Geologische Bundesanstalt
Geological Survey of Austria

Electrical Resistivity Tomography at Gamanjunni, Troms, Norway 2016

contracted by:

Norwegian Water Resources and Energy Directorate
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Factsheet

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Project area:	Gamanjunni, Troms, Norway
Coordinates:	482650 | 7708113 (UTM 34 N)
Adress:	9144 Samuelsberg

Case Number (GBA):	GBA TR 741
Clerk GBA:	Mag. Stefan Hoyer Anna Sara Amabile, MSc Mag. Alexander Römer
Field Team	Hoyer, Amabile.

Applied method:	Multi-electrode Geoelectrics		
Penetration depth:	*~ 150 m*		
Scheme:	*Wenner, Schlumberger*		
	Electrode Distance [m]	Profile length [m]	Heading
Profile 1	9	747	S-N
Profile 2	9	747	S-N

Workflow:	
Order:	2016/09/15
Begin of field campaign:	2016/09/28
End of field campaign:	2016/10/07
Reporting:	2016/11/30

Introduction

The Geological Survey of Austria was contracted by the Norwegian Water Resources and Energy Directorate, represented by Gudrun Dreias Majala, to conduct Geoelectrical Measurements (Electrical Resistivity Tomography, ERT) at the rockslide site ‘Gamanjunni 3’ near Manndalen, Troms, Norway.

Data was measured using an AGI STING Multielectrode Resistivitymeter with a switch box allowing to attach Multicore cables connected to 84 electrodes. The overall profile length determines the maximum penetration depth, which is usually one fifth of the length at a rough estimate. The real penetration depth is also dependent on the conductivity of the underground. The cables brought by the Geological Survey allow a maximum electrode spacing of 10 m, in rough terrain it is advisable not to use the maximum spacing to have some buffer if some electrode has to be shifted. With 84 electrodes attached and the chosen distance of 9 m, the overall profile length is 83 x 9 m = 747 m, the total penetration depth is about 150 m.

Questions / Aims

Applying the ERT method can deliver basic information for the assessment of the base of the rockslide since loose blocks and heavily fractured rock is characterized by a much lower ability to conduct electric currents than solid rock. Hence, the conductivity contrast between the rockslide zone and the underlying rock massive should be clearly visible in the geoelectric section.

Two profiles were measured slope parallel heading South – North. The first profile (P1) covers the area of the rockslide, but as the endpoint is located just right at the boundary of the instable zone the decision was made to measure a second profile (P2) as an elongation of the first one. The data of the two profiles are then merged and inverted as one large dataset. As the two measures have a large overlap, the data quality in the central zone can be increased significantly. P2 also covers a more stable area north of the rockslide, the resistivity values obtained there serve as a reference value for solid rock. Hence, the elongation of P1 enhances the data quality, reliability and interpretability of the inversion result.

Table 1

	Profile 1		Profile 2	
	First electrode	**Last electrode**	**First electrode**	**Last electrode**
Electrode number	1	84	33	116
Profile distance	0	747	288	1035
X-coordinate (UTM 34)	482824	482644	482798	482596
Y-coordinate (UTM 34)	7707592	7708217	7707839	7708497
Elevation	690	768	770	772

