The Archaean of the Karelia Province in Finland
Edited by Pentti Hölttä
Geological Survey of Finland, Special Paper 54, 9–20, 2012

ARCHAEAN COMPLEXES OF THE KARELIA PROVINCE IN FINLAND

by
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Hölttä, P., Heilimo, E., Huhma. H., Juopperi, H., Kontinen, A., Konnunaho, H., Lauri, L., Mikkola, P., Paavola, J. & Sorjonen-Ward, P. 2012. Archaean complexes of the Karelia Province in Finland. *Geological Survey of Finland, Special Paper 54*, 9−20, 3 figures.

In this study we represent new division of the Finnish part of the Archaean Karelia Province into nine complexes: Ilomantsi, Lentua, Kuopio, Iisalmi, Rautavaara, Manamansalo, Kalpio, Siurua and Ranua. The easternmost part of the Archaean of Finland, the Ilomantsi complex belongs to the Central Karelia subprovince which is characterized by short Neoarchaean (<2.8 Ga) crustal growth period. Most of the Archaean in central Finland belongs to the Western Karelia subprovince. The Lentua complex is characterized by tonalite-trondhjemite-granodiorite series rocks (TTGs) whose age varies from 2.95 Ga to 2.73 Ga and a narrow N-S trending greenstone belt, the Tipasjärvi-Kuhmo-Suomussalmi belt, where the ages of volcanic rocks vary from c. 2.95 to c. 2.80 Ga. Sanukitoid intrusions with an age of 2.72 Ga occur throughout the Lentua complex. Metasediments with a deposition age close to 2.70 Ga and 2.71-2.69 Ga granodiorite-granite-monzogranite (GGM) series rocks are common in the central and southern parts of the Lentua complex. The Kuopio complex includes the Archaean gneiss domes and tectonic slivers within Proterozoic metasediments and consists of TTG gneisses and migmatites with a few sanukitoid and quartz diorite intrusions. The Iisalmi complex is characterized by Mesoarchaean 3.2 Ga TTGs and amphibolites, c. 2.70 Ga quartz diorite-quartz monzonite (QQ) intrusions and medium pressure (9-11 kbar) granulites metamorphosed at 2.70-2.60 Ga. Chemically altered rocks and pervasive Proterozoic deformation are common in the Rautavaara complex where all dated rocks are Neoarchaean, < 2.80 Ga. The Kalpio complex mainly consists of metasediments that are arkosic gneisses, mica schists/gneisses and gneissic quartzites. The Manamansalo complex is composed of NeoArchaean TTG gneisses with amphibolite layers and micaceous paragneisses. In the Karelia Province the Siurua complex contains the oldest Mesoarchaean and Paleoarchaean rocks in a small area where there are TTGs whose ages range from 3.50 to 2.96 Ga. In the Siurua complex there is a large granulite facies area that was metamorphosed at low pressures (5-6 kbar). TTGs dated from the Ranua complex are 2.83-2.73 Ga. In the eastern part of the complex there is a large area of metasediments, and smaller paragneiss localities are also met in the northern parts of the complex. Quartz diorites-quartz monzonites dated at 2.70 Ga are also found in the Ranua complex.

Keywords (GeoRef Thesaurus, AGI): complexes, Karelia Province, Fennoscandian shield, Archean, Finland

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INTRODUCTION

In this paper we have divided the Finnish part of the Archaean Karelia Province of the Fennoscandian Shield into nine complexes on the basis of lithological, structural, metamorphic and geochronological differences between each other. The usage of the term complex follows the classification of the North American Stratigraphic Code (2005), where a complex is defined as "an assemblage or mixture of rocks of two or more genetic classes, i.e., igneous, sedimentary, or metamorphic, with or without highly complicated structure". Reflecting the fact that the Archaean bedrock mainly consists of rather monotonous gneissic tonalite-trondhjemite-granodiorite series rocks (TTGs), the geological differences between the complexes are in many cases not very prominent, but some lithological, geochemical and age differences do exist from one complex to another. The complex division follows that presented in the digital geological database of Finland (http://www.geo.fi/suomkalliop.html).

