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BABEL3&3a: Crustal-Scale Structures of the Precambrian Svecofennian Accretionary Orogen in the Fennoscandian Shield

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A series of seismic deep reflection profiles in Finland – FIRE profiles – image the crustal-scale structures of the Precambrian Svecofennian accretionary orogen in the Fennoscandian Shield (Figure 40.1a) (Lahtinen *et al.*, 2005; Kukkonen *et al.*, 2006). The exposed surface hosts granitoid intrusions and low P–high T metamorphic rocks (Korsman *et al.*, 1999), typical for large hot orogens.

The near vertical reflection data are the crustal-scale migrated NMO-stacks from FIRE3. They are displayed as instantaneous amplitude sections, averaged both horizontally and vertically and plotted as greyscale intensities (technical detail in Kukkonen *et al.*, 2006). The section is plotted without normalization, that is, the amplitudes of the different areas in each section are comparable. In the sections, large-scale reflectivity changes are pronounced, whereas the details of individual reflections are obscured.

In the geological interpretation it is assumed that reflections image mainly primary igneous or secondary tectonic contacts formed during folding/faulting. Weak reflectivity generally indicates monotonous intrusions and older crustal pieces in which the internal structure has been homogenized in the scale of reflectivity prior to deformation. Near vertical strike-slip zones are observed indirectly as they are associated with transparent zones with decreased reflectivity and displacement of continuous reflections.

FIRE3 profile displays a heterogenous structure where reflectivity patterns change both vertically and laterally (Figure 40.1b). Comparison of the reflection section with the tomographic velocity model (Figure 40.1b, top) (Hyvönen *et al.*, 2007) suggests a three-layer structure with distinct reflection and velocity properties in each crustal layer. The upper crust is associated with 5.8–6.2 km s^{-1} velocity and *Vp*/*Vs* ratios of 1.68–1.70; the middle crust with 6.3–6.6 km s^{-1} velocity and *Vp*/*Vs* ratios of 1.71–1.74; and the lower crust with 6.8–7.6 km s^{-1} velocity and *Vp*/*Vs* ratios of 1.74–1.76. Subcontinuos subhorizontal reflective boundaries separate these layers. The profile images also a lateral structural change from eastern Archean parts through a boundary zone into the western Paleoproterozoic part.

Common to all the parts is that the lower crust has a subdued and patchy subhorizontal reflectivity that dies out at the Moho boundary marked by a small amplitude decrease in background reflectivity coinciding with the wide-angle reflection Moho. In the western to central parts, the middle crust has two components: large blocks of poorly reflective background material boarded by high amplitude, shallow-to-steeply dipping crustal-scale reflections. Listric to anticlinal reflections sole out at the middle and lower crust boundary. In the eastern parts, the middle crust has large blocks of both poorly and well-reflective material (Ma). In the central parts, the upper crust displays fine-scale structures with listric reflections flattening at a highly reflective upper-middle crustal boundary. In the eastern parts, the upper crust displays small-scale thrusts and normal faults.

FIRE3 profile transects the core of the Svecofennian orogeny. It has been interpreted to image accretion by stacking and thrusting (Figure 40.1c, top) (Kukkonen *et al.*, 2006; Sorjonen-Ward, 2006) or by stacking and thrusting followed by inversion to normal faults during lateral spreading and gravitational collapse and formation of super-infrastructure (Figure 40.1c) (Korja and Heikkinen, 2008; Nikkilä *et al.*, 2016). Note that thrusting is one mechanism of stacking taking place at different scales (Mukherjee, 2014). Large-scale crustal structures along FIRE3 might result from gravitational collapse of the thickened and thermally matured hot Svecofennian orogenic crust (Figure 40.1c, middle and bottom) (Nikkilä *et al.*, 2015).