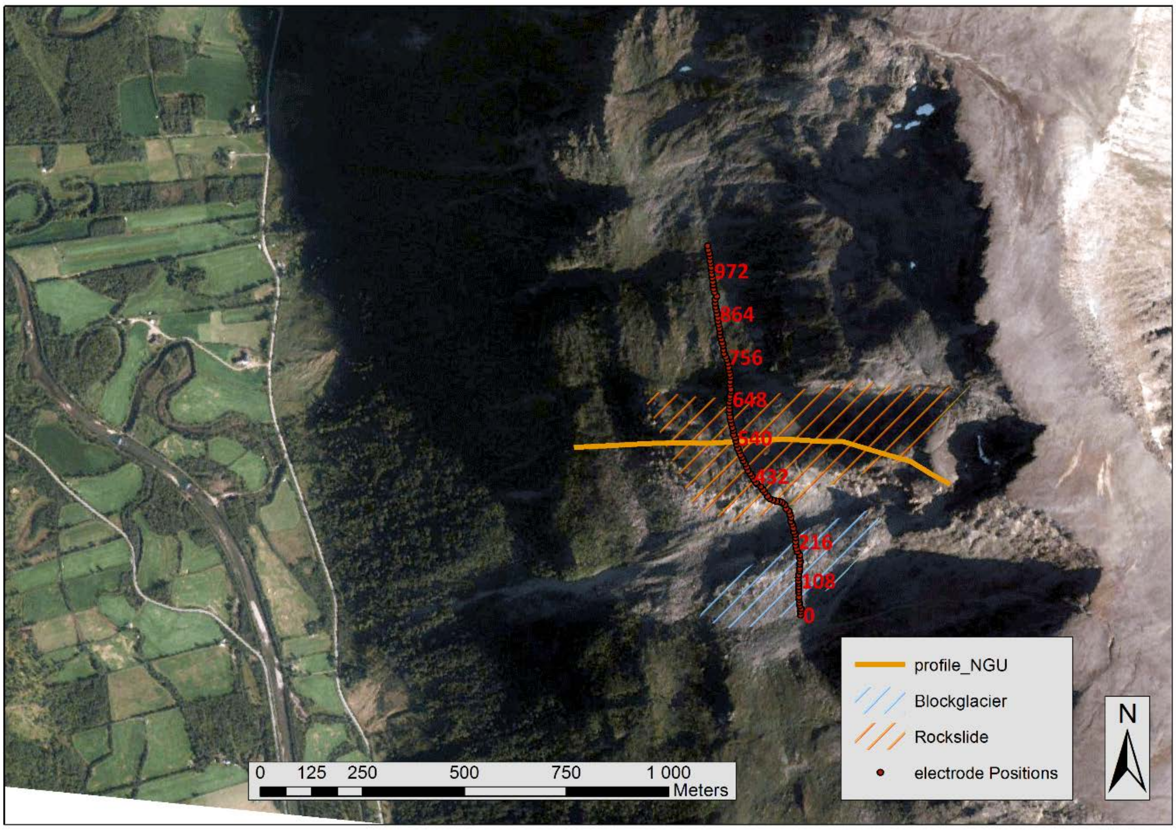


Figure 1: Overview of the geoelectric profile. In the southern part (approx. between electrode position 0 and 220), the profile crosses a block glacier. The rockslide is located approx. from pos. 400 – 650.

ERT Method

Within the last several years, the geoelectrical method has become a routine geophysical method to investigate subsurface geometry and structural pattern of landslides (e.g. Perrone et al. 2006). Electrical Resistivity Tomography delivers a cross-sectional view of the resistivity distribution along a vertical profile. One ERT dataset consists of thousands of single measures, where different combinations of electrodes are used. For each single measure current is injected at one electrode couple (C_1, C_2) and the voltage is measured at another couple (P_1, P_2) [see Figure 2].

