Ba & LREE ENRICHED MANTLE BELOW THE ARCHEAN CRUST OF SCOTLAND

Martin Menzies, Department of Geology, University of London (RHBNC), Egham, Surrey TW20 0EX, England
Alexander Halliday, SURRC, East Kilbride, Glasgow G75 0QU, Scotland
Zenon Palacz, Earth Sciences, Open University, Milton Keynes MK7 6AA, England
Robert Hunter, Earth Sciences, Cambridge University, Cambridge CB2 2EW, England
Christopher Hawkesworth, Earth Sciences, Open University, Milton Keynes MK7 6AA, England

INTRODUCTION

Controversy has arisen over the relative contribution of crust and mantle during the formation and evolution of Scottish igneous rocks emplaced in the Silurian-early Devonian and the Tertiary period. Whilst many studies have concentrated on an evaluation of the extent of contamination and the provenance of the crustal rocks presumed to have been involved, others have turned their attention to the polybaric history of the volcanic rocks including a detailed assessment of their source region. An inherent assumption in the majority of these ventures has been that the mantle beneath the N.W. Highlands of Scotland is relatively depleted and similar to the source of Atlantic MORB. This could prove to be a dangerous assumption since studies in S. Africa and Antarctica have revealed the presence of extremely heterogeneous lithospheric mantle. Although possibly underlain by relatively homogeneous MORB-OIB mantle this chemically complex lithospheric keel may modify asthenospheric magmas during their ascent to the surface or even act as an independent source for more unusual magmas.

LOCH ROAG XENOLITH DIKE

Peridotite and pyroxenite xenoliths found in a monchiquite dike on the island of Lewis, Scotland (Upon et al 1983) are enriched in barium, the light rare earth elements and in some instances niobium. Megacryst suites indicate the presence of a mineralogically complex upper mantle as they are characterised by apatitie $\pm$ mica $\pm$ corundum $\pm$ zircon $\pm$ Nb rutile $\pm$ anorthoclase. A time-integrated response to the low Sm/Nd and Rb/Sr ratios has resulted in an extremely variable Nd isotopic composition ($^{143}Nd/^{144}Nd$ = 0.51247-0.51097) (εnd = -3.4 to -32.6) and a limited variation in Sr isotopic composition ($^{87}Sr/^{86}Sr$ = 0.70415-0.70636) (εsr = -5.0 to +26.4). These data are very similar to Lewisian and Moinian metamorphic rocks and as such their isotopes could be thought of as "crustal" in character (fig.1). Furthermore these data overlap with that observed in garnet inclusions in megacrystic diamonds from kimberlites (Richardson et al 1984). and with lamproites - Group II Kimberlites (Fraser et al 1985). Model ages indicate that the pyroxenite-peridotite assemblage was affected by the influx of a LREE enriched, Rb depleted melt or fluid some 1.2 Ga ago. The remarkable similarity in isotopes and trace element characteristics (low Rb/Sr, low Rb/Ba) of the xenoliths and lamproites leads us to suggest that the melt responsible for this metasomatic enrichment was lamproitic. Hebridean mantle has evolved, locally, in a manner similar to that occurring below the S. African and N. American cratons.

EVIDENCE FOR CHEMICALLY ENRICHED LITHOSPHERIC MANTLE

Several investigators of Scottish volcanic rocks have commented on the need for "locally" heterogeneous mantle enriched in Ba, Sr, LREE with repositories for elements like P, Ta and Nb. Moreover, in a detailed study of Siluro-Devonian volcanism it was noted that volcanic rocks of the S.W. Highlands had systematically higher concentrations of Sr, K, Ba, P and the LREE in the more Ni-rich undifferentiated samples (Thirlwall 1982). A mantle source with a time integrated enrichment in incompatible elements would better explain these features than any model involving crustal contamination. A similarly unusual mantle contribution may account for the trace element and isotopic provinciality apparent in so many Scottish granitoids. The Scottish granitoids become enriched in Ba, Sr, LREE and impoverished in Rb and Th towards the northwest. Isotopically these rocks are more "Lewisian-like" indicative of either extensive contributions from the basement via assimilation and melting or some contribution to their chemistry from lithospheric mantle enriched in incompatible elements (Halliday et al 1986). Several independent lines of evidence appear to indicate that beneath the older crustal regions of N.W. Scotland the possibility exists for the presence of mantle that is chemically enriched and has with time become isotopically distinct from the mantle tapped by magmas erupted in the Midland Valley of Scotland, or elsewhere in the North Atlantic volcanic province. Hence, the apparent regional chemical anomalies in the Scottish mantle defined by the enhanced trace element concentrations of Silurian-Devonian lavas and Palaeocene volcanic rocks of the British Tertiary province may result from the involvement of trace element enriched Hebridean lithospheric mantle like that found at Loch Roag.

