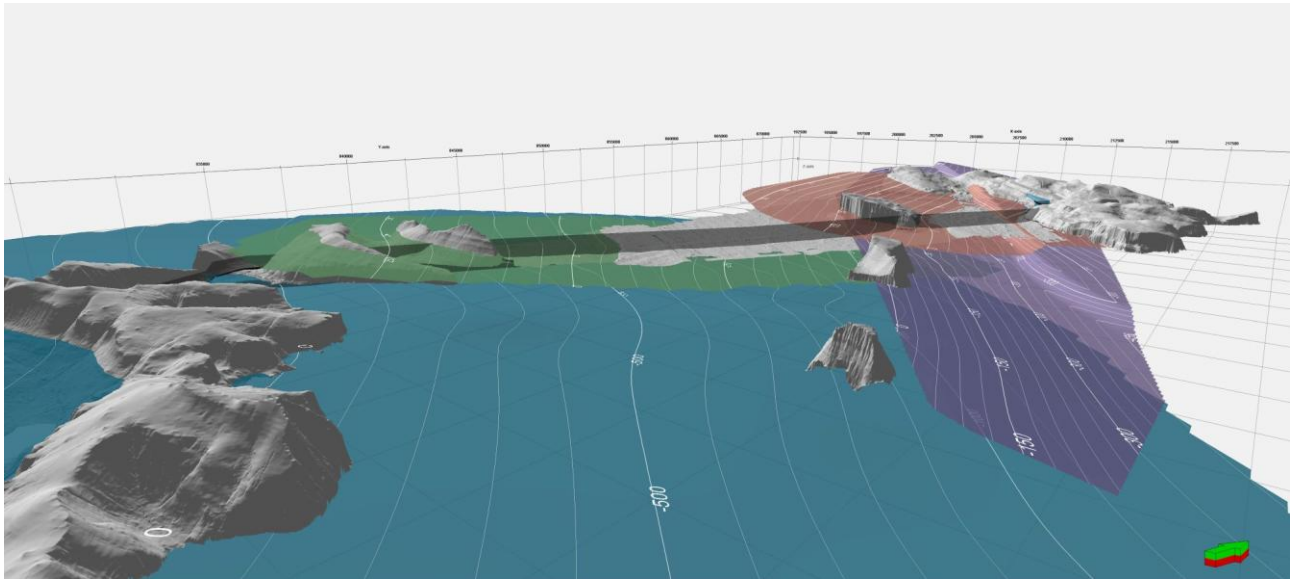
Geological description of the Suðuroy tunnel area.

Report to P/F Suðuroyartunnil



Written and compiled by:

Uni K. Petersen, Turid Hátún Madsen, Uni E. Árting, Bartal Højgaard, and Heri Ziska

Jarðfeingi report JF-J-2025-05

JARÐFEINGI
Faroese Geological Survey

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Executive Summary

A subsea tunnel is planned between between the islands of Sandoy and Suðuroy. This tunnel, which is called the Suðuroyar Tunnel, starts in Djúpadalur on Sandoy and resurfaces in Sandvík on Suðuroy.

Jarðfeingi has been commissioned by P/F Suðuroyartunnilin to produce a geological description of a chosen tunnel route. Previous studies in the area, which investigated three different tunnel options have previously been done by Jarðfeingi, and the work in relation to these informed Jarðfeingi as to what kind of information would help in filling the gaps in previous studies.

It was decided that a better constraint on the A-horizon (top of the Beinisvørð Formation) was needed near both ends of the tunnel. Therefore, wells were drilled in Sandvík and on Skúgvoy, with the well on Skúvoy having the added task of providing geophysical information (log-data), that would help tie the drilled geology to the seismic data acquired offshore. One well was also drilled near the planned entry point in Djúpadalur in order to constrain the local geology, this was supplemented with new fieldwork both on Sandoy, Skúvoy and Suðuroy. Information in inaccessible areas was acquired by drones.

One key task was to map out fractures and dykes that might intersect the planned tunnel profile. These are, where the bedrock (basalt) is exposed, easy to map. This becomes challenging where there is an overburden. To address this, magnetic data were acquired. Offshore multibeam bathymetric data were used. To ensure optimum connection to the geology along the coast was targeted specifically with photos and observations from a boat.

The area between Skúgvoy and Suðuroy is all subsea with no outcrop on either side to inform geological analysis. Seismic data is an aid, but Geochemical data were also used in order to further constrain the stratigraphic correlation over such a long distance. The total data coverage is seen on Figure 1.

The integration of onshore geology, well logs, geochemistry and seismic data has enabled a confident correlation between Suðuroy and Skúgvoy. The integration did, also solve a discrepance between different data types on eastern part of Sandoy compared to the western part and Skúgvoy. The discrepance, which had made correlations across ambiguous, is due to the area being subjected to tectonic stress, which has created a fold which runs sub-parallel to the west coast of Sandoy between Skarvanes and the village of Sandur, offsets the geology 170-180 m.

These results show that that planned tunnel will start in the Enni Formation on Sandoy, where it will intersect a section with volcaniclastic sediments separating the lava flows. After drilling through these it will enter the fold, where it will drill upp (stratigraphically) through the unit again, and then once more down through the unit (Figure 2). After penetrating the unit, the third time it drills through the compound flows of the Malinstindur formation, which it remains within until it terminates in Sandvík.

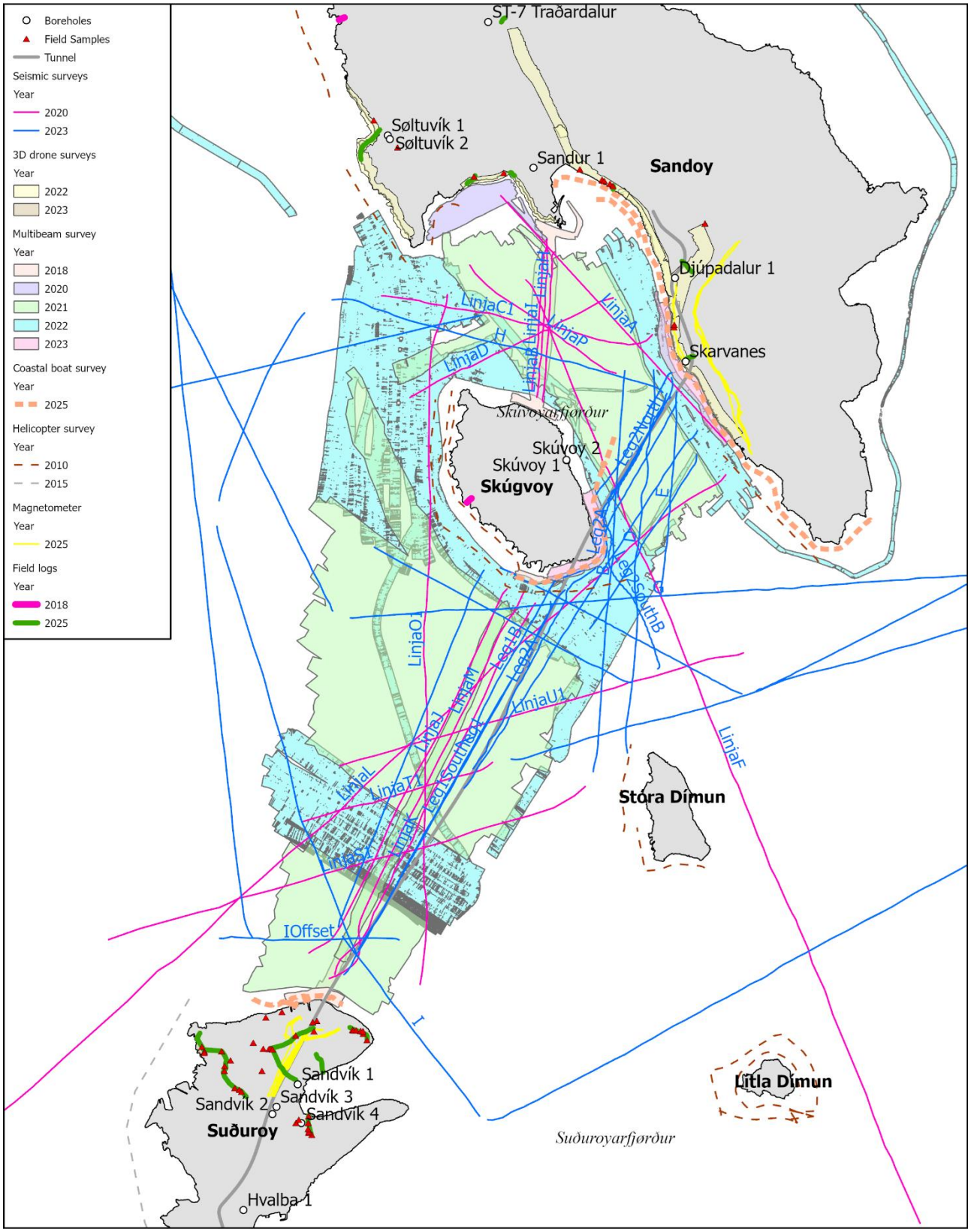


Figure 1. Data coverage map shows the extend of different surveys done in regards to the Suðuroy subsea tunnel from 2016 to 2025 (same as Figure 8).

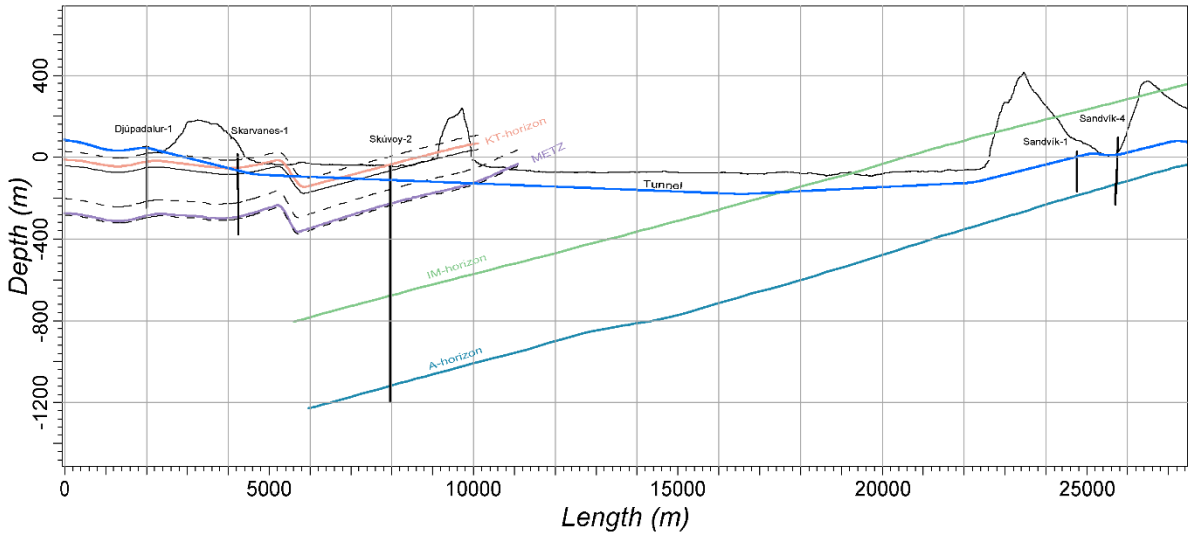


Figure 2. Cross section the tunnel profile (same as Figure 86).

Field work, supported by magnetic surveying, has shown the presence of some fractures and dykes (Figure 3). Some of these can be traced offshore on the Bathymetric data near Sandoy, Skúvoy and Suðuroy, while others do not have an expression on the bathymetry data. Similarly, there are instances where interpreted lineaments (fractures) on the bathymetric data are not seen on coastal survey data or by fieldwork. These fractures are mostly seen in the area around Sandoy and Skúgvoy and to some extent just north of Suðuroy.

Most of the area between Suðuroy and Skúgvoy is devoid of lineaments on the available bathymetry data, suggesting only a few fractures and/or dykes in the area. The Malinstindur formation is often sparsly fractured compared to the Beinisvørð and Enni Formations, which can be the reason that there is little evidence in the bathymetry data, that suggests large fractures or dykes in the area between Skúvoy and Suðuroy. It is, however, not possible to verify this due to the long distance to onshore observations.

Further work to better understand the nature and extent of the fold, including how the process of folding might have affected the fracture pattern of the folded units can be addressed by wells targeting the fold as well as further fieldwork on the northern part of the island, where the fold is seen.

Further work to increase the confidence in the possible absence of fractures between Suðuroy and Skúgvoy, can include acquisition of magnetic data acquired no more than 10 m from the seabed.

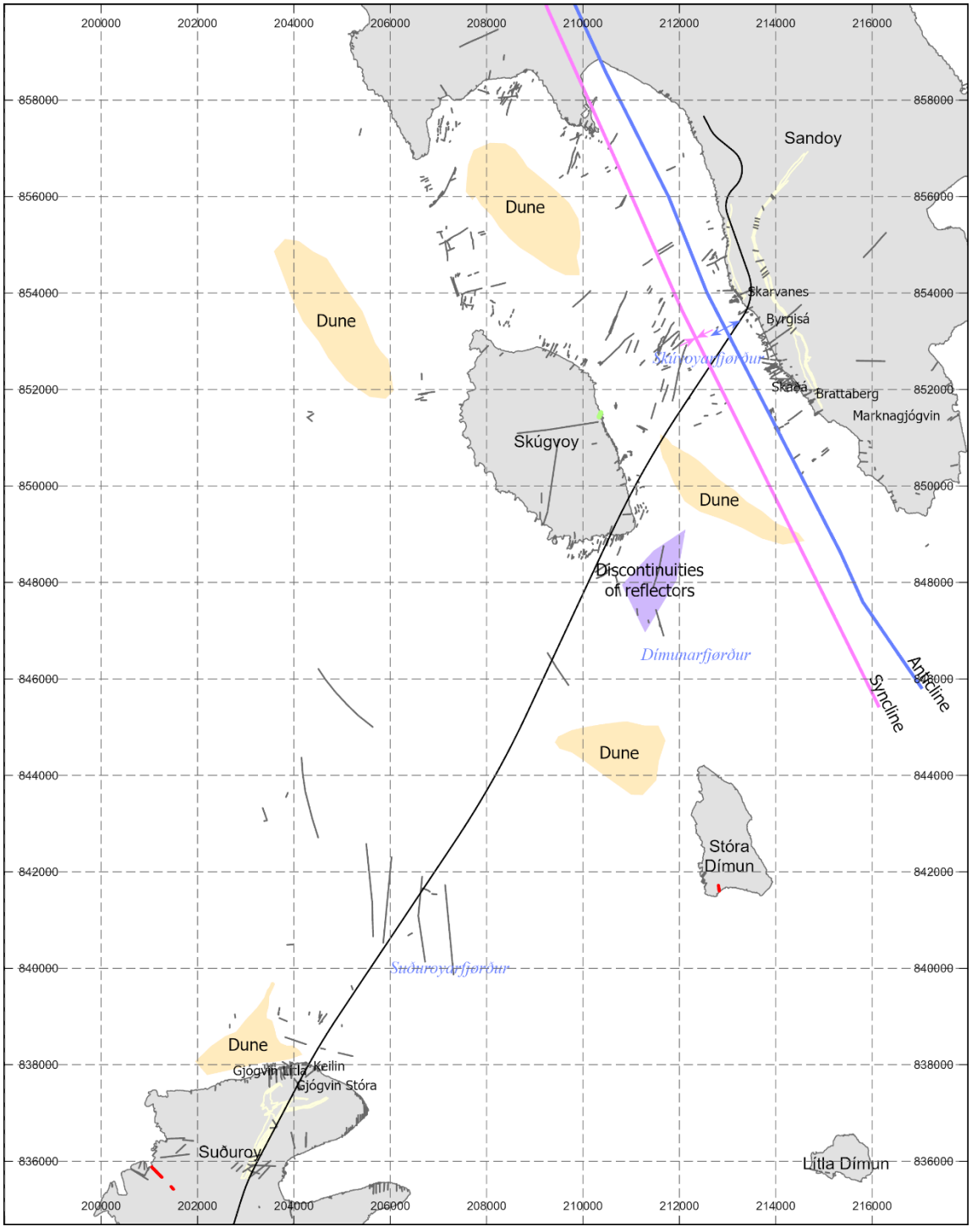


Figure 3. Map of relative large lineaments, fractures and dykes in the project area (same as Figure 34).

Introduction

Jarðfeingi has been commissioned by P/F Suðuroyartunnilin to produce a geological description of a chosen tunnel route from Djúpadalur on Sandoy to Sandvík on Suðuroy (Figure 4). This description builds on previous work done in related to planning of the Suðuroytunnil (Heinesen, Madsen, & Højgaard, 2018; Petersen, Madsen, Árting, & Højgaard, 2022), but is updated with new data, which includes three new boreholes, one in Djúpadalur, one on Skúgvoy and one in Sandvík. Additional new 2D seismic reflection data (Petersen, 2023) and multibeam bathymetric data have been acquired where there were gaps in the data coverage. Onshore observations have been expanded with new fieldwork (Appendix D and E). Magnetic data have been acquired onshore in order to optimise the chance of locating fracture zones, and geochemical analysis (Appendix F) has been performed to improve the confidence in the geological correlation across Suðuroyarfjørð.

This report only gives geological description of the main tunnel from Skarvanes to Sandvík. Therefor the side tunnel to Skúvoy and the tunnel from Sandvík to Hvalba are not included in this report.

The report also includes relevant summaries from other tunnels in similar stratigraphy both subsea tunnels and onshore tunnels.



Figure 4. Topographic map of the project area including place names and the existing roads (red) between villages and sail routes (blue dashed) between islands. The planned subsea tunnel trace, SUTU-Linja11, rendered with solid black line, connects the islands of Sandoy and Suðuroy and traverses beneath the island of Skúvoy.

History of tunnel line

Two drafts, “Linja 3” and “Linja 3.1” of the tunnel line were received from LBF on the 3rd of April 2023. The drafts were tended to be placeholders until Norconsult delivered their version. The drafts included two different versions of side tunnels to Skúvoy. Jarðfeingi received a new version, created by Norconsult, from LBF on the 1st of February 2024 called “plan-og-profil_2023-10-12". This version did also have a side tunnel to Skúvoy, although both the main tunnel line and side tunnel were different than the first drafts. A similar, if not identical version to “plan-og-profil_2023-10-12", in 3D, was received from LBF on the 18th of February 2025, named “SUTU-Linja11”. However, no side tunnel to Skúvoy was included in this version. “SUTU-Linja11” was later confirmed on the 2nd of September 2025 by LBF to still be valid, however, only from station 6.5 (see map Appendix C). Therefore, “SUTU-Linja11” is the version used in this report. Be aware that a later version, “1A”, has been created and presented by Norconsult and P/F Suðuroyartunnilin, respectively. According to LBF, it is believed that “SUTU-Linja11" and “1A” are identical. However, the station numbering is different in “1A” to “SUTU-Linja11”, and the side tunnel to Skúvoy in “1A” is different than all previous versions mentioned here.

Geology of tunnel area

The Palaeogene (66–23 Ma) Faroe Islands Basalt Group (FIGB, 62–55 Ma) consists of seven formations, which are, from oldest to youngest, Lopra, Beinisvørð, Prestfjall, Hvannhagi, Malinstindur, Sneis, and Enni Formations (Passey & Jolley, 2009; Rasmussen & Noe-Nygaard, 1969, 1970), Figure 5. The lowermost, Lopra Formation (>1,000 m thick), is composed of various volcaniclastic lithologies and sills and is only encountered in the Lopra-1/1A borehole. The Beinisvørð Formation (ca. 3,300 m thick) is dominated by thick, laterally extensive, aphyric sheet lobes (Figure 6) and is exposed to the south and the extreme west of the archipelago. The Prestfjall Formation (ca. 15 m thick) consists of various volcaniclastic sedimentary units including coal. The Hvannhagi Formation (< 100 m thick) is a mixture of interbedded basaltic tuffs and volcaniclastic sedimentary units. Prestfjall and Hvannhagi Formations are exposed in the northern part of Suðuroy and in the western part of Vágoy. The Malinstindur Formation (ca. 1,400 m thick) is predominantly composed of compound flows (Figure 6) consisting of olivine-phyric, through aphyric and plagioclase-phyric basalt, and is found throughout the islands except from the extreme southern, western, and eastern parts. The Sneis Formation (< 50 m thick) is a sandstone-conglomerate sequence that has been intruded by distinct aphyric tabular basalts. The uppermost Enni Formation (ca. 700 m thick) is composed of interbedded sheet lobes (akin to those of the Beinisvørð Formation) and compound lava flows (akin to those of the Malinstindur Formation) and is exposed throughout the central and northern regions. The Lopra, Beinisvørð, Malinstindur and Enni Formations constitute most of the total thickness of the FIBG.

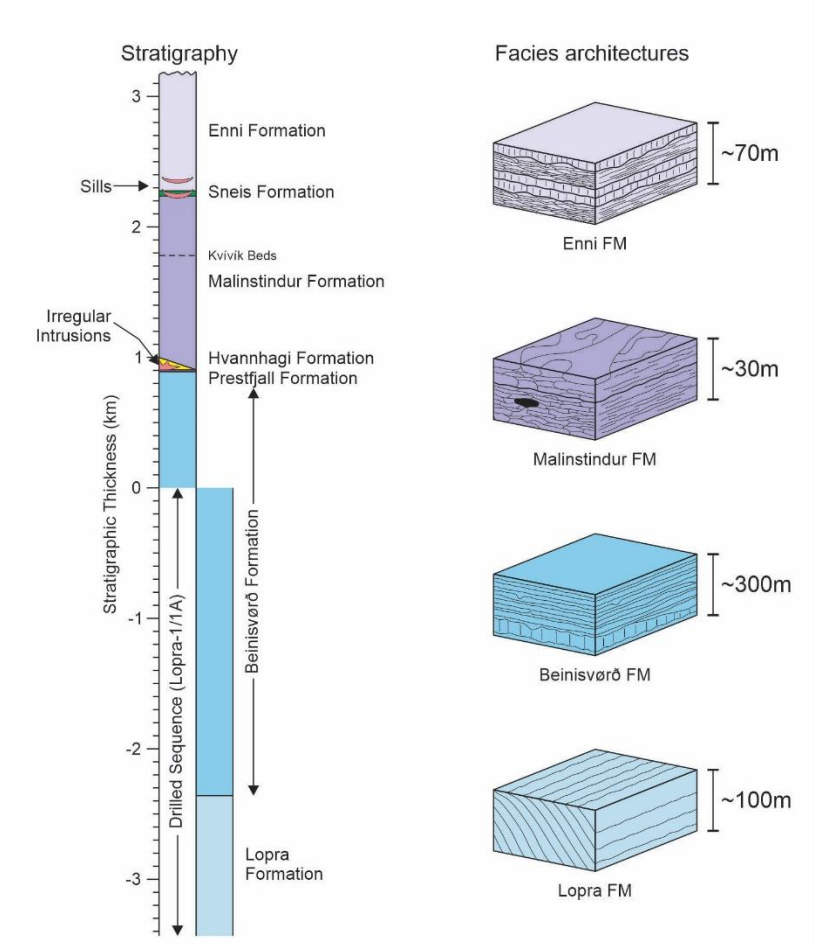


Figure 5. Stratigraphic column for the onshore Faroe Island Basalt Group. Facies architectures are given to the right of the column. After Rasmussen and Noe-Nygaard (1969) modified by Passey and Jolley (2009).

The tunnel between Sandoy and Suðuroy traverses significant parts of the stratigraphy mentioned above, starting in the Enni Formation on Sandoy, going through most of Malinstindur Formation towards Suðuroy. The section between Sandoy and Skúvoy mainly consists of the Enni Formation, thus being composed of simple flows with thick sedimentary beds and of compound flows. The section between Skúvoy and Suðuroy mainly consists of the Malinstindur Formation, which is composed of compound lava flows having relative few and thin sedimentary units.

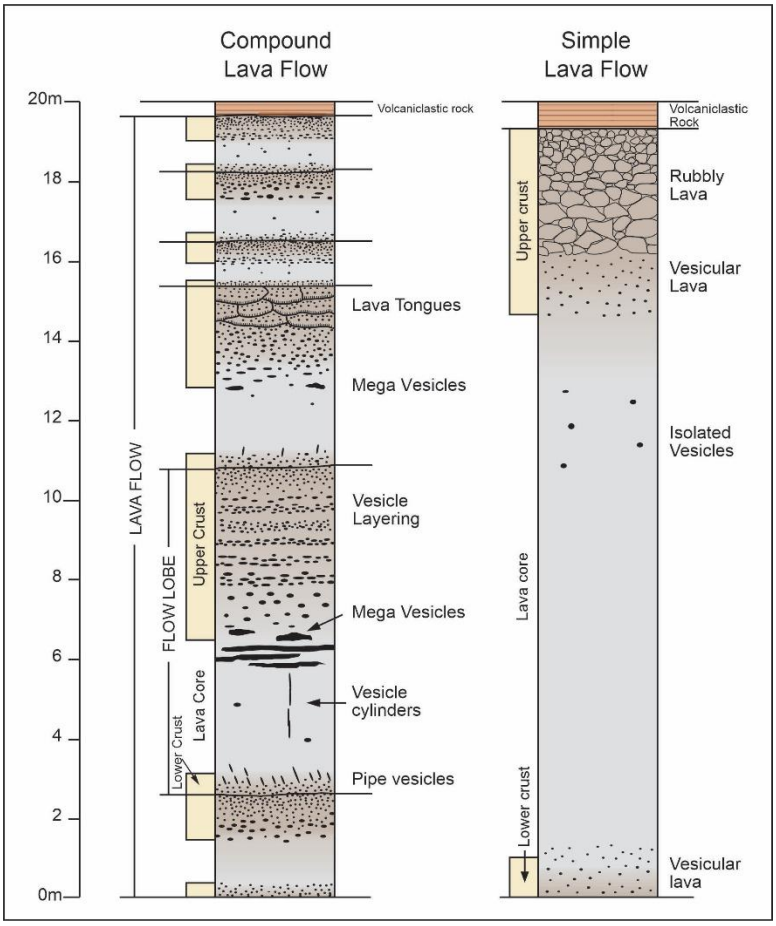


Figure 6. Simplified vertical sections through compound lava flows, typical for the Malinstindur Formation (left) and simple lava flow (sheet lobes), typical for the Beinisvørð Formation (right). The Enni Formation is composed of both above mentioned types. Modified after Waagstein (1998), and Passey and Bell (2007).

Previous studies

Previous tunnels in same stratigraphy

There are several large tunnel projects, both subsea and onshore, in the same stratigraphic interval as the planned Suðuroy tunnel. Figure 7b shows the stratigraphic location of the onshore tunnels. Figure 7c shows the stratigraphic location of the subsea tunnels and Figure 7d the related cores and wells. In addition, there are two scientific cored deep wells covering most of the stratigraphic interval of interest (Figure 7d).

These combined data sets and experience from tunnelling in the area supplements the data gathered for the Suðuroy tunnel. Reports and maps documenting these works are available from Jarðfeingi on request.

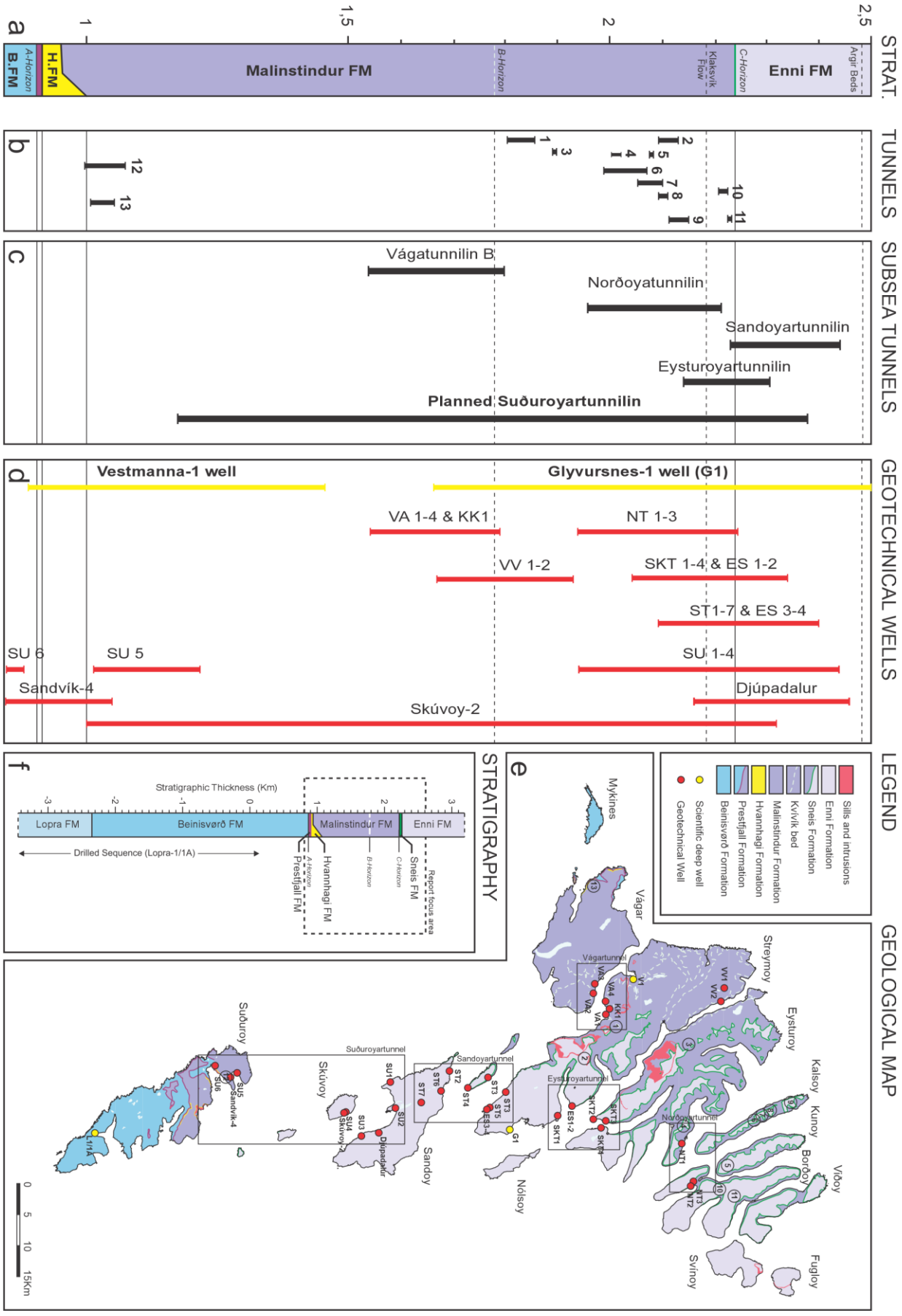

a
STRAT.
B.FM
H.FM
Malinstindur FM
Enni FM
A-Horizon
B-Horizon
C-Horizon
Klaksvík Flow
Argir Beds
1
1,5
2
2,5
b
TUNNELS
c
SUBSEA TUNNELS
Vágatunnilin B
Norðoyatunnilin
Sandoyartunnilin
Eysturoyartunnilin
Planned Suðuroyartunnilin
d
GEOTECHNICAL WELLS
Vestmanna-1 well
Glyvursnes-1 well (G1)
VA 1-4 & KK1
NT 1-3
VV 1-2
SKT 1-4 & ES 1-2
ST1-7 & ES 3-4
SU 6
SU 5
SU 1-4
Sandvík-4
Djúpadalur
Skúvoy-2
LEGEND
Sills and intrusions
Enni Formation
Sneis Formation
Kvívík bed
Malinstindur Formation
Hvannhagi Formation
Prestfjall Formation
Beinisvørð Formation
Scientific deep well
Geotechnical Well
e
GEOLOGICAL MAP
Mykines
Vágar
Streymoy
Eysturoy
Kalsoy
Kunoy
Borðoy
Viðoy
Fugloy
Svínoy
Nólsoy
Sandoy
Skúvoy
Suðuroy
Vágartunnel
Sandoyartunnel
Eysturoyartunnel
Norðoyartunnel
Suðuroyartunnel
f
STRATIGRAPHY
Stratigraphic Thickness (Km)
Lopra FM
Beinisvørð FM
Malinstindur FM
Enni FM
Drilled Sequence (Lopra-1/1A)
Prestfjall FM
Hvannhagi FM
Sneis FM
Report focus area
0 5 10 15Km

Figure 7. Composite figure featuring the relevant section (inset map on f) of the FIBG stratigraphy (a), existing onshore tunnels (b), subsea tunnels (c), geotechnical and scientific wells (d), geologcial map of the Faroe Islands (e), and the full stratigraphic column (f). The tunnel numbers in (b) are shown on the map (e). Leynartunnilin (1), Kollfjarðartunnilin (2), Norðskálatunnilin (3), Leirvíkstunnilin (4), Kunoyartunnilin (5), Villingardalstunnilin (6), Ritudalstunnilin (7), Mikladalstunnilin (8), Trøllanestunnilin (9), Árnafjarðartunnilin (10), Hvannasundstunnilin (11), Sandvíkartunnilin (12) and Gásadalstunnilin (13). The areas for the subsea tunnels (c) are shown on the map (e) as boxes. Locations of the scientific and geotechnical wells (d) are shown as yellow and red circles on the map (e).

Results from the Eysturoy and Sandoy tunnels

The methods used for this project are based on experiences from the geological investigations for the Eysturoy and Sandoy subsea tunnels.

A significant challenge for the Eysturoy tunnel was to establish the depth and extent of a thick sedimentary basin underneath Tangafjørður. Several seismic surveys were performed with one of the main goals to establish the sediment thickness (GEOMAP, 2006; GEOPHYSIX, 2015; Neish, 2008). Especially good control of the sediment thickness was obtained from reprocessing and analysing the data acquired in 2007 (Neish, 2007; Petersen, 2016). Here an iterative processing of marine seismic data, combining refraction seismic analysis and stacking of data, gave very good velocity control, and thus gave good control of the depth to base of the sedimentary basin.

The results were consistent with the long onshore deviated coring under Tangafjørður as well as with recognisance upward drilling during tunnel construction. The combination of reflection seismic processing and refraction seismic analysis was essential to establish the velocity model, since not all velocity information was contained in the refraction seismic data due to a velocity inversion in the sediment basin (Petersen, 2016).

In the Sandoy tunnel area, the combination of reflection seismic data with onshore mapping and core descriptions, provided means for detailed mapping along the tunnel line with strike and dip of layers, and continuation of the stratigraphy. The mapped continuation and overlap of reflectors were a strong indication of lack of major faults previously suggested in the mapped area (Passey & Varming, 2010).

A reflection interpreted on seismic data to be related to the Sneis Formation has been verified by geological mapping during tunnel construction. Similarly, a seismic reflection tied to a sequence of thick sheet lobes observed in boreholes, was also verified by the mapping during tunnel construction.

Establishing fracture zones and dykes has been considered important challenges for the two previous tunnels. However, an important lesson to be learned from the previous tunnels, is that, generally, fracture zones do not show as low velocity zones on seabed, and that low velocity zones along the seabed are related to velocity differences of beds and flows intersecting the seabed.

Data

The following section includes a brief description of each data type acquired for this report. For full description of data methodology etc. we refer to respective appendices. Figure 8 shows locations of data.

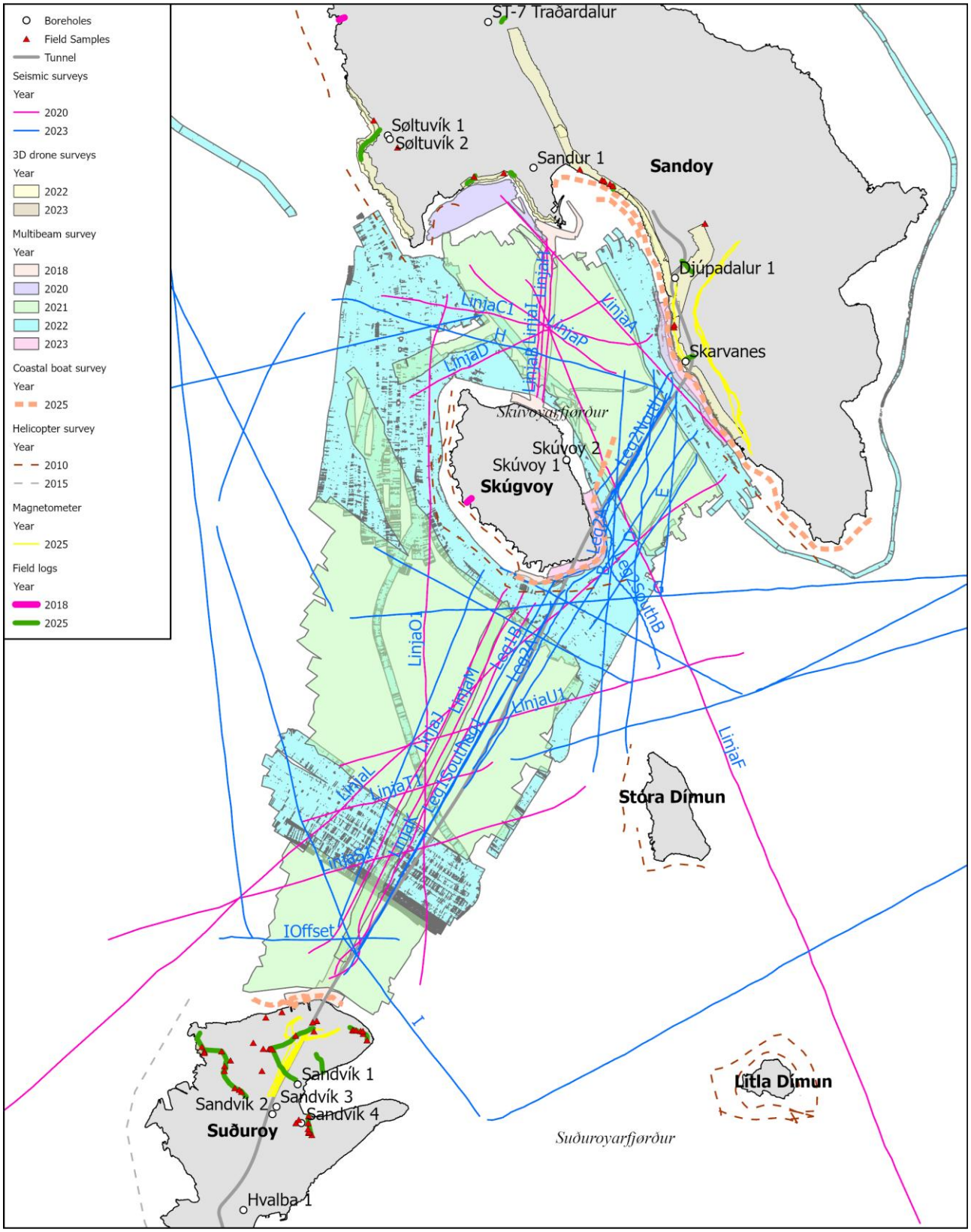


Figure 8. Data coverage map shows the extend of different surveys done in regards to the Suðuroy subsea tunnel from 2016 to 2025. Additionally, the map includes data from older surveys that have been used in this report (Højgaard, 2016; Vosgerau et al., 2011).

