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Paleostress evolution through 1.7 Gyr of geological history - Brittle deformation of the Olkiluoto Island, SW Finland, and implications on the characterisation of a high-level nuclear waste repository

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Olkiluoto Island, located in SW Finland, is being evaluated as the potential final repository for the high-level nuclear waste generated in Finland, and the repository is expected to become operational in A.D. 2020. The bedrock at Olkiluoto is formed by the crystalline basement of the Fennoscandian Shield and consists of Proterozoic amphibolite-facies metasedimentary rocks and gneisses.

During feasibility studies for deep geological repositories for high-level nuclear waste, it is essential to characterise in detail potential fluid flow pathways and structures prone to movements during the repository life span. In crystalline geological settings these consist mainly of existing brittle structures. As a part of these studies at Olkiluoto Island, we documented in detail the character and kinematics of the fault zones of the site and developed a conceptual model of the brittle deformational history of the region by using a unique fault-slip data set consisting of more than 2000 striated faults, collected from both drill cores and the walls of an investigation tunnel reaching to the depth of 420 meters. By applying iterative inversion procedures on the fault-slip data, combined with the investigation of the regional brittle structures through the analysis of key outcrops, it was possible to generate distinct paleostress tensors and to define specific tectonic events at the site. The results were strengthened by comparing the output with the known paleostress states of southern Scandinavia and by using absolute and relative time criteria.

Uniaxial compression of presumably late Svecofennian age with a regional NNW- SSE σ_1 axis was active soon after 1.75 Ga ago, when brittle deformation was first accommodated in the region. A younger transpressive paleostress field with a NE-SW σ_1 axis caused reactivation of some of the structures formed during the first shortening event. A phase of ESE-WNW extension is constrained by a number of tensors and direct field evidence and is tentatively assigned to the Gothian phase and the time of rapakivi granite formation at about 1.56 Ga. Subsequent NE-SW extension is interpreted to have accommodated upper crustal stretching and the formation and infill of the NW-SE- elongated Satakunta graben between 1.5 and 1.3 Ga. A well-constrained phase of c. NE-SW shortening, previously not described elsewhere in Fennoscandia, postdated rapakivi magmatism and c. 1260 Ma olivine diabase sills. Later E-W compression is assigned to the early stages of the Mesoproterozoic Sveconorwegian orogeny. This was followed by almost coaxial extension resulting from the late Sveconorwegian orogenic collapse at the Meso-Neoproterozoic boundary.

In order to assign absolute time constraints to the conceptual model, selected fault gouges were sampled for multiple grain size analysis of K/Ar dating of authigenic/synkinematic illite. The obtained ages range from 561.3 ± 11.2 Ma to 1382.1 ± 27.8 Ma for the < 0.1 μm fractions. By combining the geochronological results with the structural analysis of the dated fault cores, it was possible to assign tighter time constraints to several of the newly-constrained faulting episodes, thus strengthening the presented conceptual scheme.