The Archaean of the Karelia Province in Finland
Edited by Pentti Hölttä
Geological Survey of Finland, Special Paper 54, 176–213, 2012

ND ISOTOPIC EVIDENCE FOR ARCHAEAN CRUSTAL GROWTH IN FINLAND

by
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Huhma, H., Kontinen, A., Mikkola, P., Halkoaho, T., Hokkanen, T., Hölttä, P., Juopperi, H., Konnunaho, J., Luukkonen, E., Mutanen, T., Peltonen, P., Pietikäinen, K. & Pulkkinen, A. 2012. Nd isotopic evidence for Archaean crustal growth in Finland. *Geological Survey of Finland, Special Paper 54*, 176−213, 20 figures and 1 appendix.

Sm-Nd isotopic data from 400 samples provide a view of the formation of the Archaean crust in Finland and the Fennoscandian Shield. Despite problems related to secondary REE mobility, the Sm-Nd results show that a mantle reservoir with time-integrated depletion in LREE was an important source of magmas already during the Archaean. The data show that most Archaean felsic rocks in Finland have depleted mantle model ages of ca. 2.8-3.0 Ga, suggesting, together with the U-Pb zircon ages, that much of the Archaean consists of relatively juvenile crust. This is particularly true for the Kuhmo area, whereas in Suomussalmi area, the recycling of older crustal material is more pronounced. Throughout the Finnish Archaean rocks with model ages in excess of 3.3 Ga are few. The 3.5 Ga Siurua gneisses in Pudasjärvi, which are the oldest rocks recognized so far in the Fennoscandian Shield, have yielded the oldest reliable Sm-Nd model ages, up to ca. 3.7 Ga.

Keywords (GeoRef Thesaurus, AGI): absolute age, Sm/Nd, crust, mantle, Archean, Finland

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INTRODUCTION

One of the applications of Sm-Nd isotope analysis of rocks is that the results give constraints on the average crustal residence time of the rocks and their provenances. This is based on the assumption that REE fractionation associated with the crust generating processes are large compared to fractionation during later processes within the crust (McCulloch & Wasserburg 1978). A general problem related to this approach, especially with Archaean rocks, is the question whether the Sm-Nd system has remained closed since their formation. If metamorphic Sm/Nd fractionation has occurred, the results are obviously erroneous. Examples of clearly anomalous results are often related to samples which have relatively low abundance of REE and elevated Sm/Nd ratio ($^{147}Sm/^{144}Nd > 0.13$). The calculated model ages for such samples tend to be too old and do not characterize true crustal residence ages. Most of these problematic samples are relatively fine-grained volcanogenic rocks and often related to shear zones with associated high fluid flow. The opposite case is also seen where some rocks have very low Sm/Nd due to fractionation related to partial melting, providing calculated model-ages that are "too young" compared to the true protolith age.

This paper reports the Sm-Nd isotope results from the Archaean crust in central Finland. The main features of the Archaean bedrock in Finland and the Fennoscandian Shield are provided by Sorjonen-Ward & Luukkonen (2005) and Slabunov et al. (2006). The Archaean area can be divided into a few main domains, which in this paper are simply geographic areas: Pudasjärvi, Suomussalmi/Koillismaa, Kuhmo, Ilomantsi and Iisalmi (Fig. 1). Archaean rocks occur also in Lapland, particularly in the Eastern Lapland and Inari areas, but are not included here, since this volume deals with the Archaean of central Finland. The Sm-Nd data have been produced at GTK since the early eighties, mostly from samples which have been dated by U-Pb methods (A-series samples), and which have been selected to represent significant lithological units. Some samples reported in the Rock Geochemical Database of Finland (Rasilainen et al. 2007) have also been included. The Sm-Nd database consists of ~ 400 samples, from which ~ 100 have been previously published elsewhere. These papers and the compilation by Hölttä et al. (this volume) provide more detailed information of the rock types and their geochemistry, but further studies are needed to better combine the isotope results with the comprehensive geochemical information that exists. In terms of rock types the samples comprise ~ 250 granitoid, 60 mafic, 50 felsic volcanic and 40 sedimentary rocks (Appendix 1).

Sm-Nd METHODS

For whole-rock Sm-Nd analysis, 120-200 mg of powdered sample was spiked with a ^{149}Sm-^{150}Nd tracer. The sample-spike mixture was dissolved in HF-HNO_3 in sealed Teflon bombs in an oven at 180 °C (felsic rocks) or in Savillex screw-cap beakers on a hot plate (mafic rocks) for 48 hours. Prior to dissolving the residue in 6.2 N HCl, the fluorides were gently evaporated using HNO_3. Conventional cation exchange chromatography was used for separation of the light rare earth elements and Sm and Nd were separated by a modified Teflon-HDEHP (hydrogen di-ethylhexyl phosphate) method (Richard et al. 1976). Total procedural blank was <0.5 ng for Nd. Isotope ratios were measured on a VG Sector 54 TIMS using Ta-Re triple filaments. Nd isotope ratios were measured in dynamic mode and Sm isotopes in static mode. Nd ratios are normalized to $^{146}Nd/^{144}Nd=0.7219$. Based on several duplicate analyses (Appendix 1), the error of the $^{147}Sm/^{144}Nd$ is estimated to be better than 0.4 %. The long-term average $^{143}Nd/^{144}Nd$ for the La Jolla standard is 0.511850±0.000010 (standard deviation for 220 measurements during the years 1996-2010). Recent analysis on BCR-1 gave Sm=6.63 ppm, Nd=28.88 ppm, $^{143}Nd/^{144}Nd=0.512640\pm0.000010$. The ε_{Nd} was calculated using $\lambda^{147}Sm=6.54 \cdot 10^{-12} a^{-1}$, $^{147}Sm/^{144}Nd=0.1966$, and $^{143}Nd/^{144}Nd=0.512640$ for the present CHUR. T_{DM} was calculated after DePaolo (1981). Plotting and calculations of isotope data were performed using the Isoplot program (Ludwig 2003).

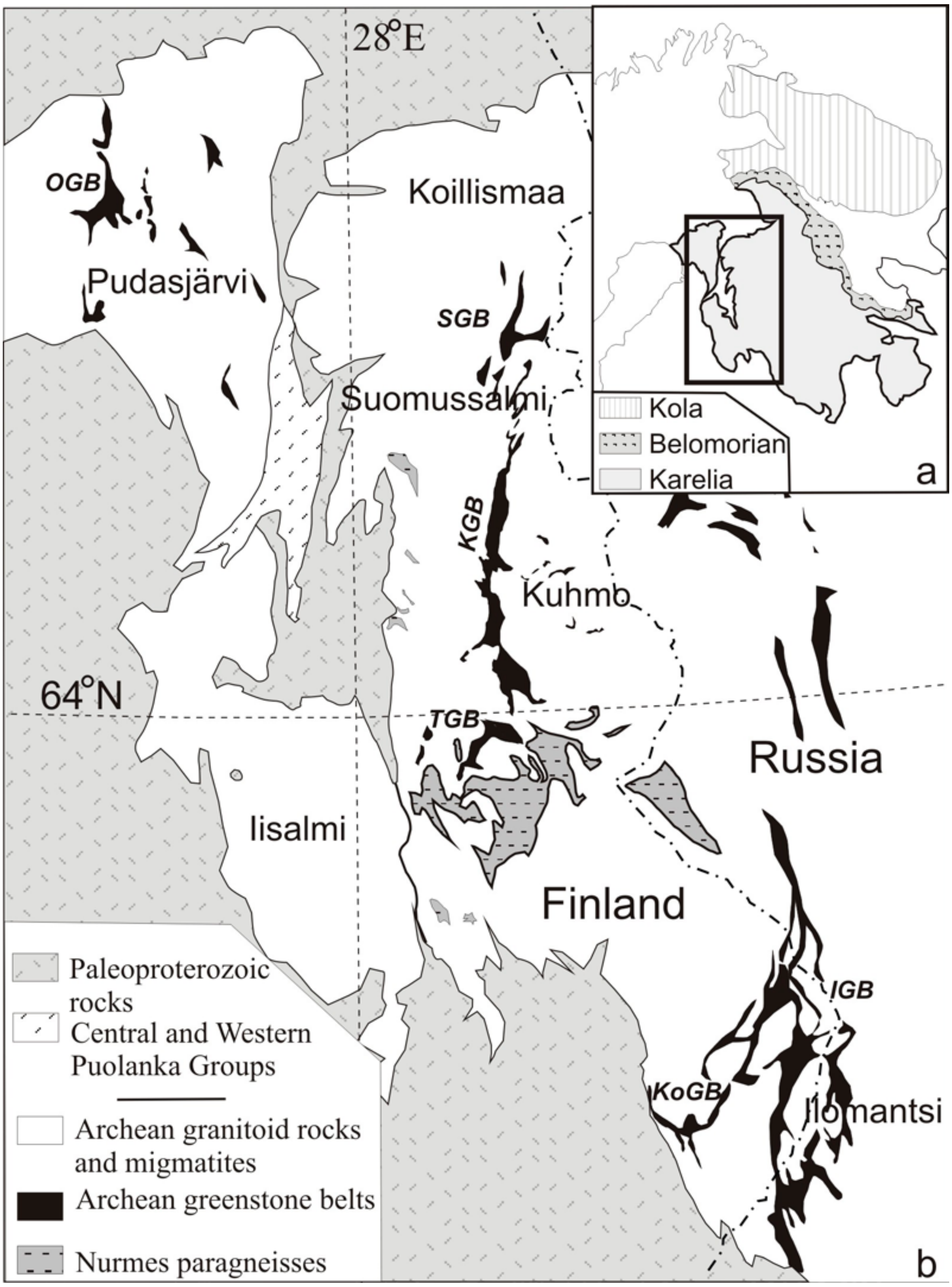

Fig. 1. (a) Major Archaean tectonic domains of the Fennoscandian Shield. (b) Generalized geological map of central Finland (after Kontinen et al. 2007, Korsman et al. 1997) showing the main Archaean units. OGB/SGB/KGB/TGB/IGB/KoGB= Oijärvi/ Suomussalmi/ Kuhmo/ Tipasjärvi/ Ilomantsi/ Kovero greenstone belt.

ARCHAEAN MANTLE

Many attempts have been made to characterize the Nd isotopic composition of the Archaean mantle by analyzing mafic-ultramafic rocks (e.g., Dupre et al. 1984, Puchtel et al. 1998, Svetov et al. 2001). However, due to metamorphic REE fractionation this has often turned out to be difficult, e.g. the 2.8 Ga komatiites from Siivikkovaara in Kuhmo belt have yielded a Sm-Nd age of ca. 1.8 Ga (Gruau et al. 1992). For those data the calculated initial $\varepsilon_{Nd(2800)}$ values range from -9 to +1.

We have also carried out Sm-Nd analyses on samples from the Kuhmo belt, those which are considered least altered. These samples include ten komatiites or komatiitic basalts from the Siivikkovaara-Pahakangas area (close to Kellojärvi in Fig. 9), five komatiites/ komatiitic basalts from other sites and four high-Cr basalts (Appendix 1). Our results are also scattered with a range in initial $\varepsilon_{Nd(2800)}$ values from -2.8 to +4.6 (Figs. 2 and 3). It remains difficult to evaluate for which samples, if any, the Sm-Nd system has remained closed since the formation of rocks. However, excluding a few strongly deviating samples, the data from the Pahakangas-Siivikkovaara area tend to give initial $\varepsilon_{Nd(2800)}$ values clustering close to +0.5, which is particularly evident in the four analyses on komatiitic metalavas from the Pahakangas profile (red triangles and isochron in Fig. 2). However, komatiitic basalts and two high-Cr basalts from other areas in Kuhmo tend to give higher initial values close to +2.5 (red squares and isochron in Fig. 2). Clearly positive initial values are also provided by three intrusive mafic rocks from the Kuhmo belt, which also have been dated by zircon U-Pb (A976, A1771, A1418, red circles in Fig. 3). A very high $\varepsilon_{Hf(2800)}$ of +14 was reported by Patchett et al. (1981) for zircon of the tholeiitic gabbro A976.

Sm-Nd analyses on the LREE enriched ultramafic rocks from the Ilomantsi belt (Fig. 1) are also scattered with a range of $\varepsilon_{Nd(2750)}$ values from -7.6 to +3.4 (green circles in Figs. 2 and 3). In contrast, the analyses on amphibolites associated with the ca. 2.72 Ga Nurmes paragneisses (Fig. 1) give consistently positive initial values at about +1.6 (Fig. 3, Kontinen et al. 2007). There are also

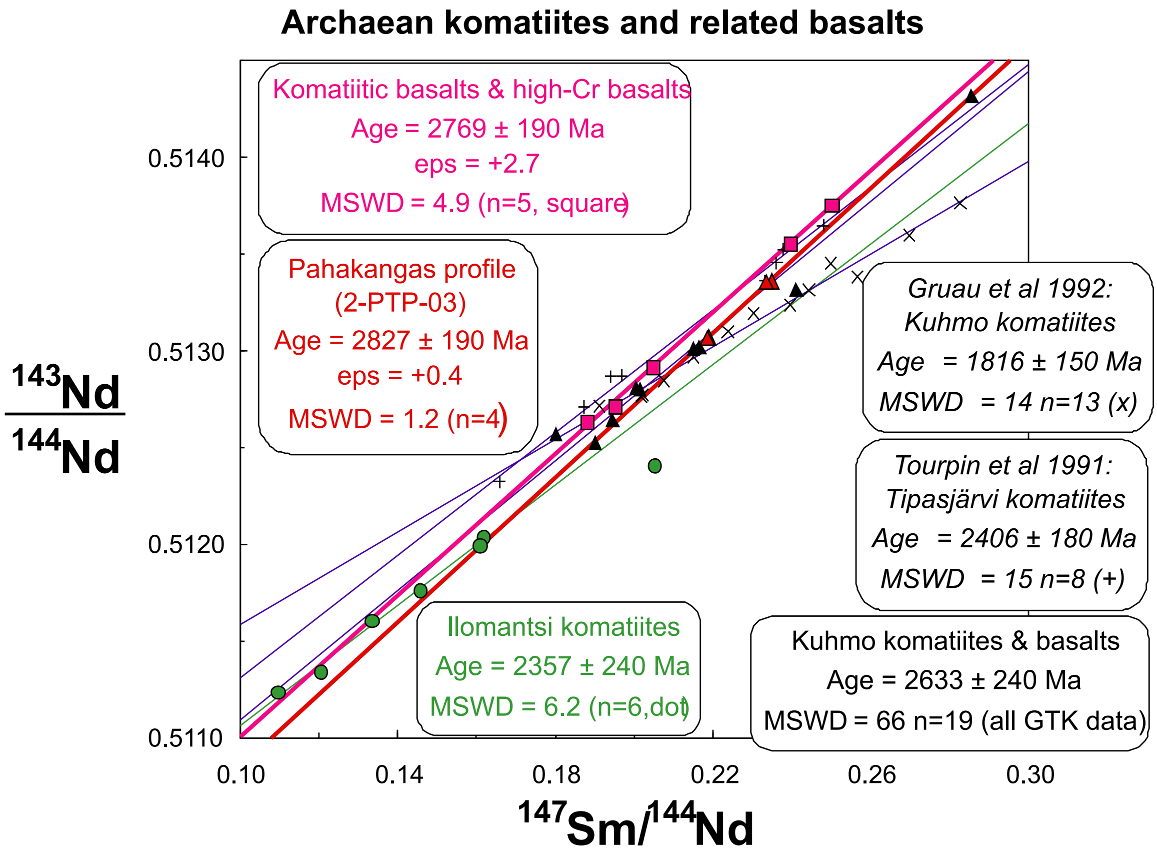

Fig. 2. Sm-Nd isochron diagram for komatiites and basalts from the Pahakangas-Siivikkovaara area in the Kuhmo belt (red and black triangles, n=13), komatiitic and high-Cr basalts from other areas in Kuhmo belt (red squares, n=5) and LREE enriched komatiites from the Ilomantsi belt (green circles). Analyses on komatiites from Kuhmo/Siivikkovaara (x) by Gruau et al. (1992) and from Tipasjärvi (+) by Tourpin et al. (1991) are shown for reference.

data on intrusive mafic rocks from Ilomantsi, Suomussalmi and Pudasjärvi areas that support clearly positive initial values. These include the 2866 ± 4 Ma gabbro A1821 from the Tormua belt (Suomussalmi), the 2802 ± 5 Ma gabbro A1782 from the Oijärvi belt (Pudasjärvi) and the 2756 ± 4 Ma gabbro from the Kovero belt (Ilomantsi) and several amphibolites from the Iisalmi area (Fig. 3). The newly discovered 2741 ± 2 Ma old Likamännikkö carbonatite and associated mafic rocks in Suomussalmi (A1912 in Fig. 4, Mikkola et al. 2011b) also strongly supports sources with positive initial ε_{Nd}, since the concentration of REE in these rocks are high and the Sm-Nd system is thus less sensitive to crustal contamination or later disturbances (Fig. 3).

The results from several felsic rocks, especially from the Kuhmo belt, also provide clearly positive initial-epsilon values. Overall, the Sm-Nd data attest to the importance of a depleted mantle source and that the model for the evolution of upper mantle by DePaolo (1981) is a useful reference.

It is tempting to consider that the $\varepsilon_{Nd(2800)}$ values of +0.5 obtained on many komatiitic samples from Kuhmo were primary signatures, which with reference to the rocks with more positive values, would suggest heterogeneity in the Archaean mantle. This speculation is consistent with the conclusion by Maier et al (in prep), who consider the geochemistry of the Kuhmo komatiites to indicate their origin in an oceanic plateau setting above a plume, derived from primitive upper mantle, rather than in a NMORB-type setting from a depleted, convecting mantle source. Other mantle sources with close to chondritic initial ε_{Nd} values are evident e.g. for the 2610 ± 4 Ma old Siilinjärvi carbonatite with $\varepsilon_{Nd(2610)} = 0$ (Figs. 3 and 15, Appendix 1) and the 2712 ± 1 Ma old high

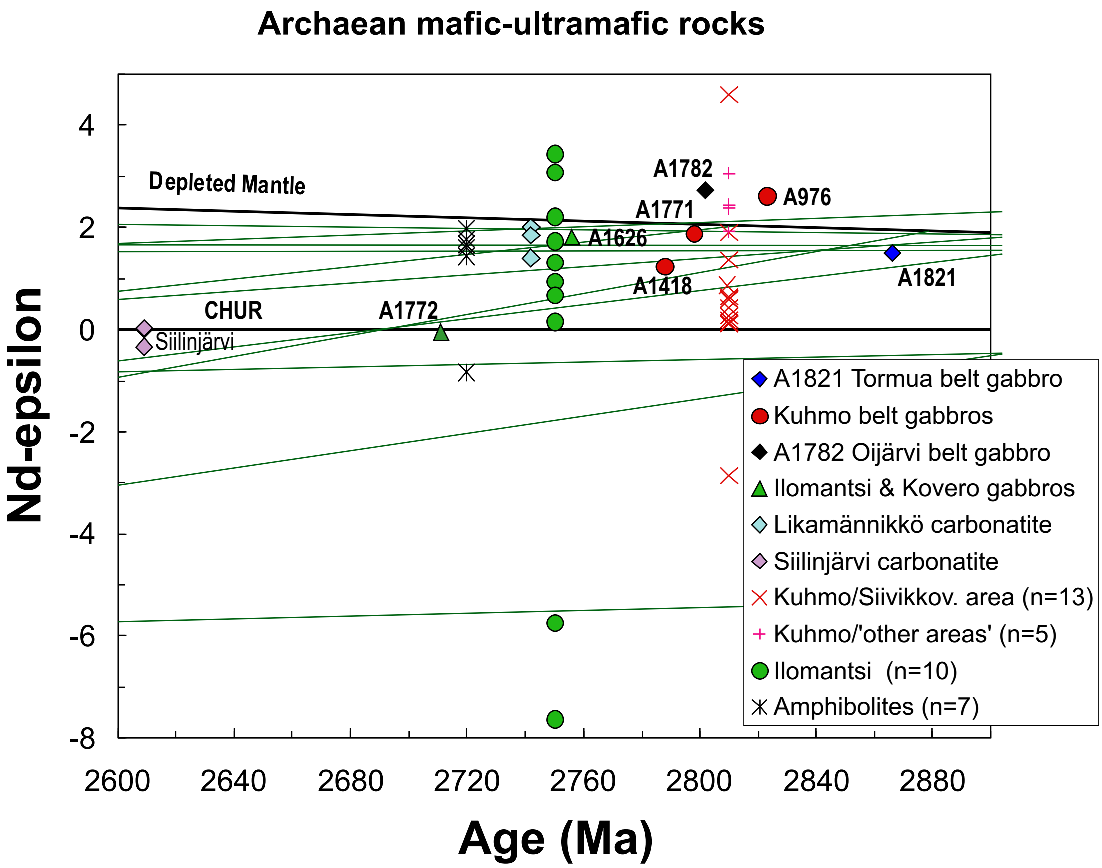

Fig. 3. Epsilon-Nd vs. age diagram for 60 Archaean mafic rocks in Finland (GTK data). Calculated initial epsilon values are shown: Kuhmo komatiites/ komatiitic basalts and high-Cr basalts in the Siivikkovaara-Pahakangas-Näätäniemi area (red ×s at 2.81 Ga, n=13), Kuhmo komatiitic and high-Cr basalts in other areas (red +s at 2.81 Ga, n=5), Ilomantsi ultramafic-mafic rocks (green circles at 2.75 Ga, n=10), 2741 ± 2 Ma Likamännikkö carbonatite (light blue diamonds), amphibolites associated with paragneisses (at 2.72 Ga, n=7, six samples at +1.6) and the 2610 ± 4 Ma Siilinjärvi carbonatite (diamonds). Symbols with sample numbers denote gabbroic samples for which the age is based on U-Pb zircon dating (A1782 – Oijärvi belt; A1821 – Suomussalmi/Tormua belt; A976, A1418, A1771 – Kuhmo belt, A1626 – Kovero belt, A1772 – Änäkäinen high REE gabbro). Also shown are the evolution lines for 12 other mafic samples (6 from the Pudasjärvi area, A1180 from the Suomussalmi belt, A1764 from the Ilomantsi area and four amphibolites from the Iisalmi complex). Depleted mantle evolution is according to DePaolo (1981).

REE alkali gabbro A1772 from Änäkäinen with $\varepsilon_{Nd(2712)} = 0$ (Figs. 3 and 11, Appendix 1). However, the observed clustering of $\varepsilon_{Nd(2800)}$ results from the Siivikkovaara-Pahakangas komatiites may be accidental, and rocks from other areas in Kuhmo, with positive $\varepsilon_{Nd(2800)}$, may better record the primary signature for the komatiitic magmatism.

KOILLISMAA & SUOMUSSALMI

To evaluate the sources and crustal residence of the felsic rocks, Sm-Nd model ages (T_{DM}) for samples with "typical" upper crustal REE patterns ($^{147}Sm/^{144}Nd < 0.16$) have been calculated using the model of DePaolo (1981). The Sm-Nd data available on the Archaean rocks from the **Koillismaa** area consist of 24 analyses of granitoids/gneisses, some of which were published by Lauri et al. (2006) and Heilimo et al. (2013) (Fig. 4). Rocks in the western areas are mostly strongly LREE enriched (low $^{147}Sm/^{144}Nd$) and give model ages in the range 2.9-3.1 Ga. In contrast, samples near the Russian border yield systematically younger model ages of ca. 2.8 Ga (Fig. 5). Many of these are included in the 2.72 Ga Kuusamo sanukitoids (Heilimo et al. 2013).

In the **Suomussalmi** area, Sm-Nd analyses have been made on samples from the granitoid areas (32 granitoids and one mica gneiss) and from the Suomussalmi greenstone belt (two mafic and 15 felsic rocks including at least three sedimentary rocks).

Most of the **granitoid** data are adopted from Mikkola et al. (2011a, b), and generally give T_{DM} ages in the range 2.9-3.1 Ga. Many of these samples have yielded U-Pb zircon ages from 2.70 to 2.82 Ga (Mikkola et al. 2011a, b), and include also the Kaapinsalmi tonalites, which have been denoted as sanukitoids (EPHE samples in Fig. 4, Heilimo et al. 2013). Two gneisses, which have older U-Pb ages, also yield older model ages at 3.28 Ga (A1856 Portinkuru) and 3.56 Ga (A79 Päivärinta). The Sm/Nd ratio in the migmatitic gneiss A79 is, however, slightly higher than in most other samples, possibly due to metamorphic effects, and hence the system likely does not register primary signatures. Replicate analyses on A79 and many other samples show that variation due to analytical errors is not significant.

Most of the **greenstone belt** samples are from fine-grained, felsic-intermediate volcanogenic rocks. The Sm-Nd data include also five duplicate analyses, which generally show good reproducibility (within 0.3 epsilon units in calculated initial ratios, Appendix 1). The exception is A1593#2, from which the analytical error is also larger than in other data, and which also contained some monazite resulting in possible nugget effect. It is evident that some rocks are strongly altered and the Sm-Nd system has been significantly disturbed. Results from the Kuhmo greenstone belt discussed above suggested that major REE fractionation in the komatiites seems to coincide with the Svecofennian regional metamorphism of the Archaean craton as registered by Rb-Sr and K-Ar isotope data (e.g., Kouvo & Tilton 1966, Kontinen et al. 1992). There are also investigations suggesting late Archaean post-magmatic alteration, including the Rb-Sr study on the Luoma Group volcanic rocks by Martin and Querré (1984), who acquired an age of 2.5 ± 0.1 Ga. Also the Pb-Pb isotope studies on whole-rock samples have provided scattered age results (Vidal et al. 1980, Vaasjoki et al. 1999).