Well logs

Vertical wells were drilled using rotary percussion drilling. The wells were drilled in 2020 and 2021 using the same equipment that is used for the conventional drilling of geothermal wells. The wells are drilled by the companies Spf. Bora and Pf. Jarðhiti.

Jarðfeingi acquired the wireline logs using logging equipment manufactured by Robertson GEO. Table 1 shows the logging suite. Table 2 shows location and depth of all wells. The location is shown on the map in Figure 8. Sandvík-2 and Sandvík-3 were drilled to 350 m and 300 m, but the wells collapsed at 150–160 m m.d. and prevented logging to full depth. These wells have been drilled in connection with the Sandvík–Hvalba tunnel and are not described in this report.

Probe	**Output logs**
High Resolution Optical Televiewer	Image, Orientation
3-arm caliper probe	Diameter
Electric Log Probe	Resistivity, Natural gamma, Temperature

Table 1. Wire line logs.

Location	**Latitude**	**Longitude**	**Elevation**	**Length**	**Well diameter**
	[m]	**[m]**	**[m]**	**[m]**	**[inch]**
Søltuvík-2	859468.1	205945.0	46.3	317.5	5
Sandur-1	858750.0	209523.1	21.4	204.0	5
Skarvanes-1	853932.0	213312.0	16.2	399.0	5
Skúvoy-1	851475.0	210343.7	4.2	393.8	6
Sandvík-1	835937.8	203656.7	28.5	198.0	5
Sandvík-2*	835189	203023	18	158.0	5
Sandvík-3*	835395	203058	5	153.0	5
Sandvík-4*	834965	203658	100	337.5	5
Hvalba-1	832808.5	202300.5	26.8	300.0	5
Djúpadalur-1 core	856005.9	213052.5	53.8	300.1	3
Skúvoy-2 core	851481.6	210349.0	3.5	1111.3	3

*Table 2. Positions of wells in FOTM (Projection: Foroyar Transversal Mercator). See Figure 5 for locations. *estimated preliminary position.*

Core scanning

The Skúvoy-2 was intended to be wireline logged. The wireline logging was primarily intended for obtaining seismic properties for the full sequence from surface at Skúvoy down to the top of Beinisvørð formation as a basis for the generation of a synthetic seismogram representing the seismic facies for most of the tunnel profile from Skúvoy to Sandvík in Suðuroy. However, the coring drill got stuck at a depth of ~1100 m, making it impossible to perform wireline logging.

Therefore, an alternative to the missing wireline logs, a core logging, was performed by Norges Geotekniske Institutt (NGI) with their Multi Sensor Core logger (MSCL-S) from Geotek Ltd in England. The core was logged for sonic velocity and density for generation of the synthetic seismogram. In addition, the core was logged for natural gamma, electric resistivity, and magnetic susceptibility. The logging of natural gamma and electric resistivity was for comparison with the wireline loggings of the other wells, that also consisted of natural gamma and electric resistivity, whilst the logging of magnetic susceptibility was part of the logging suite. The Sampling interval is 0.04 m. At each sampling point the core thickness is recorded. The logging procedure is documented in the report logging report (Lysdahl & Volla, 2025).

At Jarðfeingi QC of the logs was performed. Samplings were removed primarily based on inspection of Vp, Vs, and core diameter. By applying constraints of min/max values Vp, Vs, Vp/Vs ratio in combination with minimum value of core diameter, bad samplings were removed. In total ca. 5000 of ca. 28000 samplings were removed.

Comparison of Vp, Vs, and density to the two scientific wells at Glyvursnes and in Vestmanna (Petersen, Brown, & Andersen, 2015; Waagstein & Andersen, 2003), covering the same stratigraphic interval, show consistency in velocities. Comparison of natural gamma to natural gamma from wireline logs in boreholes in the area, show same magnitude of natural gamma but sediments do not have the significant spikes seen on the wireline logs. The measured electric resistivity is totally inconsistent with the wireline logs from the wells in the area. Probably because electric resistivity from wireline logs is based on an almost 3 m long sonde in a water filled hole whilst the core measurements are across a 0.05 m wide dry core. The difference is mainly due to electrolytes in the waterfilled pores playing a significant role in the conductivity. QC is documented in Appendix B.

Multibeam

The first multibeam survey for the Suðuroy subsea tunnel was done by Landsverk during the summer of 2018. Initially the focus was solely on a tunnel option between Sandur village, Skúvoy and Suðuroy. The small survey boat, R/V Nísan, could only handle gentle wave swells and currents and was therefore not able to cover whole leg across Suðuroyarfjørður. The multibeam dataset was acquired with a Reson SeaBat 8125 multibeam echosounder that has a swath coverage of 120° using 240 beams at 455 kHz frequency onboard the boat R/V Nísan. The depth is relative to ground zero = average sea level. The positioning GNSS (Global Navigation Satellite System) is a Trimble BX982 on board the R/V Nísan, including a Motion sensor IXSEA Octans II, in combination with a base landstation Trimble R10. The GPS system has a centimetre level position accuracy. The data was processed by Landsverk and delivered in 1 m grid resolution. Additiontal survey was done in Grótvík bay in 2020 with the same equipment but in 0.5 m grid (Figure 8).

The second multibeam survey was acquired by Landsverk early October 2021 onboard R/S Jákup Sverri. This time the focus was to cover a larger area around the tunnel. The multibeam datasets were acquired with a Simrad EM712 multibeam echosounder that has a swath coverage of 140° using 140 beams at 100 kHz frequency. The onboard RTK GNSS is a Kongsberg Seapath 380 that has centimetre level position accuracy. However, due to bad weather and unfavourable currents the survey was cut short leaving large

gaps uncovered in the study area (Figure 8). The data was processed by Landsverk and delivered in 1 m and 2 m grid resolution for the survey in Skúvoyarfjørður and Suðuroyarfjørður, respectively.

The third multibeam survey was done in 2022 by Landsverk and Umhvørvisstovan onboard R/S Jákup Sverri with the same equipment as the second survey. The focus was to fill out the areas that were abandoned due to bad weather in the second survey leg in 2021. The data was processed by Umhvørvisstovan and delivered in 2 m grid resolution (Figure 8).

The fourth multibeam survey was done in 2023 by Landsverk on board R/V Nísan, as the first survey, and the objective was to fill out coastal areas at Skarvanes and SE Skúvoy where the small boat R/V Nísan was better suited than the larger R/S Jákup Sverri. The data was processed by Landsverk and delivered in 0.5 m grid resolution (Figure 8).

The different surveys overlap in places and show some discrepancies in depth, typically a few meters but can be up to 22 m. The depth difference along the tunnel profile is up to 4.5 m but in general less than a meter between surveys from 2018, 2022 and 2023 while up to a few meters for the surveys from 2021 (Appendix MB QC). The survey from 2021 has issues with inconsistent depth up to 2.1 m, where swaths overlap. Unfortunately, the 2021 surveys cover most of the tunnel area. The lack of good quality and relative low, 2 x 2 meters grid resolution in the 2021 surveys is possibly the main reason why so few lineaments, i.e. possible fracture zones, are found within the 2021 survey area, especially between Skúvoy and Suðuroy. The total multibeam survey covers 76.5M grid points over more than 165 km², or roughly the size of Suðuroy.

Topographic data

Topographic data used in this report derive from 10 m resolution Digital Terrain Model and 2 m contour curves created by COWI A/S and Umhvørvisstovan, respectively, both based on the same aerial photogrammetry survey from 2009. Additionally, a 2 m resolution Digital Surface Model (DSM) from 2015 by Styrelsen for Dataforsyning og Effektivisering is used. The DSM is based on the Arctic Digital Elevation Model from the Polar Geospatial Center at the University of Minnesota. The Digital Elevation Model is based on high resolution stereoscopic satellite images.

Seismic data

The marine seismic data were acquired in the summer 2020 and extended in 2023 in connection with a change of the planned tunnel profile location. Position of surveys is shown in Figure 8.

The 2020 acquisition was with excellent weather conditions and good tidal current providing high quality data. The streamer was 600 m long with 96 channels at 6.25-m channel intervals. The source used was a 45 cubic inch airgun fired at 120 bars with 12.5-m shot intervals. The 2023 acquisition was with same equipment and setup and produced equally high quality data. See the processing reports for further details (Petersen, 2020b, 2023).

In 2020 there were three tunnel options (Petersen et al., 2022). The seismic profiles of the 2020 acquisition were planned along tunnel option 1. The seismic profiles of the 2023 acquisition are planned according to the drafted tunnel line from 3rd of April 2023 and are supplementing the data from the 2020 acquisition.

There are several crossing seismic profiles. These have a direction that is preferably perpendicular to the strike of the stratigraphic dip. This is to better distinguish coherent noise from primary signal when interpreting the seismic data. In addition, there are long profiles to aid the geological overview of the area (Figure 8).

Magnetometer data

A Geometrics Marine Magnetometer was used in tandem with the seismic survey in 2023, measuring the magnetic total intensity close to sea level. On land a GEM GSM-19T walking Proton Magnetometer with a SBAS GPS was used to measure the magnetic total intensity close or along the tunnel line at Skarvanes and Sandvík in June and August 2025. The aim with these measurements was to find potential magnetic anomalies that could indicate geological features like dikes, fracture zones etc.

Fieldwork

Extensive geological fieldwork has been performed in the whole area. The focus of the field work was on stratigraphy and fractures.

The stratigraphy has been logged along several streams, where the stratigraphy has been logged according to rock type and lava flow morphology. The rock types are divided in the following categories:

- Lava flows
  - Aphyric
  - Feldspar phyric
  - Olivine phyric
- Volcaniclastics
  - Volcaniclastic sandstones
  - Volcaniclastic clay
  - Volcanic breccia and agglomerate

Furthermore, the lava flows have been categorized into (Figure 6):

- Compound lava flows consisting of numerous thin (generally <1 m up to m thick) overlapping and meandering flow lobes and form a continuous topographic profile
- Simple lava flows that are relatively thick (typically > 10 m) with massive core and often with a several meters thick brecciated crust. The simple lava flows are prone to columnar jointing.

The horizons have been traced laterally in the field to be able to compare the geology from stream to stream and build the overall stratigraphy.

There has been a special focus on identifying fracture zones, describe them and determine their direction to see if they intersect the Suðuroy tunnel line.

3D photogrammetry – drone survey

To support the fieldwork a number of 3D drone images have been obtained along the coastline on Sandoy and along the extensive Traðarhamar crag/rock face in august 2022 by Landsverk. The 3D drone images have been uploaded to Drone Deploy to make it possible to follow prominent horizons over long distances. The interpretation was subsequently exported (substracted) to shapefiles and with text files with x-, y- and z-coordinates. Interpretation was imported to Petrel for further analysis. Figure 8 shows locations. See Appendix J for more details.

3D photogeological study and helicopter surveys

Vosgerau et al (2011) undertook a 3-D photogeological study on selected cliff sections to study the lateral variation of volcaniclastic rocks. Continuous high quality photos have been taken along part of the coast lines of amongst others Sandoy, Skúgvoy, Stóra Dímun and Lítla Dímun. In this area Vosgerau et Al (2011)

focused on mapping a 1–6 m thick sedimentary horizon, they call Argir Bed, and a simple lava flow they named Høvdhamarin flow.

The location of the Helicopter Surveys is shown in Figure 8.

Coastal Boat Survey

A coastal boat survey was performed on May 6th 2025. Numerous consecutive photos were taken along Southeastern part of Skúvoy and Northern part of Suðuroy where the tunnel intersects the islands. Also, a full series of photos are taken along the coast on Sandoy frá Nípubarmur to Sandalíð. (figure xx) Continuous video recordings for the same areas do also exist.

The purpose of the coastal boat survey was to inspect fractures and fractures zones, due to supposedly better exposure along the coastline.

Geochemistry

The idea behind using geochemical data to strengthen the geological understanding of the tunnel area came as a direct consequence that we were not able to do the planned wireline logging of the Skúvoy-2 well. However, as the full core was recovered, this alternative plan was established.

The basaltic lavas on the Faroe Islands are at first glance very homogeneous, geochemically. However, subtle key differences are present when looking at how the elements are distributed in separate flow units.

An intense sampling programme (60 samples) of the core, depicting each lava group/flow was performed, coupled with field campaign on Suðuroy. This resulted in a total of 106 samples of basaltic lava were sent for geochemical analyses in the Bureau Veritas Laboratories in Canada.

The geochemical stratigraphy on the Faroe Island Basalt Group has been studied for decades (Larsen, Waagstein, Pedersen, & Storey, 1999; J. M. Millett, Hole, Jolley, & Passey, 2017; J. M Millett, Hole, Jolley, Passey, & Rossetti, 2020; Rasmussen & Noe-Nygaard, 1969; Waagstein, 1988) and therefore serves as a strong added backbone for geological correlation of lava flows. The use of geochemical data in tunnel projects is however a novel experience in the Faroe Islands.

Many well-established methods describing basalt geochemistry have also been used to describe the Faroe Islands Basalt Group (Larsen et al., 1999; Waagstein, 1988). The known volcanic succession on the Faroe Islands is described in section amounts to a total stratigraphic thickness of ~ 6.5 km. The basalts are all tholeiites, i.e., hypersthene normative (assuming Fe2O3/FeO = 0.15). However, they show large compositional variations from primitive to more evolved basalts. Compositionally the lavas are traditionally divided into high-Ti and low-Ti types (Waagstein, 1988). Further the formations are characterized by REE-patterns and variations in elemental ratios.

The dataset presented in this report (Full data set in Appenix F includes major elements, trace elements, and rare earth elements (REE) from field and core samples. These data provide necessary insights into the petrogenetic evolution and geochemical characteristics of this geological sequence and allow for detailed correlation of single lavas in the greater tunnel area.

Samples

From Skúvoy-2 core detailed geochemical analysis of 60 rock samples (Figure 16 – Composite figure of Skúvoy-2), covering a depth range from 7.22 to 1105.60 m are presented Appendix F. The dataset includes major elements, trace elements, and rare earth elements (REE). Here each volcanic unit was identified, sampled and analysed.

During field work on Suðuroy and Sandoy a total number of 84 samples were collected, and based on lithology, 49 of these were analysed for geochemistry. The map in Appenix F shows the distribution of these samples. During field work, especially on Suðuroy, one of the major aims was to create a stratigraphic map, that could be projected on the tunnel profile. The samples from Sandvík are therefore also plotted on a "constructed" stratigraphic column, that is based on field mapping of the area.

Data and Results

Geochemical classification of all the samples, based on major, trace and REE elements are described and presented in a series of standard diagrams in Appenix F, along with the full dataset. Element mobility due to alteration of the lavas is commonly addressed in literature and is also considered in this study (Appendix F).

Based on analysis of the geochemical dataset, we have divided all the samples into 9 different geochemical groups. There are seven High-Ti groups, one Low-Ti group and a group of Volcaniclastic sediments. The main grouping is based on major element ratios (Figure 9). These groups are defined on scatter plots of samples from Suðuroy and the Skúvoy-2 core.

The High-Ti groups are defined by having >1,5wt% of TiO_2. The pool of High-Ti samples is again divided into sub-groups, based on their trace element ratios (Figure 10) and rare earth element (REE) patterns. One of the key-diagrams showing the division into the 7 High-Ti groups uses highly incompatible trace and REE ratios La/Nb. This ratio is not affected by various volcanic processes such as fractional crystallisation etc. Therefore, this is a good ratio to use when defining co-magmatic relationships between samples. As seen in figures 9 and 10, the various groups form relatively tight clusters. This is indicative of co-magmatism, meaning that these samples most likely are from the same volcanic episode, and thus can be correlated across the field area.

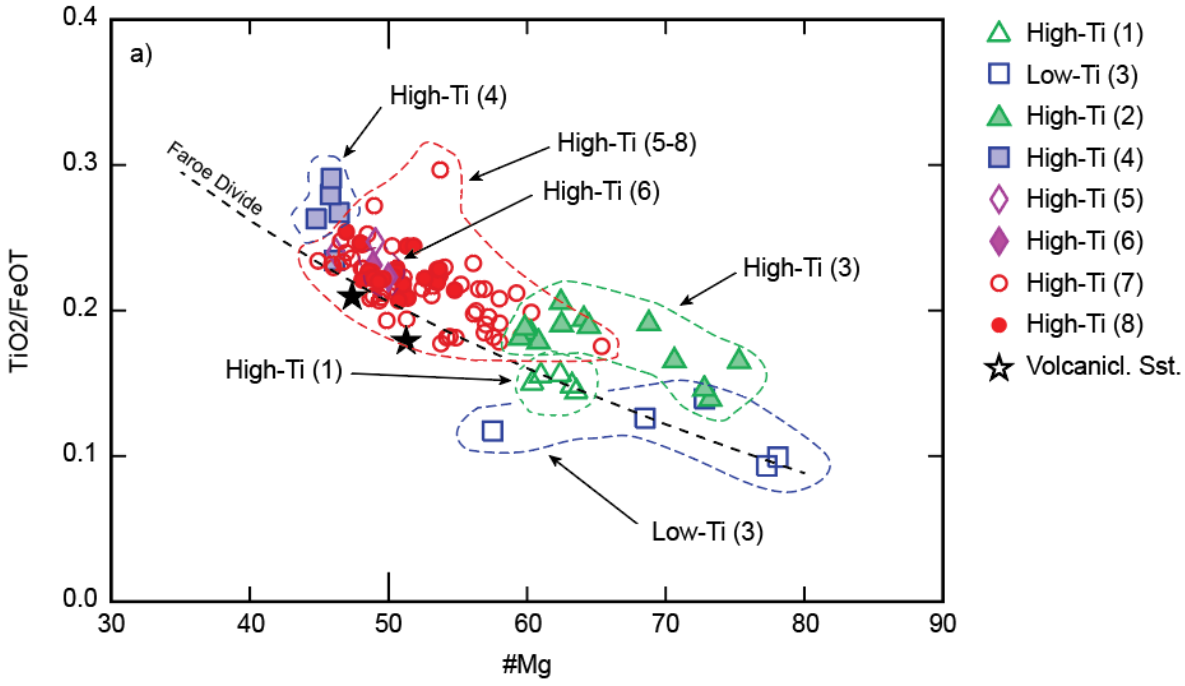


Figure 9. TiO2/FeOT vs. #Mg ratios plotted together with the Faroe Divide (Larsen, et al. XX). FeOT is calculated as (0,89 x Fe_2O_3 + FeO). All the geochemical groups plotted, and some are indicated with outlines.

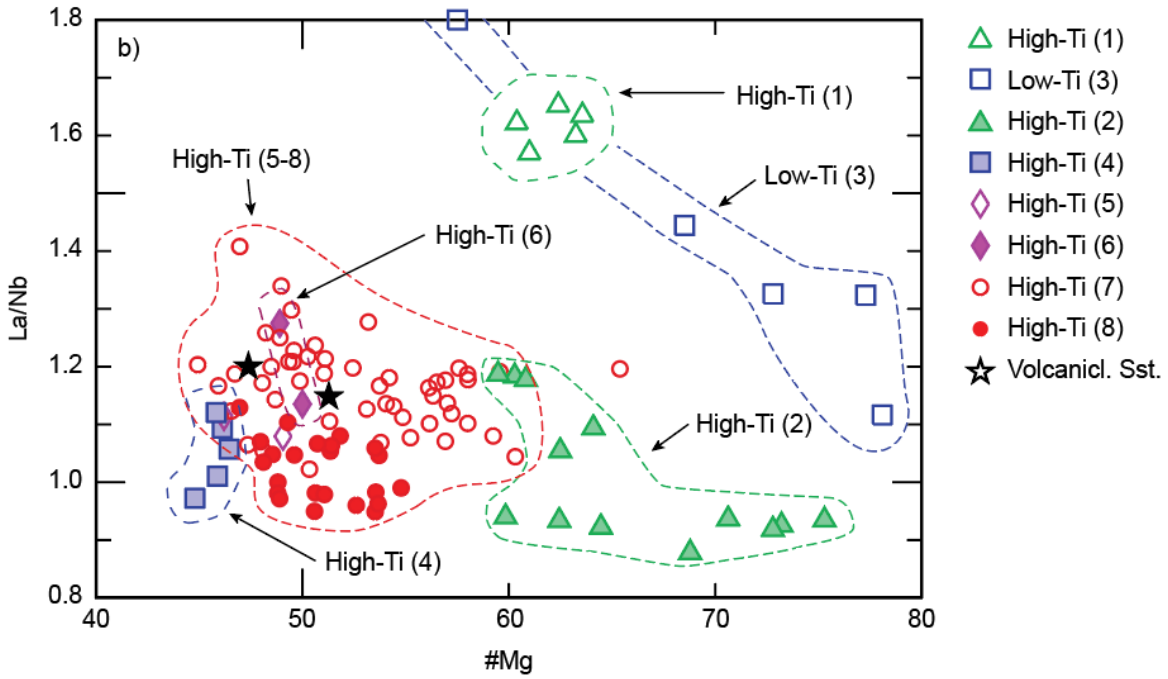


Figure 10. La/Nb vs. #Mg ratios plotted together with the Faroe Divide (Larsen, et al. 1999). #Mg is calculated as (0,89 x Fe_2O_3 + FeO). All the geochemical groups plotted, and some are indicated with outlines.

One group, **High-Ti (1)**, shows very distinct trace element ratios (La/Nb), see Figure 10. Also, in the REE patterns (see Appendix F) this group shows markedly different REE trends, with a more "depleted" LREE trend. This trend, and perhaps a bit more evolved LREE depletion, is seen in the b-horizon (IM-horizon) lavas in the northern Islands. The High-Ti (1) group is seen both in the field samples in Sandvík and in the Skúvoy-2 core samples. This group is therefore a good candidate for use in correlation. This lava group shows similar geochemistry as the ca 100 thick Eiði member, as described by (Waagstein, 1988). Furthermore, it is situated in similar position within the Malinstindur Formation as the Eiði member. Another distinct geochemical group is the **High-Ti (3)** group. This group shows the most evolved geochemical signatures with high TiO_2, Zr, P_2O_5 and low #Mg/MgO and the most enriched REE trend of all the samples. This group is also seen in both the field samples in Sandvík and in the Skúvoy-2 core samples. **The Low-Ti (2)** group is also plotted on all the diagrams as a distinct group. The geochemical signatures seen in this group are indicative for plagioclase addition (Figures 12, 13 in Appendix F). This is also seen in the hand samples (Appendix I). These samples show geochemical signatures indicative of olivine accumulation (Appendix F), which also is confirmed in field samples (Appendix I). The Low-Ti (2) group does however not appear in the Skúvoy-2 core. Therefore, we suggest that this group thins out towards the north along the tunnel profile.

Most of the samples in groups High-Ti (5-8) are difficult to separate. However, **High-Ti (6)**, do show somewhat distinct REE patterns (Appendix F), and do also plot at same stratigraphic interval, below the IM-horizon.

Stratigraphic geochemistry profiles

To correlate the defined geochemical groups across the tunnel profile from Skúvoy to Suðuroy, we will use the stratigraphy from the Skúvoy-2 core, and a "constructed stratigraphic column" from the Sandvík area. This constructed profile is based on the mapped surfaces in the area, and projection onto a "virtual"

stratigraphic column, placed at the highest point at the Borgin mountain. Here surface angle, and distance from the column make the basis for projecting the samples onto the constructed column.

Figure 11 below shows various Major, trace and REE element concentrations plotted against depth in the Skúvoy-2 core and the Constructed Stratigraphis Column in Sandvík. These data and logs geochemistry profiles will be used in the data integration part and correlated against other data types and seismic profiles.

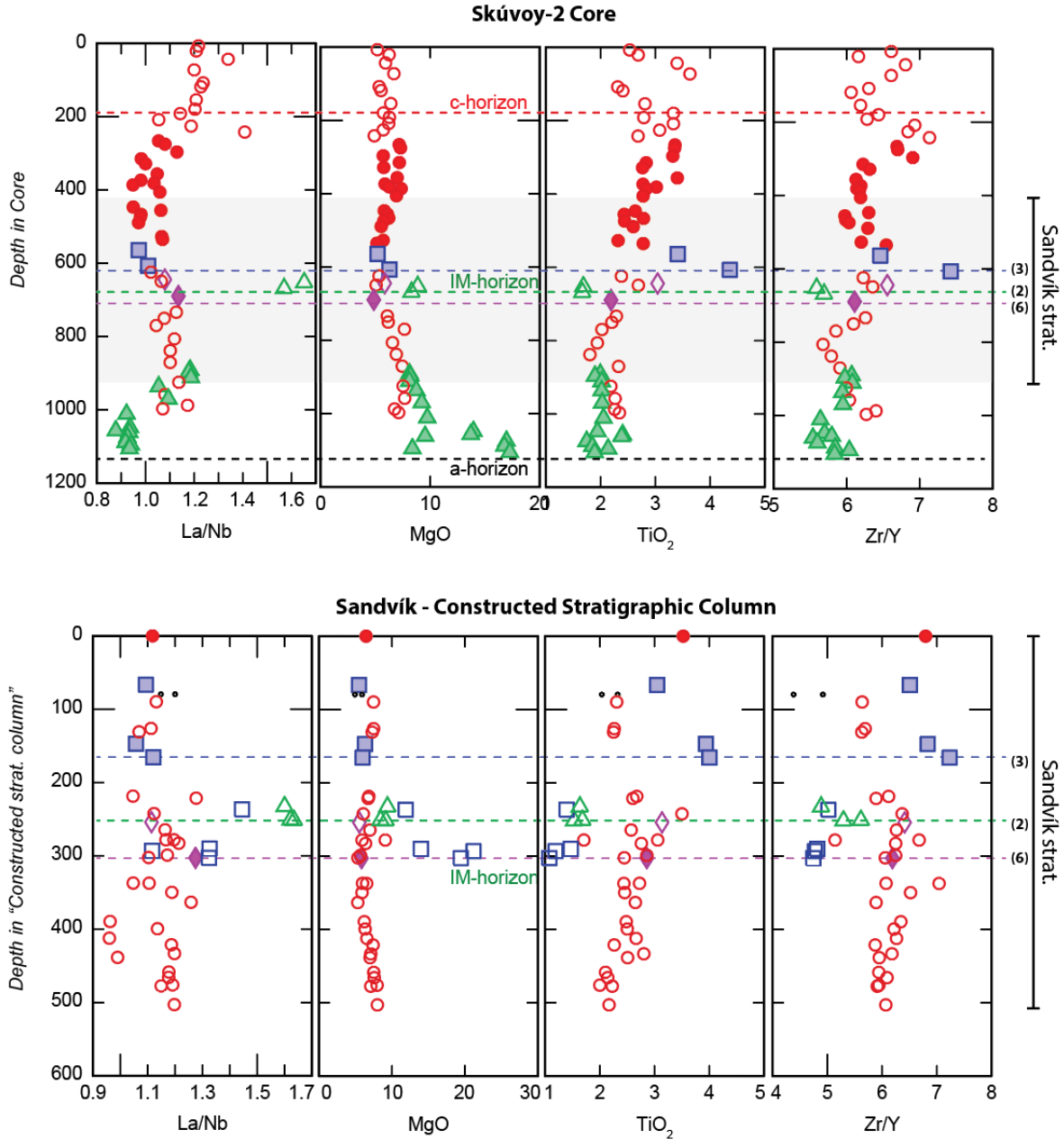


Figure 11. Geochemical data from Skúvoy-2 core and the constructed stratigraphic column in Sandvík.

Composite logs

The compilation of all data from the 9 onshore boreholes (core and wireline) in Søltuvík-2, Sandur-1, Skúvoy-1, Skúvoy-2 Skarvanes-1, Sandvík-1, Sandvík-4, and Hvalba-1 are presented in a series of composite logs (Figures 12 to 20). The composite logs comprise a series of seven columns The first column shows the lithology. The next four columns show data from caliper, natural gamma (NGAM), point resistivity (SPR), and temperature logs. The last two columns present fracture density at 1-m intervals and structural data in 50-m intervals.

Lithology

The lithological interpretations are based on visual inspections of the optical televiewer images. The lithologies used are: Aphyric basalts, coarse grained feldspar-phyric basalt, fine grained feldspar-phyric basalt, olivine-phyric basalts and volcaniclastic sand- and claystone. Furthermore, the two descriptive features volcanic breccia and core stone are used. Flow boundaries are also indicated on the lithology log.

Lithological interpretations are also based on core inspections.

Wireline Logs

Below is a brief description of the use of the log data in a geological context.

The Caliper-log shows the diameter [mm] in the borehole and states the presence of larger cavities in the borehole. These data are used as support in interpretation of televiewer, NGAM and SPR logs.

The Natural Gamma (NGAM) [API] data are used to constrain the presence of volcaniclastic sediment beds. In the composite logs the high NGAM spikes correlate very well to the interpreted volcaniclastic sediment beds in all the boreholes.

The Single Point Resistivity (SPR) [Ohm] log measures resistivity in the rocks and gives physical parameters of the rock mass. High SPR values indicate massive core of lava flows, while lower values indicate lava crusts and bases, and volcaniclastic sediments. These data are therefore useful in adding to the lithological descriptions and correlation.

The Temperature [C°] logs show changes in the water temperature in the borehole. Where deviations from the general geothermal gradient are observed, these are taken as indications of high water-flow. Deviating geothermal gradients are most visible in the Søltuvík-2 and Sandur-1 logs. Here the temperature gradients in the uppermost 280 m in Søltuvík-2 and uppermost 75 m in Sandur-1 are nearly zero. This gives indications of a down-flow of water with surface temperatures down to these depths.

The Optical Televiewer (OPTV) log scans the wall and produces images with vertical and horizontal resolution of approximately 1 mm.

The SPR and NGAM logs are used together for correlation from well to well. In some cases, the correlation can be difficult if it is only based in image log interpretation. The combination of televiewer images, SPR, and NGM logs is therefore a much more rigid tool for correlating.

Structural data from wireline logging

Interpretation of structural data is done by measuring the intersection of the fractures with the orientated borehole televiewer images. Here both strike and dip of the fractures are compiled for each fracture in the borehole.

All the fractures that were interpreted in the televiewer images were summed up by the fracture density plot (fractures pr. meter) in the composite figures. A noticeable feature is that there is a correlation between intervals with high fracture density and high SPR. These intervals correlate to massive sections of lave flows.

The rose diagrams sum up the structural data, for fractures steeper than 45 degrees, for each 50 meter in the boreholes. By using fractures steeper than 45 degrees we focus on fractures that display the tectonic fabric in the region.

Detailed descriptions of the boreholes are in appendices K to S.

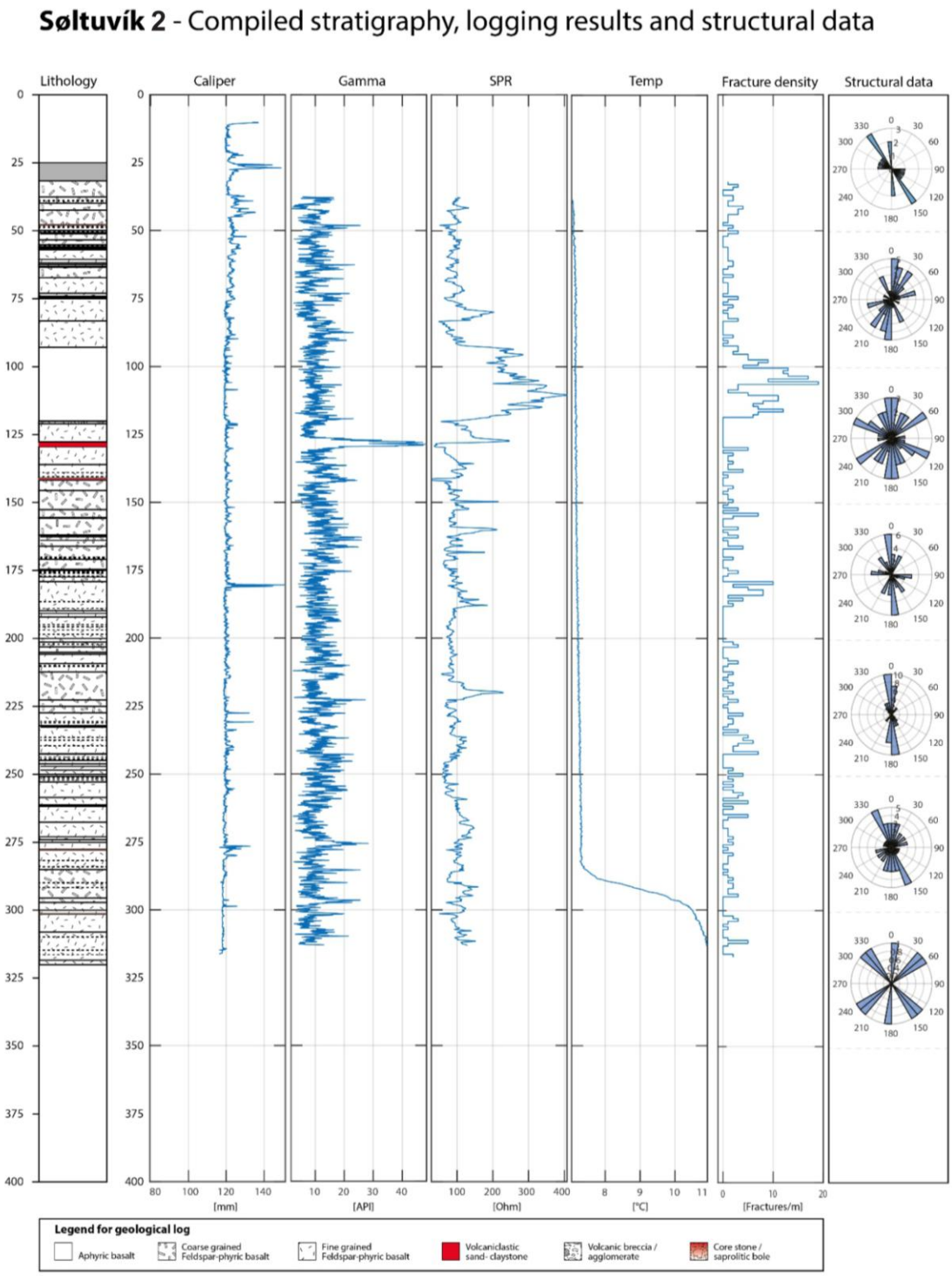


Figure 12. The composite logs for Søltuvík-2 comprise a series of columns. The first column shows the lithology, the next four columns show data from caliper, natural gamma (NGAM), point resistivity (SPR), and temperature logs. The last two columns present fracture density pr. meter and structural data in 50-m intervals

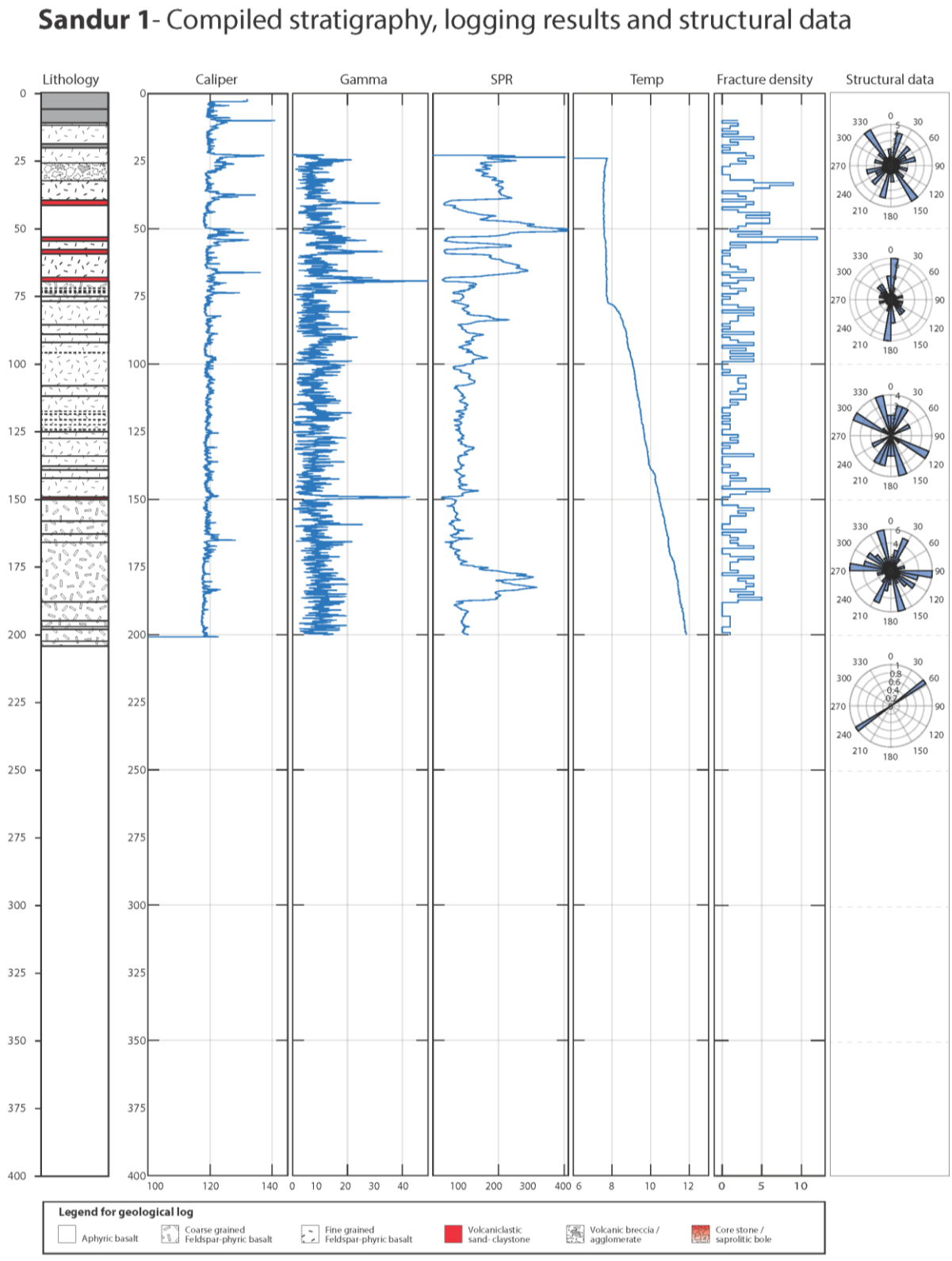


Figure 13. The composite logs for Sandur-1 comprise a series of columns. The first column shows the lithology, the next four columns show data from caliper, natural gamma (NGAM), point resistivity (SPR), and temperature logs. The last two columns present fracture density pr. meter and structural data in 50-m intervals.

