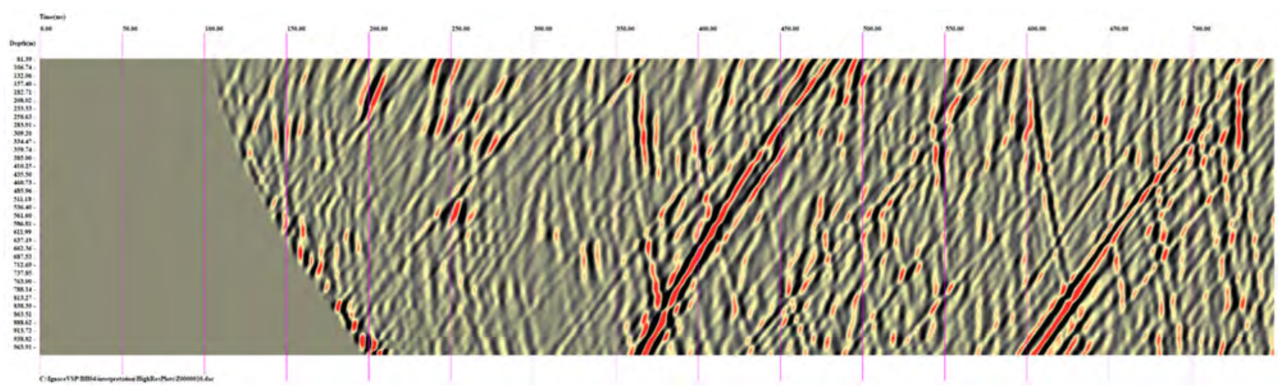
Figure 8. IG_BH04 VSP, Shot V09



Radial component

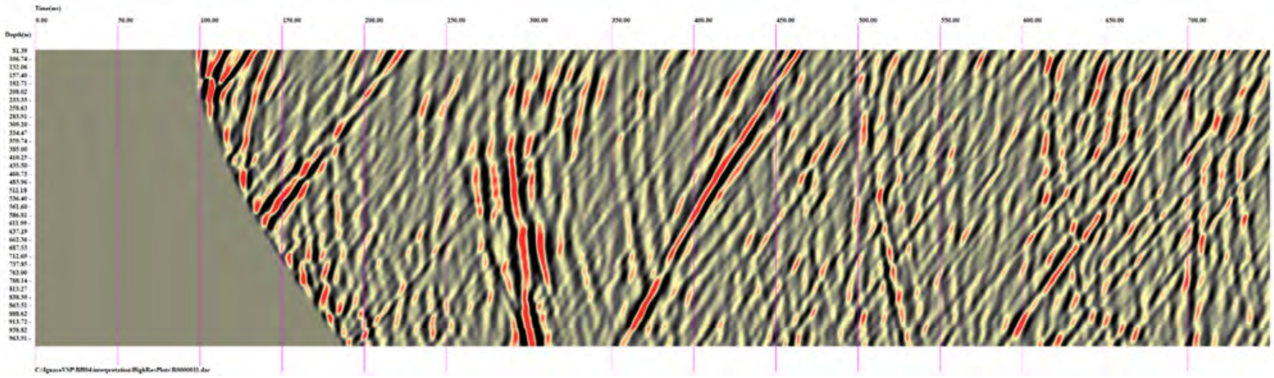


Transversal component

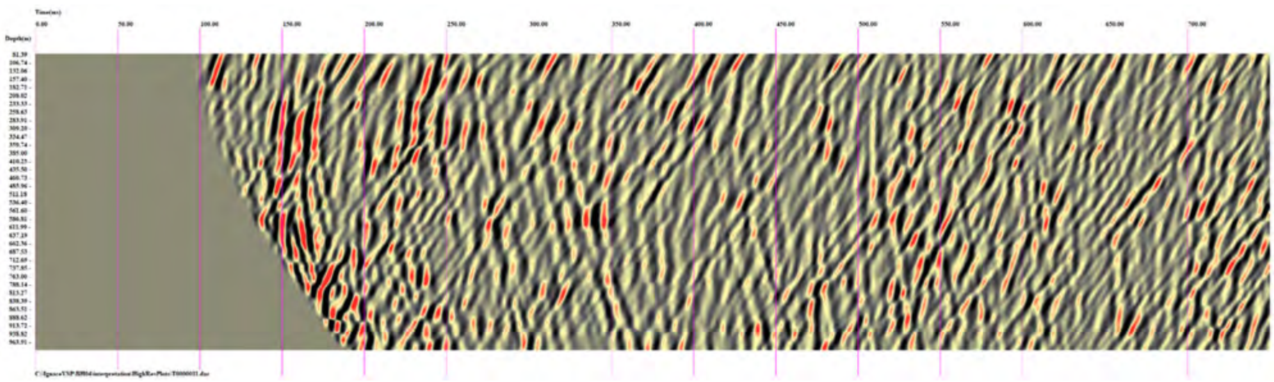


Axial component

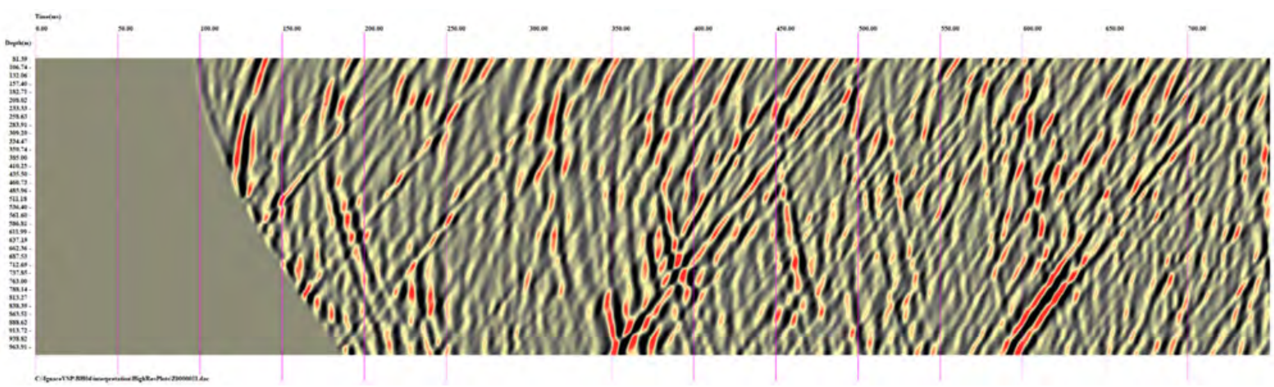
Figure 9. IG_BH04 VSP, Shot V10



Radial component

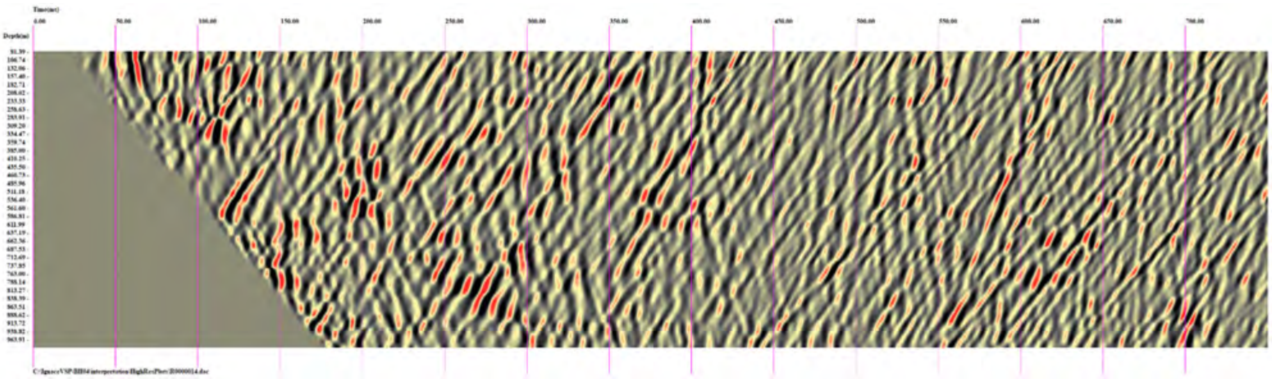


Transversal component

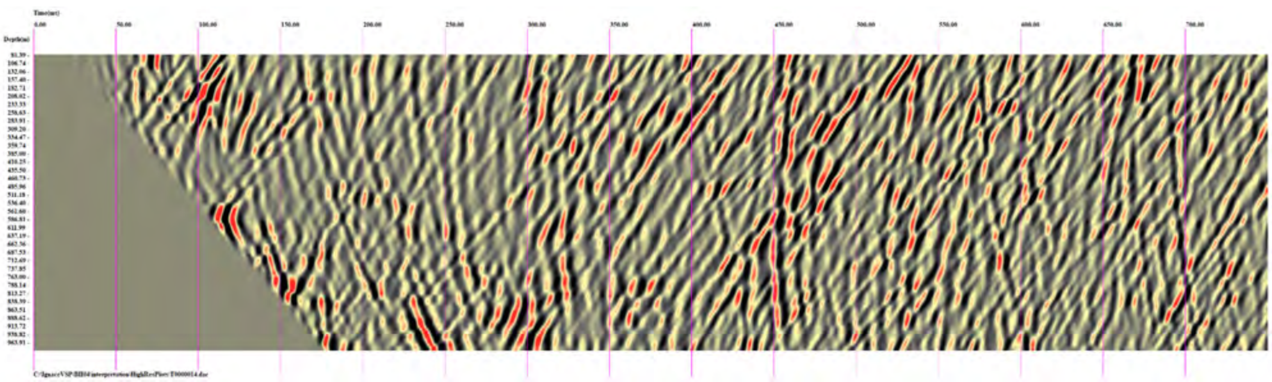


Axial component

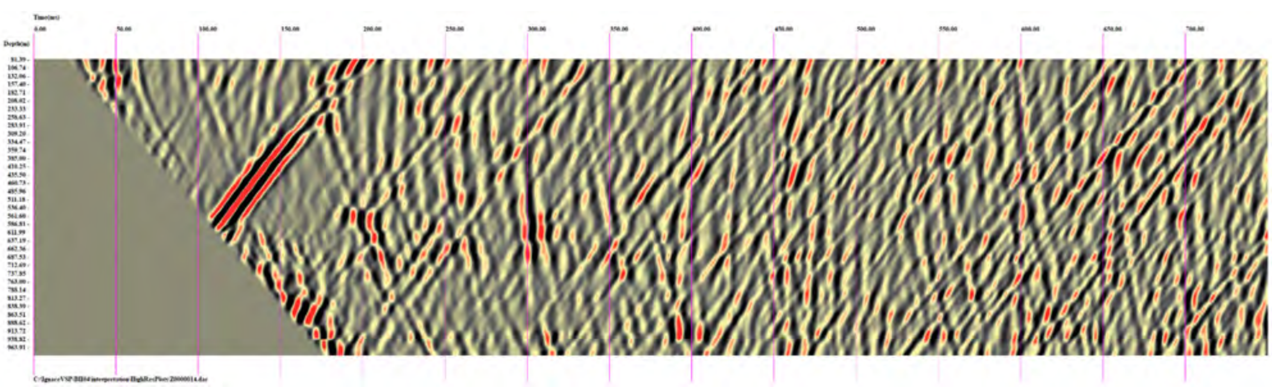
Figure 10. IG_BH04 VSP, Shot V11



Radial component

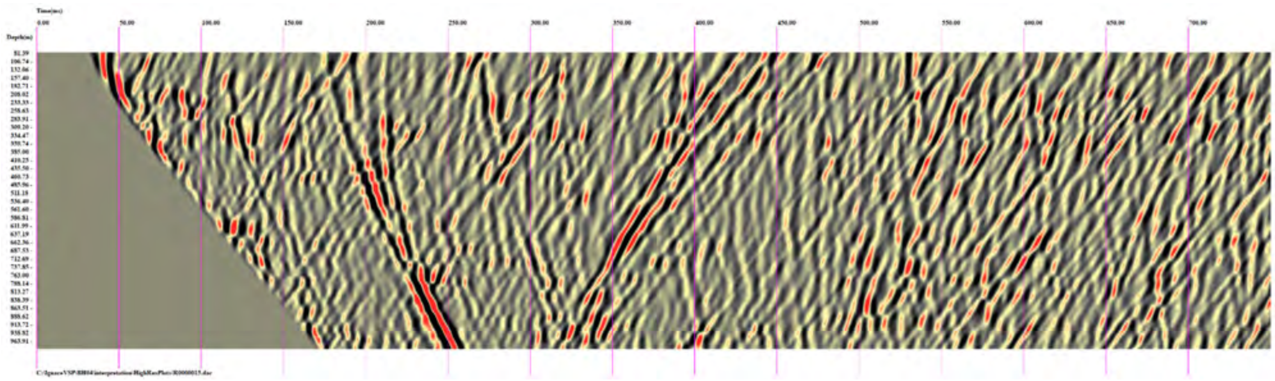


Transversal component

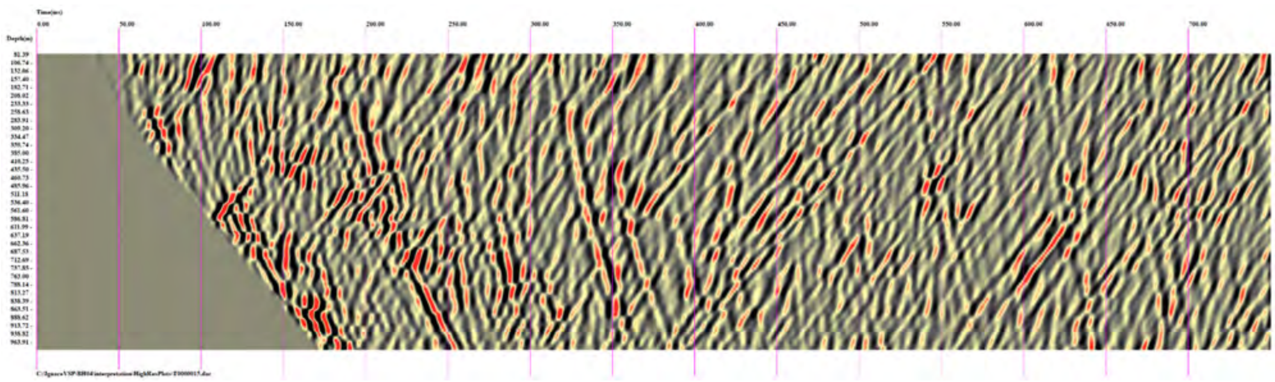


Axial component

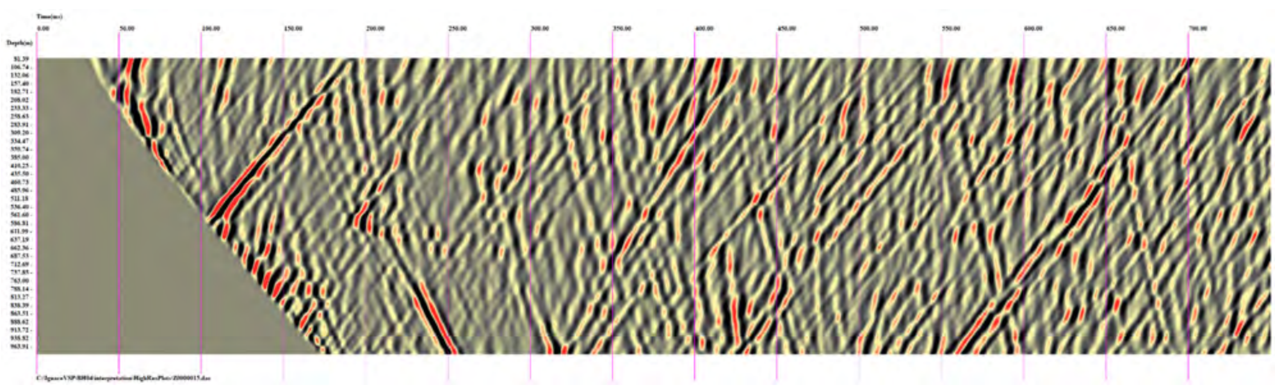
Figure 11. IG_BH04 VSP, Shot V14



Radial component

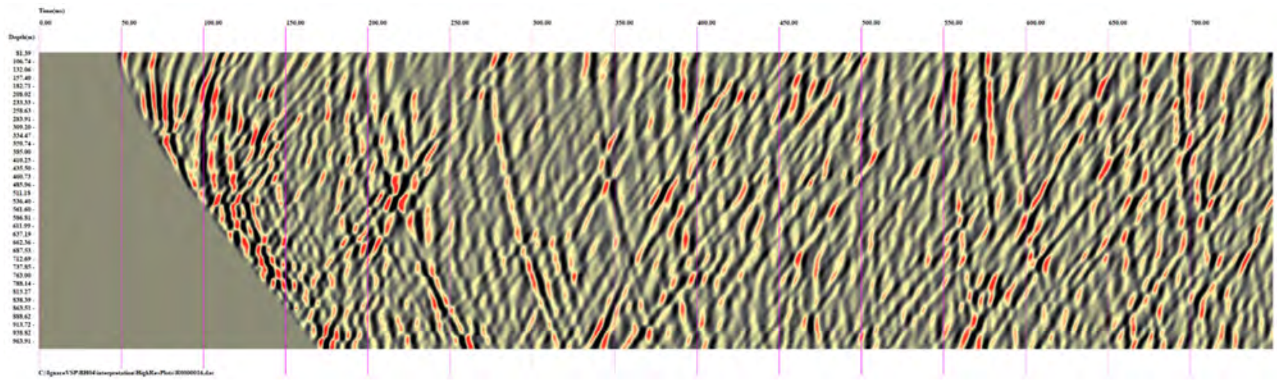


Transversal component

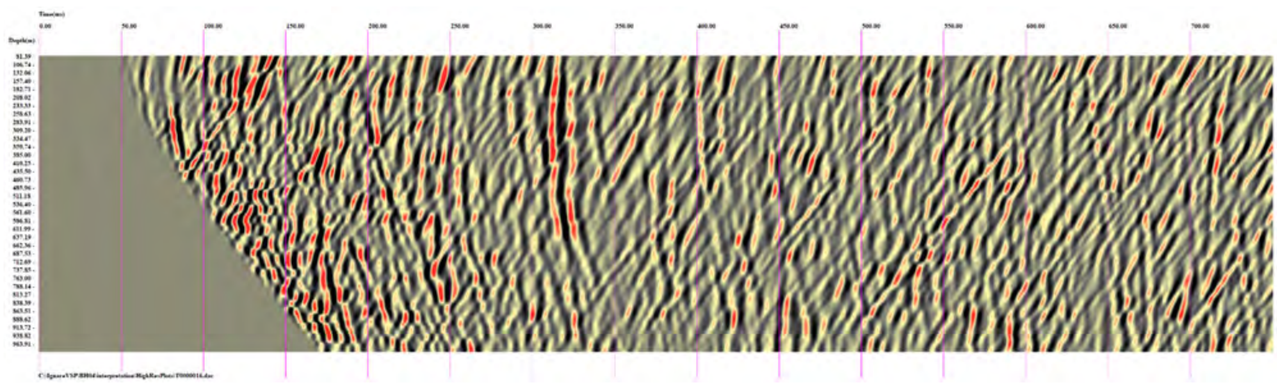


Axial component

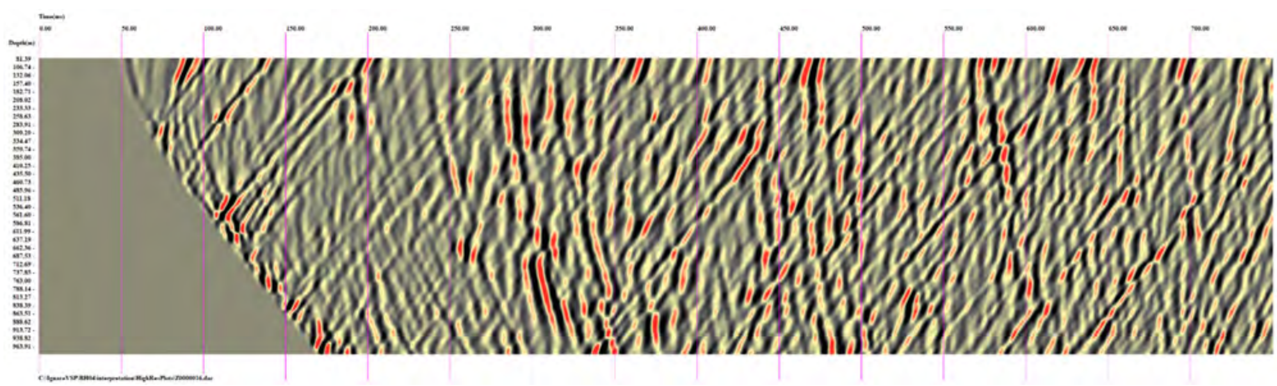
Figure 12. IG_BH04 VSP, Shot V15



Radial component

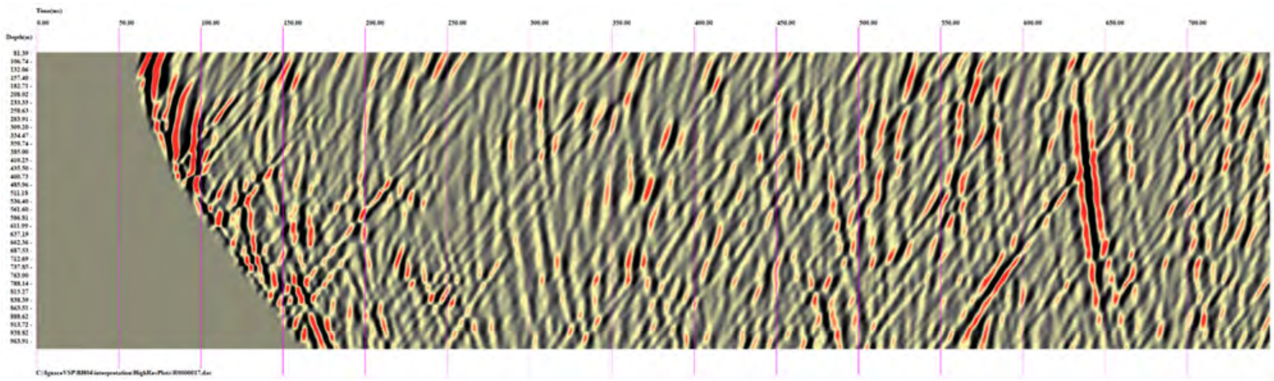


Transversal component

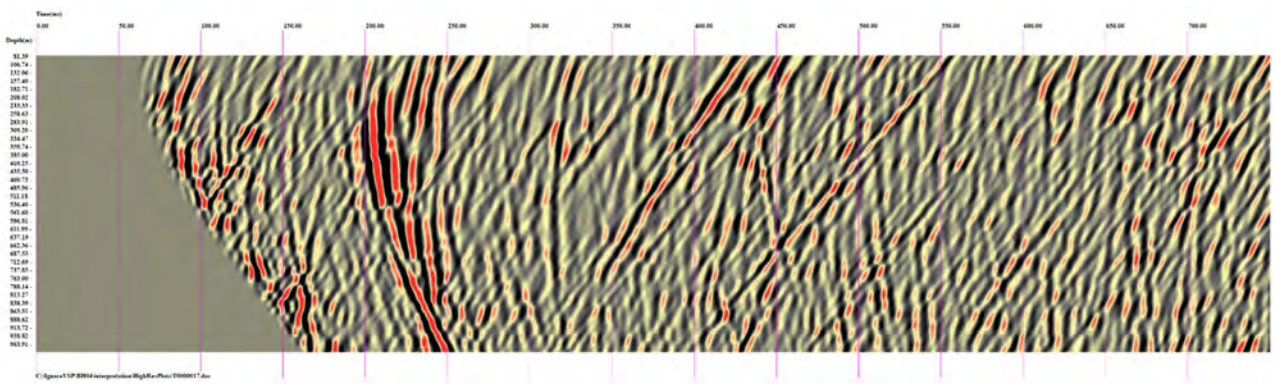


Axial component

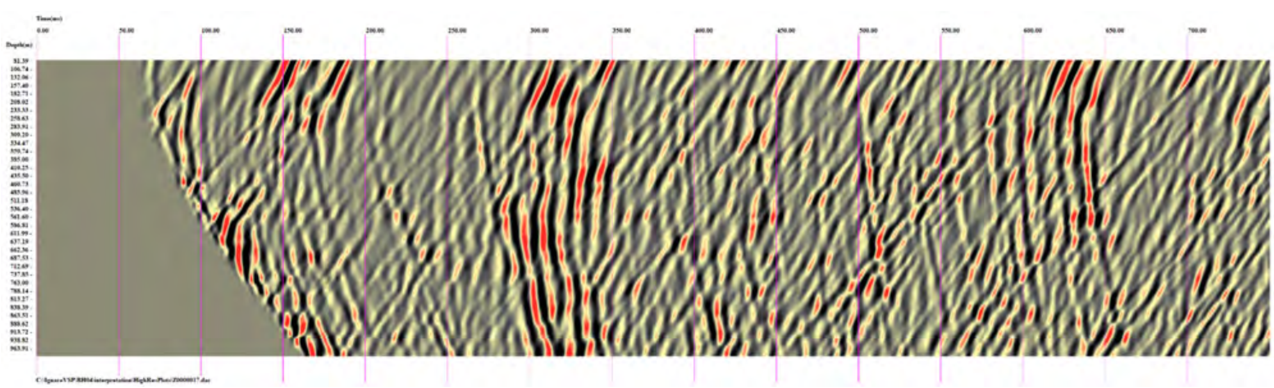
Figure 13. IG_BH04 VSP, Shot V16



Radial component

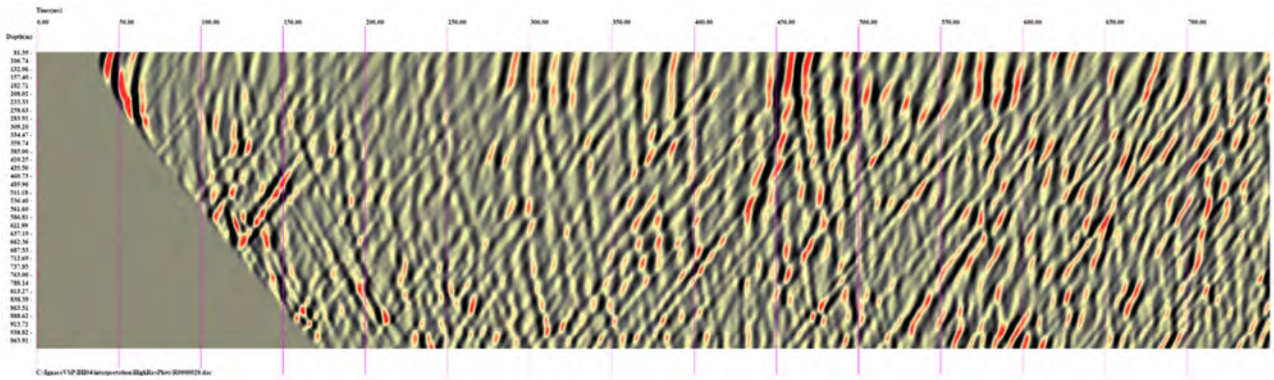


Transversal component

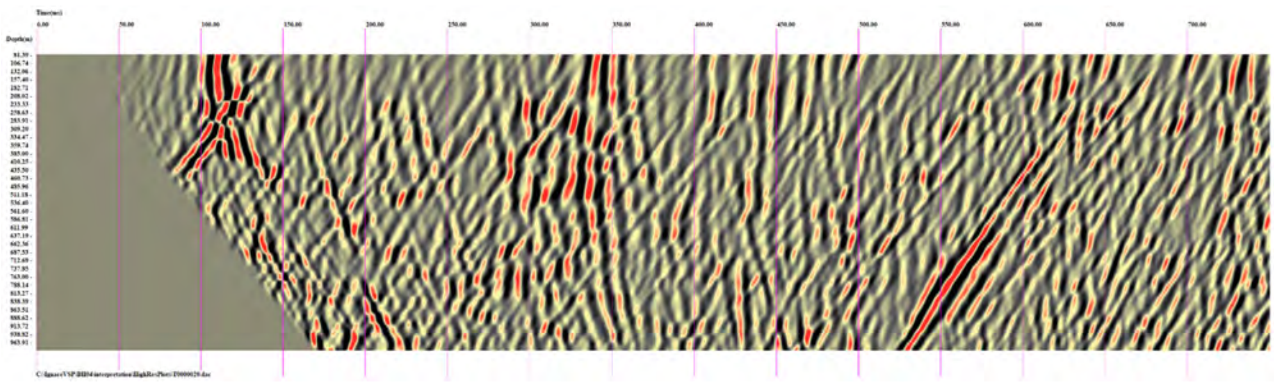


Axial component

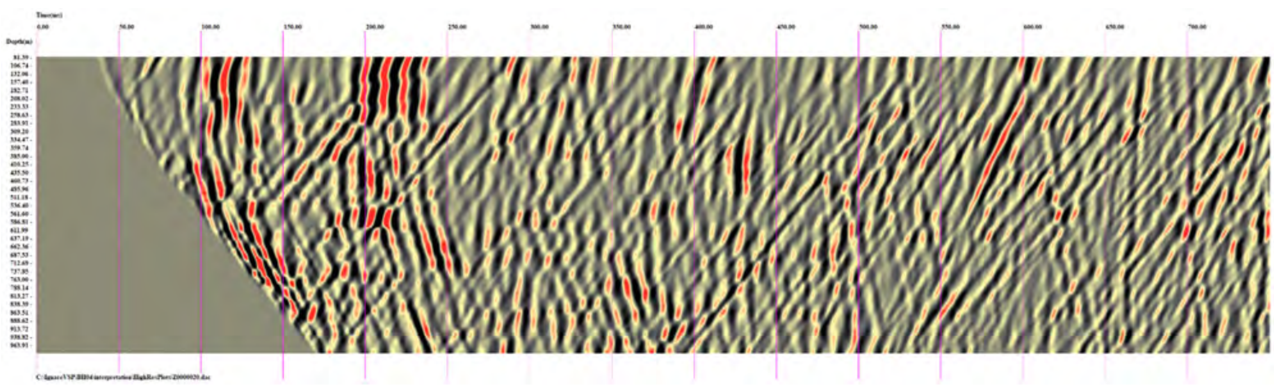
Figure 14. IG_BH04 VSP, Shot V17



Radial component

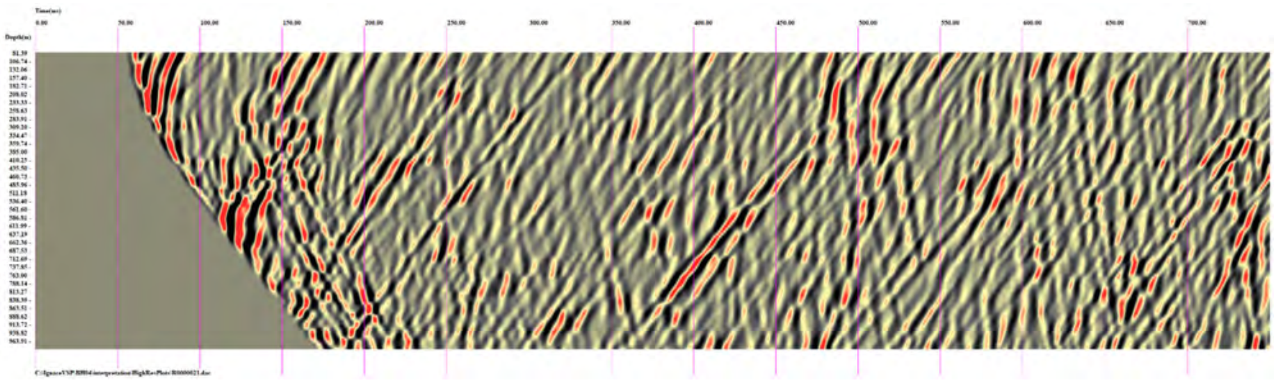


Transversal component

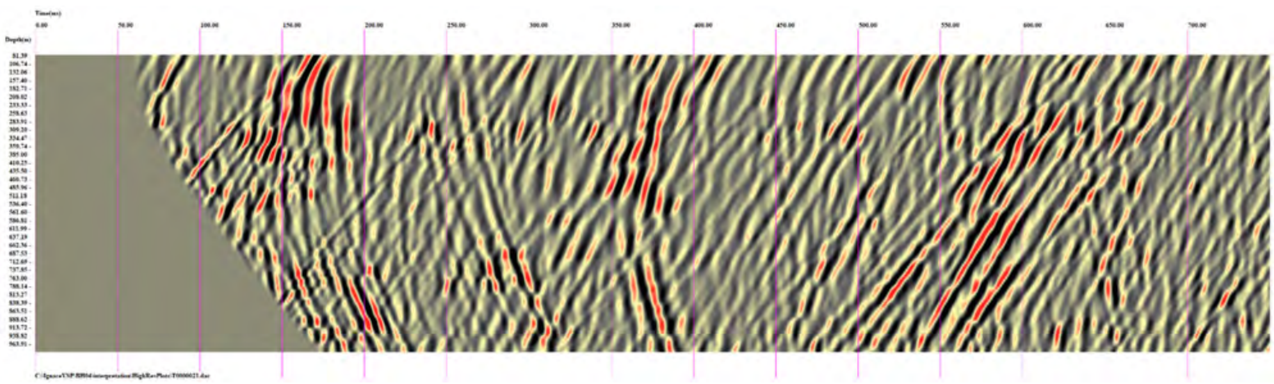


Axial component

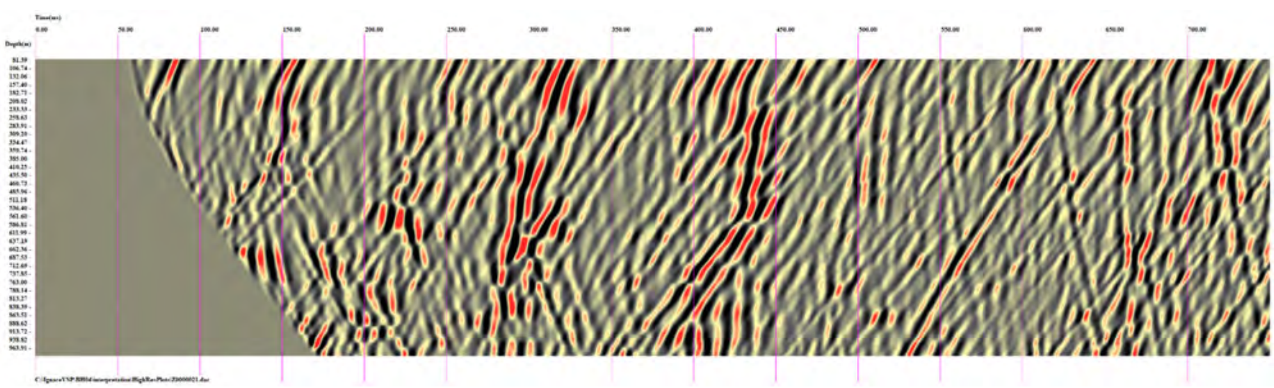
Figure 15. IG_BH04 VSP, Shot V20



Radial component

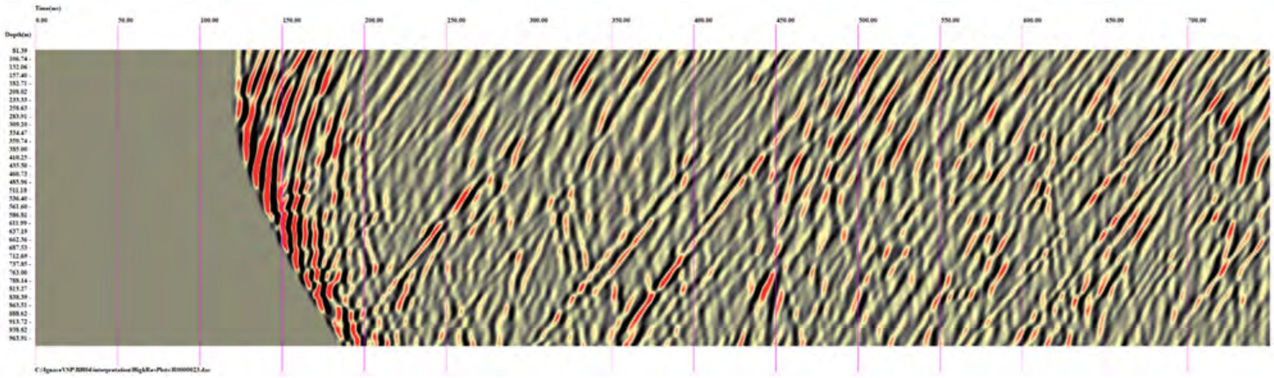


Transversal component

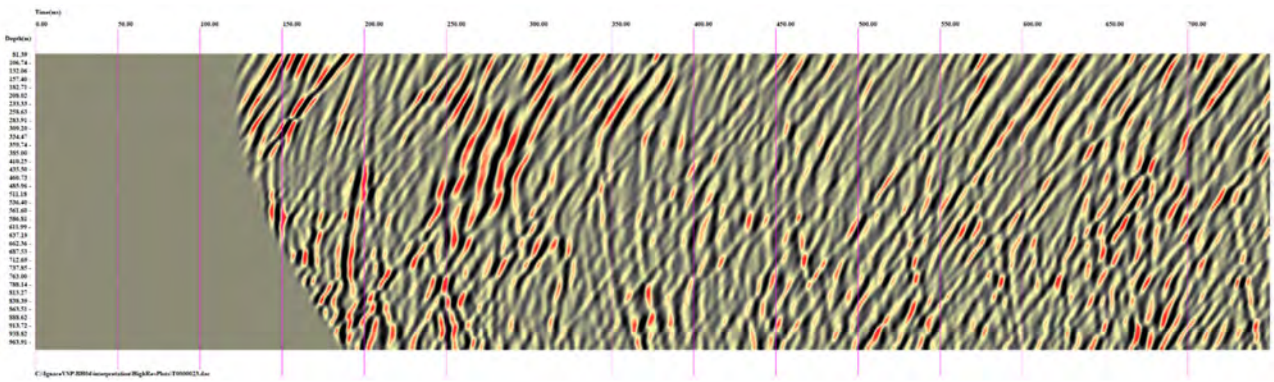


Axial component

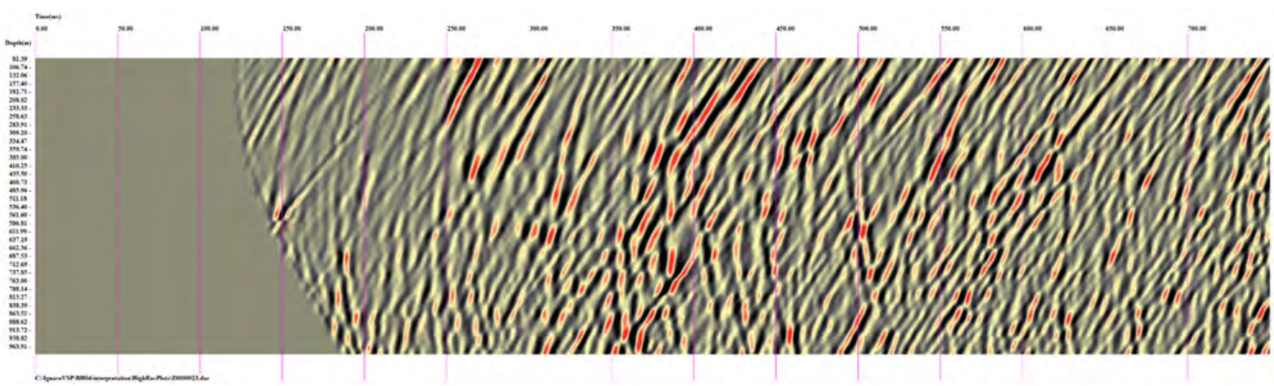
Figure 16. IG_BH04 VSP, Shot V21



Radial component

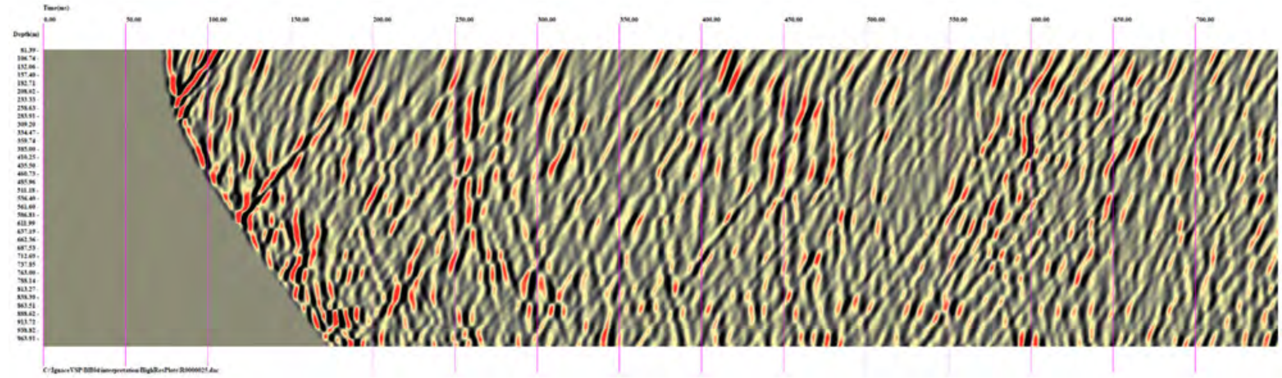


Transversal component