Two mafic volcanic rocks analyzed from the Suomussalmi belt have nearly chondritic REE ratios and initial isotopic compositions close to that of coeval depleted mantle (A1180A Saarikylä, A1821 Tormua, Fig. 6). Most of the analyzed felsic rock samples are enriched in LREE similar to upper crust ($^{147}Sm/^{144}Nd = 0.08$-0.12) and should thus be useful samples for crustal residence studies. The felsic samples consistently result in T_{DM} model ages in excess of 3 Ga (Fig. 6). It is also obvious that some samples provide meaningless results, particularly the felsic rock A1467, for which the initial epsilon at 2940 Ma is -23 and T_{DM} ca. 7.5 Ga (also checked by duplicate analysis). This sample has low REE contents (Nd<4 ppm) and elevated Sm/Nd, being clearly unrepresentative of the primary chemical composition. In a comparison with the bulk of the data, also samples A1192 (porphyry) and A1065A (fine-grained felsic rock from drill-core KR-27) provide much lower initial values and old model ages. All three of these samples are strongly altered, sheared, pale schists and are distinct from the other samples in this study. We consider that the Sm-Nd system in these samples has not remained closed since the formation of the rocks.

In light of these observations, one may speculate whether the other samples have remained

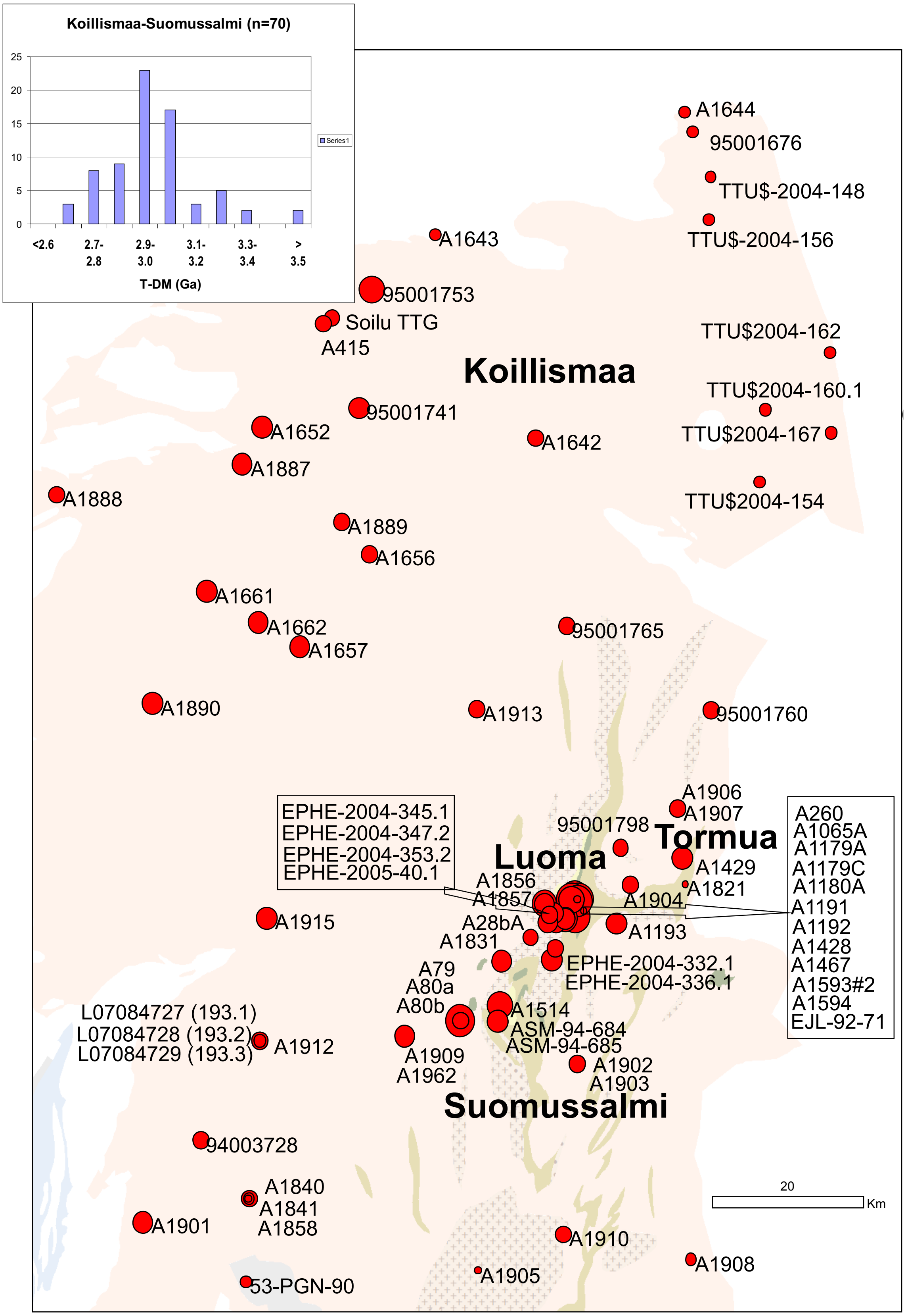

Fig. 4. Geological map of the Koillismaa-Suomussalmi area showing Sm-Nd sample sites. The size of the symbol denotes the model ages divided in six categories: < 2.7 Ga (small), 2.7-2.85 Ga, 2.85-3.0 Ga, 3.0-3.15 Ga, 3.15-3.3 Ga, >3.3 Ga (large). Model ages are not presented for mafic rocks which have $^{147}Sm/^{144}Nd > 0.16$, and symbol for these is small black circle (A1821, A1180A). The map is based on the 1: 1 000 000 geological map of Korsman et al. (1997), with the Suomussalmi greenstone belt divided into three main rock types, mafic metavolcanic rocks (brown), ultramafic metavolcanic rocks (green) and intermediate-felsic metavolcanic rocks (yellow). Rocks outside the greenstone belt consist of TTG's, intrusive rocks (stippled), amphibolites (brown) and paragneisses (grey).

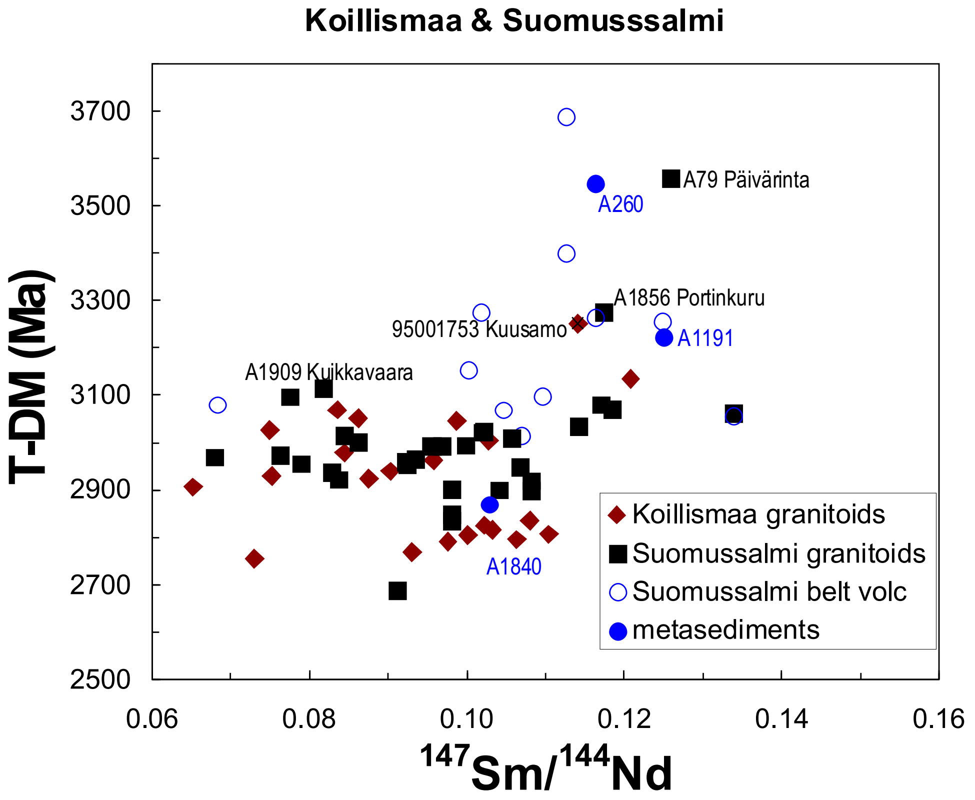

Fig. 5. Sm-Nd model ages T_{DM} for Archaean whole rock samples from the Koillismaa-Suomussalmi area. Suomussalmi belt volc= volcanogenic felsic-intermediate rocks.

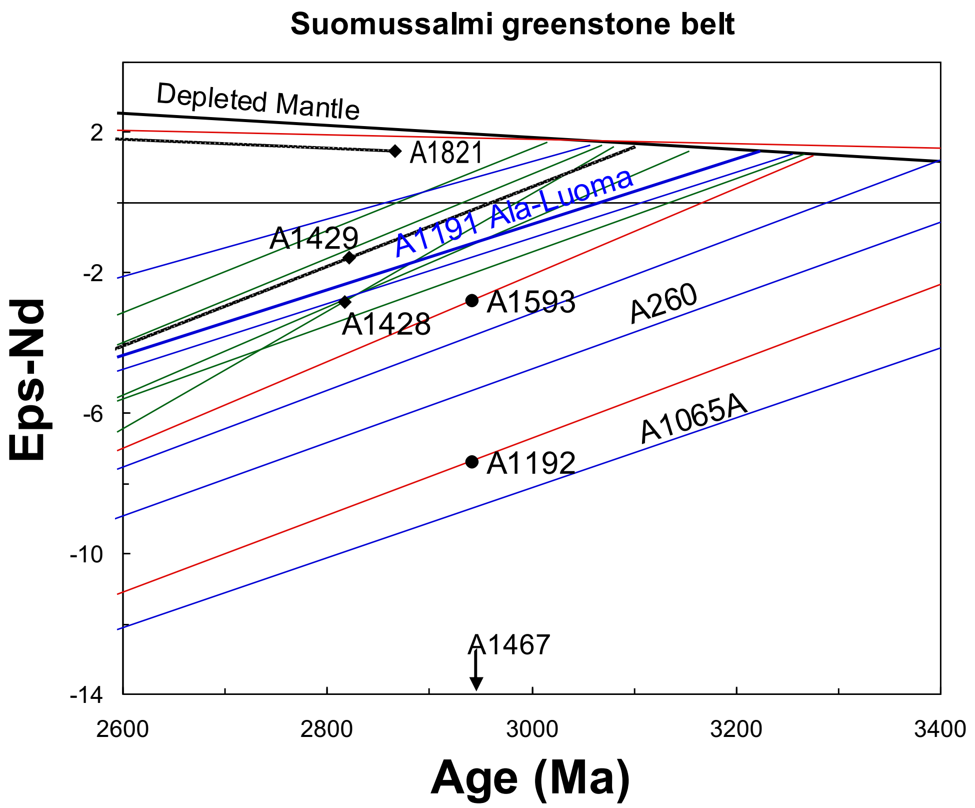

Fig. 6. Epsilon-Nd vs. age diagram for whole-rock samples from the Suomussalmi greenstone belt. In addition to evolution lines, initial ratios are shown for samples, which have been dated using U-Pb: 2.82 Ga Mesa-aho porphyry (A1428), Kilpasuo andesite (A1429), 2.87 Ga Tormua gabbro (A1821) and 2.94 Ga felsic volcanic rocks (A1593, A1192). The evolution of depleted mantle is from DePaolo (1981). Note that samples A1192, A1065A and A1467 (outside the figure) are strongly altered, pale schists and do not register primary isotope signatures.

closed. The porphyry sample A1593, which provided a U-Pb monazite age of 2942 ± 3 Ma, is texturally devoid of alteration such as seen in the related, above-mentioned samples, and could thus be assumed to preserve also its primary chemical characteristics. The Sm-Nd analyses of this sample provide ε_{Nd}(2942) of ~-3 and a model age T_{DM} of ca. 3.3 Ga. The three fine-grained, volcanoclastic rocks from the nearby Ala-Luoma site give model ages of 3.2-3.4 Ga (A1191, A1179A, A1179C), and the felsic volcanogenic rocks from Mesa-aho, 2.5 km SSW of Ala-Luoma, yield T_{DM} of 3.1-3.3 Ga (A1428, A1594, EJL-92-71, Figs. 12 and 13). Model ages in excess of 3.0 Ga are also obtained from the three volcanic rocks analyzed from Kiannanniemi located 15 km SW of Ala-Luoma (e.g. A1514 in Fig. 4), as well as from sample A1429 at Tormua (Fig. 4).

The analysis from the Mesa-aho porphyry A1428 shows high REE concentrations (Nd=52 ppm) with a very strong LREE enrichment ($^{147}Sm/^{144}Nd$ = 0.068). Another sample (EJL-92-71) a few meters north of the sampling site of A1428 also has high REE contents but a less fractionated, "typical crustal" REE pattern ($^{147}Sm/^{144}Nd$ = 0.116). The Sm-Nd analyses from these two samples suggest an age of 2.75 ± 0.05 Ga (epsilon -4), which is close to the U-Pb zircon age of 2.82 Ga for A1428. Provided that both samples originated from the same chemically and isotopically homogenous source, the result suggests that the strong LREE enrichment in A1428 is probably related to the generation of the rock at 2.82 Ga, and thus the model age of 3.08 Ga for A1428 would be "too young" to depict the age of the protolith. The model age of 3.26 Ga calculated for sample EJL-92-71 likely reflects more closely the age of the protolith.

In summary, excluding the strongly altered samples, the bulk of the data from the Suomussalmi greenstone belt yield Sm-Nd crustal residence ages (T_{DM}) of 3.0-3.3 Ga. These old model ages are supported by the inherited ca. 3.2 Ga and 3.53 Ga zircons found in the Saarikylä and Kiannanniemi samples (Huhma et al. this volume). The results can be compared with the Sm-Nd data available from the Archaean felsic rocks in Finland (Fig. 7). Although most of these results come from granitoids, some data from volcanic and

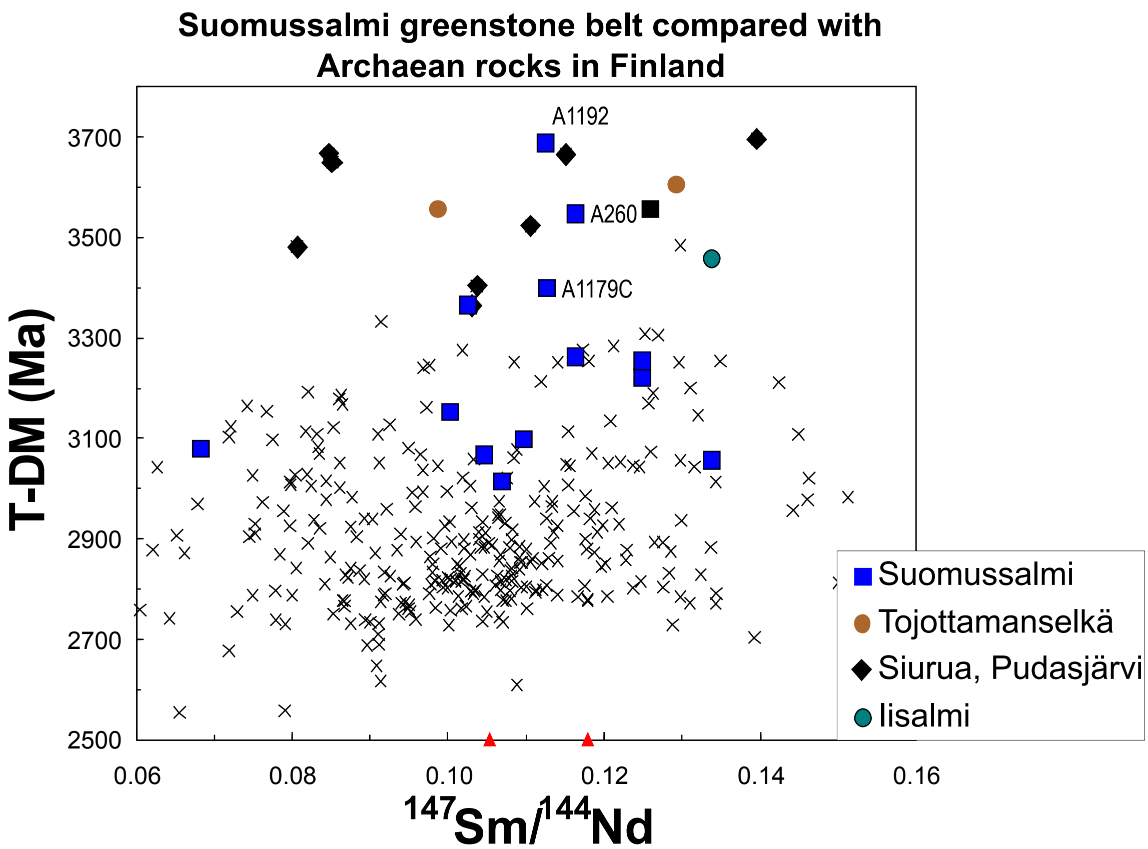

Fig. 7. Sm-Nd model age (T_{DM}) vs. $^{147}Sm/^{144}Nd$ diagram for Archaean felsic rocks in Finland. Blue squares denote samples from the Suomussalmi greenstone belt. The reference data (×) are mostly from granitoids, but include also some volcanic and sedimentary rocks (Jahn et al. 1984, Huhma 1986, O'Brien et al. 1993, Hölttä et al. 2000, Halla 2002, Hanski et al. 2001, Mutanen & Huhma 2003, Käpyaho et al. 2006, Lauri et al. 2006, 2011, Kontinen et al. 2007, Mikkola et al. 2011a, b, Huhma et al. this volume). Red triangles denote the average $^{147}Sm/^{144}Nd$ ratios for bulk (0.1179) and upper (0.1053) crust by Rudnick and Gao (2004).

sedimentary rocks are also included. Although some disturbance in the Sm-Nd system is apparent, it is also clear that samples from the Suomussalmi greenstone belt have older crustal residence ages than most rocks in other areas. Only samples from the ca. 3.5 Ga Siurua gneiss (Mutanen & Huhma 2003, Lauri et al. 2011, Huhma et al. this volume) and the 3.1-3.2 Ga gneisses from Tojottamanselkä, central Lapland (Jahn et al. 1984, Hanski et al. 2001) and the Iisalmi/Lapinlahti area (Hölttä et al. 2000) have yielded reliable model ages in excess of 3.2 Ga. The old model ages are consistent with the Pb-Pb and U-Pb record from the Suomussalmi greenstone belt suggesting stronger involvement of older crustal material than in other greenstone belts in Finland (Huhma et al. this volume, Vaasjoki et al. 1999). On the western margin of the Suomussalmi belt relatively old crustal signatures are evident also in the granitoids (A79, A1856, A1909).

KUHMO

The Sm-Nd data produced at GTK from the Kuhmo area consist of 120 samples and cover all three major rock units, i.e., the Kuhmo-Tipasjärvi greenstone belt (47 samples), granitoids (56 samples) and enclaves of Nurmes paragneiss (15 samples). Results from the Nurmes paragneisses and associated amphibolites were published by Kontinen et al. (2007) and half of the analyses on granitoid samples by Käpyaho et al. (2006).

As discussed above, Sm-Nd studies on the komatiites from the Kuhmo-Tipasjärvi greenstone belt have shown major metamorphic disturbances (Gruau et al. 1992, Tourpin et al. 1991, this paper). Results from many mafic rocks, however, suggest a mantle source which had time-integrated depletion in LREE with $\varepsilon_{Nd(2800)}$ of +2 (see above), providing a framework for crustal residence studies.

Most **granitoids** analyzed from the Kuhmo area yield T_{DM} model ages in the range 2.8-2.95 Ga, and only three samples unambiguously suggest model ages older than 3 Ga (A404, A1706, A1928, Figs. 8 and 9). Two of these gneissic granitoids give U-Pb zircon ages older than the majority of the rocks of the Kuhmo domain, where most granitoids have U-Pb zircon ages at 2.70-2.75 Ga (17 samples) and a few at 2.79-2.83 Ga (3 samples). Most of these granitoids have positive initial epsilon values, which together with the results on felsic volcanic rocks from the greenstone belt (red triangles – Kellojärvi area, green circles – Tipasjärvi in Fig. 8) clearly show that the bulk of the crust in the Kuhmo domain had to be of relatively juvenile nature. Also, most results from the sedimentary rocks within the greenstone belt (solid blue circles in Fig. 8) and Nurmes paragneisses (open blue circles) typically suggest a relatively short crustal prehistory for their sediment sources.

It should be noted that a few samples, for which the calculated model ages are above 3 Ga, were excluded from the discussion above. This is because these samples have Sm/Nd slightly higher than typical crustal felsic rocks and thus may not be relevant for T_{DM} calculations (e.g. granitoids 94003191 and A1183, and metasediments 1-KUH-88, 44-PGN-90, A1746 in Appendix 1). The Naavala migmatitic gneisses provide a related case requiring some special attention. The Naavala gneisses were among the targets for crustal genesis studies by Martin et al. (1983), who dated them, using Rb-Sr whole rock method at 2.62 ± 0.07 Ga. Subsequently GTK reported a much older U-Pb zircon age of 2.75 Ga (Luukkonen 2001) for the same rock. Sm-Nd analyses were also carried out at GTK on nine samples from the Naavala site representing the main rock types observed in the Naavala gneiss domain. These include tonalite-granodiorite mesosomes, different granitic dykes or leucosomes and an amphibolite band (A1183 and Naa samples in Appendix 1 and Fig. 8). The Sm-Nd results on these samples are strongly scattered with $\varepsilon_{Nd(2750)}$ values ranging from -3.9 to +2.3 (equivalent to T_{DM} model ages from 3.30 to 2.74 Ga). Duplicate analyses show good reproducibility and hence the reason for the scatter is related to the complex geological history of the Naavala gneiss. A particularly striking aspect is that a large difference in the Sm-Nd isotope composition can be observed even between the whole rock sample A1183 (T_{DM}=3.3 Ga) and a small piece taken from the very same locality (A1183p, T_{DM}=2.74 Ga). The REE abundance in most samples of the Naavala gneiss is fairly low and Sm/Nd high compared to typical granitoids. Thus it is also likely in this case, that metamorphic effects are mainly responsible for the scatter. However, one of the leucosome dykes/bands (Naa4) has quite high REE abundances and a T_{DM} age of 2.74 Ga, which together with the other data, suggests that material from distinct sources have contributed to the Naavala gneisses.

The results from Naavala underscore the level of caution which is needed when applying Sm-Nd

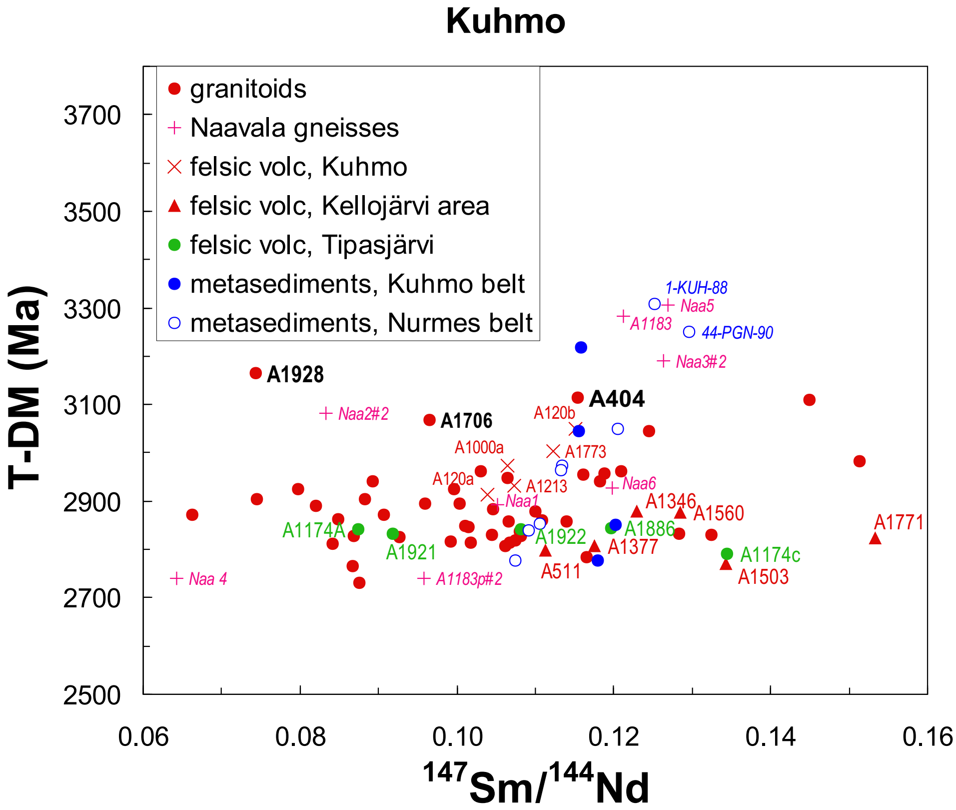

Fig. 8. T_{DM} model ages for felsic rock samples from the Kuhmo domain. Red circles: granitoids and gneisses, red +s: Naavala migmatitic gneisses; red triangles: felsic volcanic rocks and gabbro A1771 from Kellojärvi area in Kuhmo greenstone belt; red ×s: felsic volcanic rocks from other Kuhmo greenstone belt; green circles: felsic volcanic rocks from Tipasjärvi greenstone belt; blue solid circles: metasediments from the Kuhmo greenstone belt; blue open circles: metasediments from the Nurmes paragneiss belt.

data, particularly to rocks which evidently have complex geological histories, such as polymigmatitic rocks or rocks that have been subjected to retrogressive metamorphic-hydrothermal events. On the other hand, there are examples that for even widely spaced samples from a well preserved, non-retrogressed rock unit may yield results all within analytical error. These include the Koitere "sanukitoid" samples in the Ilomantsi area (Halla 2005, Fig. 11), and the Kaapinsalmi and Kuusamo "sanukitoids" discussed above (Heilimo et al. 2013, Appendix 1, Fig. 4).