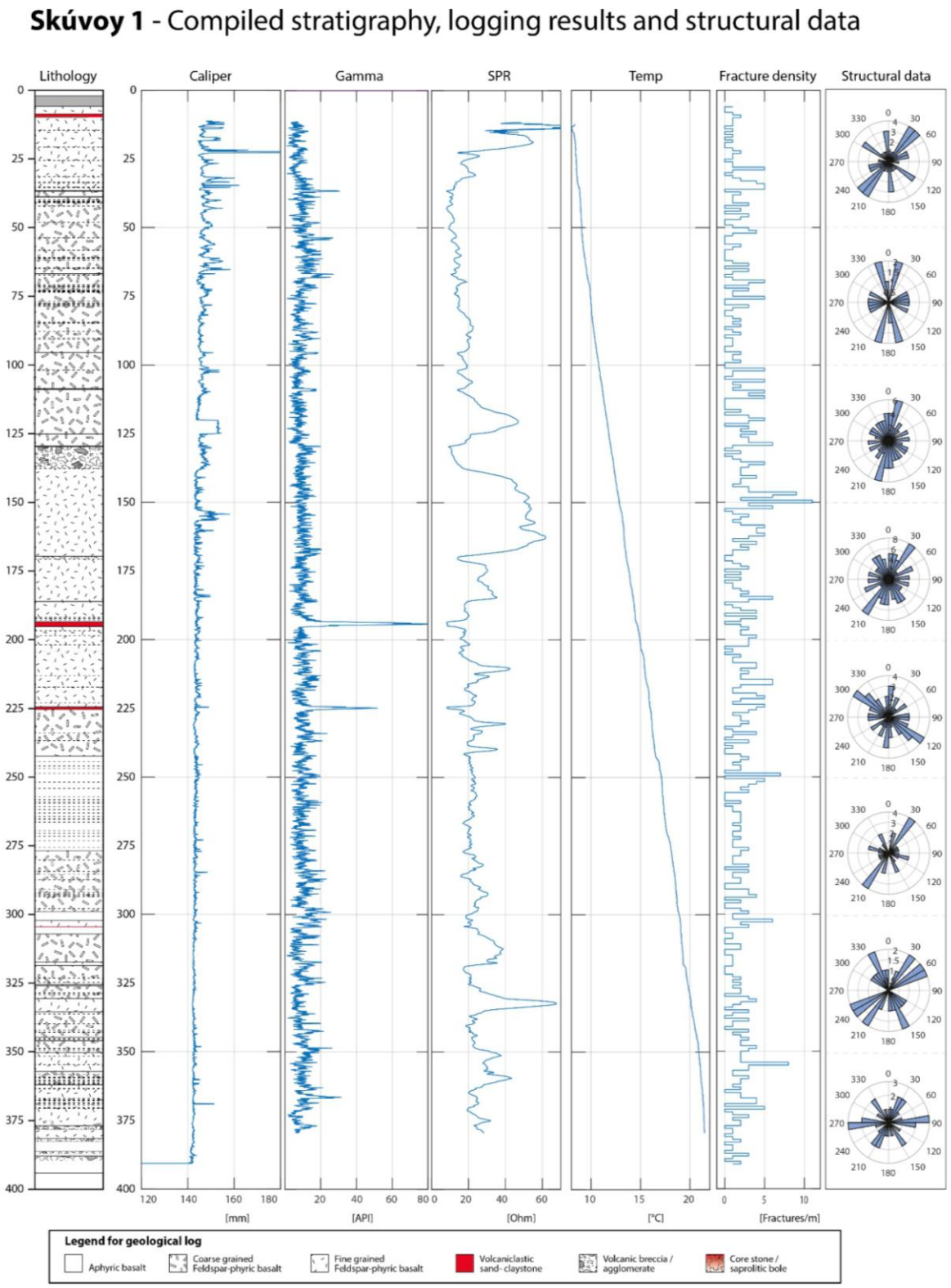


Figure 14. The composite logs for Skúvoy-1 comprise a series of columns. The first column shows the lithology, the next four columns show data from caliper, natural gamma (NGAM), point resistivity (SPR), and temperature logs. The last two columns present fracture density pr. meter and structural data in 50-m intervals.

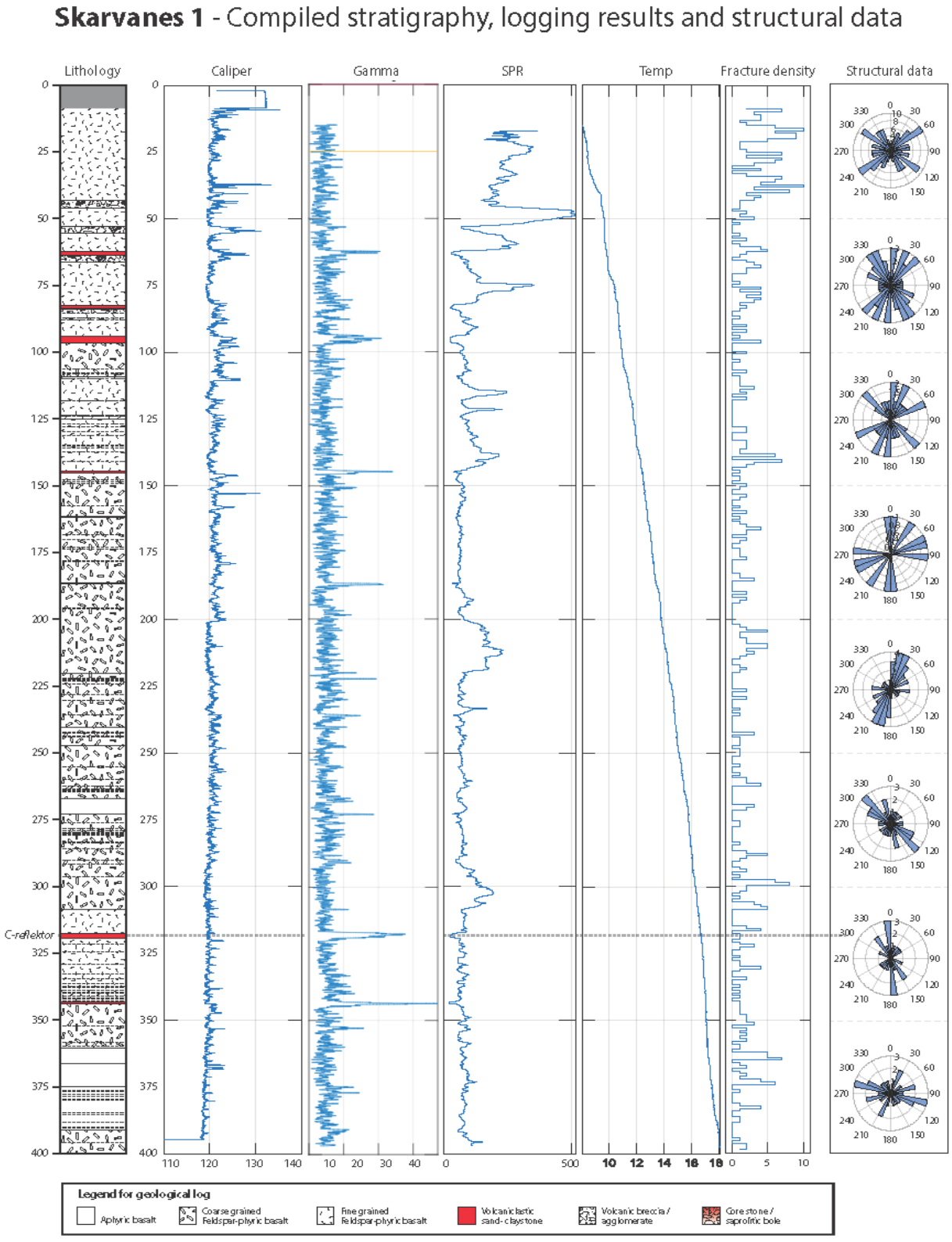


Figure 15. The composite logs for Skarvanes-1 comprise a series of columns. The first column shows the lithology, the next four columns show data from caliper, natural gamma (NGAM), point resistivity (SPR), and temperature logs. The last two columns present fracture density pr. meter and structural data in 50-m intervals.

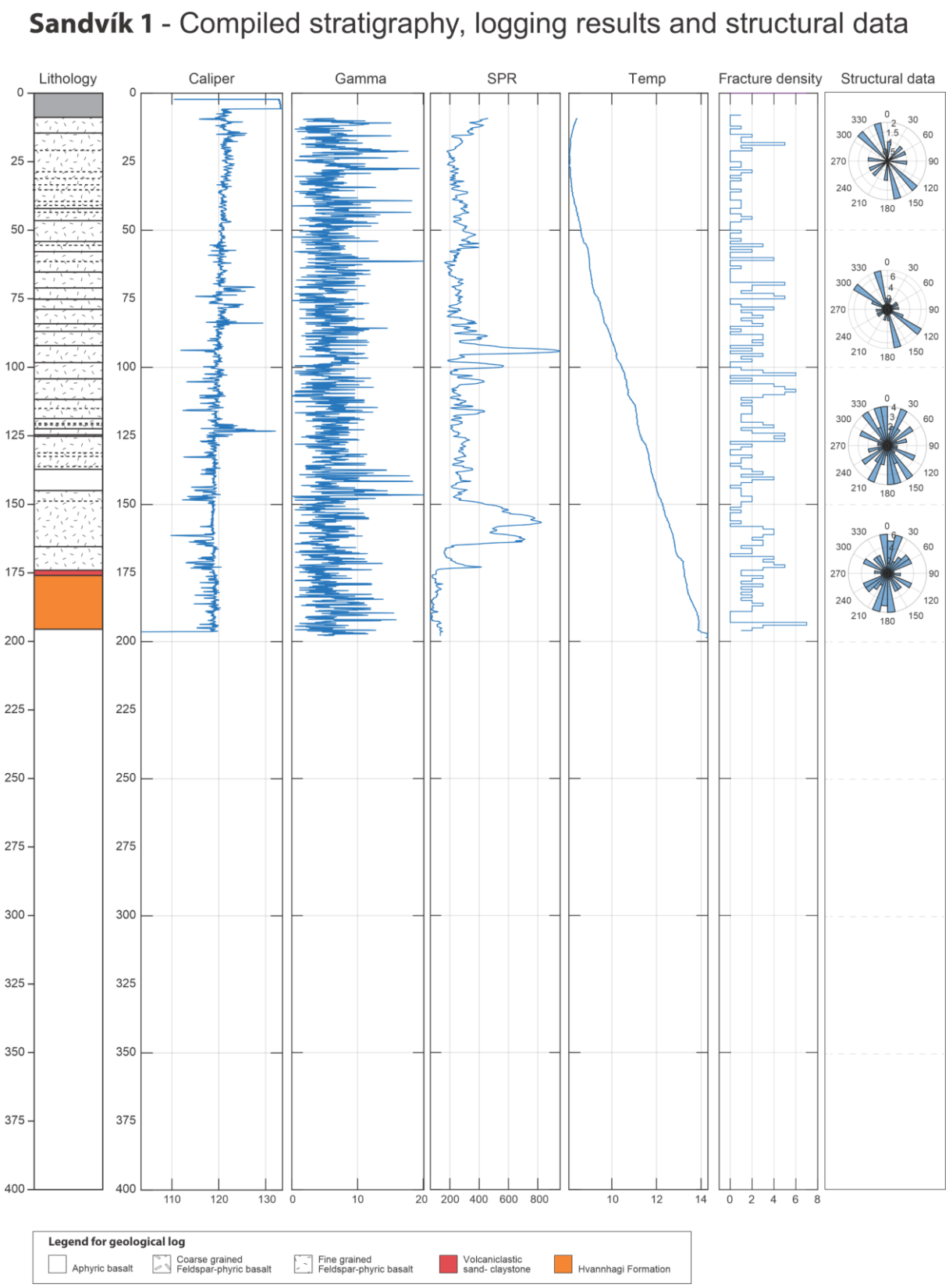


Figure 16. The composite logs for Sandvík-1 comprise a series of columns. The first column shows the lithology, the next four columns show data from caliper, natural gamma (NGAM), point resistivity (SPR), and temperature logs. The last two columns present fracture density pr. meter and structural data in 50-m intervals.

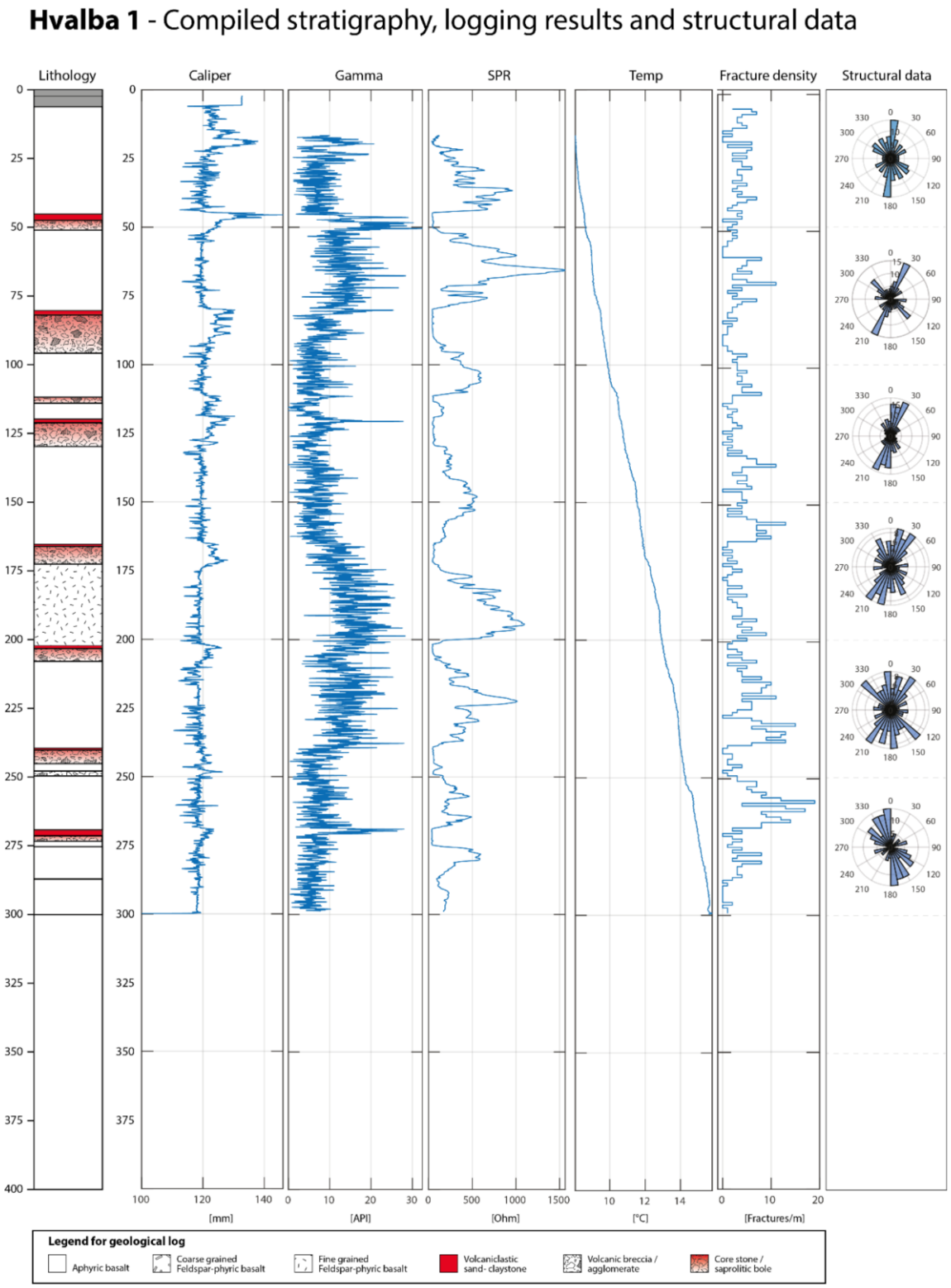


Figure 17. The composite logs for Hvalba-1 comprise a series of columns. The first column shows the lithology, the next four columns show data from caliper, natural gamma (NGAM), point resistivity (SPR), and temperature logs. The last two columns present fracture density pr. meter and structural data in 50-m intervals.

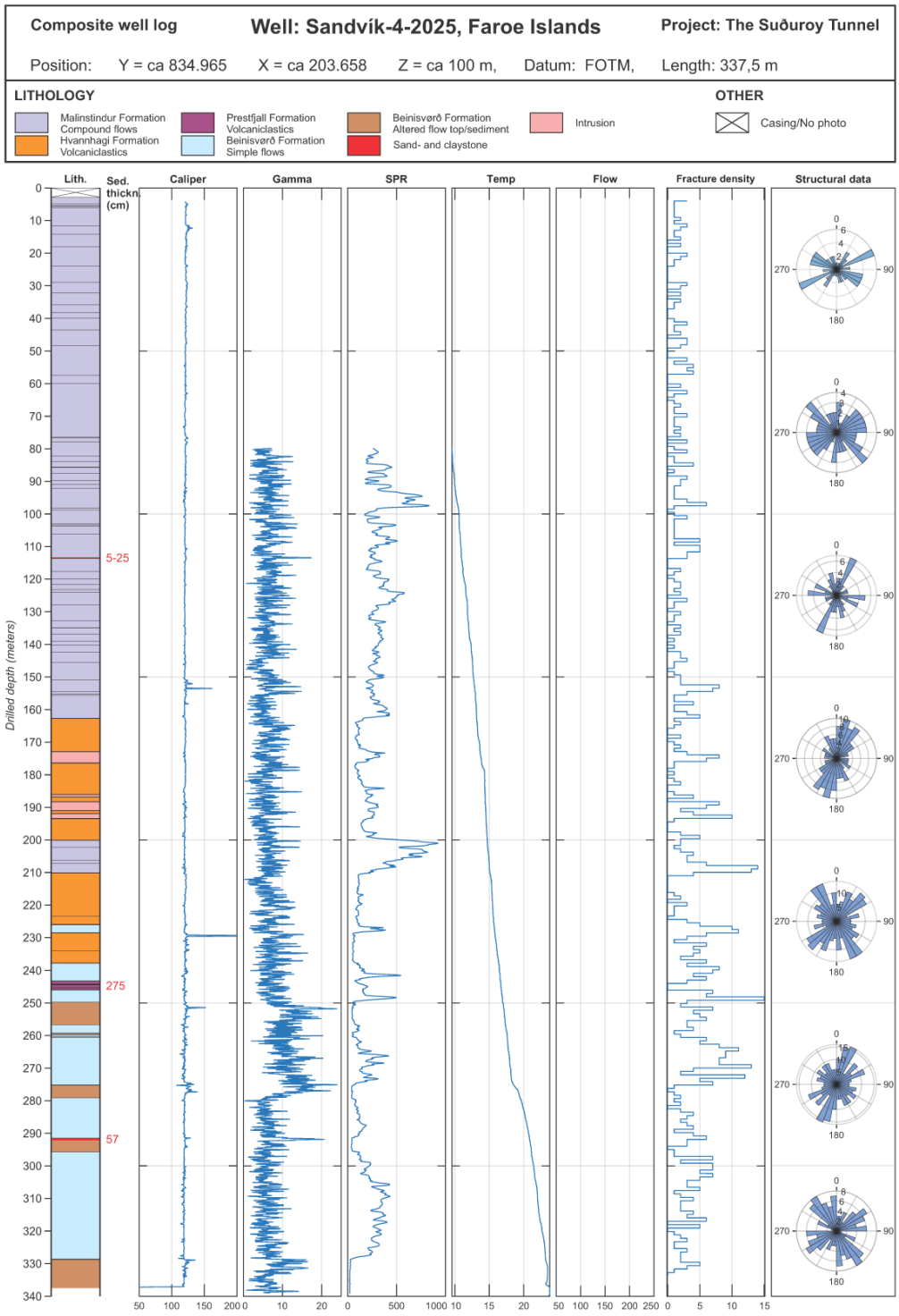


Figure 18. The composite logs for Sandvík-4 comprise a series of columns. The first column shows the lithology, the next four columns show data from caliper, natural gamma (NGAM), point resistivity (SPR), and temperature logs. The last two columns present fracture density pr. meter and structural data in 50-m intervals.

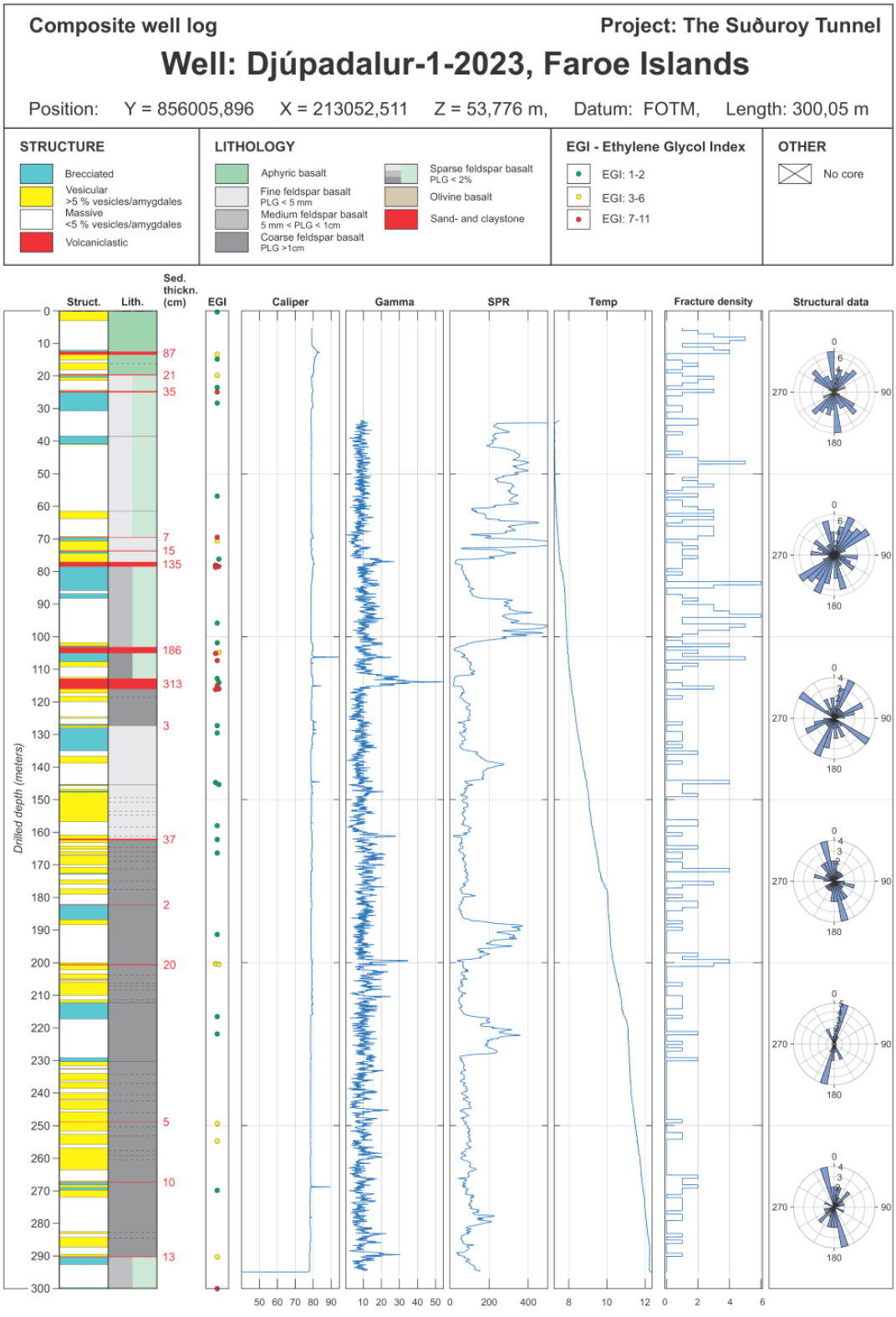


Figure 19. The composite logs for Djúpadalur-1 comprise a series of columns. The first column shows the structure and lithology. The second shows the EGI results. The next four columns show data from caliper, natural gamma (NGAM), point resistivity (SPR), and temperature logs. The last two columns present fracture density pr. meter and structural data in 50-m intervals.

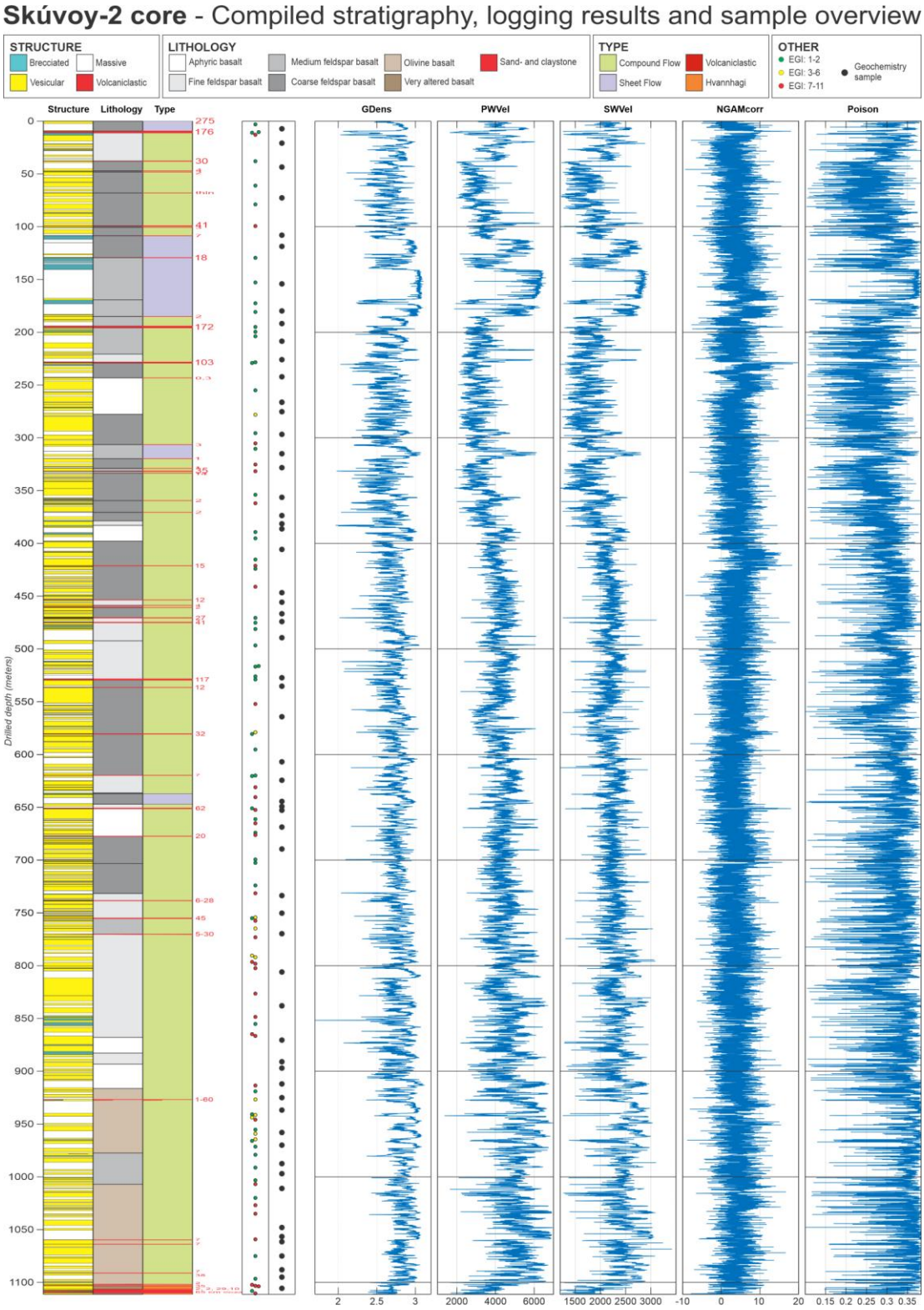


Figure 20. The composite logs for Skúvoy-2 comprise a series of columns. The first shows from left the structure, lithology, and the type. The next column shows to left the EGI results and to right the sample locations for the geochemistry. The next five columns show data from the core scanning at NGI. First: Densty, Second: P-wave velocity, Third: S-wave velocity, Fourth: Natural gamma, Fifth: Poison ratio.

Results from field work

This section draws main results and relevant field observations from the field campaign done from the entire project presented in Appendix D and E. The localities are presented in two sections, Suðuroy and Sandoy.

Suðuroy localities

In Figure 21 the localities mentioned in this section are highlighted. Furthermore, the samples taken in this area are shown (yellow circles), together with the stratigraphic logs. The 3D model of Snalingaberg is shown, and the figures related to the Boat Trip 1, is indicated.

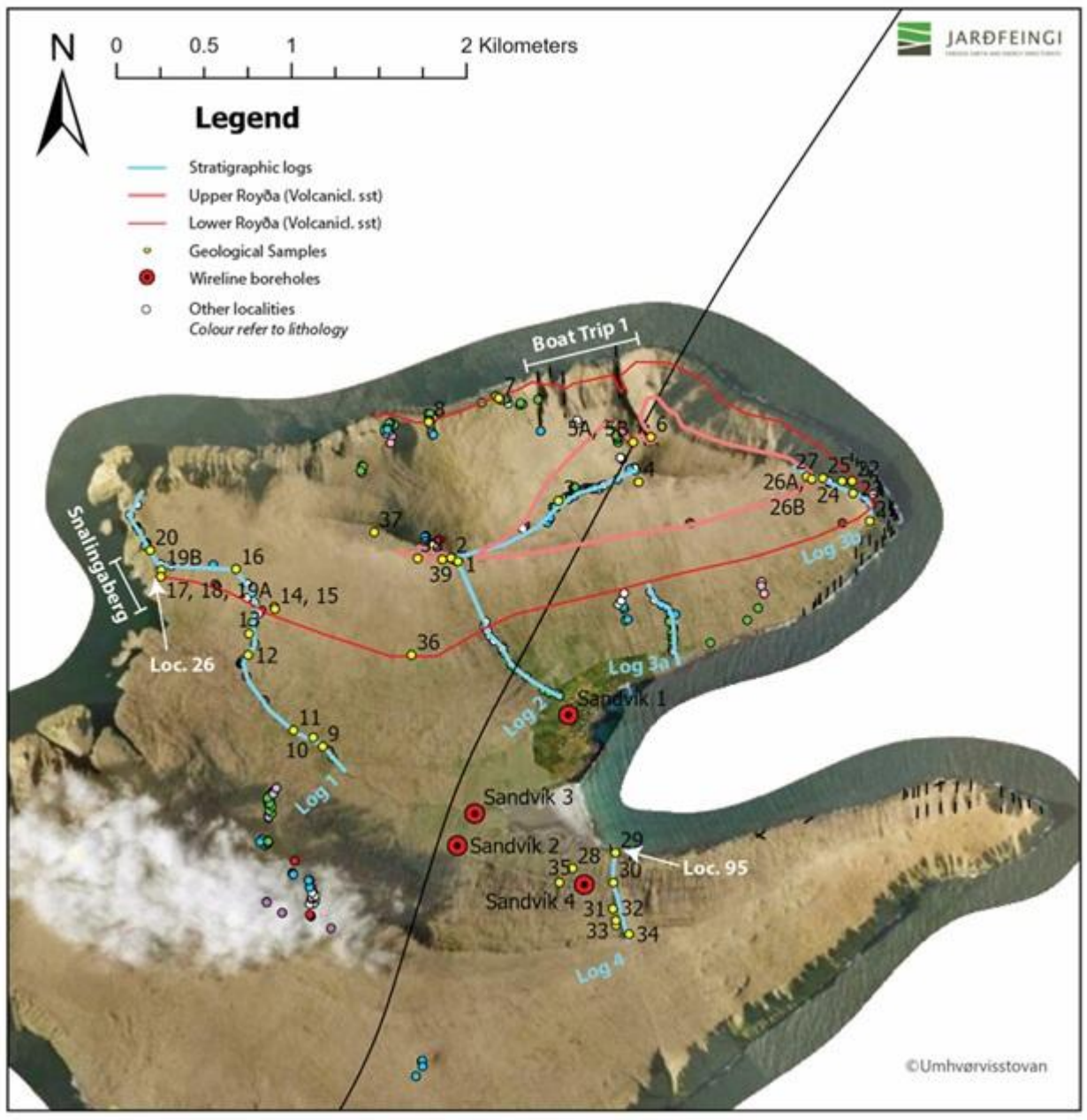


Figure 21. In this map the localities mentioned in this section are highlighted. Furthermore, the samples taken in this area are shown (yellow circles), together with the stratigraphic logs (blue). The 3D model of Snalingaberg is shown, and the figures related to the Boat Trip 1, is indicated.

In this map the localities mentioned in this section are highlighted. Furthermore, the samples taken in this area are shown (yellow circles), together with the stratigraphic logs (blue). The 3D model of Snalingaberg is shown, and the figures related to the Boat Trip 1, is indicated

Locality 26

A sequence of several lava flows and a ca. 1 m thick reddish volcaniclastic sandstone exposed et the western cliffs. Lowermost flow consists of plagioclase basalt, followed by the volcaniclastic sandstone. The next flow is an olivine accumulate, that perhaps consists of two separate flows. The base, non-vesicular, massive and columnar jointed lava flow has large olivine phenocrysts, and the upper lava flow with vesicles, is of finer grained olivine basalt, without significant olivine accumulate. Several samples (ST_Sandvík_17, ST_Sandvík_18, and ST_Sandvík_19A) are from this locality.

This sequence of lava flows is visible on the 3D drone model. The volcaniclastic sequence was labelled the "upper royða" on maps etc.



Figure 22. Sequence of several lava flows at locality 26, at the western cliffs. Yellow dotted line marks the volcaniclastic sandstone bed.

Locality – Snalingaberg

At Snalingaberg, a 3D drone survey was undertaken in 2023. Here in Figure 23, the full 3D model, a profile (a) and two zoom-in photographs (b and c) show the lava flow architecture vary from compound lava flow architecture (dominantly) to some sheet lava flows. This sheet flow in Figure 23b is olivine phyric and displays some columnar jointing. During field work, some isolated feldspar lava flows also show sheet architecture.

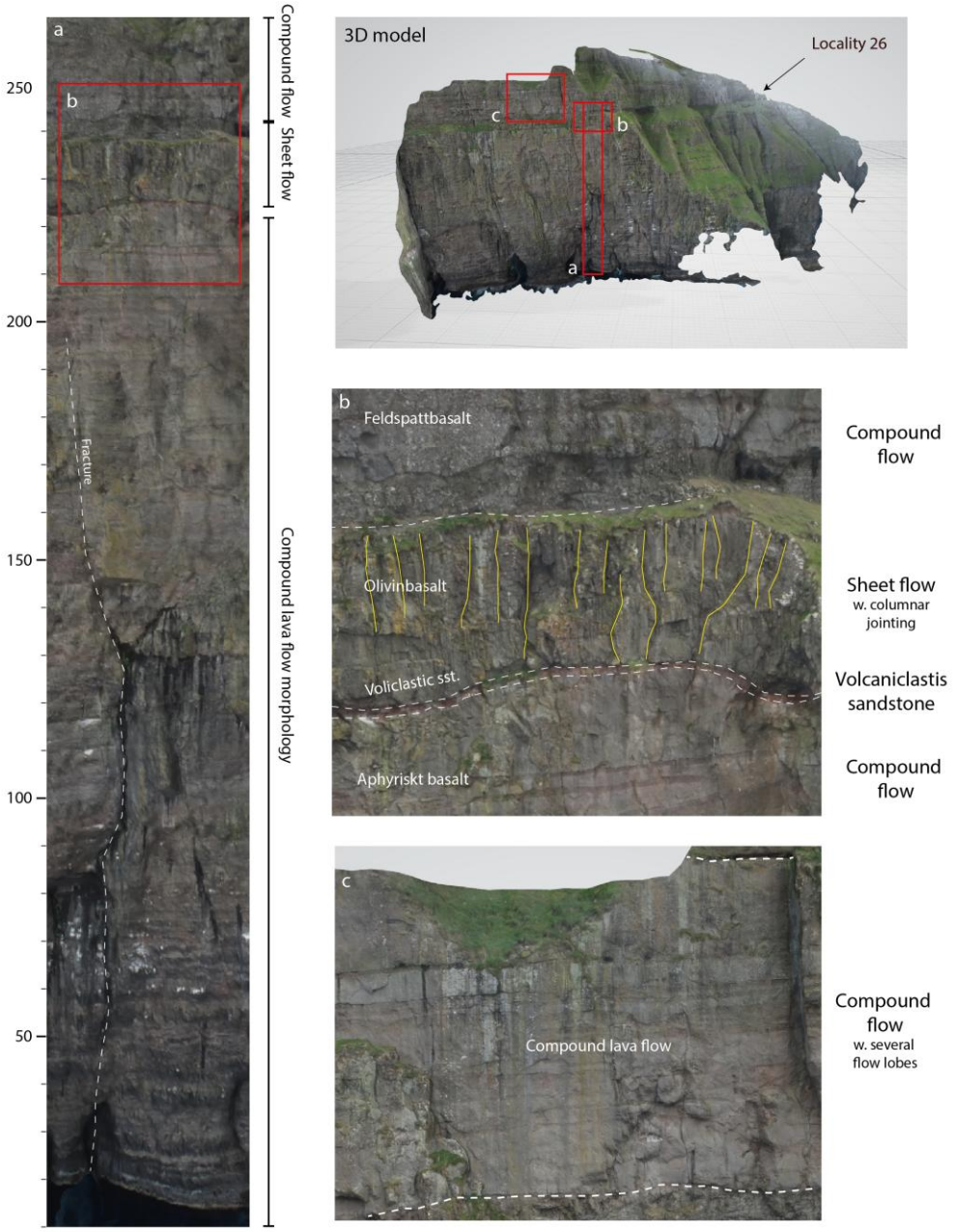


Figure 23. 3D model from Sandvík, including interpretation of various geological features. Different flow types displayed. Similar 3D models will be created on the large fractures north of Sandvík in spring of 2024.

