MINERALOGY AND PETROLOGY OF THE ARGYLE LAMPROITE PIPE, WESTERN AUSTRALIA

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PETROGRAPHY

The richly diamondiferous Precambrian Argyle lamproite pipe in the East Kimberley region of Western Australia has been described by Atkinson et al (1984a,b) and Boxer et al (this volume). The pipe is composed of olivine lamproite volcaniclastic rocks intruded by olivine (-phlogopite)lamproite dykes. The volcaniclastic lamproites consist of two basic types: polygenetic lapilli ash tuffs and ash tuffs ('sandy tuffs') composed of juvenile fragments of olivine lamproite with abundant accidental, rounded quartz grains and fragments of dissaggregated country rock sandstone, and largely monogenetic olivine lamproite lapilli tuff, hyaloclastite, and autobreccia of hydroclastic origin ('non-sandy tuff'). The juvenile clasts range from dense, blocky, poorly vesiculated, porphyritic types to highly vesiculated vitric clasts including pumice and fiamme. Many of the vitric lapilli are cored, typically by altered olivine macrocrysts, and many contain quartz grains and lithic fragments.

All the juvenile clasts contain two generations of olivine which is now entirely altered to talc±carbonate±sulphide or serpentine-septechlorite+magnetite - anhedral to resorbed macrocrysts up to 5 mm and smaller euhedral phenocrysts and microphenocrysts. The phenocrysts and microphenocrysts commonly contain tiny inclusions of chrome spinel, and in the vitric clasts, exhibit skeletal forms, particularly hopper types. The former olivine crystals are set in a groundmass which in the vitric clasts contains only tiny spinel euhedra in a serpentinous base (former glass and palagonite) whereas dense porphyritic types contain spinel, former leucite (now K-feldspar±talc±smectite), phlogopite, apatite, and oxide phases. The lamproite dykes consist of altered olivine, phlogopite, spinel, apatite, K-feldspar, and oxide phases.

MINERALOGY

Mica is characterised by low Al and high Ti contents (2-9 wt % Al_2O_3 and TiO_2) and moderate enrichment in Fe (9-14% FeO, Mg/(Mg+Fe) < 0.8). Most have low Cr, Na and Ba, and moderate F contents (<0.2 wt % Cr_2O_3, up to 0.6 wt % BaO and 2 wt % F). The Argyle micas are typical of lamproite micas but show less variation than, and are more Fe-rich than, the majority of the West Kimberley micas (Jaques et al 1986).

Chrome spinel is the most common macrocryst phase recovered in Argyle concentrates. The macrocryst spinels are distinguished from the groundmass spinels by their larger size, irregular shape, and uniformly magnesian, Ti-poor (<1 wt % TiO_2) compositions which range from magnesian aluminous chromite through to magnesiochromite with up to 67 wt % Cr_2O_3. The groundmass spinels are mostly titaniferous magnesiochromites (TMC) and titaniferous chromites (TC) containing 3-4 wt % TiO_2, 50-60 wt % Cr_2O_3, and 5-15 wt % MgO but rare grains of titaniferous aluminous magnesiochromite (TMAC, 14 wt % Al_2O_3, 16 wt % MgO) also occur as discrete groundmass grains and as inclusions in olivine. Individual grains are zoned from cores of TMAC or TMC through more Al-poor, Fe-rich TMC or TC to rims enriched in titanomagnetite. The evolutionary trend of the Argyle groundmass spinels is therefore one of decreasing Al and Mg and increasing Cr and Fe^{2+} followed by increasing Fe^{2+}, Ti and Fe^{3+}. The trend toward titaniferous magnetite is much less marked than shown by spinels from the West Kimberley lamproites.

Ilmenite occurs as ragged, irregular anhedra up to 200 um across of late-stage primary origin in the groundmass of many of the magmatic rocks and in the juvenile clasts where it ranges in modal abundance from 1 to 10 vol. %. MnO contents are high (3-8 wt %) and MgO and and Cr_2O_3 contents low (<1 wt % and < 0.5 wt %). Sphene is widespread in the groundmass where it occurs as granular subhedra and rims on ilmenite. Compositions are close to stoichiometric with low Al, Fe and Na but variable amounts of

Sr. Anatase and rutile occur as discrete granules and granular aggregates, commonly in association with Mn-ilmenite. Compositions show variable amounts of Nb (up to 2.5 wt % Nb_2O_5) and subordinate Fe. A number of other phases are present mostly occurring as groundmass phases of probable secondary origin. These include ZrTiFe-silicate and LaCe-titanate; zircon is also present. Sulphide phases include pentlandite, pyrrhotite, chalcopyrite, pyrite, sphalerite, and galena.

Priderite occurs as small euhedral crystals in the groundmass of juvenile clasts and in magmatic lamproite where it is commonly associated with ovoid blebs of carbonate in association with Mn-ilmenite and rutile. The priderites show several unusual compositional features: 1) high V contents (1.3-1.5 wt % V_2O_3), 2) high Ce_2O_3 contents (0.4-2.7 wt %; Table 1, 1-4), 3) K:Ba ratios vary widely between grains and some are strongly zoned (Table 1, 2-3), and 4) end-member K-priderite is present in some rocks (Table 1, 4). The V-Ce-priderite is comparable with a similar phase described by Mitchell and Haggerty (in press) from a Type 2 kimberlite at New Elands, South Africa (Table 1, 9).

