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Rapport: 13076		**Klassifikasjon**: Refraksjonsseismikk	
Tittel: Refraksjonsseismisk profilering RV94 Hammerfest juni 2013			
Forfatter: Peter O'Connor , poconnor@apexgeoservices.ie		**Oppdragsgiver**: Statens Vegvesen / Nord	
Kontaktperson oppdragsgiver: Bjørn Tore Olsen, bjorn.tore.olsen@vegvesen.no			
Fylke: Finnmark		**Kommune**: Hammerfest	
Feltarbeide fra - til: 13-15 juni 2013	**Rapportdato**: 17 juli 2013	**Prosjektnummer**: P13076	**Ansvarlig**: F. Ruden

Sammendrag: Seismisk refraksjonsprofilering ble gjennomført ved RV94 for Statens Vegvesen i forbindelse med oppgradering av RV94 og prosjektering av tunell ved Hammerfest. Formålet med undersøkelsene var å skaffe tilveie informasjon om løsmassemektigheter, løsmassbeskaffenhet samt bergkvalitet ved påhoggene ved Rypefjord og Breilia.

Undersøkelsene ble gjennomført ved seismisk refraksjonsprofilering for å bestemme mektigheter og kvalitet av underliggende geologi. Metoden baserer seg på seismisk hastighetsfordeling, og underliggende formasjoner bestemmes da ut fra målte seismiske hastigheter.

Ved Rypefjord ble det påvist lag bestående av et øvre tynt torvdekke, organsik jord, grus og sten, deretter oppsprukket fjell 1-5m over kompetent fjell.

I Breilia ble det et øvre lag består av 0.5-1.5m torv, organisk jord, grus og sten, deretter 0.2-4.0m med store blokker og oppsprukket fjell over kompetent fjell.

Seismisk profilering viser store variasjoner i hastighetsfordelingen som funksjon av orientering. Dette tyder på sterk seismisk anisotropi innen berggrunnen. Dette vises spesielt tydelig ved Rypefjord. Anisotropien kan skyldes foretrukne sprekk-orienteringer.

Informasjonen i denne rapporten bør revurderes når informasjon fra fremtidige grunnundersøkelser blir tilgjengelig.

Nøkkelord: Seismisk refraksjon, anisotropi

Godkjent: F. Ruden, ruden@rudenltd.com

PRIVATE AND CONFIDENTIAL

THE FINDINGS OF THIS REPORT ARE THE RESULT OF A GEOPHYSICAL SURVEY USING NON-INVASIVE SURVEY TECHNIQUES CARRIED OUT AT THE GROUND SURFACE. INTERPRETATIONS CONTAINED IN THIS REPORT ARE DERIVED FROM A KNOWLEDGE OF THE GROUND CONDITIONS, THE GEOPHYSICAL RESPONSES OF GROUND MATERIALS AND THE EXPERIENCE OF THE AUTHOR. R&P GEOSERVICES AS. HAS PREPARED THIS REPORT IN LINE WITH BEST CURRENT PRACTICE AND WITH ALL REASONABLE SKILL, CARE AND DILIGENCE IN CONSIDERATION OF THE LIMITS IMPOSED BY THE SURVEY TECHNIQUES USED AND THE RESOURCES DEVOTED TO IT BY AGREEMENT WITH THE CLIENT. THE INTERPRETATIVE BASIS OF THE CONCLUSIONS CONTAINED IN THIS REPORT SHOULD BE TAKEN INTO ACCOUNT IN ANY FUTURE USE OF THIS REPORT.

PROJECT NUMBER	13076		
AUTHOR	CHECKED	REPORT STATUS	DATE
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1. EXECUTIVE SUMMARY

R&P Geo Services AS was requested by Statens Vegvesen to carry out a geophysical survey as part of the ground investigations for tunnel construction associated with the upgrading and rerouting of the RV94 road around Hammerfest.

The investigation was conducted over the tunnel entrances at Rypefjord and Breilia. The survey comprised P-wave seismic refraction profiling conducted at the two sites.

The objectives of the survey were to provide information on the sediment and bedrock characteristics including type and thickness, depth to bedrock and bedrock quality.

The geological map for the area indicates that the survey area at Breilia is underlain by quartz-feldspar gneiss and the survey area in Rypefjord is underlain by granite-kyanite-sillimanite mica schists.