KARELIA SUBPROVINCES

Slabunov et al. (2006) and Hölttä et al. (2008) divided the Karelia Province into three terranes differing from each other in their lithological, structural and age patterns. These are the Western Karelia terrane, the Central Karelia terrane and the Vodlozero terrane (Fig. 1). The term terrane refers to a fault-bounded crustal block whose geological history differs from that of the surrounding areas (e.g. Jones et al. 1983, Jones 1990). As such a relationship between the Karelia "terranes" has not yet been adequately demonstrated and the division is based on differences in geochronology, lithology and geochemistry, we have here used the more neutral term subprovince.

Western Karelia subprovince

We divided the Finnish part of the Western Karelia subprovince into eight complexes: the Lentua, Kuopio, Rautavaara, Iisalmi, Manamansalo, Kalpio, Siurua and Ranua complexes. This division roughly follows the previous one presented by Sorjonen-Ward and Luukkonen (2005). The division is mostly based on lithological and age differences. Most rocks in the Western Karelia subprovince are Neoarchaean < 2.80 Ga, but nevertheless some complexes show older ages. The oldest Palaeo-archaean rocks of 3.5 Ga are found in the Siurua complex (Mutanen & Huhma 2003) and Mesoarchaean 3.2 Ga rocks are found in the Iisalmi complex (Hölttä et al. 2000, Mänttäri & Hölttä 2002). The oldest rocks observed in the Lentua complex are ca 2.95 Ga (Käpyaho et al. 2007, Huhma et al. 2012, Mikkola et al. 2011a). In other complexes Mesoarchaean and Palaeoarchaean rocks have thus far not been found .

Lentua complex

The Lentua complex (Fig. 3) mainly consists of migmatitic and gneissic TTGs representing long crustal growth period that can be divided three age groups of c. 2.95 Ga, 2.83-2.78 Ga and 2.76-2.73 Ga. The oldest TTG rocks are found in the Suomussalmi area in the northern part of the complex (Hyppönen 1983, Vaasjoki et al. 1999, Luukkonen 1985, Käpyaho et al. 2006, 2007, Lauri et al. 2006, Mikkola 2011, Mikkola et al. 2011a). The northern part of the Lentua complex, the Taivalkoski-Kuusamo area is separated from the southern part by E-W and SW-NE trending shear zones (Fig. 2). Displacements and rotation seen in the strike of Proterozoic dolerite dyke swarms at the fault zone suggest that the shear zones involved at least some Proterozoic tectonic displacement. A distinctive feature of the Taivalkoski-Kuusamo area is the presence of large domains of Eu-enriched leucocratic TTG gneisses.

The southern-southwestern parts of the complex are characterized by a relative abundance of gneissose sedimentary rocks, known as Nurmes paragneisses. The paragneisses are mostly migmatitic quartz-biotite-plagioclase gneisses with chemical composition almost identical to the global average for Neoarchaean greywackes. On the basis of the ages of detrital zircon grains their deposition