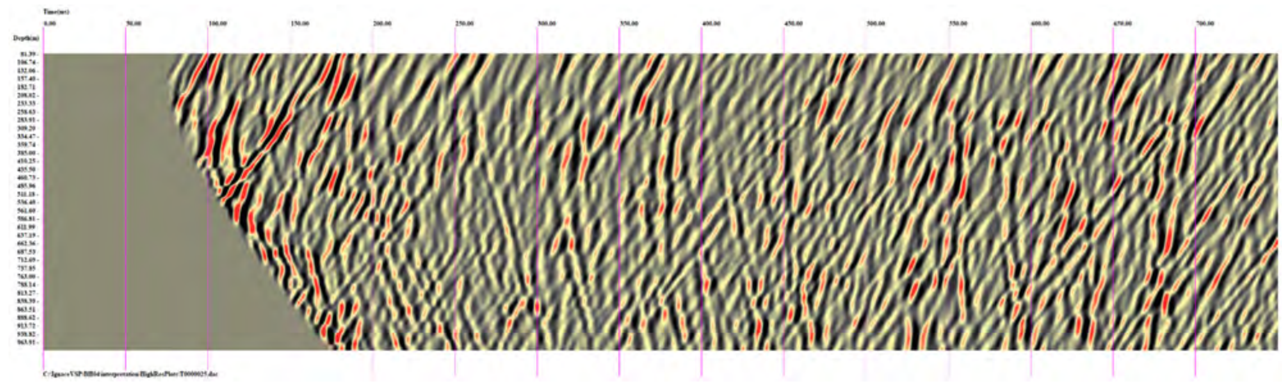


Axial component

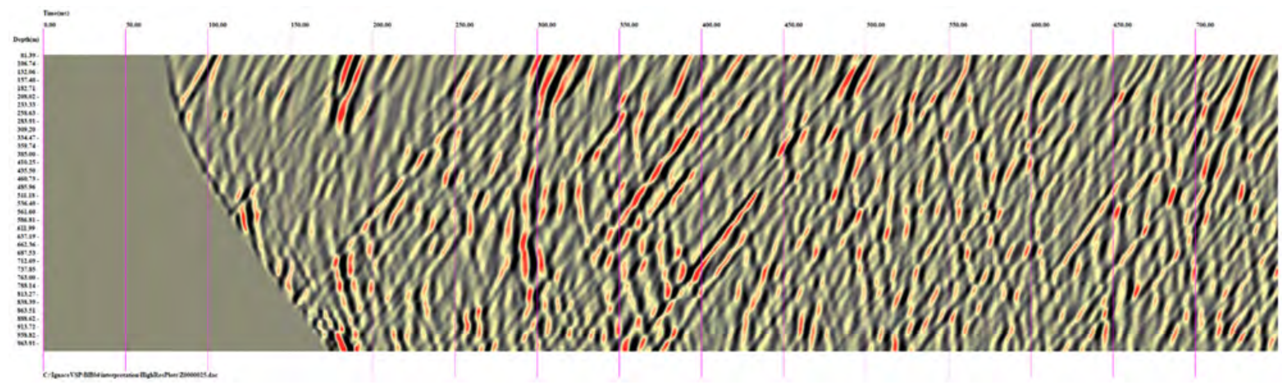
Figure 17. IG_BH04 VSP, Shot V23



Radial component

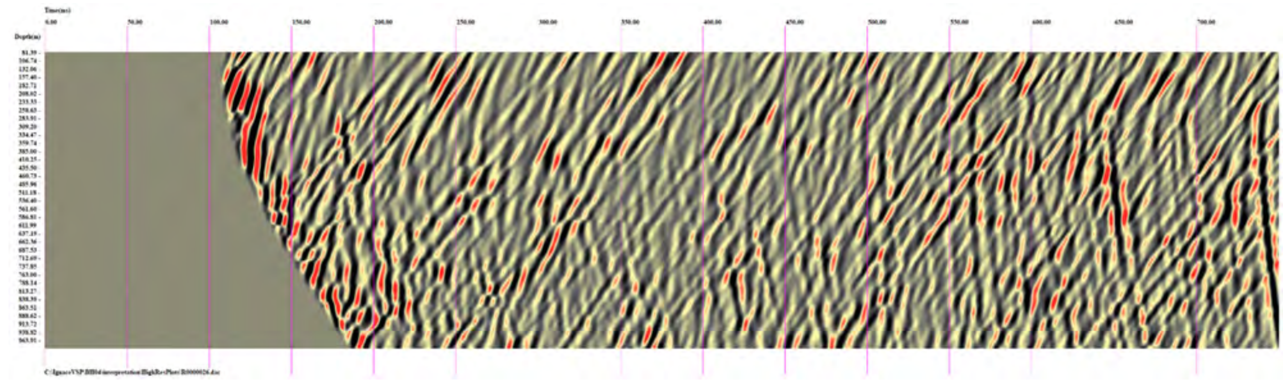


Transversal component

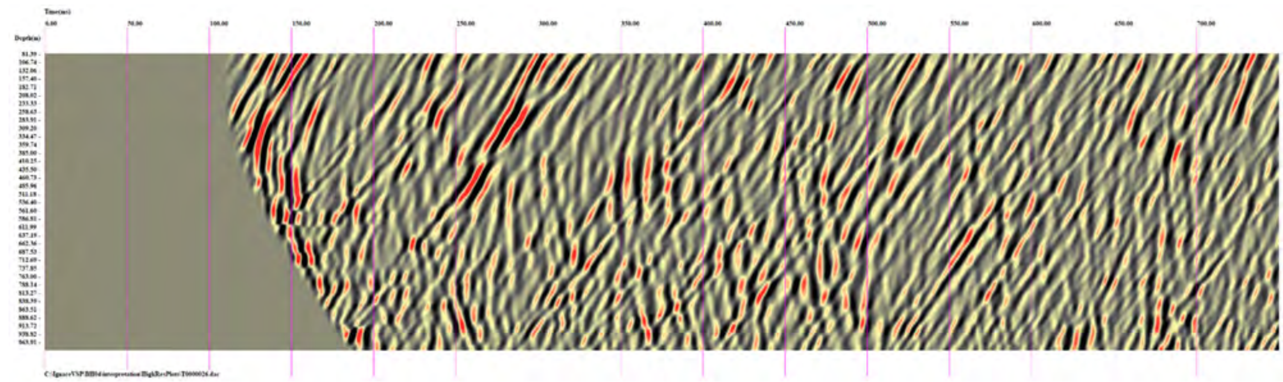


Axial component

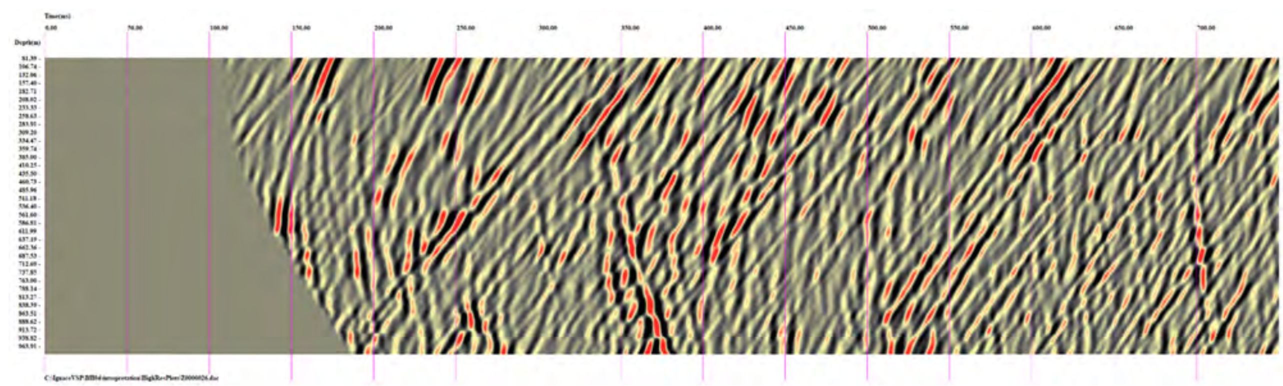
Figure 18. IG_BH04 VSP, Shot V25



Radial component

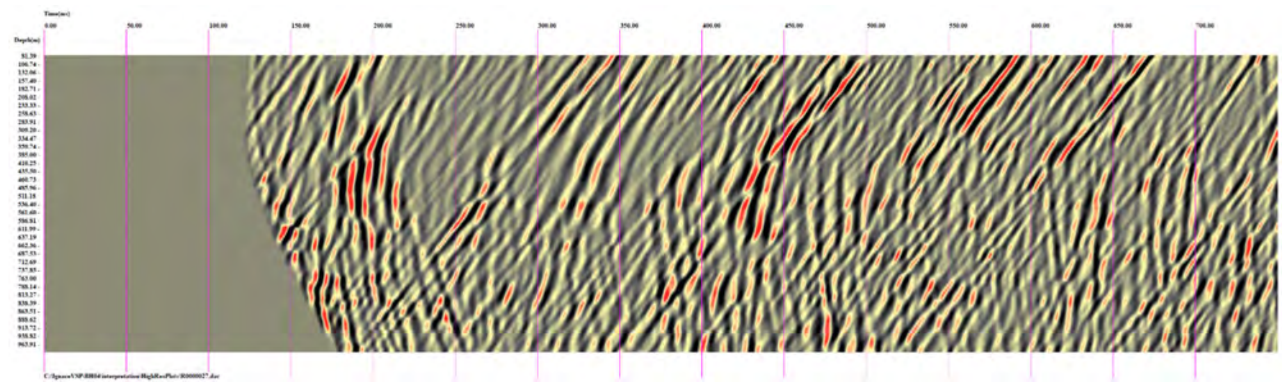


Transversal component

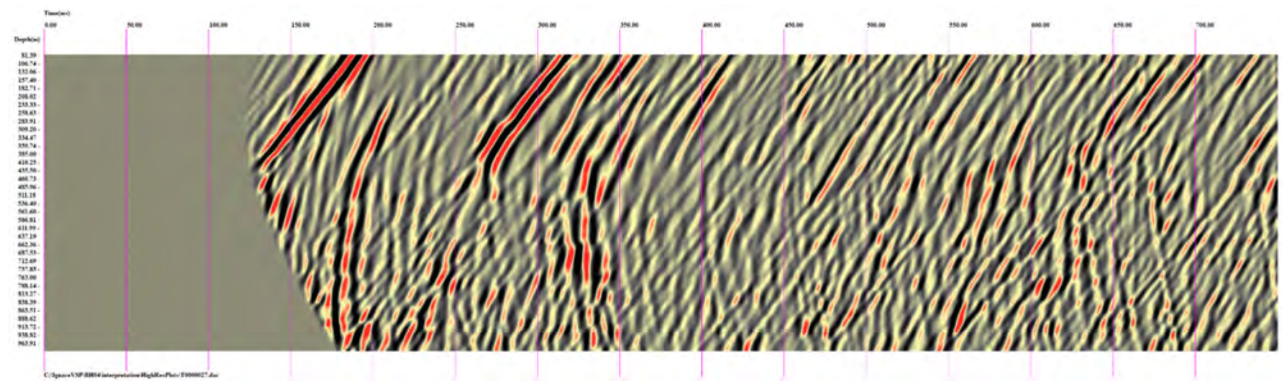


Axial component

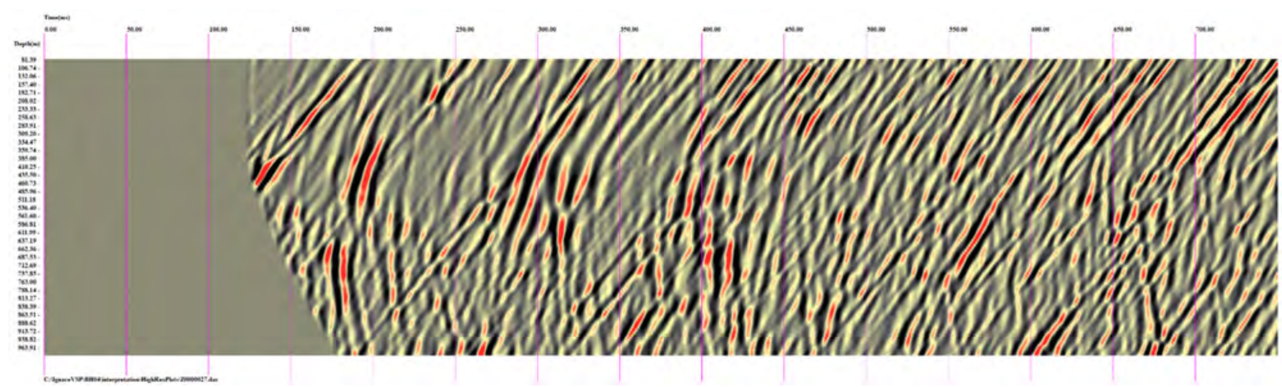
Figure 19. IG_BH04 VSP, Shot V26



Radial component

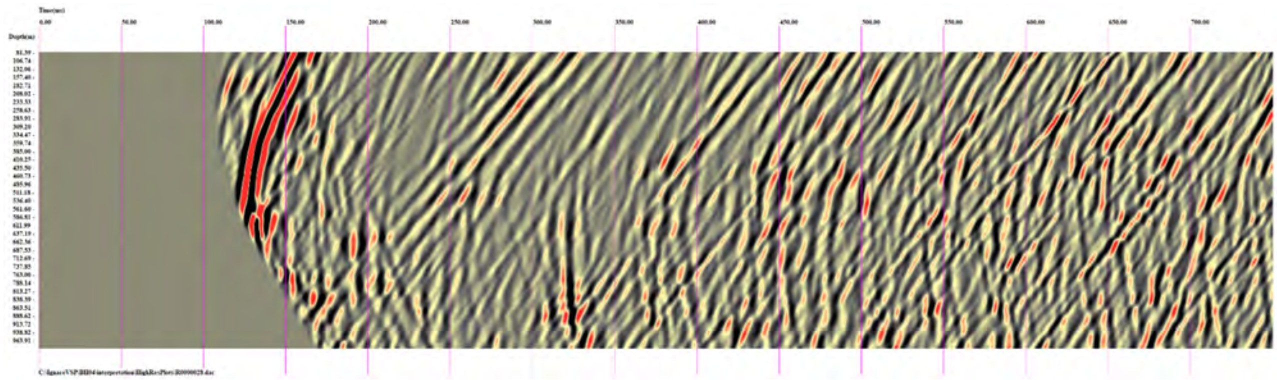


Transversal component

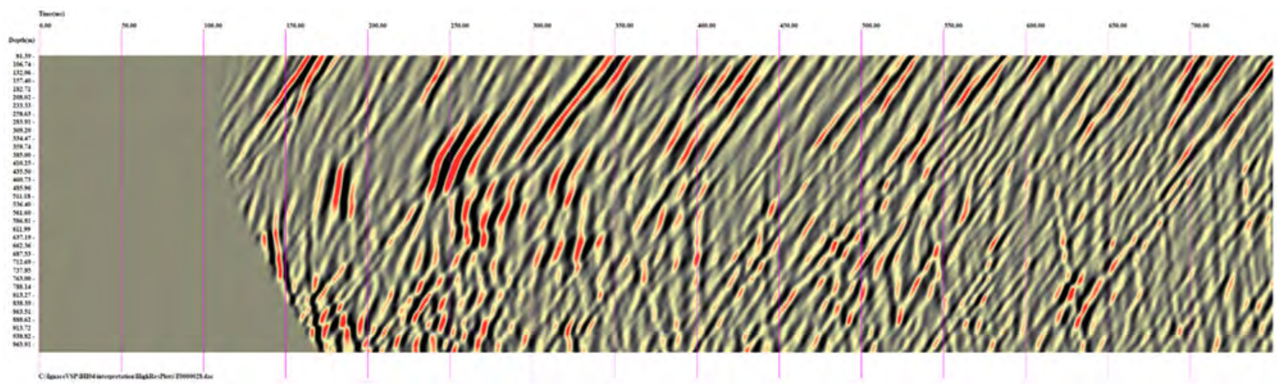


Axial component

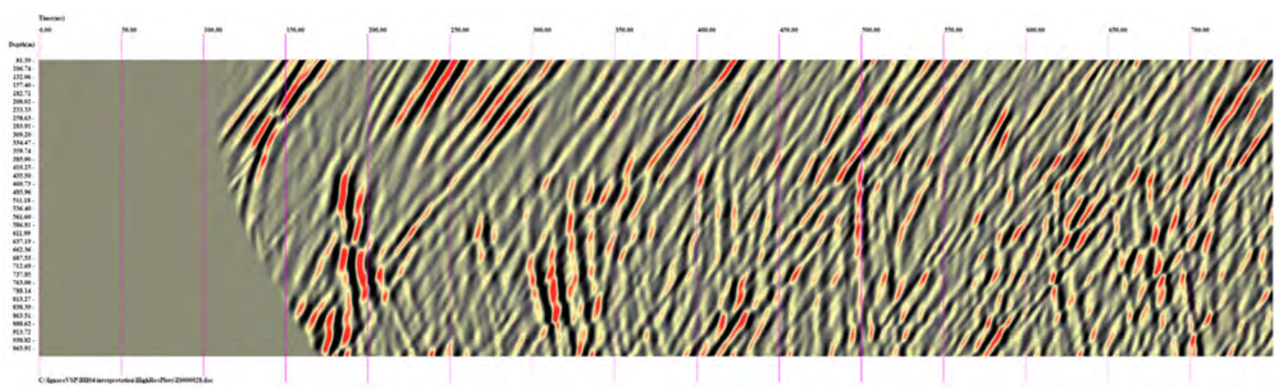
Figure 20. IG_BH04 VSP, Shot V27



Radial component

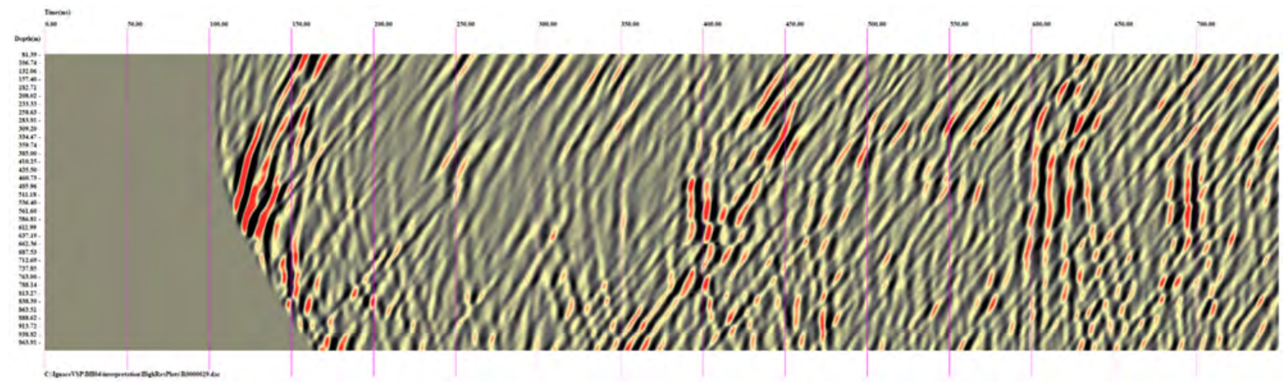


Transversal component

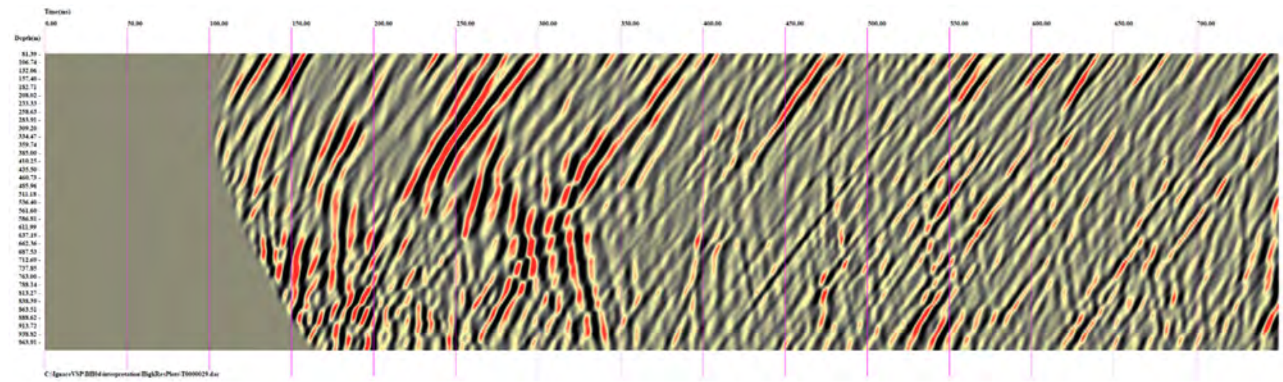


Axial component

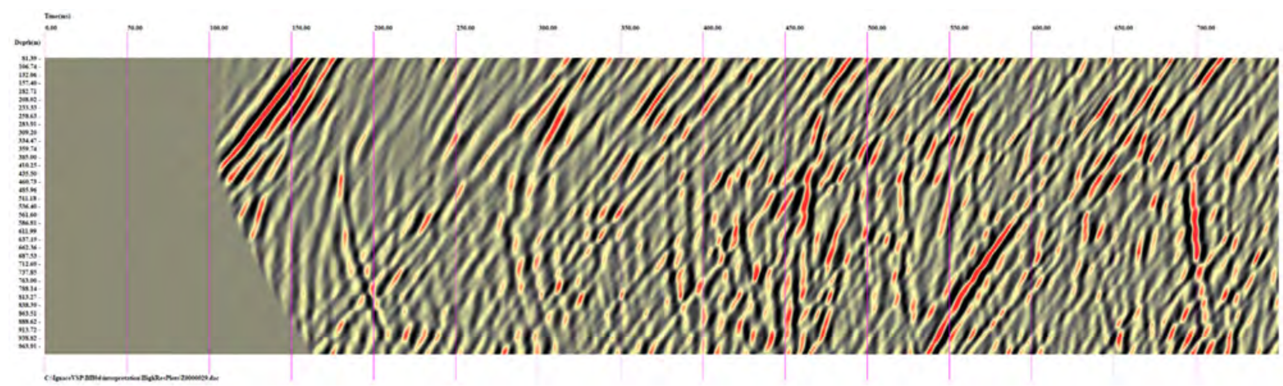
Figure 21. IG_BH04 VSP, Shot V28



Radial component

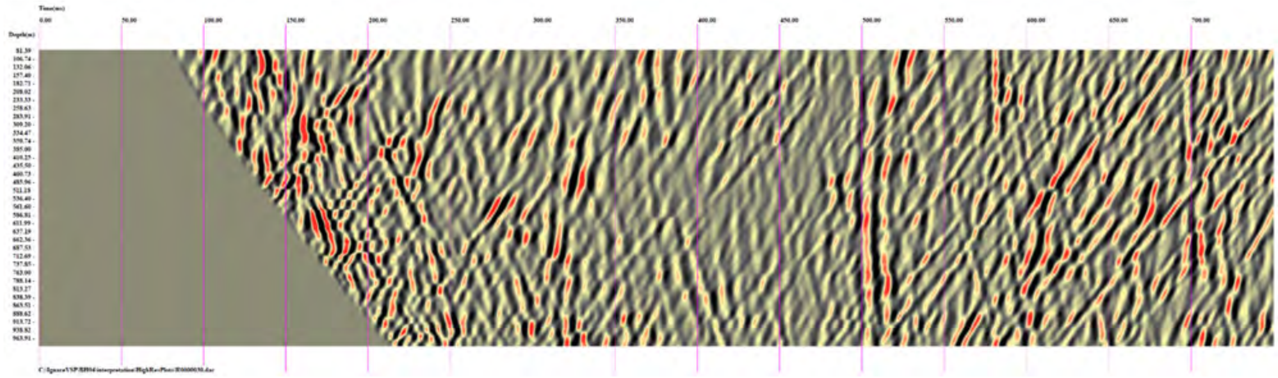


Transversal component

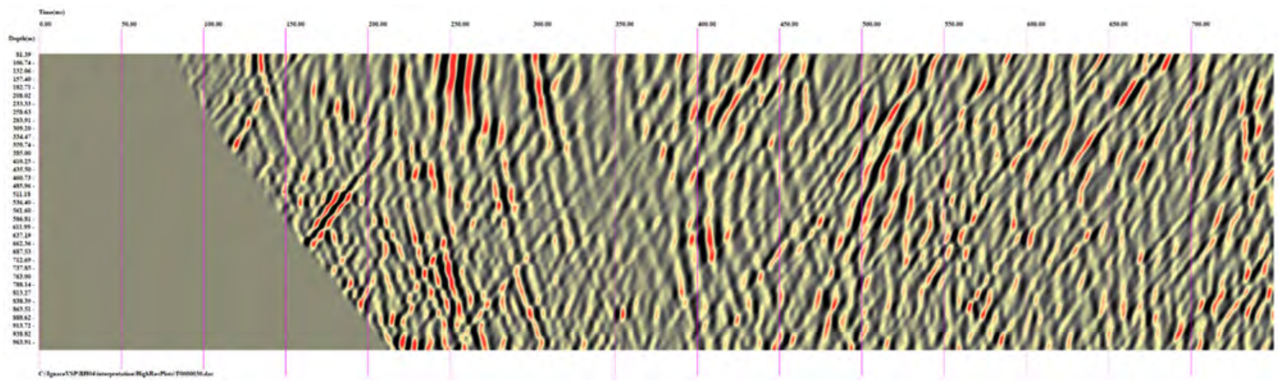


Axial component

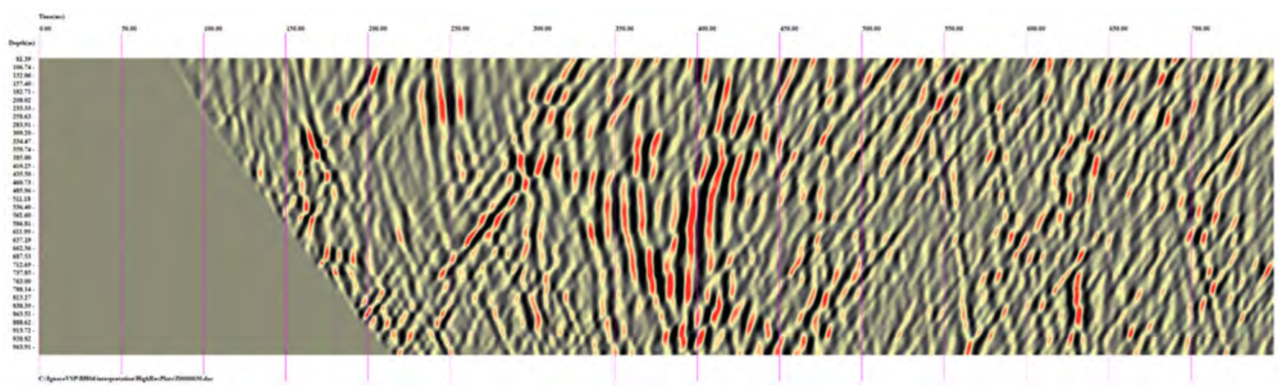
Figure 22. IG_BH04 VSP, Shot V29



Radial component

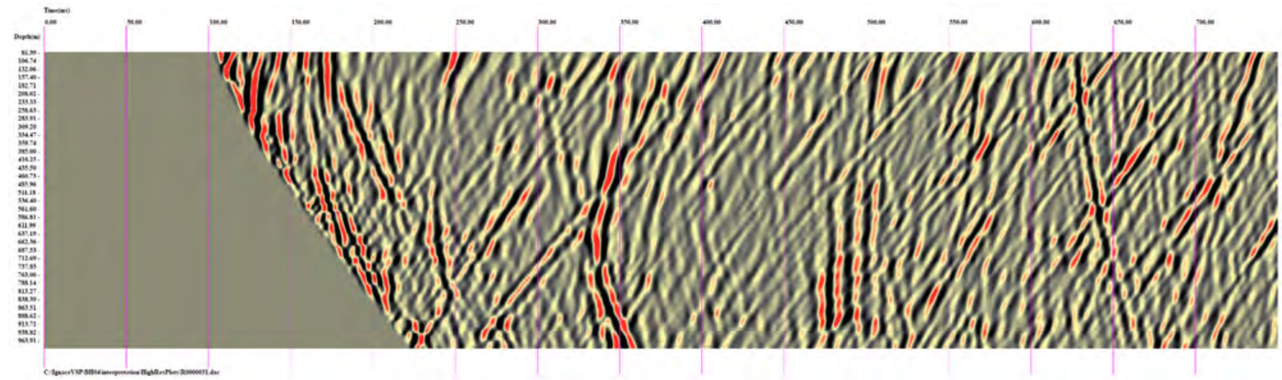


Transversal component

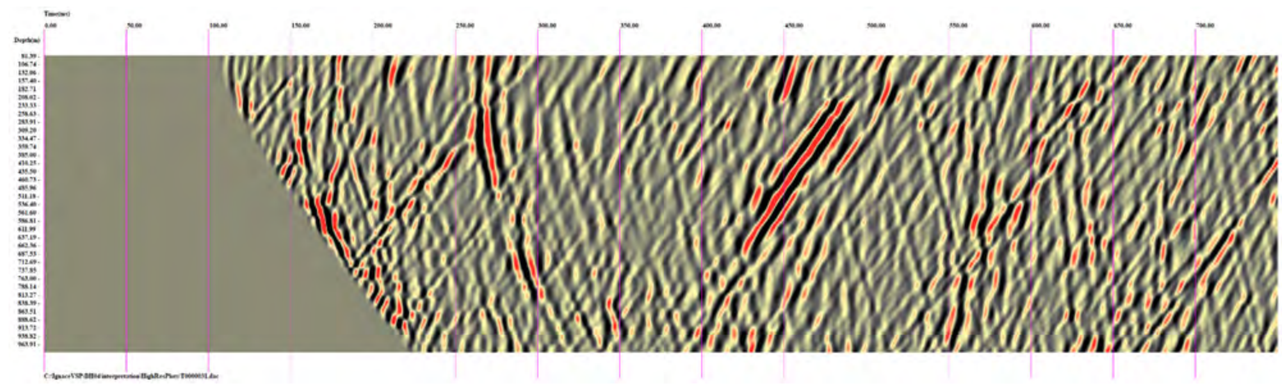


Axial component

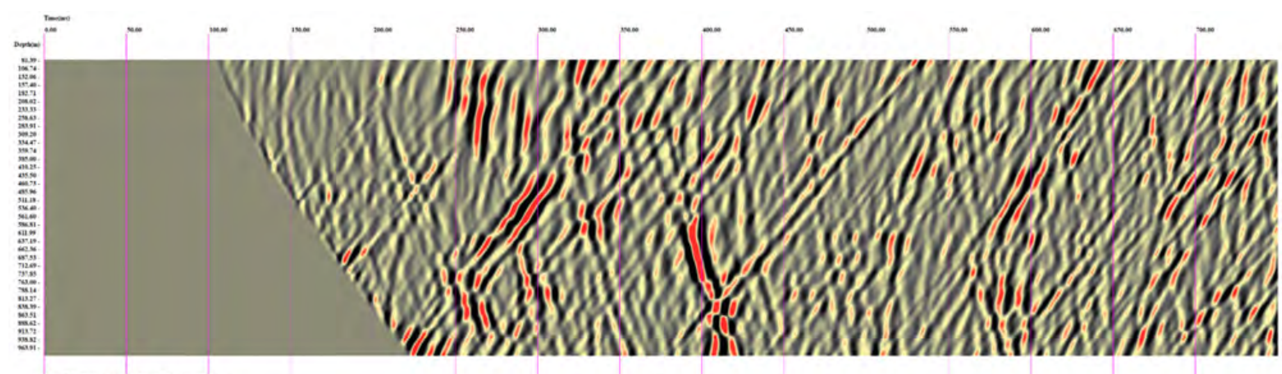
Figure 23. IG_BH04 VSP, Shot V30



Radial component

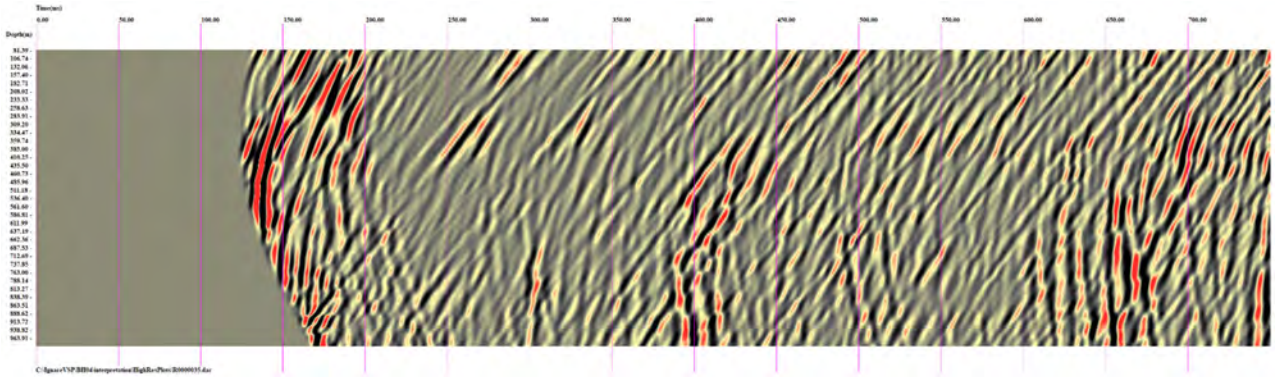


Transversal component

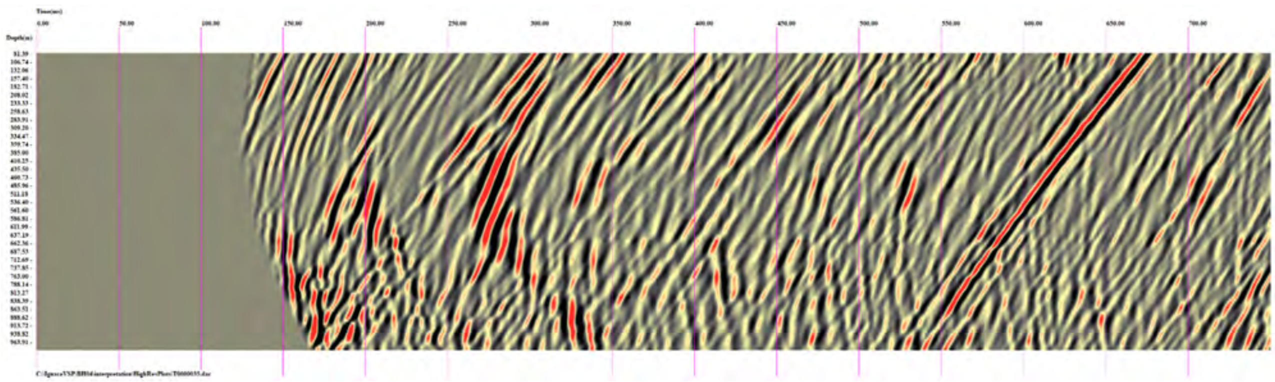


Axial component

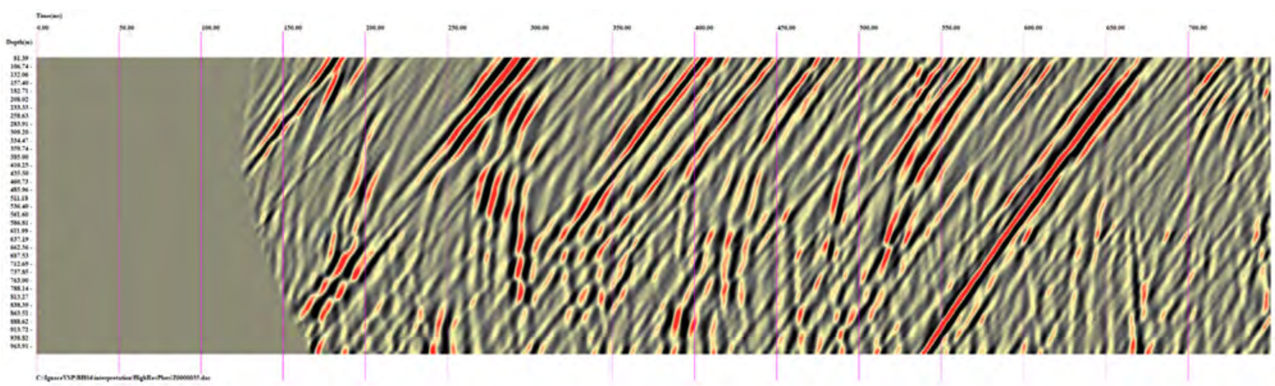
Figure 24. IG_BH04 VSP, Shot V31



Radial component

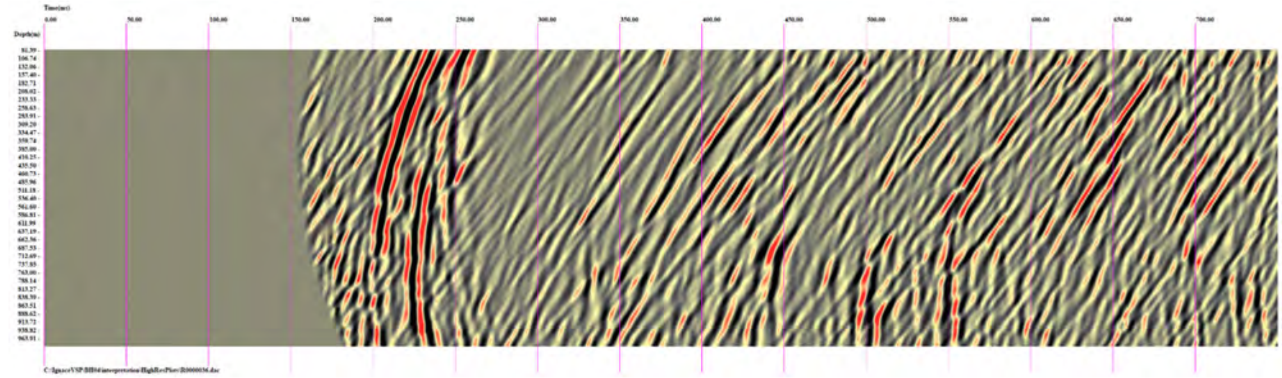


Transversal component

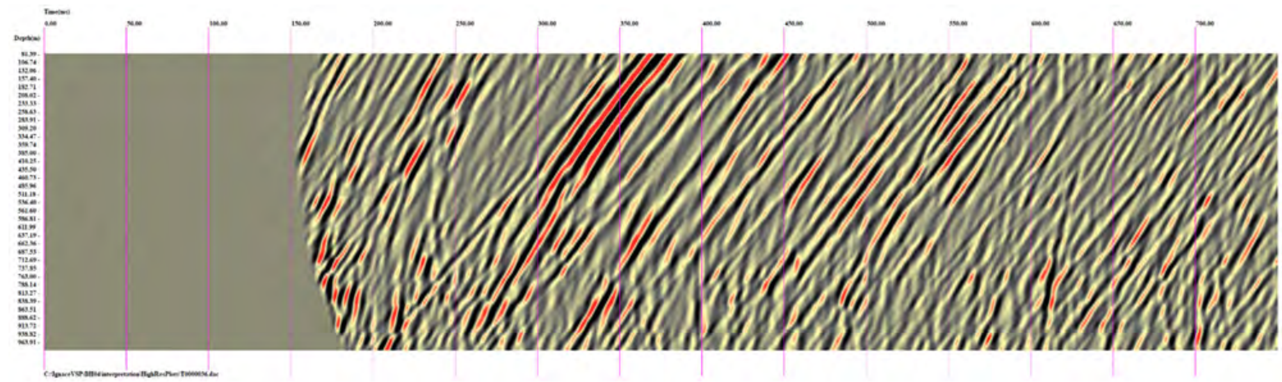


Axial component

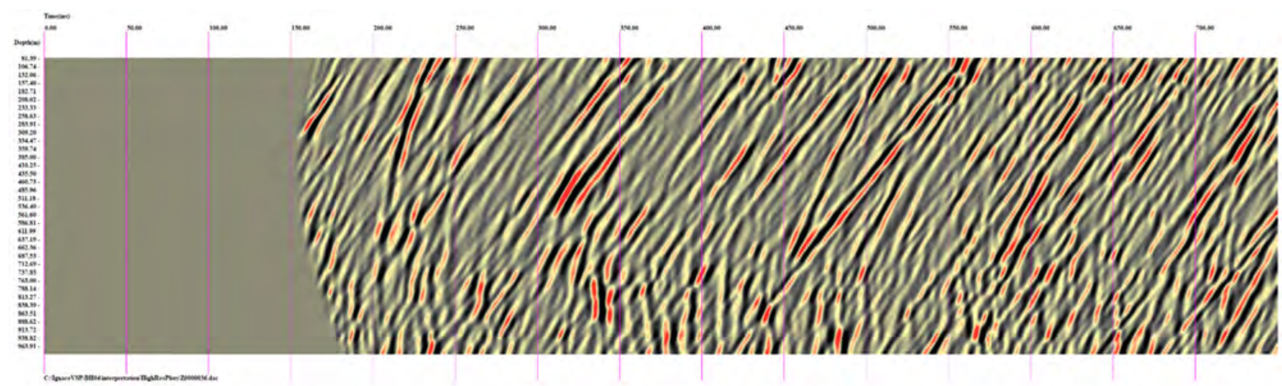
Figure 25. IG_BH04 VSP, Shot V35



Radial component

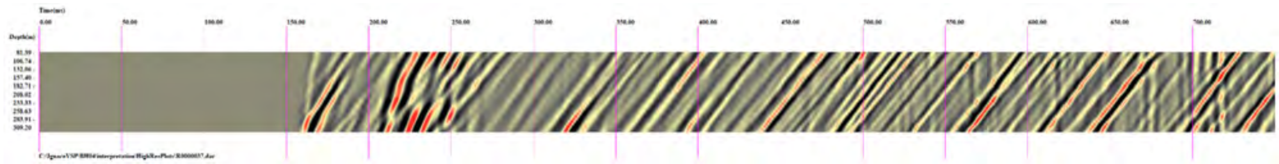