The Sm-Nd results on mafic-ultramafic rocks from the Kuhmo **greenstone belt** were discussed above. Although the results are scattered due to metamorphic effects, most komatiites and komatiitic basalts from the Kellojärvi area give $\varepsilon_{Nd(2800)}$ values of about +0.5 (red x in Fig. 10), whereas mafic rocks from other locations tend to have more positive $\varepsilon_{Nd(2800)}$ values.

In order to evaluate the crustal residence time and origin of felsic lithologies, whole rock Sm-Nd isotope compositions were measured for some of the samples which have been used for U-Pb dating. These samples were carefully selected to represent the lithological or stratigraphical units in question. The U-Pb age, if available, is used for calculating the initial ε_{Nd} values (Fig. 10). As was discussed above, there are some examples also in felsic rocks, where metamorphic effects have seriously disturbed the Sm-Nd system, rendering it impossible to get information on primary isotopic compositions. Typically, such samples tend to show LREE depletion and generally have low levels of REE. In our data set of felsic rocks, there are two samples (A788 and A1746) which yield very low apparent initial epsilon values (-22, -11) and are also clearly LREE-depleted compared to common felsic rocks (Nd 3-5 ppm). On the other hand, the calculated initial ratio for the Hetteilä mica schist sample A1774 is anomalously high (+4 at 2.74 Ga). The calculated initial ratios for ancient rocks are very sensitive to even slight changes in Sm/Nd, and in the case of this sample, for example, an increase of Sm/Nd by 6% would drop the epsilon value to +2.

In spite of these problems, the data as a whole provide useful information. The samples analyzed from the Kellojärvi area (A-series felsic volcanics and gabbros) give clearly positive initial ε_{Nd} values from +1.2 to +2.4 and thus appear to represent largely juvenile crustal material. The Sm-Nd results from the Tipasjärvi felsic volcanic rocks

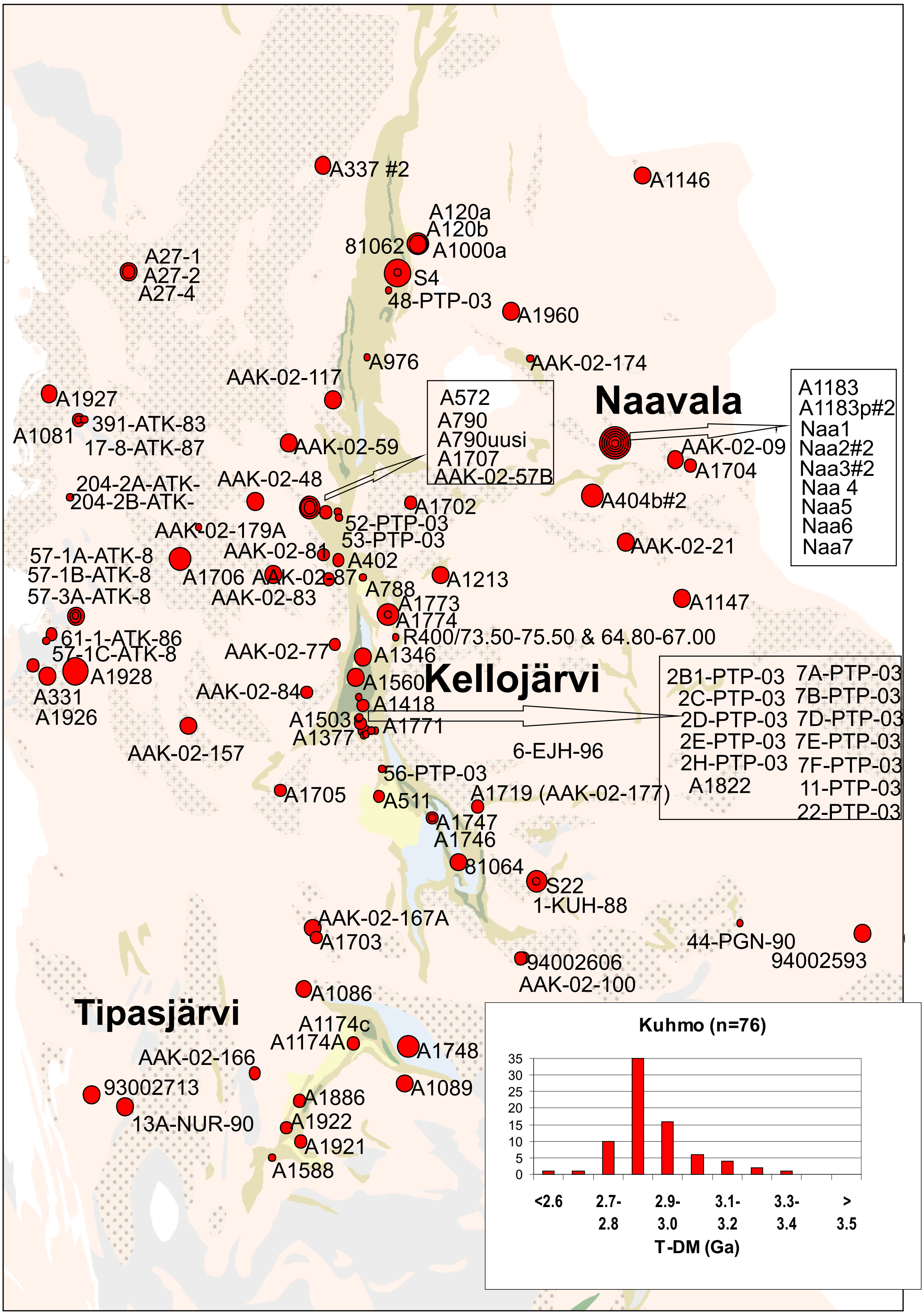

Fig. 9. Geological map of the Kuhmo area showing Sm-Nd sample sites. The size of the symbol denotes the model ages divided into six categories: < 2.7 Ga (small), 2.7-2.85 Ga, 2.85-3.0 Ga, 3.0-3.15 Ga, 3.15-3.3 Ga, >3.3 Ga (large, only one Naavala sample, likely not primary signature, see text). Model ages are not reported for samples which have $^{147}Sm/^{144}Nd$> 0.16, and symbols for these mostly mafic rocks are small black circles (e.g. A976). The map is based on the 1: 1 000 000 geological map of Korsman et al. (1997), with the greenstone belts divided into four main rock types, mafic metavolcanic rocks (brown), ultramafic metavolcanic rocks (green), intermediate-felsic metavolcanic rocks (yellow) and metasediments (blue). Rocks outside the greenstone belts consist of TTG's, intrusive rocks (stippled), amphibolites (brown) and paragneisses (grey).

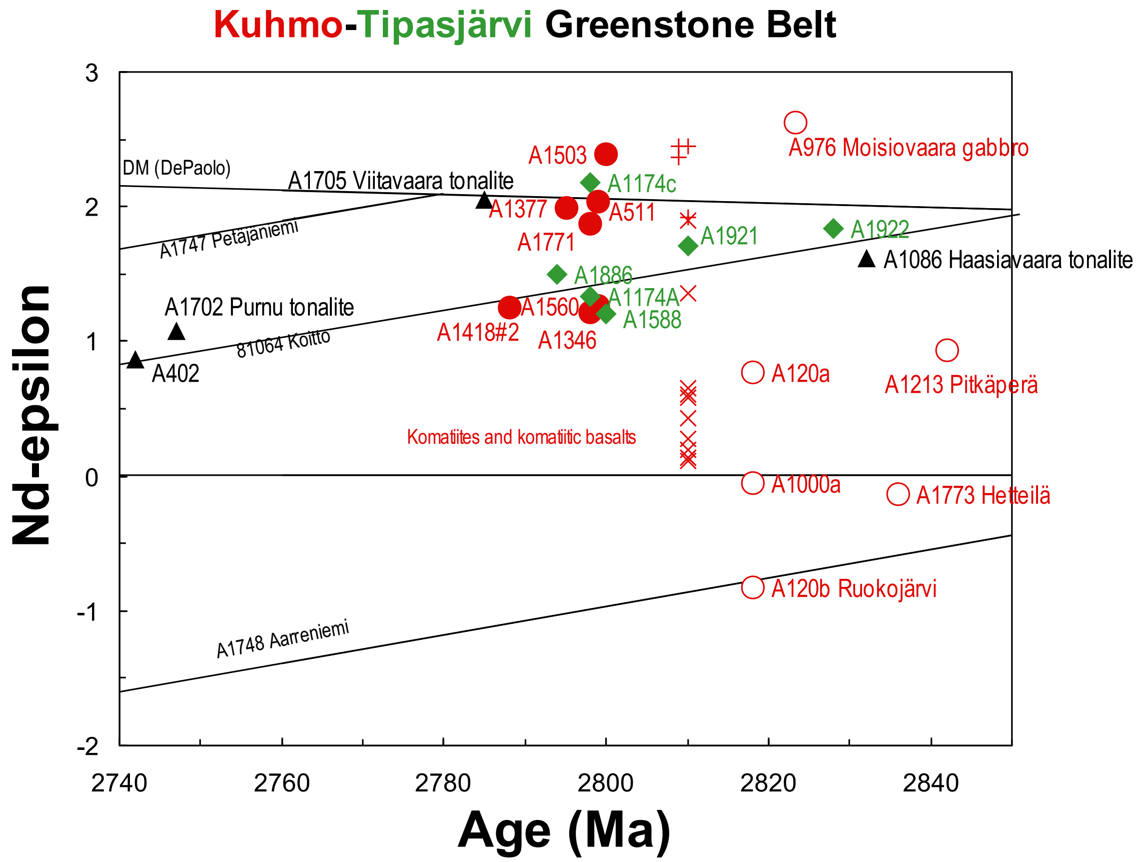

Fig. 10. Epsilon-Nd vs. age diagram for whole-rock samples from the Kuhmo and Tipasjärvi belt, showing initial values for A-series samples from the Kellojärvi area (filled red circles), komatiites and komatiitic basalts from Pahakangas-Siivikkovaara (10 samples, red ×s), other areas from the Kuhmo (open red circles for A-series, red +s for basalts) and Tipasjärvi belts (green diamonds). An age of 2800 Ma is used for A1503 and A1588, 2810 Ma for komatiites and basalts, and U-Pb zircon age for other samples. Also are shown the evolution lines for three sedimentary rocks and the model depleted mantle (De Paolo 1981). The initial epsilon values for four granitoids (triangles) are shown for reference: A1086-Haasiavaara tonalite, A1705-Viitavaara tonalite, A1702-Purnu tonalite and A402-Härmäjoki felsic dyke intruding the greenstones (Käpyaho et al. 2006).

are similar. The three samples from the 2.82 Ga Ruokojärvi volcanic unit are low in REE (Nd ~ 6 ppm), but still show normal, LREE-enriched chondrite-normalized REE patterns. They give a small range of initial values from -0.8 to +0.8 (Fig. 10).

ILOMANTSI

The Ilomantsi area, south from the Kuhmo domain, covers the southernmost part of the Archaean bedrock in Finland consisting of granitoid areas and the Ilomantsi (Hattu) and Kovero schist belts (Fig. 11). The Sm-Nd data available on the Archaean rocks from the Ilomantsi area consist of roughly 60 samples, which represent granitoids (27 samples), felsic and mafic-ultramafic volcanic rocks (23) and metasediments. Some of these results have been published in Huhma (1987), O'Brien et al. (1993), Halla (2005), and Kontinen et al. (2007).

Most of the analysed granitoids have model ages of 2.75-2.9 Ga, and only analyses from the Silvevaara/Lehtovaara pluton give slightly older T_{DM} ages of ca. 3 Ga (A339, A284, Fig. 12). This 2.75 Ga granodiorite also contains inherited zircons older than 3 Ga (Sorjonen-Ward & Claoué-Long 1993), and thus both Sm-Nd and U-Pb data suggest involvement of older crustal material in

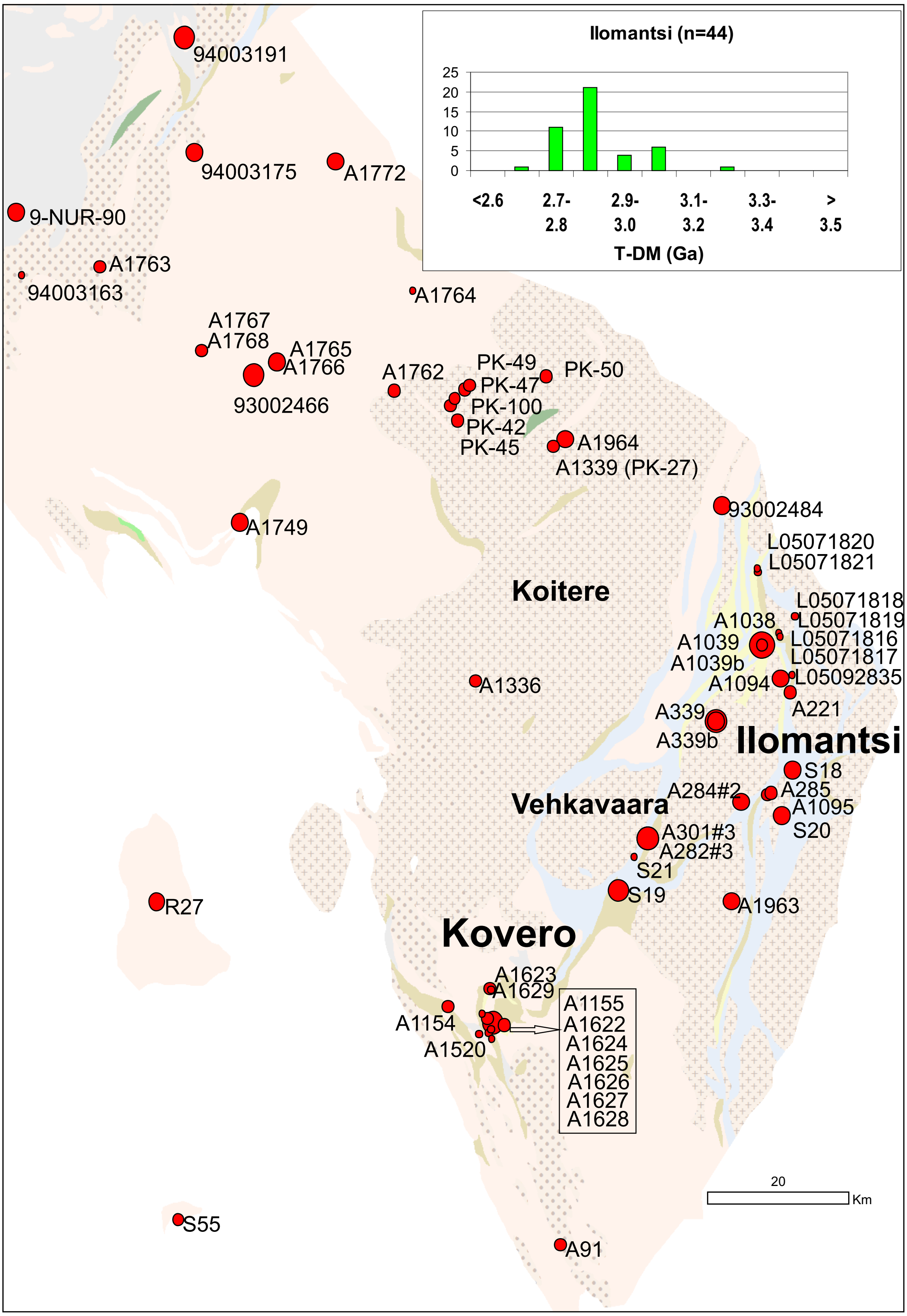

Fig. 11. Geological map of the Ilomantsi area showing Sm-Nd sample sites. The size of the symbol denotes the model ages divided into six categories: < 2.7 Ga (small), 2.7-2.85 Ga, 2.85-3.0 Ga, 3.0-3.15 Ga, 3.15-3.3 Ga two samples, probably neither with primary signatures), >3.3 Ga (large, no reliable data in Ilomantsi area). Model ages are not presented for samples which have $^{147}Sm/^{144}Nd$> 0.16, and symbols for these mostly mafic rocks are small black circles. The map is based on the 1: 1 000 000 geological map of Korsman et al. (1997), with the greenstone belts divided into three main rock types, mafic (and minor ultramafic) metavolcanic rocks (brown), intermediate-felsic metavolcanic rocks (yellow) and metasediments (blue). Rocks outside the greenstone belts consist of TTG's, intrusive rocks (stippled), amphibolites (brown) and paragneisses (grey).

the genesis of the Silvevaara pluton, as well as in the case of nearby Vehkavaara dykes (A282, A301, see Huhma et al. this volume). Also the 2.88 Ga felsic tuff A1627 from the Kovero schist belt, and sample 93002466 give T_{DM} in excess of 3 Ga, but the latter has high Sm/Nd, and possibly does not provide a relevant T_{DM} age.

As was discussed above, mafic and ultramafic volcanic rocks from the Ilomantsi greenstone belt yield a large range of initial-epsilon $\varepsilon_{Nd}(2750)$ values from -7.6 to +3.4 (Fig. 3), probably because of serious modification in Sm/Nd by metamorphic-hydrothermal fluids. The Sm-Nd results from the felsic volcanic rocks are also scattered due to metamorphic effects (Fig. 12). Especially suspect are the old calculated model ages for samples which have relatively high Sm/Nd (A1038 and A1625). A similar tendency towards elevated Sm/Nd and T_{DM} ages is also obvious with the analyses on some metasediments. Based on those felsic samples which have REE patterns close to average crustal values ($^{147}Sm/^{144}Nd$=0.09-0.12) we may nevertheless estimate that the bulk the Ilomantsi area contains relatively juvenile Neoarchaean crust. This concerns particularly the granidoids denoted as "Koitere sanukitoids" (Fig. 11), which have yielded T_{DM} model ages of ca. 2.8 Ga (Halla 2005, Heilimo et al. 2013).

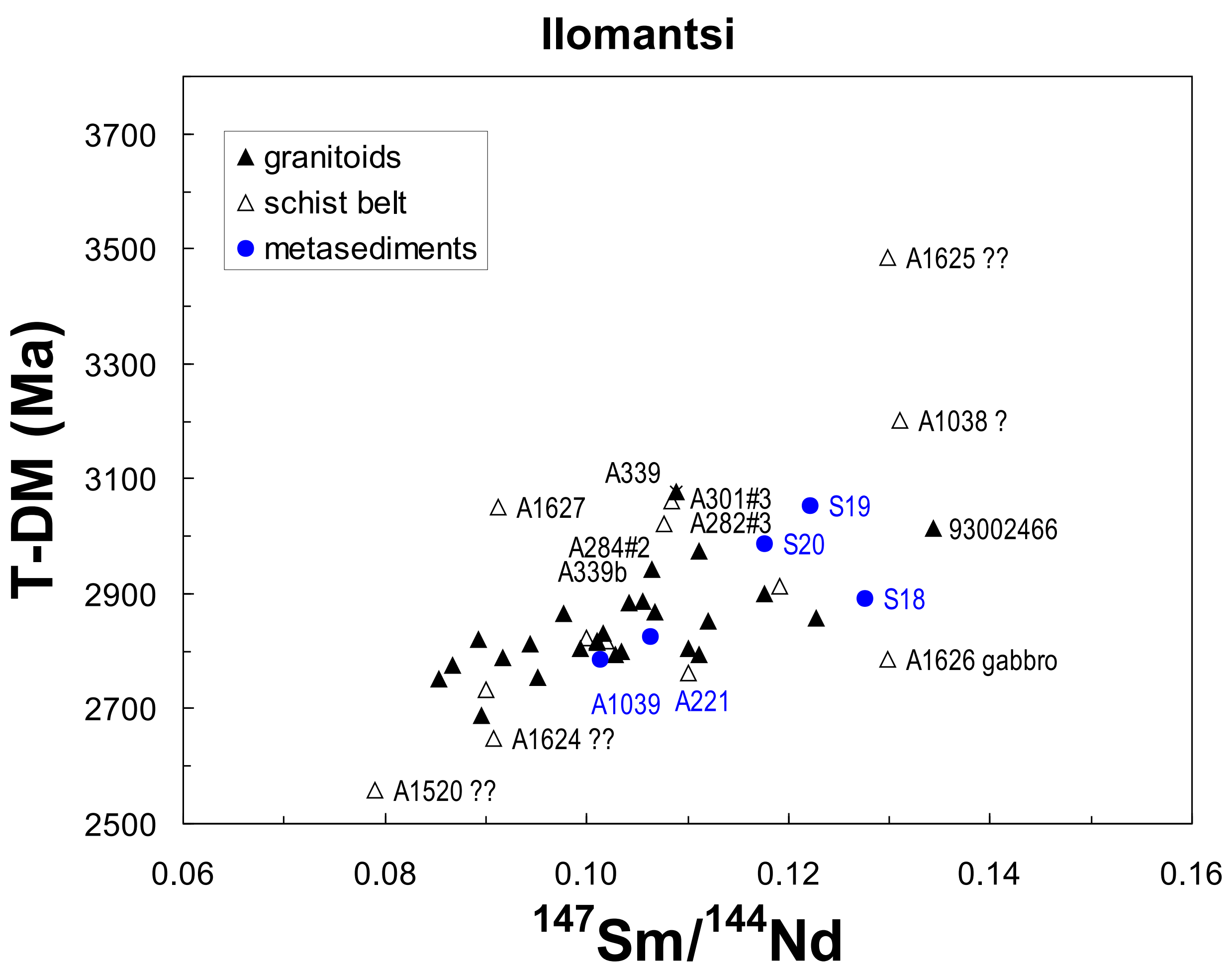

Fig. 12. Sm-Nd model ages for the Archaean rocks in Ilomantsi. Solid triangles denote granitoids and open triangles rocks from the Ilomantsi and Kovero schist belts. Blue circles are metasediments. Some samples have suffered secondary REE mobility (at least those marked with "?").

PUDASJÄRVI

The Sm-Nd data available on the Archaean rocks from the Pudasjärvi block consist of analyses on 47 granitoids/gneisses, six mafic rocks, two mica gneisses and a 2.82 Ga metadacite sample (A1783) from the Oijärvi schist belt (Appendix 1). Some of these data have been published by Huhma (1986), Mutanen and Huhma (2003) and Lauri et al. (2011). Mafic rocks analysed include a 2.8 Ga gabbro (A1782) from the Oijärvi belt and amphibolites/ mafic granulites in the granitoid areas. These rocks mostly have relatively flat REE patterns and yield positive initial epsilon values suggesting origin from a depleted mantle source.

The Sm-Nd data on felsic rocks reveal a large range of crustal residence ages with T_{DM} model ages up to 3.7 Ga (Fig. 13). An even older model age (3.86 Ga) was obtained from one sample (TM-04-9.1, Appendix 1, not shown in Fig. 13), but the relatively high Sm/Nd and low REE in this sample probably indicate metamorphic disturbances. The oldest reliable T_{DM} ages (3.67 Ga) were obtained from the tonalitic Siurua gneisses relatively devoid of granitic leucosomes. The old ages are consistent with U-Pb zircon studies, which in addition to abundant 3.5 Ga zircon grains, have recognized a few old cores up to 3.7 Ga (Mutanen & Huhma 2003, Lauri et al. 2011). The presence of such very old material is also evident from the Lu-Hf results (Lauri et al. 2011).

In addition to the classical Siurua outcrops, Sm-Nd model ages above 3.3 Ga were obtained also from migmatitic gneisses in Kolkkoaho, located 20 km north of the Siurua locality (Fig. 14). Rocks around the Siurua and Kolkkoaho sites have generally yielded model ages between 3.0 and 3.2 Ga, whereas samples from other parts of the Pudasjärvi area yield model ages mostly between 2.7 and 3.0 Ga.

The two Archaean mica gneisses (A1814, A1842) analyzed from the Pudasjärvi area have model ages of 2.81 and 2.74 Ga and thus contain relatively juvenile detritus strongly distinct from the Siurua gneisses. The young model ages of the mica gneisses are consistent with the U-Pb ages of their detrital zircon grains, which are mostly less than 2.75 Ga (Huhma et al. this volume).