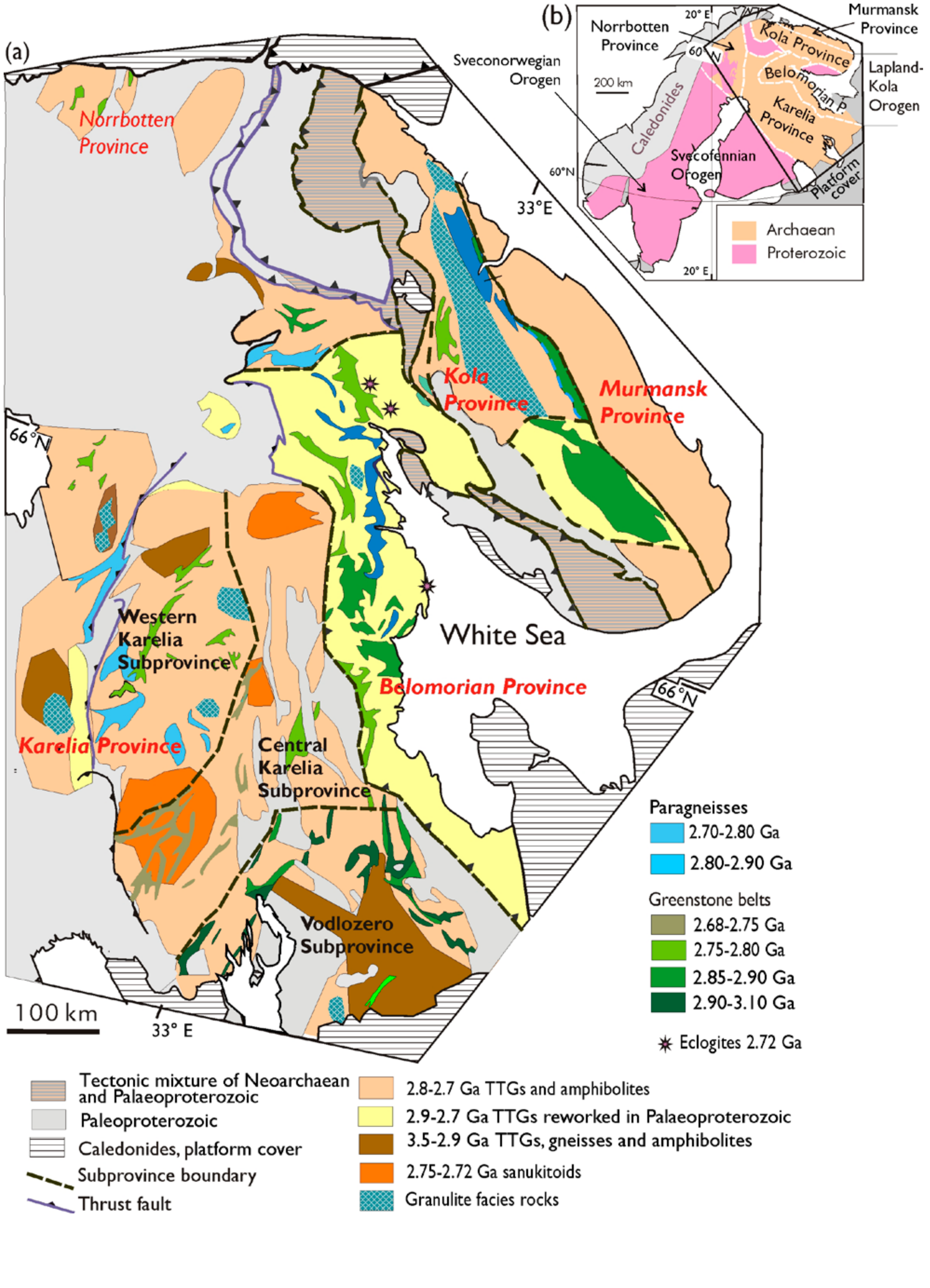

Fig. 1. Generalised geological map of the Archaean of Fennoscandia, modified after Slabunov et al. (2006) and Hölttä et al. (2008).

