Compositional variations in basalts from the Western Great Basin, California and Nevada, USA

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The Western Great Basin (WGB) is a physiographic region of internal drainage lying to the east of the Sierra Nevada, including eastern California north of the Mojave Desert and extending into western Nevada. It occupies a critical position relative to both the tectonic evolution and the lithospheric structure of the western USA, and is characterised by alkali-rich basalts which have been erupted from small monogenetic and polygenetic centres. The region straddles the boundary between, in the east, continental North America underlain by Proterozoic basement and the accreted terrains of Palaeozoic age that comprise most of California to the west, and basalts of similar major element composition occur either side of this boundary. The WGB has been volcanically active for the past 17Ma and during this time the tectonic setting changed from one dominated by the subjacent subduction zone to a trans-tensional environment which developed inland from, but in association with, the San Andreas fault system along the Pacific coast of California. The cessation of subduction beneath California created a window in the subducting slab that enlarged with time and the northwards migration of the northern edge of this slab window has been related to the northward migration in the cessation of magmatism in the Cascades and the appearance of a significant asthenosphere-derived component in the basalts of the WGB (Ormerod *et al.*, 1988). Recent magmatism is due to localised extension associated with pull-apart basins generated by trans-tensional transform fault motions.

Basalts from the WGB vary widely in their major element compositions and this study is restricted to those samples with $>4\%$MgO. Despite this limit, however, SiO_2 varies from 46% up to 56% and many of the more silica-rich samples are hypersthene-normative. However, on a total alkali-silica diagram, most analyses plot in the alkalic field. WGB basalts are also poor in Fe_2O_3 and TiO_2 relative to alkali basalts from the central Basin and Range. Typical values are Fe_2O_3 8–10% and TiO_2 1–2% in the most magnesian WGB basalts compared with 10–13% and 2.5–3.5% in recent B&R basalts. The low TiO_2 is reflected in incompatible element abundances which show pronounced negative Nb and Ta anomalies and enrichment of Ba and Sr relative to the *REE*. The *LREE* are enriched relative to the *HREE* indicative of small degrees of melting and detailed modelling of the complete range of incompatible elements shows that the HFSE anomalies are a feature of the magma source region which is also *LREE* enriched. One unexpected result of the modelling is that garnet is not a stable residual phase (Ormerod *et al.*, 1991). Radiogenic isotopes of the WGB basalts reflect the trace element enriched characteristics of this source region, with high 87Sr/86Sr (0.7040–0.7078), low $^{143}Nd/^{144}Nd$ (0.5129–0.5120) and variable Pb isotopes ($^{206}Pb/^{204}Pb$; 18.0–19.2), generally displaced above the NHRL in both $^{207}Pb/^{204}Pb$ and $208Pb/^{204}Pb$ diagrams.

Most compositional features of the WGB basalts are largely insensitive to the boundary between continental North America and the accreted terrain of California. Of the major elements only SiO_2 shows a slight difference, ranging to values as low as 46% in basalts erupted through Proterozoic basement compared with a minimum of 48% in basalts from the accreted terrain. There are no systematic differences in incompatible element abundances or ratios between the two regions. By contrast radiogenic isotopes are distinct and reflect the difference in the ages of the two lithospheric provinces. Nd model ages calculated from source Sm/Nd ratios derived from trace element inversion procedures indicate source enrichment at 1.5–1.7Ga for basalts from Proterozoic terrain whereas ages of <1Ga are more appropriate for those from the western part of the WGB. Similarly Pb isotopes from areas with Proterozoic basement lie on a linear array in the $^{206}Pb/^{204}Pb$ vs. $^{207}Pb/^{204}Pb$ diagram corresponding to a secondary isochron age of 1.8Ga. This is similar to the age of crustal stabilisation determined from Nd isotope in western US granites and suggests that the whole Proterozoic lithosphere stabilised at $\sim$1.8–1.6Ga. By contrast, Pb isotopes from basalts from the accreted terrain define a much steeper array that does not have age significance, but indicates mixing between distinct end-members, one possibly similar to Proterozoic lithosphere and the other with lower $^{206}Pb/^{204}Pb$ and $^{207}Pb/^{204}Pb$ ratios.

Radiogenic isotopes show coherent variation with incompatible element ratios. In both regions, there is a tendency for $^{87}Sr/^{86}Sr$ to decrease as Zr/Sr increases towards values typical of recent Basin and Range basalts. This has been shown by Ormerod *et al.* (1988) to be related to the northward migration of the margin of the Mendocino triple junction and the development of a slab window beneath the WGB, allowing asthenospheric melts through to the surface. In addition there is also a trend to low $^{87}Sr/^{86}Sr$ and low Zr/Sr and Nb/Sr but this is only seen in the basalts from the accreted terrain. Low HFSE/LILE and $^{87}Sr/^{86}Sr$ ratios are considered typical of fluid-related components released from subducted oceanic lithosphere and it is suggested that much of the isotope variation in the western basalts from the accreted terrain reflects the effects of subduction of the Farallon Plate during the Tertiary.

The major element differences between the WGB basalts and those from the central Basin and Range can be related to pressure of segregation from their mantle source region. Experimental studies (Hirose and Kushiro, 1993) reveal that basalts derived from low pressures are poorer in iron and richer in silica than those from higher pressures and the iron-poor, silica-rich compositions of the WGB basalts relative to those from the B&R indicate a shallower origin. This is consistent with their lithospheric incompatible element (high La/Nb) and radiogenic isotope characteristics and the lack of residual garnet inferred from trace element modelling. Moreover, comparison of the SiO_2 content of calculated primary magma compositions from the Big Pine field in the WGB with that of experimentally-derived melts suggests that the ne-normative basalts originated from pressures of 15–25kb (45–75km depth), within the lithosphere and the stability of spinel lherzolite. Similarly, MgO contents indicate temperatures of generation in the range of 1300–1450°C. Combining these pressure and temperature estimates results in a relatively normal temperature depth profile (Tp ~1350°C). This is similar to the estimate of mantle potential temperature from Bradshaw *et al.* (1993), and endorses their conclusion concerning the absence of a mantle plume beneath the present day western US.

References

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