Transversal component

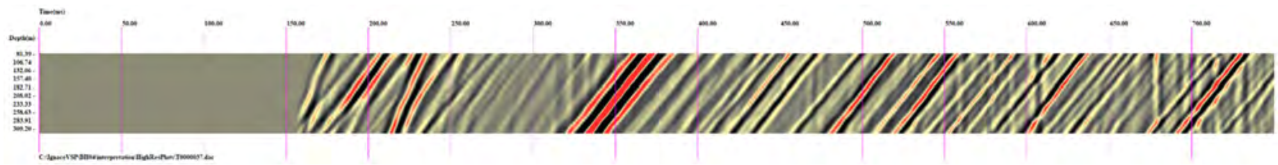


Axial component

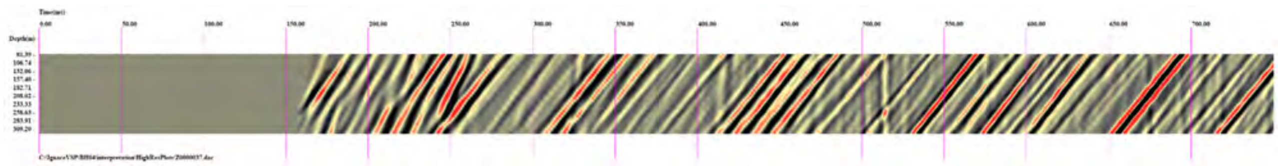
Figure 26. IG_BH04 VSP, Shot V36



Radial component

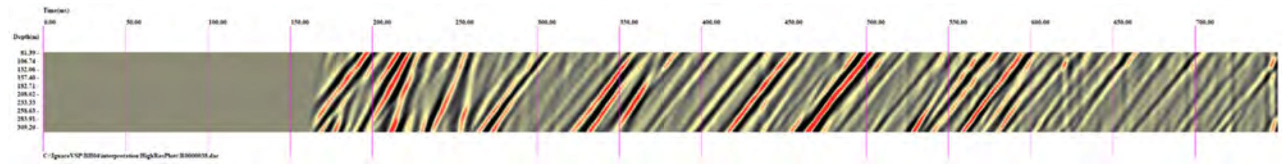


Transversal component

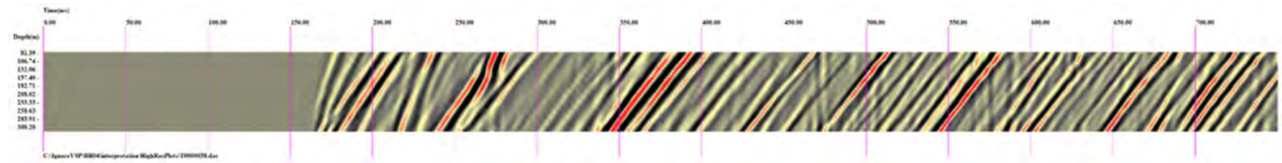


Axial component

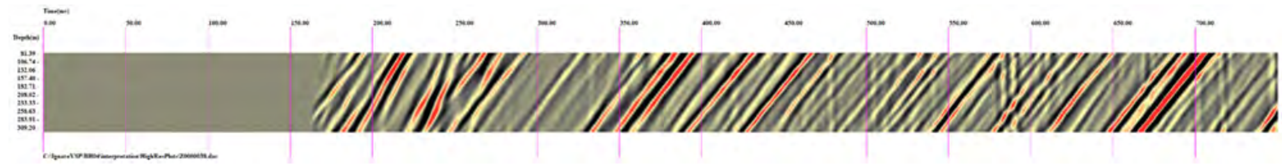
Figure 27. IG_BH04 VSP, Shot V37



Radial component

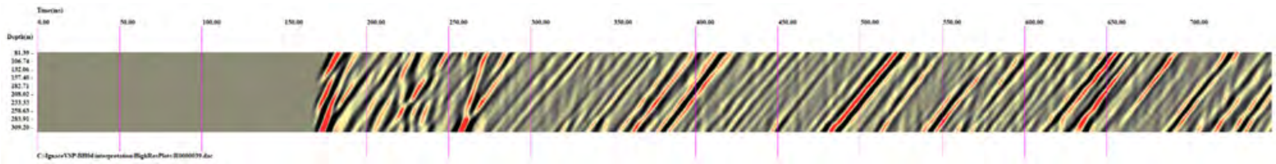


Transversal component

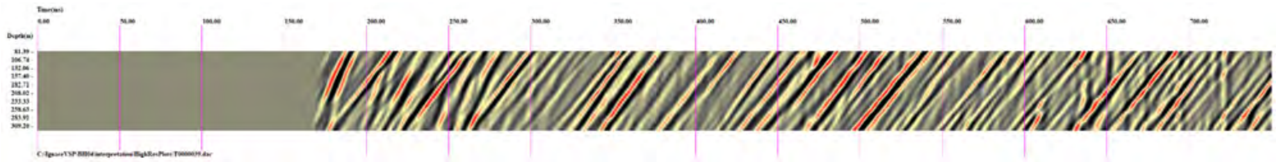


Axial component

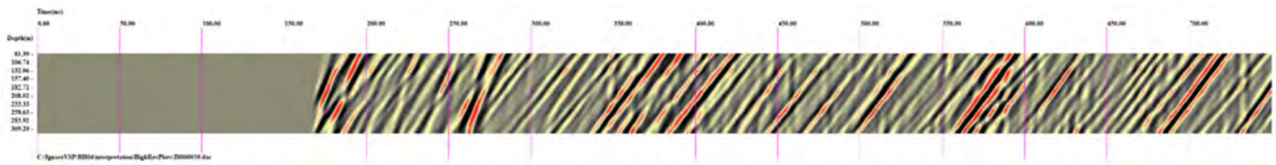
Figure 28. IG_BH04 VSP, Shot V38



Radial component

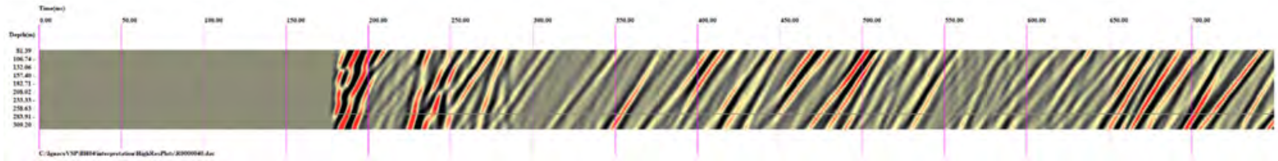


Transversal component

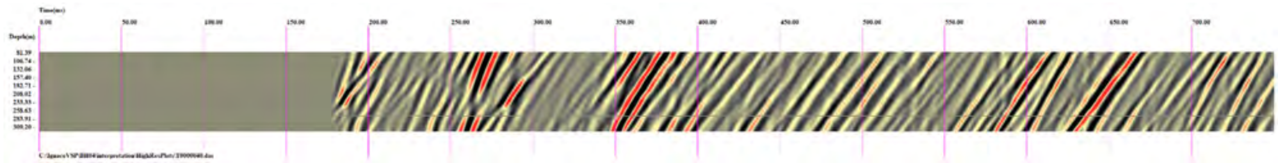


Axial component

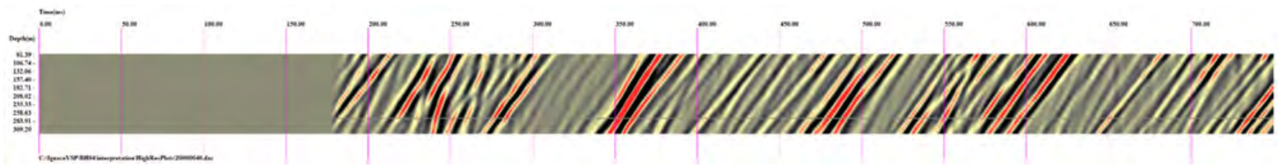
Figure 29. IG_BH04 VSP, Shot V39



Radial component



Transversal component



Axial component

Figure 30. IG_BH04 VSP, Shot V40

APPENDIX D

3D Image Point Migrations from Borehole IG_BH04

Numerous 3D migration techniques have been proposed and tested over the years. Virtually all of these rely on acquiring and processing extensive shot layouts. The extreme variability of the target orientations and characteristics specific to hardrock, would easily bring the number of needed shot number in the thousandshundreds (Schweigert, 2019).

Besides high cost and complicated logistics, an extensive deployment of shots and the dense network of source access trails required can have a significant impact on the environment. Vibrometric developed (Cosma et. al. 2010 the 3D Image Point (IP) migration method to address such concerns, especially when surveys are performed in an environmentally sensitive area. The method relies on an elliptical loop of shots, and 2-4 radial lines connecting the loop to the top of the borehole. Preexisting roads and trails are used extensively. The 3D Image Point (IP) migration supports a 3D geometrical model containing rock structures with both low and high dips and all strike directions while keeping to the minimum the interaction with the environment.

