# The megacryst-bearing Ba-Sr-*LREE*-rich lamprophyres from NW Ladoga, (Baltic Shield, Russia): Melt evolution and nature of source

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Only a few occurrences of igneous rocks with mantle and lower crustal xenoliths and megacrysts are known on the Baltic Shield (Kempton *et al.*, 1995; Arzamastsev and Dahlgren, 1993; Griffin *et al.*, 1995). In addition the megacryst-bearing Ba-Sr-*LREE*-rich lamprophyres from NW Ladoga Lake have been studied. The data obtained on megacrysts and host fairly primitive potassic lamprophyres gave new information on the geochemical features of the lithosphere source, as well as melt evolution.

## Geological setting and age of magmatism

The area of the lamprophyre magmatism is located in the SE margin of the Baltic Shield within the Svecofennian block, 25 km south of the Raahe-Ladoga suture, which separates Svecofennian block from the Karelian craton. The lamprophyres form numerous dykes (few cm to few meters thick) and small stocks about 1 km in diameter (Khazov, 1993). They are intruded into the $PR_1$ granulites, gneisses, and amphybolites. Some stocks are abundant in xenoliths of host schists and gneisses, and also contain single *Cpx*, *Bt*, and minor *Ap* megacrysts. The megacryst volume proportion amounts to 10%. The magmatism is dated by a complex of isotope methods (K-Ar, Rb-Sr, Sm-Nd) at 1700-1600 Ma and corresponds to the Early Riphean post-tectonic stage of the regional evolution. They are close in age to the Vyborg rapakivi massif and some dolerite and lamprophyre dykes in the SE Finland.

## Petrography and whole-rock geochemistry

The lamprophyres dykes are composed of continuous rock series from minette to kersantite. The larger intrusive bodies consists of shonkinites to syenites. The dyke lamprophyres have porphyritic texture with *Bt*, *Cpx* i *Hbl* phenocrysts included in the medium-grained groundmass of *Bt*, *Cpx*, *Hbl*, tabular *Fsp*-microperthite and subhedral *Pl*. The rocks usually contain both *Kfs* and *Pl*, but sometimes only *Kfs* or *Pl* present in rocks. Lamprophyres have high $Al_2O_3$ (12–17 wt.%), total alkalis (5.5–10.5 wt.%) with $K_2O/Na_2O$ 0.4–2.7, and moderate MgO (2.6–8 wt.%) with $mg$ = 39–60 (see Table). All rocks are strongly enriched in *LREE* and LILE (particularly in Ba 2000–10000 ppm and Sr 1200–3300 ppm) excluding Rb, which is relatively low (20–60 ppm), and depleted in Ni and Cr (either < 100 ppm), Nb, Ta, and U.

## Megacrysts and host rock mineral chemistry

A kersantite stock contains *Cpx*, *Bt*, and minor *Ap* megacrysts 2–5 cm long. The compositional

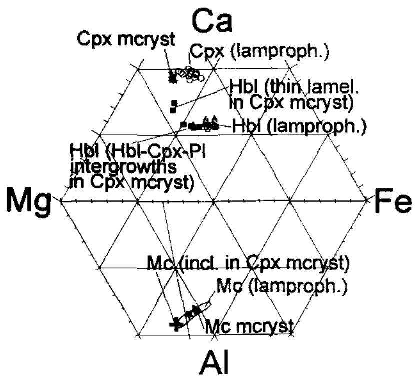


FIG. 1. Compositions of megacrysts and host-rock minerals.

TABLE 1.

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| $SiO_2$ | 42.94 | 42.23 | 43.64 | 48.31 | 51.60 | 50.69 |
| $TiO_2$ | 2.11 | 1.66 | 2.08 | 2.39 | 1.98 | 1.41 |
| $Al_2O_3$ | 13.20 | 13.95 | 12.73 | 14.42 | 13.80 | 15.75 |
| $Fe_2O_3$ | 11.58 | 12.21 | 11.55 | 11.38 | 9.00 | 10.49 |
| MnO | 0.16 | 0.24 | 0.15 | 0.16 | 0.12 | 0.17 |
| MgO | 7.84 | 7.03 | 6.86 | 5.63 | 4.89 | 3.78 |
| CaO | 9.33 | 8.63 | 9.47 | 8.93 | 7.35 | 5.83 |
| $Na_2O$ | 2.32 | 2.32 | 2.90 | 3.97 | 4.65 | 3.67 |
| $K_2O$ | 3.58 | 4.51 | 4.68 | 2.16 | 3.81 | 4.84 |
| $P_2O_5$ | 3.51 | 3.74 | 2.81 | 1.13 | 1.63 | 1.19 |
| *mg* | 57 | 53 | 54 | 49 | 52 | 42 |
| Co | 35 | 30 | 39 | 34 | 24 | 33 |
| V | 168 | 123 | 168 | 112 | 140 | 123 |
| Sc | 19 | 18 | 21 | 19 | 15 | 18 |
| Rb | 41 | 56 | 59 | 27 | 37 | 41 |
| Ba | 9147 | 6584 | 10080 | 2539 | 5990 | 6458 |
| Sr | 2618 | 2505 | 3044 | 1753 | 2244 | 3247 |
| Ta | 0.7 | 1.0 | 0.5 | 1.0 | 1.3 | 0.4 |
| Nb | 0 | 8 | 0 | 8 | 11 | 0 |
| Hf | 6.0 | 13.1 | 3.8 | 6.9 | 12.3 | 4.5 |
| Zr | 93 | 118 | 47 | 125 | 147 | 48 |
| Y | 33 | 47 | 29 | 26 | 30 | 21 |
| Th | 20 | 33 | 13 | 6 | 17 | 12 |
| U | 0.0 | 3.8 | 0.0 | 1.3 | 2.6 | 0.0 |
| La | 911 | 1113 | 922 | 300 | 480 | 786 |
| Ce | 1311 | 1555 | 1281 | 436 | 721 | 1088 |
| Nd | 776 | 807 | 717 | 235 | 358 | 637 |
| Sm | 64.2 | 76.7 | 67.4 | 27.0 | 35.3 | 53.5 |
| Eu | 16.3 | 20.8 | 16.9 | 8.0 | 9.4 | 14.7 |
| Tb | 3.7 | 4.3 | 3.6 | 2.1 | 1.9 | 3.0 |
| Yb | 3.4 | 5.1 | 2.7 | 2.8 | 3.1 | 2.6 |
| Lu | 0.41 | 0.39 | 0.75 | 0.35 | 0.29 | 0.34 |

