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U-Pb DATINGS IN THE SODANKYLÄ SCHIST AREA, CENTRAL FINNISH LAPLAND

by
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The bedrock of the Sodankylä schist area consists mainly of Paleoproterozoic volcanic and sedimentary rocks penetrated by mafic and felsic intrusives. This paper reports c. 200 conventional U-Pb analyses mainly on zircon. A total of 34 samples were studied from 12 mafic intrusions, 3 granitoids, 5 metavolcanic rocks and 4 metasediments. Many samples yielded discordant and heterogeneous data, either due to inheritance or effects of metamorphism.

The age results obtained suggest that a supracrustal belt running on the southwestern side of the Sodankylä schist area and continuing inside the Central Lapland Granite Complex is late Archean in origin. Besides amphibolites, it includes mainly different kinds of gneisses associated with 2775±25 Ma old felsic volcanic rocks. The Proterozoic volcanic succession starts with felsic extrusives, which have yielded an age of 2438±11 Ma and seem to be coeval with the emplacement of the layered mafic intrusions which indicate the break-up of the Archean continent at the beginning of the Proterozoic eon.

The overlying volcano-sedimentary pile is penetrated by intrusive rocks of various ages. The most reliable results from mafic intrusions include ages such as 2222±6 Ma (Harjunoja), 2148±11 Ma (Rantavaara), 2070±5 Ma (Ahvenselkä) and 2055±5 Ma (Rovasvaara). Accordingly, the age of deposition of the Sodankylä and Savukoski Group supracrustal rocks is considered older than 2.22 Ga and 2.05 Ga, respectively.

A granodiorite associated with a gabbroic rock inside the schist area yields an age of 1891±5 Ma indicating that intrusions of the Haaparanta Suite are not restricted only to western Lapland. The 1.8 Ga thermal episode in the area is manifested by an age of 1808±8 Ma for a granite pegmatite dyke, as well as a few U-Pb ages on titanites. Several granites formed at this stage contain zircons inherited from older, presumably Archean sources.

Key words (GeoRef Thesaurus AGI)*:* absolute age, U/Pb, zircon, metavolcanic rocks, intrusions, gabbros, metadiabase, granites, Paleoproterozoic, Archean, Sodankylä, Lappi Province, Finland

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INTRODUCTION

The Central Lapland Greenstone Belt in northern Finland is part of a widespread, c. 1000 km long NW-SE trending Paleoproterozoic supracrustal belt, extending from Russian Karelia to northern Norway and Sweden. On the basis of lithology, the Central Lapland Greenstone Belt can be divided into subareas, which are from southeast to northwest the Kuusamo schist area, the Salla greenstone area, the Sodankylä schist area and the Kittilä greenstone area. The Peräpohja schist belt further southwest records the same early Proterozoic regime, but is separated from the Central Lapland Greenstone Belt by a large granitic terrain, about 20,000 km^2 in extent, called the Central Lapland Granite Complex and generally considered to be principally Proterozoic in age.

The Sodankylä Schist area occupies the middle part of the Central Lapland Greenstone Belt. The bedrock consists mainly of Proterozoic supracrustals containing volcanic and sedimentary rocks penetrated by mafic and felsic intrusives. Direct age determinations on volcanic rocks have generally been difficult and only few age data have been available. Instead, dating of several intrusive rocks has been successful. The data considered in this paper are based on c. 200 conventional U-Pb analyses of zircons and represent 34 rock samples taken by several researchers during the last decades. Most of the dated rocks are mafic intrusions and some of the ages have been published earlier. However, as their analytical data are still unpublished and as additional analyses and even resampling has been done in some cases, all the data will be published here.

Because of the fact that, probably due to later metamorphism, many samples contain heterogeneous zircon populations and yield discordant data, no precise ages could be determined for many of the rocks. Dating rocks containing inherited zircons, such as S-type granites is hard by conventional methods and requires ionprobe techniques. The same applies to detrital zircons in sedimentary rocks. In spite of these problems, several reliable ages for mafic intrusions have been obtained and these give information of separate magmatic phases, some of which have produced also extrusive rocks.

It must be stressed that all the described lithological units have undergone metamorphism and consequently all rock names should also carry the prefix meta-. However, for simplicity and to avoid tautology it is not used in this paper. It should be also mentioned that the map in Figure1, based on the 1:1,000,000 bedrock map of Finland, does not show all lithological variations in the study area.

GEOLOGICAL OUTLINE

The Central Lapland Greenstone Belt consists of areas where either volcanic or sedimentary rocks are prevailing. The middle part of the belt, roughly the area between Sodankylä and Savukoski, is dominated by sedimentary rocks and is called the Sodankylä schist area (Räsänen 1991). It is bounded in the southeast with a gradational contact to the Salla greenstone area but in the northwest its contact with the Kittilä greenstone area is tectonic. The area is bounded in the northeast by the Archean Basement Complex and comes in contact with the Central Lapland Granite Complex in the southwest (Fig. 1).

The geological outline of Finnish Lapland was drawn by Mikkola (1941) and the bedrock mapping at the scale 1:100,000 initiated in the Sodankylä district in the beginning of the 1970s (Tyrväinen 1983). Based on studies of the Lapland Volcanite Project, Räsänen et al. (1996) presented a formal stratigraphic classification scheme, where the Paleoproterozoic supracrustal rocks of the Central Lapland Greenstone Belt were divided into seven groups. From oldest to youngest, they are the Salla, Onkamo, Sodankylä, Savukoski, Kittilä, Lainio and Kumpu Groups. The same classification together with the type formations was also used by Lehtonen et al. (1998).

Well-preserved sedimentary rocks occur in the Sodankylä schist area and it is easy to observe that the volcanic rocks of the Salla and Onkamo Groups form anticlinal structures while the rocks of the Savukoski Group are placed in synclinal structures. However, the bedrock is polyfolded and all supracrustal rocks have been thrust eastwards, appearing now as different kinds of bulging longitudinal lithological units which can be traced on low-altitude geophysical maps. In places the folds have been overturned which, coupled with faults and overthrusts of varying intensity, has caused both discontinuities and repetitions of the supracrustal sequences.

The Proterozoic supracrustal lithology of the Sodankylä schist area starts with felsic volcanic rocks which belong to the Salla Group. However, they are not ubiquitous, and e.g. at Möykkelmä mafic and ultramafic volcanic rocks of the Onkamo Group lie directly on basement granitoids (Räsänen et al., 1989).

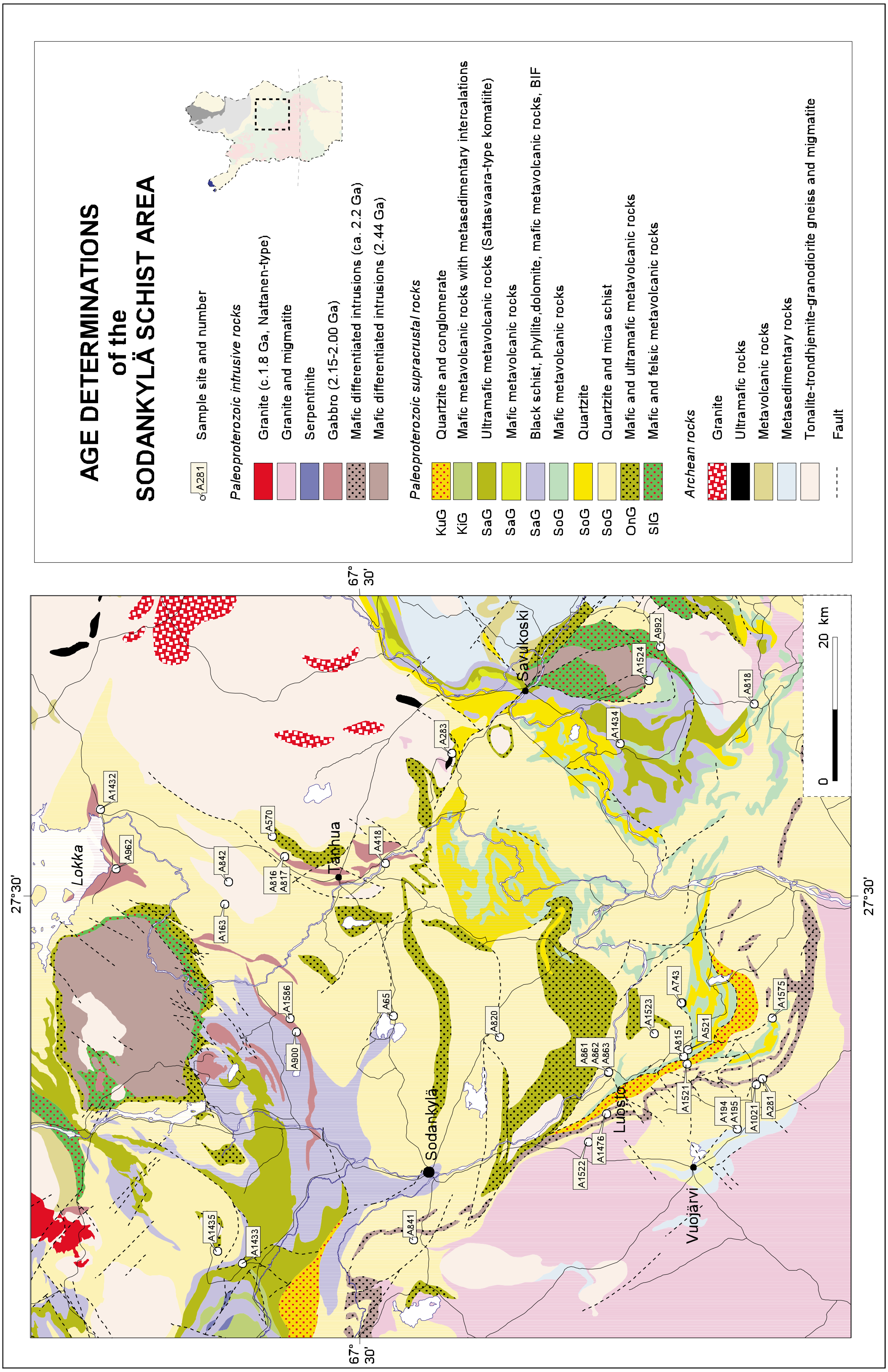

Fig. 1. Geological map of the Sodankylä Schist area. KuG = Kumpu Group, KiG = Kittilä Group, SaG = Savukoski Group, SoG = Sodankylä Group, OnG = Onkamo Group, SlG = Salla Group.

In the Central Lapland Greenstone Belt these rocks are volcanic products of the earliest Proterozoic continental break-up, and seem to be spatially closely related to 2.4 Ga old layered intrusions supporting an intracontinental, rift-related origin as interpreted in the Salla (Manninen 1991) and Kuusamo areas (Räsänen 1999). In the Sodankylä schist area, they are overlain by conglomerates, epicontinental clastic sediments and associated volcanic rocks of the Sodankylä Group, which represents a later stage of rifting with sedimentation and coeval volcanism.

On the whole the supracrustal pile thickens laterally westwards and the rocks of the Savukoski Group appear on the top of the Sodankylä Group. They start with graded schists and contain minor dolomites, black quartzites and sulfide-bearing black schist. These are intruded by the Keivitsa mafic intrusion dated at 2.05 Ga (Mutanen & Huhma 2001, *this volume*). The schists are overlain by mafic and ultramafic volcanic rocks and several mafic and ultramafic dykes, called diabases and olivine gabbro-diabases, which penetrate the Keivitsa intrusion (Mutanen 1997). These dykes are Mg-basalts and komatiites in chemical composition and resemble the komatiites of the Sattasvaara Formation, ranging from Mg-basalts to basaltic and peridotitic komatiites (Räsänen 1996). Chemical data suggest that these dykes may form part of the Sattasvaara Formation. However, reliable age data of these rocks are still missing.

In the west, a major tectonic zone marked by a chain of ophiolitic serpentinites (Hanski 1997) occurs on the eastern border of the Kittilä greenstone area (Lehtonen et al. 1998) and separates the rocks of the Savukoski Group from the volcanic rocks of the Kittilä Group. U-Pb ages of 2.01 Ga for felsic porphyries and a Sm-Nd age of 1.99 Ga for tholeiitic basalts of the Vesmäjärvi Formation on the top of the Kittilä Group have been reported (Hanski et al. 1997). Also a U-Pb age 1.92 Ga for a felsic dyke has been reported (Lehtonen et al. 1992).

Polymictic conglomerates and associated quartzites of the Kumpu Group overlie unconformably the folded supracrustal pile described above. Most of these coarse clastic deposits occur in the western part of the Central Lapland Greenstone Belt and based on U-Pb ages of 1.88 Ga for granitoid pebbles of conglomerates (Hanski et al. 1997) they are post-collisional molasse deposits. They are found also in the Sodankylä Schist area (Haimi 1977, Räsänen 1977, Nikula 1985). A typical feature of these conglomerate-quartzite deposits is that they are not more than a few kilometers wide, but may reach thicknesses of more than two kilometers. At Pyhätunturi, in the southern part of the area, occurs a similar thick sequence of well-exposed conglomerates and quartzites, which unconformably overlie supracrustals of the Sodankylä Group. Based on sedimentary studies they are interpreted to be mainly a river-born deposit (Räsänen & Mäkelä 1988) and are called the Pyhätunturi Formation assigned to the Kumpu Group (Räsänen et al. 1995).

The Central Lapland Granite Complex is heterogeneous and composed of various Proterozoic granites post-dating the crustal thickening during the Svecofennian orogeny, as discussed by Gaál and Gorbatschev (1987). This granitic complex, close to 20 000 km^2 in size and so far poorly known, includes remnants of Proterozoic schists and a variety of Archean rocks. For example, the Suonivaara granodiorite about 15 km SW of Sodankylä, which is one of the Archean basement rocks (Tyrväinen 1979, 1983), is an inhomogeneous gneissose granite associated with migmatitic cordierite-, garnet-, staurolite- and andalusite-bearing mica gneisses together with quartz-feldspar gneisses. These gneisses, though they are folded and granitized to variable degrees, can be followed for tens of kilometers southeastwards through the granitoid terrain. In the Vuojärvi area, they are much better preserved and associated with felsic volcanic rocks (Räsänen 1986a).

ARCHEAN ROCKS

A194 and A195 Keski-Loviselkä felsic volcanic rock. Keski-Loviselkä lies on the southwestern border of the Sodankylä schist area, close to Vuojärvi, about 40 km south of Sodankylä (Fig. 1). In the key area, felsic volcanic rocks occur in association with cordierite-, garnet-, staurolite- and andalusite-bearing mica gneisses called the Loviselkä Formation. All rocks are isoclinally folded and the felsic volcanic rocks have been metamorphosed to quartz-feldspar gneisses. In spite of folding, sedimentary structures are well-preserved and show that the porphyroblast-bearing mica gneisses with quartzitic lower parts, containing almost complete Bouma-cycles, are proximal turbidites in origin. The rocks can be traced southeastwards into the granitoid complex and the latest mapping results indicate that similar turbiditic gneisses together with Archean felsic volcanics can be found as a long NS-trending belt on the western side of the Kuusamo Schist area (Räsänen & Vaasjoki 2001, *this volume*).

The felsic volcanic rocks at Keski-Loviselkä are dacites or quartz andesites and differ from the associated mica gneisses in chemical composition for example by having higher SiO_2- and lower Al_2O_3 and $Fe_2O_3^{tot}$ contents. They display a cyclic appearance suggesting a partly reworked tuff/tuffitic (ash-flow) deposit. The lower part of a unit, about 10 m in thickness, is massive but contains some mica-rich intraclasts. It is overlain by a 1-2 m thick ripple-cross laminated part and capped by parallelly laminated calcareous layers. Diamond drilling conducted by Rautaruukki Co. in the late 1970s has shown that they also include layers of felsic volcaniclastic rocks, which may be pyroclastites in origin. However, the stratified upper part suggests that they are redeposited and probably originate from a mass flow of volcanic debris carried by a turbidity current further down slope into a basin, while the associated turbiditic greywackes indicate the contemporaneity of sedimentation and volcanism.

Sample A194 is taken from the massive lower part and under microscope the rock is granoblastic and very fine grained (0.01-0.4 mm). It consists of oligoclase, quartz and biotite with muscovite, chlorite and K-feldspar. Magnetite, apatite, rutile and zircon, up to 0.1 mm, are common accessory minerals. The zircon occurs as yellowish short prisms, which often have slightly rounded edges. In the fine-grained (-200 mesh) heavy fraction crystals are generally clear with sharp edges. Sample A195 was taken from the graded tuffites, which include some brecciated parts rich in scapolite. It contains more biotite and also some titanite, but otherwise it does not significantly differ from the massive unit in mineral composition. The appearance of the zircon population does not much differ from zircon crystals of the massive part.

Analytical results are given in Appendix I and a concordia diagram is shown in Figure 2. The four discordant U-Pb analyses from zircons in the massive flow A194 define a trend which gives an upper intercept age of 2775±25 Ma, and a lower intercept of 430±150 Ma. The large MSWD of 16 is due to incompatibility of the two most discordant analyses. It is quite unusual that heavy zircons (A) do not yield analysis closer to concordia compared to the less heavy fraction C. As the old analyses (both A and C) have been made using separate Pb and U spike solutions, it may be conceivable that e.g. occasional weighing error could explain the problem. We have to point out, however, that several duplicated analyses in the laboratory have yielded consistent results.

If the analytically somewhat inferior fraction A is omitted from the calculation, the upper intercept age for the massive flow A194 becomes 2777±3 Ma. The overlying tuffites (A195) register an upper intercept age of 2780±72 Ma with an MSWD of 9, which may reflect the incorporation of external detrital material into this rock. The titanite in this rock (not shown on the diagram) is slightly discordant, but nevertheless demonstrates a later, Paleoproterozoic thermal event, most likely during the Svecofennian orogeny.

A283 Kivivuotsonselkä ultramafic volcanic rock. Kivivuotsonselkä lies on the northeastern border of the Sodankylä Schist area about 10 km northwest of Savukoski (Fig. 1). The bedrock consists of granitic gneisses and ultramafic rocks, which are overlain by supracrustal rocks (Juopperi 1986). The ultramafic rocks are komatiites and display well-preserved lava structures with cumulate bases overlain by spinifex-textured zones and flow top breccias (Räsänen 1984). They occur in conjunction with granitic gneisses and, in addition to orthogneisses, there occur also plenty of cordierite-, garnet- and

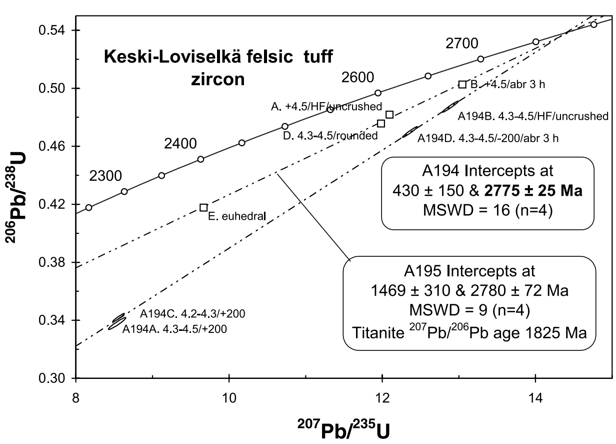

Fig. 2. Results for U-Pb analyses on zircons from the Keski-Loviselkä felsic rocks. The ellipses denote the analytical error on the 95% confidence level.

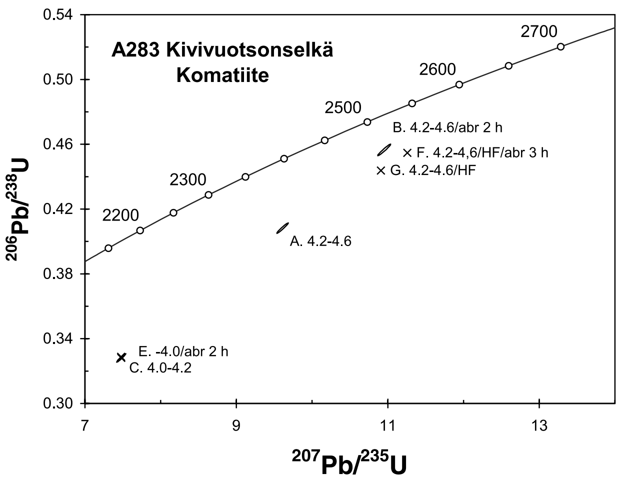

Fig. 3. Results for U-Pb analyses on zircons from the Kivivuotsonselkä komatiite.

staurolite-bearing paragneisses as layers reminiscent of primary bedding.

