INTRODUCTION

Active worldwide research on rapakivi granites and related mafic and intermediate rocks has shown that this lithologic assemblage is an important tool in the study of the composition of deep continental crust and subcontinental mantle (see Haapala & Rämö 1999 and references therein). In any one area, the radiogenic isotope composition of the rapakivi granites reflects the overall age of the unexposed lithosphere that they occupy (e.g., Rämö 1991, Neymark et al. 1994, Rämö et al. 1995, Andersson 1997, Dall’Agnol et al. 1999). This has recently been particularly well established for the ~1.5 Ga rapakivi granites of central Sweden that show a substantial Archean source component although no Archean crust has been found to be exposed in that area (Andersson 1997).

In the first part of the 1990’s, the rapakivi batholiths of Russian Karelia were studied for Nd and Pb (as well as Sr) isotopes that implied a mixed Archean-Paleoproterozoic source, in contrast to the clearly younger source characteristics of the rapakivi granites farther to the west in southern Finland (Rämö 1991, Neymark et al. 1994). The latter turned out to be quite homogeneous in terms of Nd and Pb isotopes with a clear Paleoproterozoic signature for all plutons extending from the Åland Islands in the west to the Finnish-Russian border in the east (Rämö 1991).

The Russian Karelian rapakivi batholiths (Salmi and Ulyalegi; Fig. 1a) are situated at the contact zone of the Archean and Paleoproterozoic crustal domains of the Fennoscandian Shield and their mixed (Archean-Proterozoic) isotopic signature is thus quite understandable. Recent studies on the Mesoproterozoic (Amantov et al. 1996, Rämö et al. 2001a) Valamo dolerite of the Jotnian Lake Ladoga basin have suggested that a Neoproterozoic subcontinental lithosphere (with $\varepsilon_{Nd}$ [at 1.46 Ga] of ~ -9 and initial $^{87}\text{Sr}/^{86}\text{Sr}$ of ~0.705) probably underlies the north-central part of Lake Ladoga (Upton et al. 1998, Rämö et al. 2001a; Fig. 1). This suggests that the Archean-Proterozoic boundary may continue at depth farther to the southwest than the present exposed boundary northwest of Lake Ladoga (Fig. 1a). In order to examine whether the easternmost part of the Wiborg batholith in Russian Karelia (southwest of Lake Ladoga) records a major Archean source
component, a rapakivi granite sample from the town of Vyborg (Viipuri) was analyzed for Nd and Pb isotopes. This report presents the acquired data and their due implication.

SAMPLE

The analyzed sample, OTR-98-4, was collected in downtown Vyborg at a roadcut immediately to the west of the Bastion of Pantsarlahti, ~900 m south-southeast of the Castle of Vyborg (Fig. 1b). It is a coarse-grained hornblende-biotite granite with ovoidal alkali feldspar megacrysts (diameter 1–3 cm; occasionally up to 5 cm) some of which are mantled by oligoclase. Quartz is found as short prismatic (drop-like) early crystals (diameter up to 0.5 cm) and as anhedral grains in the groundmass, plagioclase (An20-30) is present as turbid subhedral grains up to 0.7 cm in diameter. The main mafic silicates, biotite and hornblende, fill the interstices of feldspars and early quartz. Accessory minerals include apatite, zircon, fluorite, and oxide.

In terms of its petrography, sample OTR-98-4 is a pyterlite (cf. Wahl 1925, Vorma 1976) that, according to Simonen and Vorma (1969), covers ~6% of the Finnish part of the Wiborg batholith. Overall, the bedrock of the downtown region of Vyborg is composed of pyterlite that is rather homogeneous, save for subtle variation in the size of the alkali feldspar megacrysts.

RESULTS

For the Vyborg pyterlite, Nd isotopic composition was determined from whole-rock fraction and Pb isotopes were measured for both whole-rock and alkali feldspar. The results of the isotopic analyses are shown in Table 1 and Fig. 2. Detailed descriptions of the analytical procedures can be found in Rämö et al. (2001b).
Isotopic composition of pyterlite in Vyborg (Viipuri), Wiborg batholith, Russia

Table 1. Nd and Pb isotopic composition of Vyborg pyterlite

<table>
<thead>
<tr>
<th>Sample name</th>
<th>OTR-98-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sm (ppm)</td>
<td>18.44</td>
</tr>
<tr>
<td>Nd (ppm)</td>
<td>95.60</td>
</tr>
<tr>
<td>147Sm/144Nd</td>
<td>0.1166</td>
</tr>
<tr>
<td>143Nd/144Nd</td>
<td>0.511719 ± 0.000009</td>
</tr>
<tr>
<td>εNd (1640 Ma)</td>
<td>–1.1</td>
</tr>
<tr>
<td>TDM(Ga)</td>
<td>2.071</td>
</tr>
<tr>
<td>206Pb/204Pb</td>
<td>19.134</td>
</tr>
<tr>
<td>207Pb/204Pb</td>
<td>15.723</td>
</tr>
<tr>
<td>208Pb/204Pb</td>
<td>38.280</td>
</tr>
<tr>
<td>206Pb/204Pb</td>
<td>16.459</td>
</tr>
<tr>
<td>207Pb/204Pb</td>
<td>15.458</td>
</tr>
<tr>
<td>208Pb/204Pb</td>
<td>35.819</td>
</tr>
</tbody>
</table>

Note: Isotopic analyses at the Geological Survey of Finland (GTK). For analytical procedures, see Rämö et al. (2001b).

