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Multiscale 3/4D-modelling of mineral belts – examples from the Skellefte Mining District, Sweden

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Determining the scale and amount of detail for regional 3/4D models is a challenge as both the geological structures and source data typically vary significantly in proportions. This is also the case in the Palaeoproterozoic Skellefte District, Sweden, an inverted volcanic arc covering an area of ∼120 by 30 km, and producing Zn, Cu, Pb, Ag and Au from volcanogenic massive sulphide (VMS) and orogenic gold deposits. The Skellefte District is a modelling target in two currently running projects: "ProMine" and "VINNOVA 4D modeling of the Skellefte District".

The most detailed models from the district, the Kristineberg and the Vargfors Basin, are approximately in the same scale but constrained by completely different types of data: exploration- and production-related drilling in the Kristineberg mine area allows for good control down to ∼1500 m below the surface, whereas some of the structures may be correlated to even greater depths by interpreting the two new seismic reflection profiles and new MT-data acquired during the 4D modelling project. The main challenges in the Kristineberg area arise from the lack of outcrops around the mine, and the strong ore-related alteration hampering the control over the primary lithostratigraphy. The key issue in the future modelling will be in integrating the flat-lying seismic reflectors at > 2 km depths with the steeper, ore-controlling faults higher in the crust into a model respecting both the regional geometry and kinematics.

Contrary to the Kristineberg area, the Vargfors Basin is well-exposed and allows for detailed field-mapping, and thus for good control on the structural geometry and distribution of lithological units. Additional constraints are provided by measurements on apparent resistivity and induced polarization of the shallow subsurface down to ∼1200m levels. Results from these data sets have locally been confirmed by drill core observations. Owing to the low bulk strain of this specific area, in spite of sparse drilling, it has a good potential for revealing the relationship of the ore-critical volcanic-sedimentary contact in time and space. The main challenges in this sub-area are, firstly to define a kinematic framework honouring the displacement sense, style and offset along the compartment-bounding faults, and secondly to correlate the modelled geometry beyond the scale of basin to the greater depths imaged by the seismic reflection investigations.

District-scale modelling benefits from the more detailed sub-projects described above. Its focus lies in understanding the larger-scale tectonic evolution of the region, but will eventually provide feedback to the more local-scale models, thus also contributing to the exploration models and ore targeting. The tectonic models will benefit from a total of five new and two previously acquired reflection seismic profiles, 103 broadband MT sites, potential field modelling, and age constraints on both the age of lithological units and, indirectly, on the age of basin inversion.

The geological surfaces and solids have been modelled with gOcad software with the Sparse plug-in, from Paradigm and Mira Geosciences, respectively. The step over to the fourth dimension is so far comprised of conceptual modelling, but will in the future be applied to all scales and modelling targets. Initial 4D-animations have been constructed using Midland Valley Exploration's MOVETM platform. More specifically, the 2D-block was used for initial model construction and later conditioning, whereas the 3D-block served as the platform to the model completion and visualization.

Experience from modelling the Skellefte District has shown that the differences in local geology, and thus

on the modelling scales, provide interactive feedback between the different sub-projects and, hence, help in constructing regionally valid geological 3/4D-models.