Between the granitic gneisses and the komatiites there is a 1-3 m thick ultramafic chlorite-rich hybrid rock, which in places contains partly melted and at their rims corroded xenoliths of granitic gneisses.In addition to chlorite, amphibole and biotite are the major minerals, while magnetite, apatite, ilmenite and zircon are common accessories. Zircon, up to 0.3 mm in size, is mainly euhedral but turbid with rounded edges.

Sample A283, taken by H. Juopperi in the 1980s, is a chlorite-rich hybrid rock. Chemically it is a komatiite, but it is contaminated and strongly enriched in LREE indicating that the rock originated from a hybrid melt, which was formed by thermal erosion of country rock by hot komatiite flows. This is a common phenomenon and often occurs during the ascent of an extremely hot komatiitic magma or when it flows over a felsic base rock (e.g. Groves et al. 1986, Juteau et al. 1988).

The analytical data are given in Appendix 1 and a U-Pb concordia diagram is presented in Figure 3. From the seven fractions treated, one (D) was analyzed only for its lead isotopic composition, and is consequently not shown on the diagram. The two most discordant fractions (C and E) are almost identical and overlap in Figure3. There is considerable heterogeneity in the other four fractions, and no proper age result can be obtained apart from the bulk zircons being of a definitely Archean origin. Given the komatiitic nature of the rock and its established contamination, it seems likely that the zircons are xenocrystic and reflect rather a minimum age for the country rocks than the time of lava extrusion. In fact, the Kivivuotsonselkä komatiite flows can be Paleoproterozoic in origin.

PROTEROZOIC ROCKS

Felsic volcanic rocks

A992 Purkkivaara felsic tuff. Purkkivaara is a hill 20 km south of Savukoski (Fig. 1). In the area there occur extensive felsic volcanic rocks consisting of amygdaloidal lavas and tuffs, called the Purkkivaara formation. In the southeast, it is associated with quartzites and minor garnet-staurolite gneisses, while 5 km to the northwest, at Akanvaara, the felsic volcanics are in contact with a southeastward-facing layered gabbro intrusion capped by a granophyre (Räsänen 1983). TheAkanvaara gabbro is c. 2430 Ma old (Mutanen & Huhma 2001, *this volume*) and was investigated in detail during prospecting activity by the GTK in the 1990s. It is well-documented by Mutanen (1997), according to whom the magma intruded into the supracrustal rocks described above and *"all the acid volcanites intersected by diamond drill holes below the intrusion are hornfelses"* and *"the hornfelses analyzed so far are compositionally affected by the intrusion and hence resemble the ferrogranophyres of the roof"*. Thus the age of the Purkkivaara felsic volcanic rocks, dacites and rhyolites in chemical composition, is of considerable interest.

Sample A992, taken in the 1980's, is a crystal tuff from a large outcrop on the southeastern slope of the Purkkivaara hill. The rock is very fine-grained, its weathered surface is whitish gray with thin biotite-streaks while the fresh surface is dark gray in color. All the outcrops are schistose due to strong axial plane cleavage associated with folding which has generally destroyed the primary structures. However, it is occasionally obvious that the rocks were originally stratified. There exist layers up to few tens of cm's thick containing very fine-grained lithic fragments and plagioclase crystals, up to 1-2 mm in size, and alternating homogeneous layers with obscure contacts without plagioclase. Also amphibole-bearing interlayers containing abundant biotite exist among them.

Microscopically plagioclase ($An_{\sim 10}$) forms eu- and subhedral or roundish crystals up to 2.5 mm in size and the crystals are commonly twinned. Some crystal-rich layers contain broken crystals indicative of pyroclastic fallout deposits. The very fine-grained matrix is principally composed of quartz and plagioclase with biotite, while amphibole is a common accessory mineral. The amount of secondary sericite is highly variable and usually magnetite is also present.

Four samples, both flows and tuffs, were taken in the 1980s from these volcanic rocks of the Purkkivaara formation. However, only a small amount of very fine-grained zircon was extracted. They are commonly brownish in color and often have a crushed appearance. They are not rounded and a quarter of the zircons exhibit tetragonal prismatic crystal forms with L/B 1.5-2. Some transparent crystals occur as well.

The zircon has a high uranium content, and is consequently of very low density, providing discordant analyses. The four analyses give an upper intercept age of 2412±40 Ma, but the high MSWD (24) shows scatter in excess of analytical error (Fig 4.). It should be emphasized that the two most

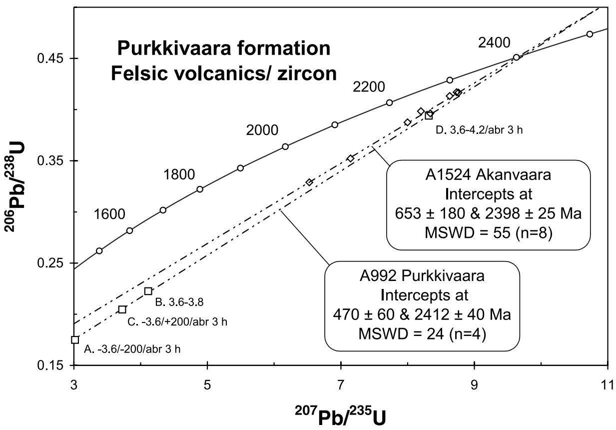

Fig. 4. Results for U-Pb analyses on zircons from the Purkkivaara felsic tuff and the Akanvaara quartz-feldspar porphyry.

discordant analyses were made on unusually low-density zircon and should be treated with caution. It is likely that the felsic volcanic rocks are Proterozoic, but the exact age remains obscure. The obtained age estimate is close to the age of the Akanvaara layered mafic intrusion, 2.43 Ga, (Mutanen & Huhma 2001, *this volume*), suggesting that felsic volcanism may have been associated with this enormous mafic magmatic event.

A1524 Akanvaara quartz-feldspar porphyry. Akanvaara is a large hill about 15 km south of Savukoski (Fig. 1.). The bedrock comprises felsic volcanics of the Purkkivaara formation and plagioclase-phyric amygdaloidal flows associated with quartz-feldspar porphyries. They are overlain by quartzites and schists of the Ritaselkä formation in the east and south. In the north, they are closely associated with granophyric rocks lying on the top of the Akanvaara layered mafic intrusion without any observed sharp contact.

Sample A1524 was taken from a rhyolitic quartz-feldspar porphyric rock representing a massive flow with quartz-filled vesicles on top. It contains 1-2 mm phenocrysts of quartz and feldspar in a very fine-grained granular groundmass composed of quartz and feldspar with biotite and sericite. Magnetite, some carbonate mineral and also zircon are present. Albitic plagioclase exhibit lamellar twinned euhedral phenocrysts up to 2.5 mm in size, which contain minute inclusions of quartz and potassium feldspar. Some phenocrysts of quartz show angular hexagonal outlines obscured by embayments and minute inclusions of feldspar. Also granophyric crystallization of quartz and potassium feldspar exists and spherulitic structures of plagioclase are not uncommon. The structures indicate high-temperature devitrification of natural glass found in volcanic rocks.

Sample A1524 yielded abundant zircon, which occurs as euhedral, relatively short, pale-brown crystals. In contrast to the previous sample (A992) much of the zircons are heavy (+4.3), but somewhat turbid. Eight U-Pb analyses made on sub-milligram quantities are technically good, but give scattered data on the concordia diagram (Fig. 4.). The data points define a line which has an upper intercept at 2398±25 Ma, and a lower intercept at 653±180 Ma (MSWD=55!). The most deviating points represent clear zircon (D) and abraded long crystals (F), and without these points the intercepts would be 2394±11 Ma and 629±79 Ma (MSWD=7). The heterogeneity observed is considered to be due to metamorphic effects presumably during 1.8-1.9 Ga tectonothermal events. Similar, more pronounced effects have been observed e.g. at the Siikakämä intrusion (Mertanen et al., 1989). The data available do not allow reliable dating, but it is very likely that the age of volcanism is fairly close to the age of the Akanvaara gabbro, which is considered intruding these volcanics.

A1432 and A1498 Sakiamaa volcanics. Sakiamaa is in the northeastern corner of the Sodankylä Schist area about 60 km north of Savukoski on the southern shore of the Lokka reservoir (Fig. 1). The lithological information on the area is mainly based on works by Mikkola (1937, 1941), according to whom the bedrock consist of quartzites and mica schists together with leptitic schists. At the time the term leptite was used for most felsic schists of unknown origin composed principally of quartz, feldspar and mica, often with gneissose fabric. Some targets of these poorly known rocks have been reinvestigated and the rocks described formerly as quartz-feldspar schists or mica arkoses are, in fact, felsic volcanics in origin. They include stratified tuffs and plagioclase crystal tuffs containing also felsic interflows. These are associated with garnet-bearing quartz-feldspar schists and garnet-staurolite gneisses and quartzites. Chemically the volcanics are dacites and rhyolites.

Samples A1432 and A1498 were taken from a massive part of the volcanic unit, which is about 80 m thick and contains also stratified tuffites. The massive rock, about 5 m thick, is a very fine-grained slightly orientated plagioclase-phyric lava with granoblastic groundmass containing also vesicles, up to 3 mm in diameter, filled with quartz, epidote and chlorite. Quartz, saussuritized plagioclase exhibiting eu- to subhedral phenocrysts up to 1 mm in size and deep green hornblende are the main minerals, while chlorite, magnetite, biotite, epidote and titanite are common accessories. Also apatite and some hematite are present.

Zircon in sample A1432 occurs as small subhedral grains, which range from light-colored turbid to dark-

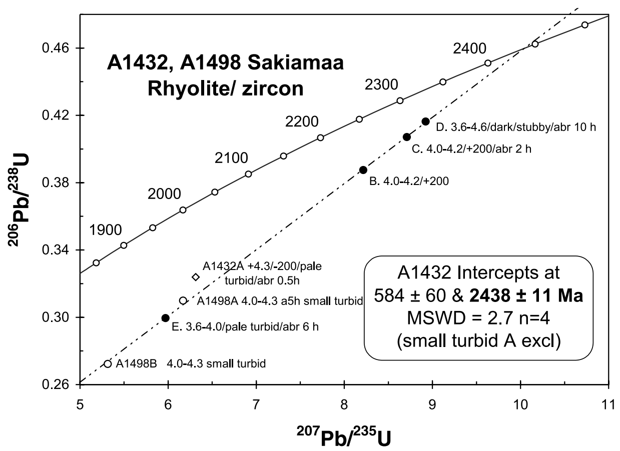

Fig. 5. Results for U-Pb analyses on zircons from the Sakiamaa felsic volcanics.

ish and fairly clear. Results of analyzed zircon fractions are given in Appendix I and the concordia diagram is presented in Figure 5. In spite of a high contents of uranium, the analyses on the dark zircon are not particularly discordant. Instead, an analysis on the heaviest fine-grained (-200 mesh), though turbid zircon (A) is badly discordant, although its uranium content is lower. This analysis lies clearly off the line defined by the others, and suggests disturbances due to metamorphism. The four analyses (on +200 mesh) yield an upper intercept age of 2438±11 Ma and a lower intercept at 584±60 Ma (MSWD=3, Fig. 5).

The zircon age estimate of 2438±11 Ma demonstrates volcanism coeval with the plutonic phase that generated numerous layered mafic intrusions in northeastern Fennoscandian Shield generally, and in particular the local Koitelainen and Akanvaara layered intrusions, dated at 2.43 Ga (Mutanen & Huhma 2001, *this volume*), lying on either side of the Sodankylä Schist area.

Mafic intrusions

A281 Harjunoja mafic sill. Harjunoja lies in the southwestern part of the schist area about 45 km south of Sodankylä (Fig. 1). The bedrock consists of quartzites, dolomites and siltstones associated with minor felsic volcanic rocks together with phyllites and carbonaceous schists. This volcano-sedimentary rock association, called the Harjunoja Formation, is penetrated by a dyke swarm composed of highly magnetic differentiated mafic sills. The magnetic susceptibility of the sills is about 100 times higher than that of the surrounding rocks and, consequently, they can be traced on aeromagnetic low-altitude maps for more than 50 km along strike.

The thicknesses of individual sills vary from tens to hundreds of meters, and they may reach one kilometer in total. The sills are differentiated and the thickest contain serpentinized olivine cumulates at the base, but generally the lowermost rocks are olivine-bearing pyroxene cumulates composed of variably uralitized pyroxene and epidotized labradoritic plagioclase with magnetite. The upper differentiates are gabbroic cumulates composed of plagioclase (An_{20-30}), amphibole, biotite, magnetite and epidote. Also some magnetite-rich plagioclase cumulates are present.

Sample A281 was taken from a coarse-grained gabbroic differentiate of the upper part of a sill and it contained abundant zircon. The zircon population is quite homogeneous and euhedral crystals possess well-developed (100) and (101) crystals faces, indicating a high temperature during crystallization (e.g. Pupin 1981). There also exist needle-like (L/B>5) crystals of zircon, which could indicate a fast crystallization rate. In addition, there are also glassy zircons, which exhibit numerous crystal faces.

Results of analyses are listed in Appendix I. The high $^{208}Pb/^{206}Pb$ ratio of suggests that when the rock crystallized Th and U were not yet fractionated in the source melt. The concordia plot for zircons is presented in Figure 6. The glassy zircon fractions of (F,G,H) are least discordant and a linear fit through all 12 zircon fractions has an upper intercept at 2222±6 Ma and a lower intercept at 383±58 Ma with an MSWD of 7. Exclusion of the most discordant fraction J from the calculation does not significantly alter these figures.

The obtained U-Pb age of 2222±6 Ma for the

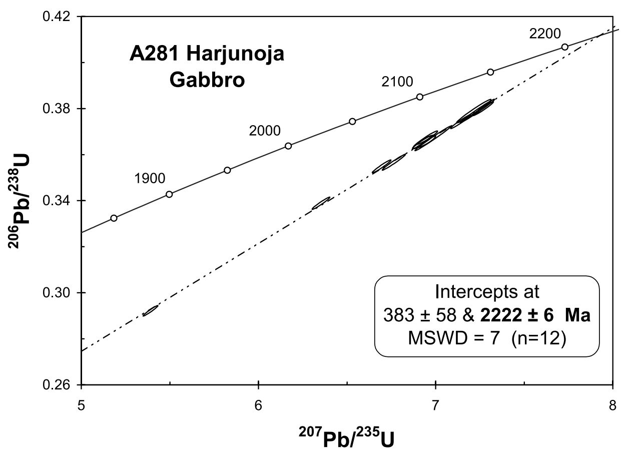

Fig. 6. Results for U-Pb analyses on zircons from the Harjunoja mafic intrusion.

Harjunoja layered sill is in good agreement with the Sm-Nd mineral age of 2.26±0.04 Ga for the same intrusion at Ahvenvaara (Huhma et al. 1996). A differentiated sill-like intrusion at Haaskalehto, which occurs about 20 km NW of Sodankylä, yields an U-Pb zircon age of 2220±11 Ma (Tyrväinen 1983; A892) and a similar Sm-Nd age of 2.19 Ga. From Silmäsvaara, 10 km further NW, a Sm-Nd age at 2.22 ±0.05 Ga is reported by Huhma et al. (1996). All these rocks have initial Nd-ratios close to the chondritic value. Similar differentiated dykes in the Salla area at Jokinenä and Pirtinkehäkukkura yield U-Pb zircon ages of 2209±10 Ma and 2202±2 Ma (Lauerma 1995; A379, A420+A830), respectively. Silvennoinen (1991; A847 Jäkäläniemi) reported a U-Pb age at 2206±9 Ma for a long dyke in the Kuusamo area and, there are abundantly quite similar differentiated mafic dykes in the Peräpohja area. E.g. at Kallinkangas, a U-Pb age of 2216 Ma has been obtained (Perttunen & Vaasjoki 2001, *this volume*).

A900 Rantavaara gabbro. Rantavaara is a hill about 20 km NNE from Sodankylä (Fig. 1.) where a mafic intrusion called the Rantavaara gabbro is exposed. It is a part of a more extensive, 200- 500 m thick sill-like intrusion, which can be traced for almost 25 km along strike roughly in a NE-direction. At Rantavaara the NW dipping (40-50°) intrusion is slightly differentiated containing minor ultramafic rocks at base, but the bulk consists of gabbroic rocks characterized by alternating plagioclase- and amphibole-rich magmatic layers with varying thickness. Epidotized plagioclase and green hornblende are the main minerals, often with chlorite, while titanite and magnetite are common accessories with some pyrite.

The intrusion penetrates quartzites and graded Al-bearing mica schists, which have been found on its southern side and are interpreted to represent the uppermost sedimentary rocks of the Sodankylä Group (Räsänen et al. 1996). Later it has been observed that on the northern side the intrusion is in contact with black schists and it has been presumed (Lehtonen et al. 1998) that the intrusion penetrates also the lowermost rocks of the Savukoski Group. The contact between the rocks is covered and, according to diamond drillings, it is sheared. No signs of a thermal effect caused by the intrusion have been observed in black schists; in contrast, they are highly folded against the intrusion. Based on low-altitude geophysical maps and ground measurements the black schists run for kilometers along the northern side of the intrusion. However, minor black schists are found also on the southern side of the intrusion, but also their contact with the intrusion consists of highly sheared and broken rocks as observed in drill cores. All these observations indicate a tectonic contact and support an interpretation of a thrust. Actually, this black schist may be one of those several thrust sheets observed in the Rajala area, which accompany the overthrust of the Kittilä greenstones.

Earlier an age of 2130±30 Ma was obtained for the Rantavaara intrusion and, based on its high ε_{Hf} value of +9.8, Patchett and Kouvo (1986) concluded that the rock originated from a depleted mantle source. This is supported by Nd-Sm data from a pyroxenite at base of the intrusion, which shows an ε_{Nd} value of +3 also compatible with a depleted mantle source (Huhma et al., 1996). Sample A900 is a very coarse-grained hornblende-rich gabbro pegmatoid, which yielded abundant zircon. The separated zircons are generally fragments of larger grains, exhibiting still sharp crystal edges and shiny surfaces. The transparency is generally moderate. In addition to the old data we have picked clear zircon for three new U-Pb analyses. All seven analyses provide a chord which gives an upper intercept age of 2148±11 Ma and a lower intercept of 652±190 Ma (MSWD=4, Fig. 7).

A1586 Metsävaara gabbro. Metsävaara is a hill about 2.5 km northeast from Rantavaara (Fig. 1.)and consists of the same intrusion, which here displays excellent magmatic layering rich in plagioclase. Sample A1586 was taken from a light-colored and coarse-grained gabbro. Separation yielded a small amount of clear zircon. A U-Pb analysis is slightly discordant and plots on the chord defined by sample A900 (Fig. 7).

The data presented here confirms the previous age results for the Rantavaara gabbro and the obtained U-Pb age of 2148±11 Ma can be regarded as the age of this extensive mafic intrusion. However, it is highly doubtful to argue that the intrusion penetrates the black schists at the base of the Savukoski Group.

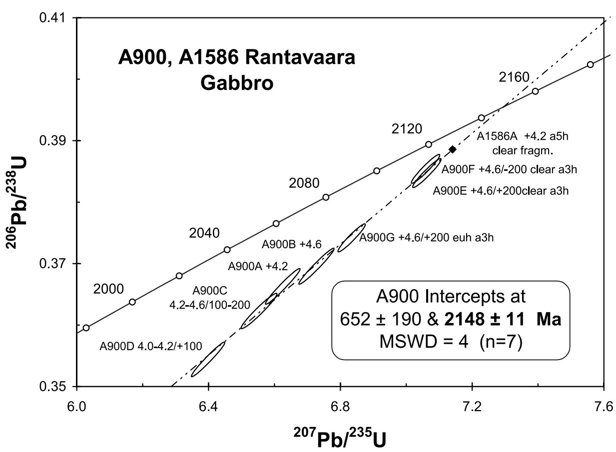

Fig. 7. Results for U-Pb analyses on zircons from the Rantavaara mafic intrusion.