Nd isotopes

The Vyborg pyterlite has quite high contents of Sm (18.44 ppm) and Nd (95.60 ppm) and it is strongly enriched in the light rare earth elements with 147Sm/144Nd of 0.1166. This is typical of the Finnish, and for that matter, the Proterozoic rapakivi granites in general (e.g., Rämö & Haapala 1995). The present-day εNd value, calculated using chondritic values of 143Nd/144Nd = 0.51264 and 147Sm/144Nd = 0.1966. The initial εNd value, calculated using chondritic values of 143Nd/144Nd = 0.51264; reported error is 2σ. Pb isotopic ratios reported relative to the NBS 981 standard.

Pb isotopes

The whole-rock and alkali feldspar Pb isotopic ratios of the Vyborg pyterlite are relatively high and roughly conform to the Stacey and Kramers (1975) model for average crustal Pb (Fig. 2b). The whole-rock – alkali feldspar pair defines a trend with an age of ~1600 Ma and a Th/U of ~3.2. The age, although quite imprecise, is compatible with the U-Pb ages measured for the Finnish part of the Wiborg batholith; these cluster around 1640 Ma (Vaasjoki 1977, Suominen 1991, Vaasjoki et al. 1991, Alviola et al. 1999). The Stacey and Kramers µ2 value and second-stage model age for the feldspar fraction are 9.87 and 1373 Ma, respectively.

DISCUSSION AND CONCLUSION

In Fig. 2a, the initial isotopic composition of the Vyborg pyterlite is shown and compared to the composition of the Finnish and Russian Karelian rapakivi granites in an εNd vs. age diagram. Quite clearly, the Vyborg pyterlite conforms to the samples previously analyzed from the Finnish part of the Wiborg batholith and from the other Finnish rapakivi granites (Rämö 1991). These define a narrow evolution path with Nd model ages clustering around 2.1–2.0 Ga, whereas the Russian Karelian rapakivi granites are clearly less radiogenic, show more scatter, and have clearly older model ages.

The uranogenic Pb isotopic composition of the Vyborg pyterlite is compared to that of the alkali feldspar and whole-rock fractions analyzed from the Finnish and Russian Karelian rapakivi granites in Fig. 2b. Again, the pyterlite is compatible with the Finnish granites that fall along the growth curve of the Svecofennian crust, and it grossly deviates from the Russian Karelian feldspars and whole-rocks that show a much more unradiogenic composition and presumably reflect a major source component in a low-U/Pb Archean lower crust (Rämö 1991).

The Nd and Pb isotopic composition of the pyterlite from Vyborg shows that the easternmost (Russian) part of the Wiborg batholith also had a Paleoproterozoic protolith with no substantial contribution from an Archean source. As the rapakivi granites probably reflect, through anatexis, averaged isotopic composition of preexisting deep crust (e.g., Rämö 1991, Rämö & Haapala 1995), this suggests that the concealed Archean domain...
recorded by the dolerite in the Ladoga region does not extend southwestward across the Karelian Isthmus to the Wiborg batholith.

ACKNOWLEDGMENTS. Sampling in Vyborg was done in 1998 on a private trip to examine Finnish Continuation War (1941–1945) battle stations at Sormenkräki, Rajajoki. I would like to thank the staff of the Unit for Isotope Geology, Geological Survey of Finland for help while making the isotope analyses and Tuure Rämö, my father, for help in compiling the sketch map of Vyborg. Lars Rämö provided thin sections of the pyterlite and Martti Lehtinen was kind enough to apply a special cleaning procedure to remove lichen. Critical reviews of the manuscript by Veli Suominen and Matti Vaasjoki and editorial comments by Yrjö Kähkönen were helpful. Supported by the Academy of Finland (project 36002). Contribution to IGCP Projects 315 “Rapakivi Granites and Related Rocks” and 426 “Granite Systems and Proterozoic Lithospheric Processes”.

REFERENCES

Alviola, R., Johanson, B.S., Rämö, O.T. & Vaasjoki, M. 1999. The Proterozoic Ahvenisto rapakivi granite – massif-type anorthosite complex, southeastern Finland, Pe...