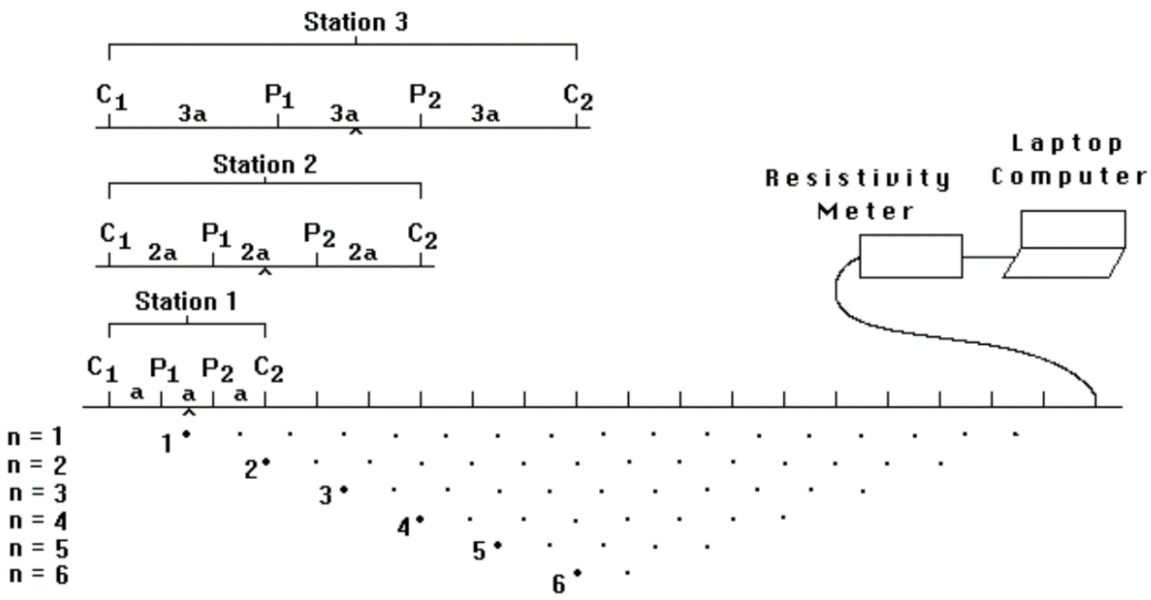


Figure 2: The principle of ERT measurement [Geotomo, 2010]: Sequence of measurements to build up a pseudosection. The shortest combinations (e.g. "Station 1") plot in pseudodepthlevel n=1, "Station 2" in level n=2 and so on.

The principle of ERT is based on introduction of the geometric factor ***k***, a function of electrode configuration with the unit of length, into Ohm's Law:

$$Ohm's\ Law: \quad R = \frac{U}{I} \qquad [\Omega]$$

$$with: \quad \rho = k \cdot R \quad [\Omega \cdot m]$$

$$yields: \quad \rho = k \cdot \frac{U}{I} \quad [\Omega \cdot m]$$

where ***R*** is the resistance, ***ρ*** denotes the apparent resistivity, ***U*** the (*measured*) voltage and ***I*** the (injected) current. For a first assessment of the apparent resistivity distribution and the data quality, ***ρ*** can be plotted vs. the pseudodepth – the generated image is the so-called pseudosection [Figure 2 and Figure 3]. Inversion algorithms create a resistivity section and compute synthetic pseudosections from that initial model. Comparison between the measured and the synthetic pseudosection allows the algorithm to adjust the resistivity model iteratively until a previously defined cut-off criterion is met.