Two seismic velocity layers were interpreted at Rypefjord. Layer 1 varies in thickness from 1 to 5m and has been interpreted as peat, organic soil, gravels and boulders, and fractured rock. It is thickest along Line 1 and in the low lying (valley) parts of line 2.

Layer 2 at Rypefjord represents competent bedrock. The most significant feature of the data is the large difference between the bedrock seismic velocity on Line 1 and Line 2. The most likely cause of this is anisotropic variation due to fracturing of the bedrock. The average seismic velocity between the two lines in 3450 m/s.

Three seismic velocity layers were interpreted at Breilia. Layer 1 varies in thickness from 0.5 to 1.5m and has been interpreted as peat, organic soil, gravels and boulders. Layer 2 varies in thickness from 0.2 to 4.0m and has been interpreted as large boulders and fractured rock. Layer 3 is competent bedrock.

The pattern of increased seismic velocity of the bedrock for lines running SW-NE also occurs at Breilia but not to the same extent as at Rypefjord, indicating that similar anisotropic effects exist here. Also the decrease in bedrock seismic velocity from Line 1 to Line 3 (towards the NW) indicates poorer rock quality in this direction.

Any available engineering geological, borehole or rock strength data for the Rypefjord and Breilia sites should be incorporated into a revised version of this initial seismic report.

2. INTRODUCTION

R & P Geo Services AS was requested by Statens Vegvesen, to carry out a geophysical survey as part of the ground investigations for a tunnelling project related to the upgrade and rerouting of the RV94 roadway around the town of Hammerfest.

2.1 Survey Objectives

The objectives of the survey were to:

1. Provide information on the type and thickness of the sediments.
2. Estimate the depth to bedrock and the type and quality of bedrock.

2.2 Site Background

The investigation was carried out over the locations of two tunnel entrances at Breilia in Hammerfest and in Rypefjord about 4km to the south.

The survey area at Breilia covers approximately 0.18Ha of open northwest – southeast oriented hillside with topography ranging 20-45 mOD. Outcrop and very large boulders are present over much of the site with a thin layer of vegetation consisting of moss and heather.

In the south the Rypefjord survey area covers approximately 0.5Ha with topography varying from 20-57 mOD. The area is cross cut by small ridges and valleys oriented northeast – southwest. The hillside is cover by moss, heather and low lying shrubbery with outcrop and boulders present.

Fig.2.1. Survey locations (highlighted in red).

Fig.2.2. Breilia Location

Fig.2.3. Rypefjord Location

2.2.1 Geology

The Geological Survey of Norway (NGU) geology map (Fig.2.4) indicates that the Breilia site is underlain by grey, coarse grained quartz-feldspar gneiss of a tonalitic composition. Layers of granitic-gneiss and pegmatite veins are also present. The map shows the survey area lies close to a contact with feldspar rich, middle – coarse grained sandstone to the east.

The Rypefjord survey area lies within light coloured granite-kyanite-sillimanite-micaschists which show migmatisation with pegmatite.