A841 Pittiövaara albitite. Pittiövaara hill lies 10 km west of Sodankylä (Fig. 1). The bedrock is dominated by quartzites comparable to the Virttiövaara Formation in lithology. Arkose quartzites with mica schist interlayers exist but greenish sericite quartzites are dominating and they contain fuchsite-bearing layers. These quartzites are cut by a dyke, called "albite diabase" and represented by sample A841, for which an upper intercept of 2132±30 Ma has been reported by Tyrväinen (1983). The sample A841 shows a high ε_{Hf} value of +4.5 (Patchett et al. 1981).

The rock represented by sample A841 is a fine-grained carbonate-bearing albitite, composed mainly of albite and quartz with carbonate, magnetite, mica and other accessory minerals. Gabbroic rocks occur close to the place where the sample A841 was taken and more albitites are found about 8 km southwards. On reinvestigation, it has turned out that most albitites are associated with gabbroic rocks and it is evident that the gabbro is more extensive than previously thought.

Zircon in sample A841 occurs as turbid stubby prisms, which are quite typical for many "albite diabases". The analytical results for sample A841 are shown in Appendix 1 and presented on a concordia diagram in Figure 8. The six old analyses are fairly discordant and scatter slightly along the line, which gives intercepts at 362±190 and 2135±31 Ma (MSWD=13). The upper intercept provides the minimum age, but as the zircon is turbid and the data discordant and slightly scattered, the exact age of this sample remains unknown.

A962 Povivaara gabbro pegmatoid. The Povivaara mafic intrusion lies about 60 km northeast of Sodankylä, on the southern shore of the Lokka reservoir (Fig. 1). It is the middle part of a larger intrusion, up to several kilometers long, which has been brittle during folding and broken into pieces. It consists of two or three parts separated by schists and cut by mafic dykes. The investigated portion is composed of slightly differentiated gabbroic rocks, which include alternating plagioclase- and amphibole-rich magmatic layers, up to some meters thick, resembling the Rantavaara intrusion (A900 and A1586) discussed before. The intrusion has chilled margins and penetrates quartzites and mica schists. Close to the contact of the gabbro there exists a hornfels-like schist rich in biotite, which indicates that the schists are thermally affected by the intrusion.

Sample A962 was taken by A. Karvinen in order to find out whether or not the intrusion is a satellite of the 2.43 Ga old Koitelainen layered intrusion, which lies only a few kilometers westwards. The rock is a slightly scapolitized coarse-grained gabbro-pegmatoid with abundant zircon and rutile. The zircon is euhedral and long (L/B>5) prismatic crystals are common. Some zircons contain unidentified inclusions. Although only three fractions were analyzed, the upper intercept age of 2142±5 Ma seems quite reliable (MSWD=0.33). The lower intercept is at 438±48 Ma. A U-Pb concordia diagram is shown in Figure9 and the analytical results are given in Appendix I.

The age result the Povivaara intrusion shows clearly that it is not a satellite of the Koitelainen intrusion (2.43 Ga), but belongs to another magmatic phase which intruded about 300 Ma later.

A418 Koskenkangas gabbro. Koskenkangas is about 40 km east of Sodankylä in the vicinity of Tanhua. This intrusion is one of poorly exposed gabbro intrusions continuing as a chain for at least 10 km but reaching a thickness of no more than 400 m. Sample A418 is taken from a 2-3 km long intrusion consisting mainly of medium-grained and homogeneous gabbro showing only minor differentiation. However, some hornblende-plagioclase bands indicate primary magmatic layers. The gabbro is surrounded by quartzites

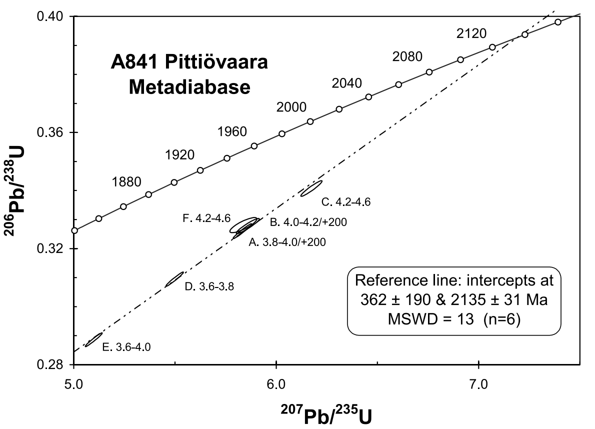

Fig. 8. Results for U-Pb analyses on zircons from the Pittiövaara metadiabase.

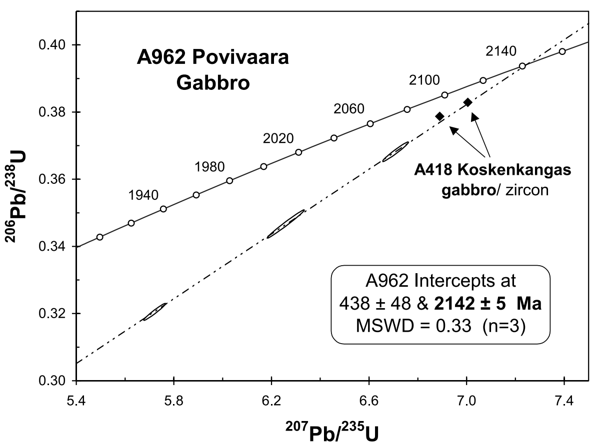

Fig. 9. Results for U-Pb analyses on zircons from the Povivaara and Koskenkangas gabbros.

and mica schists of the Sodankylä Group, but the contacts are covered.

The gabbro is quite even-grained and composed of hornblende and andesine as the main minerals,while zircon and rutile are common accessory minerals. As mentioned earlier, there are many similar gabbro intrusions in the Tanhua area and the sample was taken to determine the age group of these longish gabbros. Only two analyses are available and results of them are listed in Appendix I. A concordia diagram with plotted data is shown in Figure 9. The data plot close to the concordia and, as the less discordant heavy fraction (A) plots close to the chord defined by the previous sample A962, it is likely that all these gabbros are part of the same magmatic event as the intrusions of Povivaara (A962) and Rantavaara (A900+A1586) described before.

A816 and A817 Kylälampi gabbro. The Kylälampi intrusion occurs also in the Tanhua area about 45 km east of Sodankylä, close to the eastern border of the Sodankylä Schist area (Fig. 1). This highly magnetic intrusion is unexposed and was investigated by diamond drilling by Rautaruukki Co. in the 1970s. The intrusion faces to the west and consists of layered gabbroic rocks, which penetrate amphibolites and associated felsic volcanics. All of the intrusive rocks are amphibole- and albite-altered and contain abundantly magnetite. Two samples, A817 and A816, were taken by Rautaruukki Co.

Drilling did not reach the base of the intrusion, but the lowermost rock, more than 150 m thick in drill core, is a mafic biotite-bearing gabbro containing variable amounts of magnetite and quartz and carrying enclaves of amphibolite and volcanic rocks. The middle part, about 40 m thick in drill core, is more felsic and composed of an albite-magnetite rock with a sheared upper contact. The upper part, 17 m thick in drill core, consists of light-colored albitite with a varying amount of magnetite. The roof of the Kylälampi intrusion consists of volcanic rocks and, in drill core, they are penetrated by several albitite- and gabbro-dykes. Actually, this highly magnetic body could be the northernmost end of a more extensive gabbroic massif continuing over 10 km southwards and reaching a thickness about half a kilometer.

Sample A817 is taken from albite-magnetite rock, called albitite, at a depth between 78.70-93.00 m in the middle part of the intrusion. The rock is fine-grained, slightly orientated and dark gray in color consisting mainly of albite and magnetite with quartz. Biotite and hornblende are common accessory minerals and diopside, apatite and carbonate are also present together with titanite and leucoxene.The texture is granoblastic, but there are relics of saussuritized subhedral plagioclase crystals, up to 3 mm in size, indicating the primary texture. Zircon is transparent and exhibits needle-like crystal forms with well-developed crystal faces. Some platy and short prismatic, transparent crystals are present.

Data, listed in Appendix I, exist for six zircon fractions and titanite. As shown on the diagram in Figure10, a linear fit through the zircon analyses has an upper intercept at 2114±6 Ma. The least discordant points represent abraded fractions (F and G), but also an analysis of the HF-pretreated zircons (E) provides similar ratios. The nearly concordant titanite with a $^{207}Pb/^{206}Pb$ age of 1802±10 Ma, indicates a later metamorphic event.

Sample A816 is also from the Kylälampi intrusion and was taken from the same drill core as sample A817. The rock, taken from the upper part of the intrusion from the depth interval 50.00-64.00 m, represents a light gray, slightly reddish-colored albitite. In drill core its upper contact is characterized by a layer

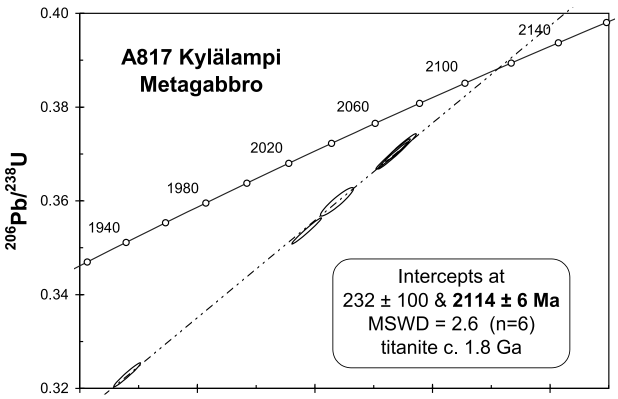

Fig. 10. Results for U-Pb analyses on zircons from the Kylälampi metagabbro A817.

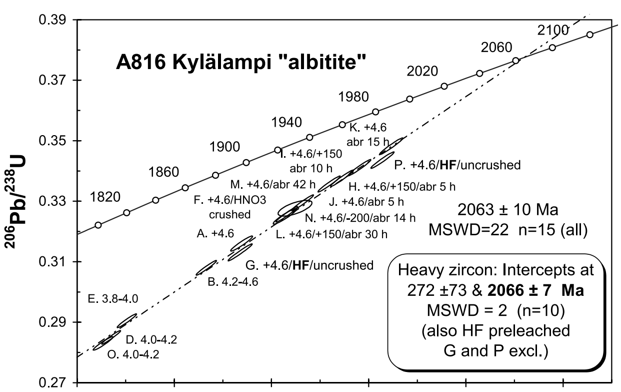

Fig. 11. Results for U-Pb analyses on zircons from the Kylälampi "albitite" A816.

of calc-silicate rock, while the lower contact with albite-magnetite rock is highly sheared. As said above, the roof of the intrusion consists of volcanic rocks penetrated by albite dykes and, on that ground, this rock could also be interpreted as a dyke. However, no proper chilled margins have been observed.

The rock is hypidiomorphic or weakly ophitic in texture. Albite, as 1-3 mm sub- and euhedral crystals and as large crystal-aggregates, and quartz are the main rock-forming minerals, while light green amphibole and magnetite are common accessory minerals with some titanite. Zircon crystals are euhedral and transparent, and do not seem to differ from the zircons in sample A817. However, their analyses give a different result.

Results of 15 analyses are given in Appendix I, and a concordia diagram with plotted data is presented in Figure11. The regression of all points provides a chord with intercepts at 2063±10 Ma and 193±97 Ma. However, the high MSWD (22) shows that the data are scattered. It is particularly obvious that the HF treated heavy fractions G and P plot off the line (Fig. 11). As there is a potential danger of U/Pb fractionation during HF-leaching, these analyses should be considered with caution.Rejecting these two and the analyses on less heavy (<4.2 g/cm^3) zircon, the intercepts would be at 2066±7 and 272±73 Ma (MSWD=2, n=10).

The conventional interpretation of the upper intercept age would suggest that in the Kylälampi drill core there exists intrusive material of two different ages. It should be noted, however, that all data are discordant and scatter exists as discussed above. An alternative interpretation would involve significant metamorphic effects on zircon at 1.8-1.9 Ga, in which case the primary magmatic age would be much older than the apparent upper intercept. In such case, however, one might expect even more scatter than observed.

A818 Ahvenselkä mafic dyke. Ahvenselkä lies about 30 km to the south of Savukoski (Fig. 1). The bedrock consists mainly of quartzites and mafic volcanic rocks, but felsic volcanic rocks occur as well (Räsänen 1983). However, the local bedrock is almost entirely covered and observations are based mainly on samples obtained by percussion drilling and on some diamond drill cores of Rautaruukki Co. drilled in the 1970s during their activity in the area.

Sample A818, called then an albite diabase, was also taken from a mafic dyke by Rautaruukki Co. in the 1970s. The outcrop is quite small but according to the aeromagnetic low-altitude map the dyke is several tens of meters thick and about 500 m long. It penetrates reddish quartzites, which are mainly arkosic in composition and contain calcareous and mica-bearing interbeds. The quartzites are overlain by mafic volcanic rocks.

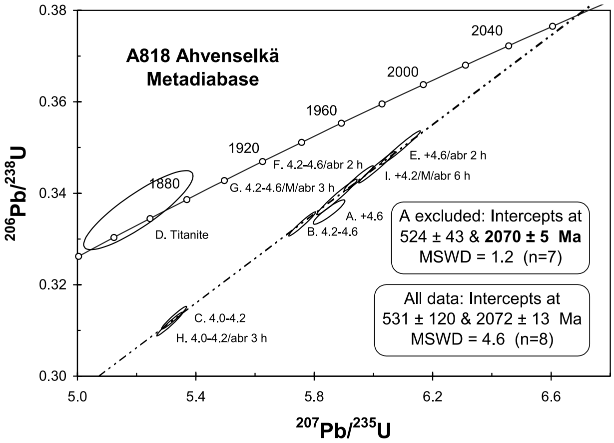

Fig. 12. Results for U-Pb analyses on zircons from the Ahvenselkä metadiabase.

The dyke is medium-grained and massive in appearance. Hornblende and plagioclase are the main minerals, but the rock is altered. Plagioclase (An_{25-35}) displays albitized euhedral crystals with saussuritized cores rich in minute epidote and sericite. Hornblende is uralitic, slightly fibrous or flaky in appearance and contains relics of pyroxene. Quartz is also present and magnetite, titanite and scapolite are common accessories. Zircon is euhedral as prismatic crystals with well developed (100) and (101) crystal faces.

Results of zircon and titanite U-Pb analyses are listed in Appendix I. The $^{208}Pb/^{206}Pb$ ratios are relatively high (c. 0.6), which may indicate that Th and U were not fractionated in the melt. A regression of all 8 discordant zircon analyses gives intercepts at 531±120 and 2072±13 Ma (MSWD=4.6). Compared to other data, analysis A is of poor quality and without it the upper intercept age would be at 2070±5 Ma and the lower 524±43 Ma (MSWD=1.2, Fig. 12). The analysis for titanite is concordant but rather imprecise. Nevertheless, it indicates a later thermal event in Svecofennian times at 1836±30 Ma.

A820 Rovasvaara gabbro. Rovasvaara lies about 20 km southeast of Sodankylä (Fig. 1). Sample A820 was taken in the 1970s in connection with investigations made by Rautaruukki Co. The first age estimate (2060±2 Ma) was published by Patchett et al. (1981).

The Rovasvaara gabbro is part of an intensely folded mafic intrusion, tens of kilometers in length with a thickness varying from 100 m to almost 500 m. In the Oraniemi area it penetrates the rocks, which were previously known as the classical Kumpu-Oraniemi sedimentary series of Mikkola (1941). Later Saverikko (1977) stated that, in the Oraniemi area, the supracrustal succession is intensely folded and lies on gneissic granitoids. At the same time it was also observed that the Kaarestunturi Formation, which is one of those typical 'Kumpu rocks', lies unconformably on highly folded rocks resembling the Oraniemi supracrustals. In addition, Räsänen (1977) found that mafic diabases do not penetrate this coarse clastic formation as argued by Hackman (1927). In contrast, the highly polymictic conglomerate at the base of the formation contains a lot of pebbles derived from mafic diabases and gabbros. These two university theses demonstrated that no connected Kumpu-Oraniemi sedimentary series exists. Based on two misinterpreted ages of volcanic rocks, Saverikko (1988) assumed the Oraniemi supracrustals to be Archean in origin. According to the current interpretation the Rovasvaara gabbro penetrates the Paleoproterozoic quartzites and aluminous mica schists of the Sodankylä Group.

The gabbro is mainly small- to medium-grained and quite homogeneous in appearance but, locally, it also contains more differentiated and coarse-grained, plagioclase-rich cumulates and exhibits ophitic texture. The most common rocks are hypersthene-gabbros, composed of pink pyroxene and plagioclase (An_{40-50}) with some hornblende and magnetite. Uralitized hornblende-rich parts contain biotite while epidote is a common product of altered plagioclase.

Sample A820, originally a pyroxene-plagioclase cumulate, is a very coarse-grained, pegmatoid variety of the gabbro. It is amphibolitized and epidotized and contains plenty of magnetite and accessory titanite with zircon. Initial $^{176}Hf/^{177}Hf$ ratio of the zircons shows an ε_{Hf} value of -3.2 (Patchett et al. 1981) indicating that the basaltic source material was crustally contaminated when compared to a depleted mantle source (Patchett & Kouvo 1986).

Since then, two additional fractions of zircons were analyzed at the GTK. The zircons are euhedral and exhibit splintery and platy crystal forms. Long needle-like crystals with L/B>10 are quite characteristic. Results of all analyses are listed in Appendix I and a concordia diagram is presented in Figure 13. A regression through 4 slightly discordant zircon fractions has an upper intercept at 2055±5 Ma and a lower intercept at 347±58 Ma (MSWD=0.02). An analysis on zircon with red pigment (E) is off the line, and omitted from the calculation.

The U-Pb age of this gabbro, 2055 Ma, is the same as that of the Keivitsa mafic intrusion, 2057±8 Ma (Mutanen & Huhma 2001, *this volume*) and also in good agreement with the U-Pb age of 2060±8 Ma from an albite gabbro at Riikonkoski in the Kittilä area (Rastas et al. 2001, *this volume*). Furthermore, the Sm-Nd data of the Keivitsa intrusion, which lies within the schists of the Matarakoski Formation at base of the Savukoski Group, yields an initial ε_{Nd} value of -3.5

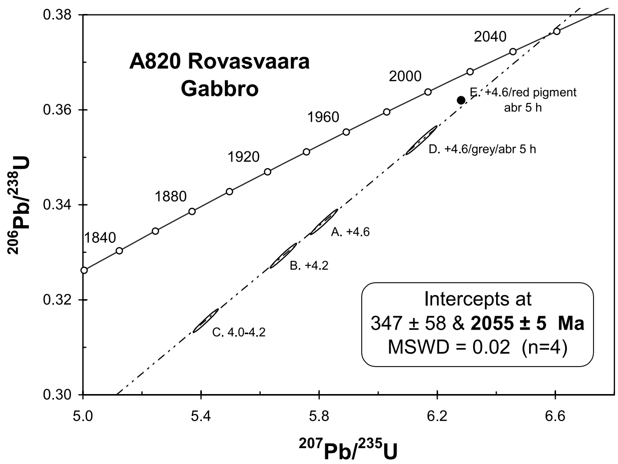

Fig. 13. Results for U-Pb analyses on zircons from the Rovasvaara metagabbro.

(Huhma et al. 1995), which shows that it is crustally contaminated as demonstrated by Mutanen (1997).

