Numerical Modelling for Improvement of the Interpretation of Geoelectrical and Induced Polarization Measurements

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Numerical Modelling for Improvement of the Interpretation of Geoelectrical and Induced Polarization Measurements

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SUMMARY

With a general knowledge about the geological setting it is possible to use numerical modelling of geoelectrical and IP data to obtain useful experience for the interpretation of real measurements. In this case the vertical extension of a dolerite dyke has been modelled and compared with real data. It is obvious from the resistivity modelling that it in this particular case not is possible to say anything about the vertical extension of the low resistive zone in the real measurements. Based on the experience from the IP modelling it is much clearer that the dyke extends to the bottom of the model. By combining different methods which exploits different physical properties a better and more reliable interpretation can clearly be done.

Introduction

Even though geoelectrical imaging has been used with success in several tunnel project (e.g. Cardarelli et al., 2003; Cavinato et al., 2006; Dahlin et al., 1999; Danielsen, 2007; Ganerød et al., 2006) the question asked by the engineers and decision makers is always: “How reliable are the results?”. This can be difficult to answer, so numerical modelling is a useful tool to learn more about how to interpret IP and geoelectrical data in a specific geological environment. The numerical modelling is done in order to better understand and interpret measurements performed in connection to a tunnel project in Southern Sweden. The models are based on general information about the geological setting and borehole logging at the site.

Method

The models are based on values from resistivity logging of two core drilled boreholes and general information about the geology in the specific area. It is known from aeromagnetic maps that at the specific site there is an approximately 50 metre wide dolerite dyke having a, for the area characteristic, positive anomaly. The location of the dyke has also been pinpointed using a ground based magnetometer. According to Wikman and Bergström (1987) these dolerite dykes are standing vertical or with a slight dip towards northeast. Therefore the general model resembles a dolerite dyke in an otherwise gneiss dominated bedrock. In the lithological contacts the rock is often fractured, highly water bearing and has an increased mineralization because of contact metamorphosis. The dolerite itself is a very tight formation without fractures. The minerals can also have a needle-shape and be parallel oriented (Wikman and Bergström, 1987). The water decreases the resistivity in the fracture zone and as mentioned in Dahlin et al. (2002) the mineralization increases the IP effect of the zone. The resistivity log also showed that fracturing of the gneiss decreases the resistivity considerably.

Several different models where the dip of the dyke is varying as well as the vertical extension were tested. Here is only given three examples of a vertical structure with different vertical extension, see figure 1 and 2. In all the models the resistivity of the matrix is 5000 Ωm whereas the resistivity of the dolerite is 3000 Ωm and 500 Ωm in the contact zone. For the IP model the IP effect of the matrix and the dolerite is 40 mV/V. In the top 5 metre of the model the IP effect is 20 mV/V. The IP effect of the contact between dolerite and gneiss is 100 mV/V.

Numerical modelling of resistivity and IP data is done using RES2DMOD. Prior to the inversion in RES2DINV the data are imposed with 5% noise. This is done in Matlab using a random function which gives Gauss generated values with average 0 and variation 1. The Gauss generated values are multiplied by 5% and then added to the original data.

The electrode array used for the modelling and the field measurements is pole-dipole. This array was chosen in order to get a larger penetration depth, as defined by median depth of penetration. Both measured profile and models are 400 metre long. Data are measured with Lund Imaging system using cables with 5 metre electrode spacing. The information and experience from the inverted models is then used for the interpretation of the field data.

Results

The result of the inversions of the vertical structure can be seen in figure 1 and 2. The three models (called A, B and C) can be seen in the left side of the figures are the inverted resistivity and IP models are in the right side of the figures.