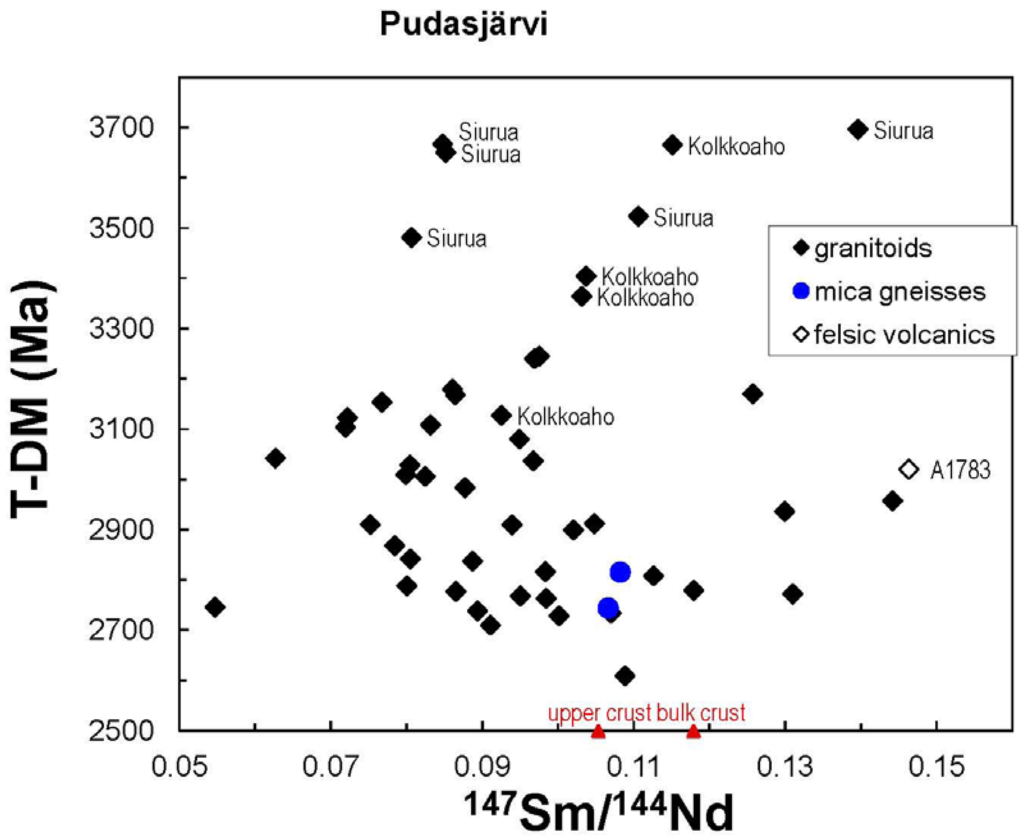

Fig. 13. Sm-Nd model ages T_{DM} from the Pudasjärvi area. The Sm/Nd ratios for average bulk and upper crust are from Rudnick and Gao (2004).

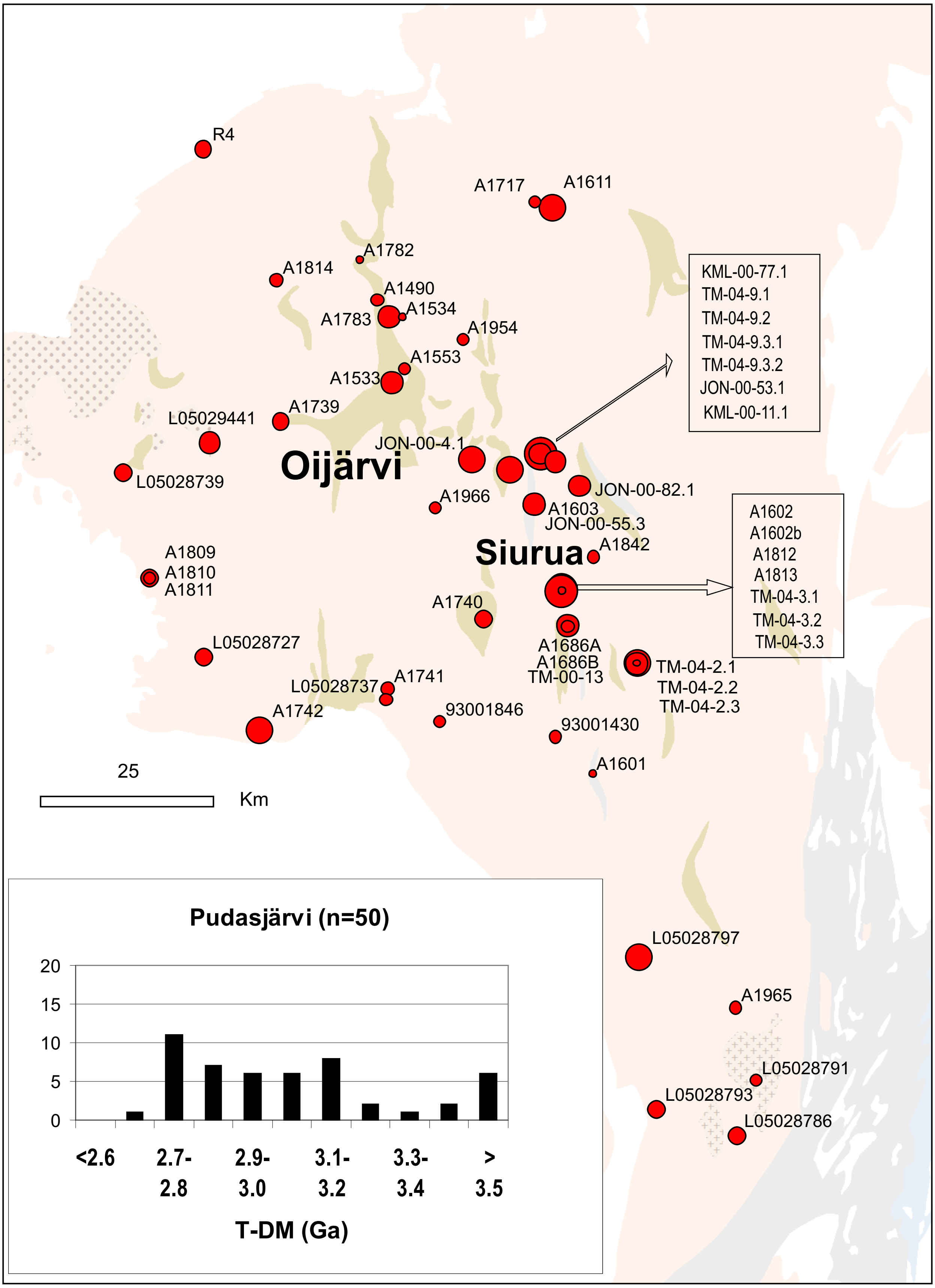

Fig. 14. Geological map of the Pudasjärvi area showing Sm-Nd sample sites. The size of the symbol denotes the model ages divided into six categories: < 2.7 Ga (small), 2.7-2.85 Ga, 2.85-3.0 Ga, 3.0-3.15 Ga, 3.15-3.3 Ga, >3.3 Ga (large). Model ages are not presented for mafic rocks which have $^{147}Sm/^{144}Nd$> 0.16 (A1601, A1782). The map is based on the 1: 1 000 000 geological map of Korsman et al. (1997), where main units are the Oijärvi greenstone belt (brownish), granitoid areas and paragneisses (grey).

IISALMI, MANAMANSALO & CENTRAL PUOLANKA GROUP

Most of the 25 Sm-Nd analyses available from the Iisalmi complex have been published by Hölttä et al. (2000), Halla (2005) and Lauri et al. (2011). These results show that the 3.1-3.2 Ga old rocks from the Lapinlahti site also give T_{DM} model ages in the same range (Appendix 1, Figs. 15 and 16). The calculated model age for sample A76 is clearly older, but the high Sm/Nd leaves room for speculation of possible open system behavior. The Sm–Nd data on samples from other localities in the Iisalmi complex provide T_{DM} ages generally in the range of ca. 2.75–2.82 Ga.

The nine granitoid samples from the Manamansalo area, between the Iisalmi and Pudasjärvi terrains, display older average Sm-Nd model ages than the samples from Iisalmi, Ilomantsi and Kuhmo areas. Four analyzed volcanic rocks from the Central Puolanka Group in the Kivesvaara area, east from the Manamansalo granitoid-gneiss complex (e.g. A1292 in Fig. 16), display Sm-Nd characteristics typical for Archaean rocks in Finland, suggesting Archaean ages for these relatively well-preserved intermediate to felsic supracrustal rocks.

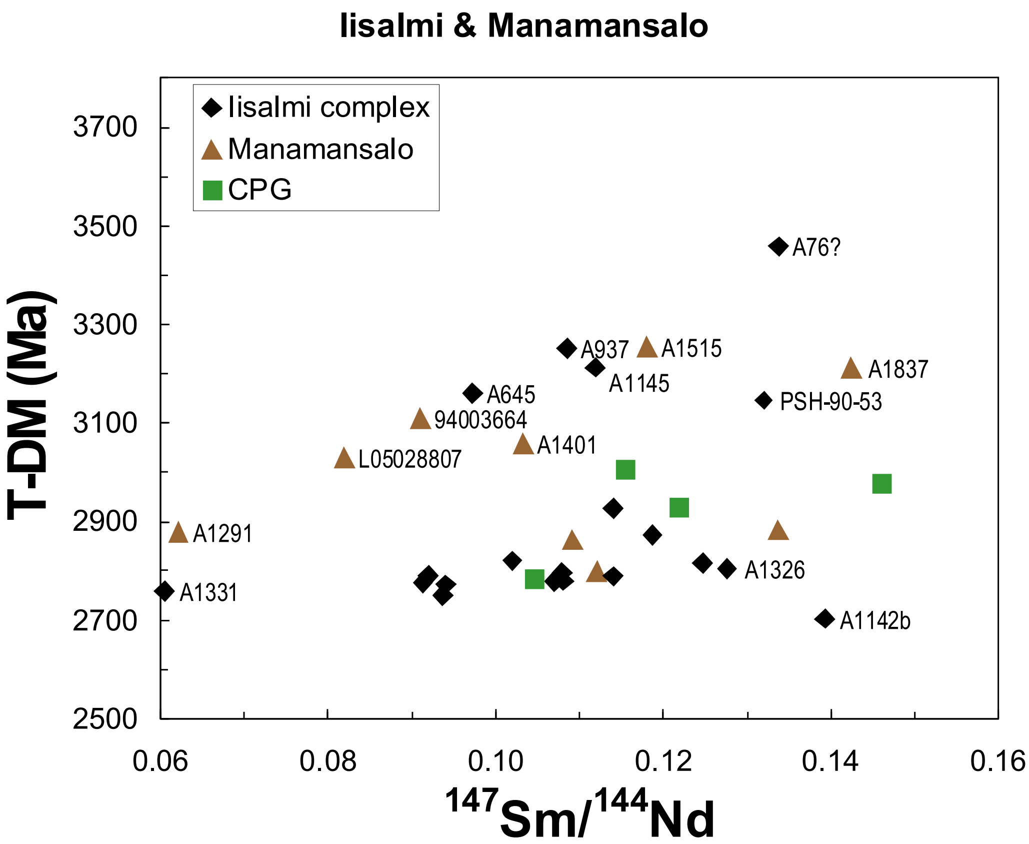

Fig. 15. Sm-Nd model ages for the Archaean rocks in the Iisalmi (diamonds) and Manamansalo (triangles) areas, and four volcanic rocks from the Central Puolanka Group (CPG, green squares).

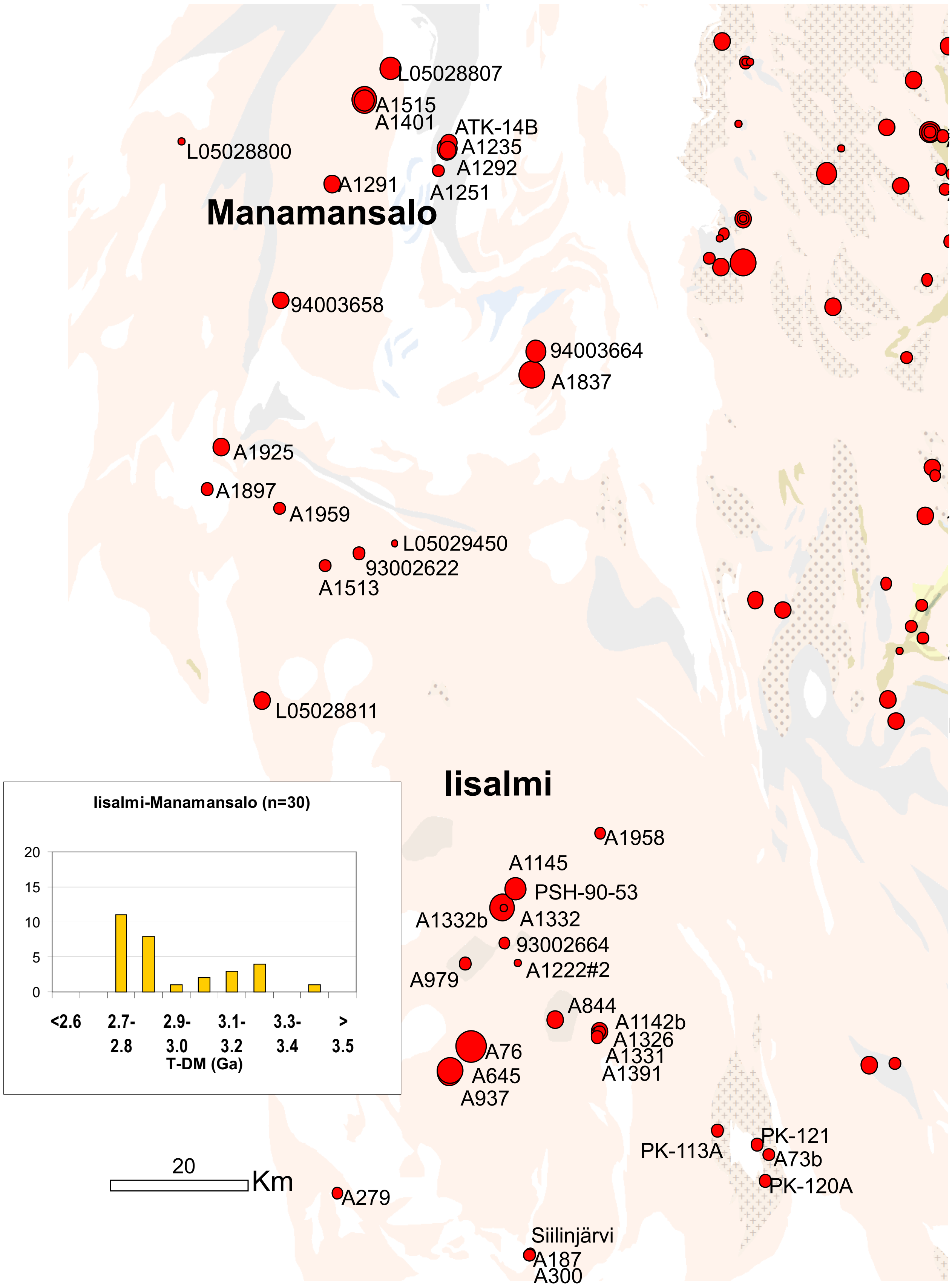

Fig. 16. Geological map of the Iisalmi complex and Manamansalo areas showing Sm-Nd sample sites. The size of the symbol denotes the model ages divided into six categories: < 2.7 Ga (small), 2.7-2.85 Ga, 2.85-3.0 Ga, 3.0-3.15 Ga, 3.15-3.3 Ga, >3.3 Ga (large, only sample A76, likely not a primary signature). Model ages are not presented for mafic samples which have $^{147}Sm/^{144}Nd$> 0.16. The map is based on the 1: 1 000 000 geological map of Korsman et al. (1997), where the main rock types consist of TTG's, intrusive granitoids (stippled), and paragneisses (grey).

DISCUSSION

The Sm-Nd isotopic data reviewed here provide a general view of the formation of the 2.6-3.5 Ga Archaean crust in Finland representing a large part of the Fennoscandian Shield. However, the picture provided is somewhat blurred as in many places secondary effects on the Sm-Nd system have been strong, resulting in compositions that are virtually useless for evaluating primary signatures. The main reason for post-formation open system behaviour has in many cases traced back to CO_2-rich metamorphic-hydrothermal fluids, which are able to dissolve and transport REE (Tourpin et al. 1991, Gruau et al. 1992). Alteration effects are most common in fine-grained volcanogenic rocks, especially if the sample locations are close to fault/shear zones. Many of the altered samples tend to have relatively low abundances of REE and exhibit depletion in LREE (Appendix 1). On the other hand, several relatively little altered rock associations, e.g. the Koitere granitoids in the Ilomantsi area provide consistent results, which suggests that the Sm-Nd systems have remained closed since the rock forming events.

Despite of the problems introduced by metamorphic-hydrothermal modification, the Sm-Nd results reviewed here clearly show that a mantle reservoir with time-integrated depletion in LREE and other incompatible elements was an important source of magmas already during the Archaean time. This observation is supported by the positive initial epsilon values obtained from the Archaean mafic-ultramafic rocks on the Russian side (e.g., Lobach-Zhuchenko et al. 1999, Puchtel et al. 1998, 1999, Svetov et al. 2001, 2004). It is possible that komatiites in Kuhmo had more primitive mantle plume sources with $\varepsilon_{Nd}(2800)$ values of +0.5 (Fig. 18) than e.g. Kostomuksha komatiites, but the secondary mobility of REE leaves room for speculation. Existence of mantle sources close to chondritic Nd-isotopic composition are supported by the 2609 ± 3 Ma Siilinjärvi carbonatite, whereas Sm-Nd results on the 2741 ± 2 Ma old Likamännikkö carbonatite imply that some mantle source materials had positive ε_{Nd}-values. Given this strong evidence for depleted mantle sources, we consider that the model of DePaolo (1981) is a useful reference when evaluating the formation of the Archaean crust.

The Sm-Nd data on samples dated by U-Pb allow evaluation of the relative importance of crustal growth versus crustal recycling. The results provide a basis for comparison between various Archaean provinces in Finland and Fennoscandia (e.g. Lobach-Zhuchenko et al. 2000), and allow also comparison with other Archaean cratons such as the Superior Province in Canada (Henry et al. 2000). There are more than 200 Archaean samples from Finland for which good-quality U-Pb zircon ages are available, and more than 90 of these have also been analyzed for Sm-Nd isotopes.

In order to further analyse the petrogenetic significance of the data reviewed above, they are shown in Nd-epsilon versus age diagrams presented in Figs. 17A-F. In the diagrams evolution lines are shown for all granitoid samples, and when a U-Pb age is available also an initial Nd-epsilon value is shown by a point on that line. The age considered in the diagrams is restricted between 2.6 to 3.2 Ga since only Siurua gneisses have yielded older U-Pb ages, i.e. ca. 3.5 Ga (Fig. 17A).

Most of the dated Archaean rocks in Finland have ages of 2.68-2.76 Ga (57%) or 2.79-2.84 Ga (25%), and only few samples are older with some clustering seen in ages at ca. 2.86 Ga, 2.95 Ga and 3.1-3.2 Ga (Huhma et al. 2011). Most of the results are from granitoids, and older rocks are typically TTG-gneisses, whereas the youngest group consists of granodiorites and tonalites denoted as sanukitoids (2.74-2.72 Ga), and leucogranitoids and leucosomes in migmatite gneisses (e.g. Käpyaho et al. 2006). It has become evident that in many areas the 2.7-2.8 Ga rocks give mostly positive initial epsilon values and represent relatively juvenile Neoarchaean crust. The felsic rocks within the Kuhmo greenstone belt represent a particularly clear example of new crustal growth from depleted mantle at ca. 2.8 Ga (Fig. 17D). This is consistent with Patchett et al. (1981), who reported an $\varepsilon_{Hf(2800)}$ of +6 for zircon in the rhyolite A511 (Katerma). Many younger, 2.7-2.75 Ga granitoids in Kuhmo may originate from this newly formed crust. Recycling of significantly older crustal materials seems to be more pronounced in the generation of the 2.7-2.8 Ga rocks in the western Koillismaa and Suomussalmi areas, where most initial values are negative (Figs. 17B and C).

The difference between Kuhmo-Tipasjärvi and Suomussalmi belts is emphasized in Fig. 18. The crustal residence ages for the Suomussalmi samples are significantly older exceeding 3 Ga. Notably this concerns not only the 2.95 Ga rocks, unique to the Suomussalmi belt, but also younger 2.82 Ga rocks.

The Sm-Nd model ages T_{DM} for all samples with "typical" upper crustal REE pattern ($^{147}Sm/^{144}Nd < 0.16$) have been compiled in a probability

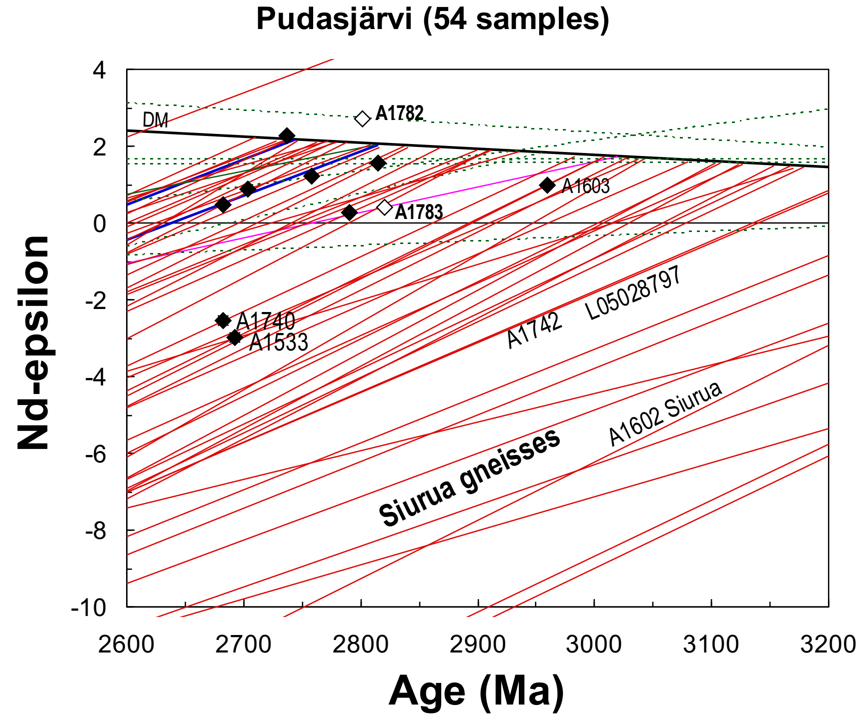

Fig. 17A. Epsilon-Nd vs. age diagram showing evolution lines (red – granitoids, green dotted – mafics, blue – mica gneisses) for the Archaean rocks from the Pudasjärvi area. Diamonds denote initial values for granitoids (solid symbols) and Oijärvi belt gabbro (A1782) and felsic volcanic rock (A1783, solid symbols) for which the ages are based on U-Pb zircon dating. DM (in Fig. 17A-F) is the depleted mantle evolution according to DePaolo (1981). The T_{DM} model age is the intersection of sample evolution with the DM curve. Samples which have T_{DM}>3.05 Ga are all from the Siurua-Kolkkoaho zone, except A1742 and L05028797.

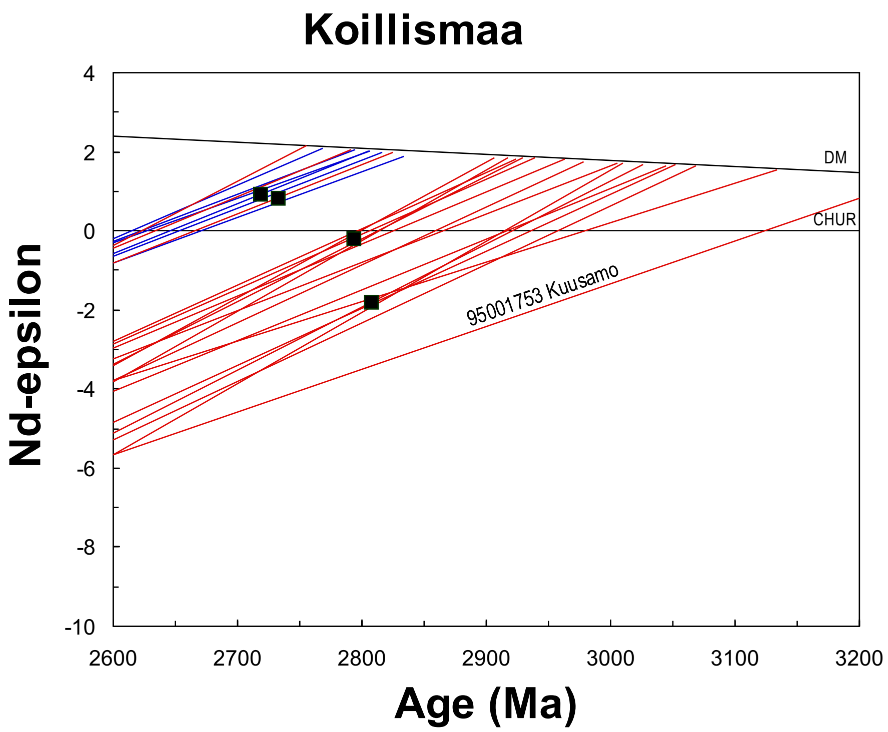

Fig. 17B. Epsilon-Nd vs. age diagram showing evolution lines for 24 Archaean granitoids from the Koillismaa area (six blue lines represent Kuusamo "sanukitoids"near the Russian border, Heilimo et al. 2013). Solid squares denote initial values for granitoids for which the age is based on U-Pb zircon dating.