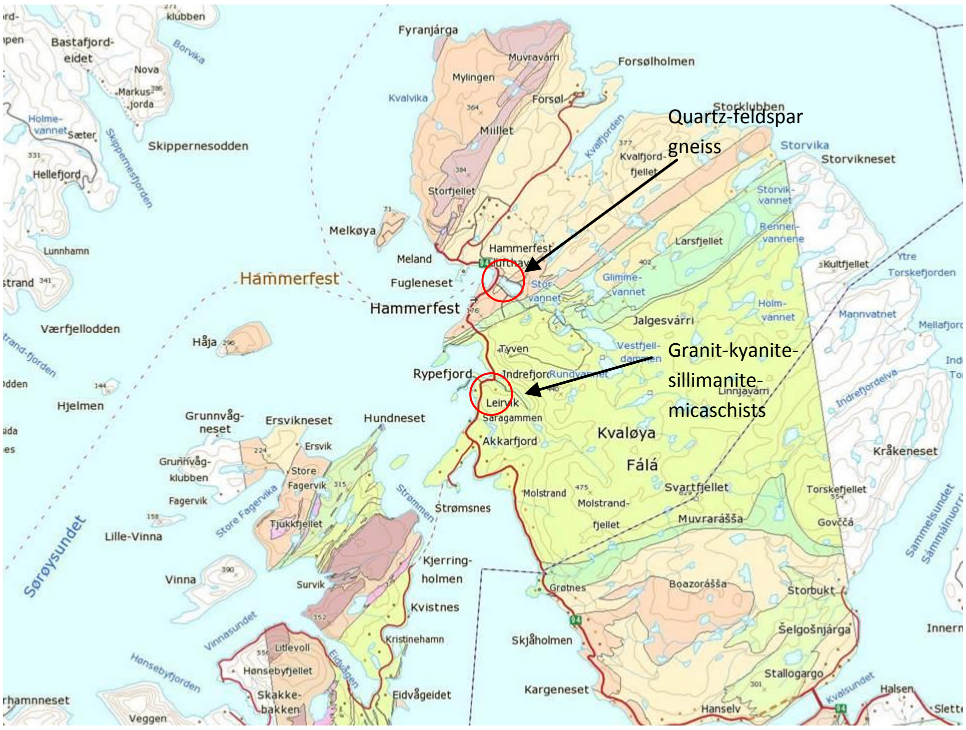

Figure 2.4. Geology of the survey locations (highlighted in red).

2.3 Survey Rationale

Seismic Refraction Profiling measures the velocity of refracted seismic waves through the overburden and rock material and allows an assessment of the thickness and quality of the materials present to be made. Stiffer and stronger materials usually have higher seismic velocities while soft, loose or fractured materials have lower velocities.

Further information on the detailed methodology of each geophysical method employed in this investigation is given in **APPENDIX A: DETAILED GEOPHYSICAL METHODOLOGY**.

3. FINDINGS

The results and interpretation of the investigation are presented in Drawings 13079_01 – 13079_07.

3.1 Seismic Refraction Profiling at Rypefjord

Seismic refraction Line 1 (S1 & S2) and Line 2 (S3 & S4) were recorded across the survey area at Rypefjord. The locations of the profiles are shown on the drawing 13079_01. Line 1 runs SW-NE parallel to the main topographic trend while Line 2 runs S-N and crosses the topographic trend.

The data quality was generally fair-good. The seismic data outlined two P-wave velocity (Vp) layers which have been interpreted as shown in Table 3.1 below.

Layer	Velocity Range (m/s)	Average Velocity (m/s)	Thickness Range (m)	Average Thickness (m)	Material
1	200-650	400	1 – 5	2	Peat, organic soil, gravels and boulders, weathered rock
2	1800-6000	3450*			Bedrock

*There is a large difference between the bedrock seismic velocity on Line 1 and Line 2. The most likely cause of this is azimuthal variation due to fracturing of the bedrock.

Table 3.1 – Seismic Refraction Interpretation for Rypefjord

2.2 Seismic Refraction Profiling at Breilia

Three refraction Lines 1 - 3 were recorded across the survey area at Breilia. The locations of the profiles are shown on the drawing 13079_04. The topography in this area was steep and irregular with very large boulders present in places.

The data quality was fair-good.

The seismic data typically outlined three P-wave velocity (Vp) layers and have been interpreted as shown in Table 3.2 below.

Layer	Velocity Range (m/s)	Average Velocity (m/s)	Thickness Range (m)	Average Thickness (m)	Material
1	200-800	450	0.5 – 1.5	0.7	Peat, organic soil, gravels and boulders,
2	550-1300	800	0.2 – 4.0	1.8	Large boulders, fractured rock
3	1900-5000	3200*			Bedrock

Table 3.2 – Seismic Refraction Interpretation for Breilia

4.0 DISCUSSION

4.1 Rypefjord

A location map and two cross sections have been generated to show the results of Lines 1 and 2 at Rypefjord. These are shown on drawings; AGL13079_01 to AGL13079 _03.

The interpreted seismic data shows two velocity layers. (Layer I has been interpreted on all seismic spreads, even in areas where rock outcrop is at the surface. This is due to the relaxation of joints in the near surface which gives rise to a very thin layer of low seismic velocity material.)

Layer 1 varies in thickness from 1 to 5m and has been interpreted as peat, organic soil, gravels and boulders, and fractured rock. Rock outcrop occurs along the elevated parts of Line 2 and at the south-western end of Line 1. Layer 1 is thickest along Line 1 and in the low lying (valley) parts of line 2. Layer 2 represents competent bedrock.

