Proceedings of the Annual Joint Conference,
Petrological Society of Korea and Mineralogical Society of Korea
May 28, 2004, Cheongju, Korea

Sr-Nd-Pb isotopic systematics of the Kovdor phoscorite-carbonatite complex, Kola Alkaline Province, NW Russia: Implications for plume-related manlte source characteristics

Mi Jung Lee[1]*, Jong Ik Lee[1], Soon Do Hur[1], Yeadong Kim[1],
Jacques Moutte[2], and Elena Balaganskaya[3]
[1]Korea Polar Research Institute, Ansan P.O. Box 29, Seoul 425-600, Korea (mjlee@kordi.re.kr)
[2]GENERIC-SPIN, Ecole des Mines, 158 Cours Fauriel, 42023 Saint Etienne, France
[3]Geological Institute, Kola Science Centre, 14 Fersman Street, 184200 Apatity, Russian Federation

1. Introduction

Although the carbonatites, with their relatively exotic mineralogy and the great diversity of associated alkaline rocks, were intensively studied for the past 50 years by igneous petrologists, there is no comprehensive petrogenetic model for these rocks. The origin of carbonatite magma has yet to be agreed upon, whether it is derived by direct partial melting of carbonated peridotite or by separation of an immiscible melt fraction from an alkaline silicate magma or by crystal fractionation of carbonated alkali silicate melts (Bell & Tilton, 2001, references there in). Recently accumulated Nd, Sr and Pb isotopic data (e.g., Kwon *et al.*, 1989; Tilton & Bell, 1994; Bell, 1998) and noble gas data (Marty *et al.*, 1998) clearly point to their mantle origin, but whether the generating site of the melts parental to carbonatites is in the lithosphere or the asthenosphere is open to debate.

The Kola Alkaline Province (KAP), located in the north eastern Baltic Shield, is one of the few regions in the world where Paleozoic alkaline-ultramafic or alkaline magmatism is well developed. More than 20 massifs of Devonian alkaline-ultramafic and alkaline rocks occur in the KAP, and sixteen of which contain carbonatites. Nd and Sr isotopic studies on many alkaline-carbonatite complexes in the KAP were carried out to determine the possible mantle components responsible for the formation of them. Based on these results, Kramm (1993) suggested the Devonian 'Kola Carbonatite Line' (KCL) which consists of two end members; one lies within the enriched quadrant, similar to an EM1 component, and the other, in the depleted quadrant, similar to a DM component. However, the lower-mantle ^{3}He isotopic signature detected in several of the Devonian alkaline massifs from Kola (Marty *et al.*, 1998) suggests an involvement of other primitive mantle component in the evolution of the KAP.

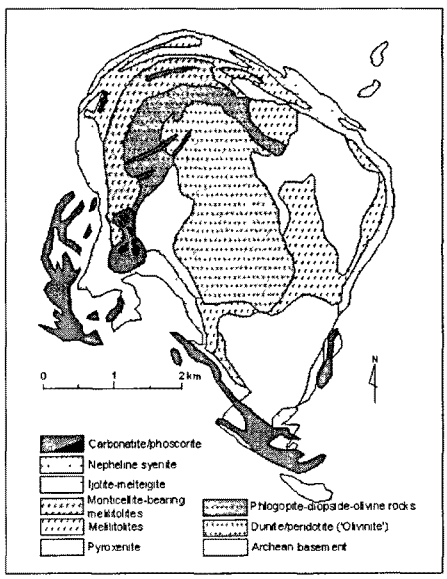

Fig 1 Geological map of the Kovdor massif in the Kola Alkaline Province

In this paper we present new Pb isotopic data for the phoscorites and carbonatites in Kovdor

massif. we will characterize the isotopic features of the ultramfic-alkaline rocks and carbonatites of the KAP and their mantle source regions, based on our new Pb-Nd-Sr isotope data and previously determined Nd-Sr data sets. Moreover, we will discuss a possibility of the involvement of a deep mantle plume component rather than the DM component.

2. Geological Setting

The Kovdor massif (Fig. 1) is a complex, multiphase, concentric intrusion, and consists of a great variety of rock types. The main rock types, from the oldest to the youngest, are (1) dunite (olivinite) and peridotite, (2) pyroxenite, (3) melilitolite and turjaite, (4) ijolite-melteigite, (5) phoscorite-carbonatite complex and (6) nepheline syenite. Ultramafic rocks (dunite, peridotite and pyroxenite) constitute central core of the massif. Melilite-rich rocks (turjaite and melilitolite) form irregular bodies around ultramafic core. Melilite-bearing melteigite could belong to the melilitolite series and not to the ijolite-melteigite series (Verhulst *et al.*, 2000). The alkaline silicate rocks of ijolite-melteigite series consist of outer rim of the massif.

A phoscorite-carbonatite complex, which is the main sampling site of this study, occurs as a plug in the southwestern part, and a few isolated carbonatite bodies cut the Precambrian gneisses and alkaline silicate rocks in the western and the southern parts. Numerous carbonatite dikes are observed over the whole of the massif. Nepheline syenites in association with ijolite-melteigite porphyries are found as small satellite bodies about 1 km away from the massif. A U-Pb age of baddeleyite from carbonatite of the Kovdor massif is 380 ± 4 Ma (Bayanova *et al.*, 1997), and corresponds to the range of 380-360 Ma for the other intrusions of the KAP (Kramm *et al.*, 1993).

