Automated co-interpretation of geophysical data for site investigation

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ABSTRACT
A methodology for automated co-interpretation of ERT (electrical resistivity tomography) and seismic refraction data is applied to a combined dataset collected in the S-E part of Norway. Seismic methods and seismic refraction in particular is a standardized tool for tunneling site investigations in Norway, while ERT is gaining increasing acceptance as a tool in this application. There is an underlying issue in using the two results and creating a manual joint interpretation. Therefore, we suggest a different approach. By using an algorithm that can do the interpretation without any bias, a further level of repeatability will be attained. Furthermore, the use of joint inversion could assist in the improvement of the overall resolution. The Norwegian road administration is planning a new 8.5 km long stretch of four lane highway from Bjørum to Skaret. The project is complex from the point that 4.2 km of the total stretch is planned to be tunneled. The results from the survey are presented in three steps. Firstly, the ERT section, secondly, the seismic refraction profile and lastly the automatically co-interpreted profile. There is no indication of changes in velocity below approximately 30 meters depth, although the ERT results indicate that there are zones delineated by lower resistivities. The automatically co-interpreted profile result is easier to interpret and helps the interpreter to find the common patterns that are more subtle in the separate profiles. The method cannot, however, create perfectly unambiguous interpretations of the geophysical data as there are different setup parameters that affect the results, but it is a tool to aid in the interpretation of the geophysics.

Keywords: Inverse modelling, ERT, refraction seismics, joint inversion

1 INTRODUCTION

1.1 Seismic refraction and geoelectrics as tools for site investigations in Norway

Seismic methods and seismic refraction in particular is a standardized tool for tunneling site investigations in Norway (Rønning et al. 2009). Seismic refraction has the ability to detect fracture zones, aid in the assessment of thickness of these zones and yield a specific seismic velocity for the investigated bedrock. The seismic velocity can then be used to qualitatively evaluate the bedrock.

There are basically two main approaches to the evaluation of seismic refraction data. Either using layer models and trying to fit the data to these models or using a tomographical approach. The advantage of using the tomographical approach is the possibility of detecting fracture zones with a limited extent in relation to the survey profile. A difficulty that appears in regions where glaciation has effectively scrapped the weathering zone clean is that there is a difficulty in transferring energy into the bedrock; this problem is often pronounced in most parts of Norway. This implies that it will be most difficult to attain information from within the bedrock, meaning that the dip and depth of fractured zones will be unknown.

ERT (electrical resistivity tomography) can be used to locate fracture zones within the bedrock, yielding further information such as zone thickness and dip (Rønning et al. 2009; Reiser et al. 2009)

1.2 Joint interpretation and joint inversion

Joint interpretation and joint inversion may yield similar results. Often they do not, joint interpretation of seismics and resistivity can be achieved by simply looking at the results from the two methods and create a joint interpretation. A further step would be to let the data from both methods assist each other while inverting the data.

There is an underlying issue in using the two results and creating a manual joint interpretation. The issue is the fact that two different interpreters will attain two different interpretations of the profiles.

By using an algorithm that can do the interpretation without any bias, a further level of repeatability will be attained. Furthermore, the use of joint inversion could assist in the improvement of the overall resolution and possibility to describe the lithology (Infante et al. 2010).

The approach that we use was first demonstrated by (Günther et al. 2006). This approach is extended by using a clustering algorithm and hereby automatically organizing the resistivities and velocities in groups with spatial coincidence. This approach takes the process one step further and into a fully automated co-interpretation of the data.

1.3 E16 Bjørum – Skaret

The Norwegian road administration is planning a new 8.5 km long stretch of four lane highway from Bjørum to Skaret. The project is complex from the point that 4.2 km of the total stretch is planned to be tunneled. The selected piece for this particular analysis is only about 700 meters long in order to reduce the amount of data for analysis.

The new E16 highway between Bjørum and Skaret is a difficult project from several perspectives. As almost half of the stretch will be tunnel, the need for deep bedrock quality assessment is pressing.
The site is located in the S-E part of Norway, as described in Figure 1. Rambøll conducted the field survey and wrote a report (Rambøll 2012) for the Norwegian geological survey and GeoVita AS. The results from the survey were interpreted and used to update an expected geological section that was first created by using the geological maps and surface mapping by an experienced local geologist.

1.4 Geology

The field site is situated in within the Oslo Rift. The rift can be subdivided into three major graben structures from the north, the Askershus Graben (AG), the Vestfold Graben (VG) and the Skagerrak Graben (SG). During Perm, the rift was experiencing volcanic activity that peaked 295-285 million years ago. Volcanic deposits of porphyry and basalt are predominant and there are volcanic rock dikes over 40 meters wide. The volcanic layers in the area are surrounded by faults and syenite dikes. Glacial events has removed large amounts of heavily weathered bedrock and replaced it with thin till layers.

