

# Geochemical constraints on genesis of Kamchatka arc ultramafic melts

V.S. Kamenetsky  
A.V. Sobolev

Vernadsky Institute of Geochemistry, Moscow 117975, Russia

## Introduction

Late Cretaceous ultramafic volcanics from Eastern Kamchatka (Russia) occur as pillow-lavas, tuffs, dykes and sills, associated with basalts within tectonic blocks, namely Valaginsky (VR) and Tumrok (TR) ranges (Sobolev *et al.*, 1990; Kamenetsky *et al.*, 1993). Picrites and basalts form a suite, genetically related to island-arc tectonic setting and characterised by elevated  $K_2O$  (1–4 wt.%) and  $K_2O/Na_2O$  (0.8–1.3) typical of shoshonite affinities. The rocks being unusually enriched in olivine phenocrysts (35–65 %) possess very high MgO contents (20–40 wt.%). The exceptionally primitive composition of the phenocryst assemblage (olivine  $FO_{88-95}$ , Cr-spinel - Cr# up to 85 mol.%) unambiguously evidences the mantle origin of primary melts and their high-magnesian composition (MgO - 19–24 wt.%), which has been confirmed by heating-stage study of melt inclusions in phenocrysts and thermodynamic modelling. The petrological study revealed the physical parameters of formation of primary melts, which are high pressure (30–50 kb) and temperature (1500–1700°C).

Here we present data on isotope, volatile and incompatible element composition of Kamchatka ultramafic melts and discuss the geochemical aspects of their genesis.

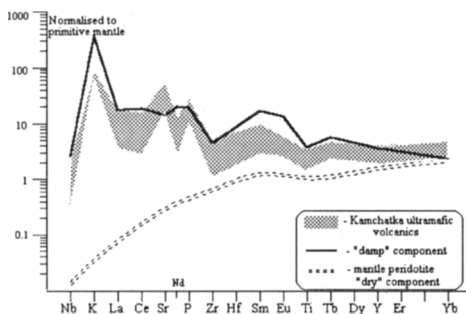


FIG. 1. Modelling of two component mixing for origin of Kamchatka melts.

## Results

Trace element compositions of homogenised melt inclusions in olivine and clinopyroxene were analysed with a Cameca IMS 3F ion microprobe (MIT, USA) - Fig. 1. Three groups of incompatible elements, each showing different level of concentration, may be distinguished: LILE (Rb, Ba, Sr, K) and P display the strong enrichment in comparison with other incompatible elements, REE exhibit intermediate level of enrichment, whereas HFSE (Nb, Zr, Ti) are obviously depleted. Despite the very similar geochemical patterns, typical of island arc magmas, some regional variations between VR and TR melts exist: TR melts are more depleted in HFSE and less enriched in LREE, LILE and P than VR melts.

The  $H_2O$  contents of melt inclusions, measured directly by a Cameca IMS 3F ion microprobe (C.P.R.G., Nancy, France), vary from 0.6 wt.% in ultramafic melts to 1.2 wt.% in melts of basaltic composition. High  $K_2O/H_2O$  ratio ( $\sim 3$ ) resembles phlogopite. Also, the melts are characterised by elevated Cl contents (0.2–0.4 wt.%), which are among the highest for any known primitive magma.

Nd and Sr isotopic compositions were measured in hand-picked clinopyroxenes. Ultramafic lavas and basalts from the same area have similar isotopic signatures:  $\epsilon Nd$ - +10.3 to +10.7 and +9.2 to +9.8, initial  $^{87}Sr/^{86}Sr$  - 0.70316–0.70333 and 0.70345–0.70358 in TR and VR, respectively.

## Discussion

Geochemical spectrum of arc magmas, characterised by high LILE/HFSE and LILE/LREE, is traditionally explained as resulting from melting of depleted mantle peridotite affected by metasomatic event, which is believed to be an interaction with subduction-related  $H_2O \pm CO_2$ -bearing fluid and/or melt ('damp' component). The negative anomalies of Nb (Ta), Zr (Hf) and Ti of Kamchatka melts form a very depleted pattern typical for multiply melted, refractory peridotite

and, therefore, may reflect the inherent property of the mantle wedge prior to the effects of subduction, assuming that these elements were not imported by metasomatic agents (e.g. Maury *et al.*, 1992; Eggins, 1993). Possibly, the mantle peridotite has been more depleted than N-type MORB mantle, and apparently, it contributed refractory components and the volumetric bulk of magmas, whereas the 'damp' component was responsible for the gross input of the incompatible elements such as LILE, LREE, P and volatiles.