The defining property of the Image Point Transform is its ability to accumulate amplitudes of curved reflection events appearing in time-distance profiles into approximately discoidal (or spherical in three dimensions) vicinities in the IP domain. Due to the reflected wavefields collapsing into such vicinities in the IP domain, the emphasizing of the reflectors consists of enhancing regions with higher amounts of accumulated amplitude. True-dip filtering can easily be performed, even for reflectors appearing in the time-distance profiles as curved events due to their dip, source offset or variable velocity field. Reflecting interfaces are defined as sets of linked piecewise planar-reflector elements rather than as collections of point diffractors. True reflectors fitting this description are enhanced by the IP transform while diffraction patterns, events produced by other wave types, multiples, and noise of any kind, tend to be suppressed. The inverse transform leads to filtered versions of the time-distance profiles. An alternative to performing the inverse transform back to the original time-distance representation is computing 2D/3D migrated images directly from the transformed IP space.

For reference, 3D Kirchhoff depth migrations were also computed for two cross-sections. The quality of the 3D Kirchhoff migration was known (Cosma et. al. 2010) to be poorer than the quality of its 3D IP counterpart, both in terms of noise and of recognizable coherence of events likely to be associated with P-wave seismic reflectors. Figure 1 and Figure 2 illustrate relevant examples, with the comparison of the migrated profiles in the W-E and S-N directions.

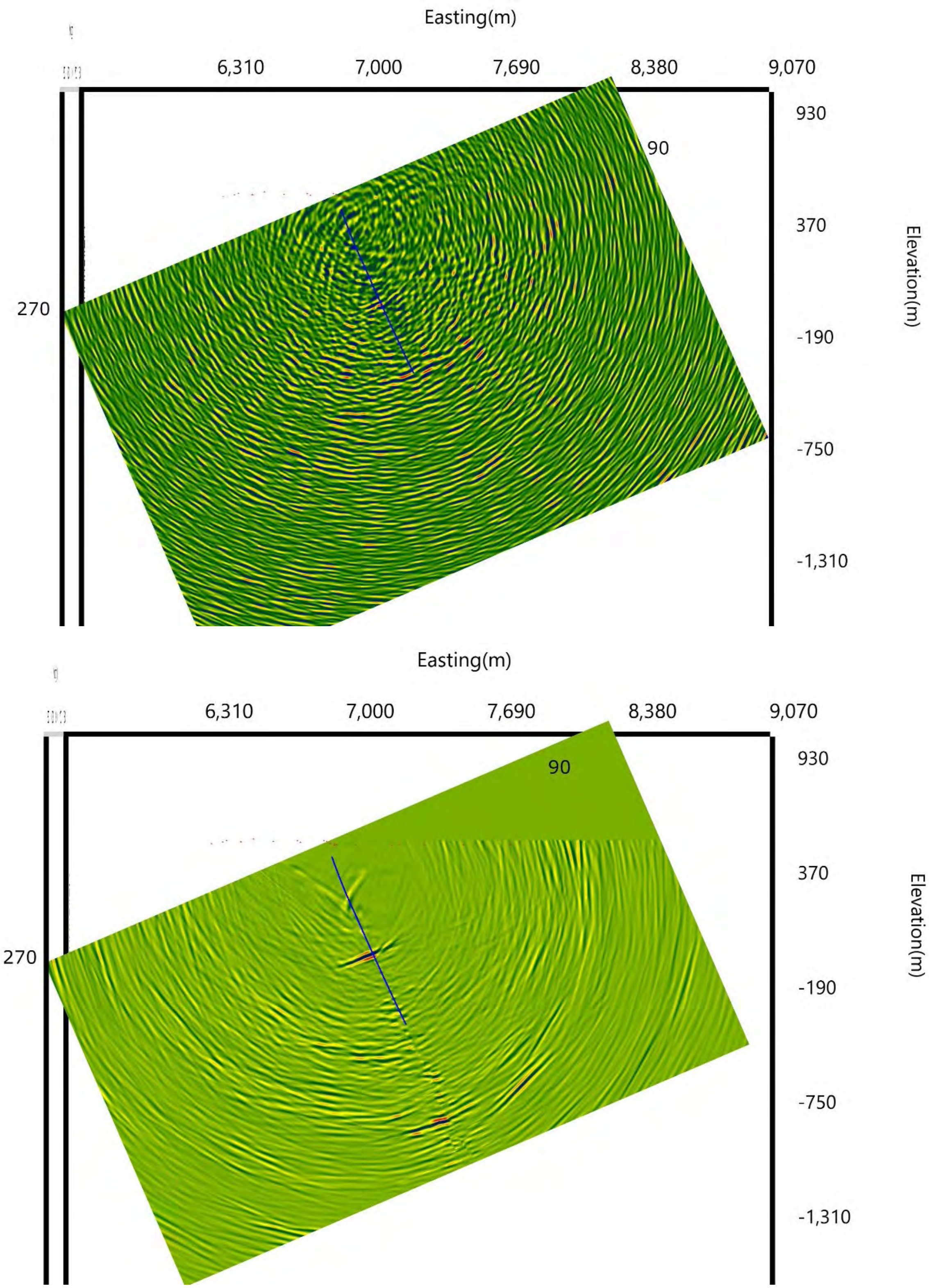


Figure 1. 3D Kirchhoff (top) and 3D IP (bottom) migrated sections, View from South.