A861, A862 and A863 Törmänen mafic dyke. Törmänen is about 30 km southeast of Sodankylä by the river Kitinen (Fig. 1). The local bedrock is characterized by fine-grained but inhomogeneous sedimentary rocks, which are penetrated by mafic dykes. The sedimentary rocks, called the Akankoski Formation, include plenty of graded and commonly reddish, hematite-bearing siltstones associated with pinkish orthoquartzites together with bedded dolomites and laminated schists rich in calcite. These sedimentogenic carbonate rocks are highly enriched in ^{13}C, calcite rocks show positive $\delta^{13}C$ values between 11.1–12.5 ‰ and dolomites 10.1–10.8 ‰ (Karhu 1993). The Akankoski Formation can be compared lithologically with the Siltstone Formation in Kuusamo, which also is an inhomogeneous sedimentary package characterized by fine-grained, hematite-bearing sedimentary rocks together with quartzites, schists and sedimentary carbonate rocks (Silvennoinen 1972, 1991). According to Karhu (op.cit.) a dolomite sample of the Siltstone Formation also yielded a highly positive $\delta^{13}C$ value of 12.1 ‰ and a calcite rock from the Kelloselkä Formation in the Salla greenstone area, which can be compared with the former in stratigraphy, has also yielded a $\delta^{13}C$ value of +12.7 ‰.

The mafic dykes reach a thickness from some meters to tens of meters and exhibit chilled margins. However, all observed contacts are schistose or sheared indicating post-emplacement movements. Commonly the dykes are small- to medium-grained, exhibit ophitic texture and contain some layer-like, coarse-grained parts rich in plagioclase. All dykes are similar in texture as well as in mineral composition indicating that they are of the same generation.

Samples A861a, A862 and A863 were taken by P. Mielikäinen in 1970s. They represent coarse-grained plagioclase-rich parts of a single dyke, called then albite diabase, composed mainly of oligoclase and hornblende. Also some biotite and quartz are present. Magnetite, titanite and epidote occur frequently as accessory minerals. Sample A861b was taken afterwards from an other outcrop of the same dyke and does not significantly differ from the others. It also consists of hornblende and plagioclase (An_{20-30}) but contains hematite in addition to magnetite. Hematite is also present in zircons, which contain zones colored reddish by hematite dust. These zones coincide with original crystal forms, which are commonly short prismatic with sharp edges.

Results of all 22 analyses are listed in Appendix I and plotted on the concordia diagram in Figure14. Analyses on the original samples are all very discordant and scattered. Nevertheless, the five analyses on sample A863 give intercepts at 2061±47 and 518±130 Ma (MSWD=9). In contrast, sample A861b yielded less discordant analyses, and particularly the clear heavy zircon handpicked from this sample gives points fairly close to concordia curve (Fig. 14). The six analyses from A816b provide a trend with an upper intercept age of 2050±14 Ma and a lower intercept at 361±130 Ma. The large MSWD of 17 suggests, however, some scatter in excess of analytical error. If the most discordant analysis on the low-density turbid zircons is rejected the intercepts would be 2054±14 and 459±170 Ma (MSWD=8). Following a conventional interpretation this upper intercept age should be considered as the best estimate for the age of magmatic zircon and intrusion. The scatter observed particularly in sample A862 would suggest significant metamorphic effects probably during the 1.8-1.9 Ga tectonothermal stage, i.e. lead loss and possibly some recrystallization of zircon. If such domains existed in

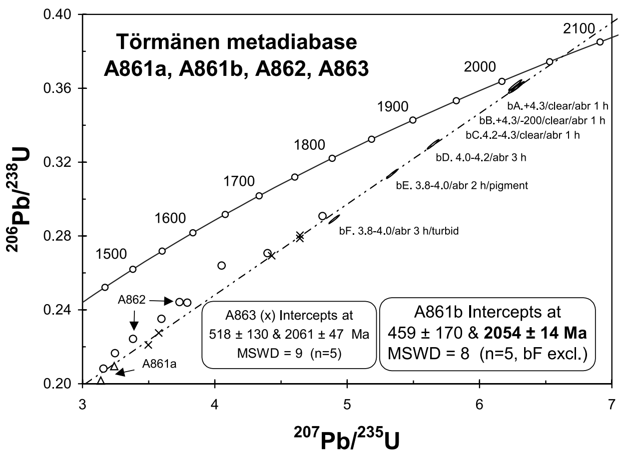

Fig. 14. Results for U-Pb analyses on zircons from the Törmänen metadiabase.

zircons which yielded the least discordant analyses (A861b), the magmatic age should be older than the apparent upper intercept.

A401, A741, A742 and A743 Mairivaara mafic dyke. Mairivaara lies about 40 km southeast of Sodankylä, 10 km north of Pyhätunturi (Fig. 1). The bedrock consist of quartzites, which are capped by mafic tuffitic schist and penetrated by a mafic dyke, called albite diabase by Mielikäinen (1979). It was then assumed that the quartzites are the same as the quartzites at Pyhätunturi and comparable to the Kumpu quartzites, which both Hackman (1927) and Mikkola (1941) regarded as youngest sedimentary rocks in Finnish Lapland, lying probably unconformably on Jatulian rocks classified as Proterozoic. In order to get an age constraint for these quartzites three samples were taken from the mafic dyke. However, owing to the correlation of the Mairivaara and Pyhätunturi quartzites, the first results yielding an age c. 2.0 Ga for the dyke together with another age c. 2.2 Ga at Värttiövaara led to a confusion in lithostratigraphy as Silvennoinen et al. (1980) concluded that the Kumpu formation (presently the Kumpu Group) represents Jatulian rocks. The underlying supracrustal succession was interpreted as Archean and called Lapponian after the term 'Lapponium' (Eskola 1932). In fact, Hackman (1927) previously presented the same conclusion, supposing that as the Kumpu quartzites at Kaarestunturi seem to be penetrated by a mafic dyke, they belong to Jatulian rocks.

The Mairivaara quartzite is reddish and mainly arkosic in composition with thin orthoquartzitic interbeds and contains typically only a little micas. Crossbeds associated with some conglomeratic interbeds containing highly weathered gneissose granitoid pebbles are common in the lower part of the quartzite, but the main part is dominated by laminar beds with some cross-bedded interlayers. The uppermost part is amphibole-bearing and includes mica-rich siltstones with laminar and ripple cross-laminated interlayers, and changes to stratified amphibole-rich tuffite. Observed sedimentary structures are indicative of deposits formed in shallow water not far from shoreline, suggesting shelf-like prograde conditions during sedimentation followed by volcanism. Later investigations have shown that the Mairivaara quartzite (Mairivaara Formation) lies close the base of the Sodankylä Group.

The Pyhätunturi quartzite was also reinvestigated and described in detail by Räsänen and Mäkelä (1988). It lies on a thick pile of highly polymictic conglomerates. The bulk of the quartzites are homogeneous ortho- and sericite quartzites containing only a little feldspars. Well-preserved primary structures exhibit alternating tabular beds from 10 cm to 160 cm in thickness, which include angular and tangential cross-bedded, horizontal-bedded and wavy-laminated sheets. Based on sedimentary structures this formation has been interpreted as a braided river deposit. Although no penetrating mafic dyke was found, Räsänen and Mäkelä (op. cit.) still assumed that the mafic lavas of the Kiimaselkä Formation overlie the Pyhätunturi Formation, which led to another confusion in general lithostratigraphy. Based on conglomerate pebbles and observations from sedimentary rocks, Laajoki (1988 p.103) explained the Pyhätunturi quartzites to be typically Jatulian rocks and as such correlative with "*the mature Jatuli-type quartzites of the third cycle*".

It is important to point out in this connection that in the 1970s there was no geophysical low-altitude map of the area and during 1970s and 1980s the role of tectonics such as faults and thrusts was almost entirely ignored in northern Finland as seen e.g. on the Geological Map of Northern Fennoscandia (1987). Later studies, based on lithological and geophysical data together with new field-observations, have suggested that both in north and east, the contact of the Pyhätunturi Formation is tectonic and the formation is separated by a fault, probably a thrust, from the mafic volcanics at Kiimaselkä and the quartzites at Mairivaara. Though the contacts of the Pyhätunturi Formation are covered, diamond drillings show that the bedrock including the Mairivaara quartzite was folded before the deposition of the Pyhätunturi Formation. Some results of these studies are also indicated on the Bedrock map of Finland (Korsman et al., 1997).

The mafic dyke is well exposed, 350-400 m thick and can be followed on outcrops for about 1 km in length. It is not differentiated, but exhibits alternating amphibole- and plagioclase-rich layers of magmatic origin. The margins of the dyke are chilled and glassy, elsewhere the rock is small- to medium-grained and ophitic in texture. Coarse-grained varieties are rare. The rock was originallypyroxene-bearing but is altered and now the main minerals are hornblende and plagioclase (An_{25-30}). The cores of plagioclase crystals are filled with minute epidote crystals. Secondary albite with subordinate quartz as well as scapolite are common. Titanite, often associated with biotite, displays large anhedral crystals or crystal-aggregates and magnetite is commonly present. Samples A741, A742 and A743 were taken P. Mielikäinen in 1970s during the first mapping activities in the area, while sample A401 was taken more recently. All samples are close to each other. Zircon occurs as small, euhedral, prismatic crystals and also some twinned crystals are found. The appearance of the zircon population is somewhat heterogeneous due to a range of colors and transparency from clear to very dark. Some baddeleyite occurs in the heavy fractions of samples A401 and A742.

There are 38 analyses of zircon fractions listed in Appendix I, and corresponding concordia diagrams are presented in Figures 15a and b. As a whole the analyses are discordant and do not provide well-defined chords on the concordia diagram. Nevertheless, excluding the two most discordant points, the data from these four closely spaced samples yield a regression line which has intercepts at 2029±7 Ma and 389±69 Ma (MSWD=38). The data for individual samples are also heterogeneous. An analysis on red opaque zircon (L) in sample A401 is discordant and clearly off the line defined by other eleven analyses, which give intercepts at 371±38 and 2038±5 Ma (MSWD=7, n=11). As some of the analyses represent very low-density material (<3.8 g/cm^3) and give highly discordant points, it should be appropriate to consider only good analyses on heavy zircon. Seven points yield a chord, which gives an upper intercept age of 2046±18 Ma, and a lower intercept of 530±260 Ma (MSWD=3, Fig. 15a). Most analyses on sample A741 represent

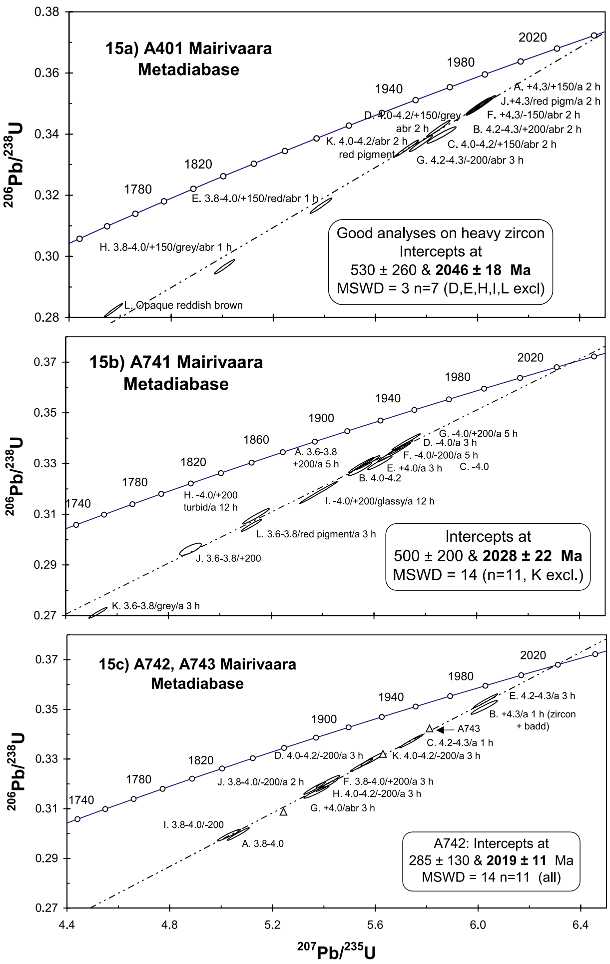

Fig. 15a) - c). Results for U-Pb analyses on zircons from the Mairivaara metadiabase.

low-density zircon. Apart of the most discordant data point (fraction K) the analyses from A741 form an ill-defined cluster which plots along a 2028-500 Ma reference line. The data from sample A742 are also heterogeneous plotting roughly along a 2019-285 Ma reference line. The three analyses on sample A743 plot close to this line.

The Mairivaara data are not unequivocal, but suggest intrusion not later than 2.03 Ga ago. The upper intercept age of 2046±18 Ma calculated for the best material of sample A401 may be considered with caution as an age estimate. However, as discussed above (Törmänen) metamorphic effects on zircon at 1.9-1.8 Ga are the likely reason for the heterogeneity observed. If such an effect was very pronounced, the age of intrusion should be older than the result of this simple calculation.

A815 Rykimäkuru mafic dyke. Rykimäkuru lies in the Luosto area about 40 km southeast from Sodankylä, 10 km west from Mairivaara and 12 km northwest from Pyhätunturi (Fig. 1.). The bedrock was mapped by Haimi as a student practice carried out for Rautaruukki Co. in the 1970s. The lithology consists principally of quartzites but there occur also schists and dolomites, as well as mafic dykes and mafic volcanic rocks, both flows and tuffs. Haimi (1977) considered that the quartzites were of same formation and, together with the quartzites at Mairivaara and Pyhätunturi, formed a syncline penetrated by mafic dykes and capped by the mafic volcanics. The idea for sample A815, taken 1977 by M. Haimi, was to produce an age constraint for the quartzite deposition.

Based on geological and geophysical information the Rykimäkuru dyke resembles that at Mairivaara, but is more deformed due to its proximity to a tectonized zone. It penetrates the fine-grained arkose quartzite of the Mairivaara Formation. It should be noted, that no dykes penetrating the Pyhätunturi Formation have been observed during careful reinvestigations in the area.

The sample A815 is ophitic and reddish in color, and rich in plagioclase containing subhedral crystals of albite up to 3 mm in size and abundant carbonate minerals. Hornblende and leucoxene after titanomagnetite are common and also minor quartz exists. Zircon occurs as short, reddish brown or pale, completely turbid crystals. The seven U-Pb analyses on zircon are very discordant and plot along a line which gives an upper intercept at 1912±18 Ma and an unusually low lower intercept at 22±49 Ma (Fig. 16). As the data are heterogeneous (MSWD=22) and very discordant, the significance of the age remains obscure.

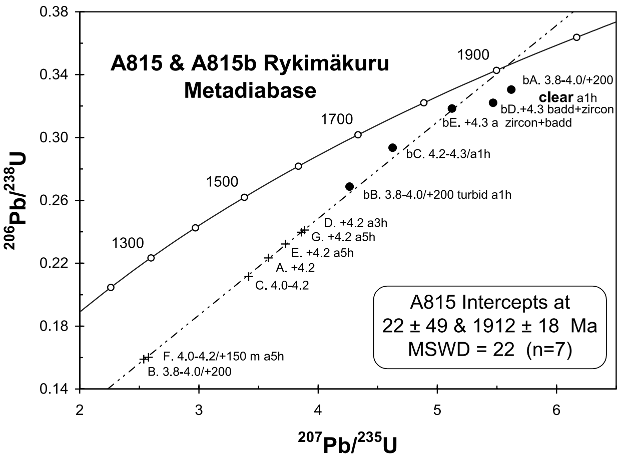

Fig. 16. Results for U-Pb analyses on zircons from the Rykimäkuru metadiabase.

In order to get better material for dating, a new sample (A815b) was taken from the Rykimäkuru mafic dyke. Sample A815b is ophitic in texture and mainly blackish gray in color containing some light-colored magmatic layers rich in plagioclase. Metamorphic hornblende containing some remnants of pyroxene and albitized plagioclase together with secondary biotite are the main minerals, while scapolite and leucoxene-altered titanomagnetite are common accessories. In addition to turbid zircon the heavy minerals separated contain transparent crystals of zircon and baddeleyite as well as zircon-baddeleyite aggregates. The five U-Pb analyses are less discordant than the data from the original sample, but do not provide any chord. Three analyses on turbid zircon are roughly on the line defined by sample A815, but an analysis on clear zircon (A) as well as the baddeleyite-dominated fraction (D) give clearly older age indications exceeding 2 Ga (Fig. 16). It should be noted that the clear zircons were picked from relatively low-density material (<4.0 g/cm^3).

There are cases where analyses on transparent zircons, baddeleyite or titanite have provided reliable age estimates for magmatic zircon, while turbid zircons in the same rock have yielded discordant data with relatively low $^{207}Pb/^{206}Pb$ ages. For example, the Jäkäläniemi mafic dyke in Kuusamo containing turbid and transparent zircons yielded originally a poor age estimate of about 2.0 Ga. Later, after baddeleyite and titanite were analyzed, their results together with transparent zircons yielded a reliable age of 2206±9 Ma as reported by Silvennoinen (1991). The same phenomenon is also observed at Susivaara, in the Peräpohja Schist belt (Perttunen & Vaasjoki 2001, *this volume*).

The results from the Rykimäkuru dyke do not allow a confident age estimate. The two analyses on the clear zircon and baddeleyite plot on a line defined by the previous sample A401 from Mairivaara, which was considered geologically analogous. Natural interpretation for the data available is, again, 1) magmatic crystallization more than 2 Ga ago, 2) followed by significant disturbance of U-Pb in zircon at 1.8-1.9 Ga, and 3) finally more recent lead loss.

Felsic intrusions

A65 Kelujärvi granodiorite. Kelujärvi lies about 20 km to the east of Sodankylä (Fig. 1). The local bedrock is composed of quartzites and associated sericite and Al-bearing schists of the Sodankylä Group, which are penetrated by a gabbroic intrusion. Sample A65, taken in the 1980s, stems from the proximity of a gabbroic massif close to a contact with sedimentary rocks composed of fine-grained, graded biotite-sericite schists, rich in albite. The same granodioritic rock occurs with a gabbro close the place where the sample was taken.

Sample A65 is a medium-grained slightly reddish gray rock with faint orientation. It is patchy in appearance, due to amphibole aggregates. The texture is hypidiomorphic and the main minerals are plagioclase, quartz and hornblende with some potassium feldspar and biotite. The plagioclase (An_{20-30}) is weakly zoned and contains inclusions of quartz and microcline. Some thin sections show abundant sericitized potassium feldspar which contains inclusions of plagioclase and forms intergrowths with quartz. Hornblende is uralitic, bluish green in color and always associated with biotite. Abundant zircon occurs as small, short, euhedral and almost even-grained translucent crystals, exhibiting well developed (100) faces. Crystal edges are sharp and no rounded grains are found.

Results of the analyses are listed in Appendix I and plotted in Figure 17. Fractions D and E are preleached in HF. All analyses are very discordant and there is a positive correlation between increasing uranium content and increasing discordance, a feature shared by many igneous rocks. The data provide a chord which gives intercepts at 1891±5 and 106±12 Ma (MSWD=0.8).

The upper intercept age coincides with the ages of collision-related granitic to gabbroic intrusions of the Svecofennian orogeny, which are common in Western-Lapland and known as intrusive rocks of the Haaparanta Suite. All the dated intrusives yield U-Pb ages close to 1.89 Ga (e.g. Lehtonen 1984, Perttunen 1987, 1991 and Väänänen 1998). However, rocks belonging to the Haaparanta Suite lying as far in the east as A65 Kelujärvi have not been recognized before.

A570 Mustatseljät granite. Mustatseljät is a hill area on the eastern side of the schist area, about 50 km northeast from Sodankylä (Fig. 1). The bedrock consists of sulfide- and garnet-bearing, mainly banded amphibolites overlain by garnet-cordierite-sillimanite gneisses and quartzites. This volcano-sedimentary package, lying on Archean granitic gneisses with a brecciated tectonic contact, is intruded by a reddish granite with biotite streaks. Sample A 570 was taken from a granite dyke, about 2 m in thickness, in order to get some age constrains for the supracrustals. The rock is a foliated, small- to medium-grained granitic apophysis, which sharply penetrates the gneisses and amphibolites.