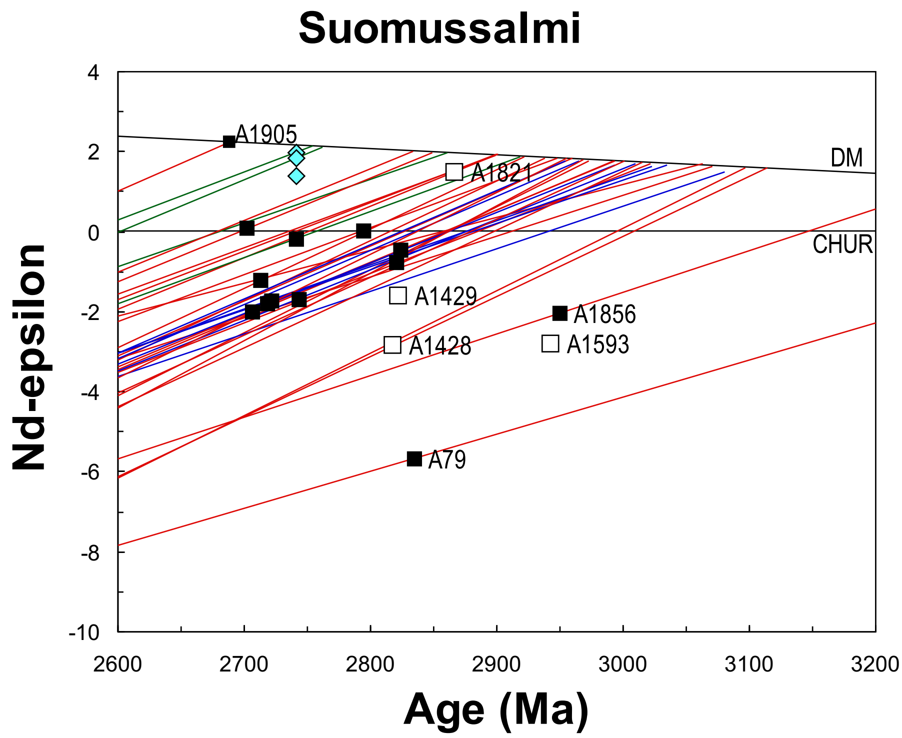

Fig. 17C. Epsilon-Nd vs. age diagram showing evolution lines for 35 Archaean granitoids from the Suomussalmi area: seven blue lines – Kaapinsalmi tonalites (Heilimo et al. 2013), four green lines – Likamännikkö rocks (Mikkola et al. 2011b). Solid squares denote initial values for granitoids for which the age is based on U-Pb zircon dating. Open squares show initial epsilon values (no evolution lines) for the dated volcanic rocks from the Suomussalmi greenstone belt. Light blue diamonds are 2.74 Ga old carbonatite from Likamännikkö (Mikkola et al. 2011b).

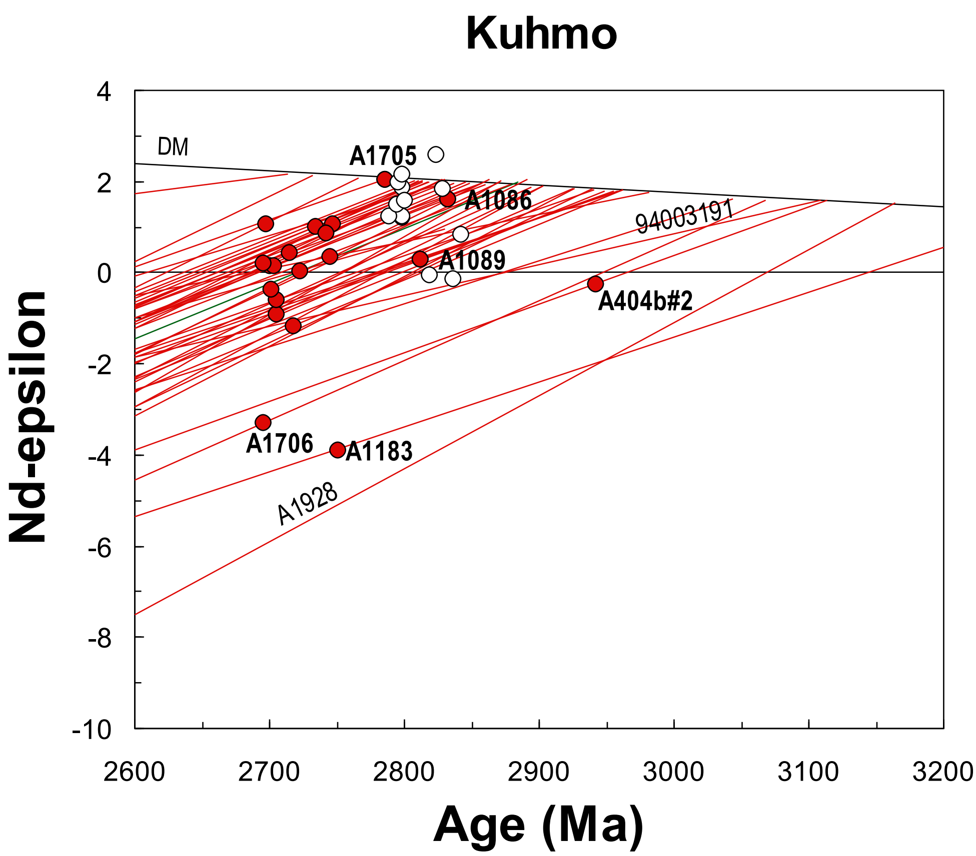

Fig. 17D. Epsilon-Nd vs. age diagram showing evolution lines for 47 Archaean granitoid samples from the Kuhmo area. Solid circles denote initial values for granitoids for which the age is based on U-Pb zircon dating. Open circles show initial epsilon values (no evolution lines) for 14 dated volcanic rocks from the Kuhmo-Tipasjärvi greenstone belt.

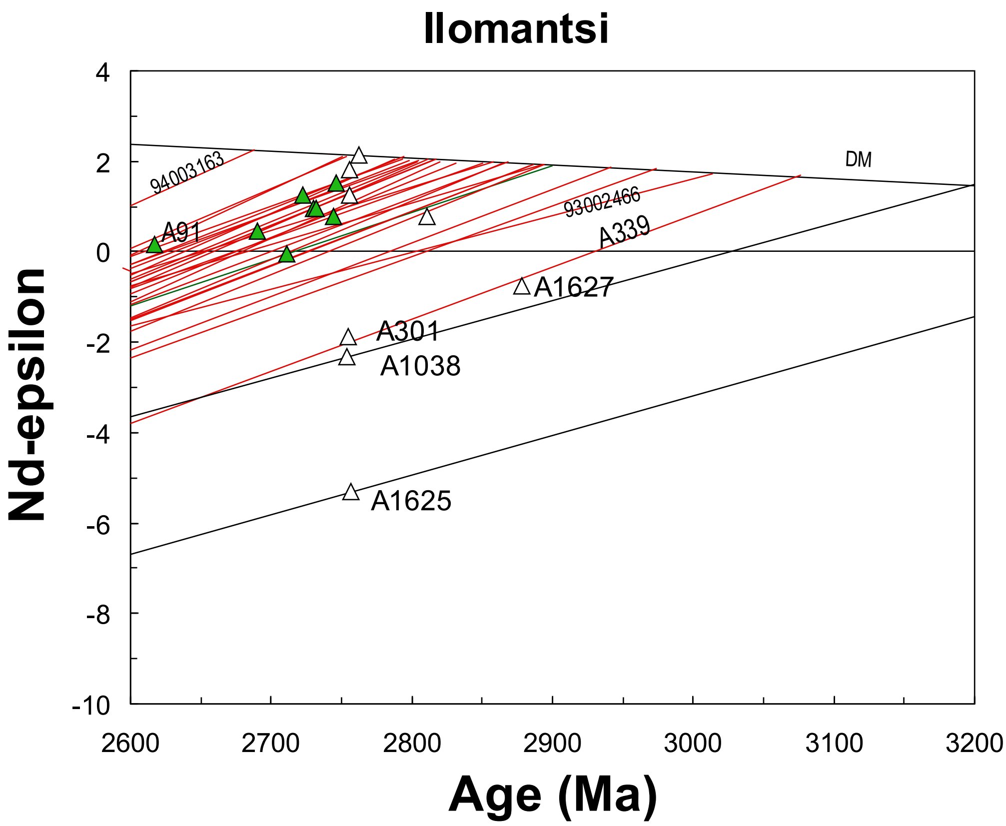

Fig. 17E. Epsilon-Nd vs. age diagram showing evolution lines for the Archaean granitoids from the Ilomantsi area (red, 27 samples). Evolution lines are also shown for two other samples with elevated Sm/Nd (A1038, A1625), which very likely do not represent primary signatures. Solid triangles denote initial values for granitoids for which the age is based on U-Pb zircon dating. Open triangles show initial epsilon values for the dated volcanic rocks from the Ilomantsi-Kovero greenstone belt.

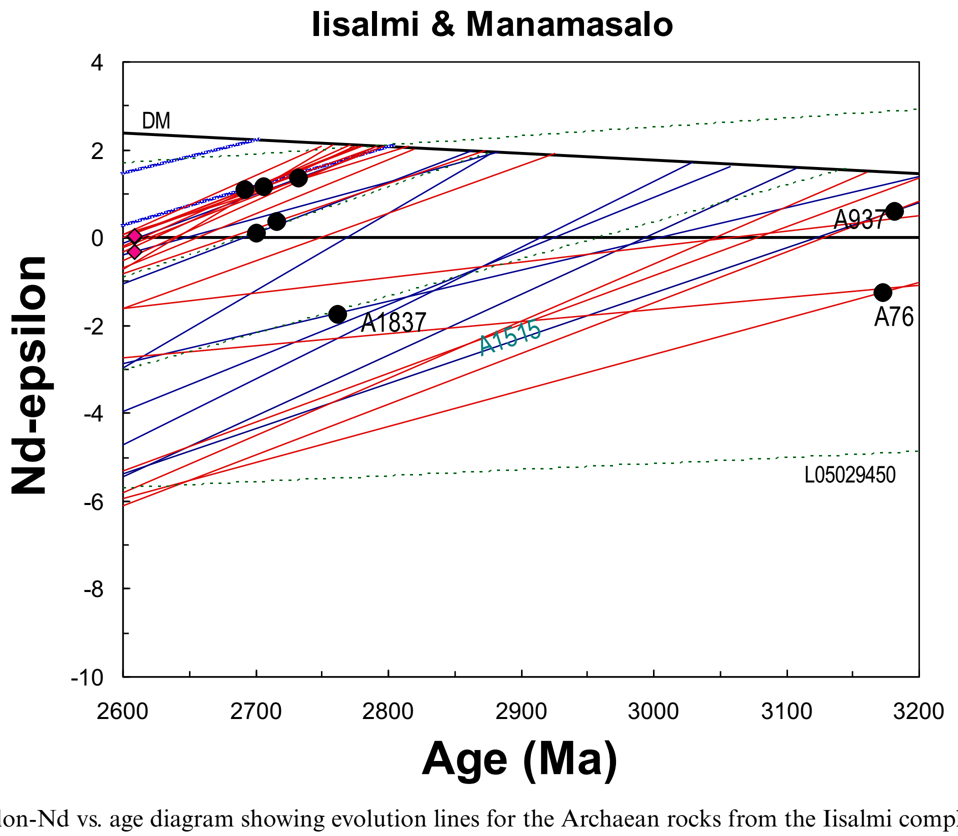

Fig. 17F. Epsilon-Nd vs. age diagram showing evolution lines for the Archaean rocks from the Iisalmi complex (28 samples, red – granitoids, green dotted – four mafic rocks, blue – two metasediments, pink diamond at 2610 ± 4 Ma – Siilinjärvi carbonatite) and Manamansalo area (9 samples, dark blue). Solid symbols denote initial values for granitoids for which the age is based on U-Pb zircon dating.

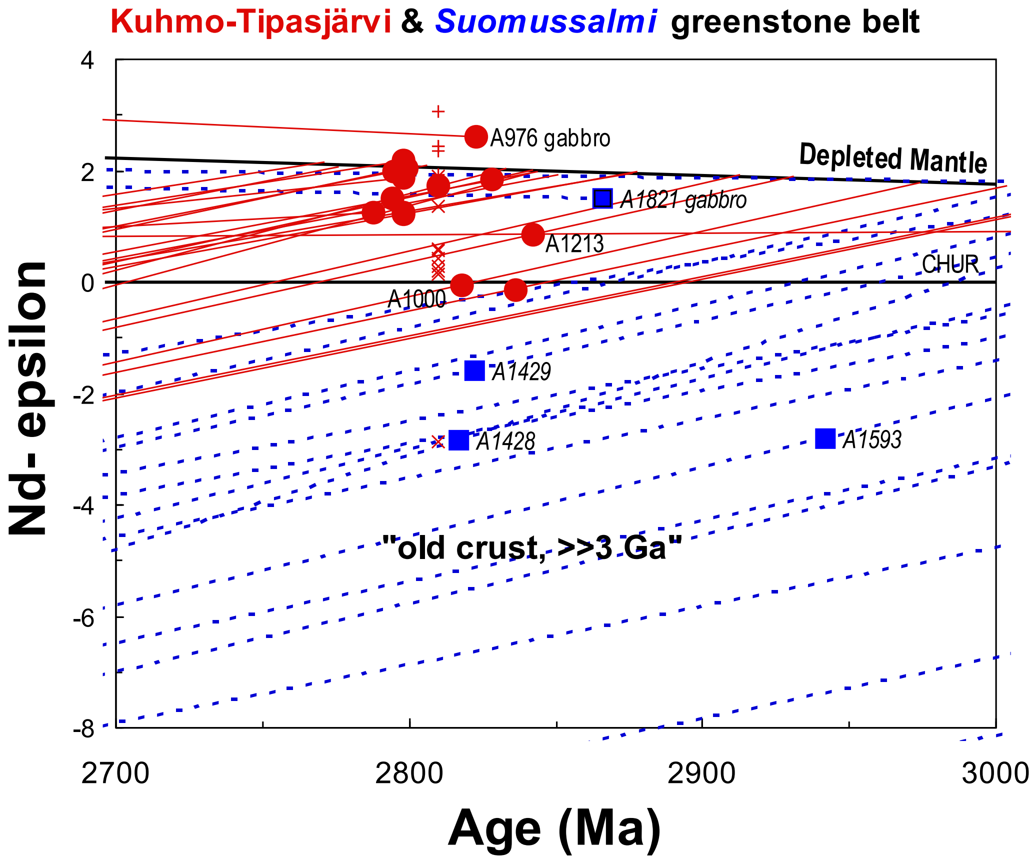

Fig. 18. Epsilon-Nd vs. age diagram showing evolution lines for mostly felsic samples from the Tipasjärvi-Kuhmo-Suomussalmi greenstone complex. Initial values are shown for samples, for which the age is based on U-Pb zircon dating. Suomussalmi: blue squares and dotted evolution lines. Kuhmo-Tipasjärvi: red circles and solid evolution lines. Komatiites and komatiitic basalts from the Pahakangas-Siivikkovaara area in Kuhmo: red x at 2810 Ma, basalts from other sites in Kuhmo belt: red +. DM is the depleted mantle evolution according to DePaolo (1981).

density diagram (Fig. 19). These results show that 80 % of the Archaean rocks in Finland have model ages of ca. 2.75-3.15 Ga, suggesting together with the U-Pb zircon ages that much of the Archaean consists of relatively juvenile crust. It should be emphasized that model ages >3.1 Ga, and particularly in excess of 3.3 Ga, are few, and some of these data may derive from samples which have not remained closed since their primary crystallization.

The samples with oldest model ages are labeled on the T_{DM} vs. $^{147}Sm/^{144}Nd$ diagram (Fig. 20). Samples with $^{147}Sm/^{144}Nd$ higher than 0.16, and thus with possibly questionable model ages, are not shown. For comparison the average crustal $^{147}Sm/^{144}Nd$ ratios reported by Rudnick and Gao (2004) are 0.1179 (bulk crust) and 0.1053 (upper crust). The sampling is not random and probably emphasizes the older end of the analyzed spectrum. Anyway, it is clear that rocks with model ages >3.1 Ga, and especially > 3.3 Ga, must be rare in Finland. Model ages older than 3.3 Ga have been obtained for some rocks from Tojottamanselkä in Central Lapland (Jahn et al. 1984, Hanski et al. 2001), Iisalmi (Hölttä et al. 2000, Lauri et al. 2011) and Suomussalmi (Fig. 5). The rocks which have yielded the oldest reliable Sm-Nd model ages up to ca. 3.7 Ga are the 3.5 Ga Siurua gneisses in Pudasjärvi, which also are the oldest rocks in Finland and Fennoscandia (Mutanen & Huhma 2003, Lauri et al. 2011). Indications of similar old ages were also obtained from the few lower crustal xenoliths (Peltonen et al. 2006).

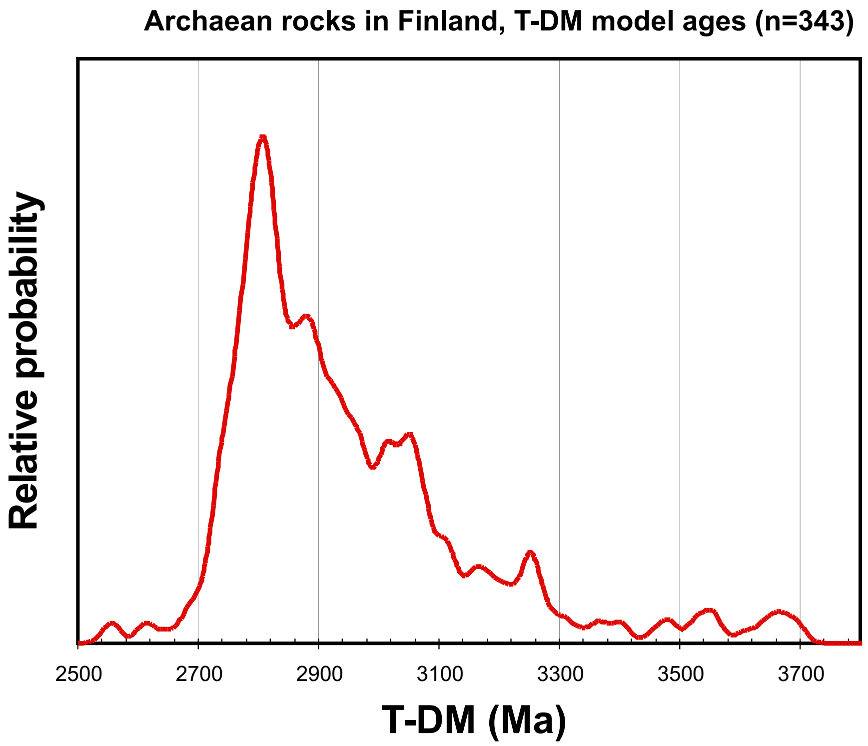

Fig. 19. Probability density plot of Sm-Nd model ages T_{DM} on 343 Archaean rocks from Finland. T_{DM} has been calculated according to DePaolo (1981) and only for rocks which have $^{147}Sm/^{144}Nd$ <0.16.

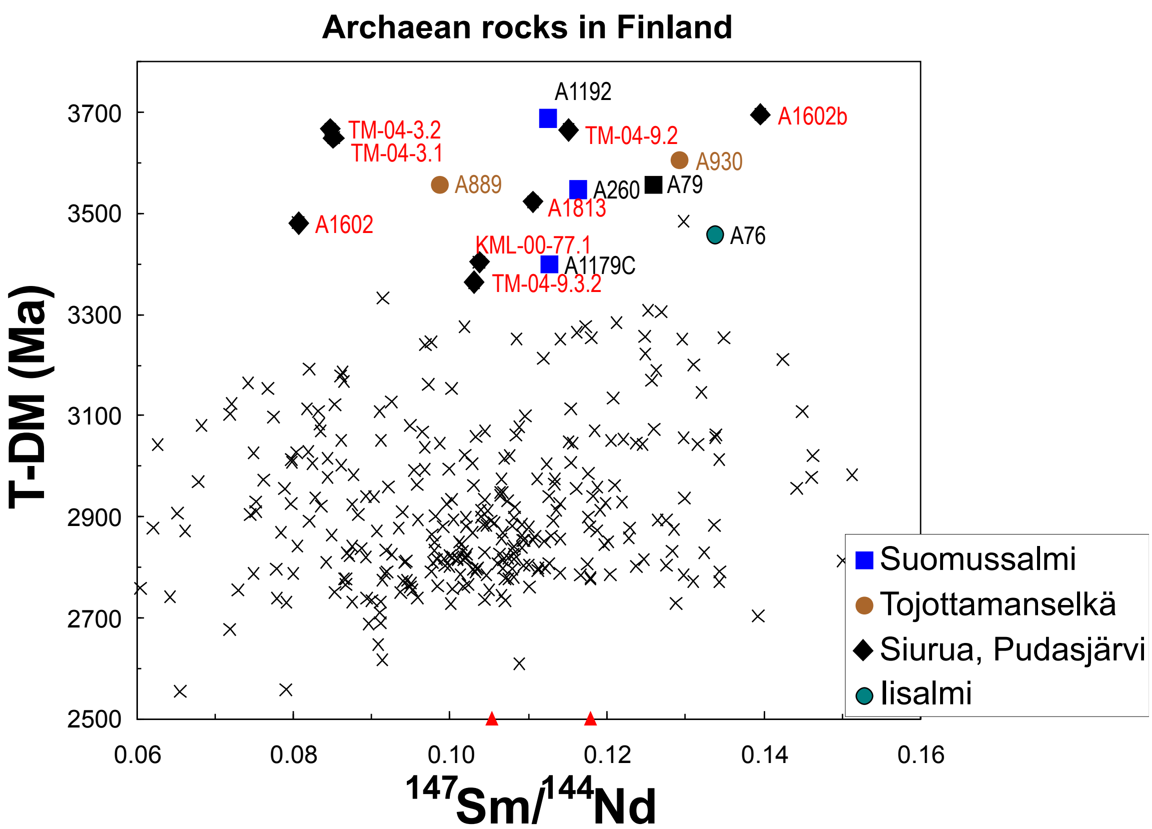

Fig. 20. Sm-Nd model ages T_{DM} for Archaean whole rock samples from Finland. Red triangles denote the average $^{147}Sm/^{144}Nd$ ratios for bulk (0.1179) and upper (0.1053) crust by Rudnick and Gao (2004).

CONCLUSIONS

Abundant combined Sm-Nd and U-Pb isotopic results available on the Archaean rocks in Finland provide a powerful means to evaluate the importance of crustal growth versus crustal recycling in petrogenesis of the various domains of this large part of the Fennoscandian Shield and Karelia Province. However, further studies are needed to better combine the isotope results with the comprehensive geochemical information.

Despite problems related to secondary REE mobility, the Sm-Nd results show that mantle reservoirs with time-integrated depletion in LREE were important sources of magmas already during the Archaean time. On the other hand, the range in initial Nd isotopic compositions of various rocks, particularly in high-REE alkaline rocks, suggests heterogeneity in the Archaean mantle.

Metamorphic effects seriously limit the use of the Sm-Nd method in studying the geochronology and genesis of komatiites. However, it is tempting to consider the $\varepsilon_{Nd(2.8\ Ga)}$ values of +0.5, obtained for many komatiitic samples from the Kuhmo belt, as primary signatures. This would be consistent with the conclusions by Maier et al. (in prep), who consider that the geochemistry of the Kuhmo komatiites indicate that the lavas were derived from a source more similar to a primitive upper mantle plume source in an oceanic plateau setting rather than an NMORB-type depleted source.

Most Archaean felsic rocks in Finland, representing >80% of the Archaean crust, have model ages of ca. 2.75-3.15 Ga, which suggests, together with the U-Pb zircon ages, that much of the Archaean consists of relatively juvenile crust. This concerns particularly the Kuhmo area. Felsic rocks in the Kuhmo and Tipasjärvi greenstone belts represent new crustal materials ultimately derived from depleted mantle-type sources with $\varepsilon_{Nd(2.8\ Ga)} \sim +2$. The bulk of the surrounding granitoids postdates the volcanism, and the isotope results as a whole suggest that the contribution of older crustal material is negligible and does not support the concept of formation of the Kuhmo belt in a rift-basin on an ancient sialic basement. In contrast, in the Suomussalmi belt, isotope results indicate a major involvement of significantly older crustal material (>3 Ga).

Model ages in excess of 3.1 Ga are few, over 3.3 very few, the >3.3 Ga ages being almost restricted to the ca. 3.5 Ga Siurua gneisses in the Pudasjärvi area. No signs of that similar 3.5 Ga crust exposed elsewhere in Finland or Fennoscandian Shield are evident in the Sm-Nd data available.

ACKNOWLEDGEMENTS

We are grateful to Hugh O'Brien for discussions and comments on the manuscript.

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Appendix 1. Sm-Nd isotope data on the Archean rocks in Finland.