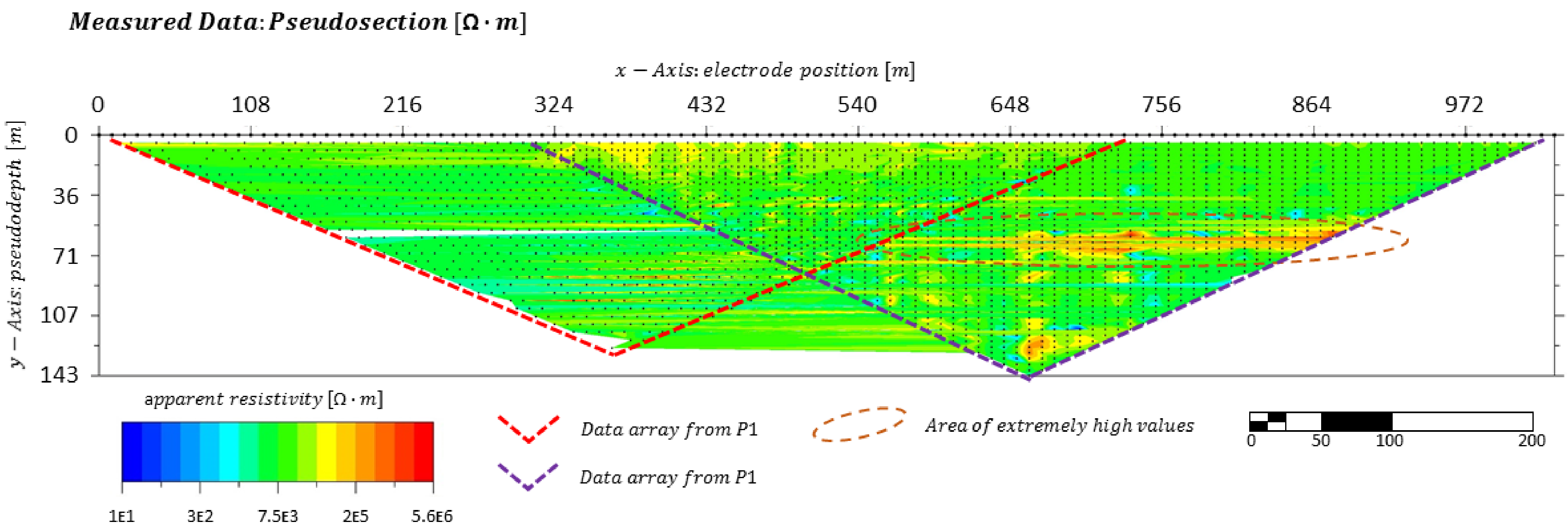


Figure 3: Pseudosection of the measured data (both profiles, P1 and P2). The black dots are a representation of the single measurements. In the right half of the profile there is a region with extremely high values, it is a matter of discussion weather these datapoints are related to anomalies in the underground or to erroneous measurements. Without additional information it is not possible to do a reliable interpretation of this feature.

Results and interpretation

The collected data is inverted using AGI Earth Imager Software ®, the result (inverted resistivity section) is displayed in Figure 4. The inversion result is well interpretable in terms of surface topology. The two high resistive areas at the southern (left) end as well as in the central part of the profile are interpreted as block glacier and the zone of the rockslide, respectively. The area between electrode position 738 and 873 m represents a more stable zone (massive rock covered with some soil and vegetation). In the north (right end) the profile crosses channels filled with loose rocks, again visible in the section as areas with elevated resistivity.

According to our experience, the thickness of a high resistive layer on top of a lower resistive zone is mostly overestimated. In this case, the thickness of the loose blocks covering the rockslide mass can be estimated with about 20 m maximum. The deeper underground (depth > 50 m) can be divided in four zones in terms of resistivity (see Figure 5). Bedrock material is outcropping at the end of the profile (area > m750), hence the area below is interpreted as 'Solid rock', this interpretation is coherent with the seismic interpretation. The other three zones are not well interpretable without further information and are called 'Zone A, Zone B, and Zone C' in the ERT standalone interpretation.

The final interpretation is carried out in synthesis with the results from the seismic survey. This combined interpretation is much more profound than the single ERT interpretation (see Figures attached). Following the seismic interpretation, Zone A can be addressed as 'Weathered Bedrock', Zone B can be seen as part of the rockslide, probably more moistened and/or with a higher content of fine-grained material than in the drained upper layer hence better conductive (lower restistivity). The deep branch of the 'decompaction zone' interpreted in the seismic survey (Figure 6, Feature I) is not visible in the ERT data, hence it does not appear in the combined interpretation. The area around Feature II in Figure 6 with slightly decreased seismic velocities could be related to ERT 'Zone C' with decreased electrical resistivity and is interpreted here as 'weathered/decompacted' zone.

Conclusions / Recommendations

The study area has to be considered as an extreme environment in terms of ERT. Owing to the high-resistive (drained) rocklayer the coupling of the current injecting electrodes to the underground is critical. For further investigations, it is recommendable to consider some effort on improvement of electrode to ground coupling. Possibilities include: application of two or even more electrodes per measurement point, longer/thicker electrodes, backfilling of the boreholes with bentonite clay, etc.

It has shown, that the combined interpretation (ERT/Seismics) is able to deliver good results, still interpretation could be improved significantly with additional information. Application of electromagnetic methods (EM) is not a suitable method for gathering additional information because these systems are not sensitive for very high resistivities. EM systems are designed for resistivity contrasts like 50 | 1000 Ohm.m at the Gammanjunni site we are dealing with a range from 2000 – 50000 Ohm.m, the EM signal would be too weak. Hence, ERT in combination with seismics seems to be the most promising geophysical methods for this environment.