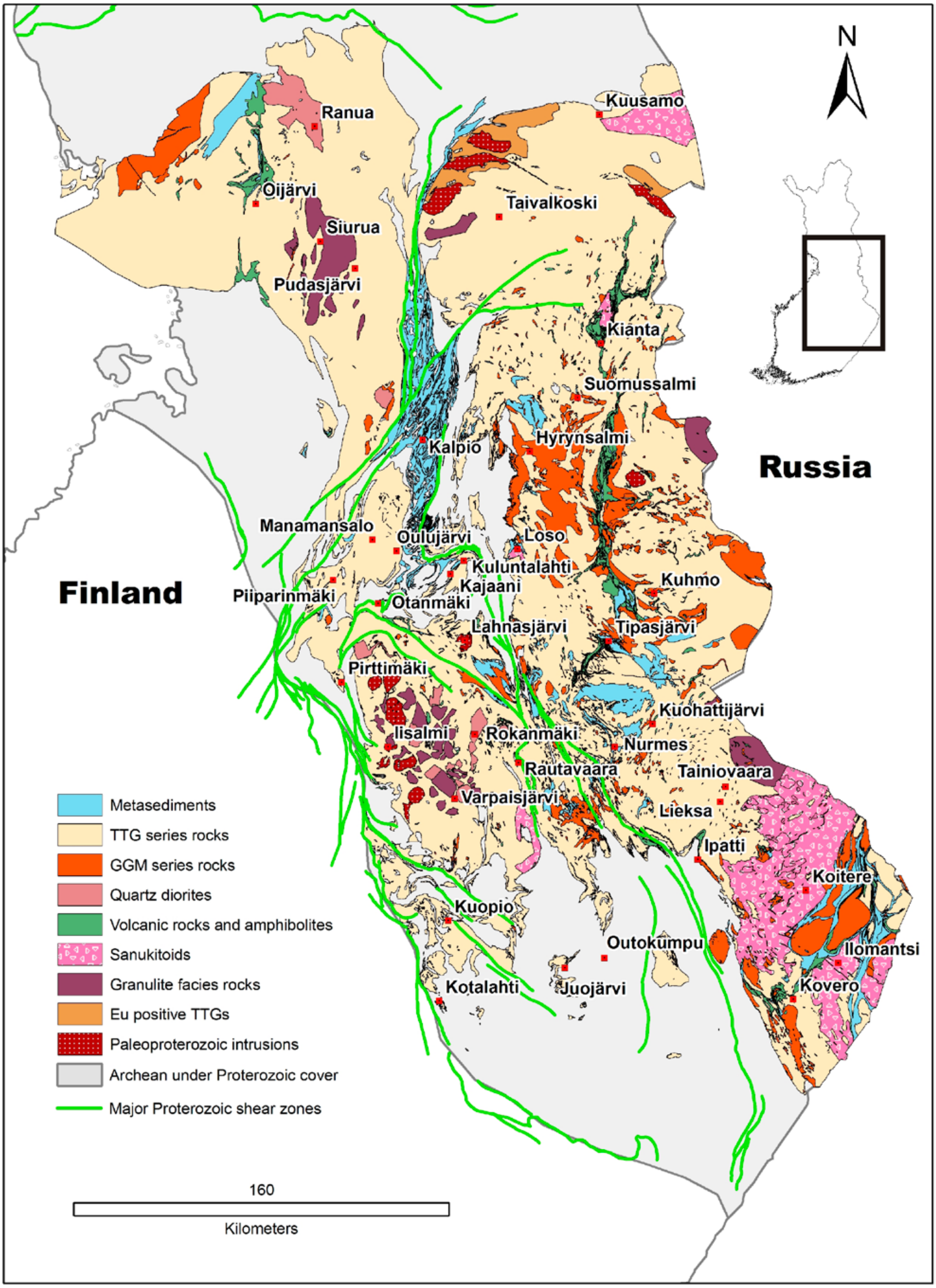

Fig. 2. A generalised lithological map of the Finnish part of the Karelia Province.
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Fig. 3. Archaean complexes of the Finnish part of the Karelia Province. The geological base map is from Fig. 2.

age is close to 2.72 Ga (Kontinen et al. 2007, Hölttä et al. 2012, Huhma et al. 2012).

The sanukitoid series intrusions in the Lentua complex are c. 2.72 Ga in age, and they are generally c. 20 Ma younger than sanukitoids in the Ilomantsi complex (Heilimo et al. 2011). Quartz diorites dated at c. 2.70 Ga are locally found in the Lentua complex (Mikkola et al. 2011a). The youngest abundant intrusives are c. 2.70-2.69 Ga granodiorite-granite-monzogranite (GGM) series rocks that are related to metamorphism and melting of the TTG crust in the Neoarchaean (Luukkonen 1988, Käpyaho et al. 2006, Mikkola 2008, Mikkola et al. 2012).

There are several minor occurences of orthopyroxene bearing enderbitic and mafic gneisses NE of Lieksa in the southeastern part of the Lentua complex, as in the Tulos granulite area on the Russian side of the state border (Slabunov et al. 2006). Metasedimentary rocks locally show granulite facies garnet-orthopyroxene-bearing assemblages. Granulites facies orthopyroxene-bearing TTGs are also found west of Taivalkoski and east of Kianta (Fig. 2).

The Lentua complex includes the Tipasjärvi, Kuhmo and Suomussalmi greenstone belts as well as some minor greenstone occurrences as narrow interlayers in TTGs such as the Ipatti greenstone belt in the southern part of the complex. Some of these consist of small serpentinite bodies with Ni mineralizations as in Tainiovaara (Pekkarinen 1980).