Sample	Location	Rock type	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$ (± 0.4%)	$^{143}Nd/^{144}Nd$	$2\sigma_m$	Age(T) (Ma)	$\varepsilon_{Nd}(T)$	T_{DM} (Ma)	Reference for Sm-Nd	comment (*	map	YKJ-North	YKJ-East
Pudasjärvi area															
Siurua-Kolkkoaho zone (N->S)															
KML-00-77.1	Kolkkoaho	tonalite gneiss	2.30	13.41	0.1037	0.510606	10	2700	-7.5	3404		L00013111	352404	7286564	3477464
TM-04-9.1	Kolkkoaho	tonalite gneiss	1.73	8.12	0.1285	0.510928	10	2700	-9.8	3864		open system?	352304	7286550	3477470
TM-04-9.2	Kolkkoaho	tonalite gneiss	2.14	11.22	0.1151	0.510705	10	2700	-9.5	3665			352304	7286550	3477470
TM-04-9.3.1	Kolkkoaho	tonalite gneiss	2.18	14.24	0.0925	0.510567	10	2700	-4.3	3127			352304	7286540	3477460
TM-04-9.3.2	Kolkkoaho	tonalite gneiss	2.13	12.50	0.1031	0.510620	20	2700	-7.0	3364			352304	7286540	3477460
JON-00-4.1	Sumusuo	granite	3.68	25.86	0.0860	0.510391	10	2700	-5.5	3179		L00013101	352301	7285759	3467663
JON-00-53.1	Karhunpesäkumpu	tonalite gneiss	2.08	15.10	0.0832	0.510390	10	2700	-4.5	3108		L00013112	352504	7285465	3479638
KML-00-11.1	Iso Yömaa	granite	2.58	16.00	0.0976	0.510585	10	2700	-5.7	3245		L00013103	352304	7284229	3473166
JON-00-82.1	Pauvankangas	tonalite gneiss	2.29	14.58	0.0949	0.510651	10	2700	-3.5	3080		L00013116	352307	7281982	3483072
A1603	Isokumpu	felsic granulite	0.81	6.10	0.0799	0.510408	11	**2960**	1.0	3009	M03		351406	7279400	3476550
JON-00-55.3	Isokumpu	enderbite	4.77	29.83	0.0967	0.510721	10	2700	-2.8	3037		L00013123	351406	7279253	3476538
TM-04-3.2	Siurua	tonalite gneiss	12.26	87.43	0.0847	0.509966	10	3500	-1.7	3667	L11		351408	7267172	3480526
A1812	Siuruankangas	mafic granulite	2.82	9.11	0.1872	0.512436	11	2700	-0.7		L11	$\varepsilon_{Hf}(T)=+2.6\pm2.0$	351402	7267127	3480533
A1813	Siuruankangas	granite leucosome	3.64	19.91	0.1106	0.510688	10	**3500**	0.8	3523	L11	$\varepsilon_{Hf}(T)=+3.5\pm5.0$	351402	7267127	3480533
TM-04-3.1	Siurua	tonalite gneiss	11.29	80.12	0.0852	0.509990	10	3500	-1.4	3650	L11		351408	7267102	3480537
A1602	Siurua	trondhjemite gneiss	10.44	78.18	0.0807	0.510025	10	**3500**	1.4	3481	M03	$\varepsilon_{Hf}(T)=-4.8\pm3.1$	351408	7267090	3480520
A1602b	Siurua	granitic leucosome	1.26	5.44	0.1396	0.511284	20	3500	-0.7	3696	L11		351408	7267090	3480520
TM-04-3.3	Siurua	mafic granulite	2.09	6.44	0.1960	0.512707	10	2700	1.5		L11		351408	7267010	3480515
TM-00-13	Soidinmaa	alaskite (granite)	1.04	6.41	0.0984	0.510956	10	2700	1.3	2763	M03		351408	7262035	3481408
A1686A	Soidinmaa	trondhjemite pegmatite	0.43	4.15	0.0627	0.510033	20	2700	-4.4	3042		3514/R301/94.55-95.25	351408	7262029	3481475
A1686B	Soidinmaa	granite/ inclusion?	98	820	0.0722	0.510150	20	2700	-5.4	3123		3514/R301/94.55-95.25	351408	7262029	3481475
A1687	Soidinmaa	dyke, Proterozoic?	6.14	25.28	0.1470	0.511911	20	2700	3.0	2595		3514/R307/15.8-18.0	351408	7261330	3481421
TM-04-2.3	Livojoen silta	tonalite gneiss	2.86	22.54	0.0767	0.510218	10	2700	-5.6	3153			351410	7256816	3491411
TM-04-2.1	Livojoen silta	tonalite gneiss	2.26	18.96	0.0719	0.510163	10	2700	-5.0	3103			351410	7256815	3491401
TM-04-2.2	Livojoen silta	amphibolite	2.99	9.19	0.1969	0.512730	10	2700	1.7				351410	7256813	3491403
Oijärvi greenstone belt															
A1782	Käärmevaara W (Ranua)	gabbro	1.47	4.20	0.2112	0.513048	11	**2802**	2.7			36-PTP-04	352210	7314017	3451513
A1783	Puljunlehto Ranua	dacite	0.55	2.27	0.1463	0.511725	10	**2820**	0.4	3020		23-PTP-04	352112	7305915	3455670
A1553	Pitkäkumpu	tonalite	2.64	15.94	0.1001	0.511012	10	**2728**	2.1	2728			352111	7298570	3457880
A1533	Surmakumpu	qu-fspar-porphyry dyke	7.32	53.63	0.0825	0.510460	14	**2670**	-3.3	3006			352111	7296640	3456110
Other Pudasjärvi (N->S)															
93001872		granodiorite	2.92	18.60	0.0950	0.510892	20	2700	1.2	2768			352209	7336660	3444840
R4	Runkaus	granite	4.24	34.08	0.0752	0.510404	28	2700	-1.4	2910	H86		2544	7329846	3428973
A1611	Korkia-aho	diorite (Ranua)	6.67	35.79	0.1126	0.511186	10	**2703**	0.9	2808	M03	$\varepsilon_{Hf}(T)=-2.5\pm2.0$	352405	7322230	3476750
A1717	Simontaival	albite-egirine-rock	0.43	2.08	0.1257	0.511228	20	2700	-2.9	3170		3524/R172/72.0-74.0	352405	7321465	3479200
A1814	Pitkäpalo Ranua	mica gneiss	4.69	26.18	0.1082	0.511101	10	2700	0.7	2815			352201	7311210	3439510
A1490	Tuore Ristisuonpalo	granodiorite	1.95	14.65	0.0805	0.510562	10	**2815**	1.6	2841			352112	7308300	3454020
A1534	Keväpalo	tonalitic gneiss	1.48	8.25	0.1088	0.511248	10	**2820**	4.8	2609	L11	open system?	352112	7305902	3457646
A1534#2	Keväpalo	tonalitic gneiss	1.47	8.14	0.1089	0.511266	10	**2820**	5.1	2586	L11	$\varepsilon_{Hf}(T)=+1.4\pm1.9$	352112	7305902	3457646
A1954	Tervonkangas	gneiss (trondhjemite)	0.96	6.68	0.0865	0.510730	11	2700	1.0	2777			352303	7302751	3466397
A1739	Veskanmaa	granodiorite	1.74	11.21	0.0939	0.510762	20	**2780**	0.1	2909			352108	7291080	3440100
L05029441	47-PSH-04	granodiorite	4.47	33.57	0.0804	0.510403	20	2700	-3.3	3028				7288134	3429931
L05028739	35-PSH-04	diorite	8.90	41.43	0.1299	0.511441	20	2700	-0.2	2936				7283902	3417477

Appendix 1. cont.

Sample	Location	Rock type	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$ (± 0.4%)	$^{143}Nd/^{144}Nd$	$2\sigma_m$	Age(T) (Ma)	$\varepsilon_{Nd}(T)$	T_{DM} (Ma)	Reference for Sm-Nd	comment (*	map	YKJ-North	YKJ-East
Other Pudasjärvi (N->S)															
A1966	Pudasjärvi	granodiorite	2.46	16.62	0.0893	0.510813	10	2700	1.6	2738		93001908	351403	7278860	3462400
A1842	Jäkälämaa, Pudasjärvi	mica gneiss	5.94	33.67	0.1066	0.511120	10	2700	1.6	2744			351409	7271905	3485074
A1809	Ärrönperä Kuivaniemi	amphibolite	3.67	14.78	0.1501	0.511881	10	2700	1.4	2813	L11		253408	7268810	3421258
A1810	Ärrönperä Kuivaniemi	granodioritic leucosome	0.43	3.25	0.0800	0.510601	12	**2682**	0.5	2788	L11	$\varepsilon_{Hf}(T)$=-3.3±2.7	253408	7268810	3421258
A1811	Ärrönperä Kuivaniemi	granite leucosome	3.13	24.09	0.0784	0.510502	10	2700	-0.6	2868	L11	$\varepsilon_{Hf}(T)$=+1.2±4.6	253408	7268810	3421258
A1740	Palomaa 2	monzonite	3.26	22.47	0.0877	0.510583	20	**2682**	-2.6	2983			351402	7263103	3469274
L05028727	10.1-PSH-04	amphibolite	4.06	17.00	0.1442	0.511710	20	2720	0.2	2957				7257618	3429116
A1741	Pahkakoski	granodiorite	2.19	13.47	0.0983	0.510913	20	**2758**	1.2	2816			351210	7253200	3455500
L05028737	30-PSH-04	granodiorite	2.92	14.97	0.1179	0.511304	20	2700	1.3	2779				7251640	3455324
93001846		granitegneiss	8.82	40.67	0.1310	0.511548	10	2700	1.5	2772			351303	7248480	3463070
A1742	Viitakangas	granite	4.23	26.37	0.0969	0.510573	20	2700	-5.7	3240			351106	7247308	3437025
93001430		quartzdiorite	1.70	9.63	0.1070	0.511133	20	2700	1.8	2734			351306	7246350	3479710
A1601	Rankkila	mafic granulite	2.27	8.27	0.1660	0.512145	10	2700	1.0		M03		351309	7241173	3485072
L05028797	162-PSH-04	tonalitegneiss	6.22	43.46	0.0864	0.510410	20	2700	-5.3	3168				7215005	3491679
A1965	Pudasjärvi	tonalitegneiss	5.57	36.94	0.0911	0.510866	10	2700	2.1	2710		94003693	344202	7207930	3505480
L05028791	155-PSH-04	enderbite	1.94	21.42	0.0547	0.510178	20	2700	1.3	2746				7197685	3508558
L05028793	159-PSH-04	tonalite	3.04	17.54	0.1048	0.510971	20	2700	-0.7	2912				7193494	3494215
L05028786	147-PSH-04	tonalite	6.16	36.50	0.1020	0.510926	20	2700	-0.6	2899				7189686	3505754
94002795		granitegneiss	5.30	36.10	0.0887	0.510721	20	2700	0.1	2837			342311	7174620	3492960
Koillismaa granitoids (N->S):															
A1644	Hanhimännikkö	gneiss	1.65	10.24	0.0976	0.510920	10	2700	0.9	2791	L06		452409	7341660	3620743
95001676		granitegneiss	2.90	24.02	0.0730	0.510501	20	2700	1.3	2755			452409	7339208	3621792
TTU$-2004-148	Kuusamo	granodiorite (sanukitoid)	4.11	24.79	0.1001	0.510956	10	**2718**	0.9	2805	Hetal		452409	7333650	3624183
TTU$-2004-156	Kuusamo	granodiorite (sanukitoid)	4.38	24.91	0.1063	0.511078	10	2718	1.1	2795	Hetal		452408	7328398	3623888
TTU$-2004-162	Kuusamo	granodiorite (sanukitoid)	7.08	38.76	0.1104	0.511146	11	2718	1.0	2806	Hetal		454103	7312019	3639916
TTU$-2004-160.1	Kuusamo	granodiorite (sanukitoid)	5.28	29.57	0.1080	0.511079	10	2718	0.6	2834	Hetal		452312	7304904	3631405
TTU$-2004-167	Kuusamo	granodiorite (sanukitoid)	5.65	36.75	0.0930	0.510853	11	2718	1.4	2768	Hetal		454102	7302068	3640066
TTU$-2004-154	Kuusamo	granodiorite (sanukitoid)	4.02	23.56	0.1032	0.511005	11	2718	0.8	2816	Hetal		452311	7295974	3630652
A1643	Meskusvaara	qu-fspar-porphyry	2.72	16.11	0.1022	0.510980	10	**2733**	0.8	2825			452211	7326529	3587885
95001753	Kuusamo	granodiorite	7.18	38.05	0.1141	0.510937	10	2700	-4.6	3251			452207	7319762	3579539
Soilu TTG	Soilu Kuusamo	tonalite gneiss	4.22	30.20	0.0844	0.510523	12	2700	-2.3	2978	L06		452204	7316238	3574281
A415	Soilu	granite	1.88	12.94	0.0875	0.510627	10	2700	-1.4	2924	L06		452204	7315530	3573114
95001741		granitegneiss	3.56	24.98	0.0862	0.510499	20	2700	-3.4	3052			452109	7305143	3577816
A1652	Kostonjärvi Taivalkoski	felsic volcanic rock	2.36	14.43	0.0987	0.510754	10	2700	-2.8	3045			354309	7302787	3565073
A1642	Raatekalliot	granite	3.29	30.46	0.0652	0.510213	10	2700	-1.7	2906	L06		452302	7301403	3601082
A1887	Haapovaara Taivalkoski	tonalite	3.72	21.88	0.1028	0.510866	10	2700	-2.0	3005			354308	7298185	3562389
A1888	Pyöreälampi Taivalkoski	trondhjemite	0.63	5.07	0.0752	0.510387	20	2700	-1.8	2929			354111	7294405	3537974
A1889	Elehvä Taivalkoski	tonalite	2.27	15.21	0.0903	0.510670	20	2700	-1.5	2939			452105	7291062	3575504
A1656	Aholamminvaara	granite	6.33	64.15	0.0596	0.510095	10	**2711**	-1.9	2917	L06		4521	7287103	3579170
A1661	Kaplaskumpu	tonalite (pyroxene)	5.18	41.73	0.0750	0.510294	10	**2808**	-1.8	3026	L06	$\varepsilon_{Hf}(T)$=-5.6±3.0	354304	7282484	3557732
A1662	Matovaara	tonalite	6.57	32.84	0.1208	0.511148	10	2800	-1.8	3134	L06		353409	7278648	3564500
95001765		granite	1.82	11.49	0.0958	0.510759	10	2700	-1.7	2963			451403	7278218	3605233
A1657	Harjavaara	granite	0.85	8.70	0.0590	0.509991	10	2700	-3.9	3010	L06	$\varepsilon_{Hf}(T)$=-8.1±3.0	4512	7275684	3569976
A1890	Kylmävaara Taivalkoski	trondhjemite	0.78	5.64	0.0835	0.510432	20	2827	-1.9	3069			353405	7268659	3550610

Appendix 1. cont.

Sample	Location	Rock type	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$ (± 0.4%)	$^{143}Nd/^{144}Nd$	$2\sigma_m$	Age(T) (Ma)	$\varepsilon_{Nd}(T)$	T_{DM} (Ma)	Reference for Sm-Nd	comment (*	map	YKJ-North	YKJ-East
Suomussalmi greenstone belt:															
A1191	Ala-Luoma	metasediment/ tuffite	2.61	12.62	0.1249	0.511188	10	2820	-2.3	3223			451303	7244464	3605840
A1191#2	Ala-Luoma	metasediment/ tuffite	2.70	13.14	0.1241	0.511182	12	2820	-2.1	3202			451303	7244464	3605840
A1179A	Ala-Luoma	tuffite/ metasediment	3.23	15.64	0.1248	0.511166	15	2820	-2.7	3256		Vaasjoki et al 1999	451303	7244464	3605840
A1179C	Ala-Luoma	tuffite/ metasediment	4.09	21.92	0.1126	0.510814	13	2820	-5.2	3400		Vaasjoki et al 1999	451303	7244464	3605840
A1065A (KR-27)	Ala-Luoma	volcanogenic schist, sheared	2.43	12.20	0.1202	0.510712	11	2820	-9.9	3878		open system?	453103	7244873	3606241
A1192	Saarikylä	felsic volcanic rock, sheared	2.01	10.81	0.1125	0.510631	11	2940	-7.4	3689		open system?	451303	7244557	3606757
A1467	Saarikylä	felsic volc. (cataclastic)	1.01	3.85	0.1582	0.510726	11	**2940**	-23.0	7452		open system	451303	7244420	3606603
A1467#2	Saarikylä	felsic volc. (cataclastic)	1.00	3.84	0.1573	0.510701	12	**2940**	-23.1			open system	451303	7244420	3606603
A1593	Saarikylä	qu-porphyry	2.04	12.11	0.1018	0.510656	10	**2942**	-2.8	3275		KJP-96-105	451303	7244289	3606589
A1593#2	Saarikylä	qu-porphyry	2.09	12.31	0.1025	0.510607	20	**2942**	-4.0	3367		KJP-96-105	451303	7244289	3606589
A260	Haaponen	greywacke	1.38	7.18	0.1163	0.510806	10	2820	-6.7	3548		low REE	451303	7242347	3606372
A1180A	Saarikylä	basalt	2.54	7.62	0.2016	0.512831	10	2820	1.9			Vaasjoki et al 1999	451303	7243107	3607416
A1428	Mesa-aho	qu-porphyry	5.89	52.16	0.0683	0.510109	10	**2817**	-2.8	3080			451303	7242081	3605002
EJL-92-71	Mesa-aho	felsic volcanic rock	6.91	35.92	0.1162	0.510975	10	2820	-3.3	3264			451303	7242111	3605001
EJL-92-71#2	Mesa-aho	felsic volcanic rock	6.95	36.09	0.1164	0.510984	10	2820	-3.2	3256			451303	7242111	3605001
A1594	Mesa-aho	tuffite/ metasediment	2.51	11.36	0.1338	0.511456	11	2820	-0.3	3057		EJL-92-70	451303	7242022	3605035
A1594#2	Mesa-aho	tuffite/ metasediment	2.50	11.27	0.1339	0.511441	10	2820	-0.6	3093		EJL-92-70	451303	7242022	3605035
A1514	Kiannanniemi	andesite	5.05	30.45	0.1002	0.510706	12	2820	-2.8	3154			451111	7231377	3596370
ASM-94-684	Hiirelä 1, Kiannanniemi	rhyolite (fragment)	3.87	21.89	0.1069	0.510941	10	2820	-0.6	3015			451110	7229424	3596143
ASM-94-685	Hiirelä 2, Kiannanniemi	andesite-basalt lava	5.17	29.87	0.1045	0.510857	10	2820	-1.4	3069			451110	7229437	3596202
A1429	Kilpasuo Tormua	andesite	4.55	25.11	0.1096	0.510939	10	**2822**	-1.6	3099			451309	7249545	3620447
A1821	Tormua	gabbro (mafic volc.)	1.92	5.63	0.2061	0.512895	10	**2866**	1.5			87-PTP-03	451309	7246318	3620818
Suomussalmi granitoids (N->S):															
A1913	Välivaara	tonalite	1.91	15.18	0.0762	0.510368	10	**2950**	1.4	2973	M11a	PSH$-2006-70	451211	7267953	3593374
95001760		granitegneiss	3.63	26.49	0.0828	0.510526	10	2700	-1.7	2938			451408	7267858	3624201
A1906	Taka-aho	tonalitegneiss (paleos.)	2.38	15.09	0.0955	0.510731	10	**2824**	-0.5	2992	M11a	PIM$-2003-128.1	451407	7255650	3619820
A1907	Taka-aho	leucogranodiorite (neos)	1.12	7.02	0.0968	0.510756	10	**2706**	-2.0	2993	M11a	PIM$-2003-128.2	451407	7255650	3619820
95001798		granodiorite	2.06	13.53	0.0921	0.510690	10	2700	-1.7	2960			451306	7250790	3612308
A1904	Marjosuo	tonalite (hornblende-)	2.69	15.28	0.1067	0.510983	10	**2795**	0.0	2948	M11a	KKK1-2005-39	451306	7246290	3613635
A1856	Portinkuru	tonalite	1.13	5.80	0.1173	0.510991	15	**2950**	-2.1	3276	M11a		451303	7243917	3602274
A1857	Teerivaara	granodiorite dyke	1.78	10.53	0.1019	0.510837	15	**2821**	-0.8	3022	M11a		451303	7243917	3602274
A1915	Tausvaara	leucotonalite	0.99	5.08	0.1184	0.511137	13	**2744**	-1.7	3071	M11a	JJE$-2006-132	353309	7242170	3565648
A1193	Saarikylä	tonalite (cataclastic)	0.73	3.27	0.1339	0.511458	12	2800	-0.5	3063			451305	7241490	3611739
A28bA	Kaapinsalmi	granodiorite (sanukitoid)	3.58	21.72	0.0998	0.510812	11	**2717**	-1.8	2994		eps-Hf= -1.5	451302	7239741	3600438
EPHE-2004-347.2	Kaapinsalmi	granodiorite (sanukitoid)	4.70	24.85	0.1142	0.511073	10	2722	-1.7	3035	Hetal		451303	7242785	3603530
EPHE-2005-40.1	Kaapinsalmi	granodiorite (sanukitoid)	3.86	24.96	0.0935	0.510711	10	2722	-1.5	2965	Hetal		451303	7242569	3602975
EPHE-2004-353.2	Kaapinsalmi	granodiorite (sanukitoid)	5.39	27.86	0.1170	0.511097	10	2722	-2.2	3080	Hetal		451303	7241716	3603778
EPHE-2004-345.1	Kaapinsalmi	granodiorite (sanukitoid)	4.59	26.21	0.1057	0.510920	11	2722	-1.7	3010	Hetal		451303	7241621	3602733
EPHE-2004-332.1	Kaapinsalmi	granodiorite (sanukitoid)	4.08	26.70	0.0923	0.510696	11	2722	-1.4	2954	Hetal		451302	7238380	3603673
EPHE-2004-336.1	Kaapinsalmi	granodiorite (sanukitoid)	4.77	28.29	0.1021	0.510836	11	2722	-2.1	3023	Hetal		451302	7236960	3603278
A1831	Kiviniemi	leucotonalite	1.51	10.63	0.0861	0.510539	10	2700	-2.6	3001	M11a		451302	7236862	3596605
A79	Päivärinta	tonalitic melanosome	2.41	11.59	0.1258	0.511026	10	**2835**	-5.7	3558			4512	7229489	3591184

Appendix 1. cont.

