MAIN GEOLOGICAL FEATURES OF FENNOSCANDIA

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The Fennoscandian Shield shares a similar geology and metallogeny with the ancient shields in Canada, Australia, Brazil and South Africa. The shield is situated in the north-westernmost part of the East European Craton and is the largest exposed area of Precambrian rocks in Europe. The shield constitutes large parts of Fennoscandia in Finland, NW Russia, Norway and Sweden. The Precambrian rocks can be followed below the Phanerozoic cover sequences of the East European platform towards the south and southeast, forming as a whole the Fennoscandian crustal segment. The Norrbotten province, with its Archaean and Proterozoic cover rocks, most probably also continues to the NW, below the Caledonian orogenic belt, and crops out again in the Lower Allochthon.

Keywords (GeoRef Thesaurus, AGI): bedrock, tectonics, orogenic belts, Fennoscandian Shield, Phanerozoic, Proterozoic, Archean, Fennoscandia

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ARCHAEAN

The Archaean crust, either exposed or concealed under Palaeoproterozoic cover rocks and granitoids, occurs in the east and north of Fennoscandia. Four major Archaean provinces have been outlined (Fig. 1; modified after Hölttä et al. 2008). The western and eastern parts of the Karelian Province comprise Mesoarchaean 2.8–3.0 Ga lithologies, but rocks older than 3.0 Ga (Fig. 1) have locally been found. The central part of the Karelian province is mainly Neoarchaean, having plutonic and volcanic rocks of 2.75–2.70 Ga in age. This age difference is also seen in the nature of volcanic rocks, where the older rocks formed in within-plate, probably oceanic, environments, whereas younger volcano-sedimentary belts show arc-type characteristics (Sorjonen-Ward & Luukkonen 2005, Hölttä et al. 2008). Sanukitoid-type plutonic rocks of the Archaean domain have ages grouping at 2740 and 2718 Ma (Heilimo et al. 2011).

The Belomorian province (Fig. 1) is dominated by 2.9–2.7 G granitoids and includes volcanic rocks formed at 2.88–2.82 Ga, 2.8–2.78 Ga and 2.75–2.66 Ga. The Neoarchaean ophiolite-like rocks and 2.7 Ga eclogites in the Belomorian province are possible examples of Phanerozoic-style subduction and collision (Hölttä et al. 2008). The Kola province (combined Kola and Murmansk provinces of Hölttä et al. 2008) is a mosaic of Mesoarchaean and Neoarchaean units, together with some Palaeoproterozoic components. The Archaean growth (accretion) of this province occurred from 2.9 Ga to 2.7 Ga and was followed by a collision with the Karelian craton at 2.72 Ga along the Belomorian province. The Archaean part of the Norrbotten province is dominantly concealed under cover rocks, and very limited data are available (Bergman et al. 2001, Mellqvist et al. 1999).

PALAEOPROTEROZOIC COVER ROCKS OF THE ARCHAEAN CONTINENTS

Rifting of the Archaean continent or continents contained in the Fennoscandian shield began in north-eastern Fennoscandia and became widespread after the emplacement of 2.50–2.44 Ga, plume-related, layered gabbro-norite intrusions and dyke swarms (Iljina & Hanski 2005). Erosion and deep weathering after 2.44 Ga was followed by the Huronian glaciation, and later deep chemical weathering again covered large areas in the Karelian province at ca. 2.35 Ga (Laajoki 2005, Melezhik 2006). Rifting events at 2.4–2.1 Ga are associated with mostly tholeiitic mafic dykes and sills, sporadic volcanism and typically fluvial to shallow-water sedimentary rocks (Laajoki 2005, Vuollo & Huhma 2005). Local shallow-marine environments were marked by deposition of carbonates at 2.2–2.1 Ga, showing a large positive $\delta^{13}C$ isotope anomaly during the Lomagundi–Jatuli Event (Karhu 2005, Melezhik et al. 2007). Along the present western edge of the Karelian province, 2.05 Ga bimodal felsic-mafic volcanic rocks of alkaline affinity are intercalated with deep-water turbiditic sediments.

No clear examples of subduction-related magmatism between 2.70 and 2.05 Ga have been found in Fennoscandia. The 2.02 Ga felsic volcanic rocks in Finnish Lapland (Kittilä in Fig. 1) occur in association with oceanic island arc-type rocks and are the oldest candidates for Palaeoproterozoic subduction-related rocks (Hanski & Huhma 2005). Associated continental within-plate volcanic rocks are possibly related to the continuing craton break-up. Bimodal alkaline-tholeiitic magmatism in central Lapland (Hanski et al. 2005) and rift-related magmatism in Kola (Pechenga) show that rift magmatism continued further until 1.98 Ga. Jormua–Outokumpu ophiolites (Fig. 1), tectonically intercalated with deep-water turbidites, are a unique example of Archaean subcontinental lithospheric mantle with a thin veneer of oceanic crust formed at 1.95 Ga along the western edge of the present Karelian province (Peltonen 2005).