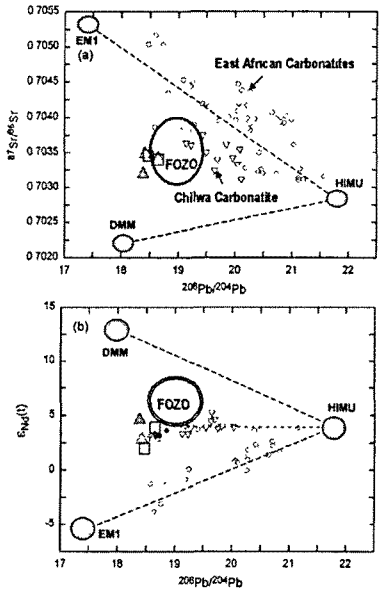

Fig 2 (a) $^{87}Sr/^{86}Sr$ vs $^{206}Pb/^{204}Pb$ and (b) eNd(t) vs $^{206}Pb/^{204}Pb$ isotope correlation diagrams of the representative rocks in Kovdor complex DMM, HIMU and EMI are approximations of mantle end-members taken from Hart et al (1992) Values for FOZO ('Focal Zone') taken from Hauri et al (1994) Other data sources East African carbonatites (Bell and Tilton, 2001)

3. Conclusions

Sr-Nd-Pb isotopic compositions from the Kovdor complex (380 Ma) in the Kola Alkaline Province, NW Russia, have been determined to define the possible mantle components responsible for the formation of ultramafic-alkaline-carbonatite magmas.

Measured rocks plot in the depleted mantle quadrant of the Nd-Sr correlation diagram with negative eSt(t) (-5.4 to -12.2) and positive eNd(t) (1.0 to 4.7). Combined with the previous results, the fairly large range of isotopic compositions of Kovdor rocks is not in favor of a simple, closed system magmatic evolution; it suggests a complex evolution implying several magma batches derived either from an isotopically heterogeneous mantle source or from various mixing proportions of two mantle reservoirs. Two end members (KCL, by

Kramme, 1993) have been suggested to explain the isotopic compositions of the Kola ultramafic-alkaline rocks and carbonatites; One is the EM I component and the other is the DM component. However, our new Pb isotopic data suggest an involvement of fairly different component from the DM, which is relatively primitive isotopic component, probably derived from a lower-mantle plume. Though the Pb isotope data are still very insufficient in the Kola Alkaline Province, the present data from the Kovdor complex suggest that one end-member of isotopically primitive component should be similar to that of 'FOZO' component, derived from the lower mantle reservoir, the so-called '5th component' in mantle plumes. Thus we propose that a Devonian equivalent of 'FOZO' component represents one of the mantle sources responsible for the formation of the ultramafic-alkaline-carbonatite complexes in the Kola Alkaline Province.

4. References

Bayanova, T. B., Kirnarski, Y. M. and Levkovich, N. V., 1997, A U-Pb study of baddeleyite from the rocks of the Kovdor massif. Doklady Akademii Nauk 356, 509-511 (in Russian).

Bell, K., 1998, Radiogenic isotope constraints in relationships between carbonatites and associated silicate rocks-a brief review. J. Petrol., 39, 1987-1996.

Bell, K. and Tilton, G.R., 2001, Nd, Pb and Sr isotopic compositions of East Africa carbonatites: Evidence for mantle mixing and Plume inhomogeneity. J. Petrol. 42, 1927-1945.

Hart, S.R., Hauri, E.H., Oschmann, L.A. and Whitehead, J.A., 1992, Mantle plumes and entrainment: isotopic evidence. Science, 256, 517-520.

Hauri, E.H., Whitehead, J.A. and Hart, S.R., 1994, Fluid dynamic and geochemical aspects of entrainment in mantle plumes. J. Geophys. Res., 99, 24275-24300.

Kramm, U., 1993, Mantle components of carbonatites from the Kola Alkaline Province, Russia and Finland: a Nd-Sr study. Eur. J. Mineral 5, 985-989.

Kramm, U., Kogarko, L. N., Kononova, V. A. and Vartiainen, H., 1993, The Kola Alkaline Province of the CIS and Finland: precise Rb-Sr ages define 380-360 Ma age range for all magmatism. Lithos 30, 33-44.

Kwon, S.-T., Tilton, G.R. and Grünenfelder, 1989, Lead isotope relationships in carbonatites and alkalic complexes: An over view. In: K. Bell (ed.), Carbonatites, Genesis and Evolution. Unwin Hyman, London, p. 360-387.

Marty, B., Tolstikhin, I., Kamensky, I.L., Nivin, V., Balaganskaya, E. and Zimmermann, J.-L., 1998, Plume-derived rare gases in 380 Ma carbonatites from the Kola region (Russia) and argon isotopic composition in the deep mantle. Earth Planet. Sci. Lett., 164, 179-192.

Tilton, G.R. and Bell, K., 1994, Sr-Nd-Pb isotope relationships in Late Archean carbonatites and alkaline complexes: applications to the geochemical evolution of the Archean mantle. Geochim. Cosmochim. Acta, 58, 3145-3154.

Verhulst, A., Balaganskaya, E., Kirnarsky, Y. and Demaiffe, D., 2000, Petrological and geochemical (trace elements and Sr-Nd isotopes) characteristics of the Paleozoic Kovdor ultramafic, alkaline and carbonatite intrusion (Kola Peninsula, NW Russia). Lithos, 51, 1-25