The most significant feature of the data is the large difference between the bedrock seismic velocity on Line 1 and Line 2. The most likely cause of this is azimuthal variation due to fracturing of the bedrock. Line 1, which has the highest bedrock seismic velocity, runs SW-NE along a topographic low. Line 2, which has the lower bedrock seismic velocity, runs across the topographic trend.

Azimuthal or anisotropic variation of seismic P-wave velocity of up to 25% in rocks with a well developed foliation, cleavage or fracture pattern is commonly observed, but the magnitude of the variation in this case is greater than usually encountered.

This pattern of topographic lows is repeated on a regional scale in the area south of Rypefjord and is presumably related to the tectonic history of the area. The average seismic velocity between the two lines in 3450 m/s.

4.1 Breilia

A location map and three cross sections have been generated to show the results of Lines 1, 2 and 3 at Breilia. These are shown on drawings; AGL13079_04 to AGL13079 _07.

The interpreted seismic data shows three velocity layers. (These have been interpreted on all seismic spreads, even in areas where rock outcrop is at or close to the surface. This is due to the relaxation of joints in the near surface which gives rise to a very thin layer of low seismic velocity material.)

Layer 1 varies in thickness from 0.5 to 1.5m and has been interpreted as peat, organic soil, gravels and boulders. Layer 2 varies in thickness from 0.2 to 4.0m and has been interpreted as large boulders and fractured rock. Layer 3 is competent bedrock.

Rock outcrop occurs along parts of all three lines.

Line 1 runs from NE-SW with apparent outcrop at the north-eastern end and very large boulders at the south-western end (the geophones were placed at the base of the large boulders so depth measurements refer to this point). The depth to competent rock along this profile ranges from 1.5 to 5.5m. The bedrock velocity is generally around 3600 m/s increasing to 5000 m/s at the north-eastern end.

Line 2 runs from SE-NW with apparent outcrop at the south-eastern end (in front of house) and some large bounders in the middle of the line. The depth to competent rock along this profile ranges from 0.5 to 4.0m. The bedrock velocity is high at the south eastern (3600 m/s) but decreases rapidly to around 2200 m/s at the north-western end. This may be due to a fault or fracture zone associated with the major break in topography that runs approximately N-S at this point.

Line 3 runs from NE-SW along the base of the topographic break mentioned above. Some outcrop also occurs on this line. The depth to competent rock along this profile ranges from 2.0 to 5.0m. The bedrock velocity is generally around 3200 m/s increasing to 4000 m/s at the south-western end.

The pattern of increased seismic velocity of the bedrock for lines running SW-NE also occurs at Breila but not to the same extent as at Rypefjord, indicating that similar anisotropic effects exist here. Also the decrease in bedrock seismic velocity from Line 1 to Line 3 (towards the NW) is indicates poorer rock quality in this direction.

5.0 RECOMMENDATIONS

Any available engineering geological, borehole or rock strength data for the Rypefjord and Breilia sites should be incorporated into a revised version of this initial seismic report.

6. REFERENCES

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7. APPENDIX A: DETAILED METHODOLOGY

7.1 Seismic Refraction Profiling

Principles

The seismic refraction profiling method measures the velocity of refracted seismic waves through the overburden and rock material and allows an assessment of the thickness and quality of the materials present to be made. Stiffer and stronger materials usually have higher seismic velocities while soft, loose or fractured materials have lower velocities. Readings are taken using geophones connected via multi-core cable to a seismograph.

Data Collection

Twelve seismic profiles were recorded between the 13th and 15th June 2013 using a Geode high-resolution 24 channel seismograph with spacings of 2m. The source of the seismic waves was a 5 kg sledgehammer.

The topography in the survey areas was variable with steep increases in elevations sometimes occurring over short distances. Ground conditions consisted of rock outcrop and rock covered by thin peat, organic soil and gravelly glacial material.

The upper 10-20cm of soft peat and organic soil was removed at each geophone and hammer location in order to give better coupling of the seismic signal. Seismic records were made at 7 hammer locations on each 24 channel (46m) set up. These consisted of two end shots, three shots within the geophone spread, and off shots at either end to provide continuous seismic coverage of the bedrock. The off shot distance was selected based on the crossover distance observed on each end shot. Up to 10 shots were stacked at each location to achieve a clear first break.