Additional Information can be gathered by boreholes, interesting targets for the geophysical interpretation are 'Zone A' between profile meter 220 and 320 and 'Zone B' at profile meter 530.

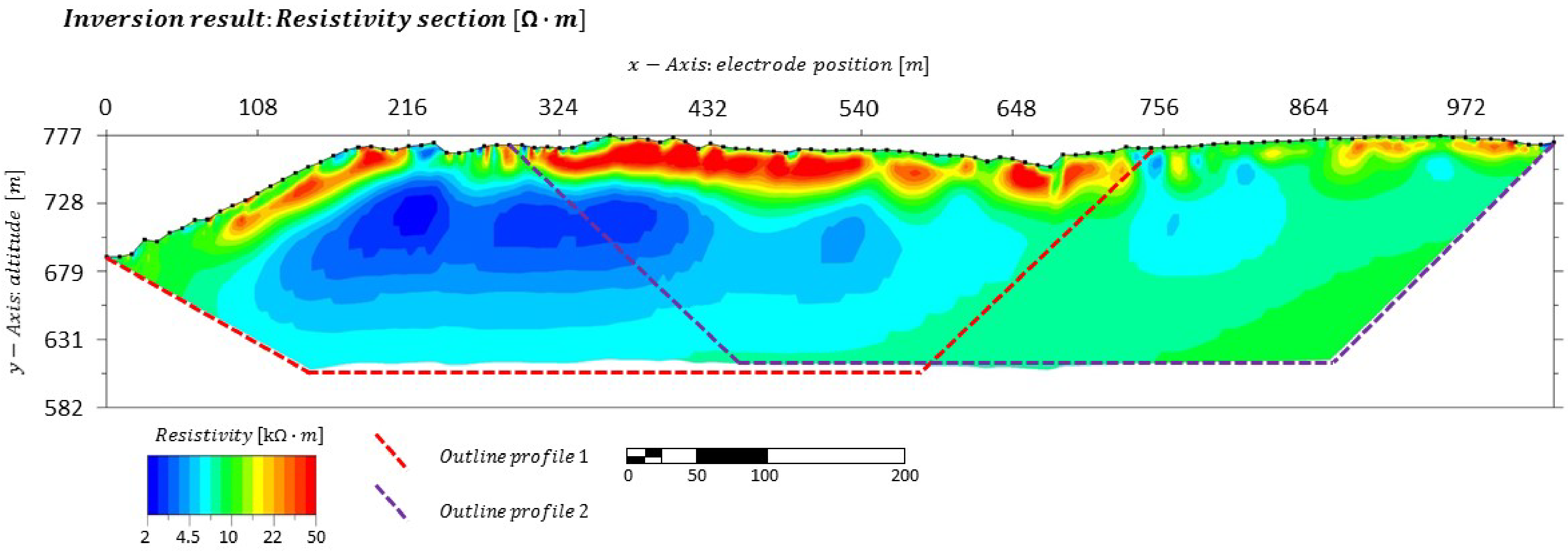
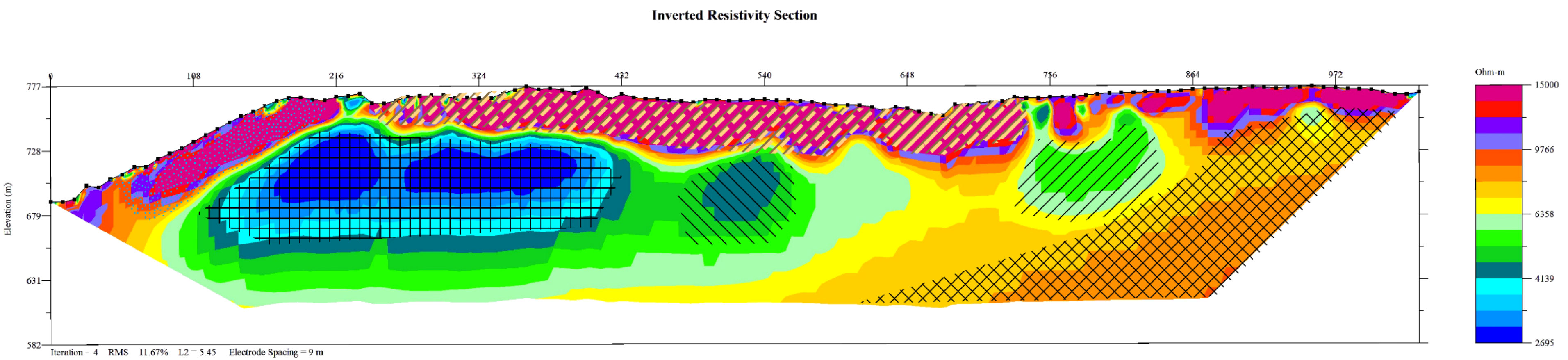