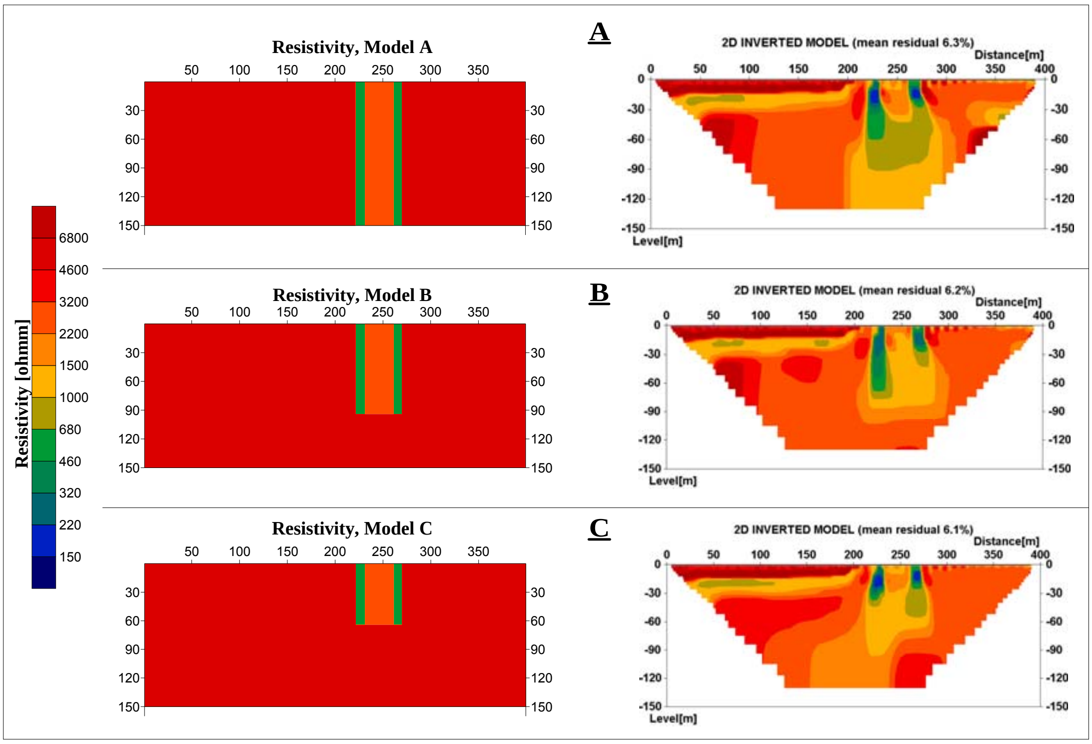

Figure 1. Model A, B and C resembles a vertical dolerite dyke with a lower resistivity in the contact zone. The resistivity of the matrix is 5000 Ωm whereas the resistivity of the dolerite is 3000 Ωm and 500 Ωm in the contact zone. The vertical extension of the dolerite varies.

The inversion result of the resistivity models, figure 1, shows only a small difference between the three models. It is not possible to resolve the bottom of the vertical structure. In all cases the resistivity of the matrix is lower than in the actual case. In left side of the inversion results there is an artefact which mistakenly could be interpreted as a three layered sequence, i.e. a very high resistive layer, a low resistive layer and high resistive layer.

The inversion results of the IP models, figure 2, shows a larger capability to resolve the full vertical extension. Close to the surface the IP effect and the width of the contact zones are correctly resolved. With depth it gets a larger horizontal extension and a lower IP effect. This is an effect of the lower resolution, i.e. the increasing size of the model cells with depth. It also seems as if the structure dips to the right. This is probably an edge effect. It can also be seen that the thin top layer is exaggerated from 5 metre to 30 metres thickness. The IP effect of both the top layer and the matrix are estimated correct.