Locality 95

Several relatively small-scale fracture systems at the shoreline. Mainly two sets of fractures and the larger system visible in the gorge (Gjógv) with strike ca. 170 (Figure 24).



*Figure 24. Fracture system at shoreline with connection with the large fault visible in the gorge (**Fejl! Henvisningskilde ikke fundet.**). Width of fault system ca. 2m (stippled lines). Looking north, towards Sandvík village.*

Locality – Boat trip 1

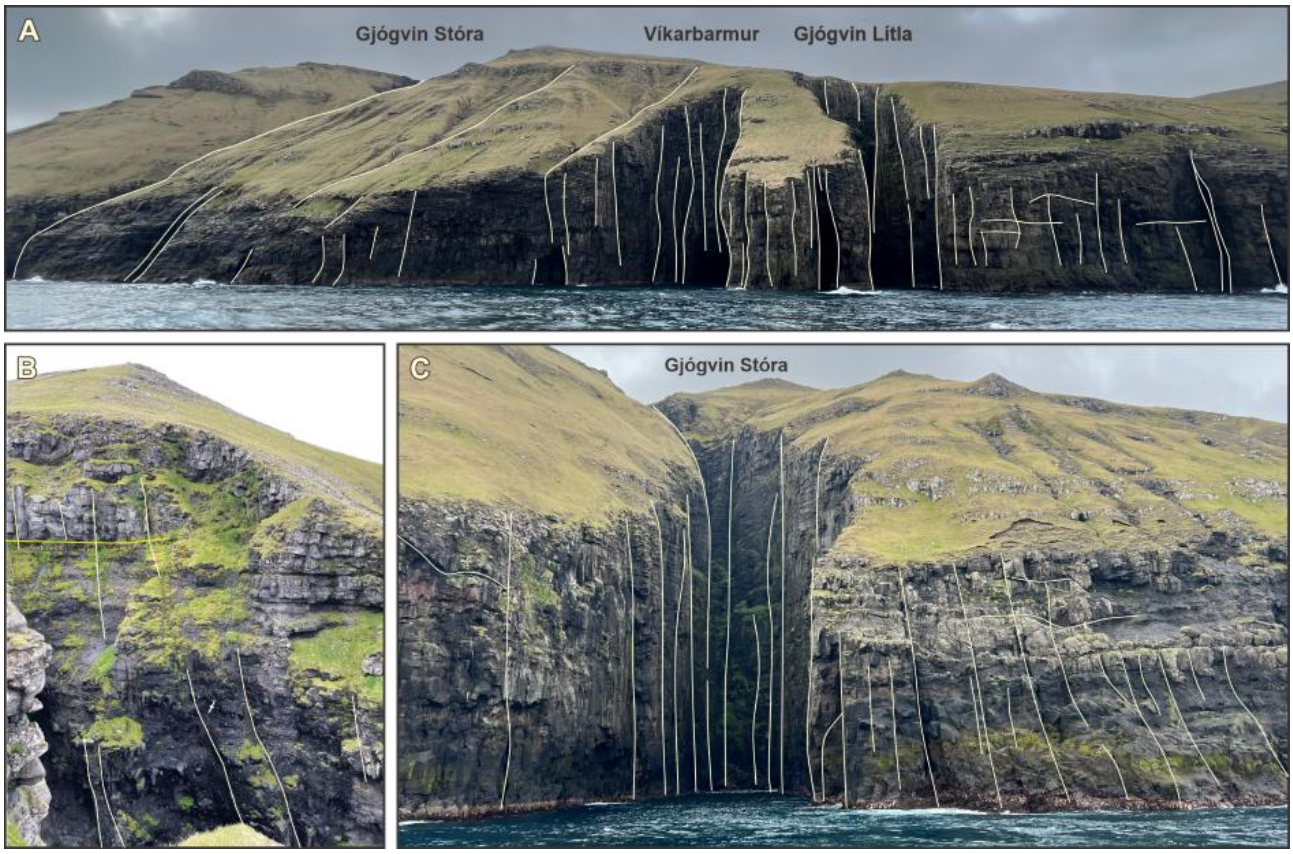


Figure 25. Northern end of Suðuroy at the location of the tunnel path showing the prominent fractures (thin lines). A: overview, B and C: Gjógvin stóra

Locality – Boat trip 2



Figure 26. Northen end of Suðuroy eastwards at the fractures zone at Keilin.Thin lines show fractures.

Sandoy and Skúvoy localities

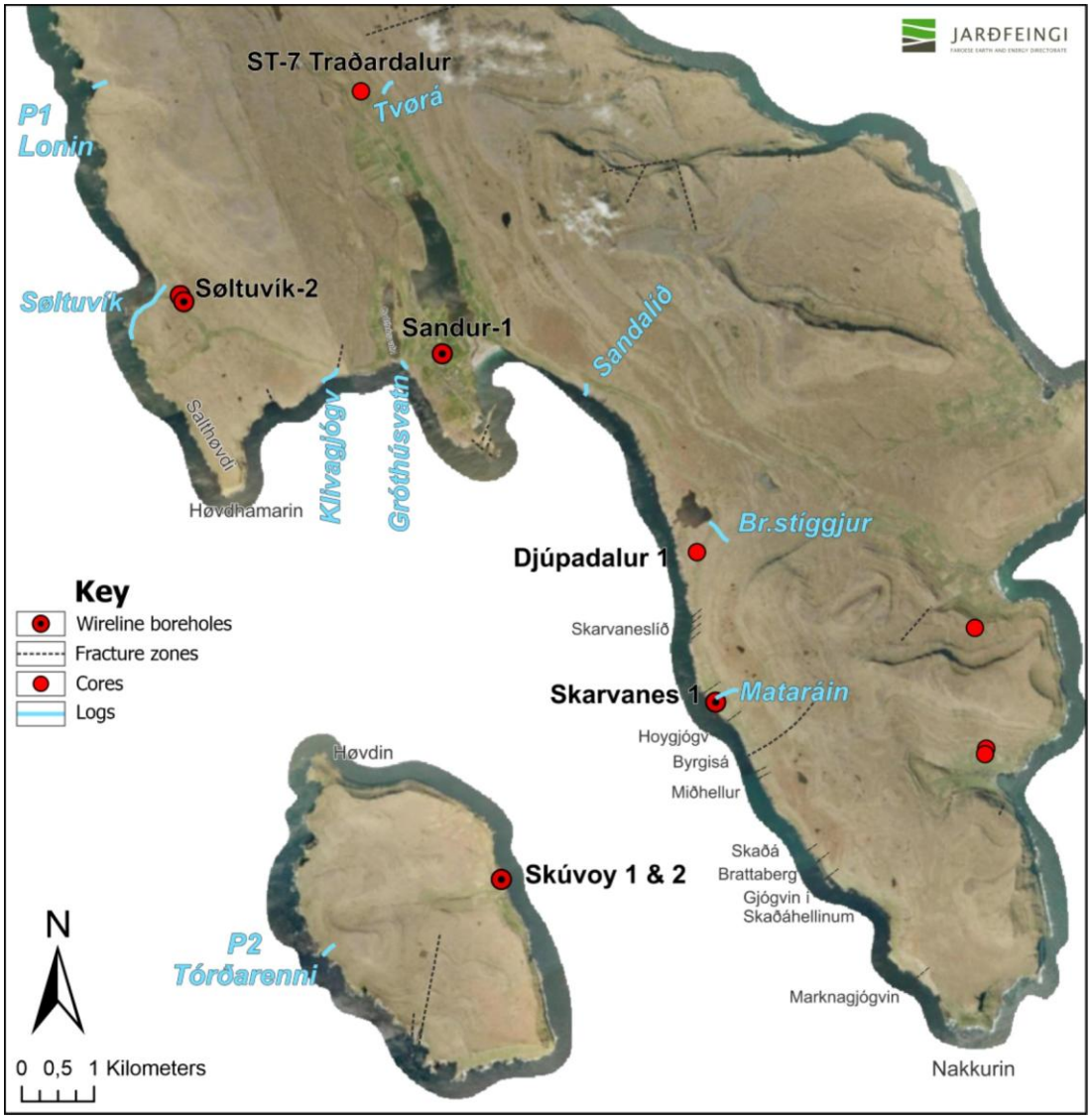


Figure 27 Sandoy and Skúvoy. Overview of field localities, logged sections, wireline boreholes, and cores.

Characteristic and recognizable layers have been identified, and an attempt has been made to map them in the field. Typical layers that can be traced are sheet lobes which often occur as a crag in the landscape. Thick sandstone layers are also useful for stratigraphic correlation. Several of these sheet lobes and sandstone layers have been given names according to localities, where they are well exposed (Figure 27 and Figure 37). The abbreviation “sst” used for sandstone layer in the text and figures.

Locality Søltuvík – Turid

Two prominent sheet lobes, that have been named in the literature. The lower is the C-horizon flow (Rasmussen & Noe-Nygaard, 1969), that is around 20 m thick and consists of weakly columnar jointed coarse feldspar phyric basalt. The upper is the Høvdhamarin flow (Passey and Jolley, 2009), that is approximately 10 m thick and consists of weakly to strongly jointed medium feldspar phyric basalt (Figure 28).

Both the C-Horizon and the Høvdhamarin flow change character from sheet flow to compound flow. Along most of the West coast from Rættarhøvdin on Northern Sandoy to Søltuvík the C-horizon flow is a sheet lobe that is 10–20 m thick (Figure 28 C). South of Søltuvík it changes character to compound flow (Figure 28 D). Høvdhamarin Flow is more than 30 m thick at Salthøvdi (Figure 28) thinning northwards to Lonin, where it is less than 10 m thick. Further North it changes character to compound flow.

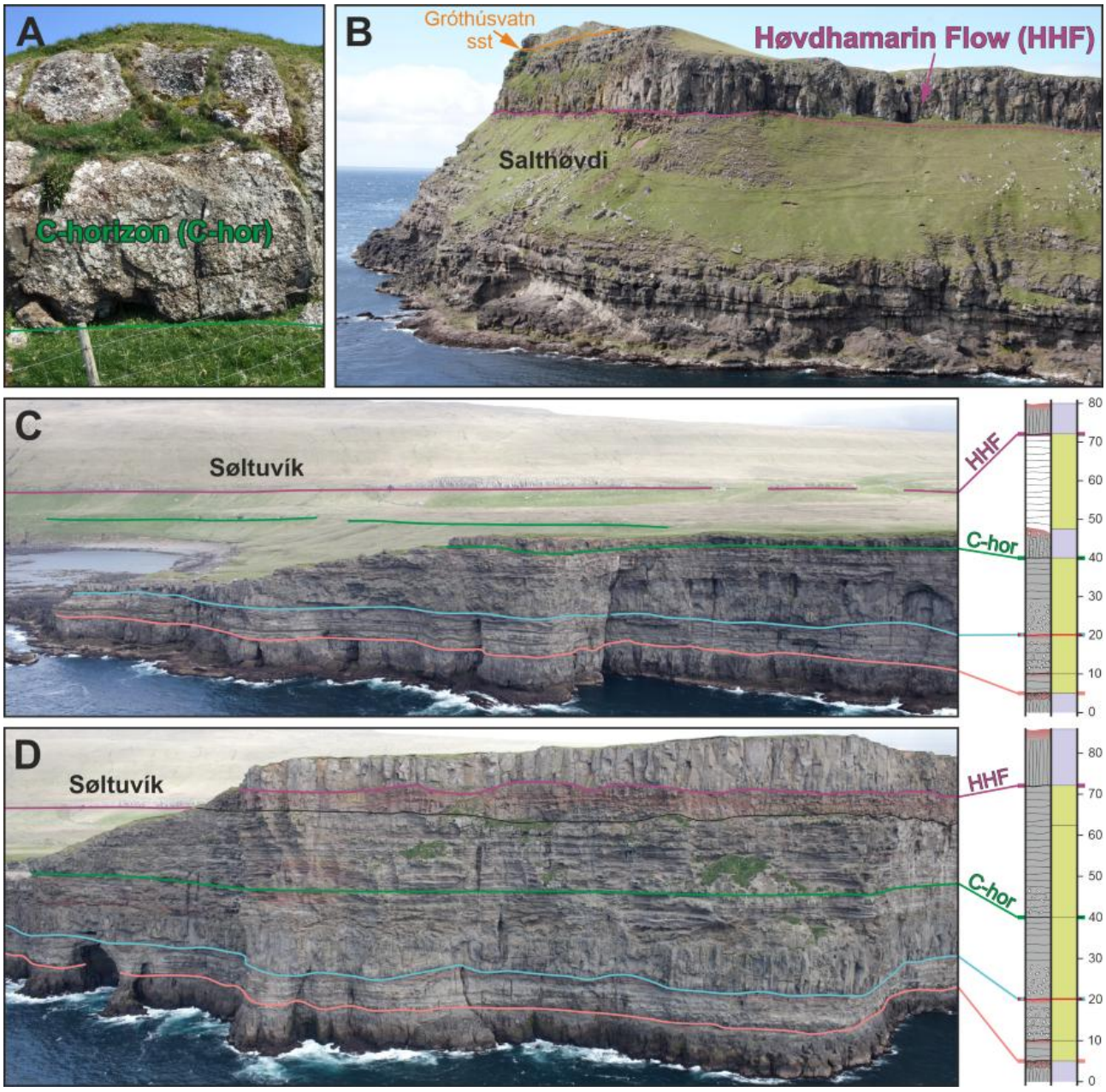


*Figure 28. Søltuvík. Location is shown in Figure 27. Vertical log: Light green is compound flows, purple is simple flows, and red is volcaniclastic units. Green line: C-Horizon, Purple line: Base Høvdhamarin Flow, Peach line: probably top of the thick sheet lobes above METZ, Orange line: Gróthúsvatn sst. **A**: The C-horizon flow. **B**: The Høvdhamarin Flow is 20–40 m thick at Salthøvdi. The Gróthúsvatn sst is exposed at the top **C**: Steep cliffs at Søltuvík. The C-horizon flow is here a thin sheet lobe. **D**: Steep cliffs at Søltuvík further South. The flows above the C-horizon have changed character to compound flows. The Høvdhamarin flow is 20 m thick and columnar jointed.*

The lowermost flow at Søltuvík is exposed at the base of the steep cliff and is a columnar jointed and fractured sheet lobe (Figure 28 C and D). It probably corresponds to the thick sheet flows above METZ. Above is an interval with compound flows with that is followed by the C-horizon flow. After a second interval of compound lava flows follows the 10 m thick Høvdhamarin flow at the top.

Locality Klivagjógv-Gróthúsvatn

The base of the Høvdhamarin Flow (purple line) is exposed at the shoreline West of Klivagjógv.

In Klivagjógv cleft the Gróthúsvatn sst (orange line) is exposed as two 0,5 m and 2 m thick sandstone layers. They can be traced along the shoreline, where they converge to one up to 3,5 m thick layer, that is exposed to the west of Urðin shoreline.

The Klivagjógv sst (peach line) is exposed at the road above Klivagjógv and to the East of the Urðin shoreline. It can be traced all the way around the Gróthúsvatn lake.

The Klivagjógv sst is overlain by an almost 20 m thick sheet lobe with a lower columnar jointed base core and a prominent red flow top. On top of this is a ca 15 m thick prominent columnar jointed sheet lobe that can be traced along the shoreline to the harbour (Figure 29).

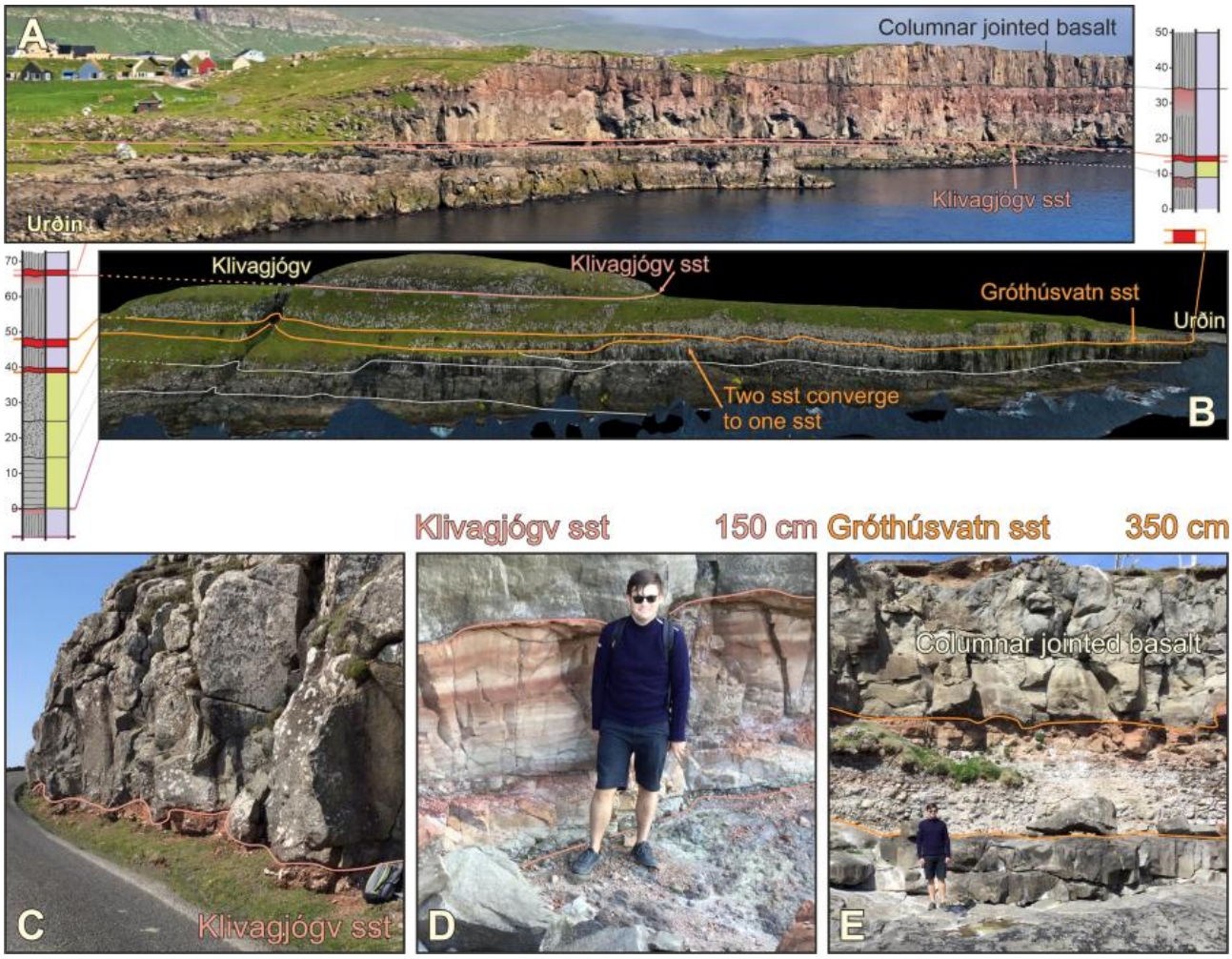


*Figure 29. The Klivagjógv-Gróthúsvatn area. **A**: Vertical cliff section at Urðin where the 1 m thick Klivagjógv sst is exposed. A ca 15 m thick columnar jointed sheet lobe can be traced along the shoreline from Urðin to the Sandur harbour B: Drone photo of the area between Klivagjógv cleft and Urðin. The Klivagjógv sst (peach line) is exposed at the road. The Gróthúsvatn sst is two sandstone layers in Klivagjógv cleft and converges to one sandstone layer at Urðin (orange arrow). **C**: Klivagjógv sst exposed at the road above*

*Klivagjógv. **D**: Klivagjógv sst exposed East of Urðin as a 150 cm thick red and green layered sandstone. **E**: The Gróthúsvatn sst exposed West of Urðin. It is 350 cm thick and layered red and green sandstone.*

Locality Sandalíð–Tvørá

The Traðarhamar crag can be followed for 5–6 km from Sandalíð to the South to the Tvørá stream towards the North. It is one of the longest crags in the Faroe Islands. 3D drone photos have been taken all along the Traðarhamar crag, which made it possible to trace certain levels for a long distance. It consists of at least 5-6 weak to strongly columnar jointed sheet flows of feldspar phyric basalt separated by 1–4 sst layers (Figure 30 top).

At Sandalíð three sandstone layers are exposed along the road. They can be traced from the road to the shoreline. The Traðarhamar sst is the uppermost sandstone (Figure 9-bottom, left). It is 75 cm thick and red. The middle sandstone (Figure 9-bottom, middle) is 150 cm thick and is green and red. The lowermost sandstone is the Sandalíð sst (Figure 9-bottom, right) that is 300 cm thick and layered with red and green layers (Figure 30 bottom).

The level of the Traðarhamar sst can be traced all along the Traðarhamar to the Tvørá stream (location in Figure 27). At the same level at Tvørá there is only a red flow top possibly with sandstone infilling fractures. The boundaries in the Tvørá stream are well exposed and the only sandstone observed is at the base of the crag. This sandstone is >150 m thick and probably corresponds to the 350 cm thick Sandalíð sst.

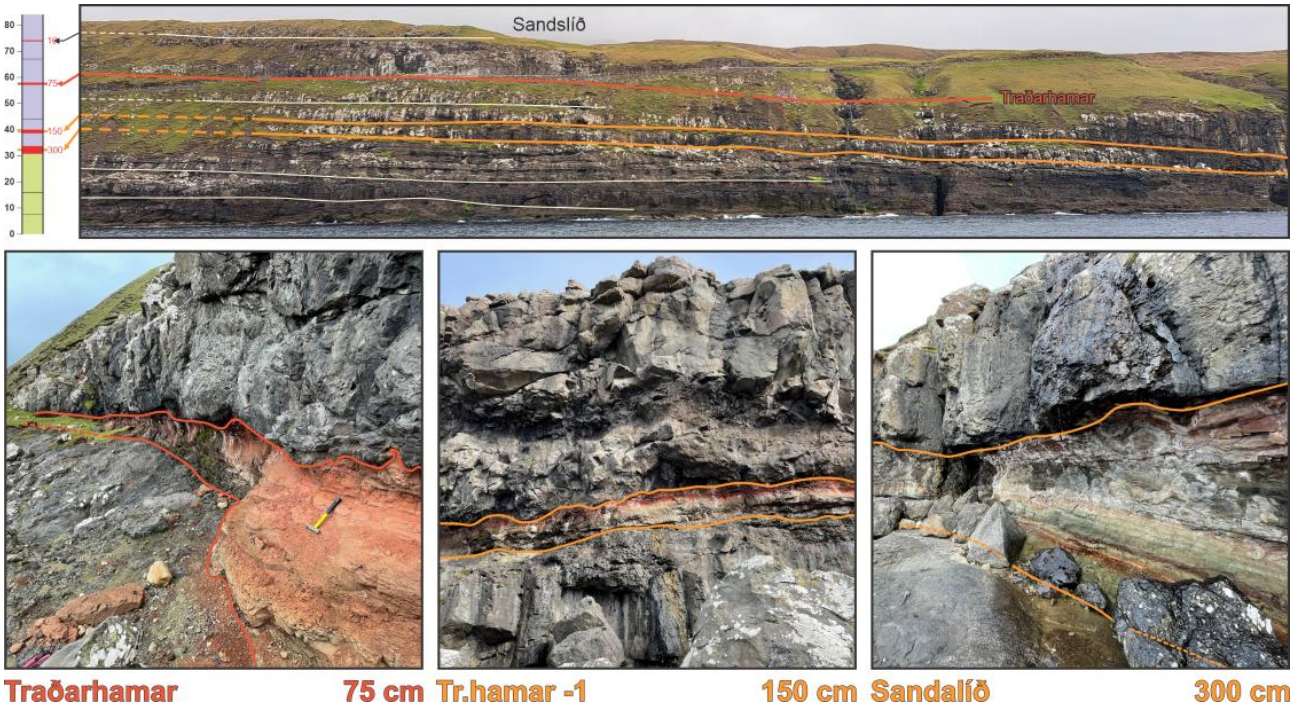


*Figure 30. Sandalíð. Three sandstone layers are exposed along the road at Sandalíð. **Top**: Sandalíð seen from a boat. Three sandstone layers can be traced from the road to the shoreline. The log:to the left of the photo shows compound flows (light green) at the base of the section. Above the Sandalíð sst are at least six 5-15 m thick sheet lobes (purple). The volcaniclastic units are red on the log. **Bottom**: The three thick sandstone layers. **Left**: The Traðarhamar sst is the uppermost and is 75 cm thick. **Middle**: The middle sandstone is 150 cm thick. **Right**: The lowermost sandstone is named the Sandalíð sst. It is 350 cm thick and is layered with red and green layers.*

Locality Skarvaneslíð-Skarvanes

A 3D drone photo of the steep Skarvaneslíð shows a prominent columnar jointed sheet lobe with an irregular altered flow top at the base of the cliff (Figure 31 A). The sheet lobe is >20 m thick and is also exposed at the coastline of Skarvanes (Figure 31 C).

The 1 m thick Skarvaneslíð sst is exposed at the road in Skarvaneslíð above the next sheet lobe. The Skarvaneslíð sst can be traced to Skarvanes, where it is exposed behind a house/garage. Above the sandstone is a sheet lobe and then an interval with compound flows (Figure 31 C and D).

At the top of the 3D drone photo from Skarvaneslíð is the 1 m thick Mataráin sst, that got its' name from the Mataráin stream at Skarvanes. Above is a columnar jointed 10–20 m thick sheet lobe of fine feldspar basalt (Figure 31 A and B).

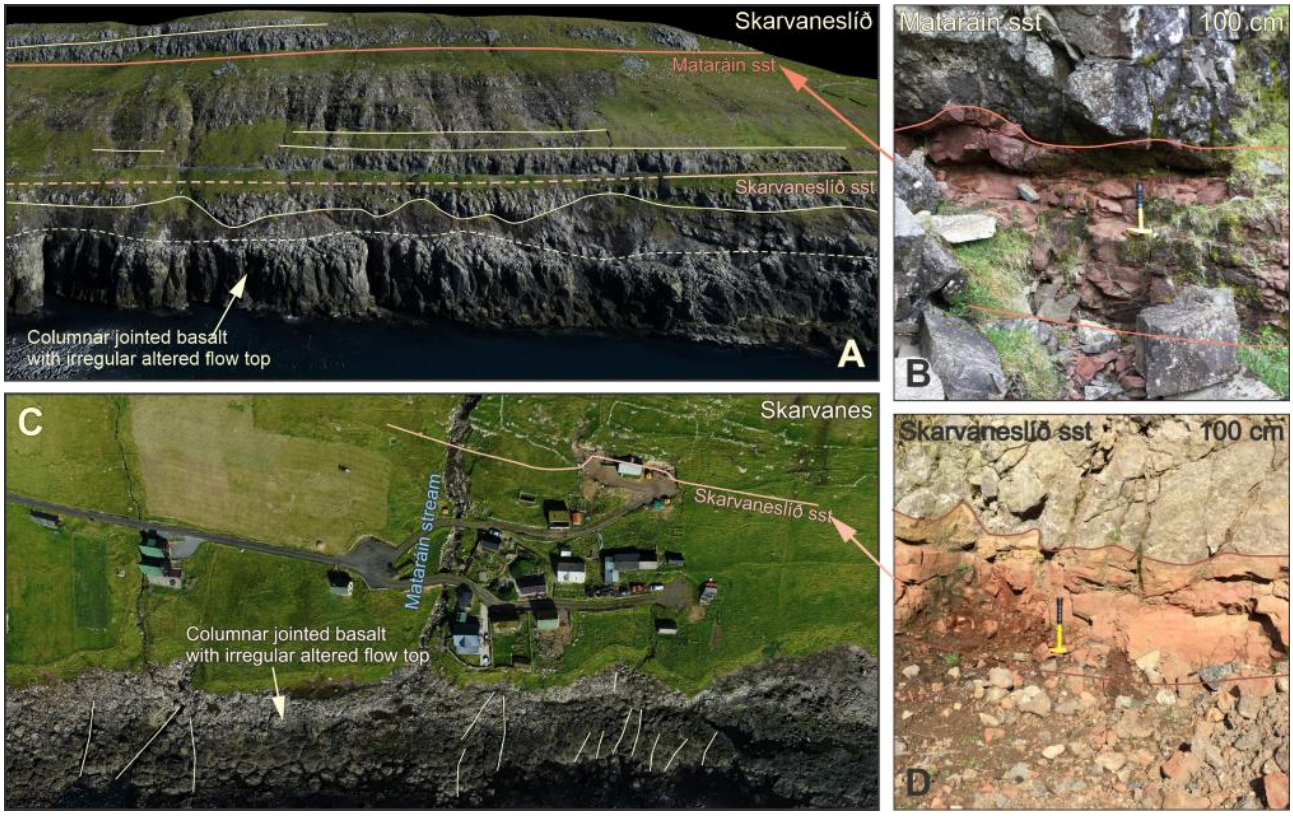


*Figure 31. Skarvaneslíð og Skarvanes. **A** 3D drone photo of the steep Skarvaneslíð. A thick columnar jointed sheet lobe with irregular altered flow top. On the road, the Skarvaneslíð sst is exposed. It is about 1 m thick. At the top of the photo is the ca 1 m thick Mataráin sst which is overlain by a >10 m thick sheet lobe. **B** Close up of the Mataráin sst in Skarvanes, which is named after the exposure at ca 90 m.a.sl. in the Mataráin stream (log in figure 2). **C**. 2D drone photo of Skarvanes, showing the columnar jointed sheet lobe at the coastline, which is also fractured. The Skarvaneslíð sst is exposed behind a house and is 100 cm thick. **D**. Close up of the Skarvaneslíð sst in Skarvanes (location Figure 27).*

Locality Skúvoy

A helicopter photo of the cliff section at Tórðarenni shows two prominent 20–30 m thick columnar jointed sheet flows at the base, which correspond to the sheet flows above METZ. Above is an interval with compound flows, that are overlain by the Høvdin sst, that is split into two layers at this location. It is followed by 15 m thick columnar jointed sheet flow then followed by another 100 m thick interval of compound flows. At the top of the cliff section are 4 thick sheet flows separated by thick sandstone layers (Figure 32 A).

At Skúvoy harbour the ca 275 cm thick upper layer of the Høvdin sst is exposed. The lower sandstone can be observed below sea level when the sea is rough and is observwed in the Skúvoy-1 and Skúvoy-2 boreholes, and is >100 cm thick. The sandstone has been displaced more than 4 m by a fault, that is located under the staircase (Figure 32 B).

The Høvdin sst can be followed all the way along the coastline of Skúvoy. Sometimes it is separated in two by a basalt flow. Other places it occurs in one layer e.g. at the Høvdin area (Figure 32 C).

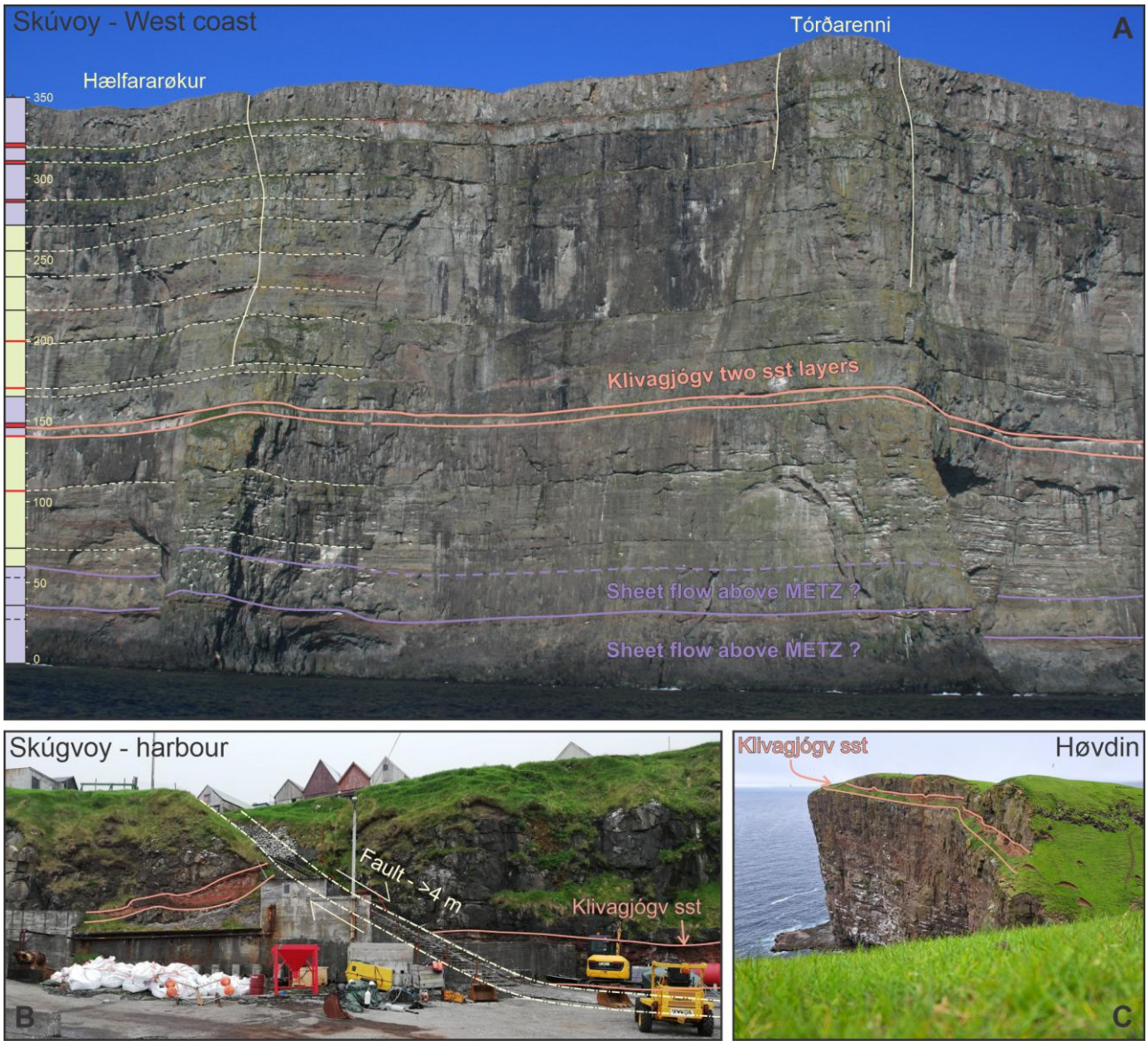


*Figure 32. Skúvoy **A** West coast of Skúvoy. Photo taken from helicopter (Vosgerau et Al (2011)) Vertical log: Light green is compound flows, purple is simple flows, and red is volcaniclastic units. Purple line: base of sheet flows above METZ, Peach: Høvdin sst split in two. Stipled light yellow lines: flow boundaries. Steep, light yellow lines indicate fractures. **B** Skúvoy Harbour. Høvdin sst upper layer is about 275 cm thick. The lower layer is observed in the Skúvoy-1 and Skúvoy-2 wells, and is >100 cm thick. The Høvdin sandstone has been displace more than 4 m due to a fault along the stairs. **C** At Høvdin locality, the sandstone occurs in one layer, that is approximately 400 cm thick. Location is shown in Figure 27.*

Locality Sandoy fracture zones

A boat trip was done in May 2025 taking overlapping photos and continuous video of the coastline of Sandoy from Nakkurin to Sandalíð (Figure 27). The photos in Figure 33 give an overview of the most important fracture zones. The photos are named after the location.

The most prominent fractures belong to the strongly columnar jointed flow that is exposed at the coastline at Skarvanes and along the steep Skarvaneslíð. The other localities show a few fractures, that can be followed as a gully or a low in the terrain.