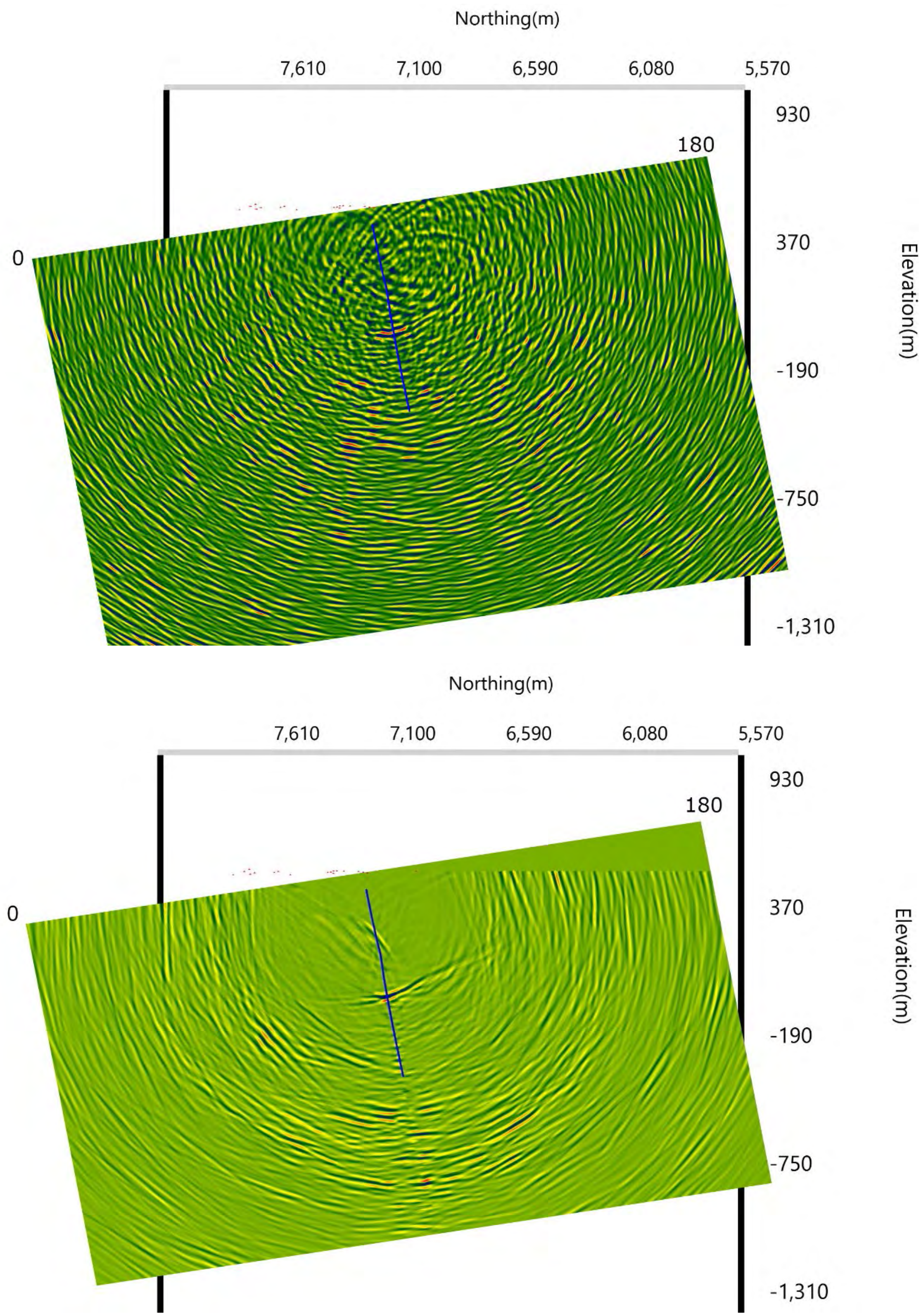


Figure 2. 3D Kirchhoff (top) and 3D IP (bottom) migrated sections, View from West.

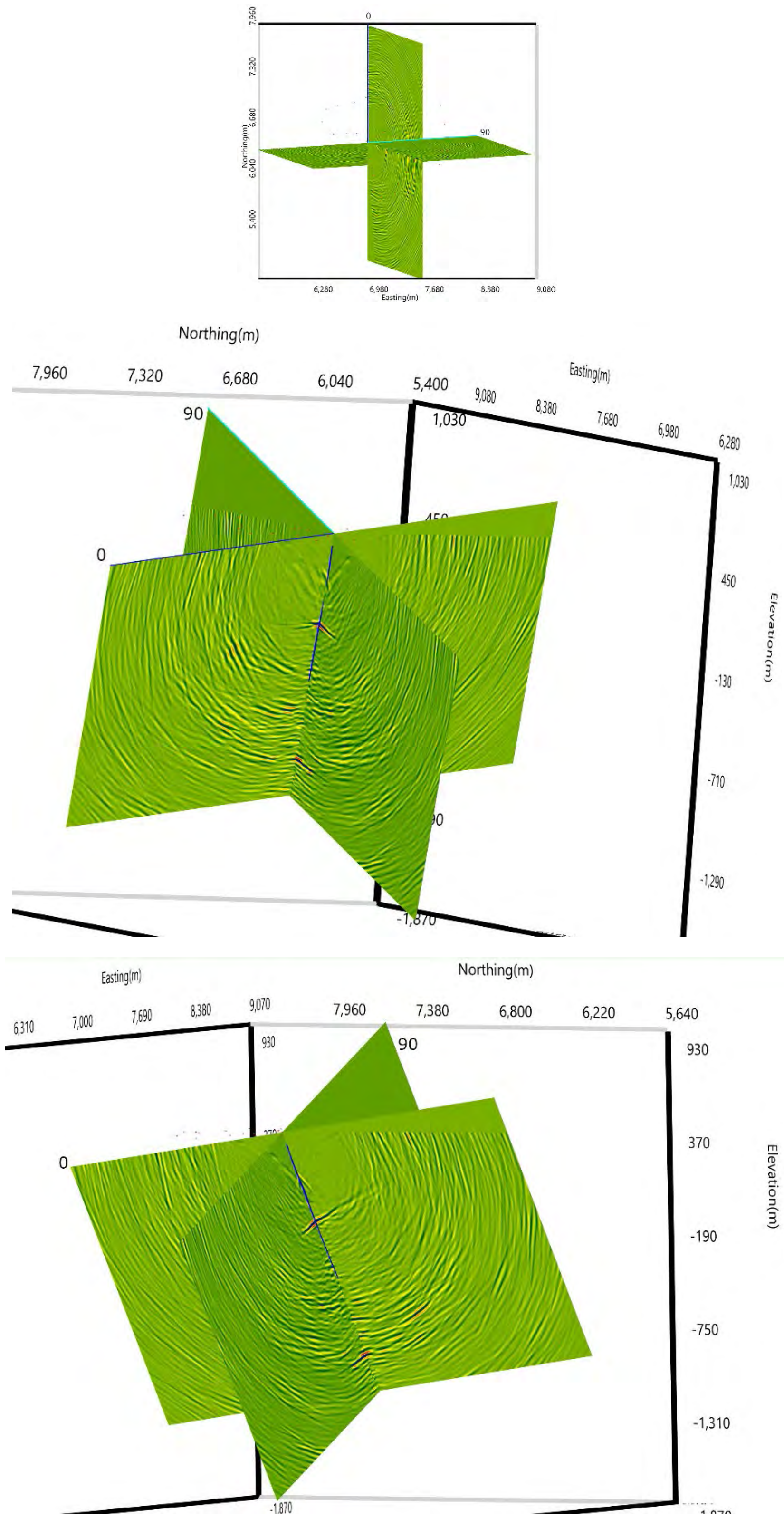


Figure 3. 3D Image Point migrated profiles, N-S (0º - 180º) and E-W (90º - 270º) cross sections around borehole IG_BH04. Azimuth 0º is at North.

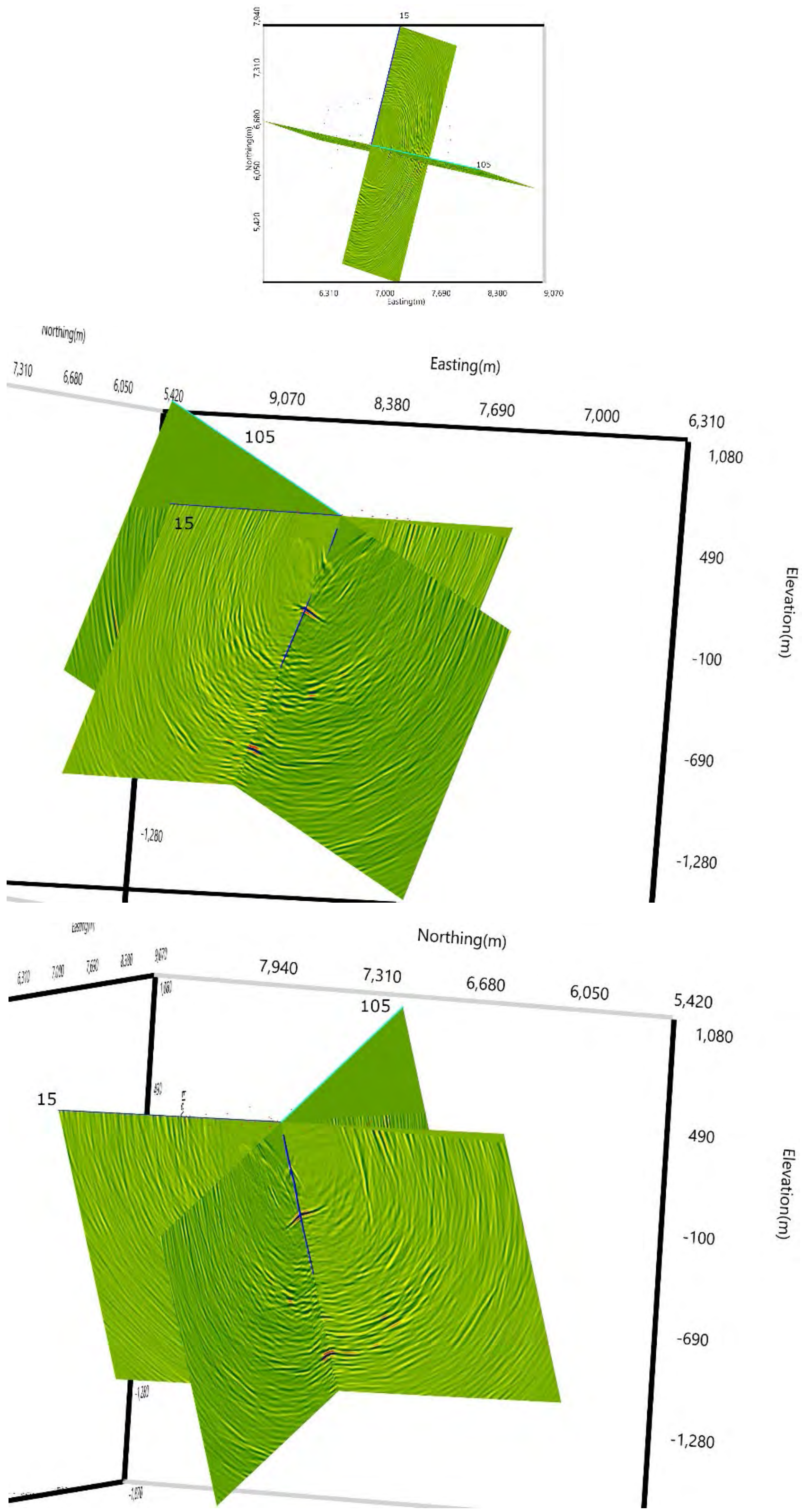


Figure 4. 3D Image Point migrated profiles, 15º - 195º and 105º - 285º cross sections around borehole IG_BH04. Azimuth 0º is at North.

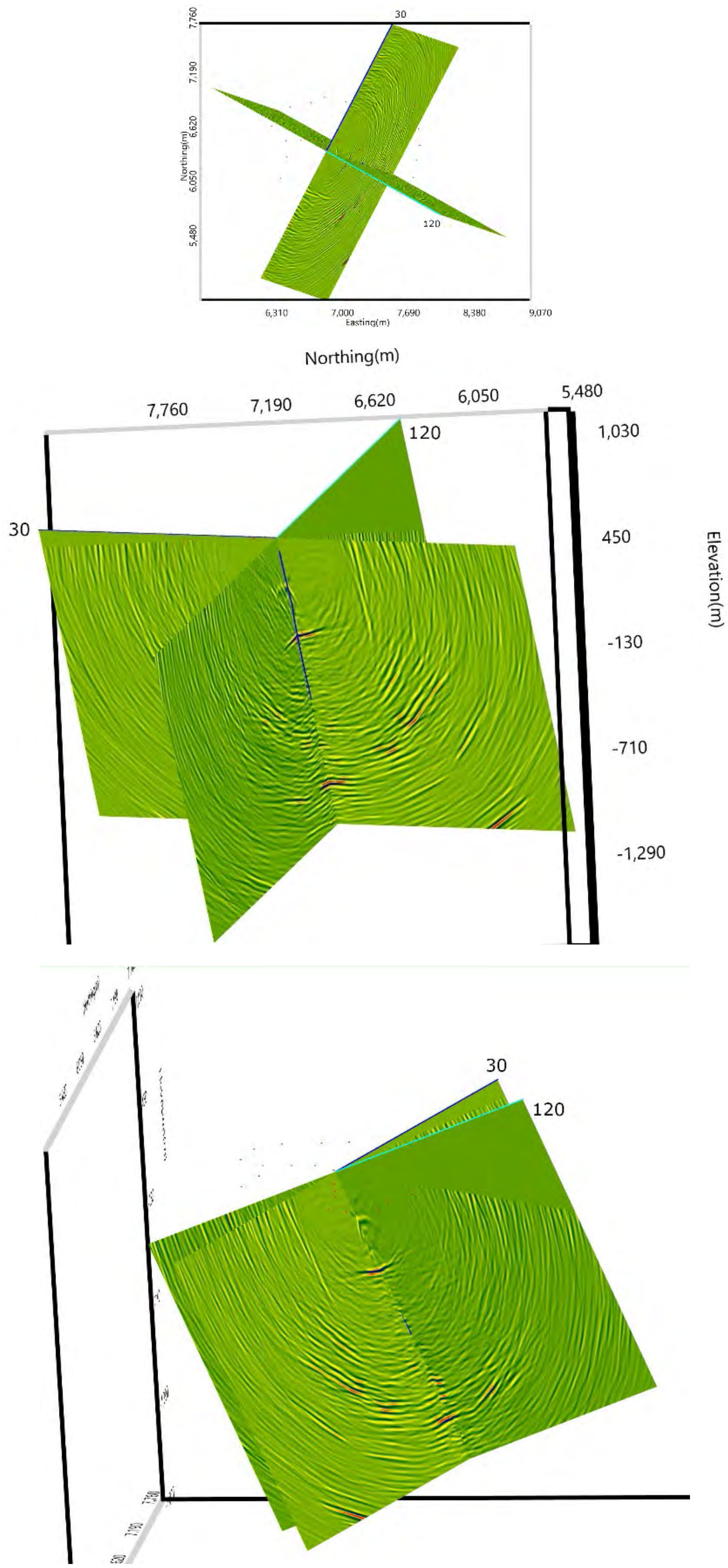


Figure 5. 3D Image Point migrated profiles, 30º - 210º and 120º - 300º cross sections around borehole IG_BH04. Azimuth 0º is at North.

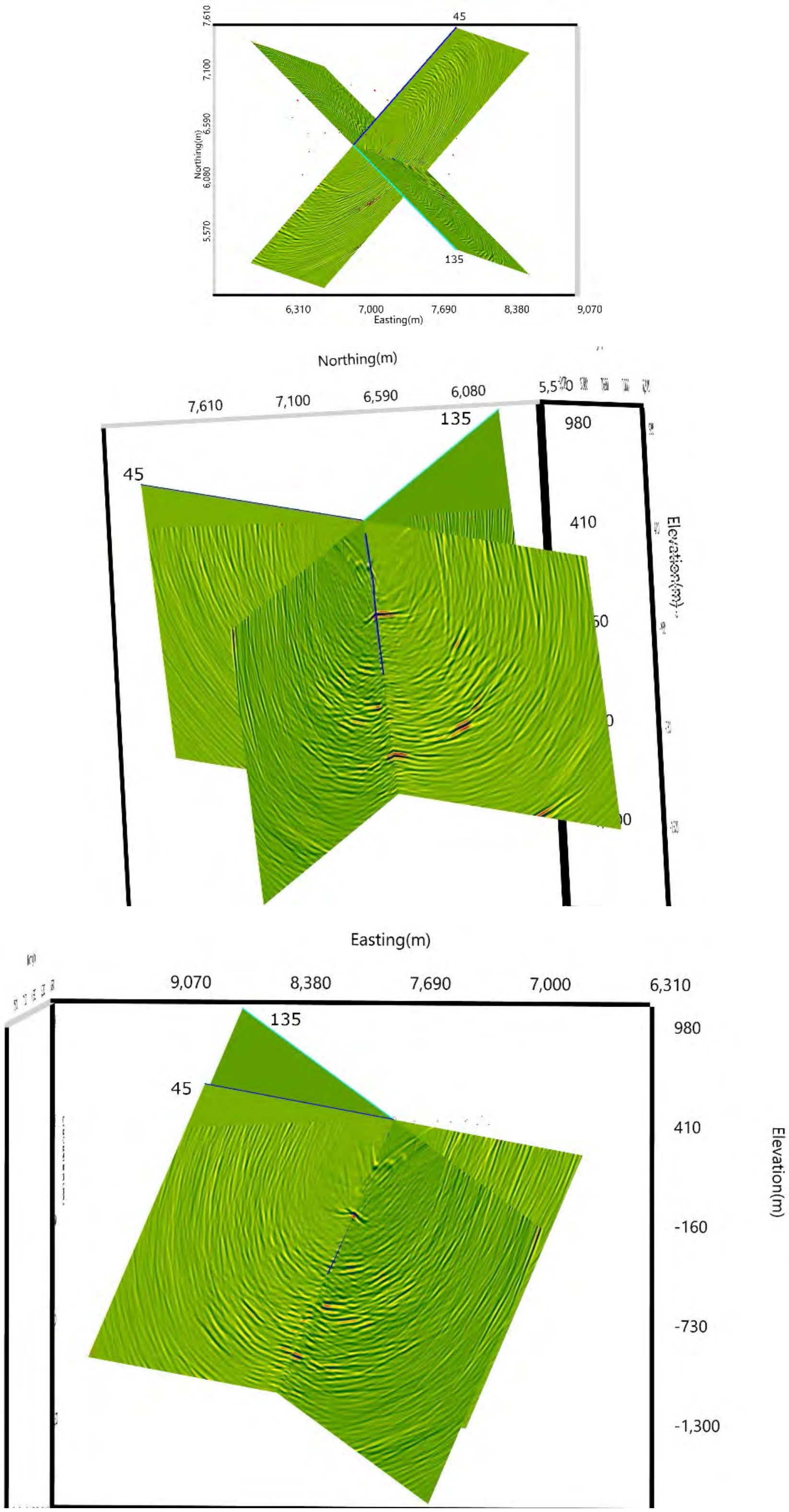


Figure 6. 3D Image Point migrated profiles, 45º - 225º and 135º - 315º cross sections around borehole IG_BH04. Azimuth 0º is at North.

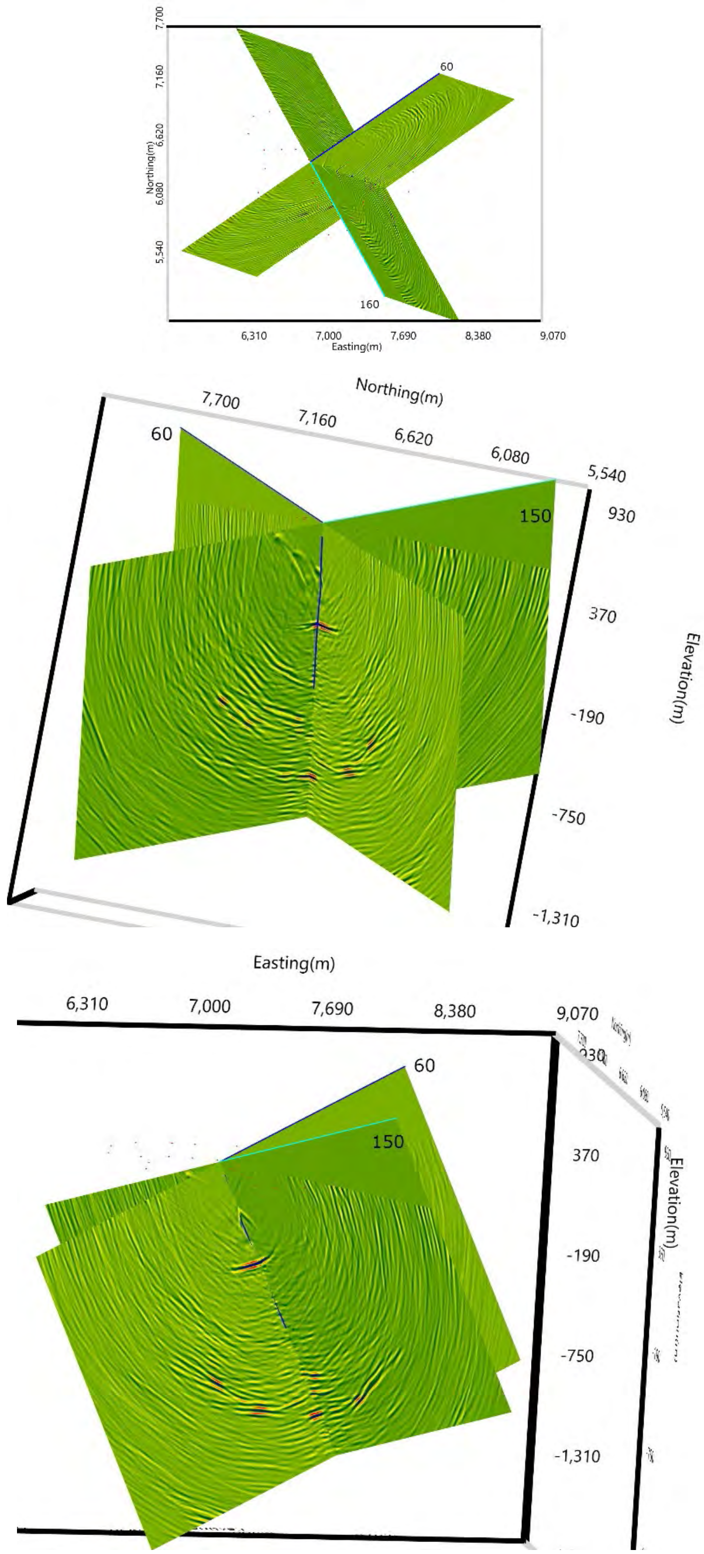


Figure 7. 3D Image Point migrated profiles, 60º - 240º and 150º - 330º cross sections around borehole IG_BH04. Azimuth 0º is at North.