Data quality was generally good. The first arrival from the bedrock was generally a high frequency, low amplitude signal which was sometimes degraded if thick soft peat or organic material was present. Only clear and unambiguous first breaks were used in the subsequent processing.

The weather was good with sunny or overcast conditions and only slight wind.

Data Processing

The recorded data was interpreted using the ray-tracing and intercept time methods, to acquire depths to layer boundaries and the P-wave velocities of these layers, using the FIRSTPIX and GREMIX programs.

GREMIX interprets seismic refraction data as a laterally varying layered earth structure. It incorporates the slope-intercept method, parts of the Plus-Minus Method of Hagedoorn (1959), Time-Delay Method, and features the Generalized Reciprocal Method (GRM) of Palmer (1980). Up to four layers can be mapped, one deduced from direct arrivals and three deduced from refractions. Phantoming of all possible travel time pairs can be carried out by adjusting reciprocal times of off shots.

Relocation

All data were located using a combination of hand-held GPS and hand measurements off walls and buildings. All datasets were referenced to the UTM coordinate system.

8. APPENDIX B: DRAWINGS

The information derived from the geophysical investigation is presented in the following drawings:

13079_01	Figure 1: Rypefjord Geophysical Locations	1:1000 @ A4
13079_02	Figure 1: Rypefjord Line 1 Seismic Refraction Data	1:1000 @ A4
	Figure 2: Rypefjord Line 1 Seismic Refraction Interpretation	1:1000 @ A4
	Figure 3: Rypefjord Line 1 S1 & S2 Seismic Velocity Data	1:1000 @ A4
13079_03	Figure 1: Rypefjord Line 2 S3 & S4 Seismic Refraction Data	1:1000 @ A4
	Figure 2: Rypefjord Line 2 S3 & S4 Seismic Refraction Interpretation	1:1000 @ A4
	Figure 3: Rypefjord Line 2 S3 & S4 Seismic Velocity Data	1:1000 @ A4
13079_04	Figure 1: Breilia Geophysical Locations	1:1000 @ A4
13079_05	Figure 1: Breilia Line 1 Seismic Refraction Data	1:750 @ A4
	Figure 2: Breilia Line 1 S5 Seismic Refraction Interpretation	1:750 @ A4
	Figure 3: Beilia Line 1 Seismic Velocity Data	1:750 @ A4
13079_06	Figure 1: Breilia Line 2 Seismic Refraction Data	1:750 @ A4
	Figure 2: Breilia Line 2 Seismic Refraction Interpretation	1:750 @ A4
	Figure 3: Breilia Line 2 Seismic Velocity Data	1:750 @ A4
13079_07	Figure 1: Breilia Line 3 Seismic Refraction Data	1:750 @ A4
	Figure 2: Breilia Line 3 Seismic Refraction Interpretation	1:750 @ A4
	Figure 3: Breilia Line 3 Seismic Velocity Data	1:750 @ A4

9. APPENDIX C: SEISMIC REFRACTION PLATES

The information derived from the P-wave seismic refraction profiles is shown in the following plates:

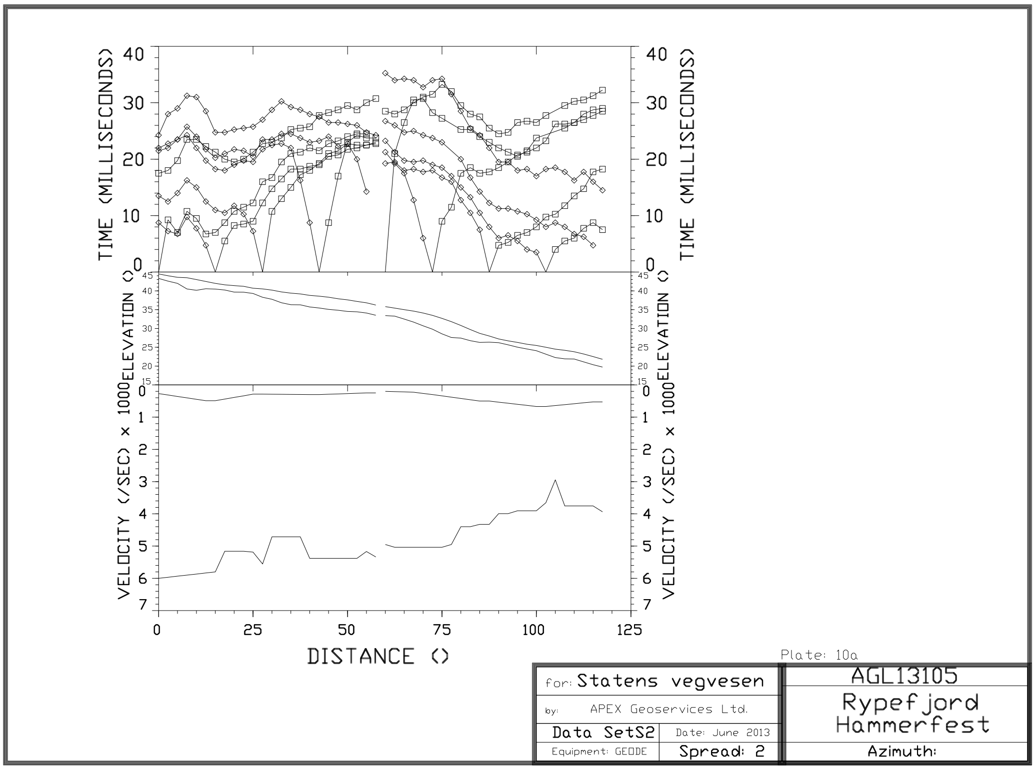

Figure 9.1. Rypefjord Line 1.

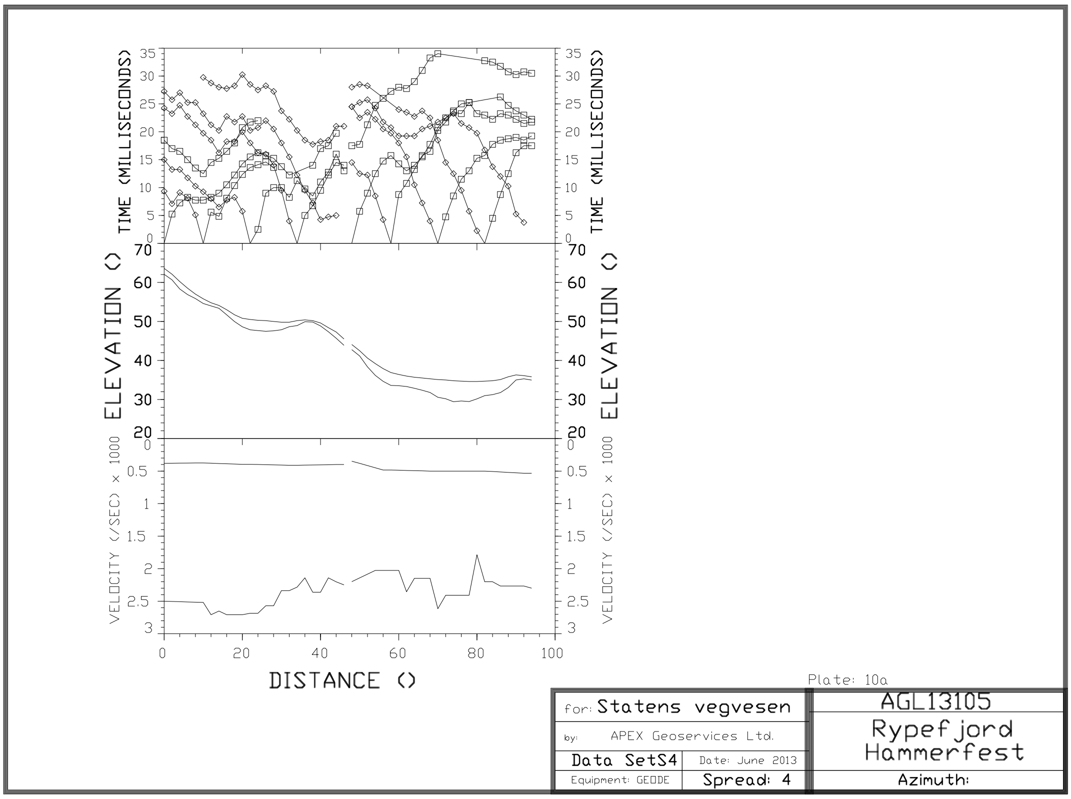

Figure 9.2. Rypefjord Line 2.

