

GEOCHEMISTRY OF THE ARGYLE LAMPROITE PIPE

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Major and trace element (including REE) abundances have been determined by XRF and INAA, and Sr and Nd isotopic ratios have been measured for the three major rock units ('sandy tuffs' = ST, 'non-sandy tuffs' = NST, and olivine-phlogopite lamproite dykes = OPLD) recognised in the Argyle (AK1) pipe (Atkinson et al 1984a,b; Boxer et al this volume; Jaques et al this volume). The aims of the study were to chemically characterise the Argyle lamproite, examine the chemical relationships between the various units and to compare the chemistry of the Argyle lamproite with lamproites from the West Kimberley (Jaques et al 1984, 1986a,b; Fraser et al 1985; Nelson et al 1986).

Geochemical study of the Argyle pipe is complicated by several factors. Firstly the bulk of the rocks are pyroclastics and the juvenile clasts are dominantly fine (lapilli and ash). Secondly, all three units have undergone low temperature alteration; olivine is totally altered to talc/serpentine, and smectite and secondary titanates (sphene, anatase) are widespread. Thirdly, the ST are polygenetic and show the effects of addition of large amounts of quartz from the country rocks; whole rock compositions of ST lie along mixing lines between country rock quartzite and lamproite approximating NST compositions. All ST data quoted for comparison with the other units refer to the least contaminated ST, i.e. those with the lowest SiO₂ (60-62 wt %) and highest MgO (12-15 wt %) contents.

Several significant observations emerge from the major element geochemistry. All three units have high contents of K₂O (4-6 wt %) and TiO₂ (2-4 wt %) and high K₂O/Na₂O (>25) and K₂O/Al₂O₃ (> 0.75) ratios typical of lamproites. Unlike the West Kimberley lamproites the Argyle rocks are generally not perpotassic. All except oxidised surface samples are magnesian and have high Mg/(Mg+Fe²⁺) ratios (0.76-0.86) consistent with mantle derivation. The NST are the most magnesian containing up to 25 wt % MgO and show the least variation in Mg/(Mg+Fe). Analyses of several of the larger lapilli in ST with petrologic features resembling OPLD show them to be similar to the more Mg-poor OPLD. CaO contents of the Argyle lamproites show a wide range from low values (4-5 wt %) typical of the West Kimberley olivine lamproites to comparatively high values which are attended by high CO₂ contents (5-12 wt %). The Argyle lamproites have very low Na₂O contents (commonly < 0.2 wt %) which probably reflect both low primary values and the effects of leaching; oxidised surface samples are almost totally leached of alkalis. Contents of P₂O₅ and F are high (1-1.5 wt % and up to 0.6 wt % respectively).

The Argyle lamproites are strongly enriched in the incompatible elements K, Rb, Sr, Ba, Pb, Th, U, Ti, Zr, Nb, Ta, Hf, and P, a feature typical of lamproites and micaceous kimberlites. NST and OPLD samples typically contain 300-400 ppm Rb and 750-1250 ppm Sr, and have high Rb/Sr ratios (0.2-0.35). The ST show a much wider range of abundances and abundance ratios but those with the highest juvenile component have ratios similar to the NST and OPLD. Although similar in terms of their Rb/Sr ratios the Argyle lamproites are much less enriched in Rb and Sr than the West Kimberley lamproites. Ba contents in the Argyle rocks show a wide range, probably reflecting secondary alteration, with average values of 1000-1500 ppm. This contrasts markedly with the very high Ba contents of the West Kimberley lamproites which are typically > 5000 ppm (Jaques et al 1984). Pb contents show a large variation reflecting secondary sulphides, especially galena. Th and U contents and Th/U ratios in the NST and OPLD are similar (Th/U = 7-8) and lower than in the West Kimberley lamproites.

Ni and Cr contents are high, particularly in the NST which average 1000 ppm Ni and 1400 ppm Cr: Ni contents in the less Mg-rich OPLD range down to 500 ppm. V (av. 100 ppm), Sc (12-15 ppm) and Y (av. 20-22) contents are low and similar in both the NST and OPLD. Zr and Nb contents are high averaging 630 ppm Zr and 190 ppm Nb in the NST and 840 ppm Zr and 240 ppm Nb in the OPLD. The ST have lower abundances as a result of the included quartz. The NST and OPLD have similar low Zr/Nb and Ti/Zr

ratios (av. 3.3-3.5, 26-27) whereas the ST have slightly higher Zr/Nb and slightly lower Ti/Zr ratios. Hf and Ta contents are high in both the NST and OPLD, the latter having distinctly higher Hf contents (av. 27 ppm cf 18 ppm). Hf/Ta ratios in the most juvenile-rich ST and NST are similar (1.5-2.2) whereas the OPLD extend to slightly higher ratios (2.4).

All three units are strongly enriched in LREE and have highly fractionated REE patterns with low abundances of HREE. La abundances in the NST lie in the range 267-416x chondrites (av. 115 ppm) and abundances are slightly higher in the OPLD (310-470x chondrites, av. 129 ppm) and much lower in the ST. HREE abundances in the NST and OPLD lie in the range 5-7x chondrites whereas the ST with higher proportions of country rock fragments extend to higher values (10x). The NST and OPLD have similar high La/Yb ratios (NST = 76-100, av. 99; OPLD = 65-123, av. 90) whereas the ST have La/Yb ratios which extend from values which overlap the magmatic rocks to much lower ratios (<50).