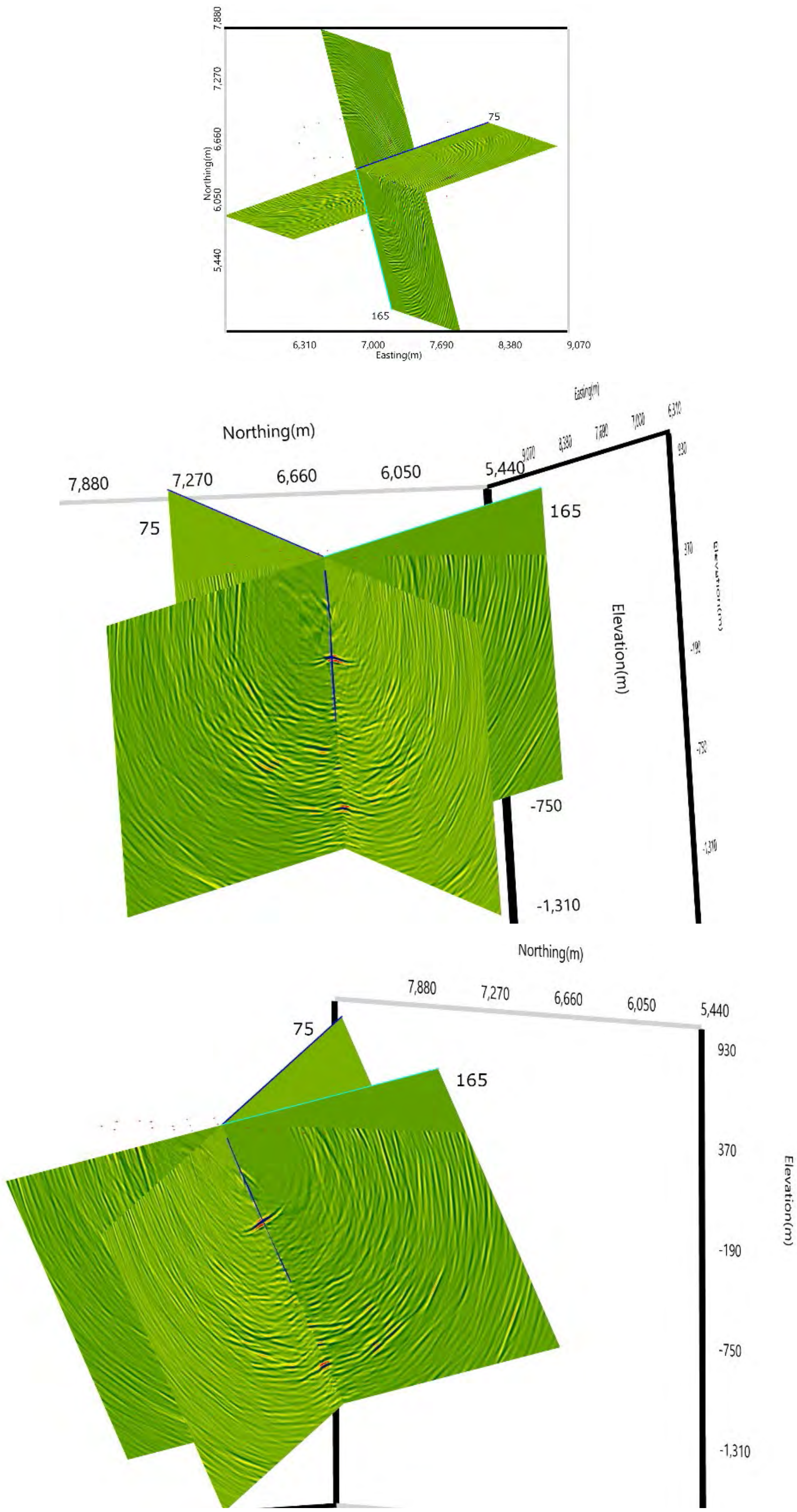


Figure 8. 3D Image Point migrated profiles, 75º - 255º and 165º - 345º cross sections around borehole IG_BH04. Azimuth 0º is at North.

APPENDIX E

Image Space Transform

The reflecting interfaces in the rock mass are generally from lithological contacts but can also be from faults, fracture zones and dissolution features. Those reflections from faults and fracture zones usually display relatively weak seismic characters and extensive processing is needed to obtain information on the position of the reflectors from the seismic profiles.

It is necessary to improve the signal-to-noise ratio, so that the later events (e.g. reflections) become visible. As the reflection coefficients are expected to be low, the reflectors cannot usually be identified by amplitude contrast. Phase consistency is a more sensitive indicator.

The Image Point transform is a technique developed for both filtering and interpretation of VSP profiles. Like the τ-*p* method, it is based on the Radon-transform, but while in the τ-*p* transform the traces are stacked along straight paths across the section, in the Image Point transform the stacking is done along paths lining up with travel times corresponding to possible real reflectors. This gives to the Image Point transform two advantages: the signal coherence can be used as effectively as possible to enhance the weak reflections and the transformed section in Image Point Space can be directly used as an interpretation tool, to estimate the strength and position of the reflectors. The approach permits the determination of both the 3-D position and local orientation of the observed reflectors. The physical meaning of the procedure is that each reflection event can be considered as being produced by an “image source” from which the signal propagates to each receiver on a direct path, much like the mirror effect in optics. The mirror on which the image source is formed is a reflecting rock feature, e.g. a fracture zone, as shown in *Figure 1*.

The Image Point transform of a depth-time profile g(z,t) is obtained by stacking along paths, all possible values of ζ and ρ, i.e. to all possible orientations of the reflecting planes.

The direct transform is expressed as:

$$\Gamma(\zeta,\rho) = \int_{z_{\min}}^{z_{\max}} g(z,t = t_r(\zeta,\rho;z))dz.$$

The function $t_r(\zeta,\rho;z)$ gives the travel times corresponding to the planar reflector specified by ρ and ζ , to the detector at the depth z:

$$t_r = \sqrt{\rho^2 + z^2 \text{-} 2z\zeta}/c$$

where

$$\rho = \sqrt{\zeta^2 + \xi^2}$$

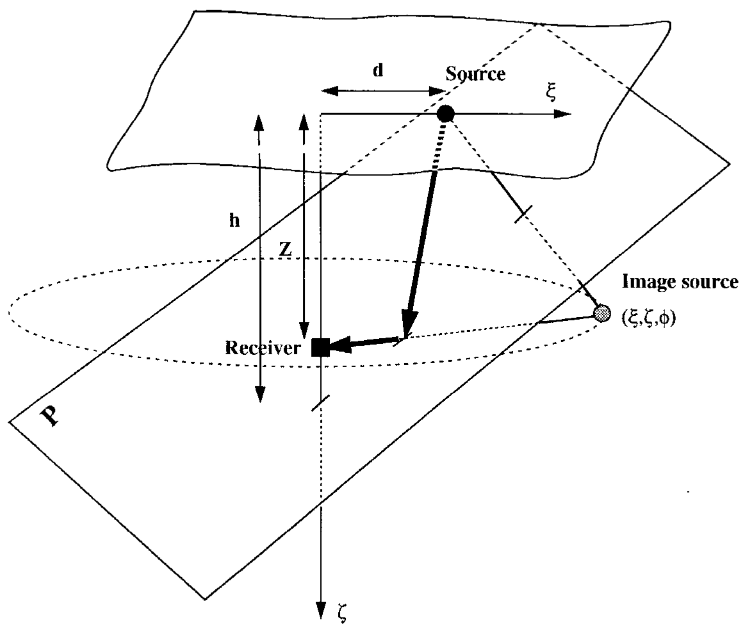


Figure 1. **Schematic presentation of the Image Point Transform**.

The inverse transform has the following expression:

$$g(z',t') = \frac{d}{dt'} H \int_{\zeta_1}^{\zeta_2} \Gamma\big(\zeta, \rho = \rho_r(z',t';\zeta)\big) d\zeta$$

where

$$\rho_r = \sqrt{c^2t^2 - z^2 + 2z\zeta}$$

The derivation and the Hilbert transform H restore the original signal shape.

In the Image Point transform, coherent reflection events collapse to points. Therefore, the signal coherence can be used as effectively as possible to enhance the weak reflections.

Within a certain range for the propagation velocity c, only real reflectors produce coherent patterns along their integration paths. Therefore, the inverse transform from the Image Point space to the depth-time space always leads to a filtered version of the reflection profile.

With the Image Point method, two of the three parameters defining the 3-D position of a reflector can be determined. The reflectors with image points located on a circle perpendicular to the borehole generate equal travel times to all detectors. In order to determine uniquely the 3D position and orientation of a reflector, means should be found to estimate the dip direction. An effective method is to use polarisation analysis. The reflected signals do not stack constructively along the image point integration path if the reflector is not a plane. This problem is solved by dividing the time-depth section into several overlapping panels, each containing a subset of the traces. For each panel, the Image Point transform is computed independently.

APPENDIX F

Interpretation of Seismic Reflectors from IG_BH04 VSP Data

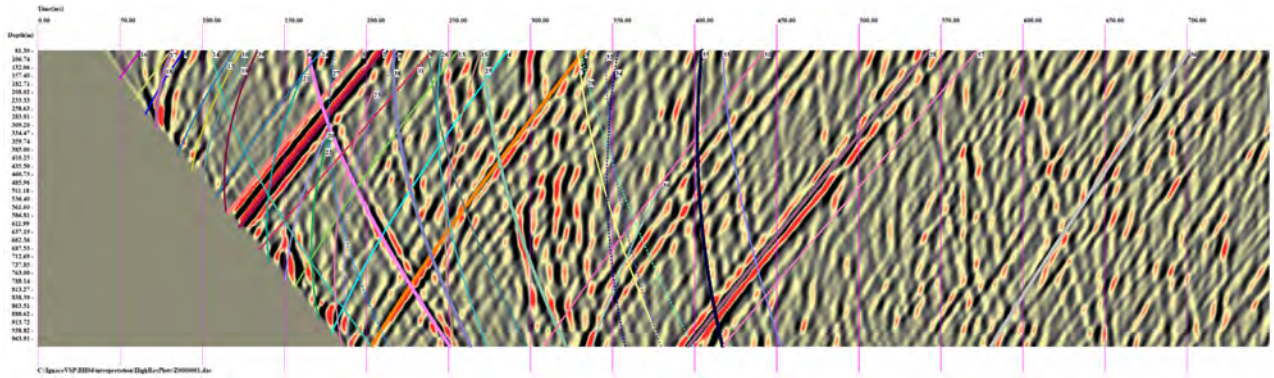


Figure 1. Axial component profile from V01.