Note: (1) megacryst-bearing kersantite, (2) minette dyke, (3) minette stock, (4) kersantite, (5) minette dyke, (6) syenite.

differences between megacrysts and minerals of the host rocks are well illustrated in Fig. 1.

The *Cpx* megacrysts are partly recrystallized into the *Hbl-Cpx-Pl* intergrowths. The *Cpx* is most magnesian (*mg* = 71–76) in megacrysts and host kersantite, while it becomes gradually more ferroan (up to *mg* = 58) in the more evolved lamprophyres. The *Cpx* megacrysts contain more $Al_2O_3$ (3.8–5.1 wt.%) in comparison with the host and other lamprophyres (0.8–3.4%). The mineral inclusions in *Cpx* megacrysts are Ba-rich *Phl* (*mg* = 69, BaO ~ 8 wt.%, $TiO_2$ = 4.3 wt.%), Sr-rich *Pl* (SrO 2.4–3.7 wt.%) and *Ap*.

The mica megacrysts have *mg* = 58–63, BaO = 3.8–5.4 wt.%, and $TiO_2$ 3.5–4.4 wt.%. The micas in

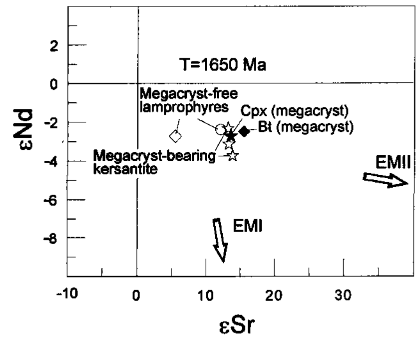


FIG. 2. Nd-Sr isotope compositions of lamprophyres from NW Ladoga.

lamprophyres show variable *mg* from 52 to 63, some lower $TiO_2$ (1.4–3.3 wt.%) and BaO (n.d. to 2 wt.%). The mica in the minette groundmass is usually poorer in BaO then that in kersantites, perhaps by its coexistence with Ba-rich Kfs.

Feldspar (both *Kfs* and Na-*Pl*) is the major mineral in lamprophyres. The *Kfs* is Ba-rich (BaO 2.5–6 wt.%) in all rock varieties. In the dyke rocks the *Kfs* usually forms tabular crystals in groundmass and contains thin lamellae of Sr-rich oligoclase (up to 3.5 wt.% SrO). *Pl* in rocks usually forms anhedral twinning-free grains.

The accessory minerals dominate in *Ap* and *Sph*. The melanocratic rocks are richer in *Ap* than the more leucocratic, which are richer in *Sph*. Opaque minerals are represented by Ti-poor *Mt* and *Py*.

## Megacryst and host rock isotope composition

Megacrysts have similar isotope composition with host rocks and form a mineral isochron with an age of ~1650 Ma. Megacrysts and lamprophyres plot on the εNd-εSr diagram within a close field; the low Rb/Sr ratio of these rocks coupled with isotope data indicates of their origin from the EMI reservoir (Fig. 2) with $T(Nd)_{DM}$ ~2 Ga.

## Conclusion

Similar isotope and chemical composition of megacrysts and host-rock minerals indicates of their cognate origin. However, the megacrysts have some compositional differences evidencing their crystallization at the earlier stages of evolution of the primitive Ba-Sr-*LREE*-rich lamprophyre magma.

The extreme enrichment of these magmas in LILE and *LREE* with low Rb/Sr ratio, and specific isotope composition could be caused by their origin from the metasomatized mantle domains of the EMI-type.