The rock is hypidiomorphic in texture and the main minerals are plagioclase, microcline and quartz, though

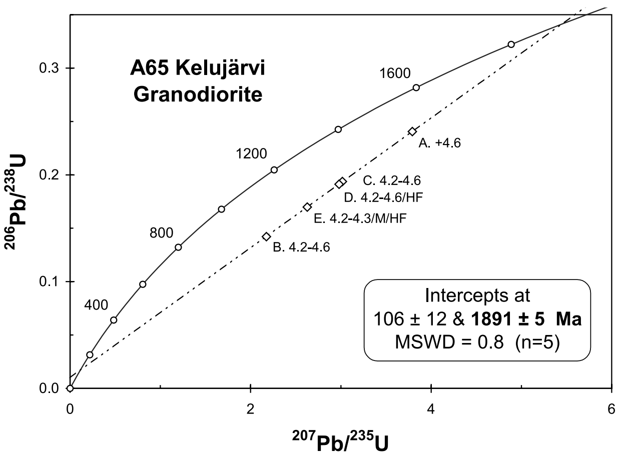

Fig. 17. Results for U-Pb analyses on zircons from the Kelujärvi granodiorite.

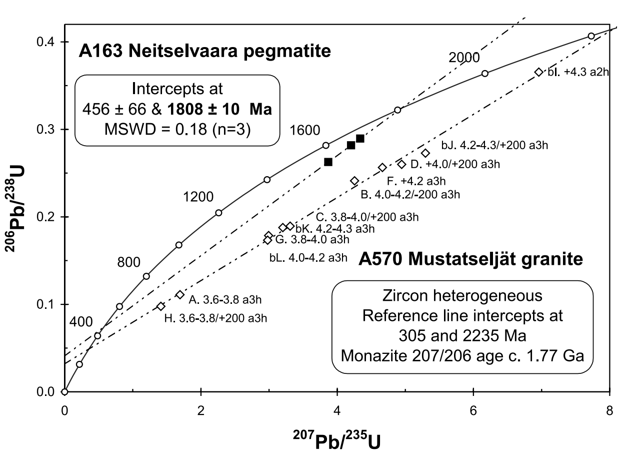

Fig. 18. Results for U-Pb analyses on zircons from the granite dykes.

microcline dominates some thin sections. Plagioclase (An_{25}) is rimmed with secondary albite and sometimes it includes a sericite-altered core exhibiting remnants of original, euhedral crystals, up to 2 mm in size, with weakly zoned textures. Biotite and muscovite together with monazite and apatite are common accessories and, in addition to zircon, also garnet, up to 2.5 mm in size, is frequent as an accessory mineral. Based on mineralogy the rock can be classified as an S-type granite.

The zircon population is somewhat heterogeneous in size and color. Turbid, red-brown grains are common, but also transparent crystals occur. The forms range from elongated euhedral simple prismatic to short anhedral. The U-Pb data are presented in the Appendix and Figure18. Most analyses on zircon are very discordant, particularly those made on very high-uranium, low-density material. The content of common lead is also relatively high. The regression provides intercepts at 2236±49 and 305±58 Ma, but the data are badly scattered (MSWD=475!). The U-Pb analyses on monazite give clearly younger age indications, the $^{207}Pb/^{206}Pb$ age being c. 1.77 Ga. This age registers either the intrusion of this granitic dyke or the metamorphism in the area. It is very likely that the upper intercept age above does not have any geological meaning due to inherited material. S-type granites like A570 may contain zircons derived from different sources including both magmatic and sedimentary rocks and, in addition, may have been mantled by a new generation of zircon afterwards. Lauerma (1982) reported a discordant "age" at 2216±70 Ma for the Hatajavaara granite (A126+A640+A641) in Salla and discussed the mixed zircon population and the origin of this inhomogeneous granite, which also contains supracrustal inclusions. Monazites in the Salla granites give U-Pb ages of c. 1.8 Ga and can be considered the date the crystallization of these granites (Lauerma 1982, Huhma 1986).

A163 Neitselvaara granite pegmatite. Neitselvaara lies in the Tanhua area about 45 km northeast from Sodankylä (Fig. 1.). The bedrock, mainly based on Mikkola (1937, 1941), is composed of weakly foliated and light-colored pinkish to grayish granite, which dominates the lithology over a large area. At Neitselvaara the granite is quite homogeneous, pinkish gray in color and weakly orientated, but it also contains inclusions rich in biotite and is penetrated by granitic dykes with sharp contacts.

Sample A163, taken in the early 1980s, represents a red-colored and coarse-grained pegmatitic granite dyke. The zircon population is relatively uniform consisting of elongated, euhedral, yellowish prisms. The three analyses shown in the Appendix and Figure18 give intercepts at 1808±10 and 456±66 Ma (MSWD=0.18). Following a conventional interpretation the upper intercept obtained should be considered as the age for the Neitselvaara granite pegmatite. This age of c. 1.8 Ga is well within the range obtained for late granites in Lapland. Isotopic studies indicate that the source of these granites originated from or at least involved Archean rocks (Patchett et al. 1981, Kouvo et al. 1983, Huhma 1986).

Detrital zircons in sedimentary rocks

A1021 Haikaraselkä quartzite. Haikaraselkä lies in the Vuojärvi district 40 km south of Sodankylä (Fig. 1.). The area is dominated by greenish sericite quartzites, called the Haikaraselkä quartzite, comparable to the Virttiövaara Formation as both of them are characterized by greenish fuchsite-bearing layers and exhibiting well-preserved ancient tidal deposits (Nikula 1985, Räsänen 1986b). The Haikaraselkä quartzite reaches a probable thickness of close to 1000 m and can be followed for tens of kilometers. It overlies the turbiditic mica gneisses associated with the Archean felsic volcanics (A194) at Keski-Loviselkä described before.

Typically, the quartzite is fine-grained and contains rounded to well-rounded quartz clasts in a sericite-rich matrix. A conspicuous feature is the bright green layers, owing to great abundance of fuchsite (1% Cr), which also reflects in the main chemistry of the quartzite (Cr>650ppm). In this association there exist brownish yellow laminae, up to 2-4 mm thick, which are rich in rutile and zircon. Sample A1021 was taken from these laminae which contain rounded detrital zircons.

Analytical results are given in Appendix I and shown in Figure19. The six analyses on detrital zircon are discordant and give $^{207}Pb/^{206}Pb$ ages from 2.70 to 2.75 Ga, which should be considered a minimum for the average zircon provenance. They do not form a precise chord, as the regression gives a MSWD of 32 and intercepts at 2856±180 and 1295±680 Ma. The data are comparable with the results from the Virttiövaara quartzite (Rastas et al. 2001, *this volume*), c.75 km NW, which exhibits the same sedimentologic features and also corresponds to the Haikaraselkä quartzite in stratigraphy. Similarly, ionprobe analyses on detrital zircons from quartzites in

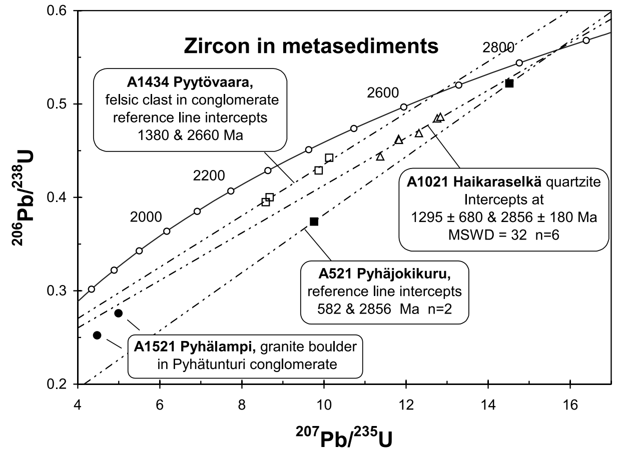

Fig. 19. Results for U-Pb analyses on zircons from the sedimentary rocks.

the Suomujärvi Complex, c. 70 km SE, are predominantly 2727±13 Ma old but also indicate another, older source (Evins 2001). So far no Proterozoic zircon population has been obtained from these quartzites which indicates that they derive from Archean rocks. However, this does not exclude the Paleoproterozoic deposition of sands.

A521 Pyhäjokikuru conglomerate. Pyhäjokikuru is in the Luosto area about 40 km southeast of Sodankylä and 10 km west from Mairivaara (Fig. 1). It is a river canyon lying in a fracture zone which cuts the bedrock and displays a lithostratigraphic section of it. The bedrock is dominated by reddish arkose quartzites belonging to the Mairivaara Formation of the Sodankylä Group and contain some conglomeratic and mica-rich interlayers. Several mafic dykes, often with albite-rich contacts, penetrate the quartzite which has been interpreted as part of the Pyhätunturi Formation (Haimi 1977, Mielikäinen 1979). The quartzite is conformably overlain by mafic volcanic rocks of the Kiimaselkä Formation displaying massive flows with amygdaloidal flow tops and tuffaceous beds. Based on lithology and lithological similarities Silvennoinen (1985) considered the Kiimaselkä volcanics part of the Greenstone Formation III, which represents a plateau-type basalt and is the best stratigraphic key horizon in the Kuusamo schist area (Silvennoinen 1972, 1991). On low-altitude geophysical maps it is characterized by magnetic highs and can be traced over very large areas in the Central Lapland Greenstone Belt. Based on similarities in lithological associations as well as geophysical and geochemical parameters, recent studies strongly suggest that this correlation is still valid and the volcanics of the Kiimaselkä and Greenstone Formation III can be compared to each other in stratigraphy.

Sample A521 was taken from the Mairivaara Formation and it represents a slightly conglomeratic interlayer of the quartzite. The rock is albitized and mainly granoblastic in texture exhibiting only weak clastic textures, however, it contains plenty of well-rounded zircons of undoubted detrital origin. Furthermore, there are two kinds of zircons, some having red pigment, while others are gray in color and do not show any pigment at all.

Only two analyses of zircons with red pigment were made, and both indicate an Archean age. The $^{207}Pb/^{206}Pb$ age of 2.84 Ga for the less discordant analysis suggests a relatively old average age for the provenance. This apparent age is quite close to the U-Pb age of 2832±10 Ma of a uniform detrital zircon population of the quartzite at Virttiövaara (Rastas et al. 2001, *this volume*) and gives more evidence for the existence of Archean rocks older than 2.8 Ga, which have been exposed and denuded while the Paleoproterozoic sands were deposited.

A1434 Pyytövaara volcanic conglomerate. Pyytövaara lies about 15 km southwest of Savukoski (Fig. 1). The local bedrock consists of mafic and felsic volcanics with a BIF, which are overlain by volcanic conglomerates and komatiites (Räsänen 1983). The volcanics were formerly known as the Jauratsi greenstone belt and, as age determinations were lacking, regarded as Archean in age (Gaál et al. 1978 and Silvennoinen et al. 1980). Later Saverikko (1983) observed that the komatiites are the uppermost volcanic rocks in the area but afterwards still considered them of an Archean age (Saverikko 1987).

During the mapping by GTK in the 1980s many samples from felsic volcanic rocks were taken to get some age constraints for the overlying komatiites, called today the Kummitsoiva Formation, but no zircon was found. Sample A1434 was taken later and it is a light-colored, fine-grained felsic boulder (about 1 m^3 in size) at the base of a volcanic conglomerate, which also contains phenoclasts of a banded iron formation.

The felsic boulder consists mainly of quartz and plagioclase (An_{20-30}) but also contains abundant tremolite and some microcline. Almost euhedral plagioclase crystals, up to 0.4 mm in size, exist but there are also roundish quartz crystals, up to 0.5 mm in size, indicating that the rock is reworked. Zircon and apatite are common accessories. The zircons are transparent and reddish in color. However, all zircon crystals seem to be slightly rounded and some of them are clearly rounded and evidently detrital in origin. This conflicts with the original attempt to constrain the age of deposition of these supracrustal rocks by dating a felsic igneous clast.

The four analyses listed in the Appendix are technically very good, but provide discordant U-Pb results

(Fig. 19). The $^{207}Pb/^{206}Pb$ ages range from 2.43 to 2.53 Ga and represent the minimum age for the analyzed material. These results do not help much in constraining the age of the Kummitsoiva Formation. However, it is known today, that the Kummitsoiva komatiites are correlative to the komatiites of the Sattasvaara Formation, in Sodankylä, and on well proven lithostratigraphic grounds can be regarded as Proterozoic in age (cf. Räsänen 1990, 1996 and Lehtonen et al. 1998). Recently Hanski et al. (2001) have obtained a Sm-Nd age of 2063±34 Ma for the Jeesiörova komatiites at Kittilä. This is an extensive komatiite-picrite association which can be traced for hundreds of km through the Finnish Lapland to Norway, where Krill et al. (1985) have reported a Sm-Nd age at 2085±85 Ma for the Karasjoki komatiites.

A1521 Pyhälampi polymictic conglomerate. Pyhälampi lies about 40 km southeast from Sodankylä on the western side of Luostotunturi (Fig. 1). The local bedrock consists of conglomerates and quartzites of the Pyhätunturi Formation, which belong to the Kumpu Group. Hematite- and carbonate-bearing fine-grained schists together with graded siltstones and pinkish quartzites of the Harjunoja Formation and mafic volcanics of the Kiimaselkä Formation belong to the Sodankylä Group. Diamond drilling has shown that the mafic volcanics of the Kiimaselkä Formation overlie the supracrustals of the Harjunoja Formation, which also includes some felsic volcanic rocks but is comparable in lithology and in stratigraphy with the Akankoski Formation on the eastern side of the Pyhätunturi Formation. The Pyhälampi conglomerates representing the coarse-clastic molasse-type deposits are the same as described by Räsänen and Mäkelä (1988) at base of the Pyhätunturi Formation and called then the Isokuru Formation. At Pyhälampi this highly polymictic conglomerate exhibits meters of thick alternating sandy and pebbly layers, some of them containing abundant boulders and cobbles of homogeneous red granite with bluish gray quartz. Because similar granites occur nearby at Vaiskonselkä in the Central Lapland Granite Complex and are generally regarded as post-orogenic, c. 1.8 Ga old (see Korsman et al. 1997), a sample was taken to get maximum age constraints for the deposition of the coarse-clastic sediments.

Sample A1521 was a well-rounded boulder, about 35 cm in diameter taken from a layer containing abundantly pebbles and cobbles of similar granite. The rock is a medium-grained and unorientated red granite. Its texture is hypidiomorphic and the main minerals are microcline, plagioclase and quartz. Both feldspars are turbid and reddish in color due to abundant pigment of dust-like hematite, and also contain hematite-filled fissures. Quartz is transparent and exhibits almost euhedral crystals, 2-4 mm in size. It contains commonly abundant linearly aligned minute inclusions of rutile, which probably cause the bluish color of quartz. The most common accessory mineral is hematite, which exists as platy crystals up to 3 mm in size. The amount of magnetite and biotite is insignificant.

The sample yielded a small amount of zircon, which is relatively large in size and dark red-brown due to pigment. Crystals are generally euhedral exhibiting often sharp edges. The two U-Pb analyses are very discordant providing $^{207}Pb/^{206}Pb$ ages of c. 2.1 Ga (Fig. 19). This should be considered as a minimum age for the material analyzed, but the age of this granite pebble remains obscure. The results obtained do not give essential information on the age of sedimentation, but on sedimentogenic grounds the Pyhätunturi Formation can be compared to similar deposits of the Kumpu Group also characterized by molasse-like, several hundreds of meters thick coarse-clastic deposits. They all are well-preserved, and typically longitudinal in shape but areally very restricted in width. Recently a U-Pb age of 1888±16 Ma has been obtained for a felsic pebble picked from conglomerates of the Kumpu Group in Kittilä (Hanski et al., 2000, Rastas et al. 2001, *this volume*). The age supports their deposition after collision-related intrusion of the Haaparanta Suite during the Svecofennian orogeny, which indicates that they are comparable to the molasse sediments proper in a tectonic sense.

Other samples

Attempts to determine the geochronology of Central Lapland have involved the collection of many samples during the last decades. Some of them have yielded no suitable material for dating, and are listed below (Table 1).

A1433 Visakuppura. At the base of the Sattasvaara Formation at Visakuppura, about 30 km NNW of Sodankylä (Fig. 1), there exist fragments and angular boulders of fine-grained felsic rocks of probably volcanic origin with highly corroded contacts because they are affected by the komatiite. Sample A1433 was taken from a felsic boulder to get some age constrains for the Sattasvaara Formation but separation yielded no zircon.

A1435 Möykkelmä. The Möykkelmä Formation about 35 km NNW of Sodankylä (Fig. 1) lies on

Table 1. Samples with insufficient material for U-Pb dating from the Sodankylä area.

Sample	Map	Northing	Easting	Locality	Rock type
A1433	371405	7507.04	3470.38	Visakuppura	Andesite (ejecta in komatiite)
A1435	371406	7510.50	3472.10	Möykkelmä	Andesite (basaltic)
A1476	362412	7456.40	3491.25	Keski-Luosto	Dacite (felsic volcanics)
A1522	362409	7458.90	3487.30	Vaiskonselkä	Granite
A1573	362411	7448.92	3493.32	Luosto	Arkosic quartzite
A1575	364201	7433.32	3504.54	Sienioja	Dacite (felsic volcanics)

Archean granitoids and consists of two ultramafic and three mafic volcanic units of unknown age. Sample A1435 was taken from the basaltic andesite member representing the middle mafic unit but no zircon was recovered.

A1476 Keski-Luosto. The Harjunoja Formation, penetrated by 2.2 Ga old differentiated sills (A281 Harjunoja, described above), consists of sedimentary and volcanic rocks. The supracrustals are poorly exposed and a part of them has been intersected by diamond drilling made by Rautaruukki Co. in 1970s. The drill cores have been reinvestigated and sample A1476, taken recently from these drill cores, represents a plagioclase-phyric felsic flow, andesite in chemical composition, associated with felsic tuffs and breccias. No zircon sufficient for conventional U-Pb analyses was recovered.

A1522 Vaiskonselkä. Vaiskonselkä is 25 km SSE from Sodankylä (Fig. 1). The area consists of medium grained red granites characterized by blue quartz and closely resembling boulders and pebbles found in conglomerates at base of the Pyhätunturi Formation (A1521 Pyhälampi, described above). Sample A1522 was taken from the granite and it contains zircon and a lot of rutile, but as the zircon population is obviously heterogeneous conventional analyses have been not done.

A1573 Luosto. Sample A1573 taken from the Luosto area about 30 km SSW of Sodankylä (Fig. 1) represents a quartzite layer of the Pyhätunturi Formation. A small amount of zircon was found among abundant rutile, but no conventional analyses have been made.

A1575 Sienioja. Sienioja lies roughly 50 km SSE from Sodankylä on the southern side of Pyhätunturi (Fig. 1). Sample A1575 was taken from a drill core made by GTK some years ago. It is a very fine-grained felsic volcanic rock, chemically a andesite, associated with fragmental and graded tuffites resembling the sample A1476 Keski-Luosto. Only a few zircon grains were recovered.

Jauratsi is about 20 km southwest of Savukoski (Fig. 1). In this area, there exist mafic and felsic volcanic rocks associated with a banded iron formation. They lie on quartzites and the whole sequence is overlain by komatiites of the Kummitsoiva Formation comparable to the Sattasvaara Formation. Three samples were taken from felsic volcanic rocks during regional mapping in the 1980s, but no zircon was found in these amygdaloidal lavas and breccias.

DISCUSSION

Dating problems

The most reliable U-Pb dating often involves heavy, clear zircon, and nearly concordant analyses. In this study such material and data are not generally available, and the U-Pb dating always involves interpretation of the analytical results. As the data are often very discordant and heterogeneous, the drawing of reliable conclusions becomes difficult if not impossible. Occasional analytical problems are conceivable, as the old analyses have been made using separate Pb and U spike solutions. However, several duplicated analyses in the laboratory have yielded consistent results, and the principal source for heterogeneity should be in zircon. Possible reasons for scatter in multigrain conventional data include primarily heterogeneous zircon populations (detrital or inherited zircon) and metamorphic effects.