Figure 4: ERT Inversion result and rough interpretation. The interpretation is consistent with a previously measured profile by NGU.
Values >16000 Ω·m (red) as heavily jointed, well drained landslide mass.
16000 > 3000 Ω·m (blue / green) as solid rock
Values < 3000 Ω·m as jointed, wet rock. (please note: Only the very lowest values (dark blue) are < 3000 Ω·m).



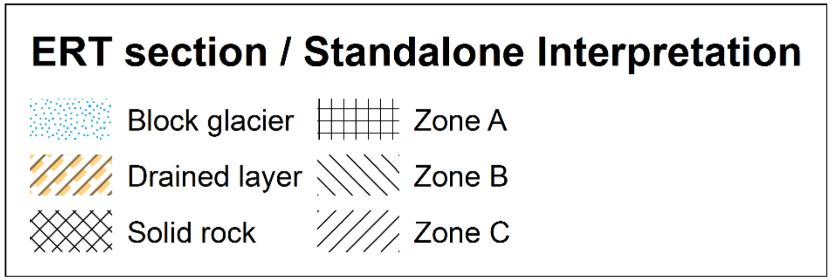


Figure 5: ERT inversion result and Interpretation. Same as Figure 4 with a different colorbar. The block glacier and the drained, upper layer of the rockslide are clearly visible and well interpretable. The intermediate values (~8000 Ωm) at the right end of the profile are interpreted as solid rock. In-between three different zones (A, B, C) can be identified but no classification can be done without additional information (seismic, drilling, outcrops, etc.)