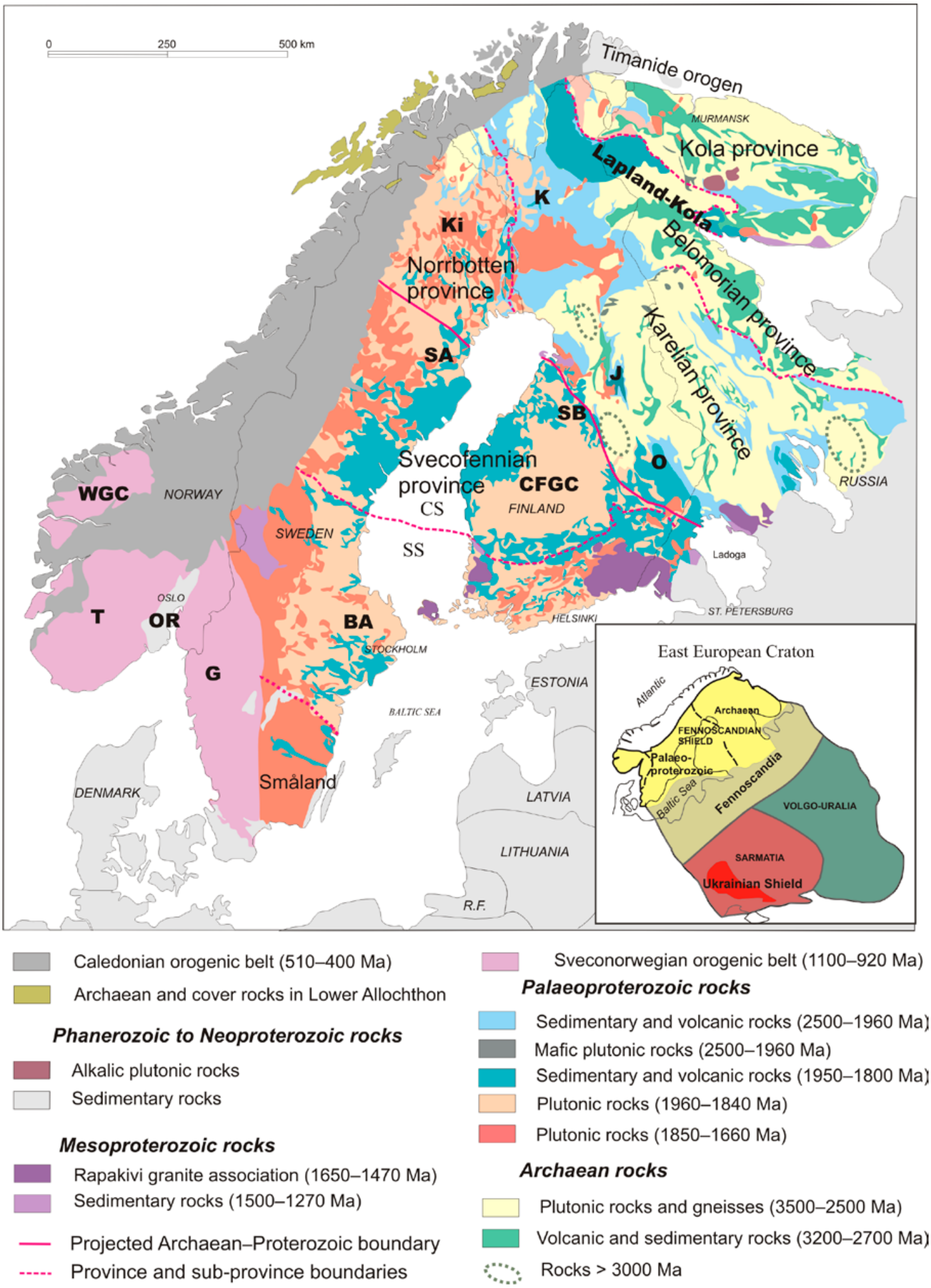

Figure 1. Fennoscandia and its location within the East European Craton. Simplified geological map based on Koistinen et al. (2001) and insert map based on Gorbatschev and Bogdanova (1993). Subareas: CS – Central Svecofennia; SS – Southern Svecofennia. Areas and localities: BA – Bergslagen area; G – Gothian terranes; J – Jormua; K – Kittilä; Ki – Kiruna; O – Outokumpu; OR – Oslo rift; SA – Skellefte Area; SB – Savo Belt; T – Telemarkian terranes; WGC – Western Gneiss Complex.

PALAEOPROTEROZOIC OROGENIC ROCKS

The main Palaeoproterozoic orogenic evolution of Fennoscandia can be divided into the Lapland–Kola orogen (1.94–1.86 Ga; Daly et al. 2006) and the composite Svecofennian orogen (1.92–1.79 Ga; Lahtinen et al. 2005, 2008). The latter is divided into the Lapland–Savo, Fennian, Svecobaltic and Nordic orogens. Whereas the Lapland–Kola orogen shows only limited formation of new crust, the composite Svecofennian orogen produced a large volume of Palaeoproterozoic crust in the Svecofennian province.