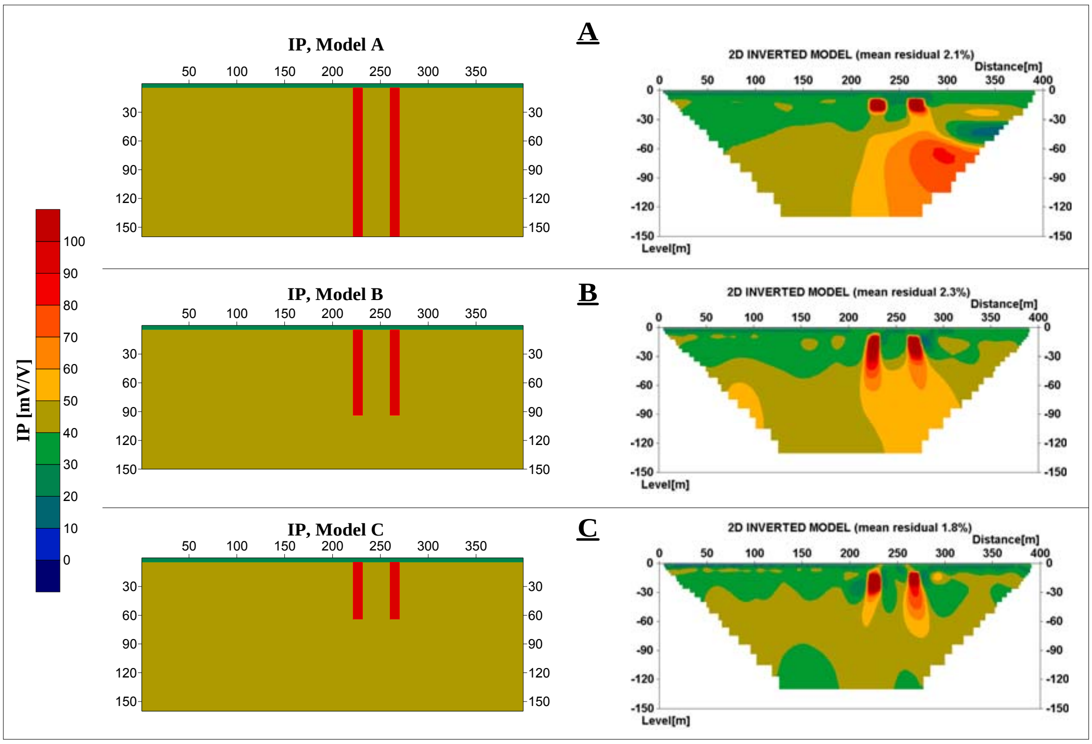

Figure 2. *Model A, B and C resembles a vertical dolerite dyke with a higher IP effect in the contact zone. For the IP model the IP effect of the matrix and the dolerite is 40 mV/V. In the top 5 metre of the model the IP effect is 20 mV/V. The IP effect of the contact between dolerite and gneiss is 100 mV/V.*

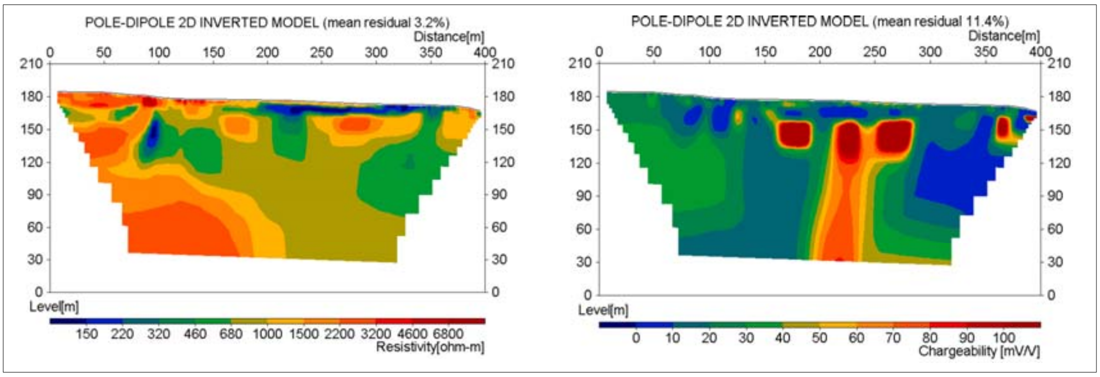

Figure 3. The inverted resistivity (left) and IP (right) data from real measurements using pole-dipole array. Notice that the depth is relative to sea level (m.a.s.l.).

The inverted resistivity and IP data from the real measurements are seen in figure 3. In the resistivity model (left) there is a low resistive zone (300-400 Ωm) from x = 200 to 250. This zone extends to 40 metres depth (~120 m.a.s.l) and fades out with depth. At x = 100 metre there is a zone with a resistivity on 100 Ωm. At the surface the resistivity is high whereas the resistivity of the matrix is 2000 Ωm. The IP model (right) has three zones with very high IP effect (> 100 mV/V) from x = 150 to 275. The zone in the middle extends to the bottom of the figure. The IP effect of the matrix is 10-40 mV/V. At x = 100 there is an area where there is an IP effect on less than 10 mV/V in connection with areas with higher effect (50-70 mV/V).

Discussion and Conclusion

Obvious the real geology is more complex than the models shown here, but with a general knowledge about the geological setting it is still possible to use numerical modelling to obtain useful experience for the interpretation of real measurements. In this case the vertical extension of a dolerite dyke has been modelled. It is obvious from the resistivity modelling that it in this particular case not is possible to say anything about the vertical extension of the low resistive zone at x = 200 to 250 in the real measurements (figure 3). Based on the experience from the IP modelling it is much clearer that the dyke extends to the bottom of the model. By combining different methods which exploits different physical properties a better and more reliable interpretation can clearly be done.

The reason for the artefact in the left side of the resistivity models has not yet been found. The modelling has also been done using the gradient array, but the artefact was still present. This has to be investigated more in the future work.

The results show that it is important to do numerical modelling of a specific geological setting. Information about the actual depth of resolution is important to bear in mind when interpreting resistivity and IP data. This kind of study can be valuable for assessing the reliability which may facilitate interpretation of results for engineers and decision makers.

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