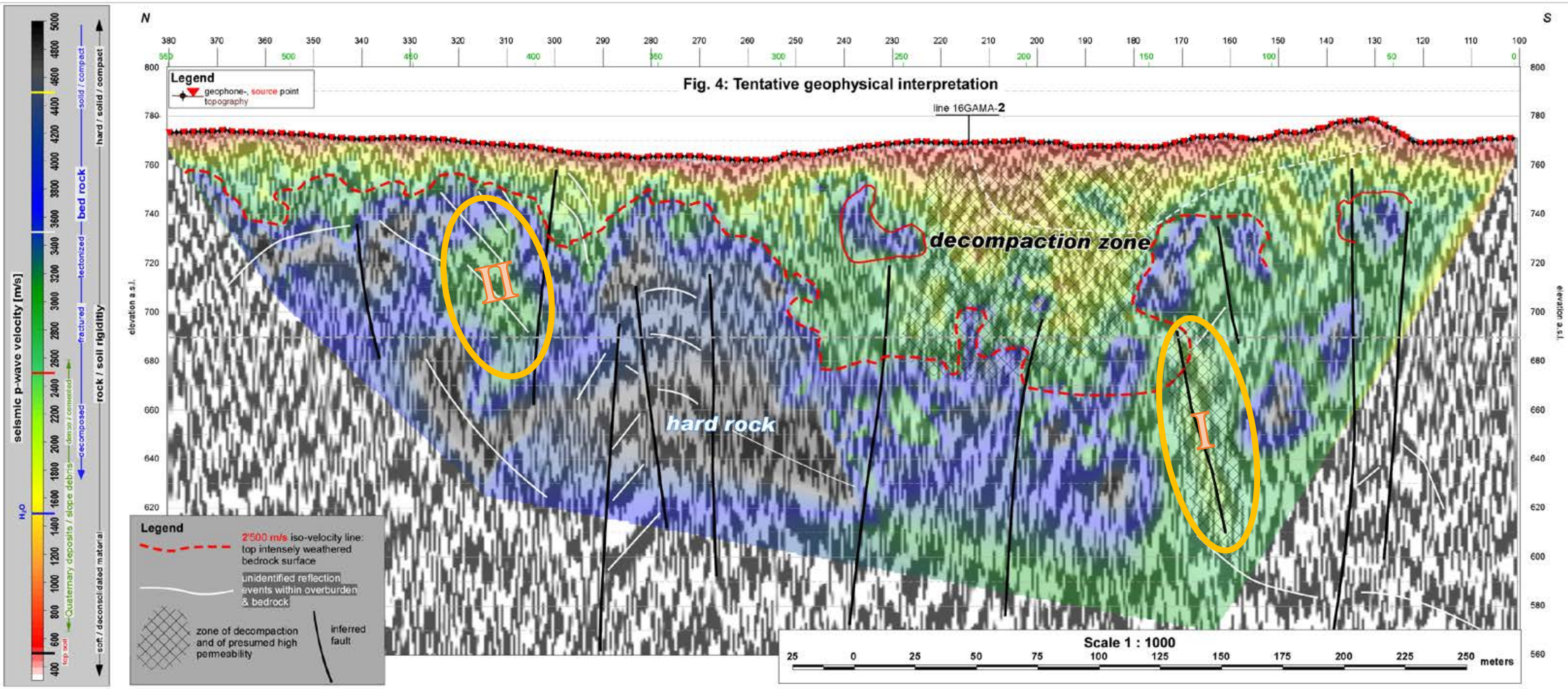


Figure 6: Seismic interpretation from the Geoexpert Seismic Report - Enclosure 1b. Please note that this figure is oriented N-S – the Geoelectric sections are all oriented S-N. The two Features 'I' and 'II' are discussed in the chapter "Results and Interpretation".