Sample	Location	Rock type	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$ (± 0.4%)	$^{143}Nd/^{144}Nd$	$2\sigma_m$	Age(T) (Ma)	$\varepsilon_{Nd}(T)$	T_{DM} (Ma)	Reference for Sm-Nd	comment (*	map	YKJ-North	YKJ-East
Suomussalmi granitoids (N->S):															
A79#2	Päivärinta	tonalitic melanosome	2.37	11.41	0.1256	0.511006	10	**2835**	-6.0	3583			4512	7229489	3591184
A80a	Päivärinta	leucosome	1.97	11.45	0.1040	0.510966	11	2700	-0.5	2900			4512	7229489	3591184
A80b	Päivärinta	leucosome	3.59	22.08	0.0981	0.510852	15	2700	-0.7	2901			4512	7229489	3591184
A1962 (95001782)	Kuikkavaara	granodiorite	2.33	17.18	0.0818	0.510359	10	2960	-0.7	3114		cf. A1909	451107	7227560	3583835
A1909	*Kuikkavaara*	*tonalite*	*3.28*	*25.60*	*0.0775*	*0.510285*	*10*	***2960***	*-0.5*	*3097*	*M11a*	*PIM$-2003-322*	*451107*	*7227559*	*3583838*
A1902	*Pärsämönselkä*	*granodioriteg-neiss (paleos.)*	*2.45*	*18.77*	*0.0789*	*0.510436*	*10*	***2719***	*-1.8*	*2955*	*M11a*	*EPHE-2004-245.1*	*451301*	*7224137*	*3606561*
A1903	*Pärsämönselkä*	*leucotonalite (leucos.)*	*0.96*	*8.61*	*0.0679*	*0.510208*	*10*	*2700*	*-2.7*	*2969*	*M11a*	*EPHE-2004-245.2*	*451301*	*7224137*	*3606561*
94003728		quartzdiorite	18.51	103.40	0.1082	0.511045	10	2700	-0.4	2899			344406	7214700	3556940
A1840	Riihivaara, Suomussalmi	mica gneiss	3.69	21.66	0.1029	0.510964	20	2700	-0.1	2869			344408	7207502	3563317
A1858	*Riihivaara*	*tonalite dyke*	*5.51*	*33.98*	*0.0981*	*0.510887*	*15*	***2702***	*0.1*	*2849*	*M11a*		*344408*	*7207502*	*3563317*
A1841	Riihivaara	granite (leucosome)	0.95	3.32	0.1723	0.511550	25	2700	-12.9			open system?	344408	7207498	3563267
A1901	*Seppäsensuo*	*tonalite*	*3.68*	*26.41*	*0.0844*	*0.510493*	*10*	***2818***	*-1.2*	*3015*	*M11a*	*PIM$-2003-616*	*344402*	*7204658*	*3549296*
A1910	*Peuravaara*	*granodiorite (porphyritic)*	*3.78*	*27.37*	*0.0836*	*0.510555*	*10*	***2713***	*-1.2*	*2922*	*M11a*	*PIM$-2003-534*	*442402*	*7203114*	*3604761*
A1908	*Joutenvaara*	*granodiorite*	*1.52*	*9.38*	*0.0980*	*0.510898*	*10*	***2760***	*1.1*	*2834*	*M11a*	*PIM$-2003-213*	*442404*	*7200009*	*3621583*
A1905	*Vaamankallio*	*leucogranite*	*2.34*	*15.55*	*0.0911*	*0.510883*	*10*	***2688***	*2.2*	*2689*	*M11a*	*PIM$-2003-12*	*442210*	*7198616*	*3593550*
A1905 #2	*Vaamankallio*	*leucogranite*	*2.32*	*15.34*	*0.0913*	*0.510880*	*10*	*2688*	*2.1*	*2696*	*M11a*		*442210*	*7198616*	*3593550*
PIM-2003-12	*Vaamankallio*	*leucogranite*	*0.70*	*2.94*	*0.1438*	*0.510944*	*11*	*2700*	*-14.8*	*4813*	*M11a*	*open system*	*442210*	*7198616*	*3593550*
A1912	*Likamännikkö*	*quartz diorite*	*7.09*	*39.59*	*0.1082*	*0.511032*	*10*	***2742***	*-0.2*	*2919*	*M11b*	*PIM$-2006-193*	*353307*	*7226964*	*3564760*
L07084727 (193.1)	*Likamännikkö*	*syenite*	*14.96*	*95.27*	*0.0949*	*0.510894*	*10*	*2742*	*1.9*	*2762*	*M11b*	*PIM$-2006-193.1*	*3533 07 B*	*7226964*	*3564760*
L07084728 (193.2)	*Likamännikkö*	*mafics*	*48.19*	*257.90*	*0.1129*	*0.511160*	*10*	*2742*	*0.7*	*2861*	*M11b*	*PIM$-2006-193.2*	*3533 07 B*	*7226964*	*3564760*
L07084729 (193.3)	*Likamännikkö*	*carbonatite*	*48.37*	*278.40*	*0.1050*	*0.511084*	*10*	*2742*	*2.0*	*2754*	*M11b*	*PIM$-2006-193.3*	*3533 07 B*	*7226964*	*3564760*
L08065994	*Likamännikkö*	*carbonatite*	*45.53*	*268.90*	*0.1023*	*0.511028*	*10*	*2742*	*1.9*	*2765*	*M11b*		*3534 07 B*	*7226964*	*3564760*
L08065996	*Likamännikkö*	*carbonatite*	*45.76*	*259.22*	*0.1067*	*0.511085*	*11*	*2742*	*1.4*	*2798*	*M11b*		*3535 07 B*	*7226964*	*3564760*
L07115671	*Likamännikkö*	*mafics*	*23.07*	*135.08*	*0.1032*	*0.511026*	*10*	*2742*	*1.5*	*2791*	*M11b*		*3536 07 B*	*7226964*	*3564760*
L07115654	*Likamännikkö*	*mafics*	*42.06*	*245.63*	*0.1034*	*0.511028*	*10*	*2742*	*1.5*	*2796*	*M11b*		*3537 07 B*	*7226964*	*3564760*
L07115670	*Likamännikkö*	*syenite*	*17.43*	*92.78*	*0.1135*	*0.511139*	*10*	*2742*	*0.0*	*2913*	*M11b*		*3538 07 B*	*7226964*	*3564760*
L07115652	*Likamännikkö*	*syenite*	*6.92*	*41.84*	*0.0999*	*0.510957*	*10*	*2742*	*1.3*	*2802*	*M11b*		*3539 07 B*	*7226964*	*3564760*
Kuhmo greenstone belt (N->S):															
A120a	Ruokojärvi	felsic volcanic rock	1.12	6.49	0.1039	0.510955	40	2818	0.8	2913			442302	7180686	3607567
A120b	Ruokojärvi	felsic volcanic rock	0.93	4.87	0.1151	0.511082	12	2818	-0.8	3049			442302	7180686	3607567
A1000a	Ruokojäri	felsic volcanic rock	1.28	7.26	0.1065	0.510962	10	**2818**	-0.1	2974			442302	7180657	3607730
81062	*Moisiovaara*	*mica schist*	*2.09*	*10.88*	*0.1158*	*0.510992*	*12*	*2800*	*-3.1*	*3219*	*M86*			*7177590*	*3605211*
S4	Moisiovaara	mica schist	1.78	5.33	0.2022	0.512746	10	2800	0.0					7177590	3605211
A976	Moisiovaara	mafic sill/ pegmatoid	3.20	8.97	0.2154	0.513123	20	**2823**	2.6			eps-Hf=+14!	442110	7168454	3601719
A1213	Pitkäperä	felsic volcanic rock	2.94	16.58	0.1073	0.511008	10	**2842**	0.9	2931			441402	7144884	3610162
A788	Polvilampi	felsic volcanic rock	1.69	5.57	0.1837	0.511246	20	**2799**	-22.7			open system?	441211	7144664	3601262
A1773	Hetteilä Kuhmo	intermed volcanic rock	3.76	20.25	0.1123	0.511055	10	**2836**	-0.1	3004			441212	7140594	3604137
A1774	Hetteilä Kuhmo	mica schist/dyke?	4.31	28.55	0.0913	0.510943	13	2740	4.1	2617			441212	7140592	3604087
A1346	Lampela	felsic volcanic rock	3.57	17.56	0.1229	0.511341	10	**2798**	1.2	2878			441210	7136051	3601218
A1560	Huuhilonkylä	felsic volcanic rock	3.78	17.80	0.1285	0.511446	10	**2798**	1.3	2876			441210	7133793	3600464
A1418	Niittylahti	gabbro	1.12	3.86	0.1747	0.512321	50	**2788**	1.6				441210	7131725	3600772
A1418#2	Niittylahti	gabbro	1.13	3.91	0.1744	0.512295	14	**2788**	1.2				441210	7131725	3600772
A1771	Kuhmo, Kellojärvi	gabbro	1.67	6.58	0.1533	0.511936	10	**2798**	1.9	2823			441112	7130834	3601214

Appendix 1. cont.

Sample	Location	Rock type	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$ (± 0.4%)	$^{143}Nd/^{144}Nd$	$2\sigma_m$	Age(T) (Ma)	$\varepsilon_{Nd}(T)$	T_{DM} (Ma)	Reference for Sm-Nd	comment[(*]	map	YKJ-North	YKJ-East
Kuhmo greenstone belt (N->S):															
A1503	Mäkisensuo	felsic volcanic rock	5.69	25.64	0.1343	0.511610	10	2800	2.4	2771			441112	7128835	3600958
A1377	Siivikko	crustal xenolith in komatiite	2.51	12.92	0.1175	0.511282	11	**2795**	2.0	2806			4411	7128059	3601375
A1822	Pahakangas	mafic volcanic rock (gabbroic)	2.21	6.88	0.1945	0.512645	10	2800	0.9			20-PTP-03	441112	7127527	3601305
A511	Katerma, Kuhmo	felsic volcanic rock	6.55	35.54	0.1113	0.511168	10	**2799**	2.0	2798		eps-Hf=+6	441111	7120960	3603082
6-EJH-96 (A2027)	Siivikko	qu-porphyry dyke	2.52	10.52	0.1450	0.511322	10	2795	-7.2	3944		open system?	441112	7128130	3602664
6-EJH-96#2	Siivikko	qu-porphyry dyke	2.58	10.87	0.1433	0.511302	10	2795	-7.0	3875		open system?	441112	7128130	3602664
A1746	Petäjäniemi Kuhmo	metasediment	0.84	3.38	0.1502	0.511221	20	2700	-11.6			open system?	441302	7118594	3609220
A1747	Petäjäniemi Kuhmo	metasediment	1.36	6.96	0.1179	0.511303	20	2740	1.7	2776			441302	7118594	3609220
81064	*Koitto Kuhmo*	*mica schist*	*2.73*	*13.72*	*0.1202*	*0.511301*	*24*	*2740*	*0.8*	*2851*	*M86*			*7113842*	*3612228*
Kuhmo greenstone belt komatiites and basalts:															
48-PTP-03	Moisiovaara N	komatiitic basalt	2.06	6.10	0.2047	0.512915	10	2800	2.5				442302	7175646	3604213
52-PTP-03	Koivulehto	komatiitic basalt	2.05	6.58	0.1880	0.512636	10	2800	3.0				441212	7151793	3598324
53-PTP-03	Arola W	komatiite	0.72	1.84	0.2354	0.513345	60	2800	-0.2			large error	441211	7151046	3598464
R400/64.80-67.00	Vuosanka	high-Cr basalt	1.62	3.93	0.2499	0.513753	10	2800	2.5				441202	7138098	3605017
R400/73.50-75.50	Vuosanka	high-Cr basalt	1.37	3.45	0.2395	0.513556	10	2800	2.4				441202	7138098	3605017
22-PTP-03	Mäkisensuo	Cr-basaltti	2.19	6.98	0.1901	0.512525	10	2800	0.1				441112	7129486	3600780
11-PTP-03	Siivikkovaara-Näätäniemi	high-Cr basalt	1.22	2.59	0.2854	0.514320	17	2800	0.8				441112	7129344	3600704
7A-PTP-03	Siivikkovaara S	komatiitic basalt	1.62	4.85	0.2015	0.512800	10	2800	1.4				441112	7128010	3602258
7D-PTP-03	Siivikkovaara S	komatiite	1.24	3.75	0.2005	0.512809	10	2800	1.9				441112	7128010	3602258
7B-PTP-03	Siivikkovaara S	komatiite	1.15	3.23	0.2149	0.513009	10	2800	0.6				441112	7128010	3602258
7F-PTP-03	Siivikkovaara S	komatiite	1.07	2.98	0.2165	0.513016	16	2800	0.2				441112	7128010	3602258
7E-PTP-03	Siivikkovaara S	komatiite	1.60	5.37	0.1801	0.512568	10	2800	4.6				441112	7128010	3602258
2B1-PTP-03	Pahakangas profile	komatiitic basalt	1.27	3.27	0.2349	0.513360	10	2800	0.2				441112	7127619	3601588
2E-PTP-03	Pahakangas profile	komatiitic basalt	1.31	3.28	0.2410	0.513318	10	2800	-2.8				441112	7127619	3601588
2C-PTP-03	Pahakangas profile	komatiitic basalt	1.45	4.02	0.2189	0.513068	10	2800	0.3				441112	7127619	3601588
2D-PTP-03	Pahakangas profile	komatiitic basalt	1.32	3.41	0.2335	0.513355	10	2800	0.6				441112	7127619	3601588
2H-PTP-03	Pahakangas profile	komatiite	0.93	2.57	0.2184	0.513066	10	2800	0.5				441112	7127619	3601588
56-PTP-03	Hietaperä	komatiitic basalt	1.68	5.21	0.1951	0.512710	20	2800	1.9				441112	7123890	3603424
TOH-206-93	Kellojärvi Kuhmo	serpentinite (komatiitic)	0.45	1.34	0.2003	0.512929	17	2800	4.3				4412		
Tipasjärvi greenstone belt:															
A1174C	Taivaljärvi	felsic volcanic rock	1.44	6.48	0.1344	0.511602	29	**2798**	2.2	2792		shaft, 485 m down	432212	7094249	3600135
A1174A	Taivaljärvi	felsic volcanic rock	0.96	6.66	0.0875	0.510693	10	2798	1.3	2841		shaft, 95 m down	432212	7094249	3600135
A1886	Tipasjärvi Sotkamo	felsic volcanic rock	5.32	26.84	0.1197	0.511298	10	**2794**	1.5	2844			432208	7088033	3593943
A1922	Tipasjärvi	felsic volcanic rock	4.45	24.84	0.1082	0.511083	10	**2828**	1.8	2842			432208	7085155	3592389
A1921	Tipasjärvi	felsic volcanic rock	1.55	10.17	0.0918	0.510784	10	**2810**	1.7	2833			432208	7083631	3594042
A1588	Alakolkonjärvi	garnet-amphibolite	6.76	18.05	0.2264	0.513252	10	2800	1.2				432208	7081873	3590726
A1588 garnet			1.91	0.27	4.3740	0.566500	200								
A1748	Aarreniemi Tipasjärvi	greywacke	3.14	16.42	0.1156	0.511094	20	**2746**	-1.5	3045			432212	7093916	3606458
Kuhmo granitoids (N->S):															
A337 #1	Säynäjävaara	tonalite gneiss	4.36	25.14	0.1049	0.510898	10	**2717**	-1.9	3023			442112	7189227	3596599
A337 #2	Säynäjävaara	tonalite gneiss	4.56	26.75	0.1030	0.510902	10	**2717**	-1.2	2962			442112	7189227	3596599
A1146	*Kaartojärvet*	*gabbro (sanukitoid)*	*3.61*	*20.89*	*0.1046*	*0.510989*	*10*	***2722***	*0.0*	*2884*	*K06*		*442312*	*7188084*	*3633531*

Appendix 1. cont.

Sample	Location	Rock type	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$ (± 0.4%)	$^{143}Nd/^{144}Nd$	$2\sigma_m$	Age(T) (Ma)	$\varepsilon_{Nd}(T)$	T_{DM} (Ma)	Reference for Sm-Nd	comment (*	map	YKJ-North	YKJ-East
Kuhmo granitoids (N->S):															
A1146 plag		plagioclase	0.08	1.27	0.0398	0.510225	20	2700	7.4				442312	7188084	3633531
A1146 hbl		hornblende	6.10	30.38	0.1215	0.511321	12	2700	0.4				442312	7188084	3633531
A27-1	Konivaara	granodiorite	1.37	9.35	0.0883	0.510661	10	**2705**	-0.9	2903	K06		4421	7177694	3574219
A27-2	Konivaara	granodiorite	1.73	15.77	0.0662	0.510270	10	2705	-0.8	2872	K06		4421	7177694	3574219
A27-4	Konivaara	granodiorite	5.98	41.63	0.0869	0.510696	10	2705	0.3	2828	K06		4421	7177694	3574219
A1960	Kuhmo	tonalite	2.29	15.54	0.0892	0.510650	10	2700	-1.5	2940		94002667	442306	7173438	3618354
A1927	Honkavaara Ristijärvi	granodiorite	3.79	30.73	0.0745	0.510397	11	**2700**	-1.3	2903		421C-ATK-06	344307	7164475	3565018
AAK-02-117	Suolahdenkallio	granodiorite (sanukitoid)	6.11	34.62	0.1066	0.511042	10	2734	0.5	2857	K06			7163832	3597772
AAK-02-59	Halmejärvi	leucogranite	6.90	50.59	0.0820	0.510557	10	2705	-0.7	2891	K06			7159194	3592668
A1183	Naavala	tonalite gneiss	1.01	5.04	0.1212	0.511074	20	**2750**	-3.9	3283			441409	7159156	3630364
A1183 #2	Naavala	tonalite gneiss	1.04	5.13	0.1226	0.511078	10	2750	-4.3	3328			441409	7159156	3630364
Naa3#2	Naavala 3 #2	tonalite gneiss	0.99	4.74	0.1263	0.511235	10	2750	-2.5	3190			441409	7159156	3630364
Naa5	Naavala 5	tonalite gneiss	0.95	4.54	0.1269	0.511186	16	2750	-3.7	3305			441409	7159156	3630364
Naa 2	Naavala 2	granitic dyke	2.67	19.28	0.0838	0.510440	20	2750	-3.0	3069			441409	7159156	3630364
Naa2#2	Naavala 2 #2	granitic dyke	2.67	19.39	0.0833	0.510417	10	2750	-3.3	3083			441409	7159156	3630364
A1183p	Naavala	small sample/ A1183	1.28	7.85	0.0984	0.510942	107	2750	1.7			large error	441409	7159156	3630364
A1183p#2	Naavala	small sample/ A1183	1.20	7.56	0.0958	0.510927	10	2750	2.3	2740			441409	7159156	3630364
Naa1	Naavala 1	granodiorite, mobilized	1.30	7.44	0.1052	0.510995	13	2750	0.3	2892			441409	7159156	3630364
Naa 4	Naavala 4	granodiorite, dyke?	10.00	94.00	0.0643	0.510358	10	2750	2.3	2741			441409	7159156	3630364
Naa4#2	Naavala 4 #2	granodiorite, dyke?	9.43	86.50	0.0659	0.510377	10	2750	2.1	2752			441409	7159156	3630364
Naa6	Naavala 6	coarse granite dyke	0.49	2.47	0.1198	0.511253	54	2750	0.1	2927			441409	7159156	3630364
Naa7	Naavala 7	amphibolite	1.99	5.61	0.2140	0.512972	10	2750	0.3				441409	7159156	3630364
AAK-02-09	Vitikko, Vartius	granodiorite	1.29	8.14	0.0959	0.510812	15	2700	-0.7	2894	K06			7157360	3637311
A1704	Vartius	granodiorite	1.34	6.50	0.1015	0.510954	31	**2700**	0.2	2846	K06		441412	7156717	3639073
A404b#2	Lylyvaara	tonalitic melanosome	4.55	23.82	0.1154	0.511050	10	**2942**	-0.3	3114			441409	7153484	3627739
AAK-02-48	Syvänoro	granodiorite/granite	7.80	40.59	0.1161	0.511160	30	2686	-1.1	2955	K06			7152855	3588839
A1702	Purnu	tonalite	1.99	14.30	0.0842	0.510657	10	**2747**	1.1	2811	K06		441103	7152723	3606741
A1707	Pohjanjärvi	leucogranite	2.17	11.16	0.1182	0.511210	26	**2705**	-0.6	2941	K06		441212	7152140	3595059
A572	Arola	granodiorite	4.14	24.61	0.1017	0.510979	10	**2734**	1.0	2814	K06		441212	7151667	3596926
AAK-02-57B	Arola	felsic inclusion in Arola grdr	3.81	23.19	0.0993	0.510932	10	2700	0.5	2817			441212	7151652	3596897
AAK-02-179A	Riihivaara	granodiorite	1.03	5.89	0.1051	0.510486	10	2686	-10.5	3629	K06	open system?		7149989	3582291
AAK-02-21	Raatolehto	granodiorite (sanukitoid)	4.00	22.73	0.1064	0.510974	10	2734	-0.8	2949	K06			7148475	3631560
AAK-02-81	Iso Niskavaara	granodiorite (sanukitoid)	5.83	32.62	0.1081	0.511087	10	2734	0.9	2827	K06			7147109	3596734
A1706	Pieni Tuomaanjärvi	granodiorite	3.04	19.07	0.0965	0.510692	10	**2695**	-3.3	3068	K06		441205	7146616	3580113
A402	Härmäjoki	granodiorite dyke	5.05	28.24	0.1080	0.511081	10	**2742**	0.9	2837	K06		441211	7146491	3598393
AAK-02-83	Lauttajärvi	granite	5.40	38.30	0.0849	0.510633	10	2700	-0.3	2863				7144925	3590913
AAK-02-87	Latvalampi	granodiorite (sanukitoid)	6.75	38.45	0.1061	0.511066	10	2734	1.2	2808	K06			7144421	3597300
A1147	Lentiira	microtonalite	14.95	99.66	0.0907	0.510734	10	**2701**	-0.4	2871			441410	7142378	3638087
61-1-ATK-86	Pitämänsuo Sotkamo	diorite (Loso sanukitoid)	11.90	69.10	0.1044	0.511022	10	2700	0.5	2830	K06		343407	7138480	3565290
AAK-02-77	Majakangas	granodiorite (sanukitoid)	5.48	30.85	0.1074	0.511082	10	2734	1.0	2818	K06			7137384	3598014
A331	Loso	diorite (Loso sanukitoid)	8.41	50.24	0.1011	0.510944	12	**2719**	0.3	2849	K06		343407	7135100	3563200
A1928	Sarvilampi Sotkamo	granodiorite (nebulitic)	2.24	18.19	0.0743	0.510160	10	**2965**	-1.7	3164			343407	7134499	3568058
A1926	Ansosuo Sotkamo	diorite gneiss ("Loso")	15.46	81.93	0.1140	0.511183	10	**2715**	0.4	2857		437-ATK-07	343407	7133922	3564832

Appendix 1. cont.

Sample	Location	Rock type	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$ (± 0.4%)	$^{143}Nd/^{144}Nd$	$2\sigma_m$	Age(T) (Ma)	$\varepsilon_{Nd}(T)$	T_{DM} (Ma)	Reference for Sm-Nd	comment [(]	map	YKJ-North	YKJ-East
Kuhmo granitoids (N->S):															
AAK-02-84	Kauppinen	granodiorite gneiss	2.61	18.04	0.0875	0.510782	16	2700	1.7	2732				7132153	3594695
AAK-02-157	Lampovaara	leucogranite	1.42	10.75	0.0797	0.510475	10	2697	-1.7	2926	K06			7128565	3581076
A1705	Viitavaara	tonalite	2.69	13.92	0.1166	0.511274	11	**2785**	2.1	2785	K06		441109	7121621	3591704
A1719	Siikalahti	granodiorite (sanukitoid)	5.08	33.18	0.0926	0.510802	10	**2695**	0.2	2825	K06	AAK-02-177		7119821	3614489
AAK-02-167A	Romuvaara	leucogranite	1.75	10.62	0.0996	0.510860	10	2697	-1.1	2925	K06			7106738	3595473
94002593#3		granodiorite	6.08	33.39	0.1100	0.511093	10	2700	-0.1	2879			443104	7106131	3658934
A1703	Katajavaara	leucogranite	2.55	17.76	0.0867	0.510739	12	**2697**	1.1	2766	K06		441107	7105667	3595878
94002606		granitegneiss	3.52	16.61	0.1283	0.511465	10	2700	0.8	2832			441304	7103485	3619776
AAK-02-100	Risteli	tonalite	2.25	10.28	0.1324	0.511489	10	2830	0.9	2830	K06			7103410	3619440
A1086	Haasiavaara	tonalite	2.44	13.30	0.1108	0.511118	10	**2832**	1.6	2860	K06		432209	7100126	3594392
AAK-02-166	Vetelänvaara	tonalite	3.44	19.46	0.1067	0.511073	10	2830	2.2	2814	K06			7090977	3588767
A1089	Huuskovaara	tonalite	1.51	7.69	0.1188	0.511211	10	**2814**	0.3	2958	K06		432211	7089923	3606066
93002713		tonalitegneiss	7.60	37.97	0.1210	0.511254	10	2700	-0.8	2962			334408	7088720	3569860
A1085	Halmejärvi	tonalite	2.71	10.83	0.1513	0.511837	10	**2745**	0.3	2982	K06		432207	7075307	3589072
94003191		quartzdiorite gneiss	9.11	38.02	0.1449	0.511659	10	2700	-1.2	3109			432407	7074206	3631667
A790	Pohjanjärvi	granite	1.74	8.45	0.1245	0.511273	10	2700	-1.6	3044			441212	7152182	3595099
A790uusi	Pohjanjärvi	granite	8.76	31.38	0.1688	0.512252	10	2700	2.1	2714			441212	7152182	3595099
Ilomantsi (Hattu) schist belt:															
M8603917	Poikapää	mafic pillow lava	3.21	9.79	0.1984	0.512305	22	2750	-7.2		O93	open systems	433307		
M8603917 #2	Poikapää	mafic pillow lava	3.49	10.73	0.1964	0.512344	14	2750	-5.8		O93	open systems	433307		
M8603967	Tiittalanvaara	amphibolite	1.63	4.49	0.2187	0.513108	10	2750	1.3		O93				
A1038	Poikapää	andesite	3.67	16.94	0.1311	0.511331	10	**2754**	-2.3	3201	O93	open systems?	433307	6993805	3713236
A1038 #2	Poikapää	andesite	3.87	17.72	0.1320						O93	open systems?	433307	6993805	3713236
A1038 #3	Poikapää	andesite	3.92	17.96	0.1318	0.511328	16	2754	-2.6	3230		open systems?	433307	6993805	3713236
A1038b	Poikapää	andesite	3.75	14.10	0.1606	0.511534	10	2754	-8.9			open systems	433307	6993805	3713236
A1039	Poikapää	metasediment	3.07	18.30	0.1013	0.510996	11	2750	1.7	2786	O93		433307	6993805	3713236
A1039 #2	Poikapää	metasediment	3.15	18.80	0.1013						O93		433307	6993805	3713236
A1039 #3	Poikapää	metasediment	3.18	18.83	0.1019	0.510994	10	2750	1.4	2802			433307	6993805	3713236
A1039b	Poikapää	metasediment	4.57	27.51	0.1003	0.510951	11	2750	1.2	2820		second sample	433307	6993805	3713236
A282#3	Vehkavaara	felsic dyke	3.32	18.65	0.1076	0.510951	12	2750	-1.5	3021			4244	6968216	3697163
A301#3	Vehkavaara	felsic dyke	2.40	13.38	0.1084	0.510941	12	**2755**	-1.9	3061			4244	6968216	3697163
A1095	Kivisuo	felsic porphyry dyke	3.14	18.62	0.1019	0.510982	10	**2756**	1.3	2818	O93		424408	6974009	3714000
S21	Ilomantsi	mica gneiss	3.17	14.20	0.1349	0.511386	32	2750	-2.6	3254	H87	133-SL-69	424402	6965830	3695191
S18	Ukkolanvaara Ilom	mica schist	2.11	10.02	0.1276	0.511422	14	2750	0.7	2893	O93	53-SL-67	424409	6977221	3717596
S19	Ilomantsi/Eno	mica schist	3.56	17.64	0.1221	0.511225	10	2750	-1.2	3053	O93	15/68	424210	6961361	3692996
S20	Leppärinne Ilom	mica schist	2.80	14.37	0.1176	0.511174	11	2750	-0.6	2986	O93	95-SL-68	424408	6971208	3716024
A221	Hattuvaara	mica schist	3.94	22.39	0.1063	0.511060	10	2750	1.2	2826	O93		433307	6987579	3717193
Ultramafic rocks from Hattu schist belt															
L05071816	Ilomantsi	ultramafic rock	0.83	3.43	0.1457	0.511764	20	2750	0.9	2898		HJO-86-30	433307	6995360	3715648
L05071817	Ilomantsi	ultramafic rock	0.72	2.71	0.1617	0.512041	20	2750	0.7	2989		HJO-86-32	433307	6994985	3715775
L05071818	Ilomantsi	ultramafic volcanic rock	0.50	1.88	0.1608	0.511998	20	2750	0.2	3070		KJP-87-80.2	433308	6997601	3717957
L05071819	Ilomantsi	ultramafic volcanic rock	2.21	10.00	0.1334	0.511606	20	2750	2.2	2744		KJP-87-80.1	433308	6997601	3717957
L05071820	Ilomantsi	ultramafic volcanic rock	2.66	14.67	0.1096	0.511236	20	2750	3.4	2652		KJP-87-14.2	433308	7003532	3712622
L05071821	Ilomantsi	ultramafic volcanic rock	2.46	12.36	0.1204	0.511345	20	2750	1.7	2785		KJP-87-16	433308	7003931	3712603
L05092835	Ilomantsi	mafic volcanic rock	2.52	7.44	0.2051	0.512406	20	2750	-7.6				433307	6989794	3717520

Appendix 1. cont.

