Komatiite-tholeiite and boninite series volcanic associations of the Abitibi greenstone belt: Plume-protoarc interaction, and crustal growth

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Komatiite-tholeiite sequences and boninite series volcanic rocks are spatially associated at several localities along a 300 km strike sector of the late Archaean (2.7 Ga) Abitibi greenstone belt, Canada. Examples include the Kidd volcanic complex (KVC) and volcanic sequences in Tisdale and Whitney Townships near Timmins, Ontario, as well as volcanic sequences near Val d'Or, Quebec. In the field, the different types of flows interdigitate on a scale of 10's to 100's metres.

Komatiites include Munro, or Al-undepleted type, and Barberton, or Al-depleted type. Spinifex textured Al-undepleted komatiites at the KVC and Whitney localities, like Munro counterparts, are characterized by near-chondritic Al_2O_3/TiO_2, Ti/Zr, and Zr/Y ratios. They have (1) near-flat *HREE*, (2) variable *LREE* depletion (La/Sm_n 0.4 to 0.8), and (3) small positive Hf anomalies relative to Sm, with Zr/Hf < 36. Spinifex textured Al-depleted komatiites at the Tisdale and Whitney localities have Al_2O_3/TiO_2 4 to 12, and convex up *REE* patterns, where $La/Sm_n = 0.4$ to 0.8 and Gd/Yb_n 1.2 to 1.9. Zr and Hf anomalies become more negative as Al_2O_3/TiO_2 decreases but Gd/Yb_n increases. Accordingly, the coexistence of Al-undepleted and Al-depleted komatiites was not uncommon: Al-undepleted komatiites are interpreted in terms of deeper melt segregation in a mantle plume with residual majorite garnet at > 400 km, whereas Al-undepleted komatiites reflect melt segregation at shallow levels.

Mg-, Fe-tholeiites are spatially associated with the komatiites. They have near-flat *REE* patterns over a continuous range from 4 to 20x chondritic abundance. Mg#, Cr, and Ni decrease continuously with increasing *REE*, Th, Nb, Zr, Hf and Y. The most primitive have near-chondritic interelement ratios. This magma series is interpreted to represent dynamic partial melting in the outer envelope of the mantle plume from which the komatiitic liquids were derived. Collectively, the tholeiites have a continuous range from negative to positive anomalies of Nb relative to Th and La, similar to Phanerozoic and Recent ocean plateau basalts and some ocean island basalts (Saunders *et al.*, 1988). Alteration and crustal contamination can be ruled out as the source of the anomalies. The negative anomalies are consistent with recycling of subduction-influenced subarc mantle, or continental crust, into the mantle, and the positive anomalies recycling of ocean crust processed through a subduction zone (Saunders *et al.*, 1988; McDonough, 1991). Consequently, the plume from which the komatiites and tholeiitic basalts were derived was multi-component, as demonstrated from trace element and isotope systematics on Phanerozoic and Recent plume-related basalts (Mahoney *et al.*, 1993).

Compositionally, the boninite series flows range from Mg# = 81–45, TiO_2 = 0.17–0.41, and Ni = 1020–310 ppm. They are characterized by high Al_2O_3 (12–16 wt.%) contents, and Al_2O_3/TiO_2 (60–84) ratios. In common with Phanerozoic boninites, these flows have negatively fractionated *HREE* (Gd/Yb_n = 0.4–0.6), Zr/Y (1.4–2.2) less than the primitive mantle value of 2.4, and variably positive Zr and Hf anomalies, where Zr/Hf < 36, but variably negative Nb anomalies. *LREE* vary: Four of a population of 38 boninite series flows meet the boninite definition of SiO_2 > 53% and Mg# > 60 given by Crawford *et al.* (1989). Collectively, the boninite series overlap spinifex textured Al-undepleted komatiites in terms of TiO_2 and Zr contents, but are much more aluminous, possess higher Al_2O_3/TiO_2 ratios and Sc and Yb contents, but lower Gd/Yb_n and Zr/Y ratios. The boninites are interpreted to have formed in a protoarc from second stage metasomatic enrichment of a mantle source highly depleted during first stage melt extraction, as in the model of Stern and Bloomer (1992).

The spatial association of plume-related ocean plateau komatiite-tholeiite sequences with boninite series volcanic flows, over 300 km, is interpreted as in terms of interaction of an active mantle plume with a convergent margin. The preservation of these diverse magma associations is consistent with plume-subduction zone interaction similar to that proposed in the model of Abbott (1996).

References

Abbott, D.H. (1996) *Lithos*, **37**, 113–27.

Crawford, A.J., Falloon, T.J. and Green, D.H. (1989) In: Crawford, A.J. (Ed), *Boninites*, 1–49.

Mahoney, J.J., Storey, M., Duncan, R.A., Spencer, K.J. and Pringle, M. (1993) In: Berger, W.H., Kroenke, L.W., and Mayer, L.A., eds., *Proceedings of the Ocean Drilling Program, Scientific Results*, **130**, 3–22.

McDonough, W.F. (1991) *Phil. Trans. Royal Soc. London*, **A335**, 407–18.

Saunders, A.D., Norry, M.J. and Tarney, J. (1988) *J. Petrol.*, **29**, 415–45.

Stern, R.J. and Bloomer, S.H. (1992) *Geol. Soc. Amer. Bull.*, **104**, 1621–36.