Trace element data show that the NST and OPLD have very similar abundances and abundance ratios of incompatible elements whereas the ST show a much wider range of abundances due the inclusion of varying amounts of accidental fragments. On incompatible element ratio plots (e.g. Ti/Zr vs Zr/Nb) the ST form a field which overlaps all or part of the other two units. The similarity between all three units in the Argyle pipe is clearly shown on plots of incompatible element abundances normalised to mantle abundances. The patterns are strikingly similar with abundances of incompatible elements in the OPLD some 15 to 30% higher than the NST whereas abundances in the ST are some 10 to 60% lower than the NST. The higher abundances in the OPLD rocks is attributed largely to more differentiated character of the OPLD which contain some 10% (relative) more FeO (Fe as FeO) and about 10% less MgO than the NST. A more fractionated character is consistent with their lack of diamonds compared to the pyroclastic units (Atkinson et al 1984a). The low abundances of the ST reflect the dilution effects of incorporation of variable amounts of material derived from the country rocks. Features of the normalised plots are marked negative anomalies in K, Sr, and P. Similar negative relative anomalies in these elements are exhibited by the West Kimberley lamproites but absolute abundances are much higher. In particular the Argyle lamproites lack the marked overabundance of Ba and Rb shown by the West Kimberley lamproites.

In contrast to the trace element data which strongly suggests that the pyroclastic and magmatic rocks are comagmatic, small differences are apparent in initial Nd isotopic compositions between the NST and the OPLD and clasts in the ST. The NST have initial ϵ_{Nd} values at the time of emplacement (1178 Ma, Sun et al this volume) in the range -3.6 to -4.0 whereas the OPLD have slightly less radiogenic values in the range -4.6 to -5.3. Sr isotopic systematics in at least some of the NST appear to have been disturbed whereas whole rock $^{87}Sr/^{86}Sr$ ratios in the OPLD and magmatic clasts of OPLD-type in the ST are consistent with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7063 defined by apatite concentrates (Sun et al this volume). These small differences in isotopic composition might be due to contamination of the OPLD by Archean crustal materials but the high REE and Sr contents of the lamproites should render them relatively immune to the effects of crustal contamination. A more likely explanation is that these differences reflect small heterogeneities in their source regions, such as are observed within individual fields in the West Kimberley (Jaques et al 1986a), and/or small differences in magma generation processes such as slightly differing degrees of partial melting or reaction with wall-rocks.

Although the style of enrichment is very similar (the same elements are involved) the degree of enrichment in incompatible elements exhibited by the Argyle lamproites is much less than that shown by the West Kimberley lamproites. This is evident in the much lower abundances, particularly of Ba and La, and lower Ba/La, Th/U, La/Nb, and La/Ta, and higher K/Rb and K/Ba ratios in the Argyle rocks. The level at which the West Kimberley lamproites are enriched relative to the Argyle rocks is not uniform. Ti and K abundances in the Argyle rocks are approximately 0.8x those in the Ellendale olivine lamproites whereas Rb and Zr abundances are approximately 0.6x and La and Th abundances approximately 0.3x those in the Ellendale olivine lamproites. Nevertheless, both lamproites suites appear to have been formed by similar processes and model calculations suggest that both lamproite suites could have been derived from the same type of enriched lithosphere sources formed >2000 Ma. This enrichment is inferred to have been superimposed on a formerly depleted, refractory peridotite as evidenced by

the very low Al, Ca, Na, Y, Sc and V abundances in the lamproites themselves and by the refractory nature of the peridotitic xenoliths and xenocrysts (Jaques et al 1984, this volume; O'Neill et al this volume). The discovery of large-ion-lithophile element enriched titanates in the Argyle concentrates (Jaques et al this volume) is consistent with metasomatic enrichment of the source. The presence of eclogitic xenocrysts in concentrates from the pipe and the dominance of eclogitic paragenesis inclusions including pyroxenes with very high K contents in Argyle diamonds (Hall and Smith 1984; Jaques et al this volume) suggests that eclogitic sources are also involved.

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REFERENCES

- ATKINSON W.J., HUGHES F.E. and SMITH C.B. 1984a. A review of the kimberlitic rocks of Western Australia. In Kornprobst J. ed, **Kimberlites 1: Kimberlites and Related Rocks**, pp. 195-224. Elsevier, Amsterdam.
- ATKINSON W.J., SMITH J.B. and BOXER G.L. 1984b. The discovery and geology of the Argyle diamond deposits, Kimberley, Western Australia. **Australasian Institute of Mining and Metallurgy**, Darwin Conference, 1984, pp. 141-149.
- 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 Planetary Science Letters** 76, 57-70.
- HALL A.E. and SMITH C.B. 1984. Lamproite diamonds - are they different?. In Glover J.E. and Harris P.G. eds, **Kimberlite Occurrence and Origin: A Basis for Conceptual Models in Exploration**, pp. 167-212. Geology Department and University Extension, University of Western Australia, Publication No. 8.
- JAQUES A.L., CHAPPELL B.W., SUN S-S., LEWIS J.D. and SMITH C.B. 1986a. The West Kimberley lamproites: intraplate volcanism of extreme character. (Abstr.) **International Volcanological Congress, New Zealand**. p. 171.
- JAQUES A.L., LEWIS J.D. and SMITH C.B. 1986b. The kimberlitic and lamproitic rocks of Western Australia. **Geological Survey of Western Australia Bulletin** 132.
- JAQUES A.L., LEWIS J.D., SMITH C.B., GREGORY G.P., FERGUSON J., CHAPPELL B.W. and McCULLOCH M.T. 1984. The diamond-bearing ultrapotassic (lamproitic) rocks of the West Kimberley region, Western Australia. In Kornprobst J. ed, **Kimberlites 1: Kimberlites and Related Rocks**, pp. 225-254. Elsevier, Amsterdam.
- NELSON D.R., McCULLOCH M.T. and SUN S-S. 1986. The origins of ultrapotassic rocks as inferred from Sr, Nd and Pb isotopes. **Geochimica et Cosmochimica Acta** 50, 231-245.