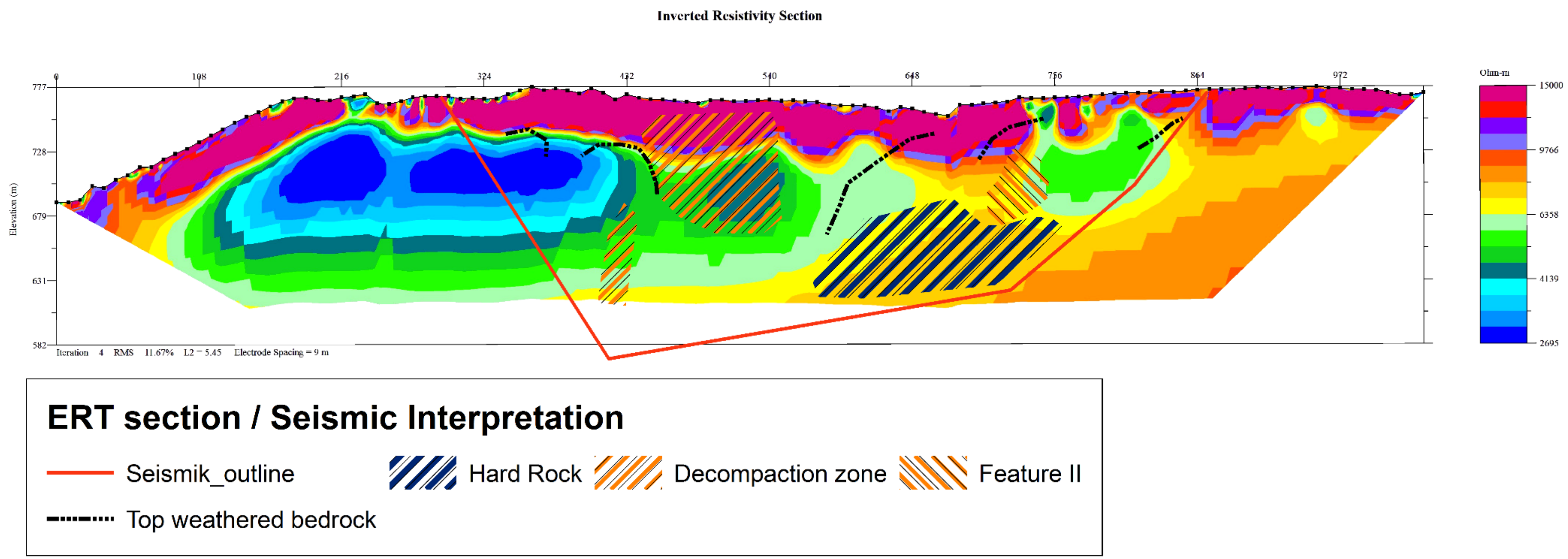
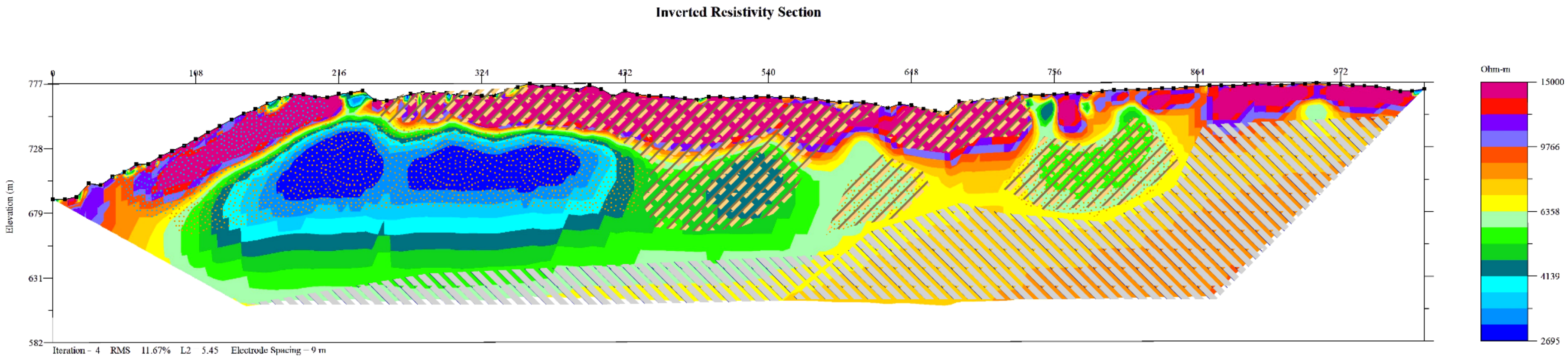


Figure 7: ERT Inversion result and seismic interpretation overlay. The seismic interpretation used in this figure is the "Tentative geophysical interpretation" (Geoexpert Seismic Report - Enclosure 1b). 'Zone B' is identified as 'Decompaction zone' by the seismic survey. 'Zone A' and 'Zone C' are located below the 'Top weathered bedrock'.



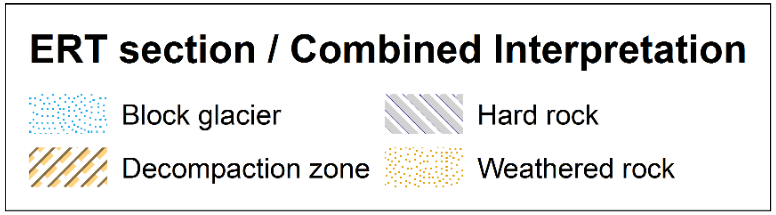


Figure 8: ERT Inversion result and combined interpretation. The combined interpretation is based on the "Tentative geophysical interpretation" (Geoexpert Seismic Report - Enclosure 1b) and the ERT results and give a much more comprehensive idea of underground conditions.

ERT Interpretation	Seismic Interpretation	Combined Interpretation
Zone A	Weathered Bedrock	Weathered Bedrock
Zone B	Decompacted Zone	Decompacted Zone
Zone C	Weathered Bedrock	Weathered/Decompacted