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Seismic 3D modelling of VHMS deposits: case studies from Pyhäsalmi and Vihanti, Finland

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In the HIRE (HIgh-REsolution reflection seismics for ore exploration 2008–2010, Geological Survey of Finland), 2D seismic reflection profiles were acquired at 15 mining camps in Finland including the Pyhäsalmi, and Vihanti districts. Both Pyhäsalmi and Vihanti are volcanic hosted massive sulphide (VHMS) deposits located in a Proterozoic volcanic belt in central Finland. In Pyhäsalmi, six seismic profiles were acquired with 45 total line kilometres. In Vihanti the total length of 12 profiles exceeds 120 km. Both Vibroseis and explosive sources were used in the surveys. In these study sites, the network of seismic profiles enables modelling of the subsurface structures well beyond the mined depths.

In the study areas, seismic velocities and densities derived from drill hole logging provide crucial information about physical rock properties forming basis for seismic interpretation. Besides the acoustic impedance, also the scale and orientation of the geological structures influence reflectivity. In Pyhäsalmi, it was shown that subvertical structures are not imaged directly with seismic reflection data and only the subhorizontal fold hinges are visible in seismic section while steep flanks need to be interpreted indirectly with the help of drill hole data and by recognizing change in reflectivity characteristics. Deformation in the Vihanti area has not been as intensive as in Pyhäsalmi, and the ore hosting volcanic sequence forms gentle folds. Reflection seismic profiles in Vihanti and Pyhäsalmi show the continuation of the volcanic lithologies underneath intrusive granites, thus expanding the area of interest for exploration. Seismic data support the interpretation that thrust faulting that occurred in a compressional tectonic setting has played a main role in deformation of these VHMS areas.

Physical properties of massive sulphides predict the ore to be strong reflector in geological settings like Vihanti and Pyhäsalmi, but no clear seismic signal was observed from the known deposit of Pyhäsalmi. Heterogeneous geological surroundings and an unfavourable shape of the ore deposit mask the seismic signal originating from the ore-host rock contact. Based on these experiences, hardrock seismic exploration is most efficiently done through geological 3D-modeling in which determination of a favourable geological setting for ore is used to target drill holes instead of only hunting bright spots.

In both study areas seismic data has increased the knowledge about areal geological structures, continuation of ore-hosting lithologies in depth and also helped to understand better the tectonic evolution of the area. These studies show that 3D modelling of seismic profiles is efficient in improving geological understanding of the structures controlling the ore deposits in thus guiding exploration efforts.