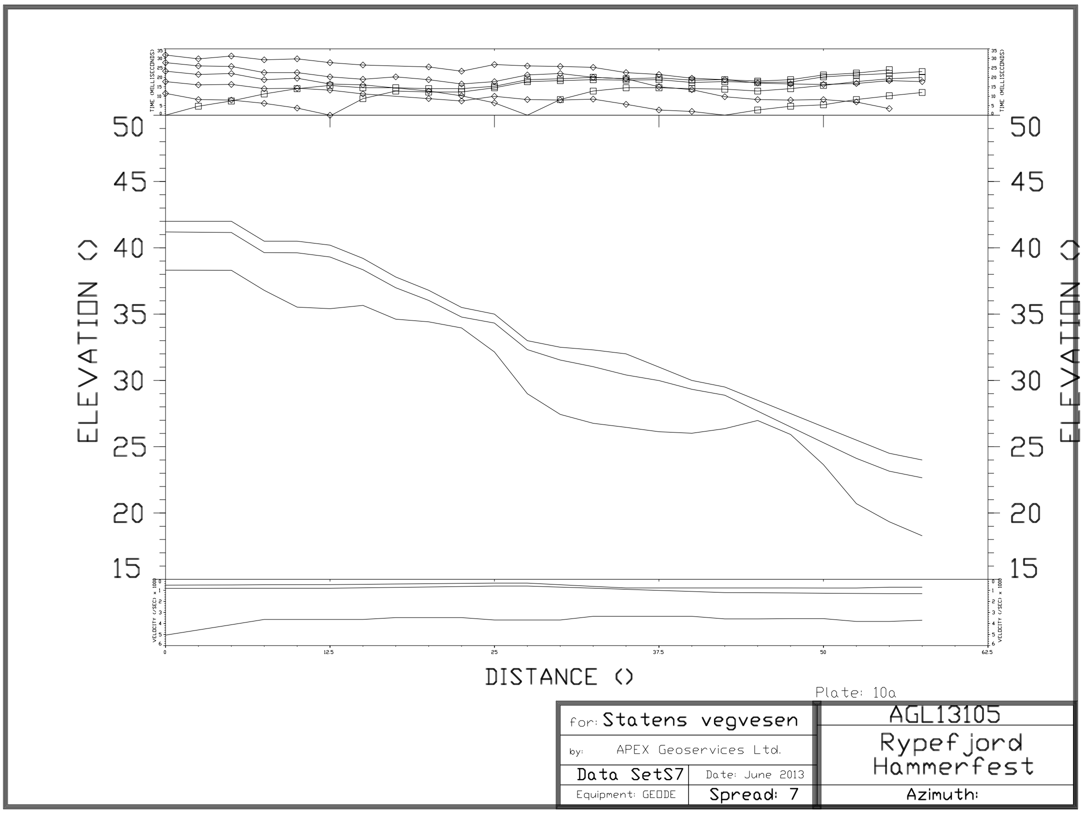

Figure 9.3. Breilia Line 1.