It is known that zircon will stay closed at high temperatures (e.g. 800°C), but may lose Pb if it experienced extended time periods at low temperatures especially when abundant fluids were available (Mezger & Krogstad 1997). Apart of clearly detrital or inherited material encountered in few samples, we consider this as the principal cause for the heterogeneity observed in this study as (1) magmatic crystallization occurred before 2 Ga and was (2) followed by disturbance of U-Pb system at 1.8-1.9 Ga, which may have involved dissolution and recrystallization of metamict zircon. Finally, (3) more recent lead loss may have occurred.

A sample subjected to this sequence should generally provide very scattered data (A862, Fig.14), but occasionally good-looking chords with geologically meaningless upper intercept ages are formed (A815, Fig.16). Generally, such chords exhibit elevated MSWD-values and apparent upper intercept ages too young for magmatic crystallization in the particular geological environment. This may be the case with the metarhyolites from the Purkkivaara formation (A992 and A1524), as well as gabbroic rocks from Pittiövaara (A841), Mairivaara (A741-A734) and Luosto (A815). Typically zircons in these gabbroic rocks are very turbid and of low-density. Examples show that transparent zircon, baddeleyite or even titanite have provided more reliable age estimates, while turbid zircons in the same rock have yielded discordant data with relatively low $^{207}Pb/^{206}Pb$ ages (Silvennoinen, 1991, Lauerma, 1995; Perttunen & Vaasjoki 2001, *this volume*; sample A861b).

Apart from zircon dating, there are occasionally problems in determining the primary rock types in highly metamorphosed and tectonized lithologies, i.e. whether a sample in question is truly magmatic with magmatic zircon or contains a detrital component.

Geological implications

The results of the isotopic analyses presented previously are summarized in Table 2.

The extent of Archean rocks

In the northeast, the Sodankylä schist area is bounded by an Archean terrain, which – excluding the gneisses of Tuntsa Suite northeast of Savukoski - is thought to consist mainly of orthogneisses. However, during this study both ortho- and paragneisses have been observed. Similar gneisses are also found on the southern side of the area, and at Keski-Loviselkä they occur with a felsic volcanic rock yielding an age of c. 2.77 Ga. In addition, associated turbiditic greywackes strongly suggest the contemporaneity of sedimentation and volcanism at that time, which is well-known in the Canadian Shield (e.g. Ojakangas 1985) and also reported from the Fennoscandian Shield (Rundquist & Mitrofanov 1993, Vaasjoki et al. 1993). These gneisses can be followed northwestwards into the Central Lapland Granite Complex and, Archean ages of c. 2.72 - 2.74 Ga are obtained from felsic volcanic rocks at Honkavaara (Rastas et al. 2001, *this volume*), about 35 km W of Sodankylä.Likewise the gneisses can be traced far southeastwards into the Archean Suomujärvi Complex, where they are highly granitized but still contain porphyroblast-bearing parts, traceable for tens of km southwards into the Posio area. At Niskavaara, Posio, on the western side of the Kuusamo Schist area, a felsic volcanic rock associated with turbiditic gneisses has a U-Pb zircon age of 2800±8 Ma, and Räsänen and Vaasjoki, (2001, *this volume*) argue that all these rocks belong to the same volcanic-sedimentary unit.

These findings suggest the presence of an extensive late Archean volcanic-sedimentary belt on the southeastern side of the Central Lapland Greenstone Belt and continuing within the Central Lapland Granite Complex. The gneisses are magnetic and, though granitized, can be seen as banded magnetic anomalies forming images of large scale fold structures on low-altitude geophysical maps. This gives reason to presume that the Central Lapland Granite Complex includes much more Archean rocks and their granitized relicts than previously thought. So far this huge granitoid terrain, about 20 000 km^2, is poorly known, but it seems likely that the Suomujärvi Complex, separated from the rest of the Central Lapland Granite Complex by a fault, actually comprises mostly Archean rocks. The basement consists of 2.82 Ga old orthogneisses, which are penetrated by 2.75 Ga granitic rocks and also includes paragneisses and quartzites containing zircons older than 2.72 Ga (Evins 2001). Felsic volcanics are yet to be recognized as the rocks were highly granitized and partly remobilized during the Svecofennian orogeny. Migmatites and penetrating granites yield heterogeneous and discordant zircon data with $^{207}Pb/^{206}Pb$ ages from 1.77 to 2.22 Ga (Lauerma 1982) comparable with the granitoids in the Tanhua area (A163, A570), on the northern side of the Central Lapland Greenstone Belt, indicating their similar geological history.

The age of the komatiites at Kivivuotsonselkä can not be compared to that of the komatiites of the Archean Kuhmo-Suomussalmi belt, which are penetrated by intrusive rocks dated at 2.74 Ga (Hyppönen 1983, Vaasjoki et al. 1999). Likewise, the ultramafic volcanic rocks of the Tulppio Suite in the Archean terrain north of Savukoski seem to be older (Juopperi 1994, Juopperi & Vaasjoki 2001, *this volume*). The Paleoproterozoic komatiites of the Vetreny Belt, in Russia, yield Sm-Nd ages of 2.44 Ga and 2.41 Ga and an associated felsic volcanic rock yields a U-Pb age at 2.43 Ga (Puchtel et al. 1996, 1997). However, the

Table 2. Summary of results of U-Pb mineral analyses from rocks of the Sodankylä schist area.

Sample	Map	Northing	Easting	Locality	Rock type	Age (Ma)	N	MSWD	Comment
A194	362407	7438.20	3489.10	Keski-Loviselkä	Felsic volcanic rock	2775±25	4	16	
A195	362407	7438.20	3489.10	Keski-Loviselkä	Felsic volcanic rock	2780±72	4	9	Titanite >1825 Ma
A283	373302	7477.88	3541.40	Kivivuotsonselkä	Komatiite	-	7	-	Archean, heterogeneous, inherited?
A992	364405	7448.85	3556.23	Purkkivaara	Felsic volcanic rock	2412±40	4	24	
A1524	364406	7450.50	3551.50	Akanvaara	Quartz-feldspar porphyry	2398±25	8	55	two deviating analyses
A1432	374110	7526.80	3533.60	Sakiamaa	Rhyolite	2438±11	4	2.7	
A1498	374110	7526.80	3533.60	Sakiamaa	Rhyolite	-	2	-	compatible with A1432
A281	362410	7434.70	3497.75	Harjunoja	Gabbro	2222±6	12	7	
A900	373201	7499.53	3502.61	Rantavaara	Gabbro	2148±11	7	4	E-Hf=+9.8
A1586	373202	7500.40	3504.50	Metsävaara	Gabbro	-	1	-	compatible with A900
A841	371306	7483.21	3473.71	Pittiövaara	Albitite	2135±31	6	13	discordant, suspect; E-Hf=+4.5
A962	374107	7524.67	3525.30	Povivaara	Gabbro pegmatoid	2142±5	3	0.3	
A418	373109	7487.16	3526.08	Koskenkangas	Gabbro	-	2	-	compatible with A962
A816	373208	7501.19	3526.98	Kylälampi	Albitite	2066±7	15	2.0	10 anal. on heavy zircon; Tit 1890±9 Ma
A817	373208	7501.19	3526.98	Kylälampi	Metagabbro	2114±6	6	2.6	Titanite 1801±13
A818	364401	7435.85	3548.25	Ahvenselkä	Metadiabase	2070±5	8	1.2	1 fraction excluded; titanite c. 1.84 Ga
A820	373102	7471.25	3501.90	Rovasvaara	Gabbro	2055±5	4	0.02	1 fraction excluded; E-Hf=-3.2
A861	362412	7456.16	3496.98	Törmänen	Metadiabase	2054±14	6	8	turbid crystals discordant, excluded
A862	362412	7456.14	3497.00	Törmänen	Metadiabase	-	9	-	heterogeneous, metamorphic?
A863	362412	7456.10	3497.06	Törmänen	Metadiabase	2061±47	5	9	discordant data
A401	364202	7445.86	3506.66	Mairivaara	Metadiabase	2046±18	12	3	7 good analyses on heavy zircon
A741	364202	7445.86	3506.56	Mairivaara	Metadiabase	2028±22	12	14	heterogeneous, 1 fraction excluded
A742	364202	7445.96	3506.66	Mairivaara	Metadiabase	2033±20	11	8	heterogeneous, 3 fractions excluded
A815	362411	7445.62	3499.23	Rykimäkuru	Metadiabase	-	12	-	heterogeneous, baddeleyite >2032 Ma
A65	373103	7486.04	3504.84	Kelujärvi	Granodiorite	1891±5	5	0.8	
A163	373208	7509.50	3520.40	Neitselvaara	Granite pegmatite	1808±10	3	0.2	
A570	373208	7502.90	3529.80	Mustatseljät	Granite	-	11	-	heterog. Inherited?, monazite >1.77 Ga
A521	364202	7445.08	3500.12	Pyhäjokikuru	Quartzite	-	2	-	Archean, apparently >2.8 Ga
A1021	362410	7435.55	3495.25	Haikaraselkä	Quartzite	-	6	-	Archean, apparently >2.8 Ga
A1434	364403	7454.48	3542.74	Pyytövaara	Felsic clast in conglomerate	-	4	-	discordant, apparently >2.5 Ga
A1521	362411	7445.20	3498.12	Pyhälampi	Granite clast in conglomerate	-	2	-	discordant, >2.1 Ga

N = number of analyses
MSWD = Mean square of weighted deviates

REE-patterns of the Kivivuotsonselkä spinifex-textured komatiites show no signs of LREE-enrichment characteristic of the crustally contaminated rocks of the Vetreny Belt. Likewise, the Kivivuotsonselkä rocks differ chemically from the Möykkelmä komatiites (Räsänen et al. 1989, Manninen 1991). Also a comparison to the Sattasvaara-type Kummitsoiva komatiites is unwarranted as the komatiite flows at Kivivuotsonselkä lie on Archean banded gneisses and are probably overlain by a pile of supracrustals which form the base of the Kummitsoiva komatiites. As the rocks do not contain any primary magmatic minerals, successful Sm-Nd dating is unlikely, and the true age of these komatiites remains unknown.

Felsic volcanism and layered mafic intrusions

An important finding concerning the Proterozoic supracrustal rocks within the Sodankylä Schist area is that the lowermost felsic flows at Sakiamaa yield an age of 2.43 Ga, comparable to ages obtained for the Purkkivaara and Akanvaara felsic volcanics. These are convincing evidence for volcanism at the start of the rifting of the Archean continent at the onset of the Paleoproterozoic coinciding with the emplacement of layered mafic intrusions at 2.43-2.44 Ga. Although volcanic rocks of this age have been previously identified elsewhere in the Fennoscandian Shield (Kratz et al. 1976, Gorbunov et al. 1985, Amelin et al. 1995, Puchtel et al. 1996, 1997), such volcanism has not been conclusively demonstrated in northern Finland before, even if several plausible candidates have been identified. These studies (see also Manninen et al. 2001, *this volume*) indicate that the volcanic rocks forming part of the 2.44 Ga igneous episode occur throughout the Fennoscandian Shield.

Periods of mafic magmatism

In spite of the dating problems discussed above, several samples from mafic intrusions have provided good results sufficient for constraining the age of mafic magmatism and associated supracrustals in the Sodankylä schist area. The data obtained show clearly that, in addition to the 2.44 Ga old Koitelainen and Akanvaara intrusions, there exist several younger generations of mafic magmatism, with U-Pb ages of 2222±6 Ma, 2148±11 Ma, 2114±6 Ma, 2070±5 Ma and 2055±5 Ma. In addition to these, the 2058±4 Ma Keivitsa intrusion is cut by komatiite dykes.

The differentiated sill-like mafic intrusions, dated to be 2222±6 Ma old at Harjunoja, penetrate quartzites with associated dolomites and schists of the Harjunoja Formation, which lies at the base of the Sodankylä Group and will be compared here to the Jatuli-type rocks in eastern Finland. The intrusions are older than the volcanics of the Kiimaselkä Formation as they do not penetrate those. On the basis of geochemistry they can not be feeder channels for the Kiimaselkä volcanic rocks. In addition to the Sodankylä schist area, similar intrusions occur also at Salla, where U-Pb ages of c. 2.21 Ga are observed both at Pirtinkehäkukkura and at Jokinenä (Lauerma 1995). The Jäkäläniemi mafic dyke in Kuusamo also yields an age of c. 2.21 Ga (Silvennoinen 1991) and in the Peräpohja schist area there exist several differentiated mafic intrusions, which belong to this age group (Perttunen & Vaasjoki 2001, *this volume*). These intrusions concentrate on the borders of Proterozoic volcano-sedimentary belts and penetrate their lowermost supracrustal rocks forming a belt, which can be followed on outcrops and as magnetic highs for hundreds of kilometers. Evidently these rocks are genetically associated with a rifting phase of the Archean craton, which occurred 2.22-2.20 Ga ago and gave rise to these enormous magmas. Their initial Nd-ratios are close to chondritic values (Huhma et al, 1990, 1996). Volcanic counterparts for them have not so far been recognized in northern Finland.

The mafic intrusions yielding U-Pb ages between 2.15 and 2.11 Ga are mainly gabbroic in composition and commonly slightly differentiated but include also albitites and albite-magnetite rocks. These intrusions, often characterized by alternating plagioclase- and amphibole-rich magmatic layers, are common in the study area. The Hf and Nd isotopic data (Patchett et al. 1981) of the Rantavaara intrusion indicate that it stems from a depleted mantle source, but no isotopic source rock studies have been done on the other intrusives of this group. Most probably the intrusives have volcanic counterparts in the area, but the relationships between the various volcanic rocks and sets of dykes are still obscure. In any case, these intrusions penetrate the graded Al-rich mica schists on top of the Sodankylä Group, but so far there is no evidence that they would penetrate the black schists at the base of the Savukoski Group.

The third group of mafic intrusions consists of gabbros and mafic dykes, which yield ages in the 2.07-2.05 Ma range, and penetrate the Matarakoski Formation of the Savukoski Group. Most of the intrusions are almost undifferentiated dykes with ophitic texture but they also include gabbroic rocks, which exhibit magmatic layering and contain both pyroxene- and albite-bearing derivatives. It has been confirmed recently that this magmatic phase also includes large ore-bearing layered intrusions like the 2.06 Ga old Keivitsa mafic-ultramafic intrusion (Mutanen 1997, Mutanen & Huhma 2001, *this volume*), which lies in the northern part of the Sodankylä Schist area. Both Hf and Nd isotopic data (Patchett et al. 1981; Huhma et al. 1995, 1996), indicate that the source material of these intrusions was crustally contaminated when compared to a depleted mantle source. Recently Hanski et al. (2001) have obtained a Sm-Nd mineral age of 2.06±0.04 Ga for the komatiites in Kittilä and demonstrated that also the extensive Sattasvaara-type komatiites belong to this magmatic episode. There is no reason to be suspicious of that age result, especially as field observations indisputably show that several basaltic and peridotitic komatiite dykes also penetrate the Keivitsa intrusion. Mutanen (1997) called them olivine diabases and based on later investigations they are chemically similar to the komatiites of the Sattasvaara Formation and will be described in another paper. The dating of these dykes is yet to be completed.

Younger igneous rocks

With regard to the younger intrusive rocks in the study area, it is worth to note that the U-Pb zircon age of 1891±5 Ma from the granodiorite at Kelujärvi represents the age of the Haaparanta Suite of intrusions. These relatively homogenous rocks have been found previously in northern Finland only in western Lapland, but according to this study, the occurrence of the Haaparanta Suite rocks is areally not so restricted. Actually, it is logical to assume that they occur in eastern Lapland as well, as the extensive granitic rocks of the Central Lapland Granite Complex continue eastwards for more than 200 km up to the Kuusamo schist area. In contrast, the granites of the Tanhua district on the eastern side of the Sodankylä schist area are heterogeneous S-type granites, which is also apparent from their discordant zircon population. The granite at Mustatseljät is garnet-bearing and, like the Hetta-type granites, contains in places supracrustal inclusions. At Neitselvaara they are cut by a pegmatitic granite dyke, which gives an age of 1808±10 Ma. This age is within the range obtained for late granites in Lapland, and together with U-Pb ages on titanites and monazites (e.g. Lauerma 1982) manifest the widespread 1.8 Ga thermal episode in Northern Finland.

Concluding remarks

The conventional U-Pb data reported in this paper have provided a geochronological framework for the evolution in Central Lapland. Several stages of magmatic activity spanning the period 2.43 - 1.80 Ga have been defined, which in early stages are related to continental rifting and later to orogenesis and reworking. However, the results for many samples have remained inconclusive, and more sophisticated methods are needed in order to unravel these problems. The contribution from Archean crust is evident in many Paleoproterozoic geological processes in Central Lapland, but the extent of Archean supracrustal rocks remains controversial. These problems are met especially in the Vuojärvi area (Fig.1) and at Honkavaara c. 30 km west of Sodankylä, where fine-grained felsic rocks interpreted as volcanic in origin have provided Archean age estimates (A194, A195 and Rastas et al. 2001, *this volume*). Several lines of evidence suggest that the bulk of the supracrustal rocks in the Honkavaara area are Paleoproterozoic in origin. These include the moderately enriched $\delta^{13}C$ value at +5.9±0.7 of the Kuoninkivaara dolomites suggesting a probable age under 2.2 Ga for these sedimentary deposits (Karhu 1993). Honkavaara lies in a highly tectonized and altered zone, where the bedrock is cut by a major thrust (the Sirkka Line) and is characterized by several faults and small thrusts associated with tectonic breccias. Accordingly, Lehtonen et al (1988) have interpreted the felsic volcanics as an Archean tectonic wedge enclosed by Paleoproterozoic rocks.