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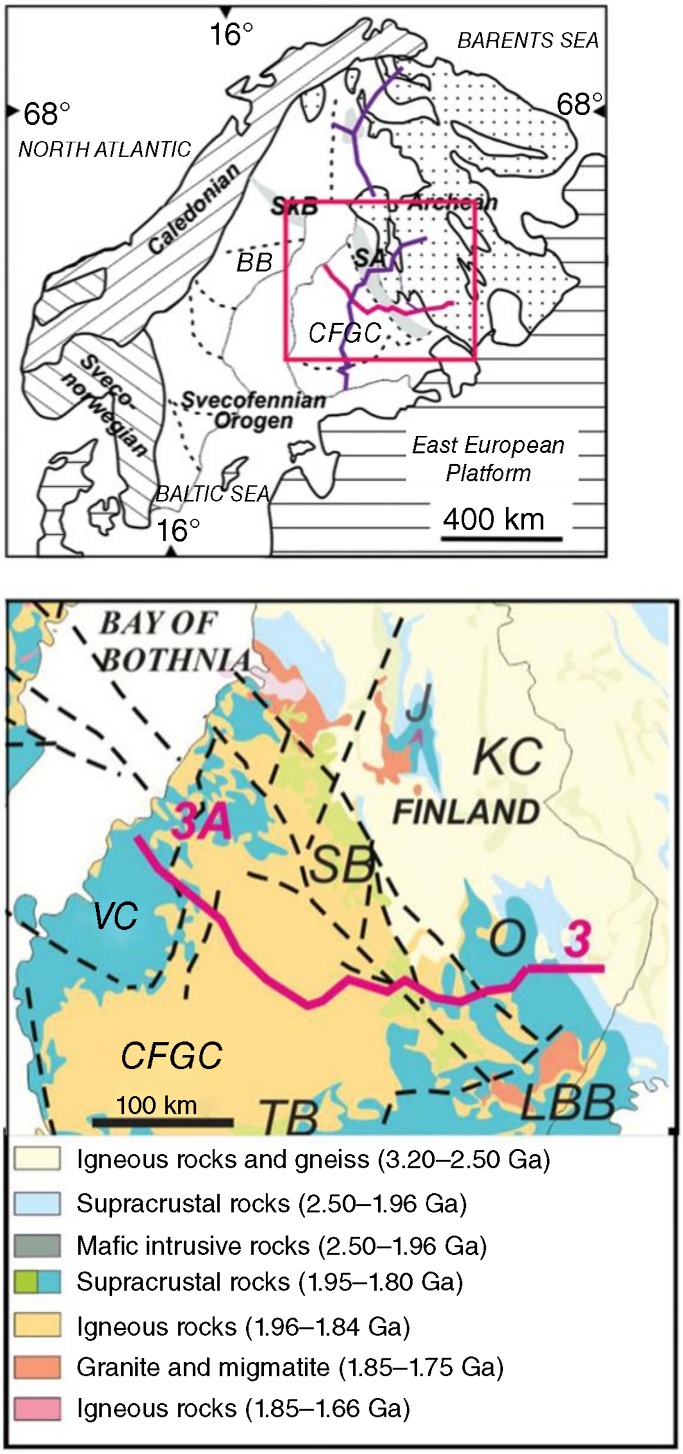

Figure 40.1a (top) FIRE3&3a line on a geological index map of Northern Europe. (bottom) FIRE3&3a a lithological map of the study area. Adapted from Lahtinen *et al.* (2005).

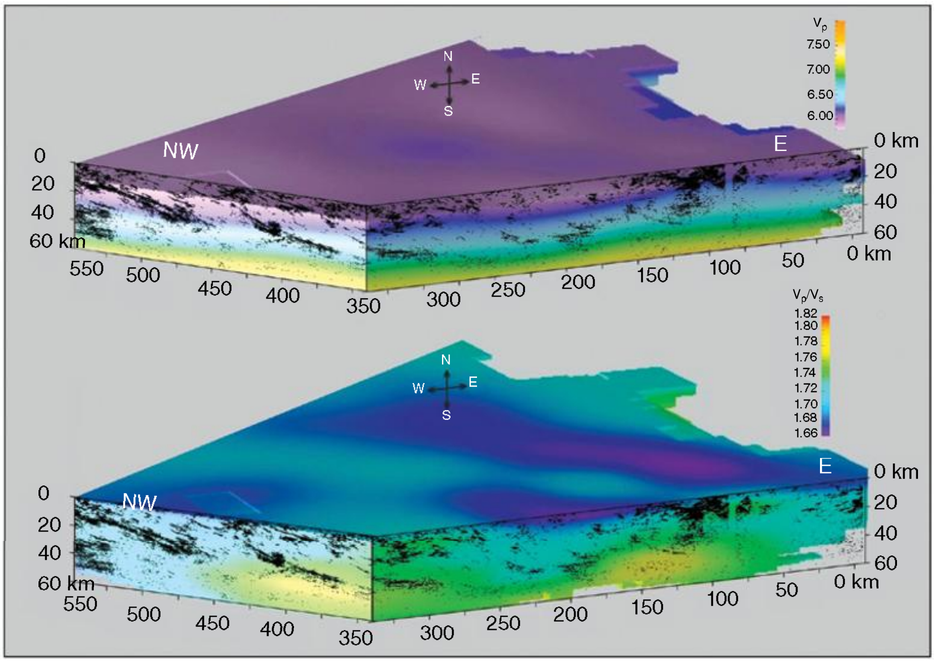

Figure 40.1b (top) Three-dimensional block diagrams of the seismic P-wave velocity and *Vp/Vs* ratio models (Hyvönen *et al.*, 2007) overlain by automatic line drawings along FIRE3&3a. A view to N. (bottom). A vertical seismic section along FIRE3&3a profile shown as an instantaneous amplitude section in greyscale. No vertical exaggeration.