The oldest U-Pb zircon ages from volcanic rocks are obtained in the lower units of the Suomussalmi greenstone belt, being c. 2.95 Ga (Luukkonen et al. 2002, Huhma et al. 2012). All other dated volcanic rocks in the Tipasjärvi, Kuhmo and Suomussalmi greenstone belts yield ages of c. 2.87-2.80 Ga (Huhma et al. 2012), as do the volcanic rocks in the nearby Kostomuksha greenstone belt in Russia (Bibikova et al. 2005b).

There are a few rare intrusive rock types in the Lentua complex. The age of the Kuohattijärvi layered pyroxenite-gabbro-anorthosite intrusion is unknown but its deformation suggests that it is Archaean. Large Paleoproterozoic c. 2.45 Ga layered mafic intrusions are found in the northern parts of the Lentua complex. In the north the complex is autochthonously covered by the c. 2.40 Ga ultramafic and mafic volcanic rocks of the Kuusamo Group overlain by Jatuli-stage cratonic-epicratonic, predominantly quartzitic metasediments (Silvennoinen 1972).

Rautavaara complex

The Lentua complex is separated in the SW from the Rautavaara complex by SE-NW trending Proterozoic shear zone (Fig. 3). In the Rautavaara complex rocks older than 2.75 Ga have not been found thus far but on the other hand only a few datings exist for the rocks of this complex. The dominant rock type is a TTG gneiss with variable amounts of amphibolite and biotite-plagioclase paragneiss as enclaves and schlierens.

The abundance of chemically altered ultramafic to felsic rocks is the distinctive feature of the Rautavaara complex. These rocks include cordierite-orthoamphibole rocks and quartz rocks with Al-silicates (andalusite, kyanite, sillimanite) and cordierite. The oldest, c. 2.75 Ga zircon grains dated in the complex are from a quartz-cordierite rock that is interpreted to derive from chemically altered felsic volcanic rock (Hölttä 1997, Paavola 1999, Mänttäri & Hölttä 2002). A quartz diorite from Rokanmäki (Fig. 2) yielded a conspicuously young TIMS zircon age of 2.68 Ga, which may result from a mixture of magmatic and metamorphic zircon grains (Paavola 1999). Other Neoarchaean igneous rocks in the area are 2.72 Ga sanukitoids and 2.66 Ga granites (Halla 2005, Heilimo et al. 2011). At least the western part of the Rautavaara complex underwent granulite facies metamorphism at c. 2.68-2.62 Ga, as is indicated by U-Pb ages obtained for metamorphic zircon and monazite. Most of the Rautavaara complex underwent pervasive Paleoproterozoic deformation and related retrograde metamorphism at 1.89 Ga in conditions at around 600°C and 5-6 kbar, which largely destroyed the Archaean granulite facies mineral assemblages (Paavola 1999, Mänttäri & Hölttä 2002).

In the north in the Lahnasjärvi area (Fig. 2) TTGs are parautochthonously overlain by early Proterozoic 2.3-2.1 Ga platform quartzites. In the northwest the complex is in a faulted contact with the Otanmäki-Kuluntalahti sliver of c. 2.05 Ga alkaline to peraluminous granites. Dykes and small bodies of often garnet-bearing c. 1.80 Ga pegmatite granite are found in the Lahnasjärvi area.

Iisalmi complex

The boundary between the Rautavaara and Iisalmi complexes possibly represents a suture between two tectonic terranes (Fig. 3), based on the drastic differences observed in lithology and ages. Chemically altered lithologies are lacking and MesoArchaean 3.2-3.1 Ga gneisses are found in the Iisalmi complex (Hölttä et al. 2000, Mänttäri & Hölttä 2002). These migmatitic gneisses comprise intermediate and mafic paleosomes, the latter compositionally resembling MORB-type basalts with flat or slightly LREE depleted rare earth element patterns (Hölttä 1997). The Iisalmi complex was intruded at 2.70 Ga by orthopyroxene-bearing quartz diorites, and was deformed and metamorphosed, locally in granulite facies, between c. 2.68-2.62 Ga, obviously together with the Rautavaara complex (Mänttäri & Hölttä 2002). The granulites are mostly garnetiferous two-pyroxene mafic and intermediate rocks for which geothermometry and geobarometry indicate crystallization at c. 800-850°C and 9-11 kbar (Hölttä & Paavola 2000).