Sample	Location	Rock type	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$ (± 0.4%)	$^{143}Nd/^{144}Nd$	$2\sigma_m$	Age(T) (Ma)	$\varepsilon_{Nd}(T)$	T_{DM} (Ma)	Reference for Sm-Nd	comment (*	map	YKJ-North	YKJ-East
Kovero schist belt:															
A1622	Otravaara	felsic volcanic rock	1.59	4.62	0.2073	0.512962	10	2750	2.5				424106	6945072	3673746
A1623	Turula	tonalite gneiss/ volcanics?	6.08	36.75	0.1000	0.510941	10	2750	1.1	2823			424109	6948327	3674878
A1624	Hämälänniemi	felsic volcanic rock	5.86	39.00	0.0908	0.510908	10	**2877**	5.5	2648		open systems?	424108	6942496	3674651
A1624#2	Hämälänniemi	felsic volcanic rock	5.94	39.51	0.0909	0.510899	10	2877	5.2	2662		open systems?	424108	6942496	3674651
A1625	Rasisuo 1	porphyry dyke	3.17	14.75	0.1298	0.511154	10	**2757**	-5.3	3484		open systems?	424108	6942918	3675005
A1625#2	Rasisuo 1	porphyry dyke	3.17	14.80	0.1293	0.511126	10	2757	-5.7			open systems?	424108	6942918	3675005
A1626	Rasisuo 2	gabbro	6.93	32.27	0.1298	0.511517	10	**2756**	1.8	2785			424108	6944375	3674468
A1627	Rasisuo 3	felsic tuff	2.86	18.99	0.0912	0.510598	10	**2878**	-0.8	3052			424108	6943876	3675201
A1628	Hämälänniemi	gabbro	1.42	3.99	0.2151	0.513133	10	2750	3.1				424108	6941671	3675077
A1629	Turula 2	felsic volcanic rock	2.17	7.50	0.1744	0.512227	10	2750	-0.2			high Sm/Nd	424109	6948211	3674940
A1154	Löytöjärvi	dacitic schist	5.61	37.63	0.0901	0.510829	10	2750	2.4	2734			424106	6945952	3668957
A1155	Linnasuo	porphyry (tonalitic dyke)	5.52	30.31	0.1101	0.511172	10	**2758**	2.1	2761			424108	6943513	3676802
A1520	Kiukoinvaara	granodiorite (dyke in mica schist)	3.16	24.19	0.0791	0.510783	10	**2754**	5.5	2558			424105	6942270	3673334
Ipatti schist belt															
A1749	Kokkokallio, Koli	qu-fspar-porphyry	3.50	17.76	0.1191	0.511242	20	**2811**	0.8	2914			431309	7010076	3639521
Ilomantsi granitoids (N->S):															
94003175		tonalite	5.23	31.47	0.1004	0.510900	20	2700	-0.5	2894			432308	7059053	3633080
A1772	Änäkäinen Lieksa	gabbro (essexite)	58.4	300.3	0.1176	0.511224	10	**2712**	-0.1	2900			434102	7057845	3653013
A1763	Ollikkalanvaara	tonalite	2.04	11.10	0.1112	0.511170	10	**2722**	1.3	2794			432304	7043837	3619769
94003163		granodiorite	4.40	29.72	0.0896	0.510856	20	2700	2.4	2688			432110	7042789	3608691
A1764	Persauslammet	amphibolite	2.87	9.39	0.1848	0.512492	20	2700	1.2				433206	7040755	3663941
A1767	Karppinen 1	granite	15.82	94.61	0.1010	0.510967	10	**2690**	0.5	2817			431408	7032730	3634136
A1768	Karppinen 2	tonalite	3.02	21.06	0.0867	0.510734	10	**2822**	2.8	2776			431408	7032730	3634136
A1765	Jamali 1	mica gneiss (mesosome)	2.18	10.40	0.1265	0.511399	10	2700	0.2	2893			431411	7031233	3644756
A1766	Jamali 2	granite (leucosome)	0.52	3.04	0.1042	0.510978	15	2700	-0.3	2884			431411	7031233	3644756
93002466		gneiss	3.94	17.72	0.1343	0.511488	10	2700	-0.8	3014			431411	7029555	3641442
PK-50	Lieksa	granodiorite (sanukitoid)	6.54	39.79	0.0993	0.510941	10	2700	0.7	2804	H05		433211	7029368	3682789
PK-49	Lieksa	granodiorite (sanukitoid)	7.66	44.72	0.1035	0.511024	10	2700	0.8	2798	H05		433208	7028199	3671937
PK-47	Lieksa	granodiorite (sanukitoid)	6.03	35.86	0.1016	0.510964	10	2700	0.3	2832	H05		433208	7027646	3671252
A1762	Emonvaara	tonalite	5.23	33.51	0.0944	0.510847	15	**2732**	1.0	2812			433205	7027479	3661337
PK-100	Lieksa	granodiorite (sanukitoid)	7.80	49.51	0.0952	0.510904	10	2700	1.4	2754	H05		433205	7026409	3669868
PK-42	Lieksa	granodiorite (sanukitoid)	6.37	41.97	0.0917	0.510814	10	2700	0.8	2788	H05		433205	7025522	3669319
PK-45	Lieksa	granodiorite (sanukitoid)	6.91	46.76	0.0893	0.510744	24	2700	0.3	2820	H05		433204	7023545	3670293
A1964	Ilomantsi	granite	7.05	40.36	0.1056	0.511004	10	2700	-0.3	2887		94002572	433210	7021049	3685422
A1339 (PK-27)	Iso Kiimalampi	tonalite (sanukitoid)	6.35	37.96	0.1010	0.510966	13	**2730**	0.9	2815	H05		433210	7020121	3683802
A1336	Sourisuo	tonalite (sanukitoid)	6.03	33.10	0.1100	0.511140	10	**2730**	1.2	2805	H05		433107	6989109	3672724
93002484		granodiorite gneiss	8.85	43.55	0.1228	0.511349	10	2700	0.5	2858			433306	7012294	3707655
A1094	Tasanvaara	tonalite	4.69	25.30	0.1120	0.511148	10	**2744**	0.8	2851	O93		433307	6989342	3715899
A339	Silvevaara	granodiorite	3.51	19.51	0.1088	0.510941	10	2750	-2.1	3077	O93		424406	6983787	3706753
A339b	Silvevaara	granodiorite	3.91	22.25	0.1064	0.510983	10	2750	-0.4	2942	O93	second sample	424406	6983787	3706753
A285	Kuittila	tonalite (sanukitoid)	4.09	24.02	0.1029	0.511019	10	**2746**	1.5	2795	O93		4244	6974252	3714489
A284#2	Lehtovaara	granodiorite (Silvevaara)	5.96	32.40	0.1111	0.511054	10	**2750**	-0.7	2974	O93		4244	6973076	3710317
A1963	Ilomantsi	granodiorite	4.05	25.04	0.0977	0.510870	10	2700	-0.2	2865		90010130	424404	6959880	3708970
A91	Kutsu Tohmajärvi	granite	5.73	40.61	0.0853	0.510727	10	**2617**	0.2	2751			423207	6914462	3684841

Appendix 1. cont.

Sample	Location	Rock type	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$ (± 0.4%)	$^{143}Nd/^{144}Nd$	$2\sigma_m$	Age(T) (Ma)	$\varepsilon_{Nd}(T)$	T_{DM} (Ma)	Reference for Sm-Nd	comment (*	map	YKJ-North	YKJ-East
Archean "domes":															
R27	*Sotkuma*	*granodiorite gneiss*	*1.98*	*11.19*	*0.1067*	*0.511039*	*60*	*2700*	*0.0*	*2869*	*H86*	*large error*	*4224*	*6959795*	*3627757*
S55	Oravinsalo	granitoid (sheared)	9.44	52.52	0.1086	0.511123	10	2700	1.0	2792			421406	6917763	3630813
Iisalmi complex (N->S):															
A1959	Iisalmi	gneiss	2.60	17.09	0.0920	0.510819	10	2700	0.8	2791		94003640	343101	7101160	3500970
L05029450	190-PSH-04	amphibolite	3.19	10.38	0.1859	0.512165	20	2710	-5.6			open system?		7096414	3517642
93002622		granitegneiss	4.08	24.20	0.1020	0.510982	20	2700	0.5	2820			334206	7095070	3512530
A1513	Naimakangas	diorite	6.79	36.00	0.1140	0.511224	10	**2706**	1.2	2789			334203	7093430	3507620
L05028811	179.1-PSH-04	amphibolite	4.95	25.38	0.1178	0.511241	20	2710	0.2	2879				7075136	3498485
A1958	Iisalmi	tonalite	8.10	52.10	0.0940	0.510870	10	2700	1.1	2772		93003031	334302	7057160	3547420
PSH-90-53	*Luotosenkoski*	*px-amphibolite*	*5.85*	*26.84*	*0.1320*	*0.511377*	*11*	*3100*	*1.2*	*3147*	*H00*		*334110*	*7049600*	*3535150*
A1145	*Kumisevanmäki*	*mesos. of interm. grl*	*5.48*	*29.60*	*0.1119*	*0.510917*	*11*	***3200***	*1.3*	*3213*	*H00*	$\varepsilon_{Hf}(T)=+0.6\pm1.5$	*334110*	*7047040*	*3533200*
A1332	*Kumisevanmäki*	*leucos. of interm. grl*	*1.91*	*6.63*	*0.1753*	*0.512135*	*11*	*2700*	*-2.5*		*H00*	$\varepsilon_{Hf}(T)=-5.7\pm5.0$	*334110*	*7047040*	*3533380*
A1332b	*Kumisevanmäki*	*mesosome*	*2.29*	*8.17*	*0.1697*	*0.512096*	*10*	*2700*	*-1.3*		*H00*		*334110*	*7047040*	*3533380*
93002664		tonalite	6.74	37.77	0.1079	0.511108	20	2700	0.9	2797			334110	7042270	3533520
A1222	*Rokuankangas*	*px-grt-amphibolite*	*2.57*	*8.59*	*0.1809*	*0.512500*	*80*	*2700*	*2.7*		*H00*		*333212*	*7039640*	*3535510*
A1222#2 (2000)	Rokuankangas	px-grt-amphibolite	2.62	8.73	0.1811	0.512460	10	2700	1.9				333212	7039640	3535510
A979	*Lampiensalmi*	*enderbite*	*8.24*	*39.93*	*0.1247*	*0.511410*	*10*	*2700*	*1.0*	*2815*	*H00*		*333209*	*7039460*	*3527870*
A844	*Varpaisjärvi*	*enderbite*	*6.84*	*34.81*	*0.1187*	*0.511263*	*10*	***2716***	*0.4*	*2873*	*H00*	$\varepsilon_{Hf}(T)=-0.3\pm1.0$	*333403*	*7031920*	*3540840*
A1331	*Jouhimäki*	*leucos. of mafic granulite*	*3.86*	*38.61*	*0.0605*	*0.510269*	*10*	*2700*	*1.1*	*2759*	*H00*	$\varepsilon_{Hf}(T)=-1.0\pm2.0$	*333403*	*7030260*	*3547250*
A1391	*Jouhimäki*	*mesos. of mafic granulite*	*4.62*	*24.50*	*0.1140*	*0.511141*	*11*	*2700*	*-0.6*	*2926*	*H00*	$\varepsilon_{Hf}(T)=+0.5\pm2.9$	*333403*	*7030260*	*3547250*
A1326	*Jouhimäki*	*grt-sill-gneiss*	*3.74*	*17.70*	*0.1276*	*0.511470*	*10*	*2700*	*1.2*	*2804*	*H00*	$\varepsilon_{Hf}(T)=-0.3\pm1.5$	*333403*	*7030000*	*3547000*
A1142b	*Jouhimäki*	*grt-crd-sill-rock*	*15.81*	*68.58*	*0.1393*	*0.511732*	*10*	*2700*	*2.2*	*2703*	*H00*		*333402*	*7029530*	*3546920*
A1142b#2	*Jouhimäki*	*grt-crd-sill-rock*	*15.59*	*68.79*	*0.1370*	*0.511710*	*10*	*2700*	*2.6*	*2667*	*H00*		*333402*	*7029530*	*3546920*
A76	*Romonmäki*	*tonalitic mesosome*	*8.24*	*37.21*	*0.1338*	*0.511260*	*10*	***3173***	*-1.3*	*3458*	*L11*	$\varepsilon_{Hf}(T)=-1.0\pm1.2$	*333208*	*7028220*	*3528760*
A76#3	Romonmäki	tonalitic mesosome	8.47	38.27	0.1337								333208	7028220	3528760
A76#4	Romonmäki	tonalitic mesosome	8.47	38.37	0.1337	0.511260	20	3173	-1.2	3458			333208	7028220	3528760
A645	*Kiikkukallio*	*trondhjemitic leucosome*	*3.08*	*19.16*	*0.0972*	*0.510640*	*10*	*3100*	*0.7*	*3161*	*L11*		*333208*	*7024960*	*3525700*
A937	*Kiikkukallio*	*tonalitic mesosome*	*3.31*	*18.45*	*0.1085*	*0.510819*	*10*	***3181***	*0.6*	*3252*	*L11*	$\varepsilon_{Hf}(T)=-0.2\pm1.5$	*333208*	*7024800*	*3525600*
A937#2	Kiikkukallio	tonalitic mesosome	3.83	21.60	0.1072	0.510800	10	3181	0.8	3239			333208	7024800	3525600
A937#4	Kiikkukallio	tonalitic mesosome	3.71	21.11	0.1062								333208	7024800	3525600
A937#5	Kiikkukallio	tonalitic mesosome	3.72	21.05	0.1067	0.510803	10	3181	1.0	3218			333208	7024800	3525600
PK-113A	*Nilsiä*	*augen gneiss*	*11.29*	*63.01*	*0.1081*	*0.511122*	*11*	*2700*	*1.2*	*2780*	*H05*		*333407*	*7016810*	*3564360*
PK-121	*Nilsiä*	*augen gneiss*	*8.95*	*59.23*	*0.0913*	*0.510817*	*10*	*2700*	*1.0*	*2775*	*H05*		*333410*	*7014930*	*3570080*
PK-120A	*Nilsiä*	*augen gneiss*	*7.08*	*45.65*	*0.0937*	*0.510879*	*10*	*2700*	*1.4*	*2750*	*H05*		*333410*	*7010000*	*3571340*
A279	Kivimäki	quartz diorite	4.78	27.01	0.1070	0.511104	20	**2692**	1.1	2778			333103	7008320	3509380
A300	Siilinjärvi	carbonatite, sövite	21.00	143.30	0.0885	0.510781	10	2609	0.0	2757			33312	7000140	3537250
A187	Siilinjärvi	"inclusion" in carbonatite	2.55	18.01	0.0856	0.510731	10	2609	0.0	2751			33312	7000000	3537100
Apatite-concentrate	Siilinjärvi	carbonatite/ apatite	107.40	706.20	0.0919	0.510821	10	2609	-0.3	2783			33312	7000000	3537100
Manamasalo															
A1401	Multasuo	qudioritic paleosome	6.80	39.79	0.1033	0.510838	11	2700	-2.8	3058			343206	7156500	3513240
A1515	Multasuo	syenite (diopside-)	67.30	344.80	0.1180	0.511018	10	2700	-4.4	3254			343206	7156500	3513240
A1291	Kaivanto	trondjhemite leucosome	0.21	2.05	0.0621	0.510182	76	2700	-1.2	2878		large error	343202	7145130	3508580
94003658		gneiss	4.43	20.03	0.1337	0.511542	10	2700	0.4	2883			343103	7129400	3501150

Appendix 1. cont.

Sample	Location	Rock type	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$ (± 0.4%)	$^{143}Nd/^{144}Nd$	$2\sigma_m$	Age(T) (Ma)	$\varepsilon_{Nd}(T)$	T_{DM} (Ma)	Reference for Sm-Nd	comment (*	map	YKJ-North	YKJ-East
Manamasalo															
94003664		gneiss	5.03	33.44	0.0910	0.510552	20	2700	-4.1	3108			343112	7122480	3538130
L05028800	167.1-PSH-04	tonalite	4.42	36.28	0.0736	0.510724	20	2700	5.4	2521		Proterozoic rock?		7150858	3486830
L05028807	175.1-PSH-04	granodiorite	5.05	37.24	0.0819	0.510433	20	2700	-3.2	3029				7160836	3517091
A1837	Karankalahti Kajaani	tonalitegneiss	7.45	31.63	0.1424	0.511564	10	2700	-2.2	3211			343111	7119308	3537523
A1897	Rahajärvi Pyhäntä	tonalite	2.58	13.89	0.1121	0.511185	20	2700	1.0	2798			341310	7103794	3490519
A1925	Saaresjärvi Vuolijoki	tonalitegneiss	5.83	32.30	0.1092	0.511087	13	2700	0.1	2863		57-ATK-06	341310	7109495	3492521
Central Puolanka Group															
A1292	Haapalanmäki	dacitic tuff	6.16	32.28	0.1154	0.511114	20	2700	-1.6	3007			343208	7149860	3525280
ATK-14B	Haapalanmäki	andesite	4.74	19.62	0.1461	0.511740	10	2700	-0.0	2978			343209	7150780	3525560
A1235	Kivesvaara	felsic tuffite	4.17	20.70	0.1219	0.511292	20	2700	-0.3	2929			343208	7149780	3525380
A1251	Petäjäniemi Paltamo	porphyry	5.09	29.39	0.1046	0.511056	10	2718	1.3	2785			343208	7147020	3524020
Nurmes paragneisses and related amphibolites, Kontinen et al 2007:															
53-PGN-90	*Lemetinkangas Hyryns*	*mica gneiss*	*4.37*	*24.17*	*0.1092*	*0.511106*	*10*	*2700*	*0.5*	*2839*	*K07*		*344407*	*7197220*	*3562940*
44-PGN-90	*Polvela Kuhmo*	*mica gneiss*	*1.63*	*7.59*	*0.1296*	*0.511273*	*10*	*2700*	*-3.4*	*3251*	*K07*	*open system?*	*441310*	*7107214*	*3644733*
44-PGN-90 #2					*0.1300*						*K07*				
57-3A-ATK-8	*Romeikonsuo Sotkamo*	*mica gneiss*	*4.90*	*26.77*	*0.1106*	*0.511122*	*10*	*2700*	*0.3*	*2854*	*K07*		*343408*	*7140390*	*3568120*
A1081	*Nenämäki (=389-ATK-83)*	*mica gneiss*	*3.71*	*20.9*	*0.1074*	*0.511112*	*10*	*2700*	*1.2*	*2776*	*K07*		*344307*	*7161640*	*3568400*
1-KUH-88	*Saarela Kuhmo*	*mica gneiss*	*2.91*	*14.04*	*0.1252*	*0.511147*	*10*	*2700*	*-4.4*	*3308*	*K07*	*open system?*	*441304*	*7111827*	*3621285*
S22	*Kuhmo*	*mica gneiss*	*2.47*	*12.38*	*0.1205*	*0.511194*	*40*	*2700*	*-1.8*	*3050*	*H87*		*441304*	*7111769*	*3621337*
A73b	*Säyneinen*	*mica gneiss*	*5.27*	*33.84*	*0.0942*	*0.510847*	*10*	*2700*	*0.6*	*2810*	*K07*		*333410*	*7013600*	*3571800*
13A-NUR-90	*Maaselän as.*	*mica gneiss*	*4.46*	*23.78*	*0.1134*	*0.511097*	*20*	*2700*	*-1.2*	*2974*	*K07*		*432203*	*7087375*	*3573828*
9-NUR-90	*Nurmes*	*mica gneiss*	*4.03*	*21.61*	*0.1126*	*0.511105*	*12*	*2700*	*-0.8*	*2940*	*K07*		*432110*	*7051065*	*3607972*
35-PGN-90	*Hirvivaara Rautavaara*	*mica gneiss*	*4.19*	*23.19*	*0.1093*	*0.511098*	*23*	*2700*	*0.3*	*2854*	*K07*		*431205*	*7025742*	*3586332*
37-PGN-90	*Petäisjoki*	*mica gneiss (pelitic)*	*7.11*	*41.12*	*0.1044*	*0.511085*	*10*	*2700*	*1.7*	*2736*	*K07*		*431205*	*7025895*	*3590029*
1-VAL-88	*Iso Juomasuo Valtimo*	*mica gneiss*	*4.00*	*21.34*	*0.1133*	*0.511103*	*10*	*2700*	*-1.1*	*2965*	*K07*		*432207*	*7072359*	*3590252*
204-2A-ATK-	*Paloniemi Ristijärvi*	*amphibolite (within mica gneiss)*	*4.12*	*14.25*	*0.1750*	*0.512343*	*10*	*2700*	*1.7*		*K07*		*3434*	*7153300*	*3567440*
204-2B-ATK-	*Paloniemi*	*grt amphibolite*	*8.21*	*27.63*	*0.1797*	*0.512422*	*12*	*2700*	*1.6*		*K07*		*3434*	*7153300*	*3567440*
57-1A-ATK-8	*Romeikonsuo Sotkamo*	*amphibolite (within mica gneiss)*	*5.45*	*19.77*	*0.1668*	*0.512178*	*11*	*2700*	*1.4*		*K07*		*343408*	*7140450*	*3568080*
57-1B-ATK-8	*Romeikonsuo*	*grt amphibolite*	*4.40*	*17.43*	*0.1528*	*0.511939*	*10*	*2700*	*1.6*	*2797*	*K07*		*343408*	*7140450*	*3568080*
391-ATK-83	*Pieni Löytösuo Risti*	*amphibolite (within mica gneiss)*	*2.15*	*6.44*	*0.2021*	*0.512840*	*20*	*2700*	*2.0*		*K07*		*344307*	*7161740*	*3568440*
17-8-ATK-87	*Pieni Löytösuo*	*amphibolite*	*2.35*	*7.31*	*0.1943*	*0.512680*	*20*	*2700*	*1.6*		*K07*		*344307*	*7161720*	*3569060*
57-1C-ATK-8	*Kuppalampi Sotkamo*	*amphibolite*	*1.25*	*3.79*	*0.2001*	*0.512660*	*40*	*2700*	*-0.8*		*K07*		*343407*	*7137780*	*3564670*

Measurements since 1990 at GTK were made on VG Sector 54 mass-spectrometer.
$^{143}Nd/^{144}Nd$ ratio is normalized to $^{146}Nd/^{144}Nd$=0.7219, error is 2 standard error of the mean in last significant digits,
Measurements on the La Jolla standard have yielded a ratio of 0.511850±10 (standard deviation for 220 measurements during years 1996-2010).
# denotes duplicated analysis
T_{DM} is calculated according to DePaolo (1981)
Age is in bold, if it is based on U-Pb dating on the same sample (reference or associated U-Pb paper), othervise it is 2700 Ma or age obtained for rocks in the same association
Italics - Sm-Nd published elsewhere (reference for Sm-Nd: H86 &87=Huhma 1986 &1987, H00=Hölttä et al 2000; H05=Halla 2005; Hetal=Heilimo et al 2013;
K06=Käpyaho et al 2006; K07=Kontinen et al 2007; L06=Lauri et al 2006; L11=Lauri et al 2011;
M86=Miller et al 1986; M03=Mutanen & Huhma 2003; M11a&b=Mikkola et al 2011a &b; O93=O'Brien et al 1993)
(* $\varepsilon_{Hf}(T)$ average±standard deviation are calculated from the zircon analyses by Lauri et al (2011), other eHf(T) from Patchett et al (1981)