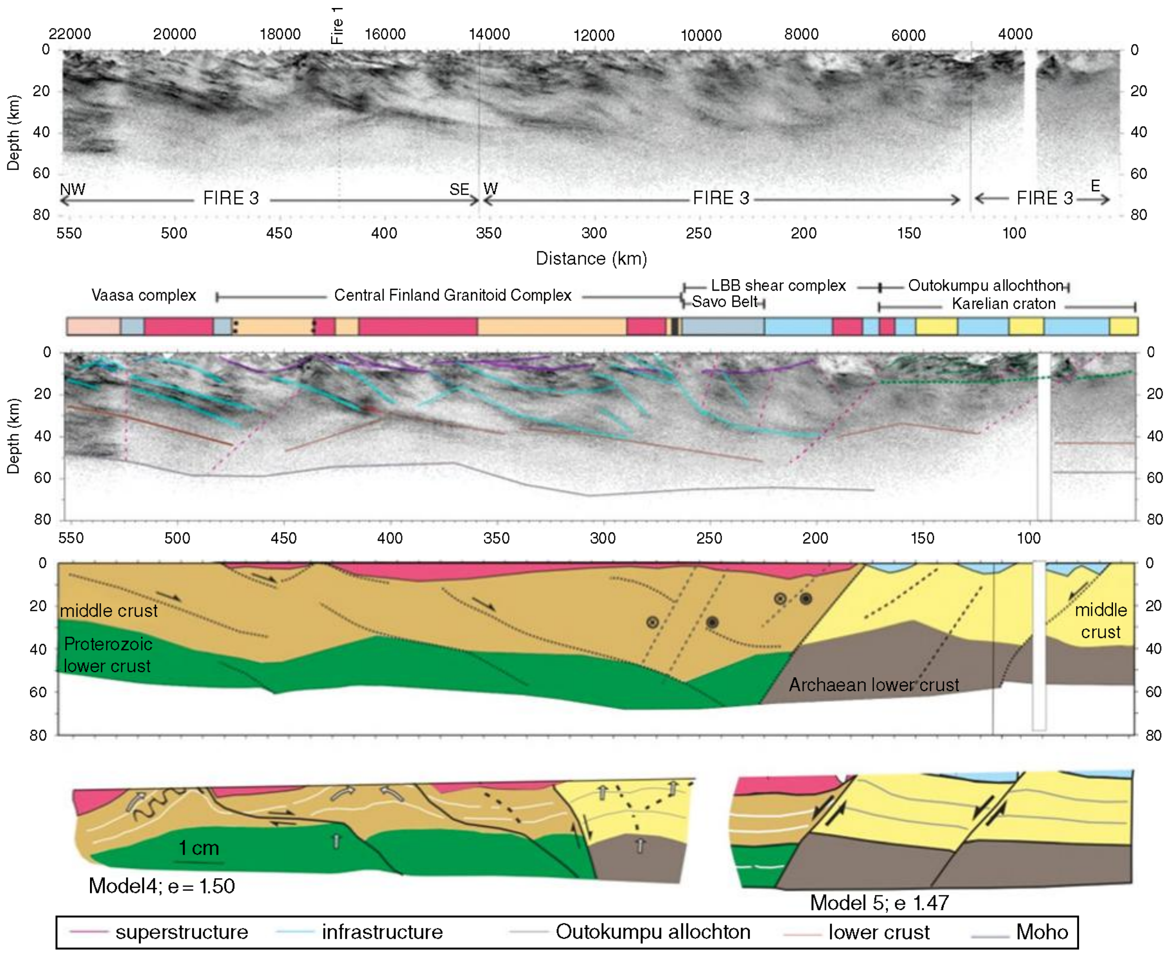

Figure 40.1c (top) A schematic geological line interpretation of FIRE3&3a profile on an instantaneous amplitude section in greyscale modified from Korja and Heikkinen (2008) and Korja *et al.* (2009). (middle) A simplified three-layer interpretation of FIRE3&3a after Nikkilä *et al.* 2015. (bottom) A comparison of analogue models of gravitational collapse of a thick three layer crust and FIRE3&3a profile. Model 4 and Model 5 by Nikkilä *et al.* (2015) are compared to the western Paleoproterozoic part and to the eastern Archean part, respectively.

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