2 RESULTS

2.1 ERT and seismic refraction from December 2011

The results from the survey are presented in three steps. The ERT results are presented in Figure 2. A high (1250-3980 Ωm) resistivity strip can be seen close to the surface. The underlying layer shows two vertical anomalies at 300 and 450 meters respectively. The apparent horizontal stratification pattern suggests horizontal geological structures. These patterns coincide with expected volcanic structures. The vertical high (1250-3980 Ωm) resistivity band at 300 meters coincides with dolerite findings at the surface, indicating a vertical dyke.

The inverted velocity section in Figure 3 shows one or two low (1000-3500 m/s) velocity layers. These layers are on top of a high (3501-5200 m/s) velocity layer, divided into three separate parts at 100 and 450 meters. The outer part of this layer contains ever higher velocities (4500-5200 m/s). The possible dolerite indicated in the resistivity profile could be present at 300 meters, indicated by a high (4500-5200 m/s) velocity zone. There is a low (3500-4000 m/s) velocity part just left of this, possibly indicating some weathering adjacent to the dyke.

The co-interpreted section in Figure 4 is based on joint inversion of the two data sets followed by cluster analysis. At 300 meters, there is visible diabase at the surface; this diabase zone could be in coherence with the blue zone. The dominating turquoise zone is more difficult to interpret, it probably consists of less weathered bedrock. The green and yellow near surface outcrop zones are probably diabase and volcanic rocks in different stages of weathering.

3. CONCLUSIONS AND OUTLOOK

The ERT results exhibit a model section with structural information throughout the depth of the sections, with zones of lower resistivities indicated to large depths. For the seismic refraction, on the other hand, there is no indication of changes in velocity below approximately 30 meters depth.

The automatically interpreted section can be easier to interpret and helps the interpreter to find the common patterns that are more subtle in the separate profiles. The evidence of a vertical volcanic dike becomes very clear in this profile.

It should be noted that the method cannot, however, create perfectly unambiguous interpretations of the geophysical data as there are for example different setup parameters that affect the results. It is a tool to aid in the interpretation of the geophysics.

Following up the geophysics with a drilling campaign is a natural step. The drilling campaign may be designed by using the results from the geophysical and thereby making the most of the drillings. A future outlook is to include drill-data and revise model using drill-data. This facilitates a very detailed assessment of rock quality and fracture zone extension.

4. REFERENCES

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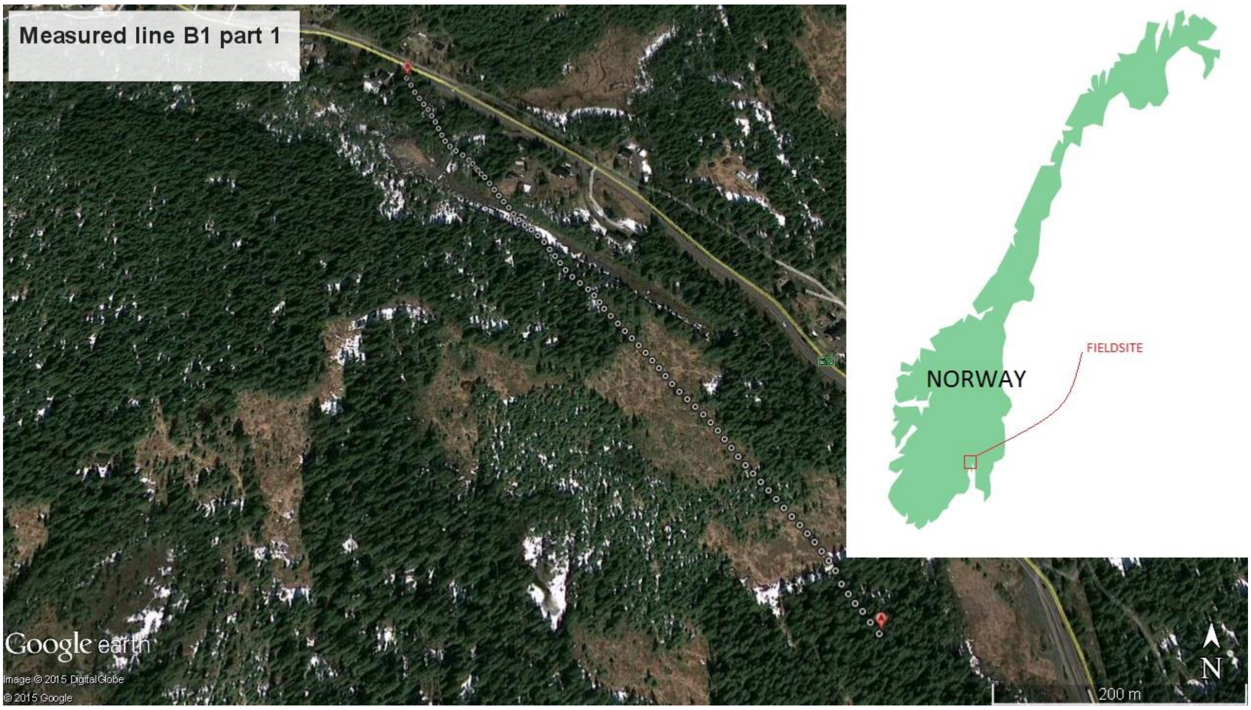