Priderite (confirmed by X-ray analysis) was also found as a 0.5 mm grain in heavy mineral concentrate from the pipe. It is also end-member K-priderite but unlike the groundmass grains contains some 9 wt % Cr_2O_3 and substantially lower contents of Ce_2O_3 and Fe with V below detection limits (Table 1, 5). Chromian-armalcolite is present (Table 1, 6), enclosed within the K-Cr-priderite grain. The assemblage is interpreted as an upper mantle xenocryst.

An as yet unidentified opaque titanate (Table 1, 7) with a composition similar to mannardite-redledgeite series $(Ba.H_2O)(V,Cr)_6O_{16}$ occurs in association with talc replacing olivine. This phase is very similar (Table 1, 8) in the A-formula Ba site to a minor phase reported from the Benfontein kimberlite-carbonatite sills by Scatena-Wachel and Jones (1984) with the exception that the small cation B-formula site is dominated by Fe^{3+} rather than Cr and V.

Table 1. Electron microbeam analyses of LIL-titanates.

	1	2	3	4	5	6	7	8	9	10
SiO_2	0.19				0.00		0.83	1.9-3.6	0.19	0.37
TiO_2	71.47	76.67	71.97	81.29	72.66	76.77	53.64	51-54	78.47	71.90
ZrO_2	0.01	0.10	0.07	0.10	0.19	0.51	0.04	0.4-0.5	0.06	0.01
Al_2O_3	0.00	0.00	0.00	0.00	1.02	0.88	0.02	1.0-1.7	0.00	0.04
Cr_2O_3	0.00	0.00	0.00		9.06	9.12	3.49		0.00	8.38
V_2O_3	1.36	1.66	1.50	1.32	0.00		5.35		1.65	
Fe_2O_3								15.6-16.1	7.10	
*FeO	7.98	7.37	8.39	6.48	3.32	6.16	5.49			4.38
MgO	0.01	0.00	0.00	0.00	0.96	5.59	0.63	2.1-3.4	0.53	1.23
MnO	0.04	0.01	0.05	0.00	0.00	0.06	0.00		0.00	0.00
CaO	0.00	0.50	0.54	0.33	0.00		0.00	1.3	0.34	0.54
SrO					0.00					
BaO	11.07	5.66	12.09	0.94	0.93		20.82	16.1-16.7	1.19	0.83
Na_2O	0.04				0.03		0.08		0.00	0.48
K_2O	4.65	6.24	3.52	7.40	9.33		0.00		9.63	9.39
Nb_2O_5					0.17	0.21		1.6		
Y_2O_3					0.00					
La_2O_3	0.00	0.00	0.00	0.00	0.00		0.00			
Ce_2O_3	2.24	1.14	2.69	0.39	0.29		3.97	0.5	0.70	
Other					0.22+		#			
Total	99.06	99.35	100.82	98.25	98.18	99.30	94.36	94-96	99.86	97.55

*Fe as FeO, +Ta_2O_5, #Sc present in spectral scans

Rare chrome diopside and enstatite, and very rare garnet have been recovered from concentrates. The chrome diopsides are Mg-rich, very poor in Al_2O_3 and Na_2O (commonly < 1 wt %), and have high Ca/(Ca+Mg) ratios, and belong to Stephens and Dawson group 5. The enstatites also have very low Al contents. The garnets are almandine-pyrope, titanian and chrome pyrope belonging to Dawson and Stephens cluster groups 3, 1 and 9. The chrome pyropes are calcium-saturated, contain up to 6 wt % CaO and Cr_2O_3, and are similar to those recovered from the West Kimberley lamproites (see Jaques et al 1986).

DISCUSSION

The Argyle macrocryst assemblage, like that of the West Kimberley lamproites, is dominated chrome spinel and diamond. The compositions of the spinels, pyroxenes and garnets in the two provinces are similar and the chrome spinels and pyroxenes are compositionally similar to the phases observed in rare altered peridotite xenoliths recovered from the Argyle pipe (O'Neill et al this volume). A feature of the xenoliths and xenocrysts is their highly refractory chemistry and this suggests that both provinces are underlain, at least in part, by reduced, refractory (olivine-rich, garnet and pyroxene-poor) peridotite.

The K-Cr-priderite discovered in the Argyle concentrate is very similar to the phase (Table 1, 10) reported by Jones et al (1982) in their study of metasomites from the Bultfontein kimberlite. The association and composition of armalcolite is very similar to the LIMA settings at Bultfontein and Jagersfontein (Haggerty et al 1983; Haggerty, 1983), and it is noteworthy that it too bears the depletion signature of substantial Cr_2O_3 (9 wt %). The discovery of LIL-titanate of similar composition to phases found in metasomites from the Kaapvaal craton provides the first direct evidence of LIL enrichment of the lithosphere beneath the Kimberley craton. Such enrichments have previously been proposed on the basis of the lamproite geochemistry and isotopic constraints (Jaques et al 1984, this volume; Nelson et al 1986). The high Cr contents in LIL-titanates from Argyle and several localities in South Africa are interpreted to indicate similar histories for the Kaapvaal and Kimberley cratons, viz. LIL enrichment of a previously depleted (refractory) subcontinental lithosphere.

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