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Appendix I. U-Pb mineral age data from rocks in the Sodankylä area

Sample information[1)	Sample	U	Pb	$^{206}Pb/^{204}Pb$	$^{208}Pb/^{206}Pb$	ISOTOPIC RATIOS[2)						Rho[3)	APPARENT AGES (Ma)		
Analyzed mineral/fraction	weight / mg	ppm		measured	radiogenic	$^{206}Pb/^{238}U$	2SE%	$^{207}Pb/^{235}U$	2SE%	$^{207}Pb/^{206}Pb$	2SE%		$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
A65-Kelujärvi granodiorite															
A. +4.6	18.9	481.4	133.8	1827	0.191	0.2406	0.65	3.792	0.65	0.1143	0.15	0.97	1389	1591	1869
B. 4.2-4.6	15.2	894.8	174.0	283	0.228	0.1421	0.65	2.175	0.80	0.1110	0.48	0.80	856	1173	1815
C. 4.2-4.6	12.5	716.7	171.6	584	0.206	0.1937	0.65	3.016	0.68	0.1129	0.20	0.96	1141	1411	1846
D. 4.2-4.6/HF	13.2	581.5	129.9	1288	0.192	0.1912	0.65	2.980	0.65	0.1131	0.15	0.97	1128	1402	1849
E. 4.2-4.3/M/HF	12.5	745.1	165.8	366	0.219	0.1698	0.65	2.628	0.75	0.1122	0.25	0.95	1011	1308	1835
A163 Neitselvaara granite pegmatite															
A. +4.2	16.6	723.8	220.5	1072	0.176	0.2627	0.65	3.869	0.65	0.1068	0.15	0.97	1503	1607	1746
B. 4.0-4.2 abr	3.5	933.3	295.5	1311	0.145	0.2818	0.65	4.204	0.70	0.1082	0.20	0.96	1600	1674	1769
C. +4.0 abr	2.5	611.0	201.6	2000	0.180	0.2896	0.65	4.337	0.70	0.1086	0.20	0.96	1639	1700	1776
A194-Keski-Loviselkä felsic lava (base)															
A. 4.3-4.5/+200	11.9	325.2	126.3	5056	0.147	0.3378	1.01	8.539	1.10	0.1834	0.33	0.95	1875	2290	2683
B. 4.3-4.5/HF/uncrushed	20.0	210.3	119.6	3634	0.156	0.4873	0.65	12.889	0.66	0.1918	0.15	0.97	2559	2671	2758
C. 4.2-4.3/+200	18.6	428.9	170.7	2257	0.158	0.3419	0.68	8.558	0.72	0.1816	0.20	0.96	1895	2292	2667
D. 4.3-4.5/-200/abr 3 h	7.0	235.2	128.6	4740	0.155	0.4699	0.65	12.362	0.65	0.1908	0.15	0.97	2483	2632	2749
A195-Keski-Loviselkä felsic lava (top)															
A. +4.5/HF/uncrushed	20.5	148.2	81.7	5078	0.141	0.4818	0.65	12.094	0.65	0.1821	0.15	0.97	2534	2611	2672
B. +4.5/abr 3 h	10.5	131.8	77.0	4422	0.156	0.5026	0.65	13.046	0.65	0.1883	0.15	0.97	2624	2683	2727
C. Titanite 3.4-3.5	23.9	100.4	31.9	3720	0.047	0.3171	0.92	4.879	0.97	0.1116	0.30	0.95	1775	1798	1825
D. 4.3-4.5/rounded	7.2	252.0	141.2	3649	0.177	0.4757	0.65	11.983	0.65	0.1827	0.17	0.97	2508	2603	2677
E. euhedral	1.9	376.1	173.5	6140	0.112	0.4177	0.65	9.668	0.65	0.1679	0.15	0.97	2250	2403	2536
A281-Harjunoja diabase															
A. +4.3/abr 13 h	14.2	352.5	194.4	1576	0.588	0.3654	0.65	6.923	0.65	0.1374	0.15	0.97	2007	2101	2194
B. 4.2-4.3/clear/abr 7 h	13.0	515.7	285.0	1979	0.639	0.3567	0.80	6.764	0.80	0.1376	0.15	0.98	1966	2081	2196
C. 4.3-4.5/clear/+150/abr 9 h	16.2	352.9	195.2	1892	0.589	0.3671	1.20	6.986	1.20	0.1380	0.15	0.99	2015	2109	2202
D. +4.3/clear/abr 3 h	2.5	284.6	151.9	2527	0.545	0.3656	0.65	6.937	0.75	0.1377	0.36	0.88	2008	2103	2198
E. 4.0-4.2/+100/clear/abr 3 h	8.3	701.0	393.3	1479	0.669	0.3549	0.65	6.695	0.65	0.1368	0.15	0.97	1958	2071	2187
F. 4.0-4.2/clear/abr 3 h	8.5	699.7	413.8	2193	0.653	0.3789	1.10	7.216	1.10	0.1381	0.22	0.98	2071	2138	2203
G. 4.3-4.5/+200/clear/abr 3 h	16.1	337.4	192.5	3112	0.590	0.3800	0.65	7.269	0.65	0.1387	0.15	0.97	2076	2145	2211
H. 4.2-4.3/clear/+150/abr 3 h	13.1	511.1	298.8	2898	0.636	0.3790	1.10	7.236	1.10	0.1385	0.15	0.99	2071	2140	2208
I. 3.6-4.0/+150/clear/abr 3 h	5.9	1201.7	659.4	3379	0.729	0.3389	0.65	6.353	0.65	0.1360	0.15	0.97	1881	2025	2176

Appendix I continued

Sample information[1)]	Sample	U	Pb	$^{206}Pb/^{204}Pb$	$^{208}Pb/^{206}Pb$	ISOTOPIC RATIOS[2)]						Rho[3)]	APPARENT AGES (Ma)		
Analyzed mineral/fraction	weight / mg	ppm		measured	radiogenic	$^{206}Pb/^{238}U$	2SE%	$^{207}Pb/^{235}U$	2SE%	$^{207}Pb/^{206}Pb$	2SE%		$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
A281J. 3.6-4.0/+150/clear/abr 5 h	6.8	1125.2	519.0	2306	0.679	0.2922	0.65	5.391	0.65	0.1338	0.15	0.97	1652	1883	2148
K. 4.3-4.5/-200/clear/abr 4 h	12.8	313.0	176.3	2161	0.589	0.3743	0.65	7.141	0.65	0.1384	0.15	0.97	2049	2129	2207
L. +4.3/abr 4 h (separated from a portion rich in epidote)	3.4	339.1	192.5	1466	0.629	0.3674	0.65	6.954	0.68	0.1373	0.18	0.96	2017	2105	2193
A283-Kivivuotsonselkä mafic lava															
A. 4.2-4.6	20.0	251.5	114.9	5496	0.125	0.4082	0.65	9.609	0.65	0.1707	0.15	0.97	2206	2398	2565
B. 4.2-4.6/abr 2 h	4.3	204.5	104.2	23338	0.123	0.4565	0.65	10.952	0.65	0.1740	0.15	0.97	2424	2519	2596
C. 4.0-4.2	17.9	481.6	178.1	7257	0.137	0.3288	0.65	7.477	0.65	0.1649	0.15	0.97	1832	2170	2506
D. +4.6	2.4			3792						0.1715	0.15				2572
E. -4.0/abr 2 h	1.2	482.4	181.0	1629	0.147	0.3281	0.65	7.479	0.65	0.1653	0.15	0.97	1829	2170	2511
F. 4.2-4,6/HF/abr 3 h	3.9	141.2	72.6	10505	0.133	0.4547	0.65	11.257	0.65	0.1796	0.15	0.97	2416	2544	2649
G. 4.2-4.6/HF	21.0	177.3	88.6	51684	0.130	0.4438	0.65	10.910	0.65	0.1783	0.15	0.97	2367	2515	2637
A401-Mairivaara albite diabase															
A. +4.3/+150/abr 2 h	17.8	454.2	182.4	11613	0.205	0.3496	0.71	6.018	0.71	0.1248	0.15	0.98	1932	1978	2026
B. 4.2-4.3/+200/abr 2 h	13.0	552.0	224.6	11370	0.224	0.3491	0.68	6.006	0.68	0.1248	0.15	0.98	1930	1976	2025
C. 4.0-4.2/+150/abr 2 h	4.3	630.1	253.0	14626	0.238	0.3418	0.65	5.847	0.65	0.1241	0.15	0.97	1895	1953	2016
D. 4.0-4.2/+150/grey/abr 2 h	1.5	577.3	233.5	3010	0.241	0.3397	0.65	5.859	0.80	0.1251	0.25	0.96	1885	1955	2030
E. 3.8-4.0/+150/red/abr 1 h	4.3	940.8	367.7	9373	0.304	0.3166	0.65	5.387	0.65	0.1234	0.15	0.97	1773	1882	2006
F. +4.3/-150/abr 2 h	15.0	439.5	175.7	9135	0.199	0.3491	0.67	6.008	0.68	0.1248	0.15	0.98	1930	1976	2026
G. 4.2-4.3/-200/abr 3 h	4.1	631.0	245.2	4395	0.203	0.3369	0.65	5.778	0.65	0.1244	0.15	0.97	1871	1943	2020
H. 3.8-4.0/+150/grey/abr 1 h	4.1	1116.5	425.9	5120	0.359	0.2966	0.65	5.009	0.65	0.1225	0.16	0.97	1674	1820	1992
I. 3.6-3.8/red pigment/abr 3 h	4.8	1400.1	434.9	3656	0.350	0.2426	0.65	3.958	0.65	0.1184	0.15	0.97	1399	1625	1931
J. +4.3/red pigment/abr 2 h	4.2	449.2	179.2	7141	0.196	0.3491	0.65	6.001	0.65	0.1247	0.15	0.97	1930	1975	2024
K. 4.0-4.2/red pigment/abr 2 h	6.1	652.7	255.0	9752	0.224	0.3354	0.65	5.724	0.65	0.1238	0.15	0.97	1864	1934	2011
L. Opaque reddish brown	5.3	881.1	280.7	5781	0.183	0.2824	0.65	4.574	0.65	0.1175	0.15	0.97	1603	1744	1918
A418-Koskenkangas gabbro															
A. 4.3-4.6	21.6	263.5	116.7	8081	0.203	0.3829	0.65	7.005	0.65	0.1327	0.15	0.97	2089	2112	2134
B. 4.2-4.3/+200	20.8	582.3	268.5	5408	0.270	0.3787	0.65	6.890	0.65	0.1319	0.15	0.97	2070	2097	2124
A521 Pyhäjokikuru albite rock															
A. +4.5 rounded red pigm a2h		121.0		1430		0.5221	0.65	14.519	0.65	0.2017	0.18	0.96	2708	2784	2839
B. 4.3-4.5 rounded red p. a2h		315.0		3308		0.3740	0.65	9.758	0.65	0.1893	0.15	0.97	2047	2412	2735

Appendix I continued

Sample information[1] Analyzed mineral/fraction	Sample weight / mg	U ppm	Pb ppm	$^{206}Pb/^{204}Pb$ measured	$^{208}Pb/^{206}Pb$ radiogenic	ISOTOPIC RATIOS[2] $^{206}Pb/^{238}U$	2SE%	$^{207}Pb/^{235}U$	2SE%	$^{207}Pb/^{206}Pb$	2SE%	Rho[3]	APPARENT AGES (Ma) $^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
A570 Mustatseljät granite															
A. 3.6-3.8 a3h	4.0	2547.0	323.0	548	0.095	0.1111	0.65	1.692	0.67	0.1105	0.17	0.97	678	1005	1807
B. 4.0-4.2/-200 a3h	5.3	807.0	234.0	639	0.166	0.2412	0.76	4.255	0.78	0.1280	0.17	0.98	1392	1684	2070
C. 3.8-4.0/+200 a3h	7.0	1349.0	296.0	616	0.113	0.1893	0.65	3.310	0.65	0.1268	0.15	0.97	1117	1483	2054
D. +4.0/+200 a3h	3.5	835.0	262.0	519	0.130	0.2600	0.65	4.946	0.65	0.1380	0.15	0.97	1489	1810	2201
F. +4.2 a3h	2.0	760.0	225.0	1060	0.147	0.2564	0.65	4.663	0.68	0.1319	0.18	0.96	1471	1760	2123
G. 3.8-4.0 a3h	2.9	1380.0	279.0	874	0.119	0.1786	0.65	2.993	0.68	0.1215	0.18	0.96	1059	1405	1979
H. 3.6-3.8/+200 a3h	2.6	2588.0	294.0	821	0.160	0.0978	0.65	1.413	0.70	0.1047	0.26	0.93	601	894	1709
bI. +4.3 a2h	2.9	468.0	203.0	1225	0.195	0.3654	0.65	6.959	0.65	0.1381	0.15	0.97	2007	2106	2204
bJ. 4.2-4.3/+200 a3h	2.0	742.0	231.0	778	0.103	0.2729	0.65	5.296	0.70	0.1408	0.28	0.92	1555	1868	2236
bK. 4.2-4.3 a3h	3.3	1071.0	243.0	515	0.150	0.1877	0.65	3.202	0.73	0.1237	0.33	0.89	1108	1457	2011
bL. 4.0-4.2 a3h	4.1	1442.0	292.0	533	0.108	0.1734	0.65	2.980	0.68	0.1246	0.18	0.96	1030	1402	2023
E1. Monazite				1274						0.1083	0.15				1771
A741-Mairivaara albite diabase															
A. 3.6-3.8/+200/abr 5 h	5.9	924.3	376.1	1771	0.276	0.3294	0.74	5.551	0.74	0.1223	0.15	0.98	1835	1908	1989
B. 4.0-4.2	3.6	1041.2	412.3	4243	0.253	0.3279	0.66	5.546	0.67	0.1227	0.25	0.93	1828	1907	1995
C. -4.0	15.4	935.4	371.7	2743	0.256	0.3303	0.68	5.623	0.70	0.1235	0.20	0.96	1839	1919	2007
D. -4.0/abr 3 h	7.7	973.5	391.4	5930	0.255	0.3363	0.71	5.702	0.71	0.1230	0.15	0.98	1868	1931	1999
E. +4.0/abr 3 h	4.0	945.0	376.3	2230	0.249	0.3305	0.65	5.579	0.65	0.1224	0.15	0.97	1840	1912	1992
F. -4.0/-200/abr 5 h	6.2	988.8	404.8	2050	0.266	0.3345	0.93	5.679	0.93	0.1231	0.15	0.99	1860	1928	2002
G. -4.0/+200/abr 5 h	7.8	905.8	377.0	1906	0.271	0.3385	0.79	5.725	0.80	0.1227	0.15	0.98	1879	1935	1995
H. -4.0/+200/turbid/abr 12 h	6.0	1050.8	390.3	4066	0.260	0.3092	0.81	5.141	0.83	0.1206	0.20	0.97	1736	1842	1965
I. -4.0/+200/glassy/abr 12 h	3.5	1291.0	520.9	3441	0.330	0.3186	1.14	5.385	1.14	0.1226	0.15	0.99	1782	1882	1994
J. 3.6-3.8/+200	13.3	1086.7	403.0	1770	0.298	0.2962	0.66	4.886	0.71	0.1196	0.45	0.79	1672	1799	1950
K. 3.6-3.8/grey/abr 3 h	1.1	1018.7	334.0	1890	0.254	0.2711	0.65	4.526	0.65	0.1211	0.16	0.97	1546	1735	1972
L. 3.6-3.8/red pigment/abr 3 h	2.8	1015.5	381.3	3139	0.286	0.3056	0.65	5.123	0.65	0.1216	0.15	0.97	1719	1839	1979
A742-Mairivaara albite diabase															
A. 3.8-4.0	7.3	972.3	342.9	2225	0.216	0.2998	0.70	5.067	0.70	0.1226	0.15	0.98	1690	1830	1994
B. +4.3/abr 1 h (zircon + badd)	1.6	500.0	195.4	4443	0.163	0.3508	0.65	6.024	0.70	0.1245	0.20	0.96	1938	1979	2022
C. 4.2-4.3/abr 1 h	4.4	729.5	276.8	4867	0.172	0.3372	0.65	5.740	0.65	0.1235	0.15	0.97	1872	1937	2007
D. 4.0-4.2/-200/abr 3 h	6.4	844.0	314.1	3551	0.180	0.3276	0.65	5.547	0.65	0.1228	0.15	0.97	1826	1907	1997
E. 4.2-4.3/abr 3 h	3.4	761.4	306.6	2602	0.175	0.3535	0.65	6.030	0.65	0.1237	0.15	0.97	1951	1980	2010
F. 3.8-4.0/+200/abr 3 h	3.3	1098.6	414.0	2302	0.214	0.3209	0.65	5.416	0.70	0.1224	0.18	0.97	1794	1887	1992
G. +4.0/abr 3 h	1.9	855.0	311.9	2002	0.186	0.3167	0.65	5.371	0.75	0.1230	0.22	0.96	1773	1880	2000
H. 4.0-4.2/-200/abr 3 h	4.2	863.0	318.9	1998	0.189	0.3195	0.65	5.412	0.65	0.1228	0.15	0.97	1787	1886	1998
I. 3.8-4.0/-200	4.1	996.0	369.0	684	0.218	0.2994	0.65	5.031	0.75	0.1219	0.22	0.96	1688	1824	1984
J. 3.8-4.0/-200/abr 2 h	2.2	1036.7	392.6	2000	0.229	0.3183	0.65	5.364	0.65	0.1222	0.15	0.97	1781	1879	1988
K. 4.0-4.2/-200/abr 3 h	4.9	867.4	327.7	3531	0.190	0.3299	0.65	5.589	0.65	0.1229	0.19	0.96	1837	1914	1999

Appendix I continued

Sample information[1)]	Sample	U	Pb	$^{206}Pb/^{204}Pb$	$^{208}Pb/^{206}Pb$	ISOTOPIC RATIOS[2)]						Rho[3)]	APPARENT AGES (Ma)		
Analyzed mineral/fraction	weight / mg	ppm		measured	radiogenic	$^{206}Pb/^{238}U$	2SE%	$^{207}Pb/^{235}U$	2SE%	$^{207}Pb/^{206}Pb$	2SE%		$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
A743-Mairivaara albite diabase															
A. 3.8-4.0	5.2	888.6	322.8	1828	0.212	0.3088	0.70	5.243	0.70	0.1232	0.15	0.98	1734	1859	2002
B. 4.0-4.2/abr 2 h	5.4	860.7	341.5	3967	0.208	0.3423	0.70	5.811	0.70	0.1231	0.15	0.98	1897	1948	2002
C. 3.8-4.0/abr 3 h	5.5	1098.5	438.7	2400	0.247	0.3321	0.75	5.630	0.75	0.1229	0.15	0.98	1848	1920	1999
A815, A815b Luosto diabase															
A. +4.2	20.7	531.0	177.0	1003	0.544	0.2234	0.65	3.582	0.65	0.1163	0.15	0.97	1299	1545	1899
B. 3.8-4.0/+200	12.5	729.0	171.0	1030	0.534	0.1590	0.65	2.537	0.68	0.1157	0.18	0.96	951	1282	1891
C. 4.0-4.2	12.1	598.0	185.0	1312	0.528	0.2115	0.65	3.417	0.65	0.1172	0.15	0.97	1236	1508	1913
D. +4.2 abr3h	4.7	539.0	189.0	2247	0.548	0.2397	0.65	3.859	0.65	0.1168	0.15	0.97	1385	1605	1907
E. +4.2 abr5h	7.4	522.0	187.0	529	0.555	0.2323	0.65	3.726	0.68	0.1163	0.20	0.96	1346	1577	1900
F. 4.0-4.2/+150 m abr5h	10.2	653.0	156.0	934	0.539	0.1602	0.65	2.577	0.68	0.1166	0.18	0.96	958	1294	1905
G. +4.2 abr5h	4.1	541.0	201.0	553	0.552	0.2411	0.65	3.886	0.70	0.1169	0.22	0.95	1392	1610	1909
bA. 3.8-4.0/+200 clear abr1h	3.0	2316.0	1029.0	26387	0.345	0.3305	1.00	5.620	1.00	0.1233	0.15	0.99	1840	1919	2005
bB. 3.8-4.0/+200 turbid abr1h	4.0	1426.0	505.0	5059	0.404	0.2688	0.65	4.264	0.65	0.1151	0.15	0.97	1534	1686	1881
bC. 4.2-4.3/abr1h	2.0	505.0	187.0	567	0.237	0.2935	0.65	4.625	0.73	0.1143	0.28	0.92	1659	1753	1868
bD. +4.3 badd (+zircon)	3.6	858.0	295.0	2808	0.096	0.3221	0.65	5.467	0.65	0.1231	0.15	0.97	1800	1895	2001
bE. +4.3 a zircon+badd	6.2	497.0	182.0	1945	0.187	0.3185	0.65	5.122	0.65	0.1166	0.15	0.97	1782	1839	1905
A816-Kylälampi albitite															
A. +4.6	27.9	227.1	81.8	849	0.124	0.3160	0.65	5.477	0.68	0.1257	0.20	0.96	1769	1897	2039
B. 4.2-4.6	31.0	444.6	156.9	1025	0.142	0.3080	0.65	5.332	0.65	0.1255	0.15	0.97	1730	1873	2036
D. 4.0-4.2	17.1	609.8	195.7	2282	0.155	0.2850	0.65	4.940	0.65	0.1257	0.15	0.97	1616	1809	2038
E. 3.8-4.0	7.4	408.0	131.5	2400	0.143	0.2905	0.65	5.005	0.66	0.1249	0.17	0.97	1644	1820	2028
F. +4.6/HNO_3/crushed	20.6	218.0	83.0	664	0.124	0.3277	0.65	5.697	1.00	0.1261	0.74	0.67	1826	1930	2044
G. +4.6/HF/uncrushed	20.7	196.3	66.1	20757	0.121	0.3131	0.74	5.471	0.75	0.1267	0.15	0.98	1756	1895	2053
H. +4.6/+150/abr 5 h	16.5	218.4	82.9	1150	0.124	0.3376	0.66	5.890	0.66	0.1265	0.15	0.97	1874	1959	2050
I. +4.6/+150/abr 10 h	22.3	215.4	80.4	2986	0.123	0.3411	0.65	5.962	0.65	0.1268	0.15	0.97	1891	1970	2053
J. +4.6/abr 5 h	20.4	214.1	81.0	781	0.122	0.3295	0.65	5.728	0.65	0.1261	0.15	0.97	1835	1935	2044
K. +4.6/abr 15 h	7.3	190.2	72.0	3935	0.130	0.3482	0.65	6.093	0.65	0.1269	0.15	0.97	1925	1989	2056
L. +4.6/+150/abr 30 h	20.5	216.0	77.7	1569	0.137	0.3257	0.65	5.663	0.65	0.1261	0.15	0.97	1817	1925	2044
M. +4.6/abr 42 h	20.8	209.7	77.0	2234	0.131	0.3357	0.65	5.837	0.65	0.1261	0.15	0.97	1865	1951	2044
N. +4.6/-200/abr 14 h	20.0	218.1	81.6	758	0.167	0.3250	0.65	5.655	0.70	0.1262	0.24	0.94	1814	1924	2046
O. 4.0-4.2	11.6	702.4	233.6	835	0.198	0.2830	0.65	4.907	0.68	0.1258	0.20	0.96	1606	1803	2040
P. +4.6/HF/uncrushed	20.8	153.1	56.8	8897	0.125	0.3436	0.65	6.057	0.65	0.1279	0.15	0.97	1903	1984	2069