Kuopio complex

The Kuopio complex is here defined to include the Archaean gneiss domes and/or tectonic slivers within Proterozoic metasediments in the Kuopio (Fig. 3), Kotalahti and Juojärvi areas (Fig. 2) which may represent tectonic thrusts of Archaean gneisses from an unknown source or root zone (cf. Park & Bowes 1983, Park et al. 1984). The possible thrusting could have been coeval with the c. 1.9 Ga obduction of the Outokumpu allochthon.

The Kuopio complex was intensively tectonically reworked during the Palaeoproterozoic. The Archaean rocks are TTG gneisses and migmatites with some sanukitoid and quartz diorite intrusions that chemically resemble similar rocks in the Iisalmi and Rautavaara complexes. No age data are available for the sanukitoids in the Kuopio complex, but the quartz diorites display 2.7 Ga ages (Lukkarinen 2008), similar to the Iisalmi and Rautavaara quartz diorites.

Kalpio complex

The Kalpio complex is characterized by the abundance of metasedimentary rocks, along with zones of TTGs especially in its western part (Laajoki 1991, Fig. 3). The metasedimentary rocks include arkosic gneisses, mica schists and gneisses as well as gneissic quartzites. Amphibolite layers which may partly represent metamorphosed dykes are common among the metasediments. Serpentinites and metagabbros, locally forming layered ultramafic-mafic sills, occur in the eastern part of the complex (Laajoki 1991). Felsic metatuffites whose age probably is c. 2.72 Ga are found in one of the youngest included sedimentary units (Huhma et al. 2000, Laajoki 2005).

The mica schists and gneisses are partly highly aluminous and display shale-normalised immobile trace element patterns characterized by deep negative Nb anomalies, LREE enrichment and HREE depletion. The patterns are very similar to the average composition of Karelia Province Archaean rocks in Rasilainen et al. (2007), suggesting that the source of the Kalpio sediments was in a similar TTG, sanukitoid and GGM rich crust as that presently exposed in the Western Karelia Province.

U-Pb datings by Vaasjoki et al. (2001) showed that the Kalpio granitoids and gneisses would typically contain dominantly Archaean zircon grains, which also suggests that they would be either Archaean rocks or Proterozoic paragneisses or gneissic granitoids with abundant inherited Archaean components. Monazite U-Pb ages for the gneisses and granites in the Kalpio complex are in the range of c. 1.81-1.79 Ga (Vaasjoki et al. 2001).

The Kajaani gneiss-granite area SE of Lake Oulunjärvi is here included in the Kalpio complex. This connection is based on similar lithologies, i.e. the presence of amphibolites-intercalated arkosite gneisses, mica gneisses and quartzite gneisses. Further support for the Kalpio correlation is provided by the presence of serpentinite-gabbro intrusions in both areas. The eastern part of the Kajaani area is dominated by gneissic TTG rocks. Their southern and eastern margin is tectonic against the A-type gneissic, peralkaline-peraluminous Proterozoic granites of 2.05 Ga.

Manamansalo complex

The Manamansalo complex south of the Kalpio complex (Fig. 3) consists of TTG gneisses with amphibolite and micaceous paragneiss layers. In the SW part of the Manamansalo complex are the Piiparinmäki and Pirttimäki areas which were described as separate complexes by Laajoki and Luukas (1988). The Pirttimäki area is formed of banded schists and quartz-feldspar gneisses with amphibolite layers, whereas the Piiparinmäki area mainly consists of gneissic TTG rocks with abundant amphibolite layers, and with abundant foliated Proterozoic granitoids in its N part. The contacts of these two areas are either lithodemic or tectonic (Laajoki & Luukas 1988).

The Manamansalo complex is still scantily dated. Two age determinations are available from the Manamansalo area, one from a tonalite gneiss and another from its pegmatite bands, giving ages of 2675 ± 2 Ma and 2663 ± 2 Ma, respectively (Vaasjoki et al. 2001). If the U-Pb age on zircon from the tonalite gneiss is not from metamorphic grains it represents the youngest Archaean tonalite so far observed in the Finnish Archaean.

One U-Pb age determination on zircon from a tonalite in the southern part of the Pirttimäki area has given an age of 2.73 Ga. Monazite from this tonalite is Palaeoproterozoic, 1.82 Ga (Pietikäinen & Vaasjoki 1999). Similar to the Kalpio Complex, Palaeoproterozoic granites and granite pegmatites are abundant in the Manamansalo complex. Similar monazite ages suggest that these complexes jointly experienced a relatively high temperature metamorphic event at the time the Proterozoic granites intruded them.