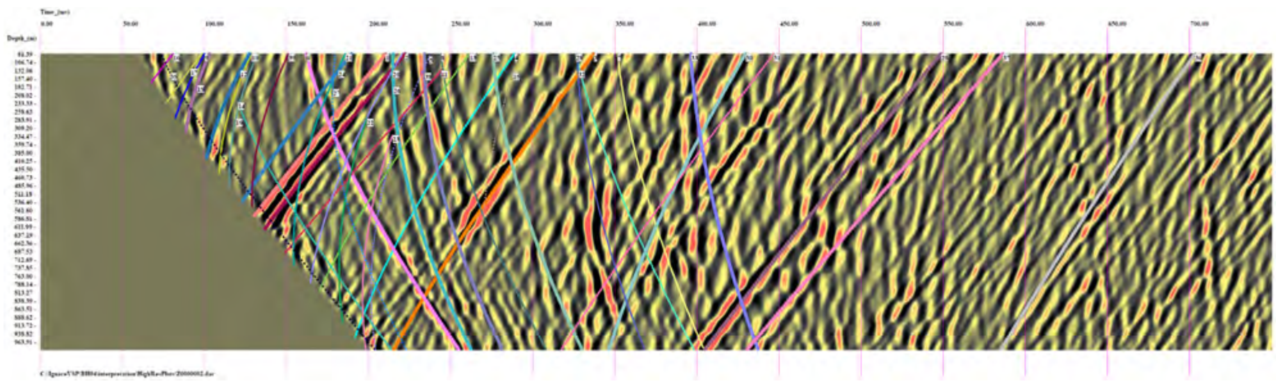


Figure 2. Axial component profile from V02

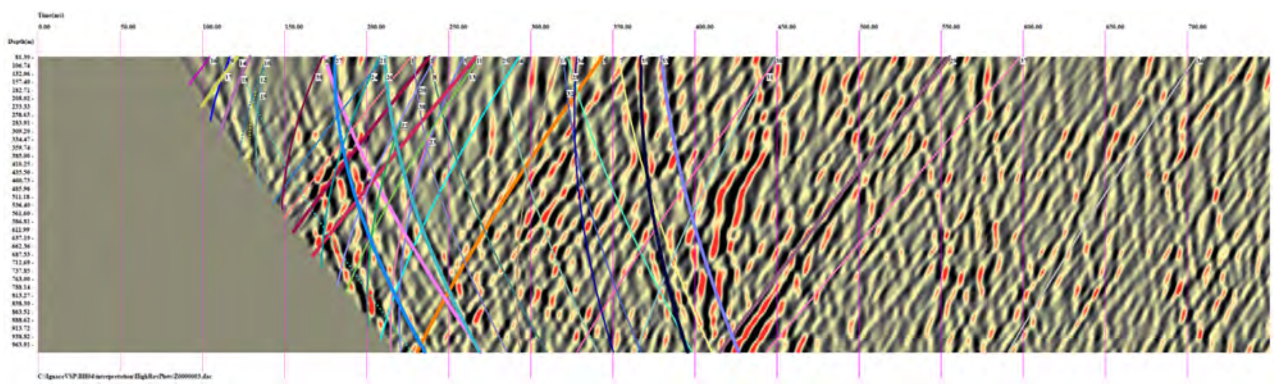


Figure 3. Axial component profile from V03

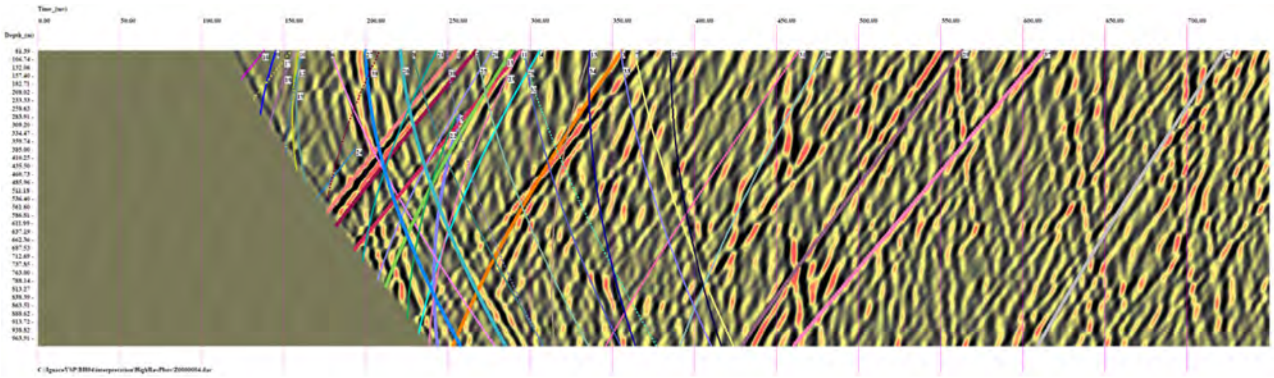


Figure 4. Axial component profile from V04

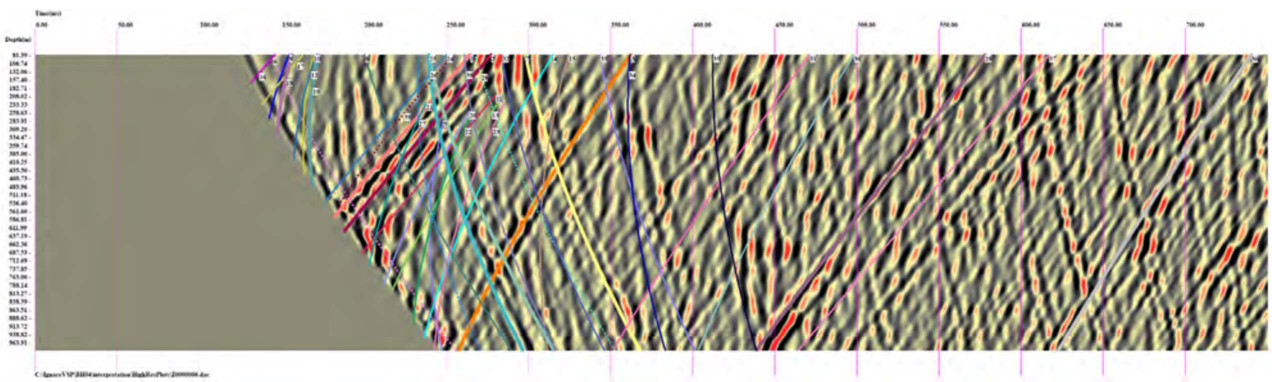


Figure 5. Axial component profile from V06

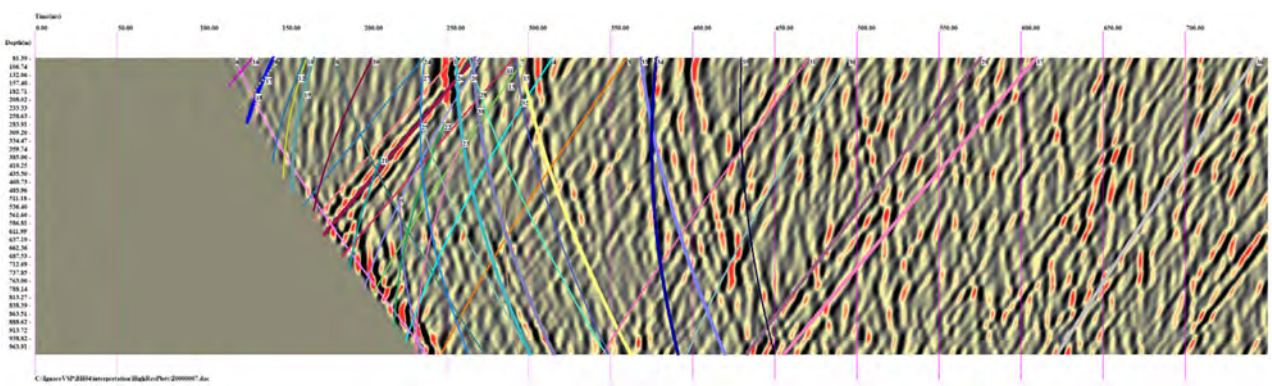


Figure 6. Axial component profile from V07

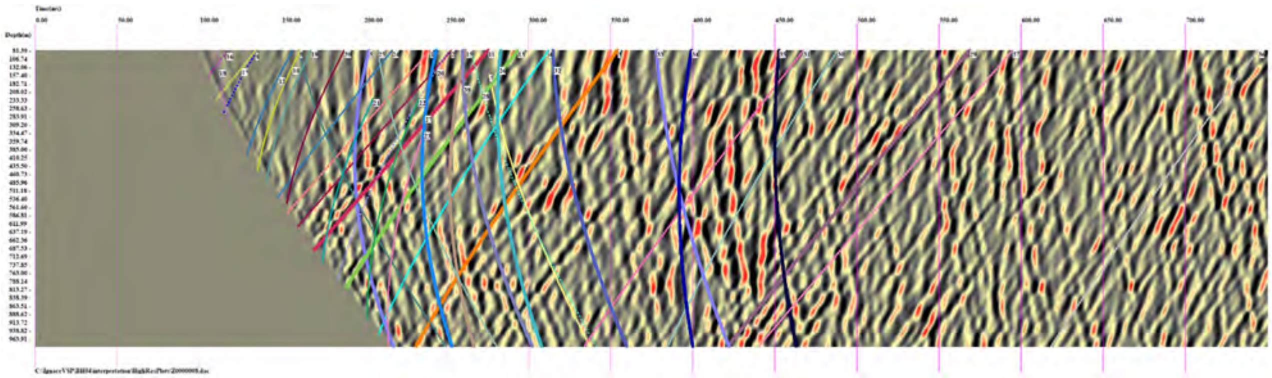


Figure 7. Axial component profile from V08

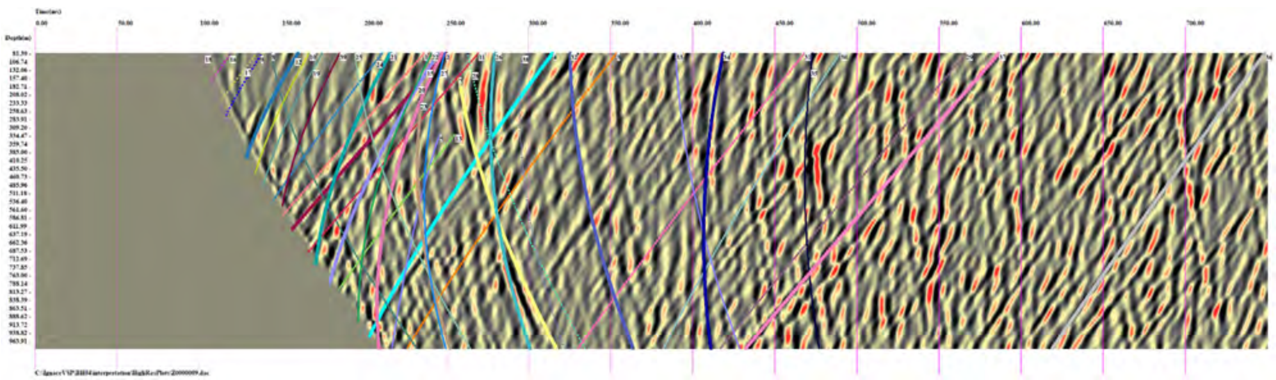


Figure 8. Axial component profile from V09

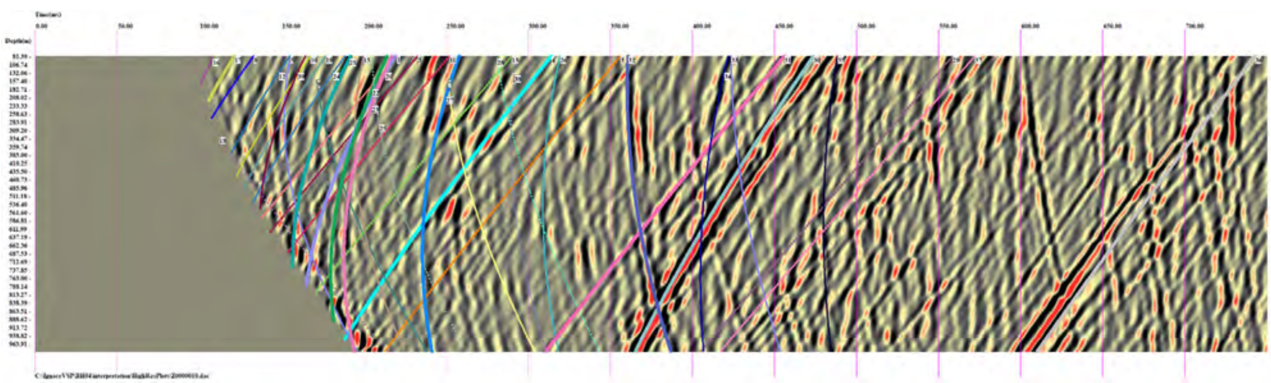


Figure 9. Axial component profile from V10

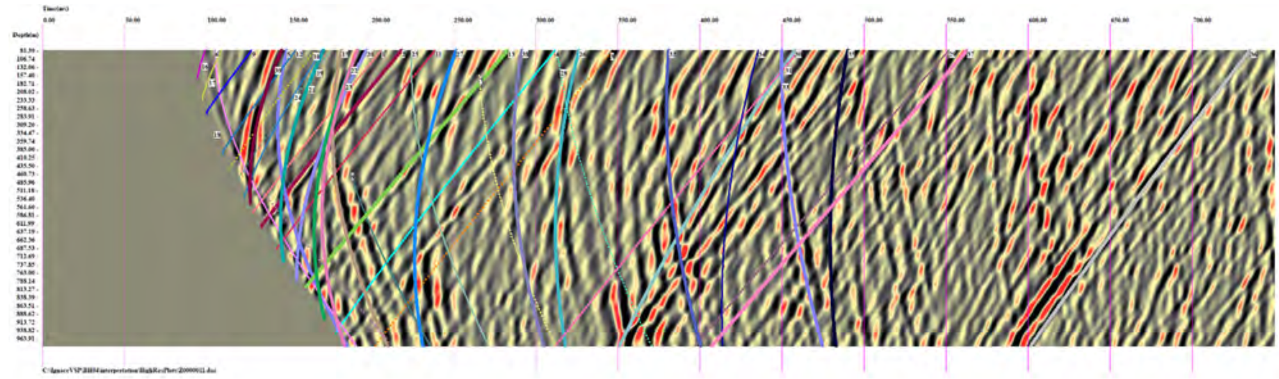


Figure 10. Axial component profile from V11

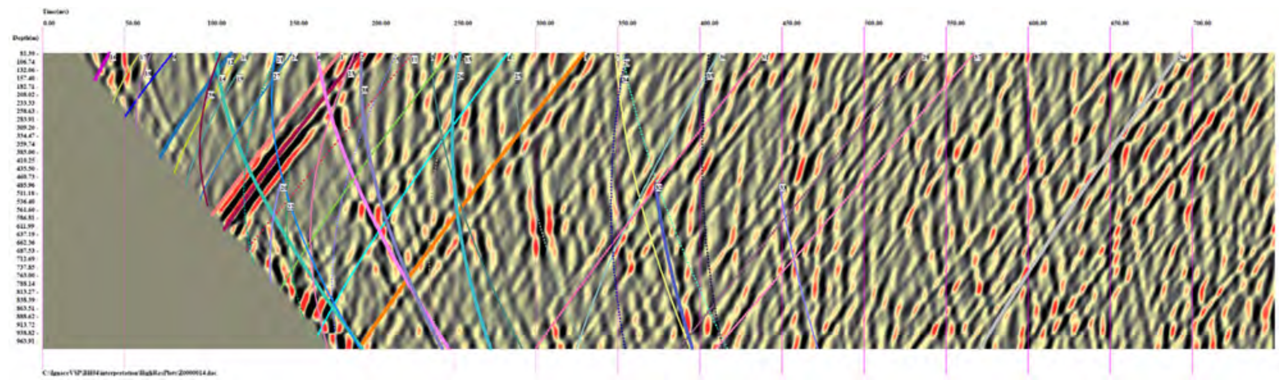


Figure 11. Axial component profile from V14

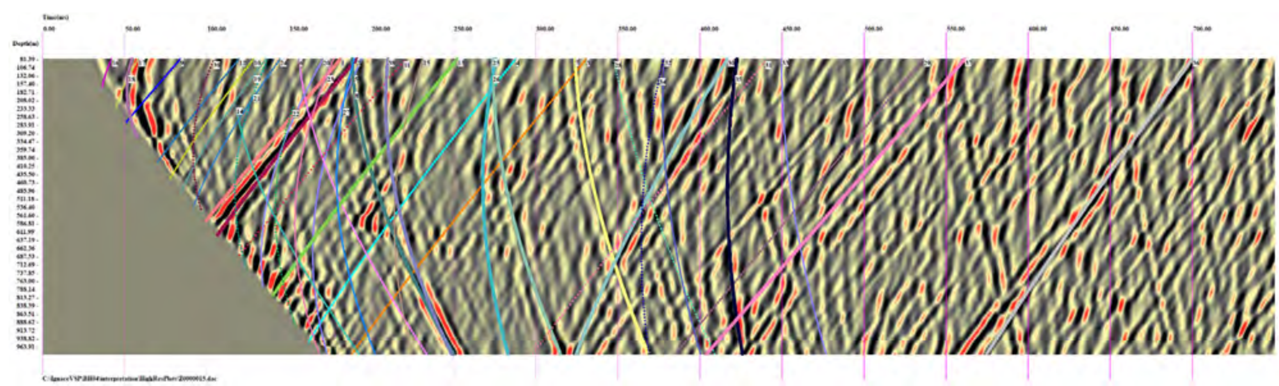


Figure 12. Axial component profile from V15

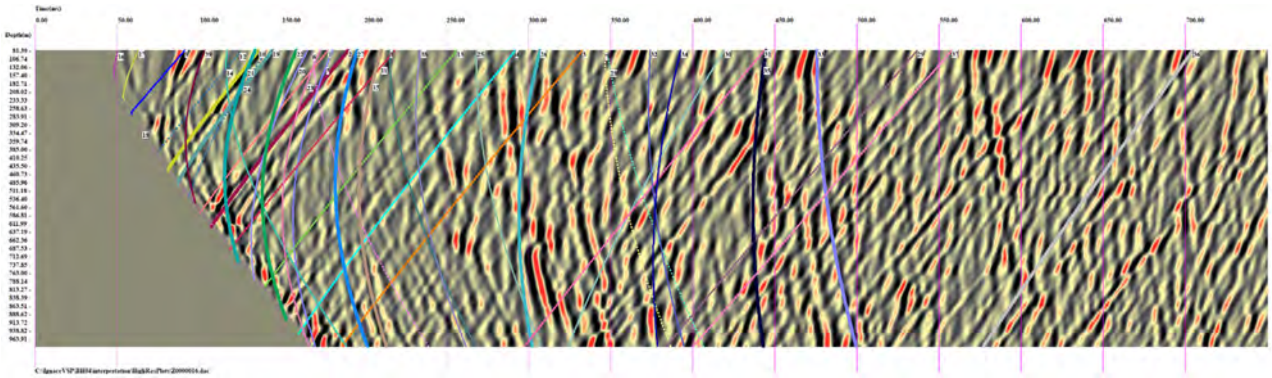


Figure 13. Axial component profile from V16

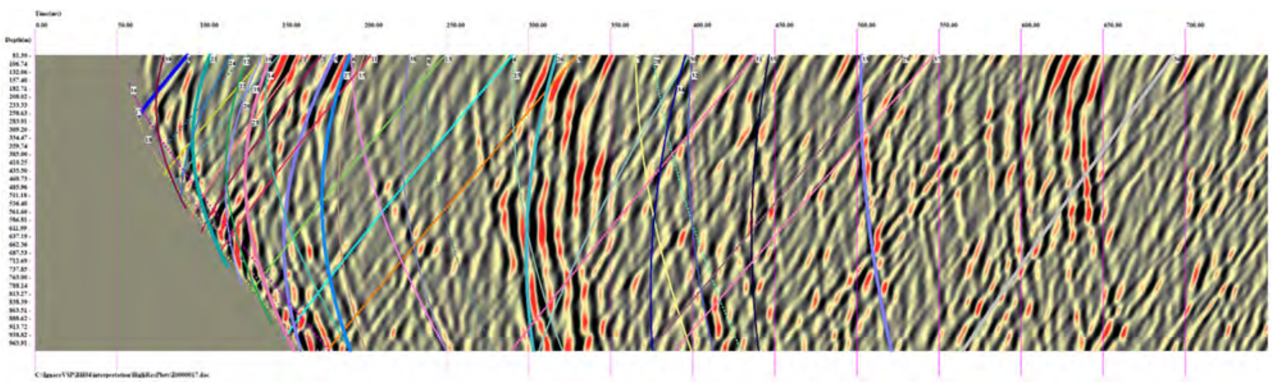


Figure 14. Axial component profile from V17

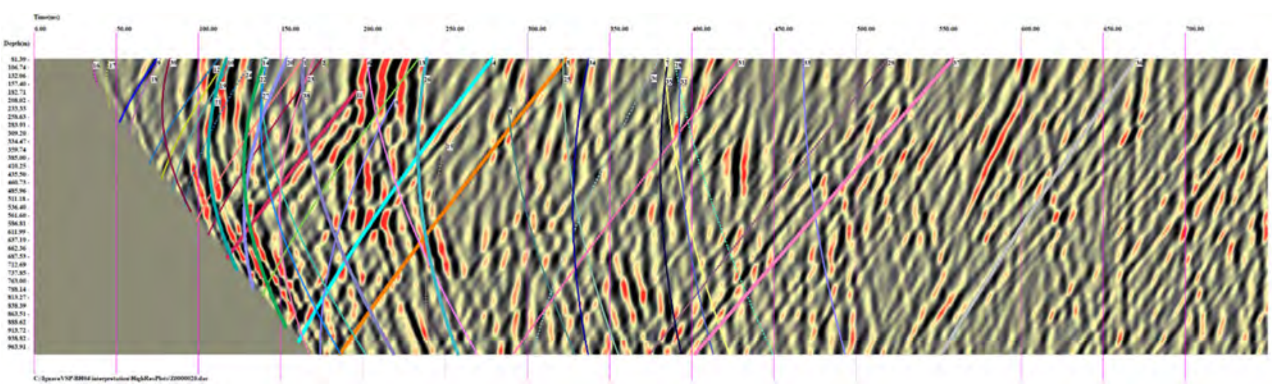


Figure 15. Axial component profile from V20

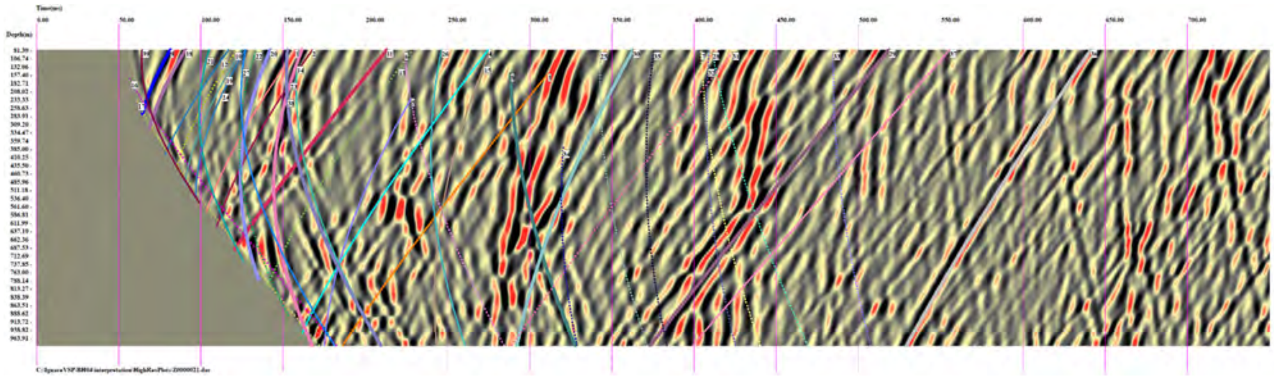


Figure 16. Axial component profile from V21

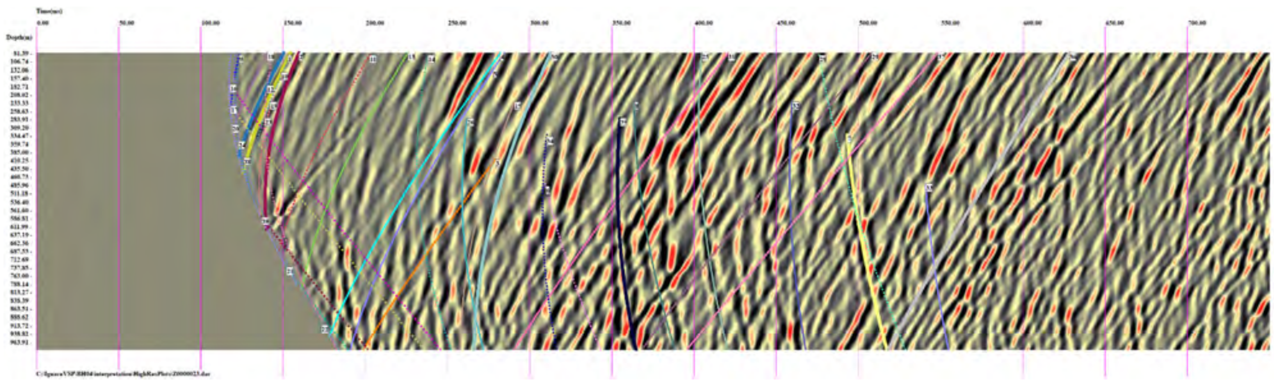


Figure 17. Axial component profile from V23

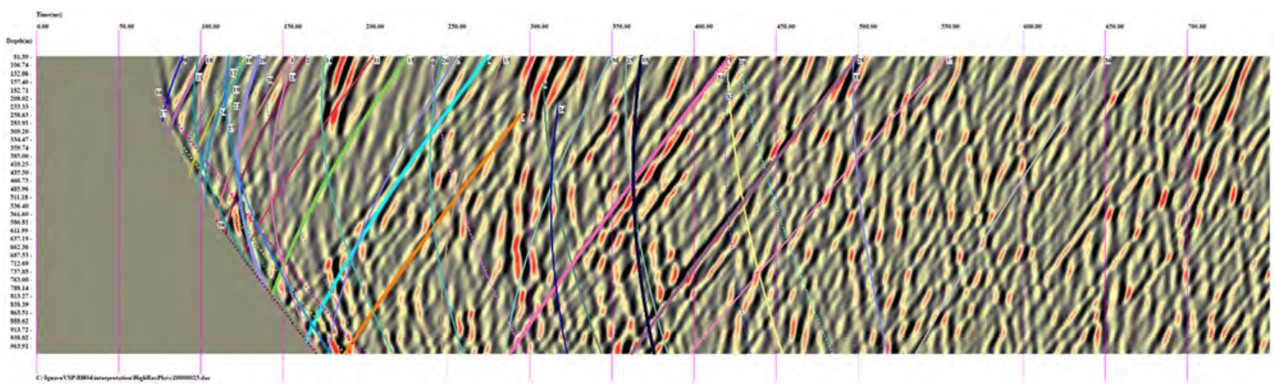


Figure 18. Axial component profile from V25

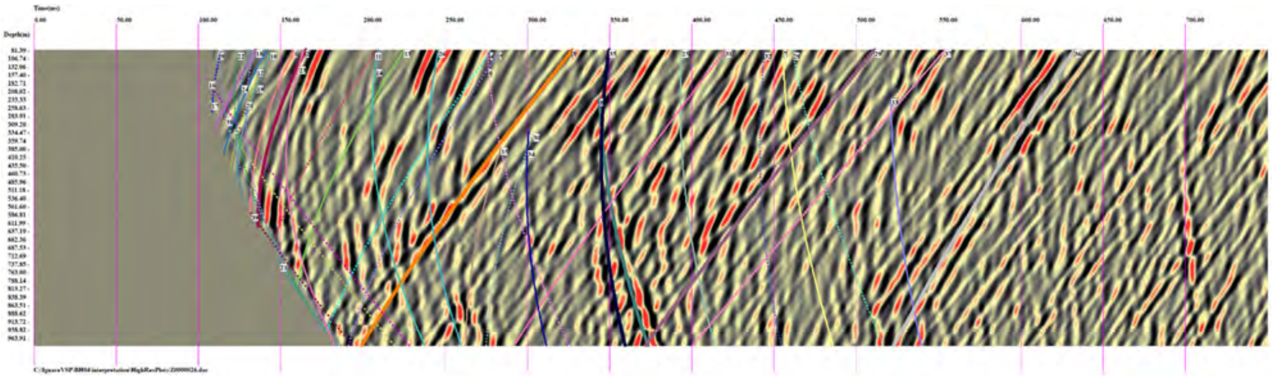


Figure 19. Axial component profile from V26

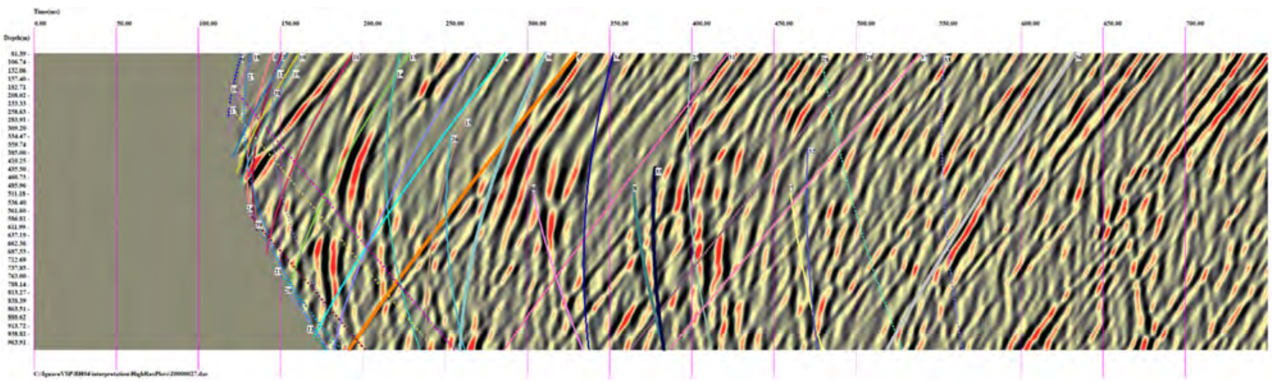


Figure 20. Axial component profile from V27

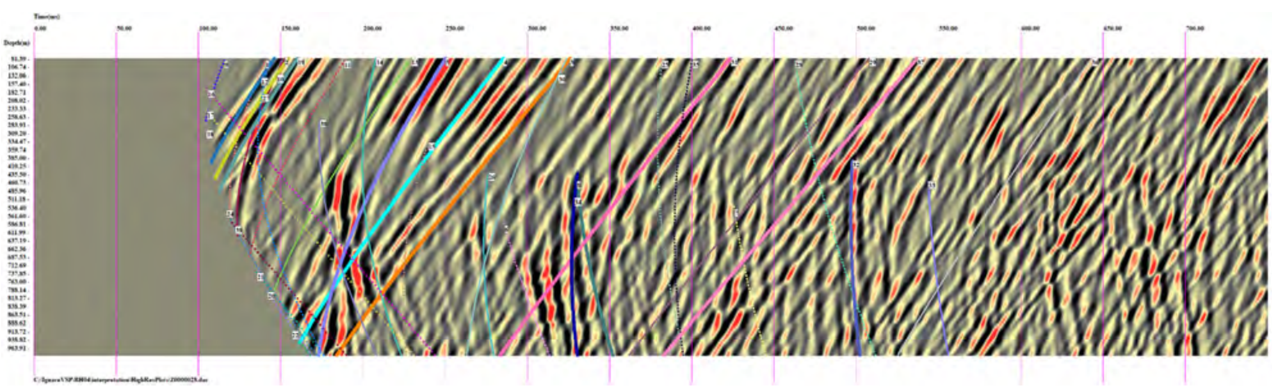


Figure 21. Axial component profile from V28

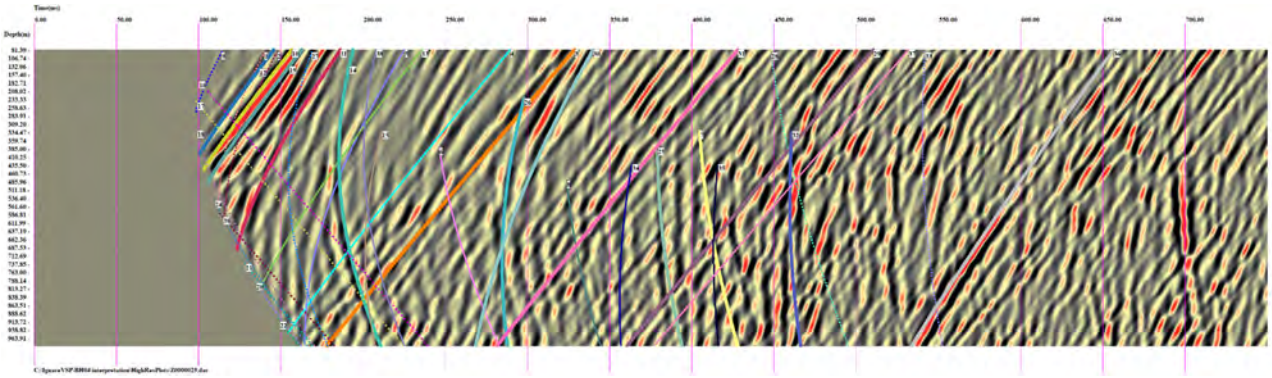


Figure 22. Axial component profile from V29

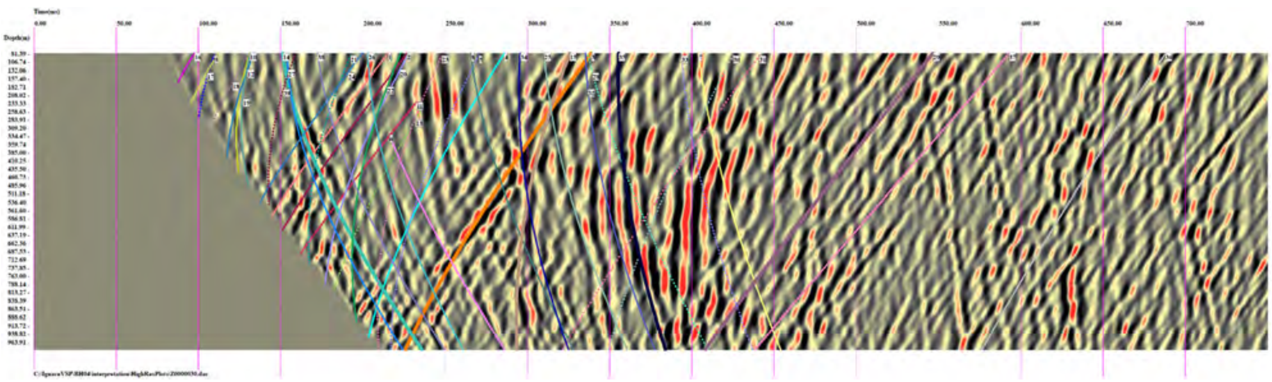


Figure 23. Axial component profile from V30

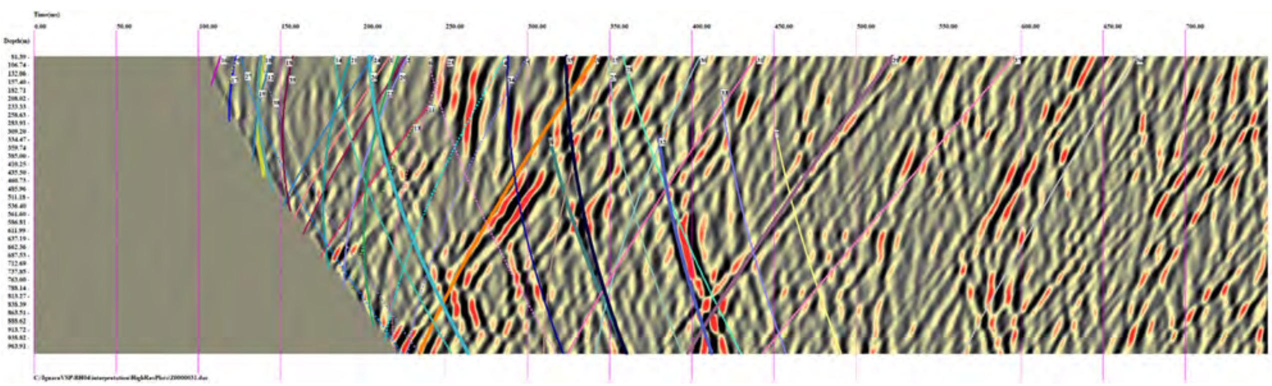


Figure 24. Axial component profile from V31

Figure 25. Axial component profile from V35

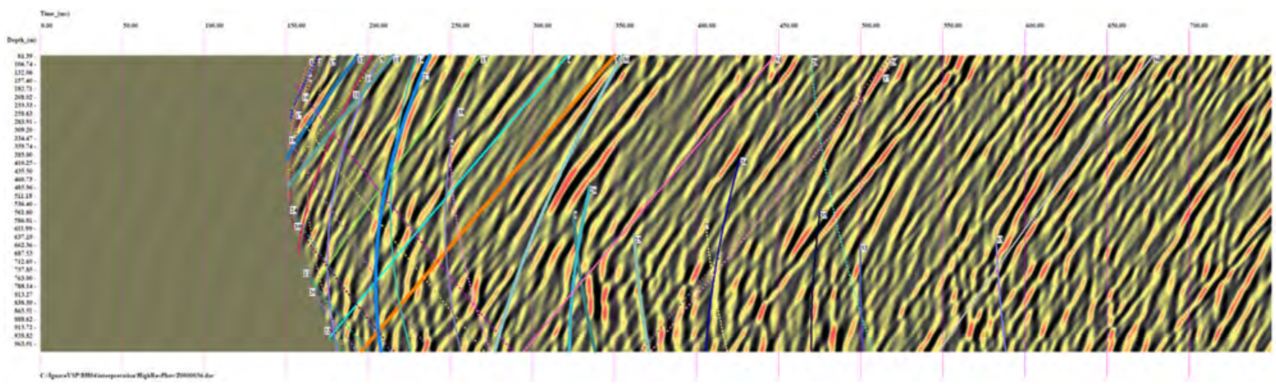


Figure 26. Axial component profile from V36

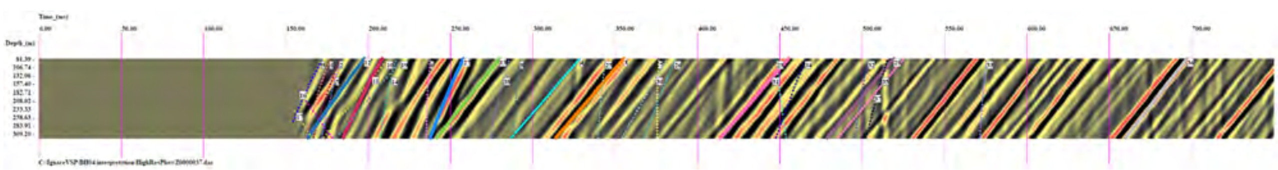


Figure 27. Axial component profile from V37

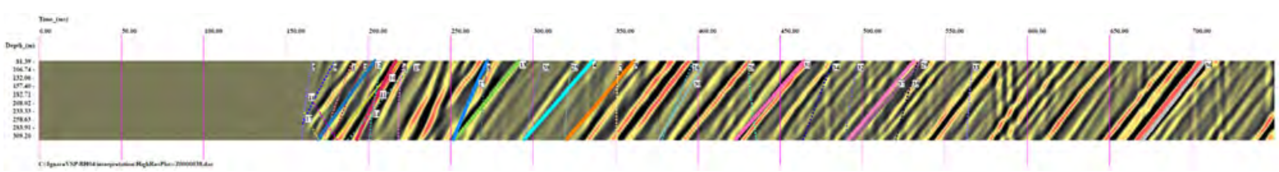


Figure 28. Axial component profile from V38

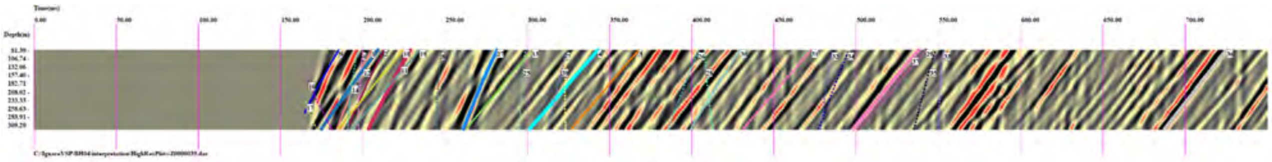


Figure 29. Axial component profile from V39

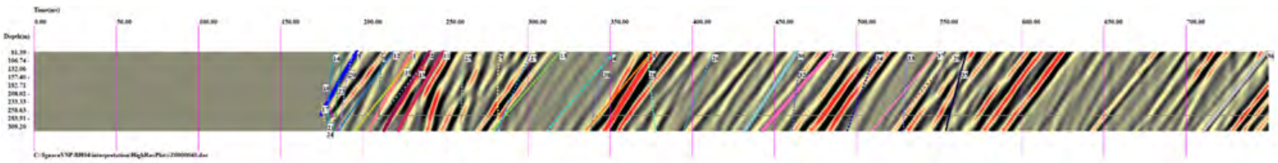


Figure 30. Axial component profile from V40

APPENDIX G

Interpreted Steeply Dipping Seismic Reflectors Possibly Associated with Lineaments Mapped from Surface

The following are illustrations of interpreted steeply dipping seismic reflectors that may be associated with lineaments mapped from surface, as described in Table 8.

