Geophysical Research Abstracts
Vol. 13, EGU2011-8176-1, 2011
EGU General Assembly 2011

Crustal flow - examples from the Paleoproterozoic Svecofennian orogen

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Svecofennian Orogen is a Paleoproterozoic analogue of a laterally spreading accretionary orogen at a convergent margin setting. The exposed parts that are composed of granitoid intrusions as well as metamorphosed and highly deformed supracrustal units representing paleo-lower-upper and paleo-upper-middle crust. Both the exposed bedrock surface and the crust below carry frozen-in kinematic indicators of the spreading processes. We have been studying these processes using seismic reflection and tomography methods as well as structural observations and analogue modeling.

The deep seismic reflection profiles (FIRE1-3) crossing the study area in two perpendicular directions suggest a three-fold layering of the thick crust (>55 km) that has developed after accretion. The crustal layers are separated by décollement zones on to which crustal reflection sole out and across which velocity steps occur. FIRE 1 and 3 profiles show complementary crustal scale structures of compression and extension in orthogonal directions. The geometric relationships of the crustal layers and deformation patterns suggest compression in WNW – ESE direction and extension in N-S direction. The upper crust spread in a brittle to ductile regime along listric, low angle and transfer shear zones, and the middle crust thinned via ductile flow and extrusion. The middle crust displays typical large scale flow structures: herringbone and anticlinal ramps, rooted onto large scale listric surfaces. Most of the major crustal structures described from the FIRE profiles could be reproduced in an analogue experiment testing convergence coupled with perpendicular extension.

A three dimensional tomography model of southern and central Finland suggests that it is composed of large scale blocks. The residual component of the tomographic model hosts azimuthal velocity anisotropy that shows consistent dip direction patterns over large areas indicating strong lateral movements of the crust. Because the direction of anisotropy varies with depth it is suggested that different layers of the crust have moved independently.

Another example of post-collisional movement of the bedrock blocks is the formation of persistent low angle lineations in most of the rock types. A new map of average lineations in Finland (78 000 measurements) displays consistent regional movement directions across the country. The patterns suggest large-scale block-movements and deformation in the upper and middle crustal after collision. It is suggested that lineations are often related to lateral spreading processes of the Svecofennian orogeny.

Granulites and migmatites, which are partially molten rocks of the middle crust, are well exposed in West Uusimaa Complex (WUC, FIRE2a), where they can be studied for midcrustal flow mechanisms and directions. Our preliminary observations from the area; E-dipping low to moderately dipping schistosity, E-dipping low angle lineations and a possible low-angle shear zone (detachment zone) coupled with the E-W- directed steeply dipping shear zones are compatible with a flow structure where the movement is in E-W direction. Especially the large-scale, steeply dipping shear zones play a central part in the mid-crustal flow architecture.

Our examples across the Svecofennian orogen suggest that the large scale architecture of lateral spreading and mid crustal flow can be studied using seismic reflection, azimuthal velocity anisotropy, average lineations combined with other structural observations.