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The accretionary Svecofennian orogen—insight from the BABEL profiles

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Abstract

The BABEL profiles B, C, 1–7 form a 1200 km long nearly continuous cross-section through the Svecofennides. The near-vertical marine reflection profiles display a wide range of crustal structures that can be associated with both the accretionary Svecofennian orogeny (1.96–1.75 Ga) and the following Subjotnian and Jotnian rift-stages (1.65–1.11 Ga). The Svecofennian accretionary orogeny took place when a number of micro-plates with island arc affinities and surface expression of a large archipelago accreted to the continental Karelian plate. Some of the accreting terranes seem to have had older cores that have acted as crustal indentors during the collision.

BABEL profiles 3 and 4 image a series of collisional terrane boundaries between Karelian continental margin, Savo arc (SA) and Central-Finland arc (CFA). In the north, the Karelian margin has been both over- and underthrust by the Savo arc. CFA comprises a folded thrust package on top of a continental nucleus and the Savo arc. The associated subduction zone and accretionary prism are interpreted to lie to the south, underneath the Bothnian basin area, where prominent NE-dipping, lower to middle crustal reflections are found along BABEL profiles 1 and 4. An oblique collision of the Central Finland arc and the continent resulted in the development of the strike-slip fault on the young, hot Savo arc.

BABEL profiles 1, 6, 7 and C image the internal architecture of the Southern and Central Finland arcs. The unusually thick crust (55–60 km) hosts unreflective, high density, mafic intrusions acting as a crustal indentor. A highly reflective antiform structure developed on the southern side of it. Southern Finland arc complex (SFA) is an imbrication structure comprising stacked slices of arc-related crust on an older continental nucleus, Bergslagen nucleus. Prior to the collision, the SFA suffered from gravitational collapse during which the crust was thinned.

Profile B images the architecture of the Central and Southern Swedish Svecofennides. The Sörmland terrane (SöB) is interpreted as the accretionary prism of the Southern Finland arc squeezed between the Svecofennian collage in the north and the advancing continent to the south. The southern continent/island arc is characterised by NE dipping crustal reflections and Moho offsets as well as step-wise increasing thickness of the crust. After the final collision, large volumes of mantle-derived material intruded the crust as large mushroom-shaped plutons. They are interpreted as the heat source for the TIB magmatism in southern and western Scandinavia.

Keywords: Reflection seismics; Tectonics; Accretion; Palaeoproterozoic; Svecofennian; Fennoscandia

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1. Introduction

The Svecofennian orogen in Fennoscandia was the first region where plate tectonic processes were suggested to have operated in the Palaeoproterozoic (Hietanen, 1975). Since then, most of the models have been based on the arc-continent collision, but the growing amount of geological and geophysical data have led to refined analysis of tectonic settings and to more complex evolutionary models. Park (1985) was the first to suggest a collage of island arcs and Windley (1993) introduced the term accretionary orogen in the Svecofennian context. The complexity of the orogen is well displayed in the recent models by Lahtinen (1994), Nironen (1997) and Korsman et al. (1999), in which the Svecofennian orogen is explained as a collage of terranes, intervening sedimentary basins and new mantle-derived material, accreted to the Karelian craton in the Svecofennian orogen. Extensional collapse of the orogen may also have affected the crustal structures (Korja, 1995).

Driving mechanisms of the Svecofennian orogeny have gained less attention in discussions that have focused on the tectonic environment of magmatism. Recently, several subterranes or individual arcs have been recognised within the Svecofennian Domain (Gaál and Gorbatschev, 1987; Korsman et al., 1997, 1999). By definition, the terranes have separate geological histories and they vary in lithology, geochemical affinities and deformational patterns. It is not clear if the Svecofennian Domain was formed in one prolonged orogeny or in several short-lived ones. To distinguish between the two processes, more data on the temporal development of structures are needed. The highly variable tectonomagmatic affinities indicate an active margin, to which either independent arc slices accreted or on which arc related environments were formed above advancing and retreating subduction zones. The second alternative would require changes in relative plate velocities. How can the two types of active margins be distinguished after collisional orogeny? How much would the thermomechanical balancing of overthickened crust subdue the differences?

Reflection profiles image changes of reflectivity which is controlled by density and velocity contrasts of the lithologies produced by tectonic processes. Individual terranes are distinguished by differences in their reflection properties: amplitude, orientation and spatial distribution of reflectivity, which are interpreted in terms of lithological variation and structure. Major changes in either lithology or structural style may introduce a seismically distinct unit, a seismic terrane.

The structural evolution of an island arc has pre-, syn- and post-collisional phases (Coward, 1994). The pre-collisional phase is controlled by the vertical and lateral growth of the arc terrane mostly by piling of the supracrustal sequences and by initial thrusting and isoclinal folding of the supracrustal rocks. When the pile is thick enough, it may be intruded by sheet-like intrusions. In the syn-collisional phase, the crust is thickened by large-scale folding, stacking of crustal pieces and voluminous magmatism associated with both waning stages of subduction and crustal melting. In the post-collisional phase, the newly thickened crust extends under its own weight and thereby thins. Thinning is initiated at the upper crust where thrust planes are inverted into extensional normal faults. This phase may be difficult to unravel from the collisional structures if the inverted structures have later been stacked to more or less original position in the succeeding orogens.

The Palaeoproterozoic collisional terranes display structures from pre-, syn- and post-collisional stages, whereas active orogenic terranes display only pre- and syn-collisional structures. Another complicating factor in the Precambrian is the reactivation of pre-existing structures. This may result in inverted structures where collisional ones are activated as extensional ones, or it may result in shear zones exhibiting several cycles of movement.

The BABEL deep seismic reflection lines in the Baltic Sea and its northern extension, the Gulf of Bothnia, in 1989 (Fig. 1), were designed to study the Proterozoic structures and evolution of the Fennoscan-

Fig. 1. BABEL profiles on a simplified geological map of the Fennoscandian Shield after Koistinen et al. (2001). *Abbreviations*: CFCG, Central Finland granitoid complex; HäB, Häme belt; J, Jormua; O, Outokumpu; OJB, Oskarshamn–Jönköping belt; PiB, Pirkanmaa belt; PoB, Pohjanmaa belt; S, Skellefte belt; SB, Savo belt; TB, Tampere belt; UB, Uusimaa belt; VäB, Västerbotten belt. (a) Major geological domains of the Fennoscandian Shield after Gaál and Gorbatschev (1987). SSD, Southwestern Scandinavian Domain. (b) Terranes of the Svecofennian. BA, Bergslagen terrane; BB, Bothnian basin; CFA, Central Finland arc; HB, Hälsingland terrane; KC, Karelian Province; NA, Norrbotten terrane; SA, Savo belt; SFA, Southern Finland arc; SöB, Sörmland terrane; TIB, Transscandinavian Igneous Belt.