Siurua complex

The Siurua complex contains the Siurua 3.5 Ga trondhjemitic gneisses which are the oldest rocks observed in the Karelia Province (Fig. 3) so far (Mutanen & Huhma 2003). Low-pressure granulite facies orthopyroxene bearing 2.96 Ga TTG orthogneisses and amphibolites are found in their vicinity (Lalli 2002, Mutanen & Huhma 2003). The Palaeoarchaean rocks are only found in a restricted area, because most age determinations in the adjacent rocks yield Neoarchaean ages. The majority of detrital zircon grains in adjacent paragneisses are Neoarchaean, 2.74 – 2.72 Ga, Palaeoarchaean grains being absent (Huhma et al. 2012).

Ranua complex

The Ranua complex (Fig. 3) consists of TTG rocks and granites dated at 2.82 – 2.73 Ga and 2.70 – 2.62 Ga, respectively (Huhma et al. 2012). The Ranua complex includes the N-S striking Oijärvi greenstone belt which mostly consists of amphibolite facies mafic and ultramafic volcanic rocks and sediments (Sorjonen-Ward & Luukkonen 2005). The existing datings give an age of 2.82-2.80 Ga for the intermediate volcanic rocks of the Oijärvi belt, but a felsic porphyry as young as 2.67 Ga was also found (Huhma et al. 2012). Paragneisses also occur locally in the Ranua complex outside the Oijärvi greenstone belt, and a large proportion of detrital zircon grains in these paragneisses are 2.74 – 2.73 Ga in age, giving the maximum deposition age (Huhma et al. 2012). The extensive Ranua intrusion in the northern part of the complex, showing variably dioritic-quartz dioritic compositions, is dated at 2.70 Ga (Mutanen & Huhma 2003). U-Pb data on metamorphic zircon grains in mafic granulites and leucosomes of migmatites indicate high grade metamorphism at 2.68 – 2.65 Ga (Mutanen & Huhma 2003, Lauri et al. 2011).

Central Karelia subprovince

Ilomantsi complex

The Central Karelia subprovince differs from the surrounding Archaean subprovinces on the basis of the predominantly Neoarchaean < 2.80 Ga age of plutonic and volcanic sequences (Vaasjoki et al. 1993, Huhma et al. 2012), of its relative abundance of sanukitoids and of the geochemistry of volcanic rocks of the greenstone belts (Hölttä et al. 2012). The Ilomantsi complex refers to the Finnish part of the Central Karelia subprovince (Figs. 1 and 3) and it includes the Ilomantsi and Kovero greenstone belts.

The oldest granitoids within the Ilomantsi complex are c. 2.76 Ga in age (Sorjonen-Ward & Claoué-Long 1993). The complex is characterized by a relatively high abundance of sanukitoids (Fig. 2), which are lacking in the Belomorian province and westernmost complexes of the Western Karelia subprovince. The Central Karelia sanukitoids are strongly differentiated and vary in composition from ultramafic to felsic. They appear to be slightly older (2.75-2.73 Ga) than sanukitoids in the Western Karelia subprovince where sanukitoids are mostly between 2.70–2.72 Ga in age (Vaasjoki et al. 1993, Bibikova et al. 2005a, Lobach-Zhuchenko et al. 2005, 2008, Käpyaho et al. 2006, Heilimo et al. 2010, 2011).

Felsic volcanic rocks in the Ilomantsi, Gimola and Khedozero-Bolsheozero greenstone belts have been dated at 2.75-2.73 Ga (Vaasjoki et al. 1993, Bibikova et al. 2005b). In the Ilomantsi greenstone belt, 2.75 Ga andesites have been interpreted to represent the lowermost stratigraphic unit of the volcanic sequence. Calc-alkaline basalt-andesite-dacite-rhyolite (BADR) series volcanic rocks, crustal signatures in the geochemistry of ultramafic rocks and high abundances of volcaniclastic greywackes in the Ilomantsi and Khedozero-Bolsheozero greenstone belts indicate that these belts originated in arc type tectonic settings (Sorjonen-Ward 1993, Slabunov et al. 2006, Hölttä et al. 2012).