CONCLUSION

Lithospheric mantle acts as a barrier to the passage of asthenospheric melts. Interaction between peridotite mantle and melts or fluids of variable chemical composition results in immediate chemical heterogeneity. The passage of time guarantees isotopic heterogeneity governed by the Sm/Nd and Rb/Sr ratios. Beneath the Archean of Scotland incompatible element enriched alkalic melts or fluids derived possibly from ancient subduction interacted with lithospheric mantle some 1.2 G yr ago. The resultant high concentrations of LREE in the wall rock and low Rb/Sr ratios produced isotopically unique lithosphere. This lay relatively undisturbed until in the Tertiary major tectonic changes due to the opening of the Atlantic led to disruption and possible involvement of this lithospheric keel in basaltic volcanism of the BTVP. The Hebridean mantle has recorded a variety of enrichment processes since the Archean resulting in the existence of enriched heterogeneous sub-Lewisian lithospheric mantle.

REFERENCES

FRASER K.J., HAWKESWORTH C.J., ERLANK A.J., MITCHELL R.H. and SCOTT-SMITH B.H. 1985. Sr, Nd and Pb isotope and minor element geochemistry of lamproites and kimberlites. Earth and Planetary Science Letters 76, 1, 57-70

HALLIDAY A.N., STEPHENS W.E., HUNTER R.U., MENZIES M.A., DICKIN A.P. and HAMILTON P.J. 1986. Isotopic and chemical constraints on the building of the Deep Scottish lithosphere. Scottish Journal of Geology Special Issue (in press).

RICHARDSON S.H., GURNEY J.J., ERLANK A.J. and HARRIS J.W. 1984. Origin of diamonds in old enriched mantle. Nature 310, 198-202.

THIRLWALL M.F. 1982. Systematic variation in chemistry and Nd-Sr isotopes across a Caledonian calc-alkaline volcanic arc : implications for source materials. Earth and Planetary Science Letters 58, 27-50.

UPTON B.G.J., ASPEN P. and CHAPMAN N.A. 1983. The upper mantle and deep crust beneath the British Isles : Evidence from inclusion suites in volcanic rocks. Journal Geological Society London 140, 145-122.

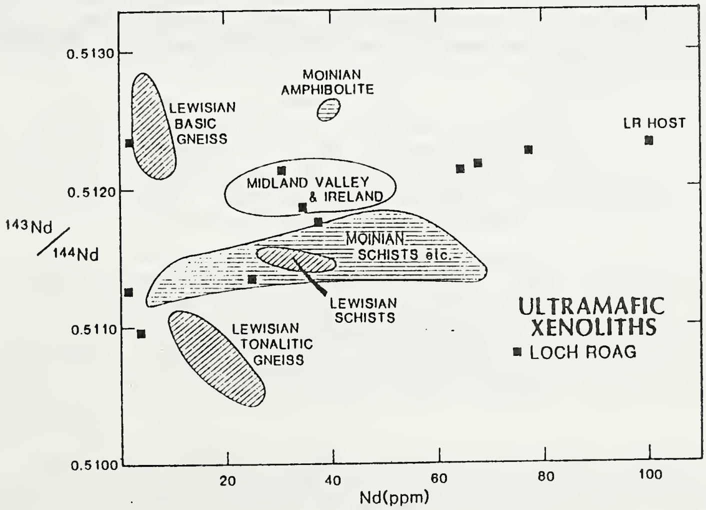

Fig.1 - Nd isotopic composition and relative abundance of Nd in Loch Roag xenoliths relative to crustal rocks.