A first stress field assessment for geothermal exploration in Gothenburg (borehole GE-1)

Maria Ask[a], Simona Pierdominici[b] and Jan-Erik Rosberg[c]

[a]Department of Earth Sciences, Uppsala University, Uppsala, Sweden, maria.ask@geo.uu.se; [b]Geomechanics and Scientific Drilling, German Research Centre for Geosciences, Potsdam, Germany, pierdo@gfz-potsdam.de; [c]Division of Engineering Geology, Lund University, Lund, Sweden, jan-erik.rosberg@tg.lth.se

This study contributes to early phases site investigations for geothermal exploration of radioactive granites in Gothenburg, southwest Sweden. The main objective of this study is to assess the orientation of horizontal stresses from borehole stress indicators, and to discuss the implications for geothermal exploration. Analyses of high-resolution acoustic televiewer (HiRAT) image data from the near-vertical, 1 km deep borehole GE-1 provide information on metamorphic features, natural fractures, and three types of stress indicators: borehole breakouts (BOs), drilling induced fractures (DIFs), and petal-centerline fractures (PCFs).

Removal of rock during drilling generates local elastic circumferential stress concentrations. For a borehole drilled parallel with the in-situ vertical principal stress, the circumferential stress magnitude varies with respect to the far-field in-situ maximum and minimum horizontal principal stresses. BOs are formed in the minimum horizontal stress direction if the circumferential stress overcomes the compressional rock strength, and DIFs are formed in the maximum horizontal stress direction if the circumferential stress exceeds the tensional rock strength (e.g. Zoback et al. 2003). PCFs represent a less well-known type of drilling-induced fracture that develop parallel with the maximum horizontal stress direction some meters below the drill bit, that subsequently is penetrated by the borehole (e.g. Kulander *et al.* 1990). As a result, PCFs may be present in both drill cores and in the borehole wall.We observed about 135 stress indicators in borehole GE-1, from 0.2 to 1.0 km depth. The results suggest that the stress field is uniformly oriented in the NNW-SSE mean maximum stress orientation. About 135 stress indicators are observed from 0.2-1.0 km depth. We further observed co-occurrence of BOs and DIFs in several sections, which is unusual for crystalline rocks.

It is not possible to fully distinguish open natural fractures from those that are sealed (filled or closed) using HiRAT data alone, but the classification of Massiot *et al.* (2018) offers a first interpretation on separating open and sealed fractures. Over 1500 pre-existing structures (natural fractures, foliation) were mapped in the borehole. The prevailing stress regime controls if natural fractures and foliation are well-oriented for stimulation. For strike-slip and normal faulting stress regimes, fractures steeply dipping towards WSW are well-oriented for stimulation, whereas shallow dipping fractures are well-oriented for simulation in a reverse faulting stress regime. Our results tentatively suggest that a strike-slip stress regime in GE-1, but additional stress measurements are needed to constrain the complete stress field at study depth and towards greater depths.

The secondary objective of this study is to test different strategies for interactive stress analysis through visual inspection of acoustic images, and to highlight the need to develop better guidelines for data interpretation. We have tested and compared three methods of data interpretation. Our results suggest that BO orientations, especially in fractured formations, increases the risk of misinterpreted data. In contrast, DIF data appear to produce similar results, regardless of analysis method.

References

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