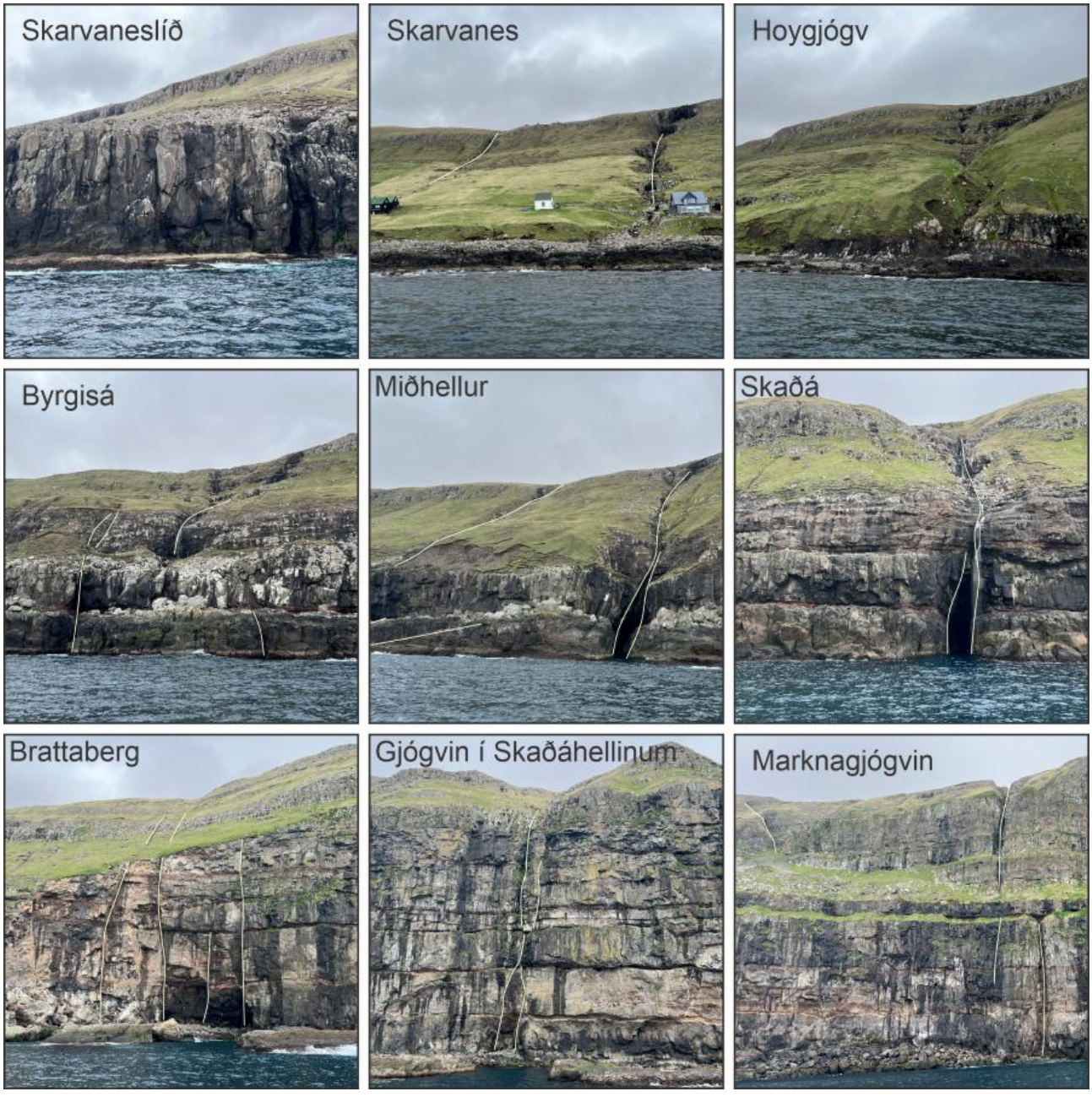


Figure 33. Fractures between Sandalíð and Nakkurin observed during the boat trip in May 2025 (locations in Figure 27). ***Skarvaneslíð****: A thick sheet lobe with prominent columnar jointing.* ***Skarvanes****: Two fracture zones.* ***Hoygjógv****: A gully at the coast South of Skarvanes.* ***Byrgisá****:A few fractures seen at the coastline.* ***Miðhellur****: Two small fracture zones.* ***Skaðá****: The fractures at the coastline can be followed as a depression in the landscape.* ***Brattaberg****: Four parallel fractures.* ***Gjógvin í Skaðáhellinum****: A couple of fractures, that result in a low in the landscape..* ***Marknagjógvin****: A couple of fractures resulting in a gorge.*

Fracture structural lineament

Mapping fractures has been mainly done from onshore fieldwork, by coastal boat surveying or helicopter or drone photography, where fractures and dykes can be observed directly on exposed bedrock surfaces. However, where the bedrock is covered with thin layer of vegetation or sediments, or inaccessible on the seafloor, the strategy is to find linear structures, or lineaments, on the surface, either as elongated depression, ridges, or abrupt, straight surface breaks. These lineaments have been mapped by identifying relevant morphological features on the seafloor from multibeam data or on land from Digital Surface Model. Lineaments can in some cases be connected to nearby fracture observations, which will boost the confidence that the lineament is related to nearby fracture, but more often lineaments are found isolated and the question if the lineament is a fracture remains unresolved. For this survey most lineaments found on the seabed, are solely found with multibeam. Some coastal near lineaments can be connected to cliff observations and/or may be found as elongated, narrow grooves in exposed bedrock. These are most likely fractures of some sort. However, the fracture relationship to lineaments found further from direct observations at the shoreline remain inconclusive. To make matters worse, the deeper parts of the multibeam surveys are more often covered with sediments, while the multibeam data are at lower resolution and of worse quality. These are probably the reasons why, so few lineaments have been observed between Skúvoy and Suðuroy. The ones, that have been found in the area are often relatively large, and the confidence that these lineaments are fractures or dykes is low.

Magnetometer have been used onshore and offshore with mixed results. The magnetometers in this survey measure the magnetic total intensity. Any abrupt changes, or anomalies, with somewhat linear and elongated shape could potentially be caused by a dyke or fracture zone. Dykes do generally cause anomalies, fracture zone can sometime be found, and in some cases basalt flow end or stratigraphic changes cause anomalies. The resolution of the magnetic mapping depends on the distance between the magnetometer and the magnetic surface. Therefore, the walking Proton Magnetometer with 2 m distance is better suited to find meter wide dykes or fracture zones, than the marine magnetometer with 10–70 m distance to the seafloor. Some anomalies have been mapped onshore at Skarvanes and Sandvík. However, the confidence that these are related to dykes or fracture zones is low at present time. Only large-scale anomaly has been found with the marine magnetometer between regional syn- and anticline (see Figure 34 or Appendix C), where the anomaly is likely not related to fracture or dyke but may be result of change in stratigraphic dip and exposed basalt flow end (See ‘Fold’-chapter for more). Strangely, relatively few lineaments have been found in the same area as the magnetic anomaly. This may be due to that the area is locally the deepest part of the seafloor which may be why the seafloor here is partly covered by sediments, potentially covering any lineaments.

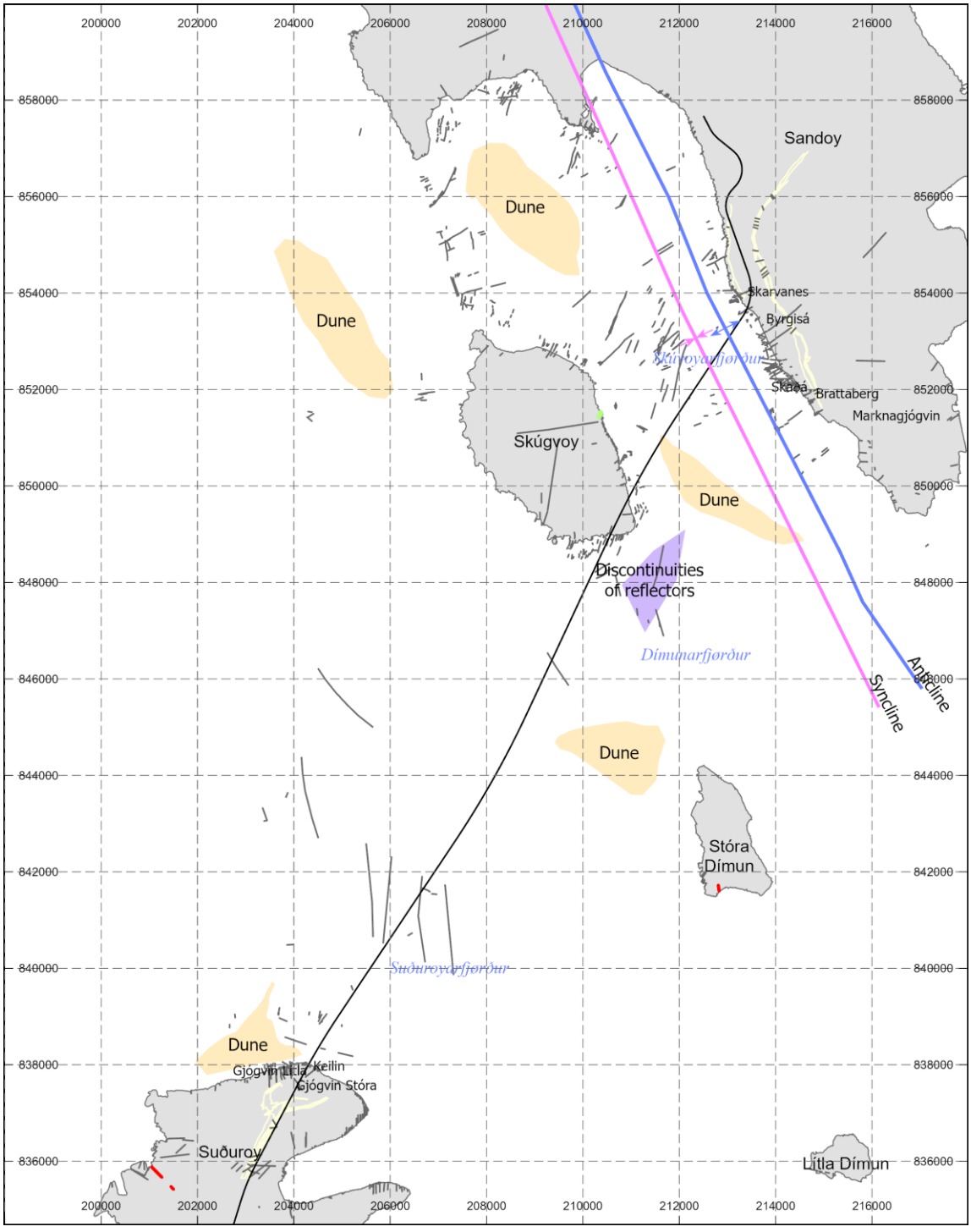


Figure 34. Map of relative large lineaments, fractures and dykes in the project area. The lineaments and fractures have the same symbol on the map, black solid lines. Dykes are mapped with red solid lines. A small normal fault has been marked with bright green color on the eastern shore of Skúvoy (see also Figure 32C). The area with discontinuities in the seismic reflectors south of Skúvoy is highlighted with purple color. Magnetometer data coverage on land, that is the basis for local lineaments interpretations (black), is highlighted with pale yellow lines. Note that many of the fractures between Skarvanes and Marknagjógvin on Sandoy, and Gjógvin Lítla, Gjógvin Stóra and Keilin on Suðuroy can be found in Figure 33 and Figure 25 and 26, respectively. Close to Skarvanes, in the area between the hinges of a regional syncline (pink) and an anticline (blue), the folds will be addressed later, very few lineaments have been found. Large sand dunes on the seabed are highlighted with yellow to show where the bedrock and associated lineaments cannot be observed with multibeam.

Correlation panels

A correlation panel spanning Skúvoyarfjørður includes four of the five surrounding boreholes: Søltuvík-2, Sandur-1, Skúvoy-1, and Skarvanes-1 (Figure 35). The correlation is based on integration of lithological interpretation of wireline logging combined with tie to seismic data in Skúvoyarfjørður. The seismic data provide the means to connect interpretations from well to well.

The Malinstindur Formation seen in the boreholes comprises typical compound flow facies architecture. Several thin flow lobes are observed in all the boreholes. Few volcaniclastic sand- and claystone beds are seen in the Malinstindur Formation. The Enni Formation is characterized by interfingering series of simple sheet flows and compound flows.

A correlation between Søltuvík-2, Skúvoy-1, and Skarvanes-1 is based on an about 1.5–2 m thick sandstone (correlation horizon in Figure 35) underlain by first fine-grained feldspar phyric basalt and second by coarse-grained feldspar phyric basalt. The correlation is to a large degree also based both on a relatively high SPR signature in a 25–30 m interval, representing massive sheet flows, on top of a thin interval of a few meters, with very low SPR in combination with a high NGAM spike, representing sediments, that correlates to the low SPR value (Figure 35).

The stratigraphic level of the sediment represents the base of a transition zone from compound flows to more frequent sheet lobes in uppermost part of the Malinstindur Formation. Note that this differs from the C-horizon of Rasmussen and Noe-Nygaard (1969), where the boundary is placed ca. 100 m higher up in this area, but it is more in agreement with the Malinstindur Sneis Unconformity (MSU) of Passey and Jolley (2009).

Note that this correlation between Søltuvík-2/Sandur-1 and Skarvanes-1 is in disagreement with the regional dip in the area. However, interpretation of the seismic data shows a fold that explains this disagreement.

Another prominent correlation, between Sandur-1, Skúvoy-1, and Skarvanes-1, is a series of 3–4 sediment beds at about 175–225 m above the base of the transition zone. In Skúvoy-1 only the lowermost of these beds is present in the borehole, but at the drill site the correlating beds above are observed in the cliffs just above. The combined thickness of the sediment beds is 5–6 m. This sediment series will be named *Sandur Beds.* The Sandur Beds span a combined thickness with the interlaying lava flows of some 30 m.

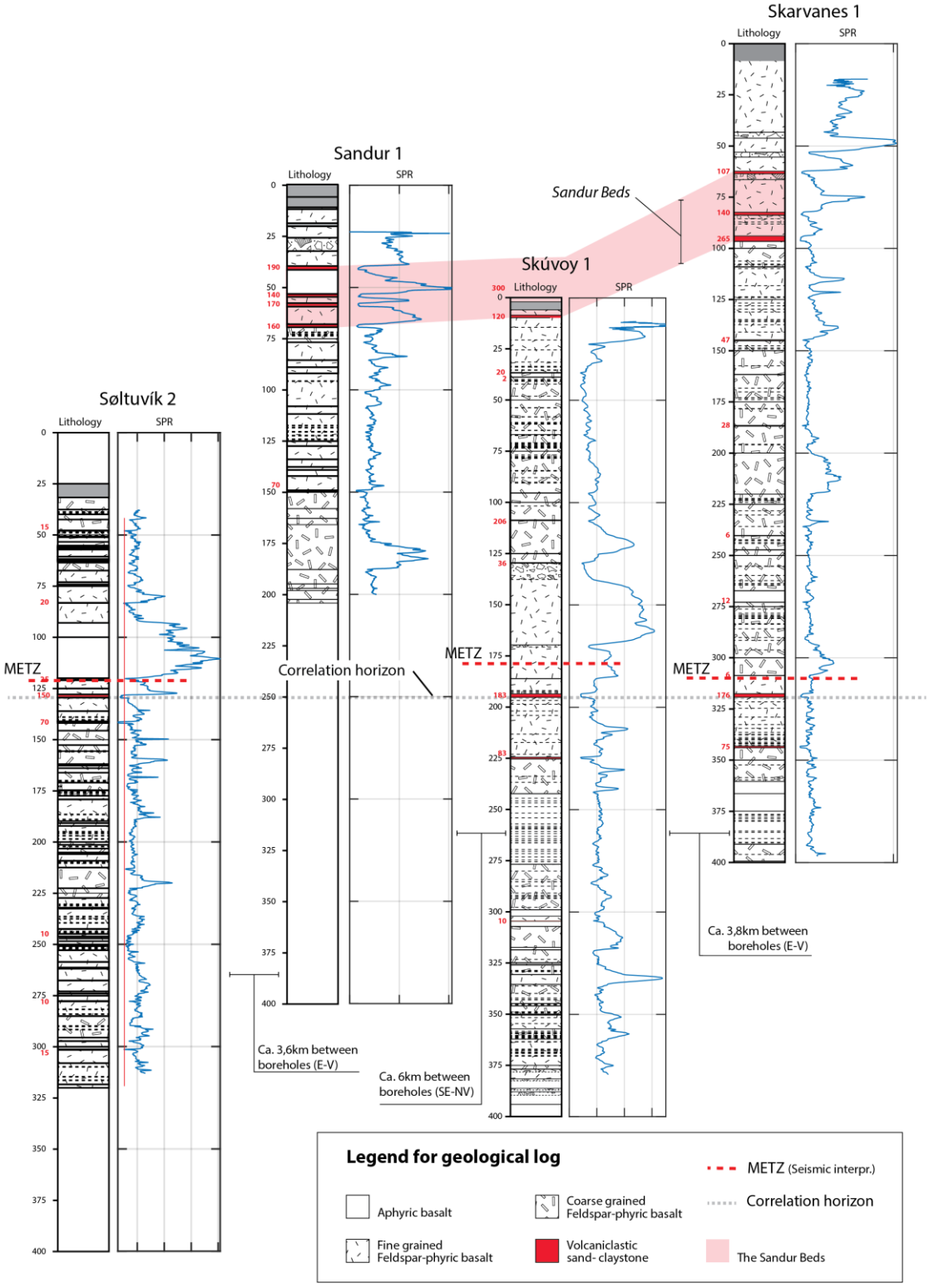


Figure 35. Correlation panel showing the four wells (Søltuvík-2, Sandur-1, Skúvoy-1, and Skarvanes-1) around Skúvoyarfjørður. Lithology and the SPR logs are used for the correlation. The logs are aligned to the C-reflector. The Sandur Beds have been highlighted in pink. Lava morphologies are marked in green (Compound flows) and purple (Sheet flows). Distances between the Awells are indicated. The METZ (Malinstindur-Enni-Transition-Zone) is defined as first positive zero-crossing related to reflection from the first sheet lobe entering the transition zone as described in Definition of regional seismic horizons on page 59.

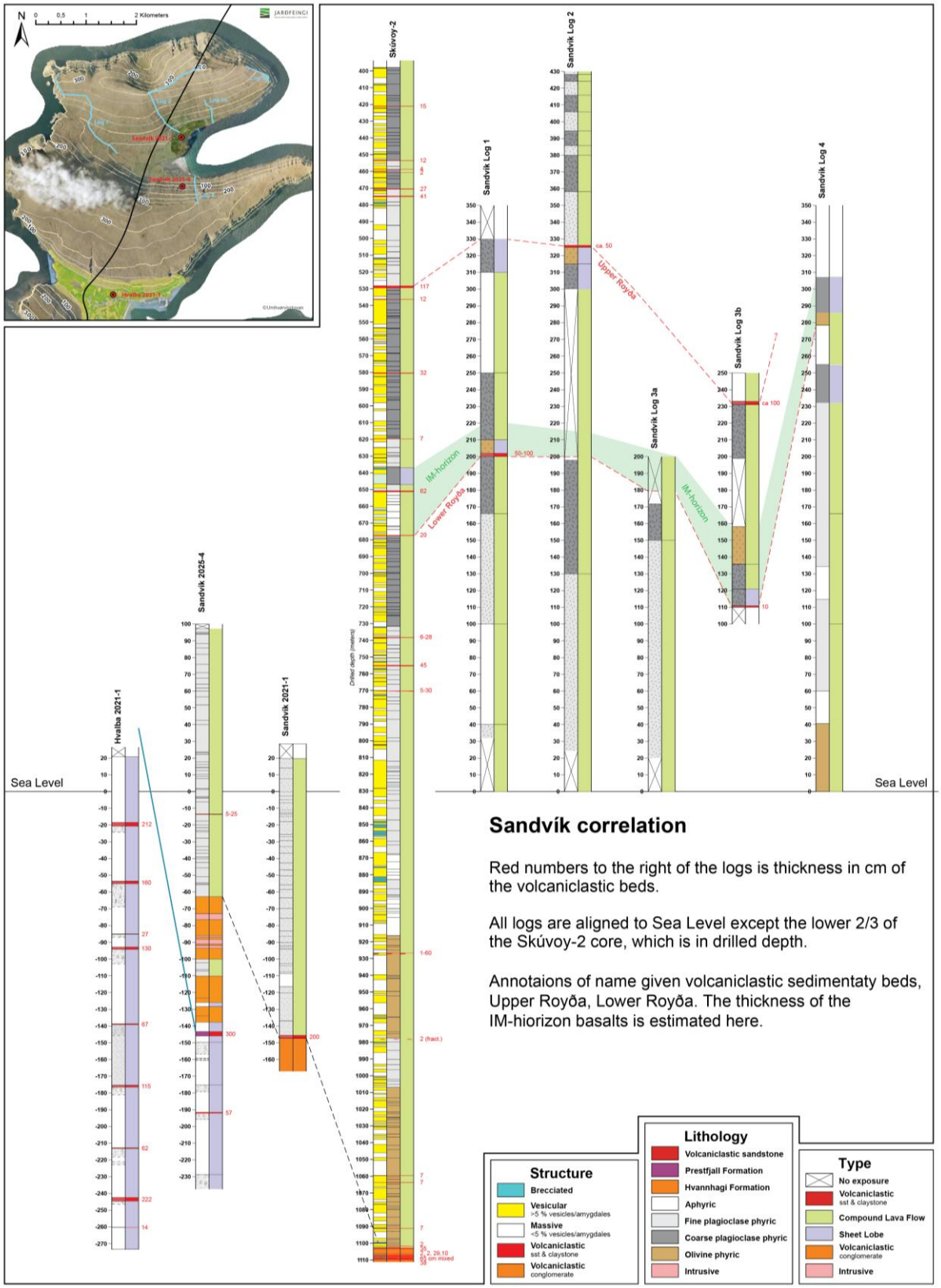


Figure 36. Correlation panel for Sandvík area aligning logs and boreholes to sea level. Elevation is relative to MSL except for the Skúvoy-2 core that is MD. Skúvoy-2 core is from 400 m to 1111 m MD. Location of logs and boreholes are in Figure 8. The names next to the logs are characteristic layers, that can be traced in the field.

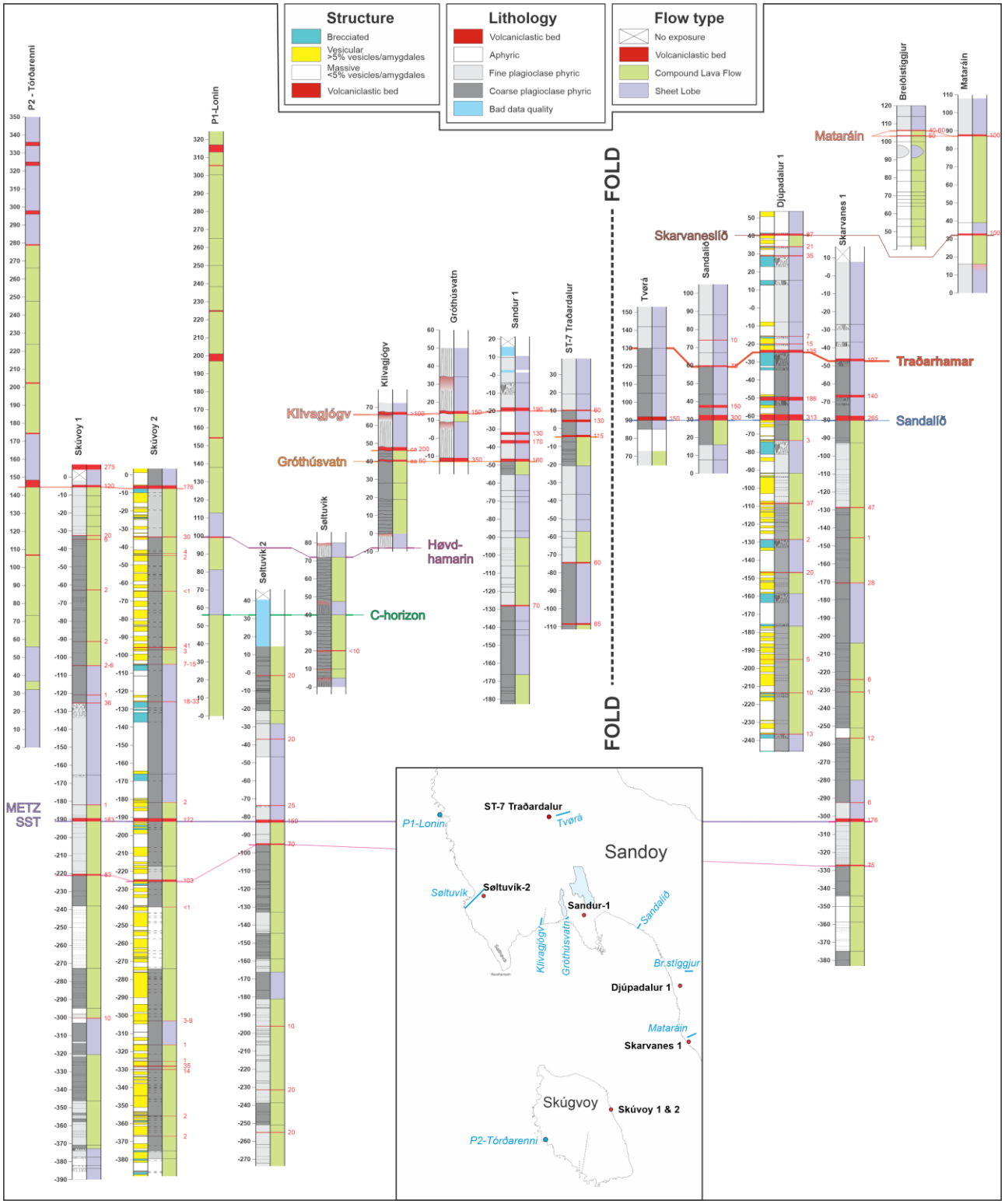


Figure 37. Correlation panel for Sandoy-Skúvoy area logs and boreholes to METZ. Elevation is relative to MSL. Only the uppermost 400 m ov Skúvoy-2 core is presented here. Location of logs and boreholes are in Figure 8. The names next to the logs are characteristic layers, that can be traced in the field.

Interpretation of seismic data

The seismic surveys for the Suðuroy subsea tunnel utilize the same method that was used in the planning of the Eysturoy and Sandoy subsea tunnels (Petersen, 2015, 2016). This method, acquiring marine reflection seismic data, and in an iterative process, combining refraction seismic modelling with interfaces from stacked seismic data, produces detailed velocity distribution along the seabed for the uppermost 100 m, and reflection seismic profiles suitable for interpretation of layering in the uppermost 100–300 m below seabed (See the processing report, Petersen, 2020b, 2023)

Reflection seismic imaging is based on timing of reflections from reflectors in the subsurface (primary reflections). Reflectors being interfaces defining changes in seismic properties i.e., density and velocity, defining the *reflection coefficient*.

The terminology for interpreted interfaces on seismic data is *a reflection* while the corresponding interface in the subsurface is named *a reflector*.

Generally, reflection seismic imaging in basalts is challenging, mainly due to the high scattering, the multiple reflection, within the basalts. The high level of scattering is a result of high contrasts of rock properties related to core and crust of basalt flows and to interbedded sediments. But, in situations with few and thin sediment beds and less pronounced difference in rock properties for core and crust, as can be the case for compound flows, basalts can be quite transparent for seismic signals. A second challenging aspect of reflection seismic imaging in shallow waters, is the seabed multiple, which limits the depth range of seismic imaging. (Petersen, 2014; Petersen et al., 2015).

Between Sandoy and Skúvoy, the basalt stratigraphy poses the challenging seismic properties, with many thick sedimentary beds and sheet lobes, and thus high level of scattered signal resulting in poor quality of stacks, although there are areas with reasonable imaging within the basalt.

Between Skúvoy and Suðuroy, the basalt stratigraphy has the most advantageous seismic properties with few and thin sediment beds and less pronounced difference in rock properties resulting in low level of scattered signal, thus providing very good seismic images.

Definition of regional seismic horizons

The basis for the seismic interpretation is taken in the seismic profile LinjaL (see Figure 38 for location). This profile is planned such that it covers the full stratigraphic sequence from the lowest part of the Enni Formation, down through all the Malinstindur Formation, and the profile is extended so it reaches to the top of the Beinisvørð Formation.

Figure 39 shows the depth converted seismic profile of LinjaL. First step is to identify multiple reflections. Figure 40 shows the first and second seabed multiple and some peg-leg multiples. Peg-leg multiples are reflections from an interface that on the way up or down are reflected between two interfaces.

Above the first seabed multiple, primary reflections can be interpreted. Figure 41 shows three prominent reflections intersecting the seabed. In fact, due to good quality of data, the reflections on this profile can even be interpreted well beyond the first seabed multiple.

The interpreted reflections are named from the lowermost in the stratigraphy, to the right on the figure, and going to the left upwards through the stratigraphy, as *A-horizon*, *IM-horizon*, and *METZ*.

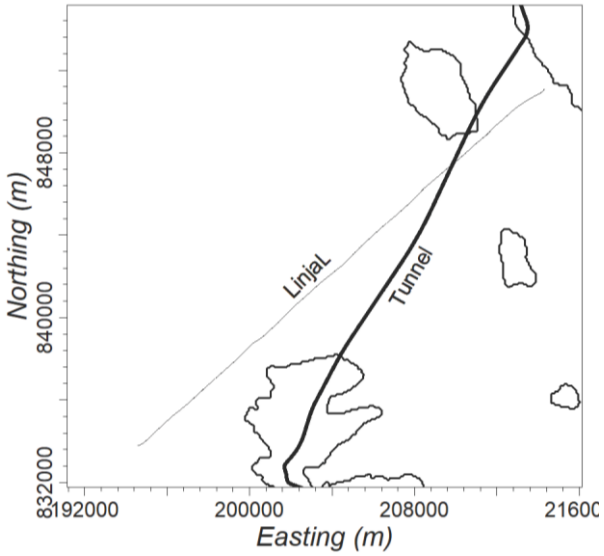


Figure 38. Location of seismic profile LinjaL.

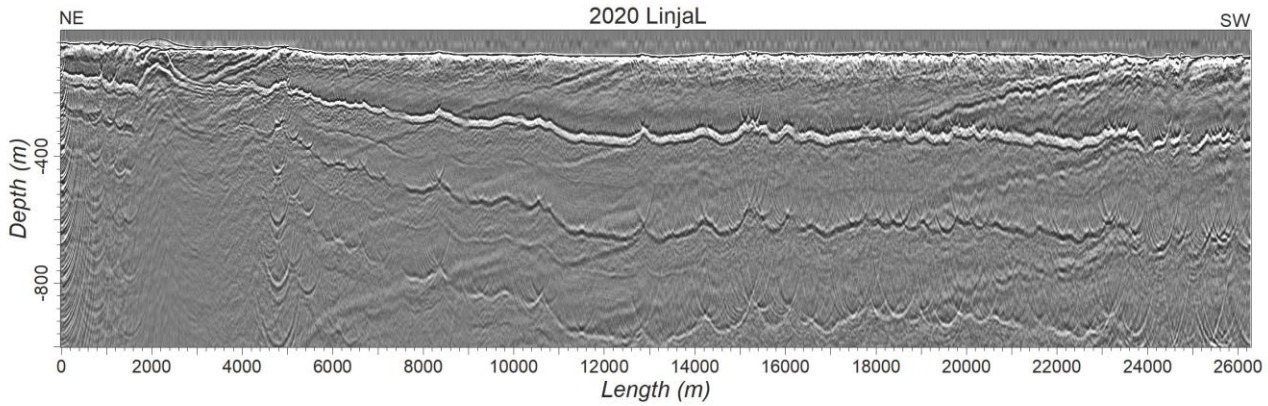


Figure 39. Depth migrated seismic profile LinjaL from north-east to south-west.

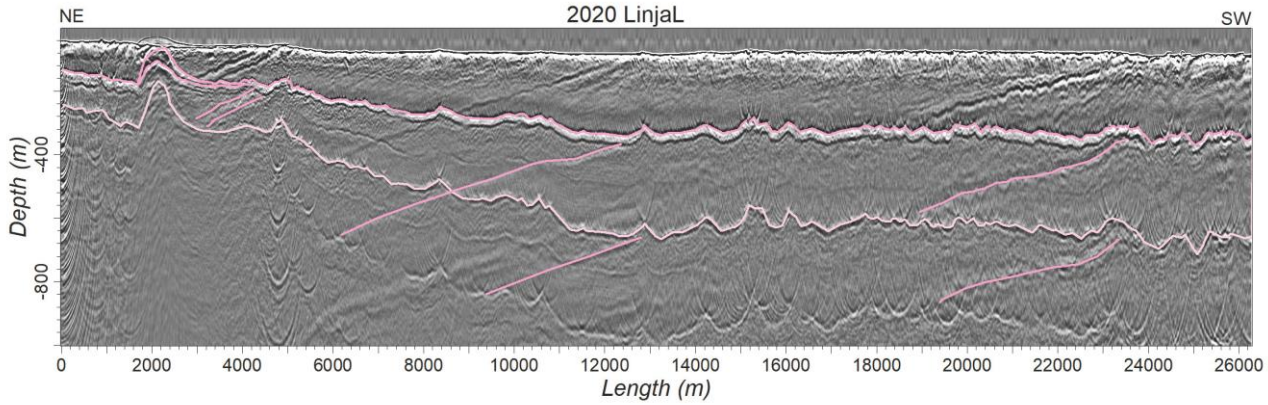


Figure 40. LinjaL with the first and second seabed multiple and the most pronounced peg leg multiples annotated.

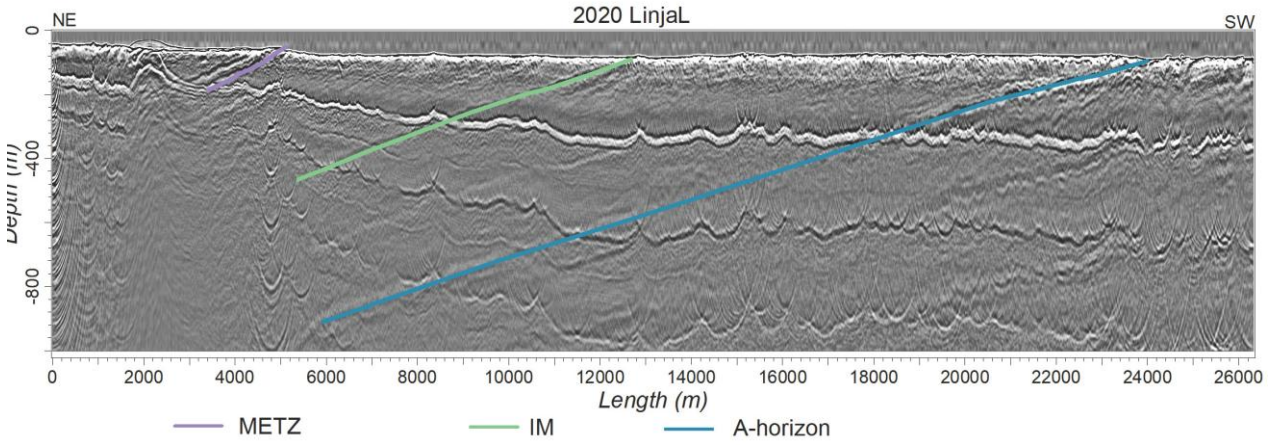


Figure 41. LinjaL with the interpreted horizons.

A-horizon

The A-horizon reflection represents the sequence from Beinisvørð, Prestfjall, Hvannhagi, to Malinstindur Formation. We suggest that the high amplitude reflection is related to the uppermost thick sheet lobe of the Beinisvørð Formation and that effects from base Malinstindur-Hvannhagi can be seen above the A-horizon (Figure 42).

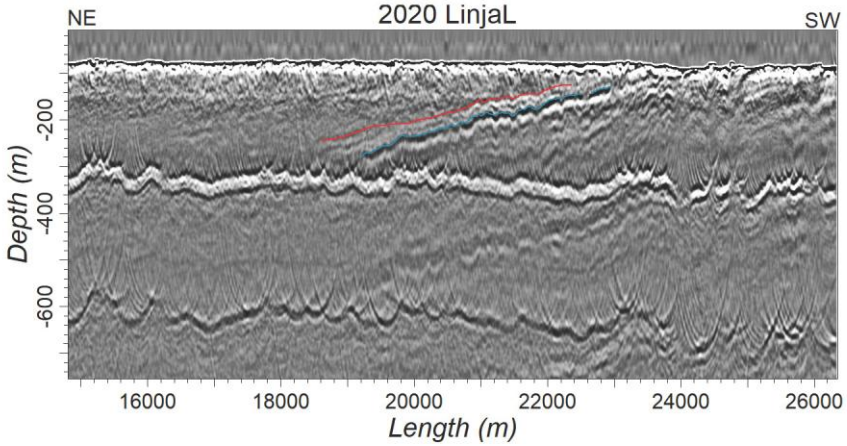


Figure 42. Section of LinjaL from Figure 41 showing detailed interpretation of the A-horizon suggested to be from the uppermost thick sheet lobe of the Beinisvørð formation. Red interpretation above marks seismic signals that could be related to Prestfjall and Hvannhagi formation.

From previous work, there is good constraint on the mapping of the A-horizon around the Faroe Islands (Petersen, 2020a; Petersen et al., 2015). Interpretation of the A-horizon presented in this work is limited by the depth migrated data only being down to 1000 m depth. However, this is covering the area of relevance for the geological description of the tunnel area (Figure 43).

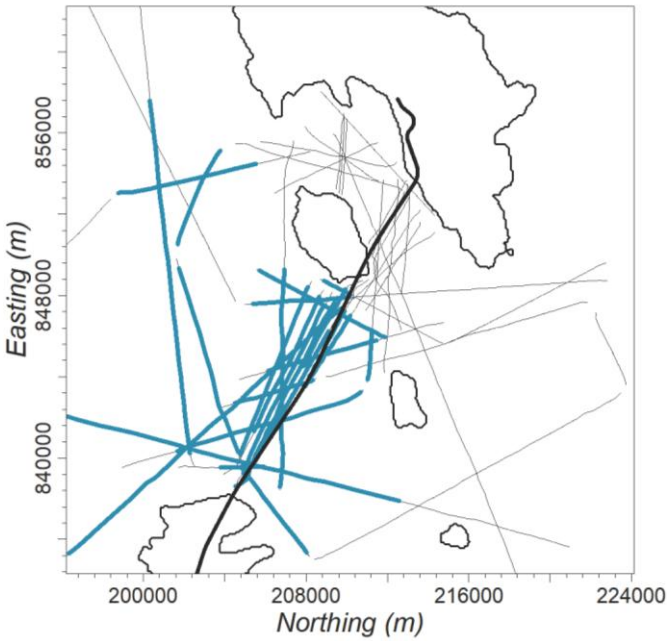


Figure 43. Interpretation of the A-horizon. To the North and the East, the A-horizon is deeper than 1000 m and is thus not covered by the depth migrated data.

IM-horizon (Intra Malinstindur)

The IM-horizon represents a coherent reflection, in the middle of the Malinstindur formation, that can be interpreted on several profiles on a large area between Skúvoy and Suðuroy (Figure 44).

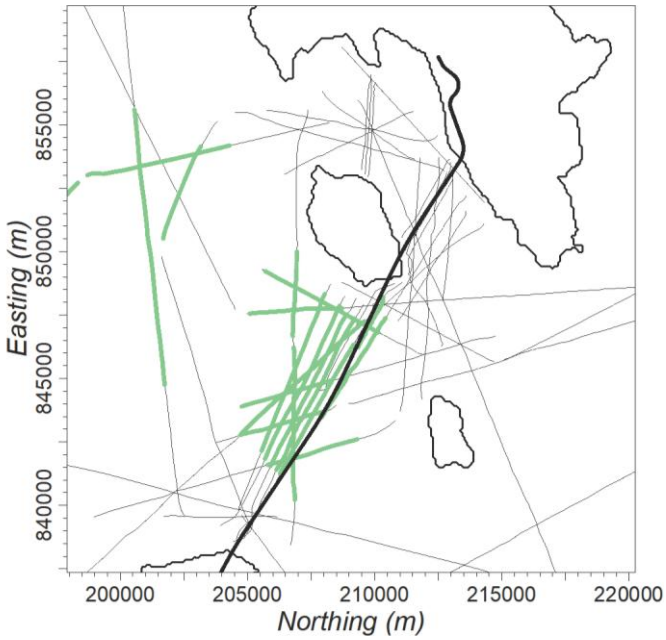


Figure 44. shows interpretation of the IM-horizon.

Malinstindur-Enni transition Zone (METZ)

The METZ relates to the correlation horizon described in Figure 35. The synthetic seismogram shows that the two thick sheet lobes above the sedimentary horizon give distinct high amplitude signature that can be

correlated to LinjaL, with the correlation point located ca. 3000 m south of the well. To facilitate interpretation, the first high amplitude positive zero crossing is taken to define the METZ. Figure 45 of the synthetic seismogram shows the tie to LinjaL. The location of the tie point is in Figure 46.