The Palaeoproterozoic rocks in the Lapland-Kola orogen (Fig. 1) include small amounts of juvenile, 1.96–1.91 Ga, island arc-type rocks and large volumes of felsic granulites (Daly et al. 2006, Huhma et al. 2011). The oldest rocks in the central Svecofennian province are the 1.95 Ga supracrustal rocks and granitoids south of the Skellefte area (Wasström 2005) and the 1.93–1.92 Ga island-arc rocks in the Savo belt (Fig.1). Arc-type volcanic rocks are slightly older (ca. 5–10 Ma) than granitoids, but the igneous rocks are predominantly 1.89–1.87 Ga in age in the Central Finland granitoid complex (CFGC) and surrounding belts (Kähkönen 2005), and in the Skellefte and Kiruna areas (Allen et al. 1996, Bergman et al. 2001). Sedimentary rocks are typically metapsammites with local intercalations of black schists and tholeiitic lavas. Abundant, ca. 1.80 Ga, plutonic rocks occur in the western part of the central Svecofennia and in northern Fennoscandia.

The southern Svecofennia in the Bergslagen area (Stephens et al. 2009) and its extension to southern Finland (Väisänen & Mänttäri 2002) comprise arc-type volcanism at 1.90–1.88 Ga with partly coeval plutonism at 1.89–1.87 Ga. Sedimentary sequences also include metacarbonate rocks, whereas graphite-bearing rocks are rare. Two metamorphic peaks, at 1.88–1.87 and 1.83–1.80 Ga, have been detected in the southern Svecofennia. A major unconformity between them is indicated by the occurrence of lateritic palaeosols (Lahtinen & Nironen 2010) and ≤ 1.87 Ga quartzites and meta-arkoses (e.g., Bergman et al. 2008). Younger syn- to post-tectonic granites (1.85–1.79 Ga) are common in southern Svecofennia.

The Småland area of the Svecofennian province includes subduction-related juvenile volcanic and plutonic rocks formed between 1.83 and 1.82 Ga. They were metamorphosed and deformed before the extrusion and intrusion of the surrounding WNW-trending, 1.81–1.77 Ga, volcanic and plutonic rocks (Mansfeld et al. 2005). The 1.81–1.77 Ga plutonic rocks can be followed northwards under the Caledonian orogenic belt to the Lower Allochthon (Fig. 1), and they form the core of the Nordic orogen proposed by Lahtinen et al. (2005).

MESO- AND NEOPROTEROZOIC

Rocks of the Gothian (1.64–1.52 Ga) and Telemarkian events (1.52–1.48 Ga), their areas indicated by G and T in Figure 1, respectively, are present in the Sveconorwegian orogenic belt in the SW part of Fennoscandia. These rocks, Palaeoproterozoic basement windows in western Norway (WGC in Fig. 1) and some of the 1.81–1.77 Ga rocks were heavily reworked during repeated orogenies in the Meso- and Neoproterozoic (Bingen et al. 2008). Rocks of the rapakivi granite association (1.65–1.47 Ga) are locally voluminous and especially characteristic for the southern Svecofennia (Rämö & Haapala 2005). The 1.34–1.14 Ga period includes some bimodal magmatism associated with sedimentation. The Sveconorwegian orogeny (1.14–0.97 Ga) involved accretion of terranes followed by post-collisional magmatism between 0.96 and 0.90 Ga (Bingen et al. 2008). A NW-trending Neoproterozoic belt (part of the Timanide orogen) occurs in the northeastern edge of the Fennoscandian Shield (Fig. 1).

The Caledonian orogenic belt (Fig. 1) consists of four levels of thrust sheets where the Lower and Middle Allochthons are generally considered to represent E-vergent thrusts of pre-collisional continental margin rocks (Gee et al. 2008). Archaean and Palaeoproterozoic parts of the Lower Allochthon are probably autochthonous and a direct continuation of the Norrbotten province rocks. Meso- and Neoproterozoic rocks are common in the Lower and Middle Allochthons. Some of the passive margin-related Neoproterozoic marine sandstones and bituminous Alum Shales in the Lower Allochthon can also be autochthonous. Most of these rocks are related to the opening of the Iapetus Ocean (Gee et al. 2008).

PHANEROZOIC

The opening of the Iapetus Ocean started ca. 600 Ma ago, and the final continent-continent collision occurred during the Scandian orogeny (430–390 Ma), followed by an orogenic collapse. The Upper Allochthon in the Caledonian orogenic belt (Fig. 1) is characterised by Phanerozoic rocks (500–430 Ma) derived from the Iapetus Ocean, including ophiolites and island-arc complexes. The Uppermost Allochthon has affinities to the Laurentian margin and can be regarded as an exotic terrane (Gee et al. 2008). Significant amounts of Devonian alkaline rocks occur in the Kola province, and voluminous Late Carboniferous to Early Triassic rift magmatism is seen in the Oslo Rift (Fig. 1).

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