Figure 1, The B1 line positions

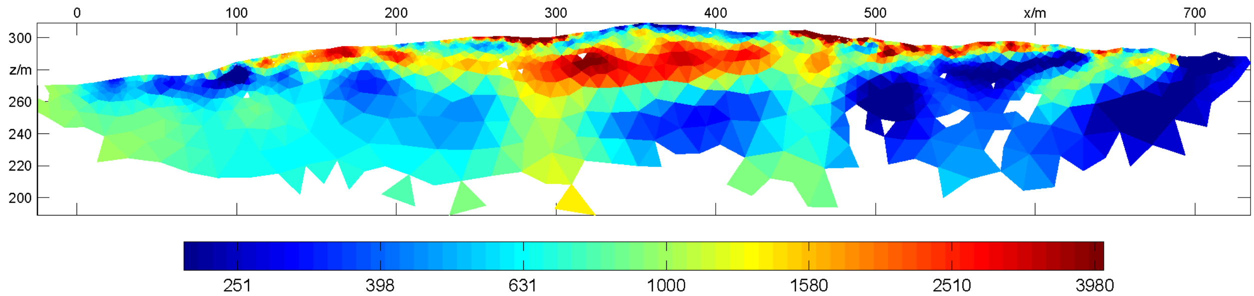

Figure 2, resistivity profile [Ohm-m]

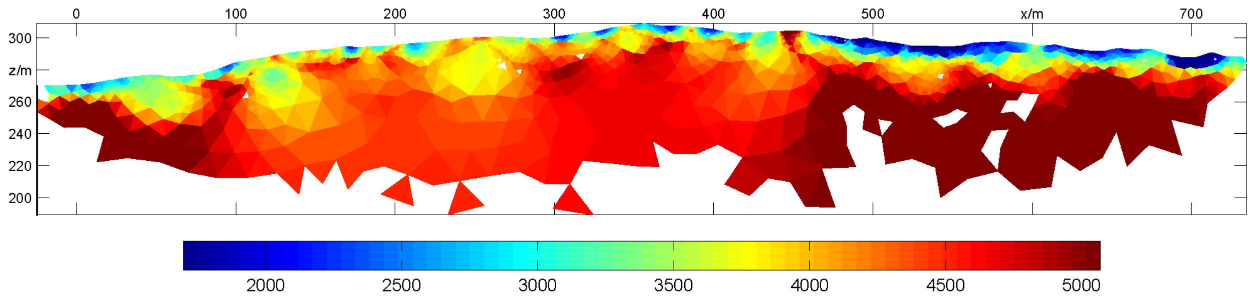

Figure 3, refraction profile [m/s]

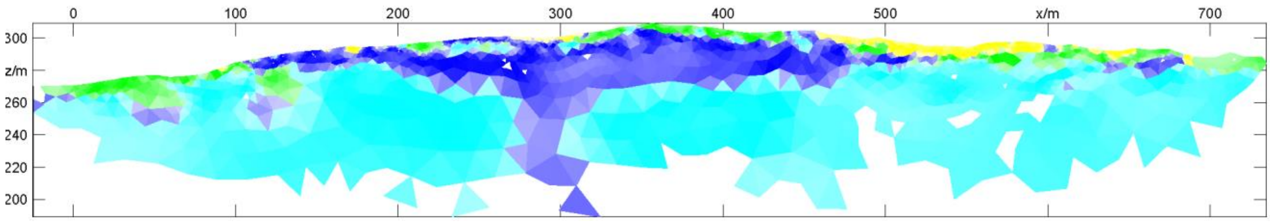

Figure 4, co-interpreted results, 4 clusters