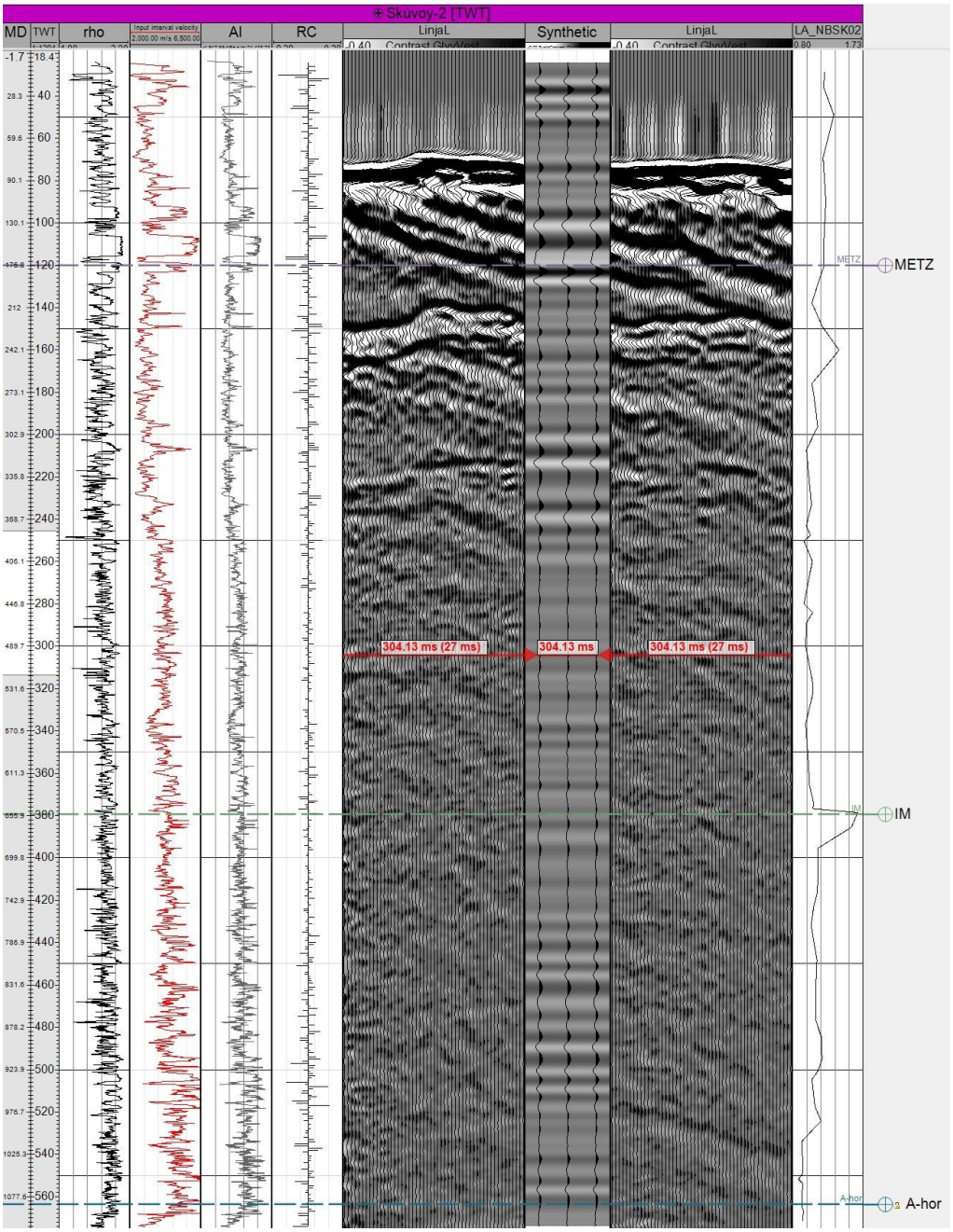


Figure 45. The tie of the synthetic to LinjaL. Defenition of METZ is annotated. IM and A-horizon from the final model are also annotated. Notice that the first seabed multiple is at ca. 150 ms. ***MD****: Measured depth,* ***TWT****: Two Way Traveltime,* ***Rho****: density log,* ***Intervelocity****: velocity log,* ***AI****: acoustic impedance,* ***RC****: reflection coefficients.* ***LinjaL*** *shows 50 traces to each side of the synthetic.* ***LA_NBSK02****: La/Nb trace element ratio used to define the IM horizon in the geochemical dataset. Notice the seismic line in synthetic panel has opposite direction to the direction of the profile in Figure 46.*

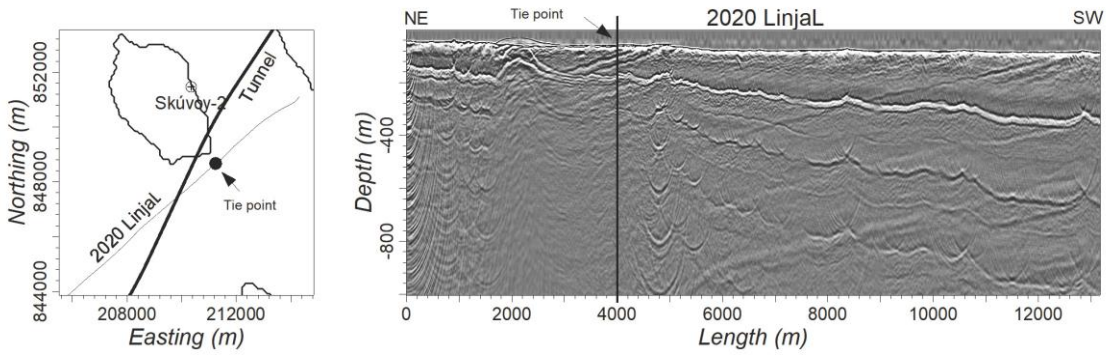


Figure 46. The figure shows positions of the well and tie point on LinjaL to synthetic seismogram in Figure 45.

The METZ reflection can be interpreted consistently in a large area, see Figure 47.

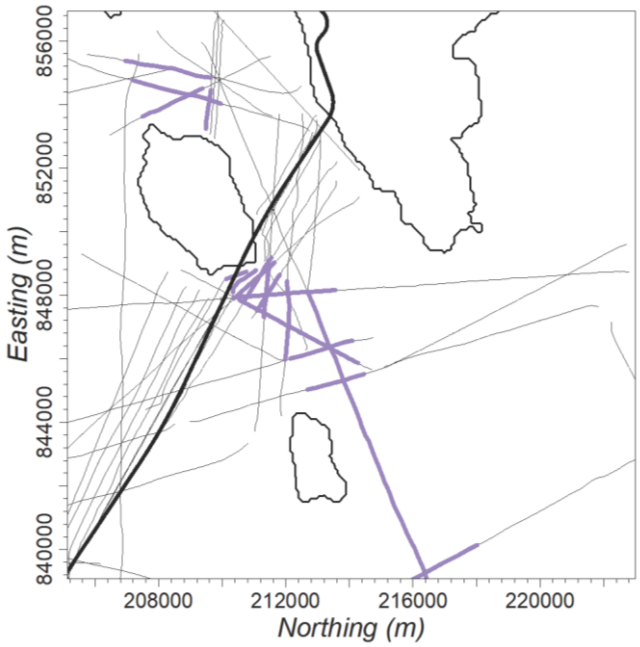


Figure 47. The map shows interpretation of the METZ reflection.

Figure 48 shows the surfaces generated from the seismic interpretation. Surface are interpolated with minimum curvature algorithm. A composite seismic profile along the tunnel path with tunnel path annotated is in

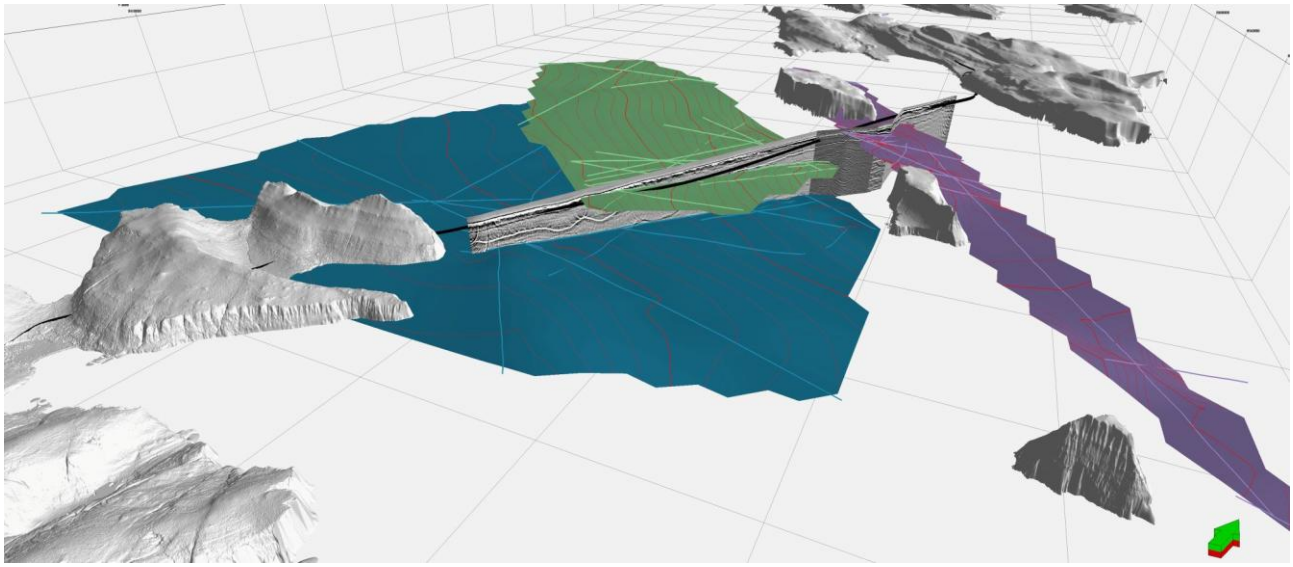


Figure 48. Interpreted surfaces used for the profiles: A-horizon (Blue), IM-horizon (Green), and METZ (Purple). Thick black lines shows tunnel path. The seismic profile is a composite profile following the tunnel path. The profile is in Figure 49 below.

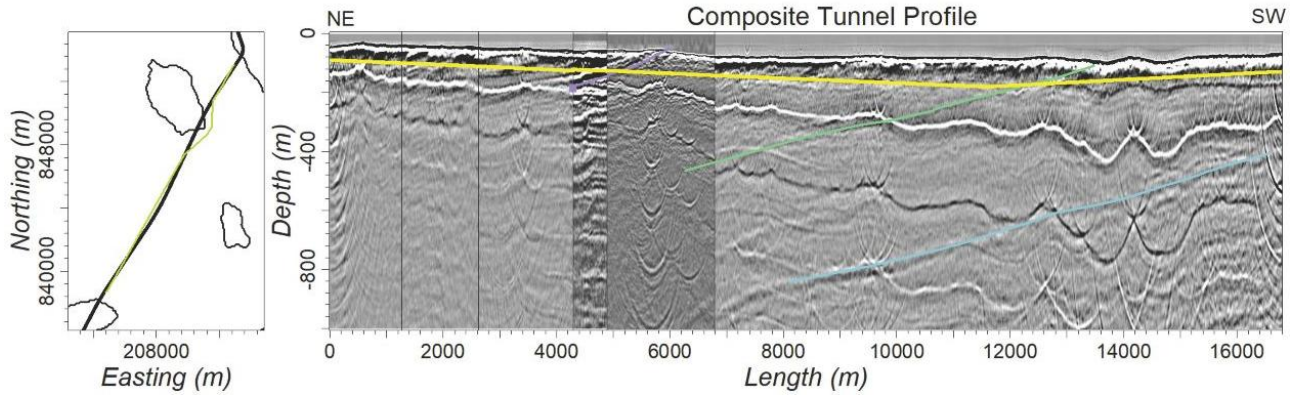


Figure 49. Composite seismic profile following the tunnel path. To left the map showing the location of the composite profile (green line) and to right the profile with interpretations annotated. Thick yellow line close to seabed is the tunnel path projected on to the profile.

Seismic interpretation in the Skúvoy–Sandoy area

Between Sandoy and Skúvoy the seismic data are of varying quality and interpretation of long ranging continuous reflections is difficult. As can been seen in Figure 47 above where interpretation of METZ is only possible north and south of Skúvoy. Although coherent signal can be seen in the area between Skúvoy and Sandoy it not of a quality to interpreted with confidence to be

Fold

However, the different coherent signals between Skúvoy and Skarvanes clearly show signs of an asymmetrical fold on some of the profiles. Especially on two profiles south of Sandoy the fold is evidently visible. The figures 50 to 56 below show interpreted synclines and anticlines with hinge points. Note that synclines and anticlines are not necessarily for same reflectors. Figure 57 shows a map of all interpretations.

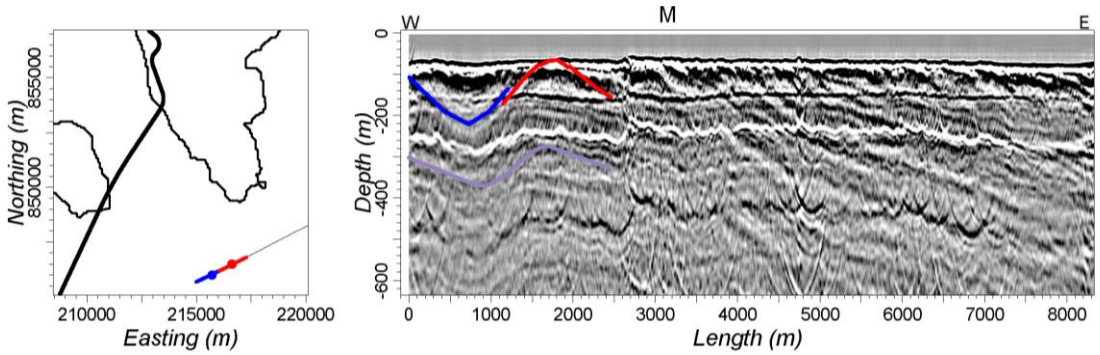


Figure 50. The map to left shows the location of the seismic profile with location of interpreted syncline (blue) and anticline (read). Points mark the hinge points. To right the seismic profile with interpretation.

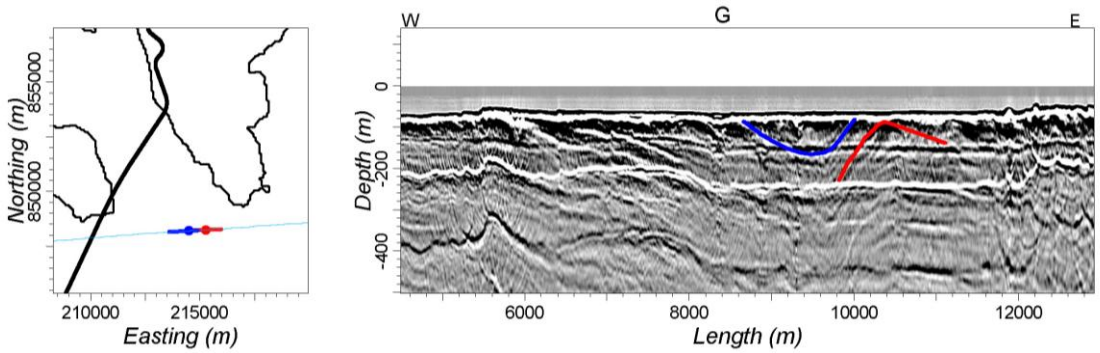


Figure 51. The map to left shows the location of the seismic profile with location of interpreted syncline (blue) and anticline (read). Points mark the hinge points. To right the seismic profile with interpretation.

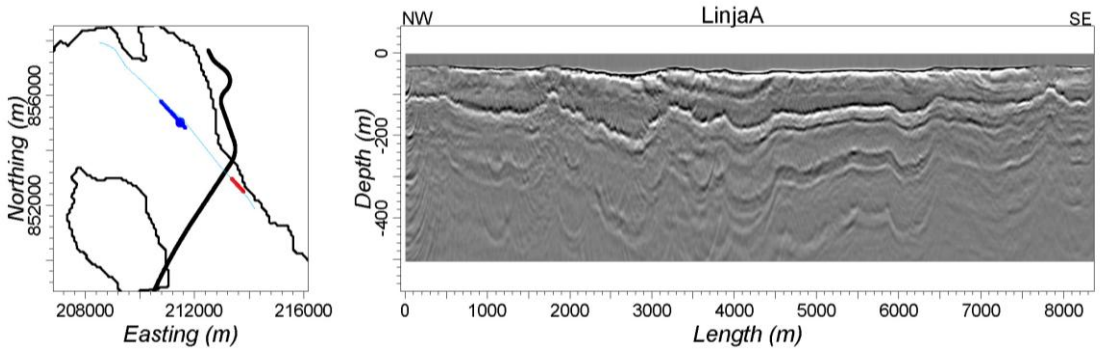


Figure 52. The map to left shows the location of the seismic profile with location of interpreted syncline (blue) and anticline (read). Points mark the hinge points. To right the seismic profile with interpretation.

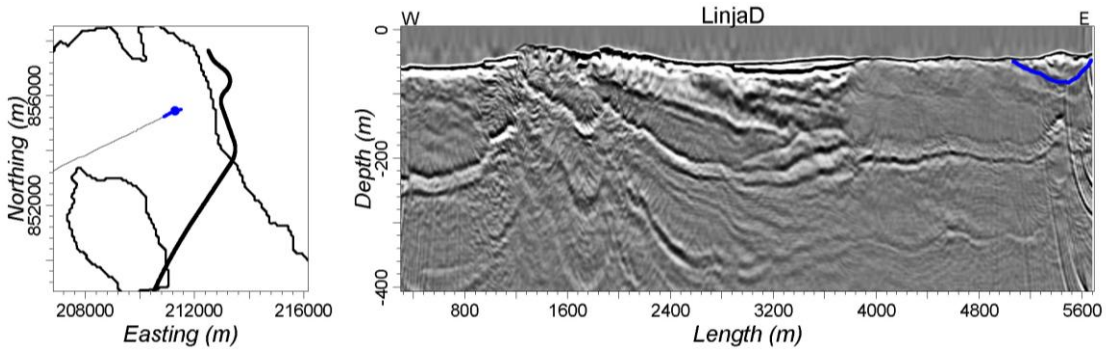


Figure 53. The map to left shows the location of the seismic profile with location of interpreted syncline (blue) and anticline (read). Points mark the hinge points. To right the seismic profile with interpretation.

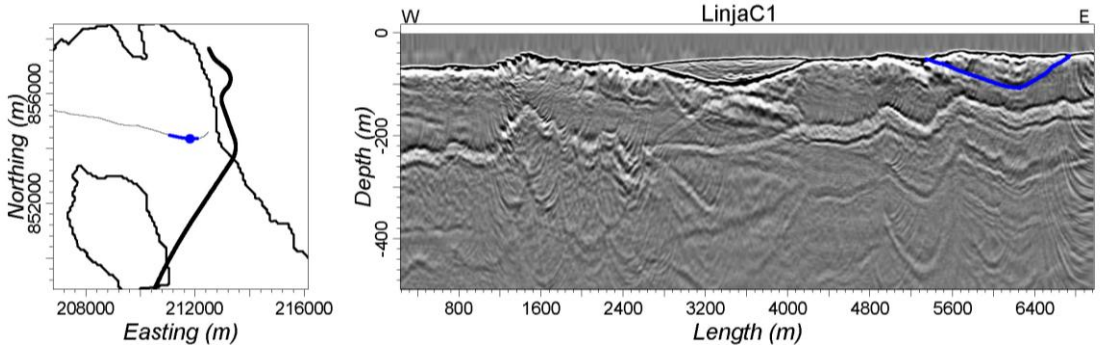


Figure 54. The map to left shows the location of the seismic profile with location of interpreted syncline (blue) and anticline (read). Points mark the hinge points. To right the seismic profile with interpretation.

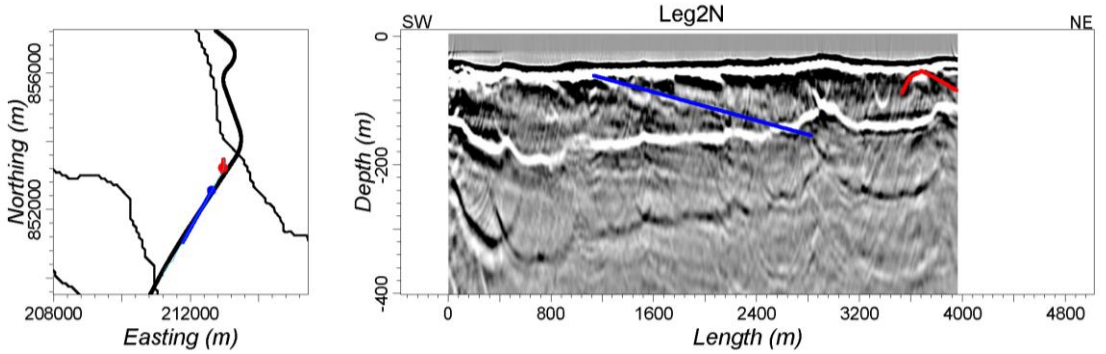


Figure 55. The map to left shows the location of the seismic profile with location of interpreted syncline (blue) and anticline (read). Points mark the hinge points. To right the seismic profile with interpretation.

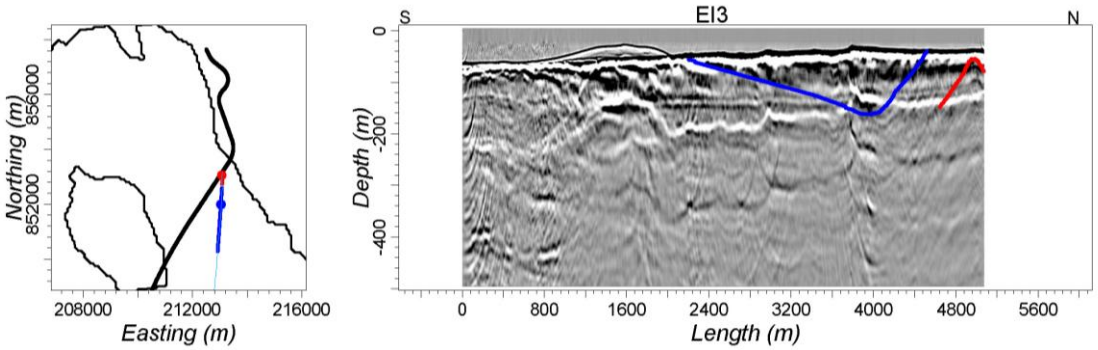


Figure 56. The map to left shows the location of the seismic profile with location of interpreted syncline (blue) and anticline (read). Points mark the hinge points. To right the seismic profile with interpretation.

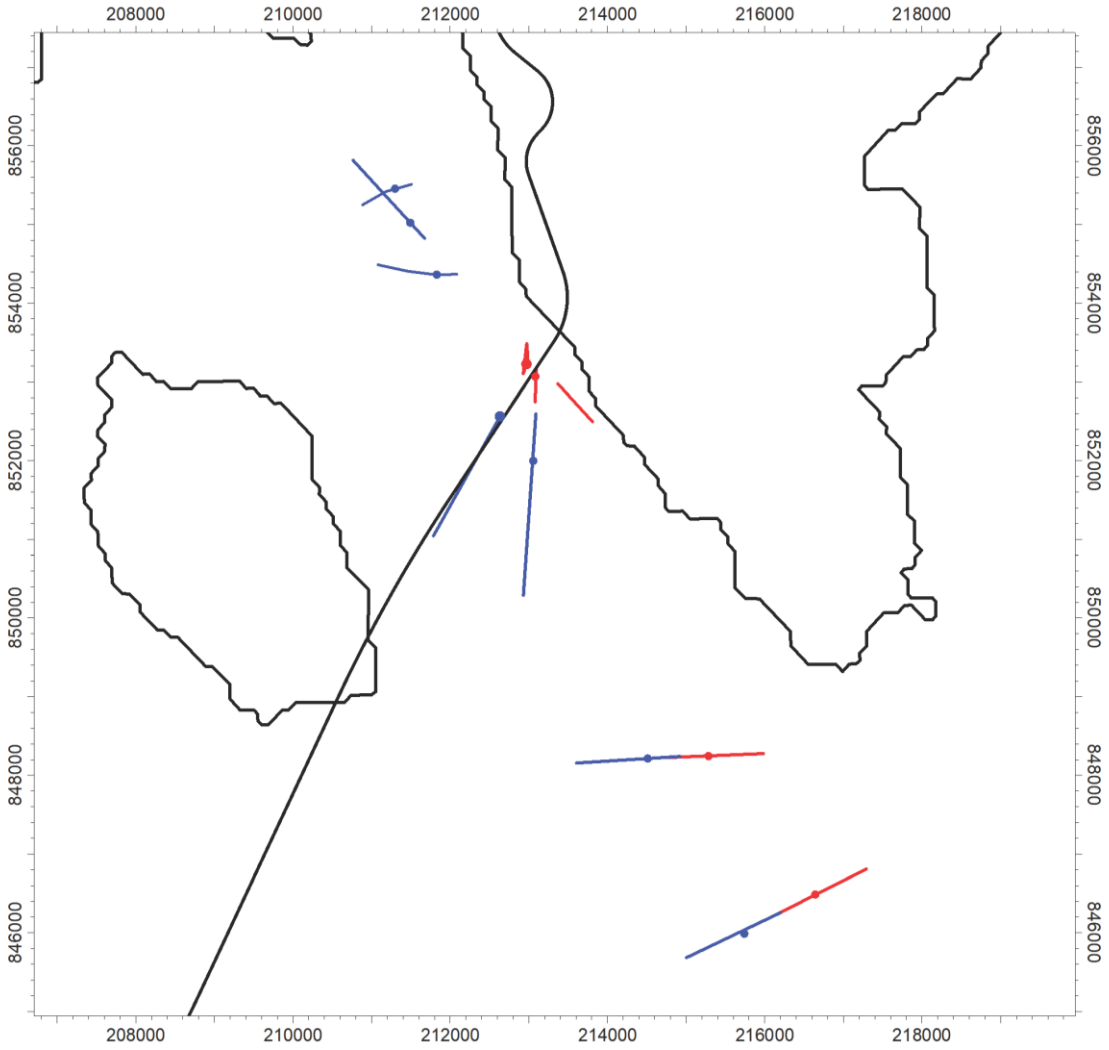


Figure 57. Map of interpreted of synclines and anticlines and hinge points.

Discontinuities of reflectors

South-West of Skúvoy there are some seismic profiles that show discontinuities in reflectors that can be interpreted as local faults lava flows of up to 17 m (Figures 58 and 59) and some show discontinuities that can be local faults or lava flow terminations (e.g. Figure 60). Figure 61 shows the combined locations. There

are more profiles in this area that show anomalies either by discontinuities of reflectors or reflectors with flexure.

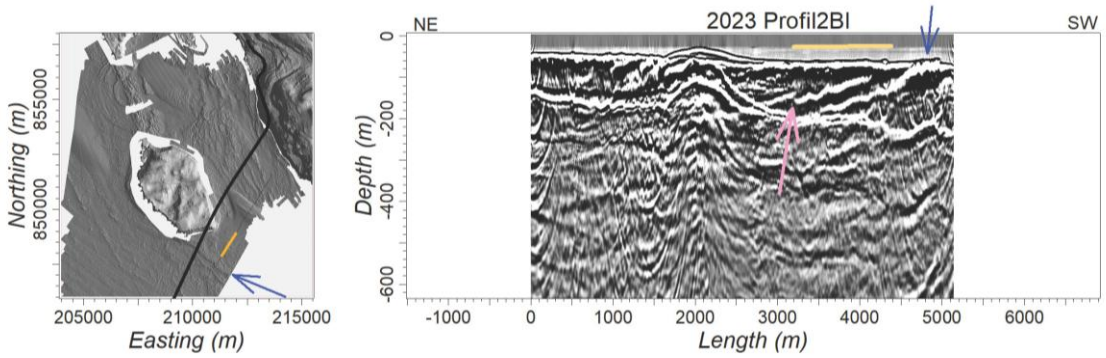


Figure 58. The map to left map with location of discontinuity. Blue arrow shows location of prominent rock face related to METZ. To right, the seismic profile with location of discontinuity marked with green. Purple arrow points to a local fault with displacement of ca. 17 m. Blue arrow points to prominent rock face related to METZ.

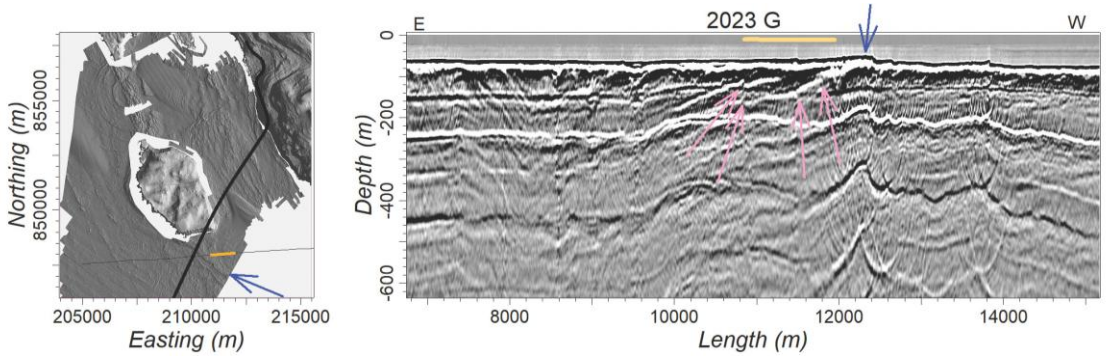


Figure 59. The map to left map with location of discontinuity. Blue arrow shows location of prominent rock face related to METZ. To right, the seismic profile with location of discontinuity marked with green. Purple arrow points to a local fault with displacement of ca. 12 m. Blue arrow points to prominent rock face related to METZ.

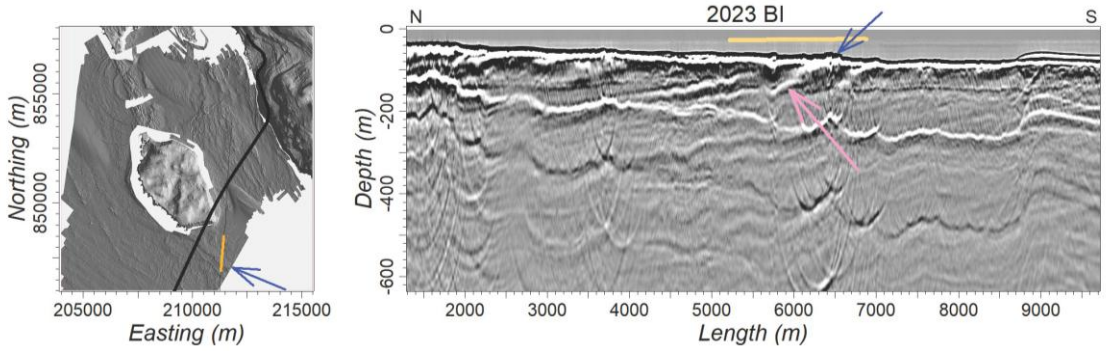


Figure 60. The map to left map with location of discontinuity. Blue arrow shows location of prominent rock face related to METZ. To right, the seismic profile with location of discontinuity marked with green. Purple arrow points to a local fault or lava flow terminations. Blue arrow points to prominent rock face related to METZ.

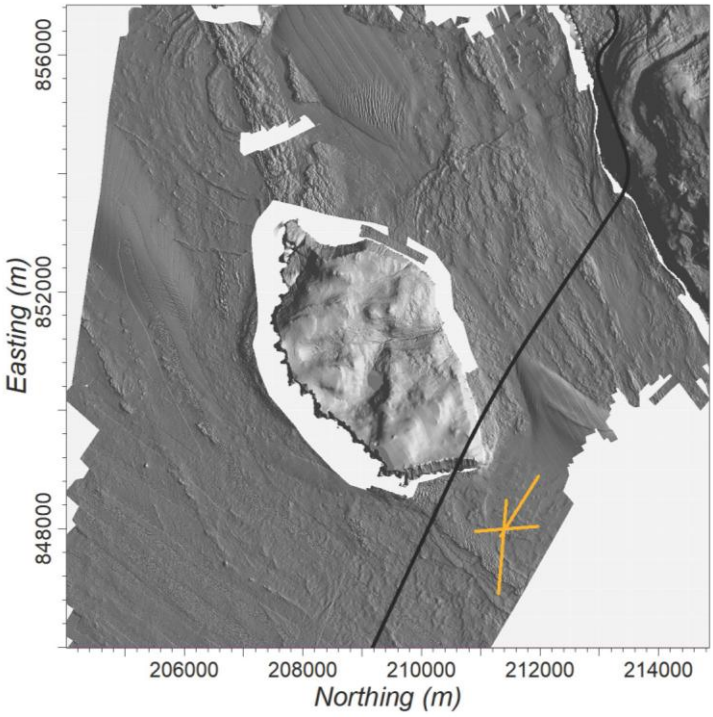


Figure 61. Green lines show locations of the discontinuity zones in figures 58, 59, and 60.

Data integration

The stratigraphic model is based on a combination of all data described above.

Observation of an asymmetric fold

The interpretation of seismic data above shows indications of an asymmetric fold between Skúvoy and Skarvanes. Bathymetry data from multibeam show additional indications of a fold. The data shows outcrop rocks with dip direction similar to the general dip direction of flows in the area. However, there are some prominent rock faces with opposite dip direction locally in the area (Figure 62).

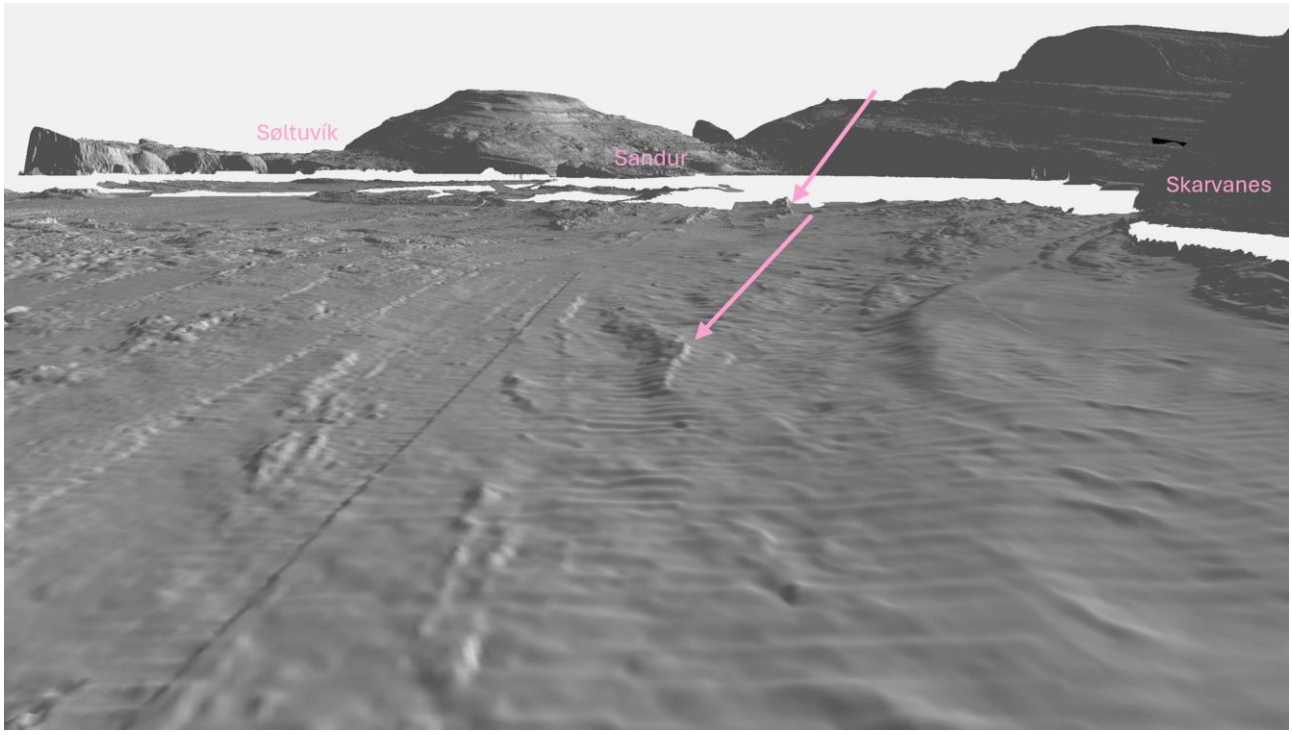


Figure 62. Bathymetry between Skúvoy and Skarvanes seen from south of Skarvanes towards north with Sandur in front view. Skarvanes is to the right. Figure is with vertical/horizontal ratio 2. The pink arrows mark Prominent outcrop rock faces with opposite dip direction.

2D top view of the area shows that in connection with the prominent rocky outcrop there is an area where seabed has different facies that could be explained by flows having opposite dip direction and steeper dip consistent with an asymmetric fold. The syncline and anticline hinge points mapped in the seismic interpretation show to be located on each side of this area also consistent with this being a fold (Figure 63).

