Geophysical Research Abstracts
Vol. 17, EGU2015-1437, 2015
EGU General Assembly 2015

Structure of the ophiolite-hosted Outokumpu Cu–Co–Zn–Ni–Ag–Au sulfide ore district revealed by combined 3D modelling and 2D high-resolution seismic reflection data

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The Outokumpu district within the North Karelia Schist Belt in eastern Finland hosts Cu–Co–Zn–Ni–Ag–Au sulfide deposits which are associated with Palaeoproterozoic ophiolitic metaperidotites that were tectonically interleaved with allochthonous metaturbidites. Extensive metasomatism of the peridotites produced a rim of quartz-carbonate-calc-silicate rocks, grouped as the Outokumpu assemblage (OKA). A tectonic history comprising various phases of folding and shearing followed by several faulting events dismembered the metaperidotites so that ore bodies cannot be easily followed along strike.

Future exploration has to expand the search into deeper areas and consequently requires better knowledge of the subsurface geology. In order to unravel the complex structure 3D geologic models of different scales have been built using a variety of information: geological maps, aeromagnetic and gravity maps, digital terrain models, mine cross sections, drill core logs combined with observations from underground mine galleries, structural measurements, and data from seismic survey lines. The latter have been used to detect upper crustal-scale structures and have been reprocessed for our purpose.

The models reveal that the ore body has formed during remobilisation of a proto-ore and is closely related to thrust zones that truncate the OKA. Later faults dismembered the ore explaining the variable depth of the different ore bodies along the Outokumpu ore zone. On a larger scale, at least four km-scale thrust sheets separated by major listric shear zones (curved dislocations in the seismic lines) can be recognized, each internally further imbricated by subordinate shear zones containing a number of lens-shape bodies of probably OKA rocks. Thrust stacking was followed by at least 3 stages of faulting that divided the ore belt into fault-bounded blocks with heterogeneous displacements: (i) NW-dipping faults with unresolved kinematics, (ii) reverse faulting along c.50°-60° SE-dipping faults , (iii) SW-NE to SSW-NNE striking faults which may have formed at an earlier stage and have been reactivated. The specific Outokumpu alteration assemblage around metaperidotite bodies combined with shear zones acting as pathways for fluids are the main vectors to mineralization. Seismic reflection data do not provide a simple tool to directly detect the sites of Outokumpu assemblage bodies at depth but they identify strong reflector zones which are characteristic for though not exclusive to the assemblage. Our approach shows that 3D modelling combining surface geology and geophysical data and a good knowledge about the structural evolution substantially improves the interpretation of reflectors and their assignments to rock units of interest. It thus enhances the chances for locating potentially economic bodies at depth and allows delineating target areas for detailed exploration.