Since the majority of Nd and Sr appears to be contributed to the mantle wedge by metasomatism, the isotopic constraints on these two elements may provide the basis for identification of the material, which has been scavenged by 'damp' component. The studied Nd isotope values resemble closely those of North Pacific MORB (e.g., White *et al.*, 1987), whereas  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios are shifted to the right border of the mantle array, but still are within the field defined for MORB. To explain the evident conflict between time-integrated depletion of the source and its enriched geochemistry we invoke an oceanic crust of depleted N-MORB composition, altered under the low-T metamorphism, as a possible source of a 'damp' component. The rocks, composed ancient oceanic crust, have an incompatible element pattern typical of N-MORB, but display a strong enrichment in LILE (except Sr) and U (e.g., Staudigel *et al.*, 1979), elevated Sr and unaffected Nd isotope ratios.

Melting of an oceanic crust slab, transformed at high pressure (>25 kb) to eclogite mineral assemblage, produce a melt (Fig.1), which is characterised by the depletion in HREE and HFSE as a result of residual garnet and rutile, by relatively low level of LREE and by enrichment in potassium in consequence of both the parental altered MORB chemistry and incongruent melting of phlogopite at pressures >40 kb (Tatsumi, 1989). However, our modelling fails to explain the enrichment in Sr, P and LREE, observed in melts studied. Therefore, an additional source of these elements is required. The alternative scenario of enrichment of sub-arc residual mantle wedge by the carbonatite melt, derived from subducted slab, has been envisaged by Sweeney *et al.* (1992). A carbonatite melt enriched in Rb, Sr and other LILE, P and LREE, but without concomitant HFSE enrichment, has been hypothesized to be an active and widespread metasomatic agent (Green

and Wallace, 1988); its role has been recently emphasized in the genesis of primitive boninitic magmas (Falloon and Crawford, 1991). This melt, experimentally determined in equilibrium with mantle peridotite (Wallace and Green, 1988), has been found to affect some natural mantle peridotite xenoliths (e.g., Ionov *et al.*, 1993). Therefore, it has a geochemical signature, which is consistent with the most pronounced characteristics of Kamchatka primary melts.

Thus, we argue that the great depth of melting and altered nature of subducted oceanic crust seem to be responsible for the unique geochemical features of Kamchatka ultramafic and related melts. Regional variations in the composition of these magmas probably result from either variations in the composition of sub-arc mantle and 'damp' component(s), and/or variations in the extent of their interaction.

#### Acknowledgements

We thank S.F. Karpenko for isotope analyses and K.T.M. Johnson for ion probe analyses of melt inclusions. This work was supported by Russian Basic Research Foundation, grant 93-05-8895.

#### References

- Eggins, S. M. (1993) *Contrib. Mineral. Petrol.*, **114**, 79–100.
- Green, D. H., and Wallace, M. E. (1988) *Nature*, **336**, 459–62.
- Falloon, T. J., and Crawford, A. J. (1991) *Earth Planet. Sci. Lett.*, **102**, 375–94.
- Ionov, D. A., Dupuy, C., O'Reilly, S. Y., Kopylova, M. G., and Genshaft, Y. S. (1993) *Earth Planet. Sci. Lett.*, **119**, 283–97.
- Kamenetsky, V. S., Portnyagin, M. V., Sobolev, A. V., and Danyushevsky, L. V. (1993) *Geochem. Int.*, **30**, 58–73.
- Maury, R. C., Defant, M. J., and Joron, J.-L. (1992) *Nature*, **360**, 661–3.
- Sobolev, A. V., Kamenetsky, V. S., and Kononkova, N. N. (1990) *Geochem. Int.*, **27**, 1694–1709.
- Staudigel, H., Frey, F. A., and Hart, S. R. (1979). In: *Init. Repts. of DSDP*, **51**, 1137–44.
- Tatsumi, Y. (1989) *J. Geophys. Res.*, **94**, 4697–707.
- Wallace, M. E., and Green, D. H. (1988) *Nature*, **335**, 343–6.
- White, W. M., Hofmann, A. W., and Puchelt, H. (1987) *J. Geophys. Res.*, **92**, 4881–93.