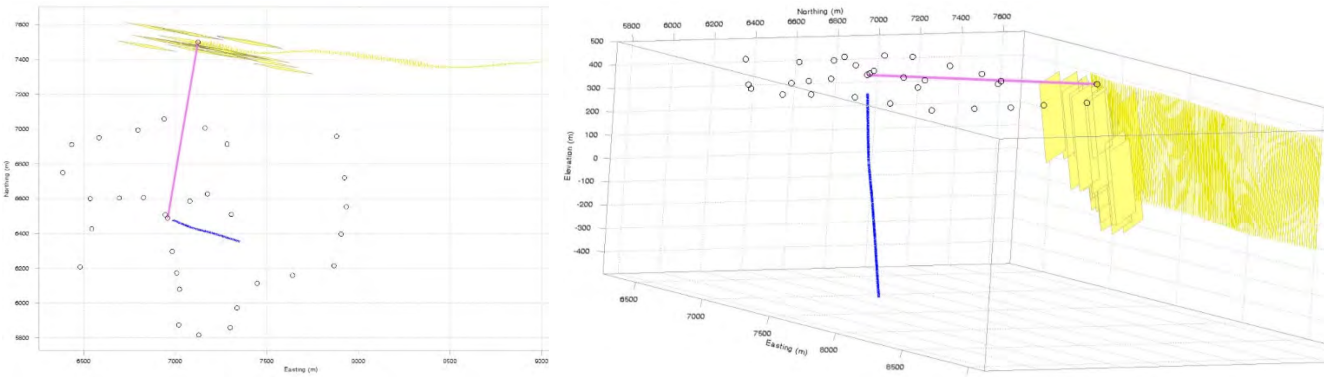


Figure 1. Reflector elements for Relf. No. 7, together with lineament IFZ016 mapped from surface. Left: view from above, Right: 3D view.

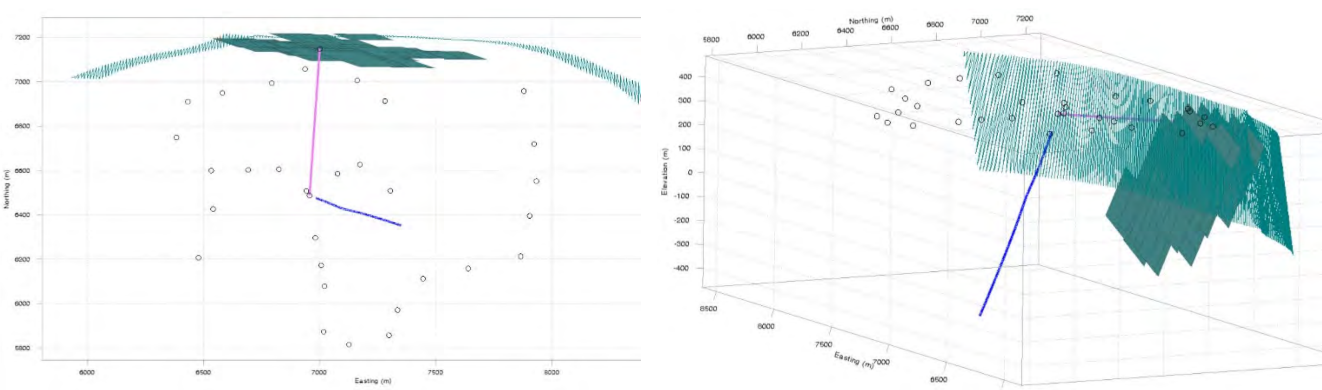


Figure 2. Reflector elements for Relf. No. 8, together with lineament IFZ019 mapped from surface. Left: view from above, Right: 3D view.

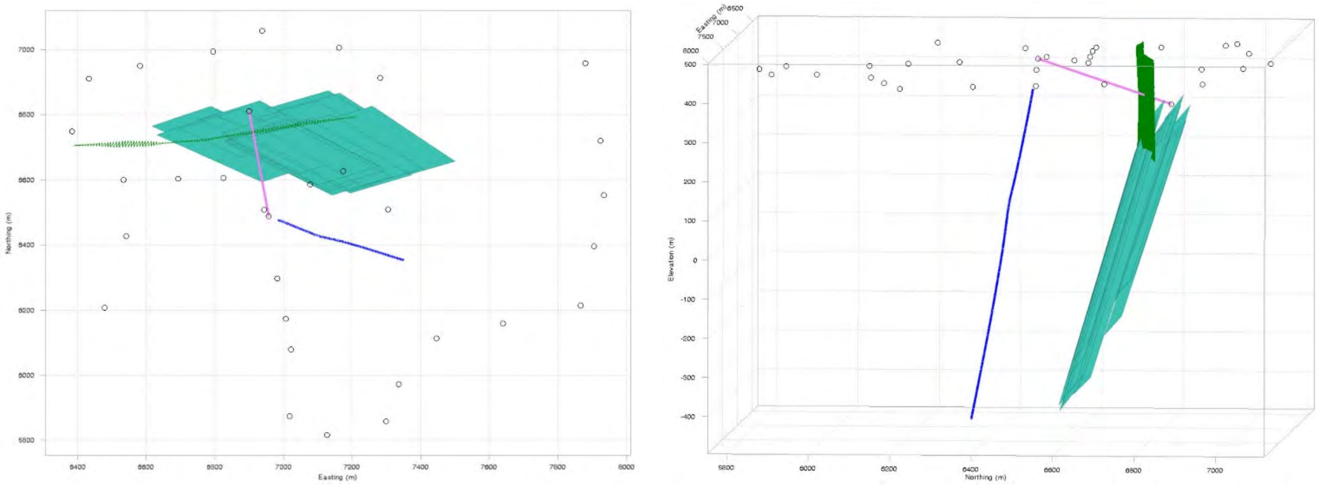


Figure 3. Reflector elements for Relf. No. 14, together with lineament IFZ036 mapped from surface. Left: view from above, Right: 3D view.

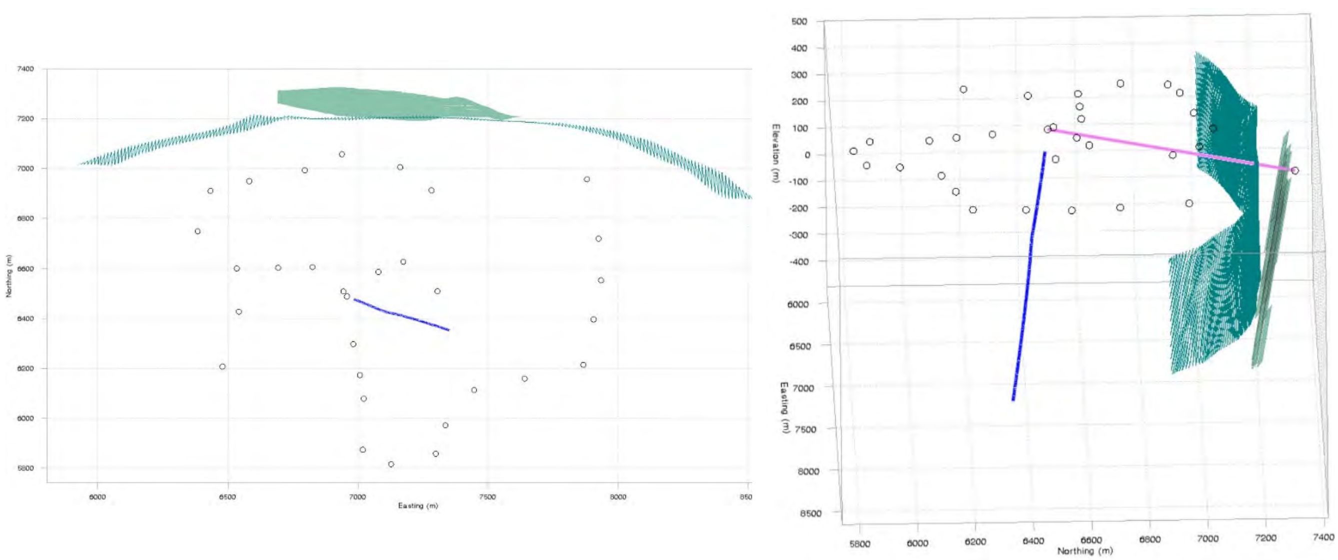


Figure 4. Reflector elements for Relf. No. 25, together with lineament IFZ019 mapped from surface. Left: view from above, Right: 3D view.

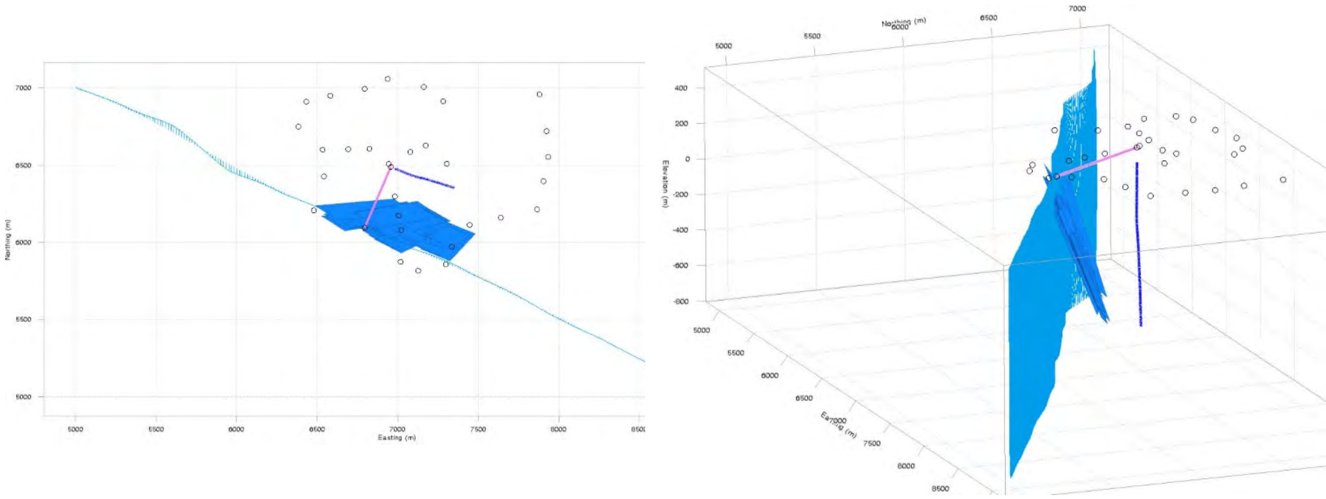


Figure 5. Reflector elements for Relf. No. 27, together with lineament DYKE01 mapped from surface. Left: view from above, Right: 3D view.

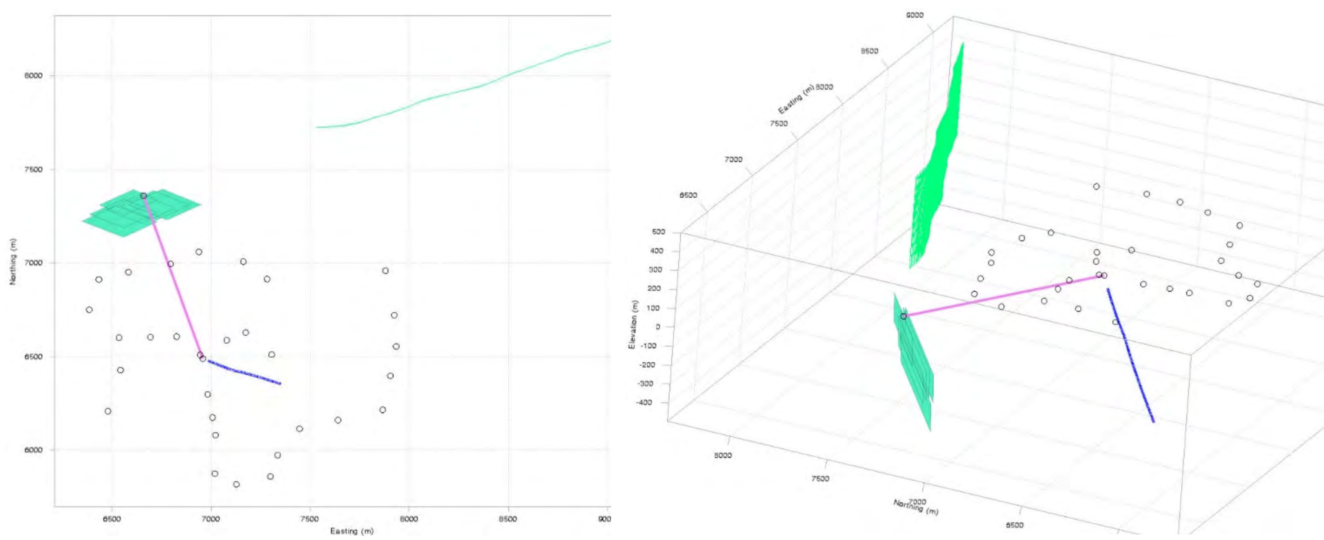


Figure 6. Reflector elements for Relf. No. 28, together with lineament IFZ018 mapped from surface. Left: view from above, Right: 3D view.

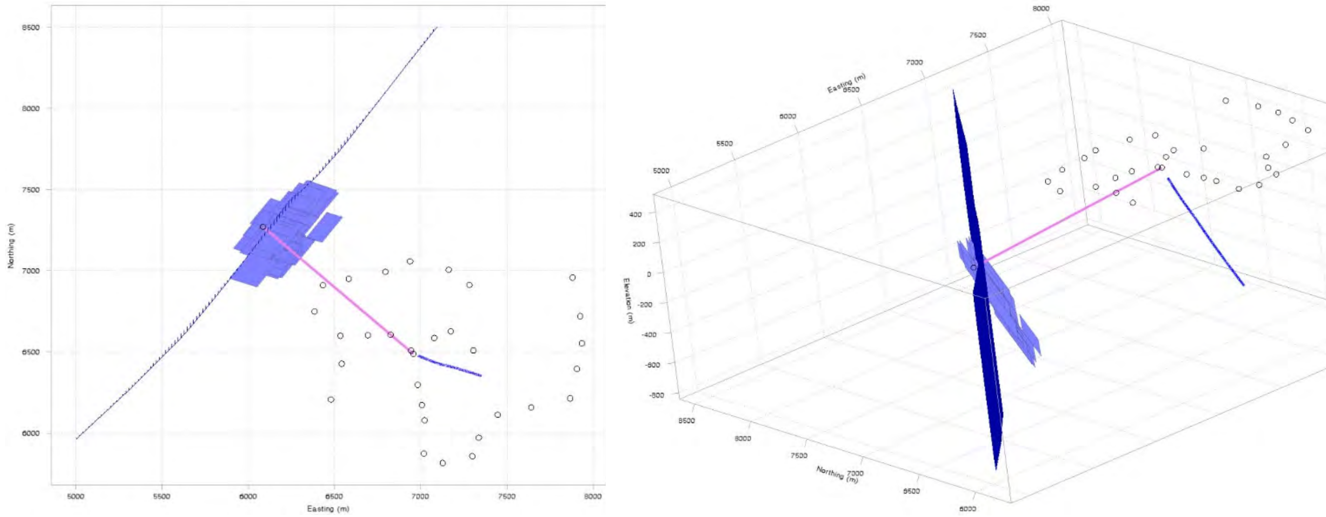


Figure 7. Reflector elements for Relf. No. 33, together with lineament IFZ004 mapped from surface. Left: view from above, Right: 3D view.

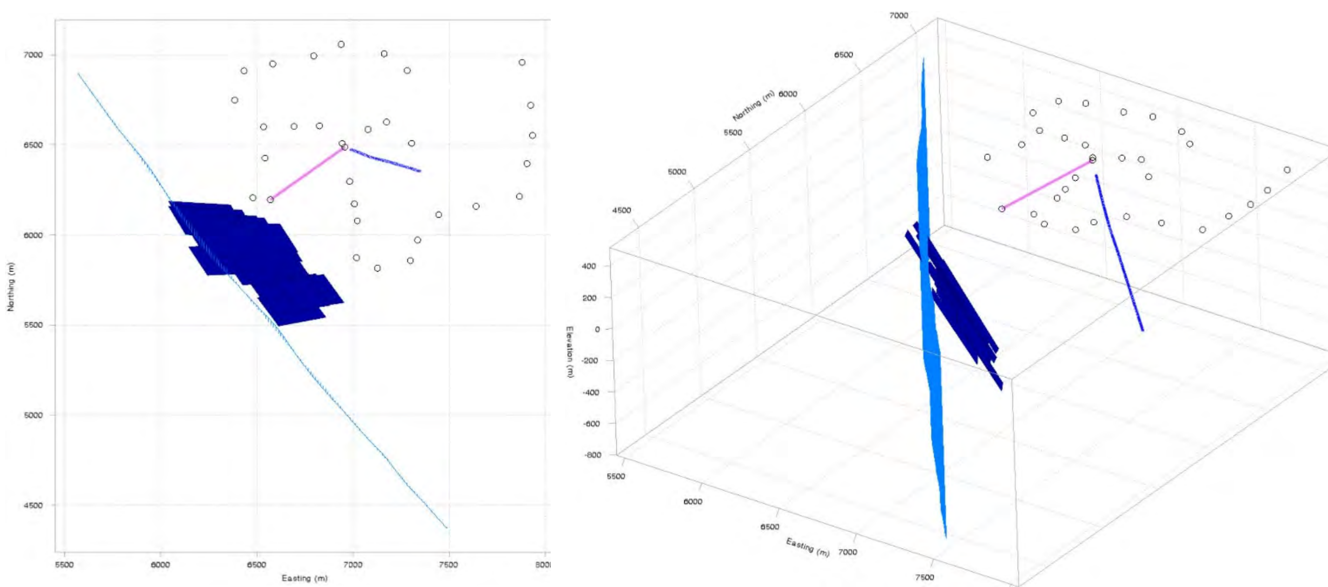


Figure 8. Reflector elements for Relf. No. 34, together with lineament IFZ012 mapped from surface. Left: view from above, Right: 3D view.

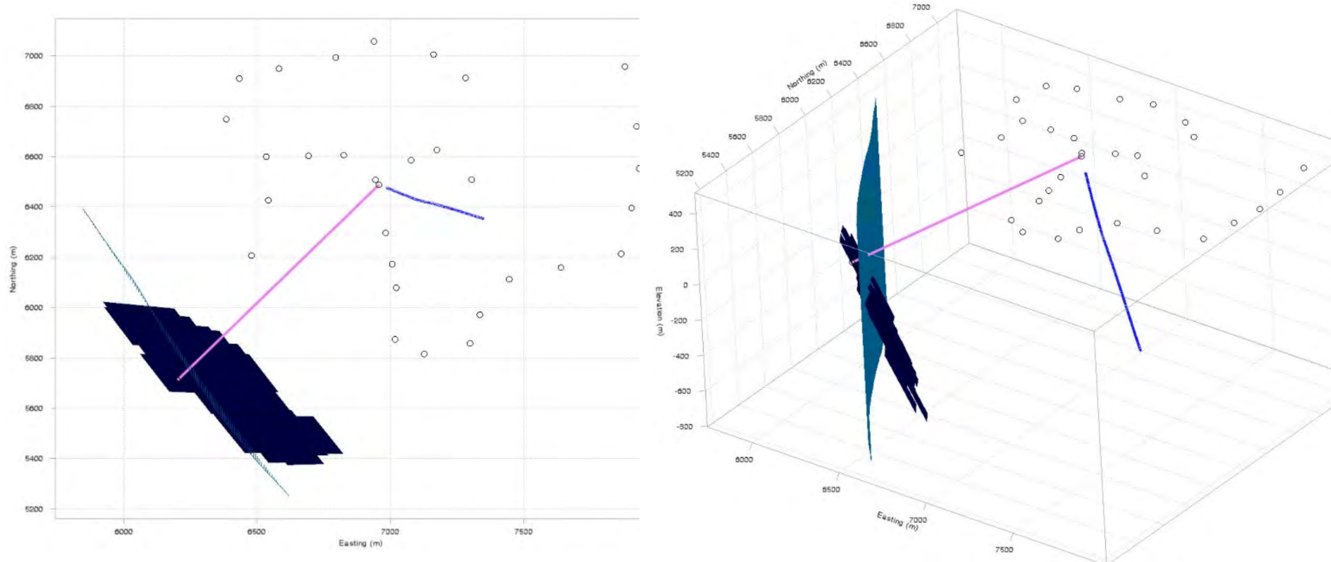


Figure 9. Reflector elements for Relf. No. 35, together with lineament IFZ030 mapped from surface. Left: view from above, Right: 3D view.

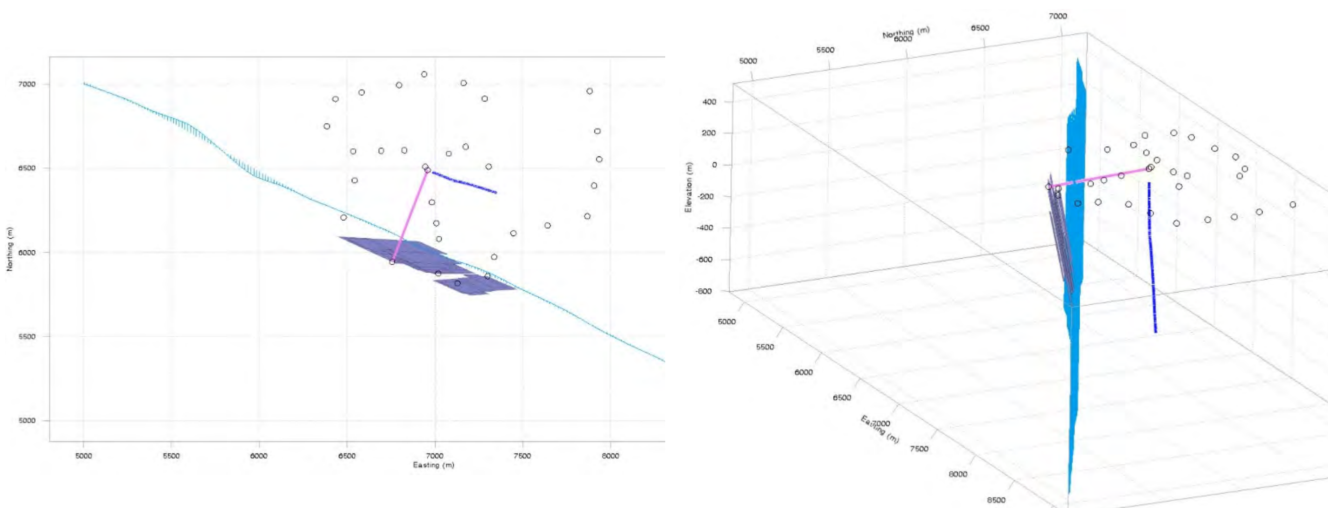


Figure 9. Reflector elements for Relf. No. 38, together with lineament DYKE01 mapped from surface. Left: view from above, Right: 3D view.