Appendix I continued

Sample information[1)]	Sample	U	Pb	$^{206}Pb/^{204}Pb$	$^{208}Pb/^{206}Pb$	ISOTOPIC RATIOS[2)]						Rho[3)]	APPARENT AGES (Ma)		
Analyzed mineral/fraction	weight / mg	ppm		measured	radiogenic	$^{206}Pb/^{238}U$	2SE%	$^{207}Pb/^{235}U$	2SE%	$^{207}Pb/^{206}Pb$	2SE%		$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
A817-Kylälampi albitite															
A. +4.6	31.5	169.0	65.9	1967	0.121	0.3537	0.65	6.372	0.65	0.1307	0.15	0.97	1951	2028	2107
B. 4.2-4.6	25.6	473.1	172.3	1545	0.139	0.3229	0.65	5.761	0.65	0.1294	0.16	0.97	1803	1940	2090
C. Titanite	28.5	45.1	19.8	1348	0.454	0.3176	0.65	4.822	0.90	0.1101	0.52	0.82	1777	1788	1801
D. +4.6/HNO_3/crushed	20.3	149.8	60.3	1482	0.126	0.3598	0.69	6.475	0.71	0.1305	0.27	0.93	1981	2042	2105
E. +4.6/HF/uncrushed	22.2	140.4	56.1	28441	0.125	0.3700	0.72	6.666	0.72	0.1307	0.15	0.98	2029	2068	2107
F. +4.6/abr 10 h	19.9	143.4	57.3	9023	0.120	0.3697	0.65	6.667	0.65	0.1308	0.15	0.97	2028	2068	2108
G. +4.6/abr 5 h	20.1	150.9	62.0	1737	0.119	0.3714	0.65	6.692	0.65	0.1307	0.16	0.97	2035	2071	2107
A818-Ahvenselkä diabase															
A. +4.6	21.0	363.7	189.0	1342	0.620	0.3359	0.65	5.850	0.75	0.1263	0.30	0.92	1866	1953	2047
B. 4.2-4.6	16.0	467.8	241.0	1742	0.632	0.3333	0.65	5.759	0.65	0.1253	0.15	0.97	1854	1940	2033
C. 4.0-4.2	15.8	552.7	270.5	1698	0.654	0.3128	0.65	5.327	0.65	0.1235	0.17	0.97	1754	1873	2007
D. Titanite	30.9	14.6	16.9	573	2.780	0.3363	2.10	5.206	2.90	0.1123	1.50	0.87	1869	1853	1836
E. +4.6/abr 2 h	3.2	429.3	236.1	1066	0.637	0.3500	0.86	6.092	0.90	0.1262	0.18	0.98	1934	1989	2046
F. 4.2-4.6/abr 2 h	2.9	553.9	295.7	1491	0.636	0.3433	0.65	5.950	0.68	0.1257	0.17	0.97	1902	1968	2039
G. 4.2-4.6/M/abr 3 h	1.7	378.0	218.5	1169	0.800	0.3392	0.94	5.877	0.95	0.1256	0.20	0.98	1882	1957	2038
H. 4.0-4.2/abr 3 h	15.2	628.6	306.5	1473	0.647	0.3114	0.68	5.312	0.68	0.1237	0.15	0.98	1747	1870	2010
I. +4.2/M/abr 6 h	10.2	506.6	280.4	886	0.655	0.3457	0.82	6.012	0.84	0.1262	0.15	0.98	1914	1977	2045
A820-Rovasvaara gabbro pegmatoid															
A. +4.6	27.8	342.2	123.5	4096	0.108	0.3364	0.65	5.817	0.65	0.1254	0.15	0.97	1869	1948	2034
B. +4.2	27.1	492.5	177.0	3925	0.128	0.3293	0.65	5.679	0.65	0.1251	0.15	0.97	1835	1928	2030
C. 4.0-4.2	16.2	703.5	246.2	3360	0.146	0.3156	0.65	5.416	0.65	0.1245	0.15	0.97	1768	1887	2021
D. +4.6/grey/abr 5 h	7.7	343.6	129.9	7358	0.110	0.3536	0.70	6.147	0.70	0.1261	0.15	0.98	1951	1996	2044
E. +4.6/red pigment/abr 5 h	9.3	361.5	139.2	9349	0.105	0.3620	0.73	6.281	0.73	0.1258	0.15	0.98	1991	2015	2040
A841-Pittiövaara albite diabase															
A. 3.8-4.0/+200	18.2	1036.7	448.1	5251	0.398	0.3260	0.65	5.833	0.65	0.1298	0.15	0.97	1818	1951	2095
B. 4.0-4.2/+200	12.0	819.9	343.9	1891	0.320	0.3278	0.65	5.860	0.80	0.1297	0.30	0.94	1827	1955	2093
C. 4.2-4.6	5.9	600.9	246.6	4097	0.256	0.3407	0.65	6.174	0.70	0.1314	0.22	0.95	1890	2000	2117
D. 3.6-3.8	14.7	890.2	357.8	4437	0.367	0.3095	0.65	5.499	0.65	0.1289	0.15	0.97	1738	1900	2083
E. 3.6-4.0	6.7	951.8	355.8	4342	0.364	0.2886	0.68	5.099	0.68	0.1282	0.15	0.98	1634	1835	2072
F. 4.2-4.6	2.3	635.2	257.7	1865	0.255	0.3281	0.65	5.838	0.94	0.1291	0.55	0.82	1828	1952	2085

Appendix I continued

Sample information[1)]	Sample	U	Pb	$^{206}Pb/^{204}Pb$	$^{208}Pb/^{206}Pb$	ISOTOPIC RATIOS[2)]						Rho[3)]	APPARENT AGES (Ma)		
Analyzed mineral/fraction	weight / mg	ppm		measured	radiogenic	$^{206}Pb/^{238}U$	2SE%	$^{207}Pb/^{235}U$	2SE%	$^{207}Pb/^{206}Pb$	2SE%		$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
A861a, A861b-Törmänen albite diabase															
aA. 3.8-4.0/abr 3 h	1.6	833.4	272.0	692	0.603	0.2095	0.65	3.239	0.70	0.1121	0.22	0.95	1226	1466	1834
aB. 3.8-4.0	12.1	791.1	250.8	811	0.630	0.2017	0.85	3.138	0.85	0.1129	0.19	0.98	1184	1442	1846
bA. +4.3/clear/abr 1 h	1.3	373.3	161.3	8335	0.267	0.3601	0.65	6.267	0.70	0.1262	0.20	0.96	1982	2013	2046
bB. +4.3/-200/clear/abr 1 h	3.6	392.3	171.6	8880	0.278	0.3608	0.65	6.288	0.65	0.1264	0.15	0.97	1986	2016	2048
bC. 4.2-4.3/clear/abr 1 h	4.4	609.6	264.7	11213	0.265	0.3618	0.65	6.270	0.65	0.1257	0.15	0.97	1990	2014	2038
bD. 4.0-4.2/abr 3 h	3.2	903.9	366.9	1390	0.260	0.3296	0.65	5.648	0.65	0.1243	0.15	0.97	1836	1923	2018
bE. 3.8-4.0/abr 2 h/pigment	4.4	1117.5	430.4	4343	0.289	0.3136	0.65	5.339	0.65	0.1235	0.15	0.97	1758	1875	2007
bF. 3.8-4.0/abr 3 h/turbid	3.0	1083.8	386.1	1697	0.271	0.2890	0.66	4.901	0.67	0.1230	0.15	0.97	1636	1802	2000
A862-Törmänen albite diabase															
A. 4.0-4.2	15.4	718.6	254.0	1860	0.535	0.2439	0.96	3.792	0.96	0.1128	0.15	0.99	1406	1590	1844
B. 3.8-4.0	10.4	843.3	250.5	1729	0.510	0.2082	0.72	3.158	0.90	0.1100	0.50	0.83	1219	1446	1798
C. 3.8-4.0/abr 3 h	1.1	876.8	280.8	1559	0.513	0.2244	0.65	3.382	0.70	0.1093	0.22	0.95	1304	1500	1788
D. +4.2/abr 1 h	2.9	614.3	253.2	2778	0.504	0.2908	0.65	4.813	0.65	0.1201	0.15	0.97	1645	1787	1957
E. +4.0/+100/abr 2 h	5.2	610.4	257.2	2026	0.657	0.2707	0.70	4.398	0.72	0.1178	0.20	0.96	1543	1711	1924
F. +4.0/-100/abr 8 h	9.0	728.7	250.7	1867	0.550	0.2352	0.71	3.596	0.71	0.1109	0.15	0.98	1361	1548	1813
G. 4.0-4.2/abr 12 h	4.7	737.5	260.9	2096	0.540	0.2442	0.73	3.733	0.73	0.1109	0.15	0.98	1408	1578	1813
H. 4.0-4.2/abr 5 h	2.6	713.0	283.1	860	0.558	0.2640	0.73	4.051	0.75	0.1113	0.22	0.96	1510	1644	1820
I. 3.8-4.0/+150/abr 4 h	6.1	804.4	259.0	765	0.528	0.2167	0.69	3.245	0.70	0.1086	0.18	0.97	1264	1467	1776
A863-Törmänen albite diabase															
A. 4.0-4.2	12.9	702.5	282.2	2603	0.529	0.2787	0.66	4.642	0.67	0.1208	0.20	0.95	1584	1756	1968
B. 3.8-4.0	12.7	790.8	262.9	1412	0.586	0.2210	1.00	3.497	1.04	0.1148	0.66	0.79	1287	1526	1876
C. 3.8-4.0/-200/abr 3 h	5.1	939.5	306.1	647	0.445	0.2275	0.85	3.576	0.86	0.1140	0.22	0.97	1321	1543	1864
D. +4.0/abr 2 h	1.7	559.5	266.4	639	0.748	0.2804	0.65	4.643	0.73	0.1201	0.24	0.95	1593	1756	1957
E. +4.0/M/abr 1 h	2.3	786.2	286.2	1319	0.403	0.2693	0.76	4.430	0.77	0.1193	0.15	0.98	1537	1717	1946
A900 Rantavaara gabbro															
A +4.2	20.08	260	113	6718	0.240	0.3663	0.65	6.625	0.65	0.1312	0.15	0.97	2012	2062	2113
B +4.6	28.76	180	78.6	2189	0.210	0.3696	0.65	6.728	0.65	0.1320	0.15	0.97	2027	2076	2125
C 4.2-4.6/100-200	25.19	401	179	1558	0.250	0.3623	0.65	6.553	0.68	0.1312	0.18	0.96	1993	2053	2114
D 4.0-4.2/+100	24.00	649	297	3458	0.350	0.3544	0.65	6.399	0.65	0.1309	0.15	0.97	1955	2032	2110
E +4.6/+200clear abr3h	0.53	211	102	3890	0.310	0.3847	0.50	7.063	0.50	0.1331	0.15	0.96	2098	2119	2140
F +4.6/-200 clear abr3h	0.22	187	86.6	2918	0.240	0.3854	0.50	7.059	0.50	0.1328	0.15	0.96	2102	2119	2136
G +4.6/+200 euh abr3h	0.29	216	97	1893	0.230	0.3742	0.50	6.835	0.50	0.1325	0.15	0.96	2049	2090	2131

Appendix I continued

Sample information[1)]	Sample	U	Pb	$^{206}Pb/^{204}Pb$	$^{208}Pb/^{206}Pb$	ISOTOPIC RATIOS[2)]						Rho[3)]	APPARENT AGES (Ma)		
Analyzed mineral/fraction	weight / mg	ppm		measured	radiogenic	$^{206}Pb/^{238}U$	2SE%	$^{207}Pb/^{235}U$	2SE%	$^{207}Pb/^{206}Pb$	2SE%		$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
A962-Povivaara gabbro pegmatoid															
A. +4.6	25.4	299.3	121.5	3592	0.133	0.3682	0.65	6.709	0.65	0.1322	0.15	0.97	2020	2073	2127
B. 4.2-4.6	25.9	465.8	180.5	3405	0.150	0.3467	1.00	6.259	1.00	0.1309	0.15	0.99	1919	2012	2110
C. 4.0-4.2	13.2	888.4	332.4	2366	0.200	0.3205	0.65	5.721	0.65	0.1295	0.15	0.97	1792	1934	2090
A992-Purkkivaara felsic volcanic rock															
A. -3.6/-200/abr 3 h	1.2	1077.7	237.6	883	0.300	0.1750	0.65	3.016	0.70	0.1250	0.22	0.95	1039	1411	2028
B. 3.6-3.8	5.5	1923.9	517.7	1882	0.253	0.2226	0.82	4.113	0.83	0.1340	0.18	0.97	1295	1656	2151
C. -3.6/+200/abr 3 h	2.6	2101.0	538.5	1206	0.294	0.2046	0.65	3.724	0.70	0.1320	0.22	0.95	1200	1576	2124
D. 3.6-4.2/abr 3 h	1.2	1572.0	715.5	6539	0.185	0.3940	0.65	8.317	0.65	0.1531	0.15	0.97	2141	2266	2381
A1021-Haikaraselkä fuchsite quartzite															
A. 4.2-4.3/-200	15.4	568.0	301.5	6189	0.116	0.4689	0.61	12.313	0.65	0.1905	0.23	0.94	2478	2628	2746
B. 4.0-4.2/-200	15.5	765.0	381.6	6363	0.111	0.4439	0.63	11.372	0.64	0.1858	0.15	0.97	2368	2554	2705
C. 4.2-4.3/+200	7.6	559.2	305.4	14400	0.118	0.4846	0.64	12.762	0.76	0.1910	0.41	0.84	2547	2662	2750
D. 4.0-4.2/+200	8.8	727.8	377.4	7837	0.110	0.4626	0.63	11.819	0.63	0.1853	0.15	0.97	2451	2590	2701
E. 4.2-4.3/abr 3 h	8.3	617.3	337.7	17284	0.113	0.4862	0.65	12.839	0.66	0.1915	0.15	0.97	2554	2667	2755
F. 4.0-4.2/abr 3 h	6.1	735.2	379.5	13122	0.110	0.4615	0.63	11.824	0.63	0.1858	0.15	0.97	2446	2590	2705
A1432-Sakiamaa felsic volcanic rock															
A. +4.3/-200/pale turbid/abr 0.5 h	0.3	602.1	232.3	1693	0.200	0.3239	0.50	6.313	0.50	0.1414	0.15	0.96	1809	2020	2244
B. 4.0-4.2/+200	5.0	1147.6	544.0	3815	0.250	0.3876	0.50	8.215	0.50	0.1537	0.15	0.96	2111	2254	2388
C. 4.0-4.2/+200/abr 2 h	0.4	1215.9	601.3	4848	0.250	0.4071	0.50	8.710	0.50	0.1552	0.15	0.96	2202	2308	2404
D. 3.6-4.6/dark/stubby/abr 10 h	0.8	2021.6	1030.3	6599	0.260	0.4164	0.50	8.923	0.50	0.1554	0.15	0.96	2244	2330	2406
E. 3.6-4.0/pale turbid/abr 6 h	0.4	2590.0	994.4	4165	0.330	0.2995	0.50	5.970	0.50	0.1446	0.15	0.96	1689	1972	2283
A1434-Pyytövaara felsic clast in volcanic conglomerate															
A. +4.5/abr 4 h	8.2	146.5	75.3	19894	0.184	0.4424	0.50	10.129	0.50	0.1661	0.15	0.96	2361	2446	2518
B. +4.5	6.9	155.6	77.2	16045	0.177	0.4289	0.50	9.872	0.50	0.1670	0.15	0.96	2300	2422	2527
4.3-4.5	8.4	382.2	171.6	18589	0.145	0.4002	0.50	8.676	0.50	0.1572	0.15	0.96	2169	2304	2426
4.2-4.3	8.6	539.5	279.9	23877	0.130	0.3949	0.50	8.581	0.50	0.1576	0.15	0.96	2145	2294	2430
A1498 Sakiamaa rhyolite															
A 4.0-4.3 abr5h small turbid	0.42	881	330	2240	0.230	0.3099	0.50	6.169	0.60	0.1444	0.30	0.87	1740	2000	2280
B 4.0-4.3 small turbid	0.64			2222	0.230	0.2723	0.50	5.314	0.50	0.1416	0.15	0.96	1552	1871	2246

Appendix I continued

Sample information[1]	Sample	U	Pb	$^{206}Pb/^{204}Pb$	$^{208}Pb/^{206}Pb$	ISOTOPIC RATIOS[2]						Rho[3]	APPARENT AGES (Ma)		
Analyzed mineral/fraction	weight / mg	ppm		measured	radiogenic	$^{206}Pb/^{238}U$	2SE%	$^{207}Pb/^{235}U$	2SE%	$^{207}Pb/^{206}Pb$	2SE%		$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
A1521 Pyhälampi granite pebble in conglomerate															
A +4.3 abr3h sharp prisms	0.24	404	142	2011	0.320	0.27590	0.5	4.9931	0.5	0.13126	0.15	0.96	1571	1818	2115
B +4.2 abr3h large prisms	0.19	385	130	1169	0.370	0.25228	0.5	4.4700	0.5	0.12851	0.15	0.96	1450	1725	2078
A1524 Akanvaara rhyolite															
A +4.3 abr6h	0.45	450	209	13255	0.140	0.41692	0.5	8.7351	0.5	0.15195	0.15	0.96	2247	2311	2368
B +4.3	0.51	522	225	11121	0.140	0.38750	0.5	7.9989	0.5	0.14971	0.15	0.96	2111	2231	2343
C 4.2-4.3	0.88	607	222	8843	0.140	0.32896	0.5	6.5274	0.5	0.14391	0.15	0.96	1833	2050	2275
D +4.3 clear	0.25	499	224	9203	0.150	0.39623	0.5	8.3409	0.5	0.15267	0.15	0.96	2152	2269	2376
E +4.3 +200 long pale	0.51	477	189	4798	0.150	0.35221	0.5	7.1444	0.5	0.14712	0.15	0.96	1945	2130	2313
F +4.3 +200 long pale abr5h	0.58	436	194	10157	0.140	0.39837	0.5	8.1992	0.5	0.14928	0.15	0.96	2162	2253	2338
G +4.3 +200 abr16h	0.54	499	230	12599	0.140	0.41320	0.5	8.6315	0.5	0.15151	0.15	0.96	2230	2300	2363
H +4.3 -200 abr16h	0.48	462	217	7708	0.150	0.41659	0.5	8.7629	0.5	0.15256	0.15	0.96	2245	2314	2375
A1586 Metsävaara (Rantavaara gabbro)															
A +4.2 abr5h clear fragm.	0.56	430	234	14126	0.480	0.38858	0.5	7.1407	0.5	0.13328	0.15	0.96	2116	2129	2142

[1] Zircon unless otherwise stated. Density (in g cm^{-3}), size (in mesh), duration of abrasion (abr, in hours), preleached in HF (HF)
[2]) Isotopic ratios corrected for fractionation, blank and age related common lead.
[3]) Error correlation for 207Pb/235U vs. 206Pb/238U ratios.
Pb blank 20-50 pg for small samples (< mg), for others 200-500 pg.
SE = standard error in the mean