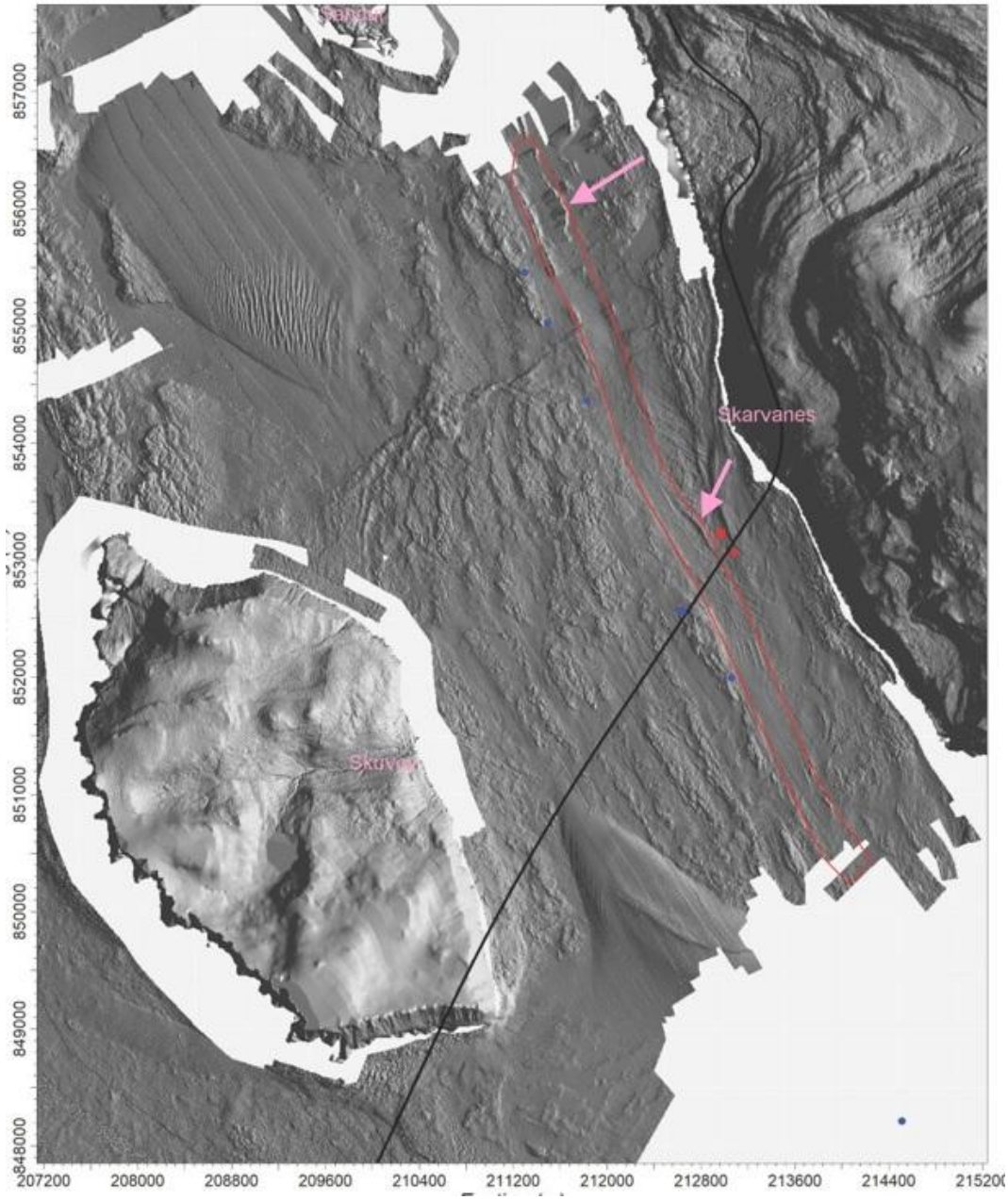


Figure 63. 2D top view of the area between Skúvoy and Skarvanes.Black line hows tunnel path. Red lines mark the area with supposet opposite dip direction. The rightmost red line intersects the prominent rocky outcrop with opposite dip direction in Figure 62 (pink arrows). Blue dots show syncline hinge points and red points show anticline hinge points.

Furthermore, Marine magnetic data shows a significant and consistent anomaly in the area with suggested opposite dip direction (Figure 64)

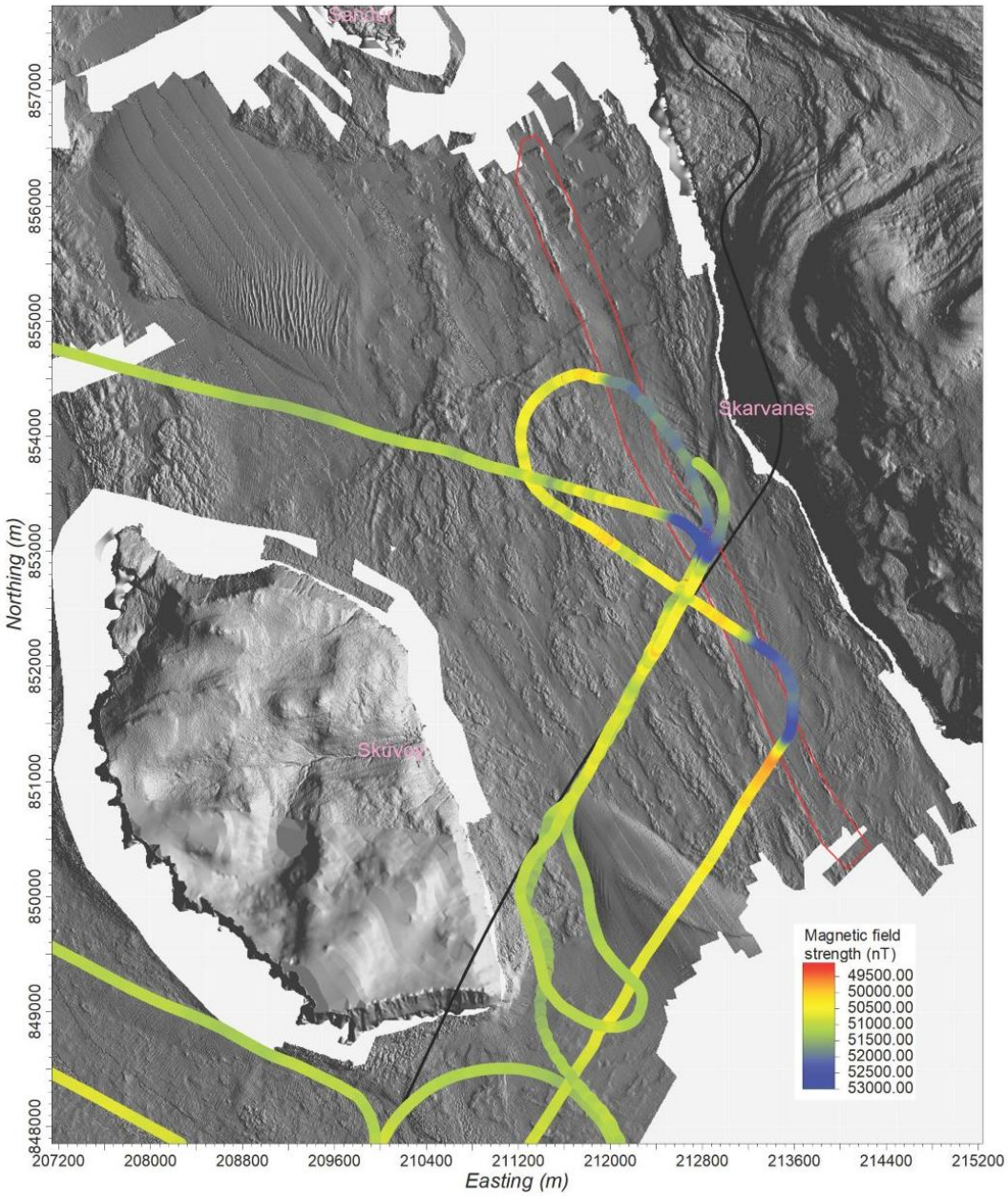


Figure 64. 2D top view of the area between Skúvoy and Skarvanes. Colored lines show magnetic measurements. At the location with suggested opposite dip direction (red lines) there is an anomaly of more the ca. 1000 nT, up to ca. 2000 nT. Black line shows tunnel path.

Another observation is that logs and field observations on western side of Sandur (village) cannot be correlated to logs and field observations on eastern side of Sandur with assumption of continuous dip and dip direction in the area (see section *Correlation panels*).

Mapping of the asymmetric fold

The correlation of the wells west of Sandur to wells east of Sandur suggests a shift in elevation of stratigraphy in the order of 160–180 m across the fold.

Horizon stratigraphic mapping of sedimentary beds in the field around Sandur have identified two prominent thick sedimentary beds. One west of Sandur named Klivagjógv and one east of Sandur name Traðarhamar horizons.

Figure 65 shows a surface, KlivagjogvWest, generated from the mapping of Klyvagjógv. The surface is extended towards east to reach the area east of Sandur where Traðarhamar is mapped.

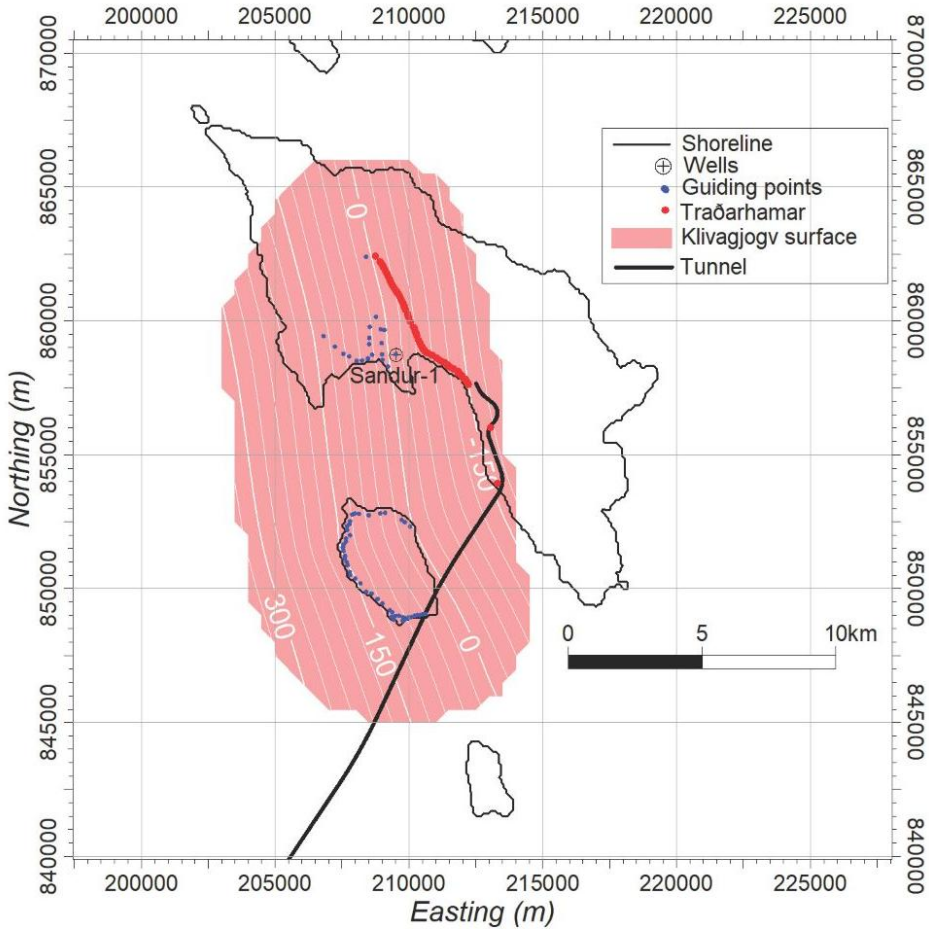


Figure 65. Klivagjógv-horizon mapping west of Sandur and around Skúvoy. Surface is generated by best-fit of plane to points.

Guided by the estimated 160–180 displacement, the Klivagjógv surface was shifted upwards to intersect the mapped Traðarhamer horizon in Traðarhamar just east of Sandur. The depth shift is 165 m. Figure 66 shows KlivagjógvWest and Figure 67 shows KlivagjógvWest lifted 165 m. Figure 68 shows closeup of the Traðarhamer where the lifted KlivagjogvWest intersects the mapped Traðarhamar-horizon. Notice that towards south the Klyvagjógv surface does not totally intersect Traðarhamar horizon mapping. This can be related to that Traðarhamer horizon has a slightly different trend and also to that southeast, towards Skarvanes, the extrapolation of the Klyvgjógv surface is quite far from data points.

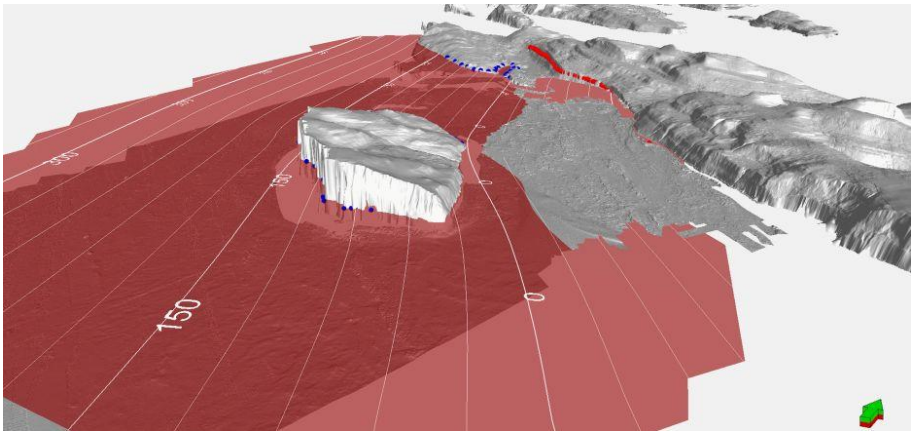


Figure 66. pre-klivagjogv

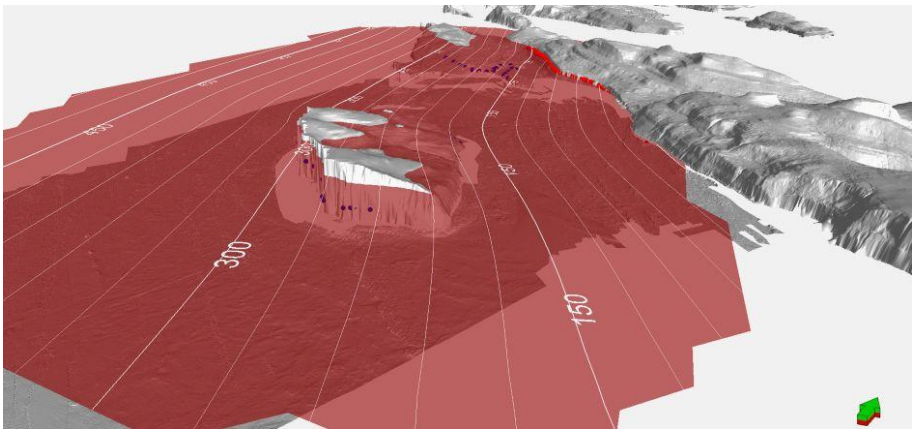


Figure 67. pre-klivagjogv plus 165

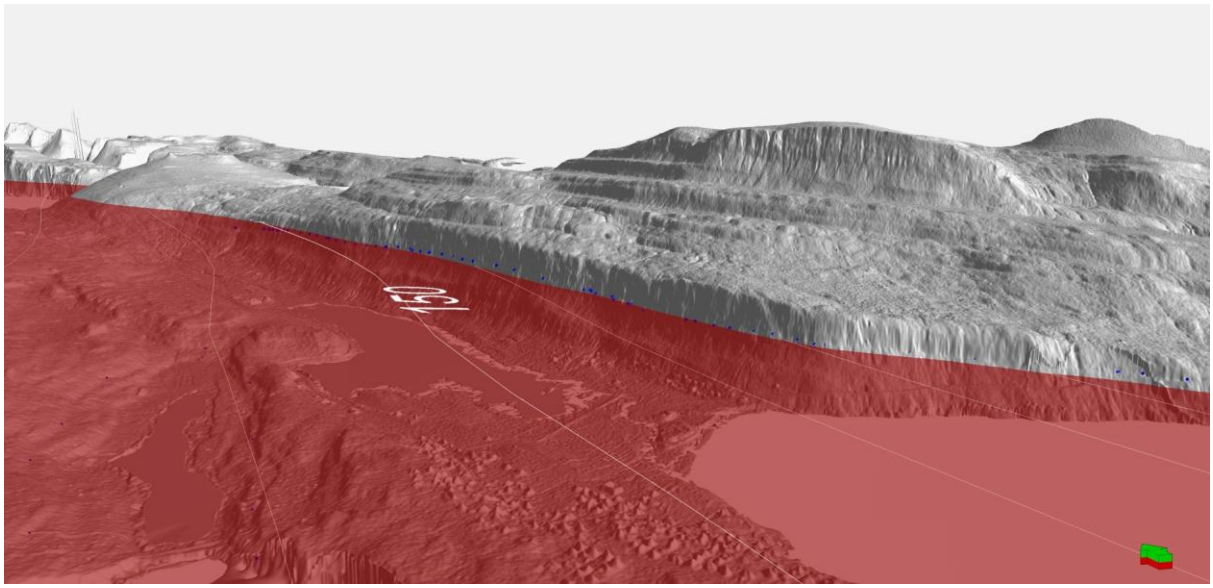


Figure 68. closeup

A pre-fold surface is constructed by combining the Klivagjógv-horizon mapping with the Traðarhamer-horizon mapping lowered 165 m. This surface represents Klivagjógv west of the syncline hinge line (Figure

69). The surface is then elevated 165 m, and this surface represents the current Klivagjógv east of the anticline hinge line (Figure 70).

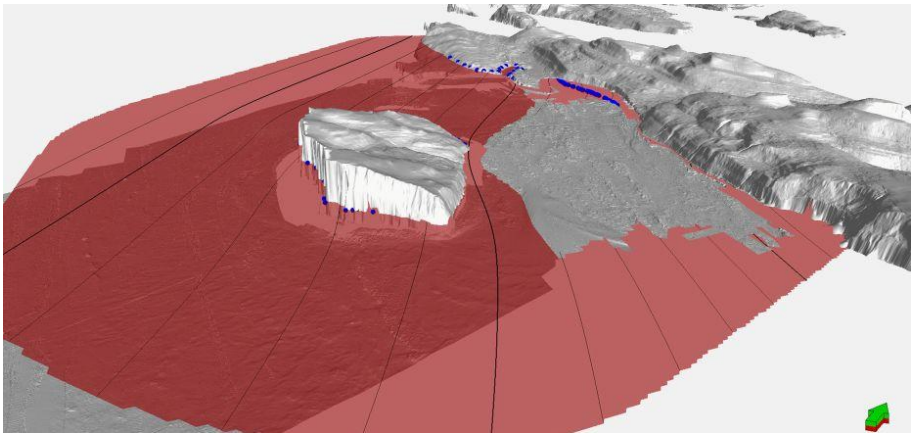


Figure 69. Klivagjógv

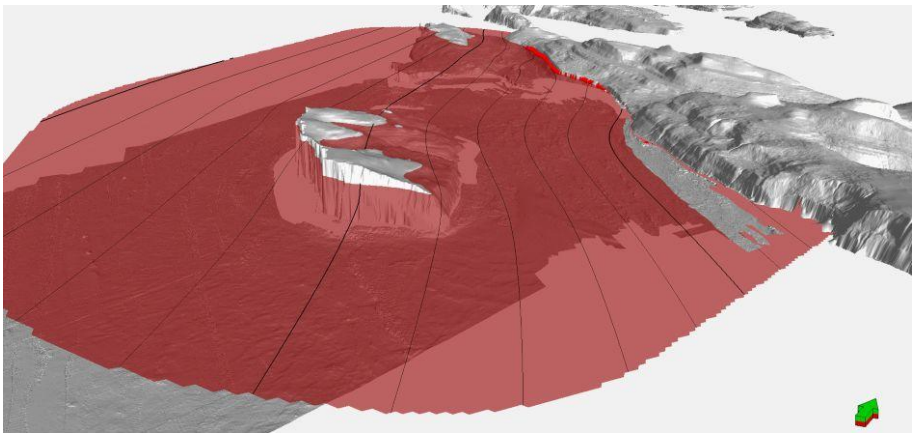


Figure 70. Klivagjogv plus 165

The hinge lines of the asymmetric fold can be estimated from the above interpretation of syncline and anticline hinge points.

The two surfaces are cut at the respective syncline and anticline hinge lines (Figure 71) and a combined surface is generated from these two (Figure 72) being the Klivagjógv-Traðarhamar-horizon used in the stratigraphic model below.

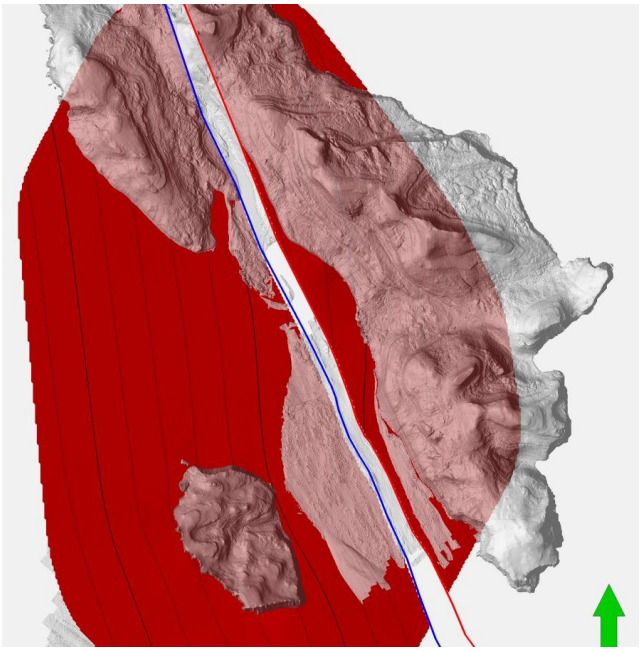


Figure 71. Cutting of the two surface in figures 69 and 70 at the respective syncline and anticline hinge lines.

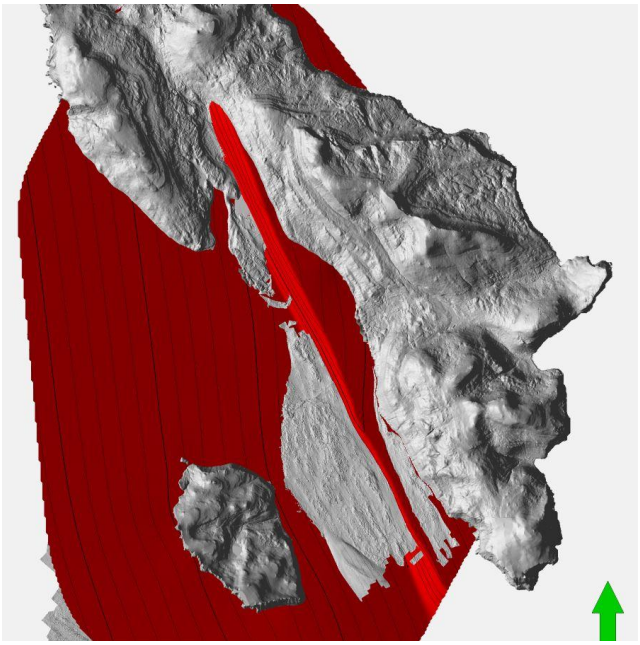


Figure 72. Regridding to the Klivagjógv-Traðarhamar-horizon.

Intersection of the horizon with seismic data was used in an iterative process to adjust the hinge lines. The presence of the asymmetric fold is conclusive, and the final horizon has good consistency with seismic data. However, the horizon is more complex than the one modelled (Figures 73 to 77).

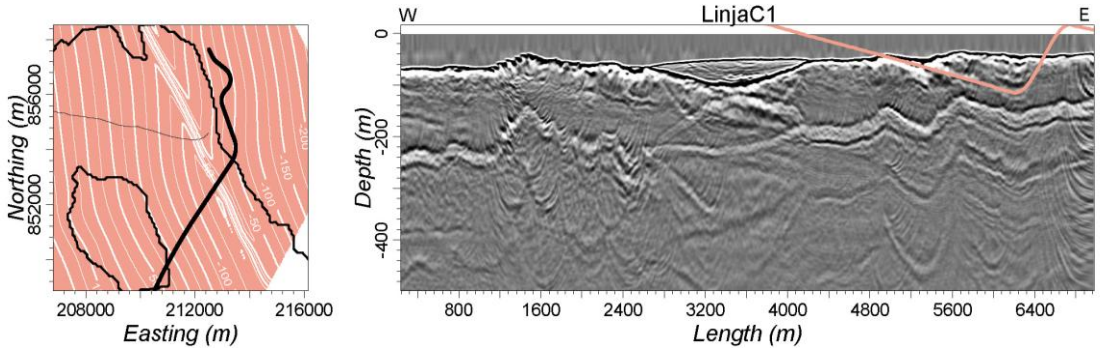


Figure 73. To left: Map with the modelled horizon. Thin blue line shows location of the seismic line; thick black line shows the tunnel. To right: The seismic line with the modelled horizon inserted. The syncline hinge point of the horizon coincides with the observations on seismic data.

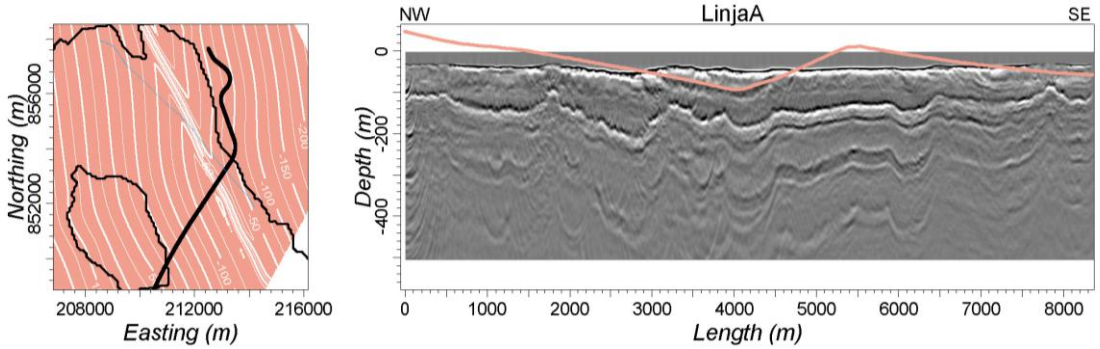


Figure 74. To left: Map with the modelled horizon. Thin blue line shows location of the seismic line; thick black line shows the tunnel. To right: The seismic line with the modelled horizon inserted. The syncline hinge point of the horizon coincides with the observations on seismic data. Anticline hinge point is not directly visible on data but the trend of the horizons after the anticline hinge point matches observations on seismic data.

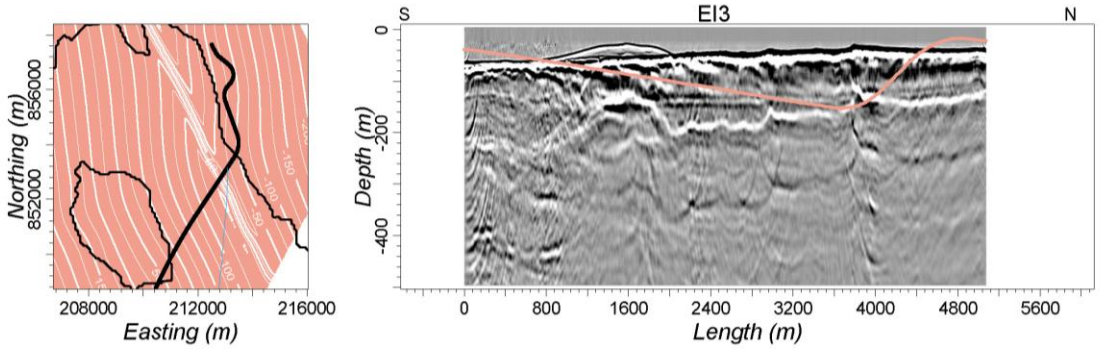


Figure 75. To left: Map with the modelled horizon. Thin blue line shows location of the seismic line; thick black line shows the tunnel. To right: The seismic line with the modelled horizon inserted. The syncline and anticline hinge points of the horizon could be more westerly than observations on seismic data. The trend of the horizon between syncline and anticline points matches the trend of the seismic data.

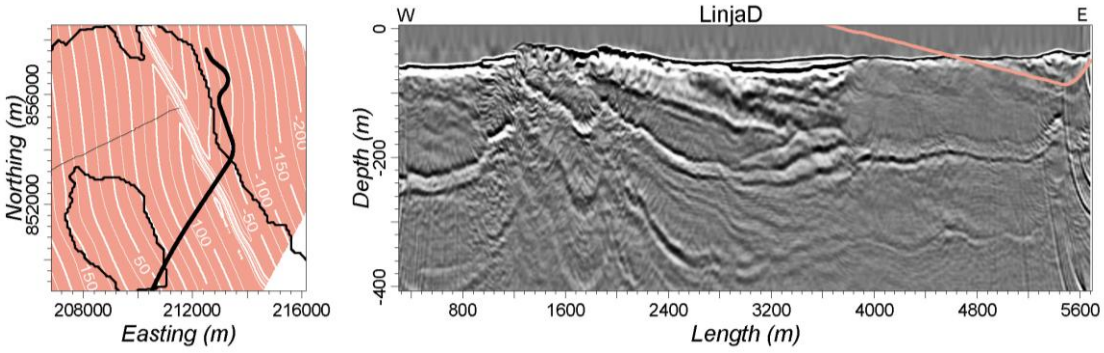


Figure 76. To left: Map with the modelled horizon. Thin blue line shows location of the seismic line; thick black line shows the tunnel. To right: The seismic line with the modelled horizon inserted. The syncline hinge point of the horizon coincides with the observations on seismic data.

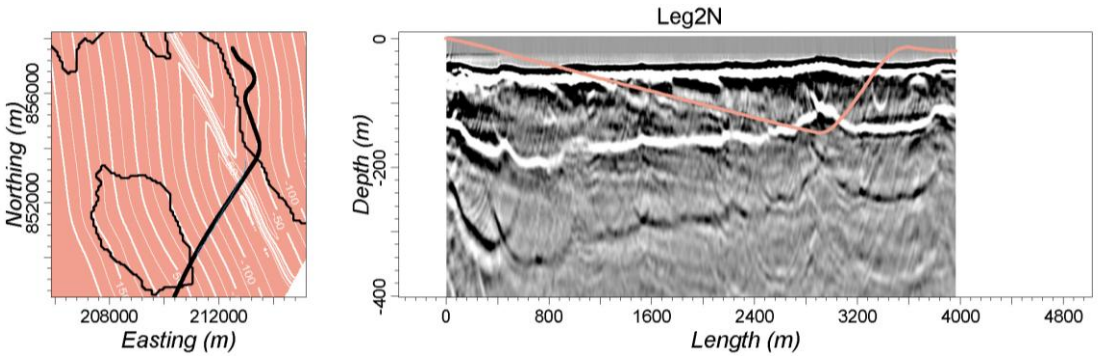


Figure 77. To left: Map with the modelled horizon. Thin blue line shows location of the seismic line; thick black line shows the tunnel. To right: The seismic line with the modelled horizon inserted. The anticline hinge point of the horizon could be more westerly than observations on seismic data.

Stratigraphic model

The main horizons used for the stratigraphic model are the A-horizon, IM-horizon, METZ, and Klivagjógv-horizon.

A-horizon

The A-horizon surface is based on the seismic interpretation of reflection from the upper most thick basalt flow in the Beinisvørð Formation and on the horizon stratigraphic mapping of the base of the overlying sediments (Figure 78).

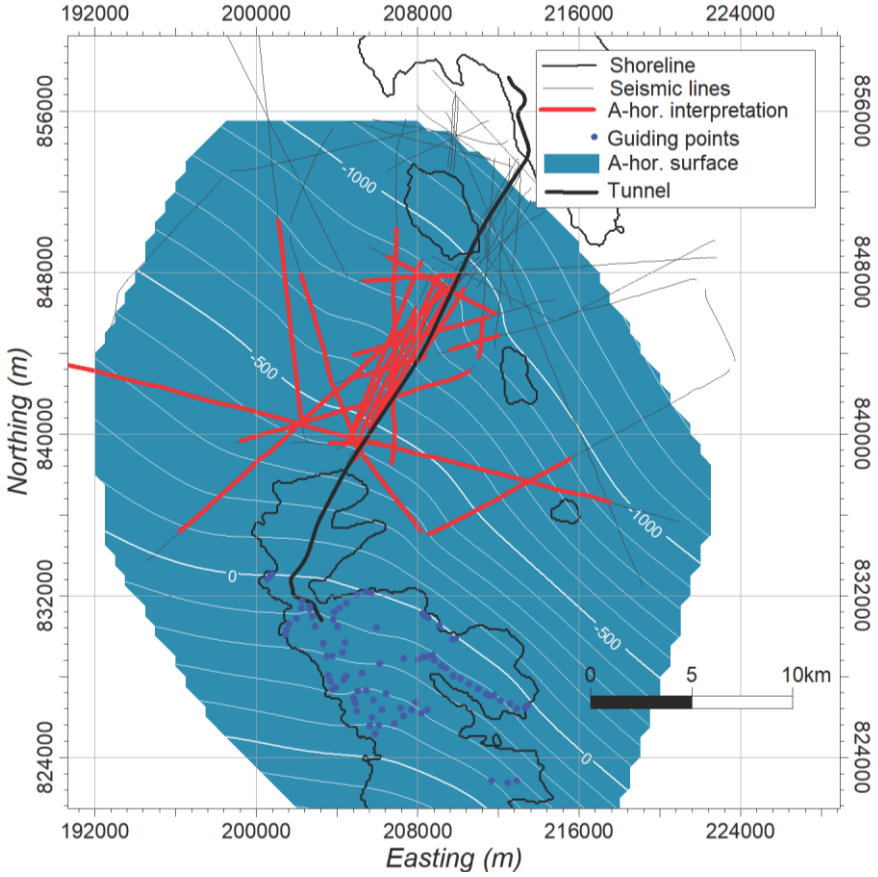


Figure 78. Red lines show seismic interpretation and blue points onshore show samples from the horizon stratigraphic mapping. Surface is from best fit of a plane. Thick black line shows tunnel path.

Intra-Malinstindur-horizon (IM-horizon)

The IM-horizon is firstly based on interpretation on seismic data. The IM-horizon intersects seabed in a location with prominent rocky outcrops seen on the bathymetry. The IM-horizon can be extrapolated towards north intersecting the Skúvoy-2 well and towards the south intersecting the mountains around Sandvík thus establishing an approximate relative stratigraphic level for the two locations.

Comparison of geochemical analysis of the Skúvoy-2 core to geochemical analysis of samples around Sandvík, partly covering the same stratigraphic interval, shows a specific set of samples with unique geochemical signature in same stratigraphic level (Figure 11 in section *Stratigraphic geochemistry profiles*).

The final IM-horizon is produced from guiding points from the seismic interpretation, guiding points from the rocky outcrops on seabed, and the location of the unique geochemical samples in Skúvoy-2 and Sandvík. The horizon is produced by fitting a best-fit plane though the guiding points. Comparison of IM-horizon to the A-horizon shows they are concordant (Figure 79). Figure 80 shows IM-horizon in 3D how it intersects the Skúvoy-2 well and the mountains around Sandvík.

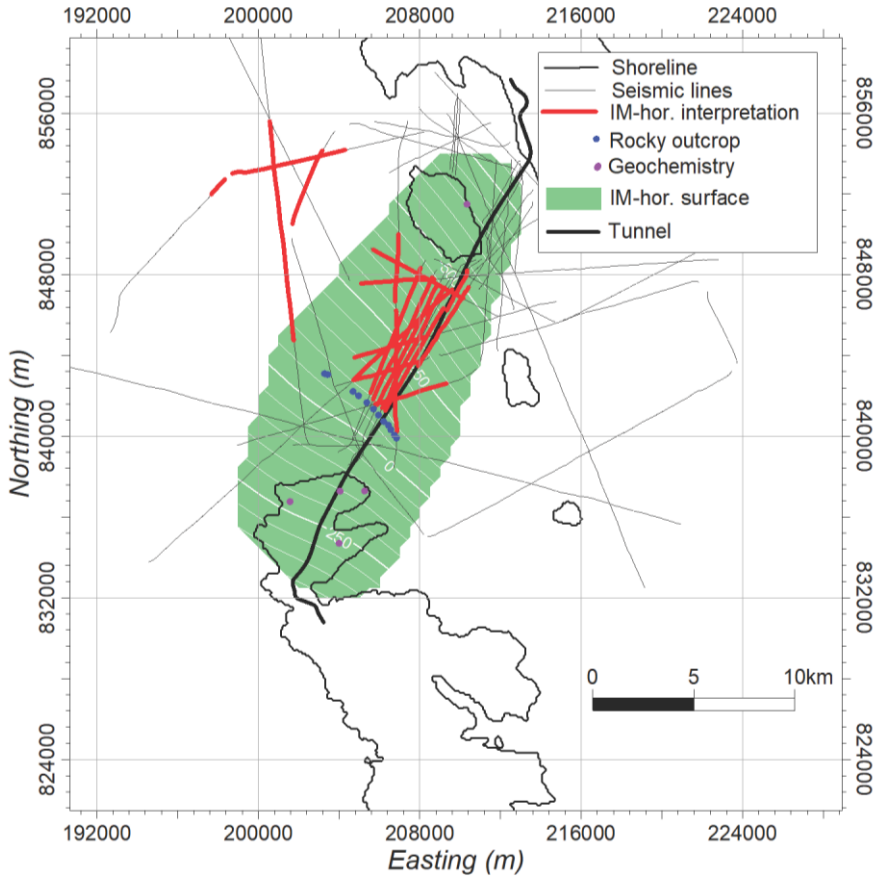


Figure 79. Red lines show seismic interpretation. It is not used directly in the surface generation but to identify rocky outcrops on seabed and to qualify that geochemical analysis well and on mountain to south are connected.

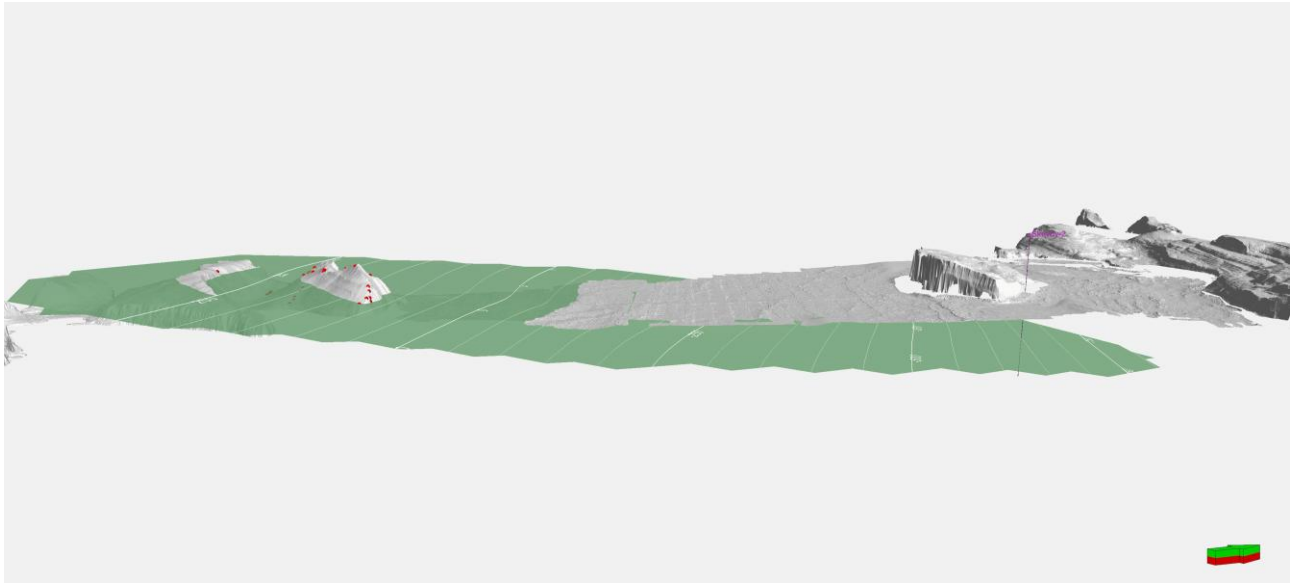


Figure 80. 3D plot of the IM-horizon. Geochemical samples used in the correlation between north and south are from Skúvoy-2 well and samples around Sandvík (red dots on mountains around Sandvík).