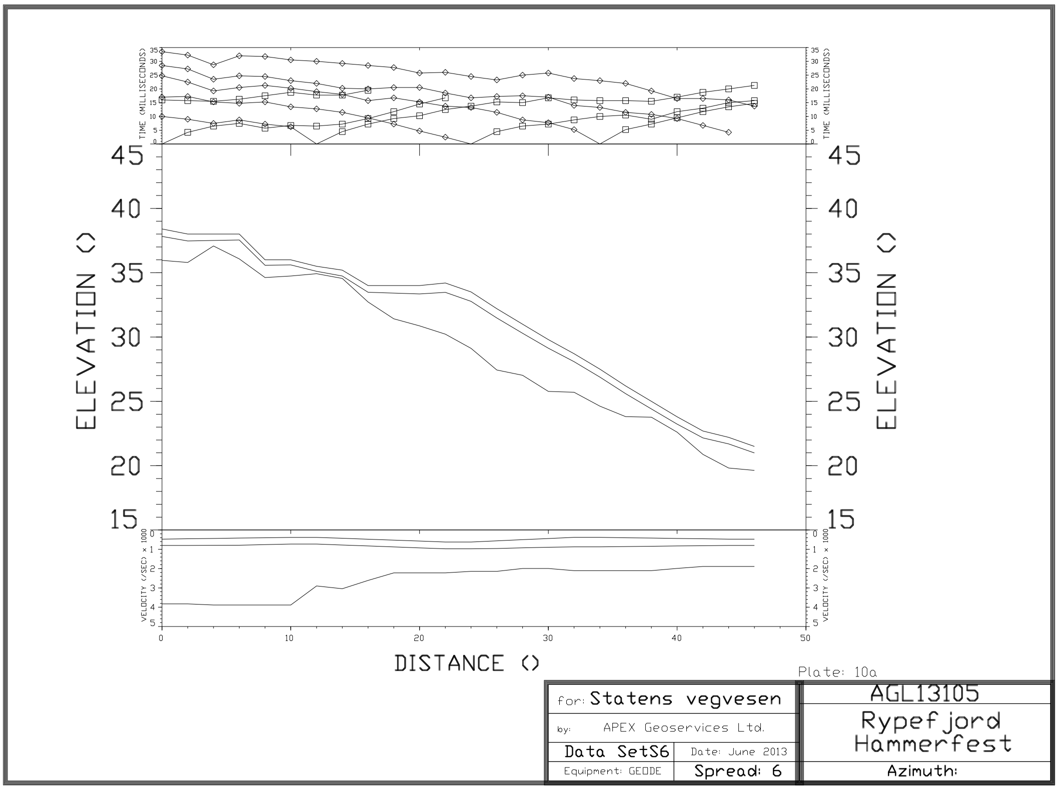

Figure 9.3. Breilia Line 2.

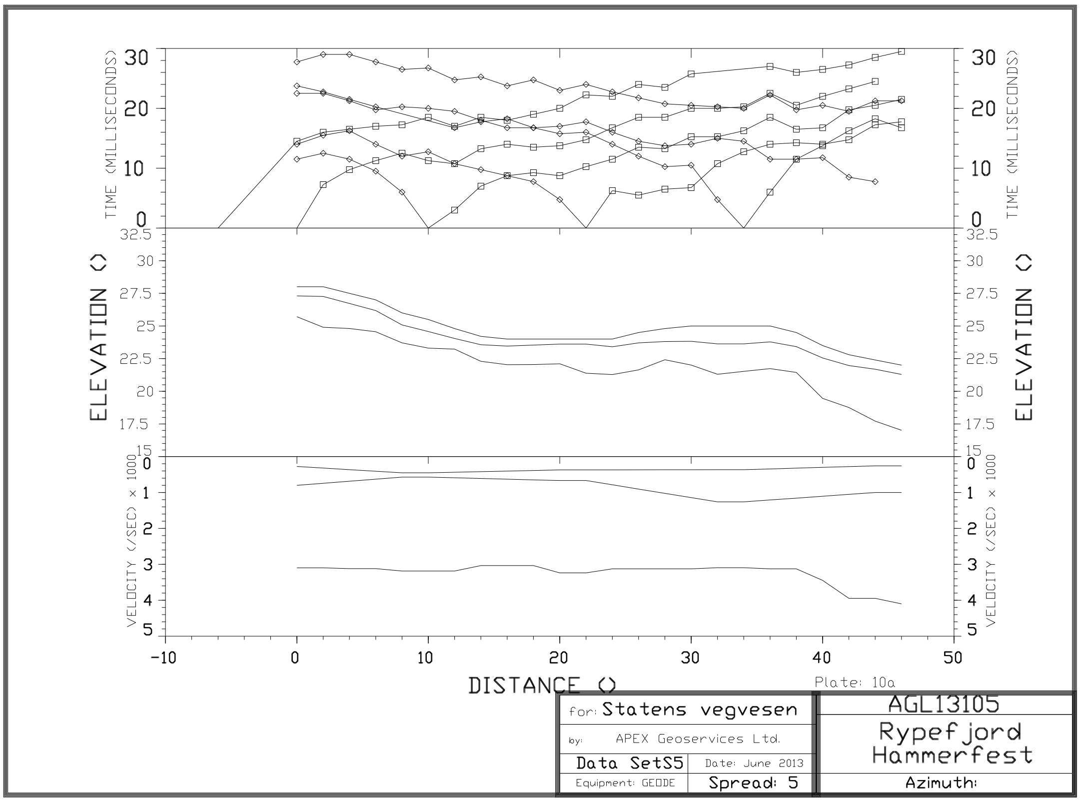

Figure 9.3. Breilia Line 3.