In the Kovero greenstone belt (Fig. 2) the oldest felsic volcanic rock is dated at 2.88 Ga (Huhma et al. 2012). There are also geochemical differences between the volcanic rocks of these two belts, e.g. komatiites in Kovero have flat or slightly LREE depleted REE patterns (Tuukki 1991), whereas komatiites in Ilomantsi are LREE enriched (O'Brien et al. 1993, Hölttä et al. 2012). However, because there are no such tectonic features between the Ilomantsi and the Kovero belts that would imply that they represent separate exotic terranes, the Kovero belt is also included here in the Central Karelia subprovince.

Vodlozero subprovince

The Vodlozero subprovince (Fig. 3) is cored by the 3.2-3.0 Ga Vodla gneiss complex which consists of migmatitic amphibolites and TTGs. Three age groups of greenstone belts are distinguished in Vodlozero: an early (3.01-2.95 Ga) group of the Vedlozero-Segozero, Sumozero-Kenozero and South Vygozero greenstone belts; a 2.9-2.85 Ga group of Vedlozero-Segozero and Sumozero-Kenozero belts and post 2.85 Ga greenstones of the Matkalahta belt. The Vodla gneisses were metamorphosed first at 3.15 Ga and then at 2.85 Ga (Sergeev et al. 2007). The Vodla gneiss complex is bordered in the west by the Vedlozero-Segozero greenstone belt, which is the oldest established convergent ocean-continent transition zone in the Karelia Province (Svetov et al. 2006). In the Vedlozero-Segozero belt 3.05-2.95 Ga island arc type tholeiitic, adakitic and basalt-andesite-dacite-rhyolite (BADR) series rocks are juxtaposed with 3.10-2.95 Ga komatiitic-basaltic series that are interpreted to represent proto-oceanic assemblages (Svetov et al. 2006). The Matkalahta belt, located in the central part of the Vodlozero subprovince, consists of alternating metasediments (quartz arenites, greywackes and carbonaceous shales) and metavolcanics of basalt-komatiite association with scarce foliated felsic metavolcanic interbeds. The ages of the detrital zircon from the metasediments vary from 3.33 to 2.82 Ga, yielding a maximum deposition age of 2.82 Ga for the Matkalahta belt. The youngest (c. 2.70-2.60 Ga) Archaean rocks are sanukitoids, enderbites and mafic dykes. In the NW part of the Vodlozero subprovince dykes are tholeiitic and ultramafic, but in the central part there are low-Cr silicious gabbronorites, e.g. the Shalskiy dyke whose U-Pb age on baddeleyite is 2.51 Ga (Bleeker et al. 2008) and the Sm-Nd mineral age is 2.61 Ga (Mertanen et al. 2006).

DISCUSSION

The above division of the Karelia Province into complexes has to be considered largely tentative. It does not necessarily represent in its details the Archaean evolution as the Western Karelia Province was largely metamorphosed and deformed at 1.9 – 1.8 Ga during the Svecofennian orogeny which caused a lot of faulting and block movements and penetrative deformation and retrograde metamorphism in large areas. Large areas have been mapped in detail in 1:100 000 scale. Our data sets are also unevenly distributed. For example, there are still areas, especially in the Ranua and Siurua complexes, that have been mapped only on a large regional scale. The age determinations are also concentrated to the greenstone belts and their adjacent areas. The evolution of the greenstone belts could be better constrained, as the detailed, belt-specific chronostratigraphic database, for example, is still in its infancy.

Consequently, we can only tentatively sketch important terrane/tectonic boundaries. One is obviously between the Ilomantsi and Lentua complexes which marks the boundary of the Western Karelia and Central Karelia subprovince. Another important terrane boundary might be between the Rautavaara and Iisalmi complexes, noting their very different lithologies and that only Neoarchaean rocks have been dated so far in the Rautavaara complex. In addition, the Palaeoarchaean rocks of the Siurua complex may represent an exotic tectonic block that has been preserved to the present day. Owing to its small size, it cannot be considered as a separate terrane but rather as an exotic tectonic sliver. However, we hope that the above-presented complex division could work as a useful common tool when we discuss the broader field relations, as well as a basis for better understanding of the tectonic classification and evolution of this fascinating part of the Earth's crust.

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