METZ

The METZ is mainly based on seismic interpretation. It also intersects seabed in a location with significant rocky outcrops. Interpretation of METZ in Skúvoy-1/2 and Søltuvík-2 are also used. METZ is also in the

Skarvanes-1 well but at a depth inconsistent with a continuous general dip in the area. But an elevation shift of 165 downwards, shows it is consistent with the mapped asymmetric fold.

METZ is therefore constructed like Klivagjógv-Traðarhamar-horizon above. The points east of the fold, that is METZ from Skarvanes-1 and interpretation of METZ on seismic data in Skopunarfjørður (Petersen, 2015), are lowered by 165 m. They are then included in data points to generate and initial surface (Figure 81). Then a copy of the surface is elevated 165 m. The former represents METZ west of the fold and the latter represents METZ east of the fold. The surfaces are cut at the syncline and anticline hinge lines as for Klivagjogv-Traðarhamar-horizon above (Figure 82).

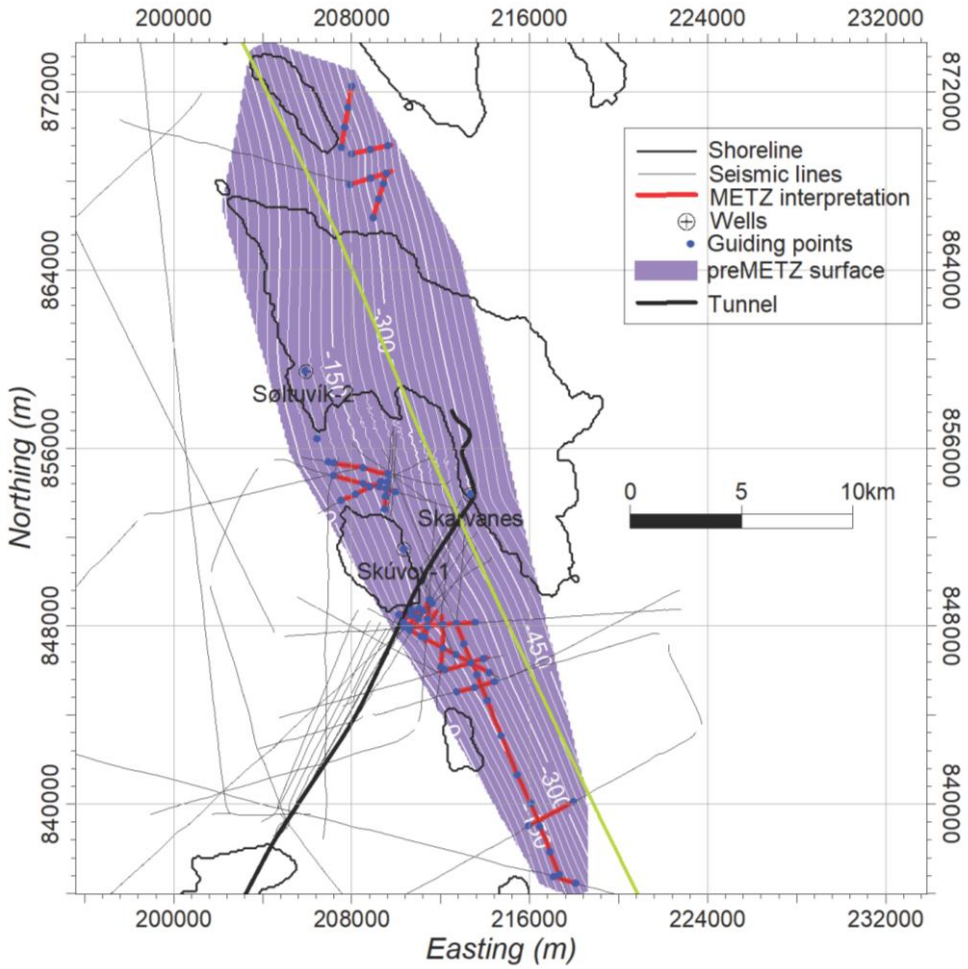


Figure 81. Pre-METZ surface. Poins east of the fold are lowered by 165 m and included in generations of a surface. By best-fit of plane through points.

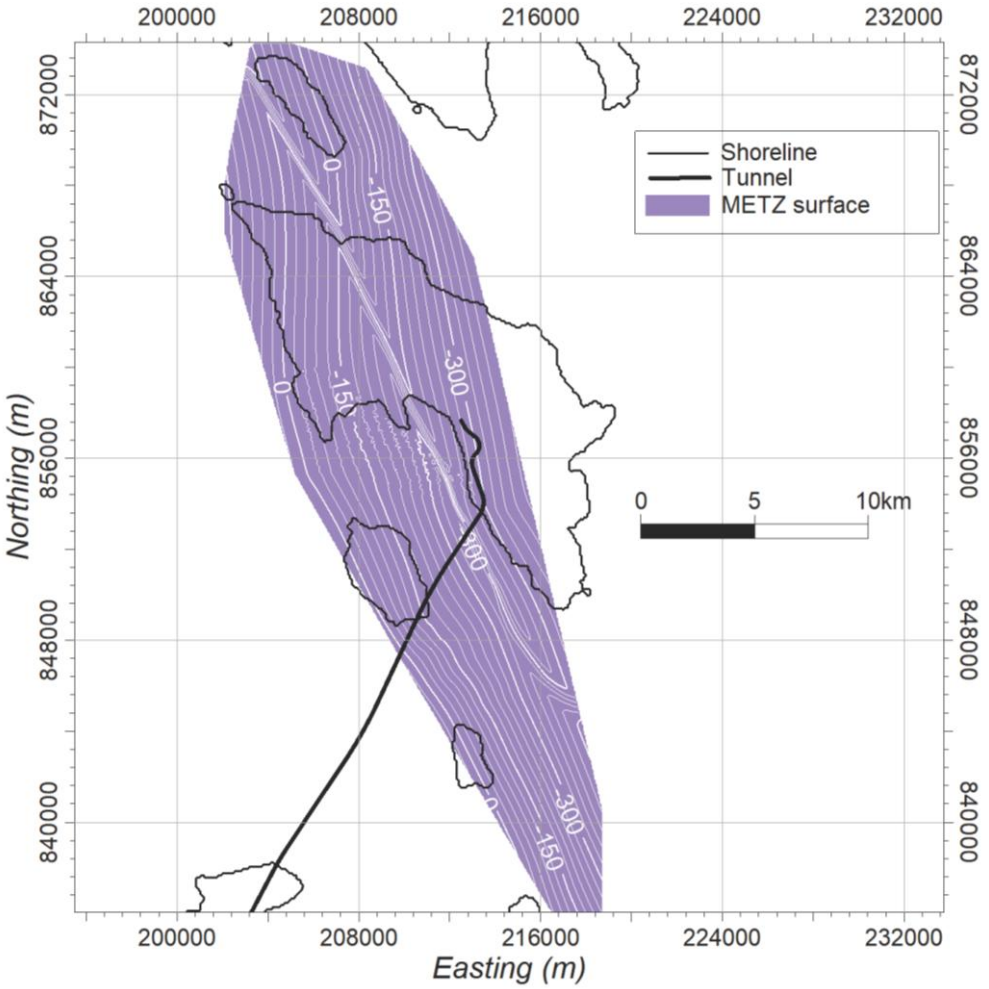


Figure 82. The surface in Figure 81 is copied and lifted 165 m. The initial surface represents METZ west of the fold and the latter the METZ east of the fold. The surfaces are cut at the syncline hinge line and anticline hinge line respectively.

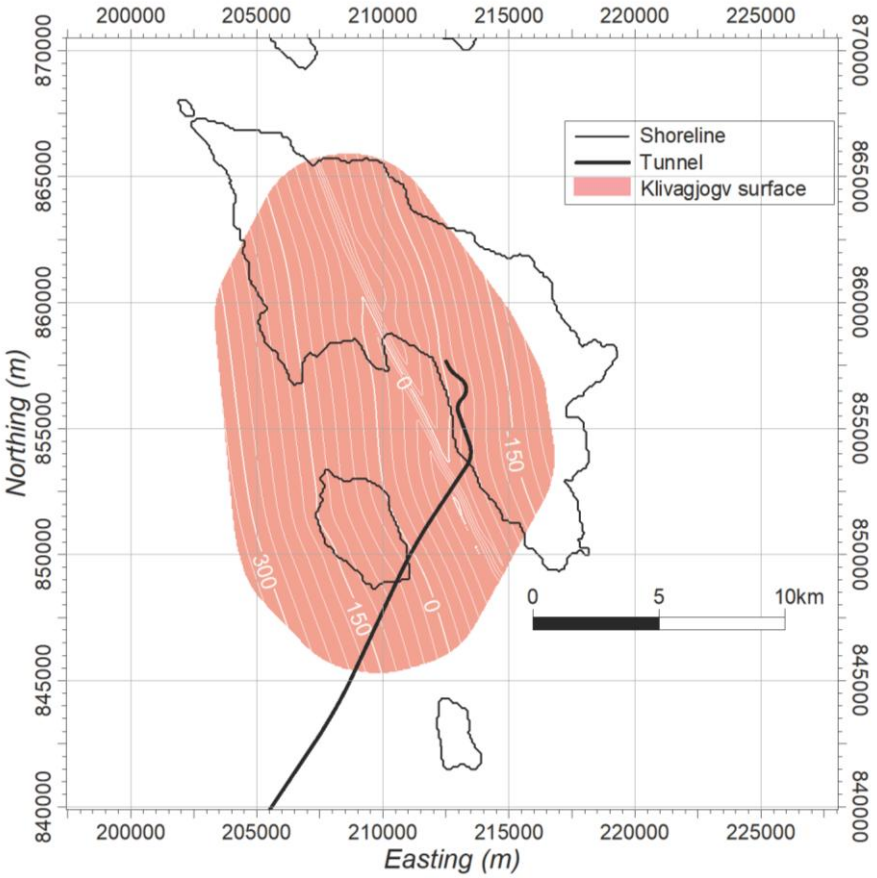


Figure 83. Klivagjógv-Traðahamar-horizon same as in Figure 72.

The model

Figure 84 shows the four main horizons in the stratigraphic model. Figure 85 shows the Horizons along the tunnel path.

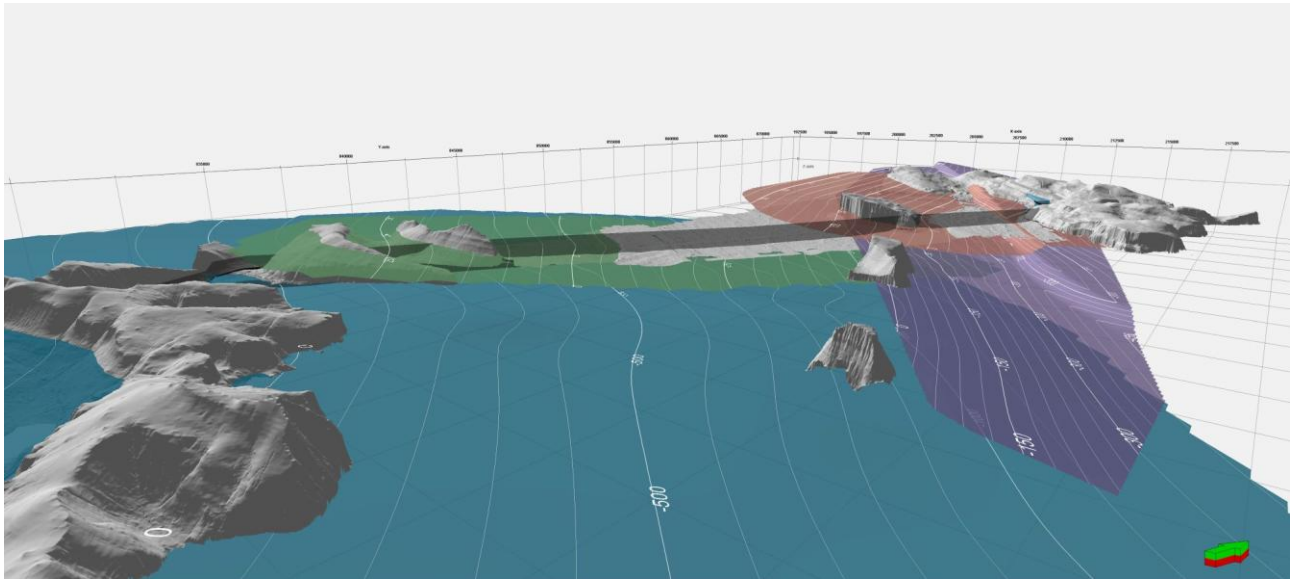


Figure 84. The four main horizons in the stratigraphic model: A-horizon (Blue), IM-horizon (Green), METZ (Purple), and Klivagjógv-Traðarhamar-horizon (peach). Vertical/horizontal ratio is 2. The vertical plan is the Intersection of the tunnel profile in Figure 85.

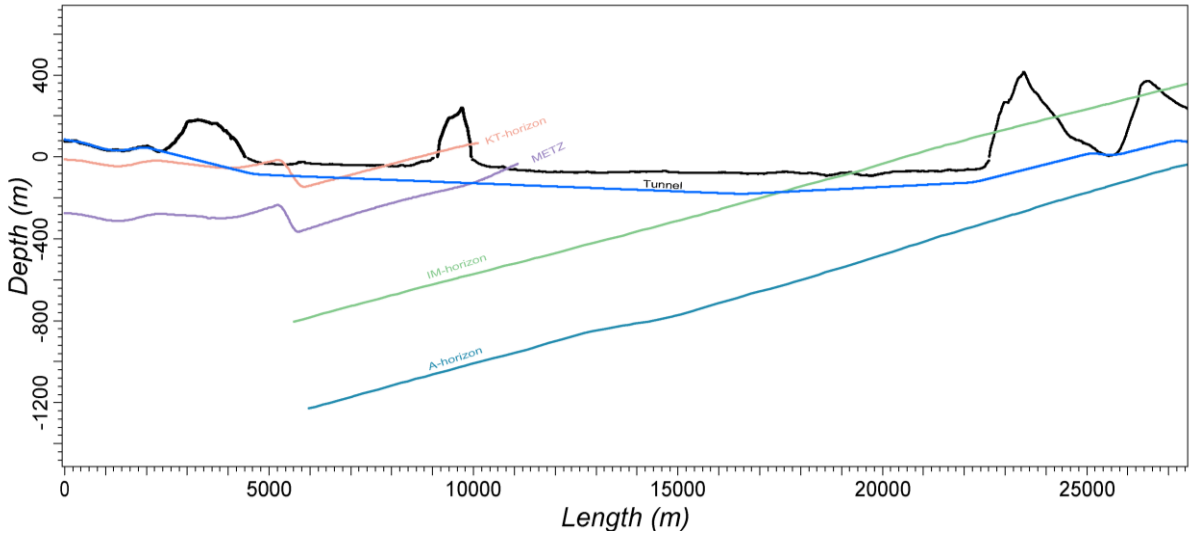


Figure 85. Intersection of tunnel profile (green) with main stratigraphic horizons. A-horizon (Blue), IM-horizon (Green), METZ (Purple), and Klivagjógv-Trøðarhamar-horizon (peach). Vertical/horizontal ratio is 5. X-aksis is in station meters.

Geological sections described

This section gives a short, descriptive overview of the geology and physical parameters in the geological sections defined by the key horizons used in this report. These horizons are;

- **A-Horizon**
- **IM-Horizon**
- **METZ**
- **Klivagjógv / Traðarhamar Horizon**

The descriptions include Lava flow architecture, lava flow type, rock types, mineralization, Q-values (Skúvoy-2 and field measurements), fracture-index, EGI values and other relevant observations. The definitions of the horizons are described in section “Interpretation of seismic data” above.

Below A-Horizon

The section below the A-Horizon is essentially the entire Beinisvørð Formation. This section of the geology is summarized here, is however not relevant for the main tunnel, as this section is below the stratigraphy the tunnel will go through.

Beinisvørð Formation

The lava flow architecture in the Beinisvørð Formation is a persistent repetition of thick (mean 20 m) sheet flows (A´a type). Each lava flow typically has a brecciated lava crust, these zones vary in thickness. The lava flow core is massive with few vesicles, and often columnar jointed. Some flows are multi-tiered, The lava floc basal crust

In between the individual lava flows, sedimentary beds are normally seen. These vary in thickness from +5 m to some 10 cm. The sediments also vary from clay (slate) to more coarsegrained sandstones, even conglomerates. The lava flows are dominantly comprised of fine-grained basalt.

The Beinisvørð Formation is only encountered onshore from Hvalba to the south and seen in boreholes in Sandvík and Hvalba. The Deep well on Skúvoy (Skúvoy-2) did not reach the depth of the Beinisvørð Formation.

A-Horizon to IM-Horizon

This section comprises both the Prestfjall Formation, Hvannhagi Formation and the basal parts of the Malinstindur Formation. The focus again here is the Malinstindur Formation, as this part of the geology is relevant for the main tunnel between Skarvanes and Sandvík.

Prestfjall Formation

The Prestfjall Formation is seen in the Sandvík-4 and Hvalba-1 boreholes. We also see the Prestfjall Formation in the field south of Hvalba. This Formation is composed of claystones and coal beds.

Hvannhagi Formation

The Hvannhagi Formation comprises a variety of lithologies that originate from geological processes related to more explosive volcanism.

The Hvannhagi Formation is not expected to be present in the main tunnel from Skarvanes to Sandvík, however it may be present in the tunnel from Sandvík to Hvalba. Therefore, this Formation only gets a

short description. We have logged the Hvannhagi Formation in the Sandvík wells (Sandvík 1–4) and in the Hvalba well (Hvalba-1).

This formation comprises a mixture of pyroclastic, volcaniclastic and intrusive rocks. The formation is also seen in the field east of Hvalba, in Reyðibarmur, in Grímsfjall and in the wells.

Malinstindur Formation (Basal parts)

This section is described in the field surrounding Sandvík and in the Skúvoy-2 core. The geological stratigraphy that spans from the the base of the Malinstindur Formation to the IM-Horizon, comprises the basal 2/3 of the formation. The lava flow architecture is comprised of dominantly compound pahoehoe lava flows. Very few volcaniclastic beds are seen in this section in the field, and in the Skúvoy-2 core shows only a few thin (1–60 cm) beds. In the basal 10 m in the core, several volcaniclastic sediments and claystones are interbedded between the lavas. This could indicate that the well was indeed terminated in the uppermost part of the Hvannhagi Formation.

In the lowermost 200m of the section (Only visible in the Skúvoy-2 core) the rock types are dominated by olivine phyric basalt (olivine basalt). There are clear signs of accumulative olivine minerals, which also is reflected in the geochemistry. This signature is also seen elsewhere on the Faroe Islands and in the overall geochemical profiles. Aphyric basalts together with fine to coarse grained feldspar basalts comprise the section up to the IM-Horizon.

The lavas that in the geochemical studies marks the IM-Horizon are aphyric, both in field samples and from the Skúvoy-2 core. This is group

During field work in Sandvík, the section from the IM-Horizon down the stratigraphy some 200m is mapped.

One particular unit (Low-Ti (3) group in the geochemical grouping, is only seen in the mountains of Sandvík, and not in the Skúvoy-2 core. We therefore assume that this unit is not a regional group. Whether the tunnel will pass this unit is unclear. If so, this will be in the section just below the IM-Horizon itself, as this is where it is found in the stratigraphy surrounding Sandvík.

Alteration in the olivine basalts is evident in the EGI values, and in core samples. Smectite minerals (Montmorillonite) are seen in both vesicles and pipe vesicles in the basalts. Also, some of the fractures are filled with this mineral.

Physical parameters summarized for the olivine basalt section at the base of Malinstindur Formation.

Physical Parameter	Min	Max	Mean
Fracture Index	0	16	4,2
Q values - core	4	600	101
EGI	1	11	4,8

Table 3. Physical parameters summarized for the olivine basalt section at the base of Malinstindur Formation. Values are from core logging, wire-line logging and field measurements. EGI values are based on core samples and field samples.IM-Horizon to METZ.

Physical parameters summarized for section above the olivine basalt at the base of Malinstindur Formation to the IM-Horizon.

Physical Parameter	Min	Max	Mean
Fracture Index	0	16	3,2
Q values - core	6	636	98
EGI	1	11	4,6

Table 4. Physical parameters summarized for the basalt section above the olivine basalt at the base of Malinstindur Formation to the IM-Horizon. Values are from core logging, wire-line logging and field measurements. EGI values are based on core samples and field samples.

Physical parameters summarized for section IM-Horizon to METZ.

Physical Parameter	Min	Max	Mean
Fracture Index	0	16	2,5
Q values - core	4	600	127
EGI	1	11	2,8

Table 5. Physical parameters summarized for the section from the A-Horizon to the IM-Horizon. Values are from core logging, wire-line logging and field measurements. EGI values are based on core samples and field samples.

METZ to Klivagjógv-Traðarhamar-Horizon

The METZ is defined on seismic profiles (Interpretation of seismic data) and is seen in several of the boreholes and cores. In short, the METZ represents the first occurrence of real prominent sheet flows in the upper parts of the Malinstindur Formation. The METZ is seen in the cores, wireline logs, in the field and in the seismic lines. On the bathymetric data the METZ is also seen clearly as a marked change on the seabed.

The lava flow architecture varies, starting with massive sheet flows, interbedded with compound lava flows. This is seen in the relevant composite logs, field profiles and on the correlation panels above.

In the Søltuvík area two sheet flows occur namely the Høvdhamarin flow, that is 10–20 m thick fine feldspar phyric lava with weak to strong columnar jointing. The other is the C-horizon flow, that also is 10–20 m thick and consists of coarse feldspar phyric basalt and is weakly columnar jointed. Both flows change character laterally to compound architecture.

The Sandur Beds is a collective term used for the 3–5 thick volcaniclastic sandstone beds within a section of some 30-m interval. The thickness of the individual beds varies, and the lava flows in between are mostly sheet flows, with columnar jointing in places. The Sandur Beds are indicated in the correlation panel (Figure 35).

The rock types seen in this section are also varying from aphyric to fine grained to coarse grained feldspar basalts. Upper lava crusts are often altered, zeolite filling in amygdales, along with clay minerals.

Physical Parameter	Min	Max	Mean
Fracture Index	0	16	3,5
Q values - core	1	600	107
EGI	1	11	3,4

Table 6. Physical parameters summarized for the section from the METZ to the Klivagjógv-Traðarhamar. Values are from core logging, wire-line logging and field measurements. EGI values are based on core samples and field samples.

Above the Klivagjógv-Traðarhamar-Horizon

The geology from the Klivagrógv/Traðarhamar Horizon is

The first 40-50 m are dominated by sheet flows, followd by a section of compound lava flows. The sheet flows are columnar jointed, with the Klivagjógv-Traðarhamar volcaniclastic sedimentary horizon at its base.

Some of the flows show brecciated flow tops. The dominant rock type is fine grained variants of feldspar basalt. This section is logged in the field, and seen in the Sandur-1, Djúpadalur-1 and Skarvanes wells.

Physical Parameter	Min	Max	Mean
Fracture Index	0	34	5,4
Q values - core	6	600	58
EGI	1	11	3,3

Table 7. Physical parameters summarized for the section above Klivagjógv-Traðarhamar Horizon. Values are from core logging, wire-line logging and field measurements. EGI values are based on core samples and field samples.

Geology of the tunnel profile

The geological mapping in the area, in combination with the stratigraphic model in Figure 85, is the basis for the geology of the tunnel profile (Figure 86).

From north the tunnel starts in the lower part of the Enni Formation. It is characterized by sheet flows and compound flows and interbedded sedimentary horizons. At Skarvanes the tunnel intersects the Sandur beds that is 5–6 m combined thickness of sediment beds in combination with interlaying lava flows located from Klivagjógv-Traðarhamer-horizon and 30 m below. Due to the fold, the tunnel intersects Sandur beds three times. At first intersection the tunnel path is approximately following the stroke of the horizon (Figure 87) which can result in the tunnel stays in Sandur beds for a rather long distance. At second and third intersection the tunnel path is in dip direction and the length that tunnel stays in Sandur beds will thus be shorter.

A 40-m thick section of sheet flows of massive columnar jointed lavas is with the base at Klivagjógv-Traðarhamar-horizon and up to 40 m above. It will also be intersected 3 times. Below, when the tunnel reaches approximately Skúvoy, there is 80 m thick interval with massive columnar jointed lavas with the base just below the METZ.

Below METZ, west of Skúvoy, the tunnel enters the part of Malinstindur Formation that is characterized by compound flows and few and thin interbedded sedimentary horizons. However, given the morphology of the compound flows, local sedimentary beds that can be up to meters thick (Petersen & Madsen, 2021). From here towards the end point in Sandvík, the tunnel traverses down through most of the Malinstindur Formation.

Below METZ the Skúvoy-2 core contains two sheet flows of ca. 10 m thick one of them locateted in connection with the IM-horizon. Bathymetric data also indicate a few outcrop rocks that could be interpreted as sheet flows.

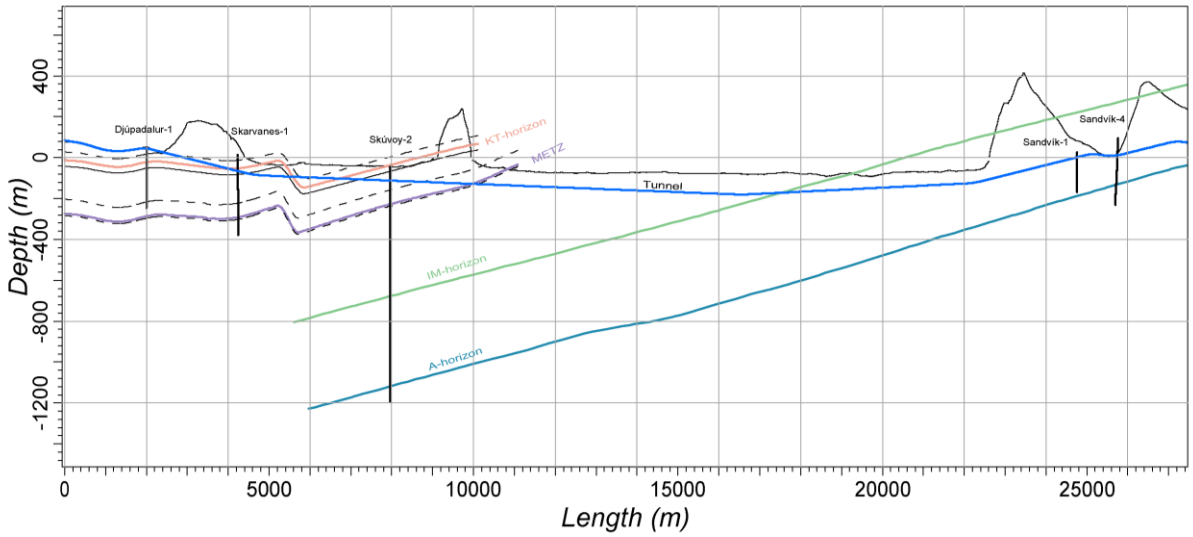


Figure 86. Cross section the tunnel profile. Notice the intersection of A-horizon with Skúvoy-2 well is artificial and is due to that Skúvoy-2 well has not been included in the generation of the A-horizon. Skúvoy-2 well ends at or close to the A-horizon. Vertical/horizontal ratio is 5. X-aksis shows station meters.

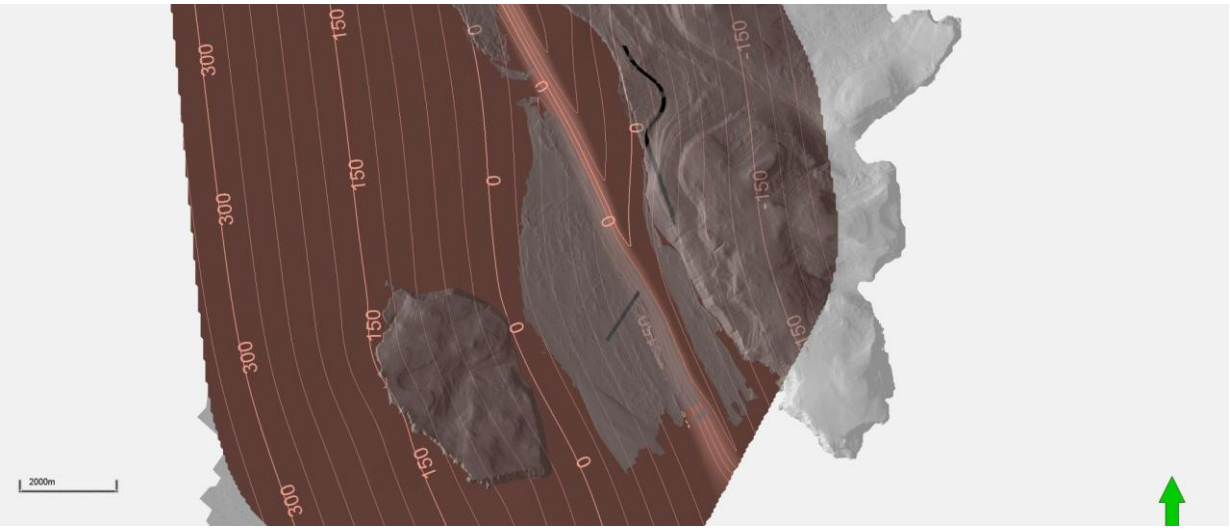


Figure 87. The tunnel path (black line) crossing Klivagjógv-Traðahamar-horizon (solid surface) with bathymetry and Sandoy and Skúvoy (transparent surfaces). Sandur beds is in a 30-m interval below Klivagjógv-Traðarhamar-horizon. Contour levels are meters relative to MSL.

Recommendations

Further mapping of the fold

Although the presence of the fold between Skúvoy and Skarvanes and the approximate location is conclusive, there are indications that it is more complex than modelled in the report. The nature of the fold is not totally understood and observations in the Skopun area at the north end of the island (not documented in this report) weakly indicate that it could be a *fault propagation fold* where the fault is at the level of METZ.

A series of four onshore wells across the fold, located across the southern end of Sandsvatn penetrating METZ would give more insight into this and better understanding of the structural movement across Skúvoyar fjørð between Skarvanes and Skúvoy (Figures 88 and 89).

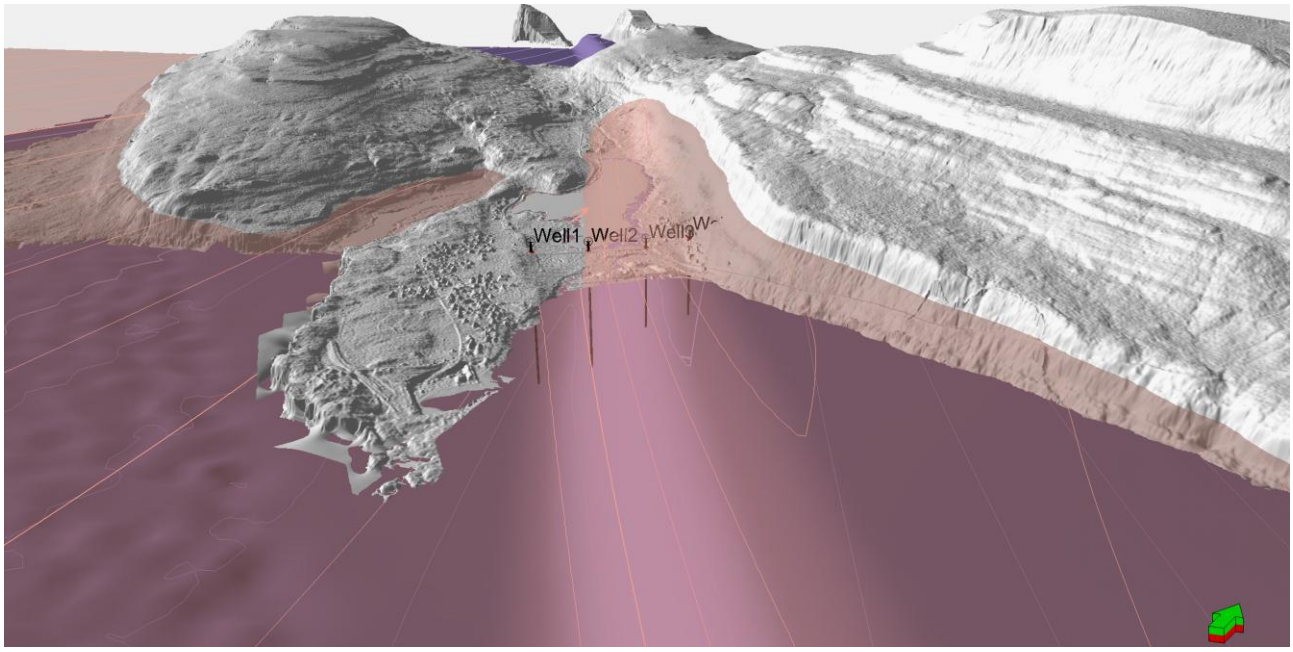


Figure 88. Suggested approximate location of four wells for mapping the fold down to METZ. Figure 89 shows the cross section. Peach color transparent surface shows Klivagjógv-Traðarhamar-horizon.

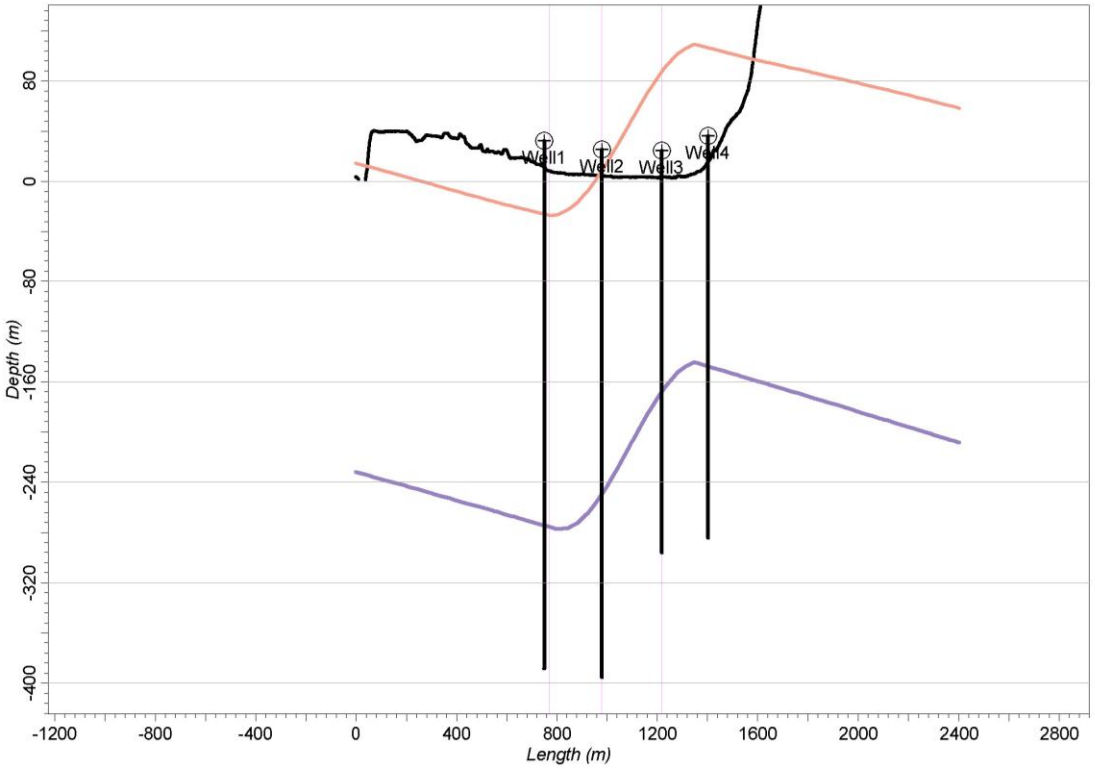


Figure 89. Cross section of the wells in Figure 88. Well1 and Well2 are 400 m deep and Well3 and Well4 are 300 m deep. With Klivagjógv-Traðarhamar-horizons (Peach) and METZ (Purple).

The lack of observed fractures, dykes and lineaments between Skúvoy and Suðuroy gives some concern. The quality of multibeam data in the area is not sufficient to rule out that no fractures can be found here with multibeam. Therefore, it should be considered to revisit the area, perhaps with multibeam with higher resolution in smaller areas where the bedrock is known to be exposed.

Magnetometer can be a vital tool to map out fracture zones or dykes in areas that are covered with vegetation or sediments. It could be used in areas where the tunnel trace is covered with sediments. Moreover, magnetometer can map out the magnetic anomaly found by the asymmetric fold in Skúvoyarfjørður and potentially map the spatial extent of the fold.

Appendix list

Appendix A - QC of multibeam

Appendix B - QC core logging, synthetic, and refraction seismic velocities

Appendix C - Map of the Suðuroyar tunnel

Appendix D - Field localities - Suðuroy

Appendix E - Field work – Sandoy/Skúvoy

Appendix F - Geochemistry

Appendix G -Ethylene Glycol Index (EGI) – cores and field samples

Appendix H – Q-system cores

Appendix I - Field and core samples

Appendix J – Photo Profiles from Sandoy

Appendix K -Søltuvík-2 borehole

Appendix L - Sandur-1 borehole

Appendix M - Skúvoy-1 borehole

Appendix N - Skarvanes-1 borehole

Appendix O - Sandvík-1 borehole

Appendix P - Hvalba-1 borehole

Appendix Q - Skúvoy-2 core

Appendix R - Djúpadalur-1 core

Appendix S - Sandvík-4 Borehole

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Appendix C The Suðuroy subsea tunnel - geological profile

