GEOLOGY, PETROLOGY AND GEOCHEMISTRY OF THE BOW HILL LAMPROPHYRE DYKES, WESTERN AUSTRALIA

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The Bow Hill dykes, a swarm of micaceous ultramafic and mafic lamprophyres, occur at long. 128° 13' E, lat. 16° 43'S, some 125km SW of Kununurra and 22 km W of the Argyle (AK1) pipe, in the East Kimberley region of Western Australia (Fig. 1). They were discovered by the Ashton Joint Venture in 1980 after detrital andradite garnet and lamproitic chromite were recovered in routine stream sediment sampling (Atkinson et al 1984). The suite intrudes Early Proterozoic Bow River Granite of the Lamboo Complex. Rb-Sr and K-Ar dating of phlogopites suggest an an emplacement age for the dykes of 815 Ma (Pidgeon et al this volume). However, this age is approximately 100 my younger than obtained by Rb-Sr based on whole rock samples with the initial ratio (0.7057) defined by clinopyroxene separates (Sun et al this volume).

Eight individual dykes ranging in thickness from a few cms to 13m and up to 2 km long are emplaced en-echelon over a strike length of 19 km. The strike direction is NNE and sub-parallel to the major structures within the Halls Creek Mobile Zone such as the Dunham Fault (Fig. 1). Exposures are poor and the dykes deeply weathered. The dykes are surrounded by a marked fenite zone up to several meters wide in which chlorite and alkali amphibole are conspicuous. Alteration farthest from the dykes

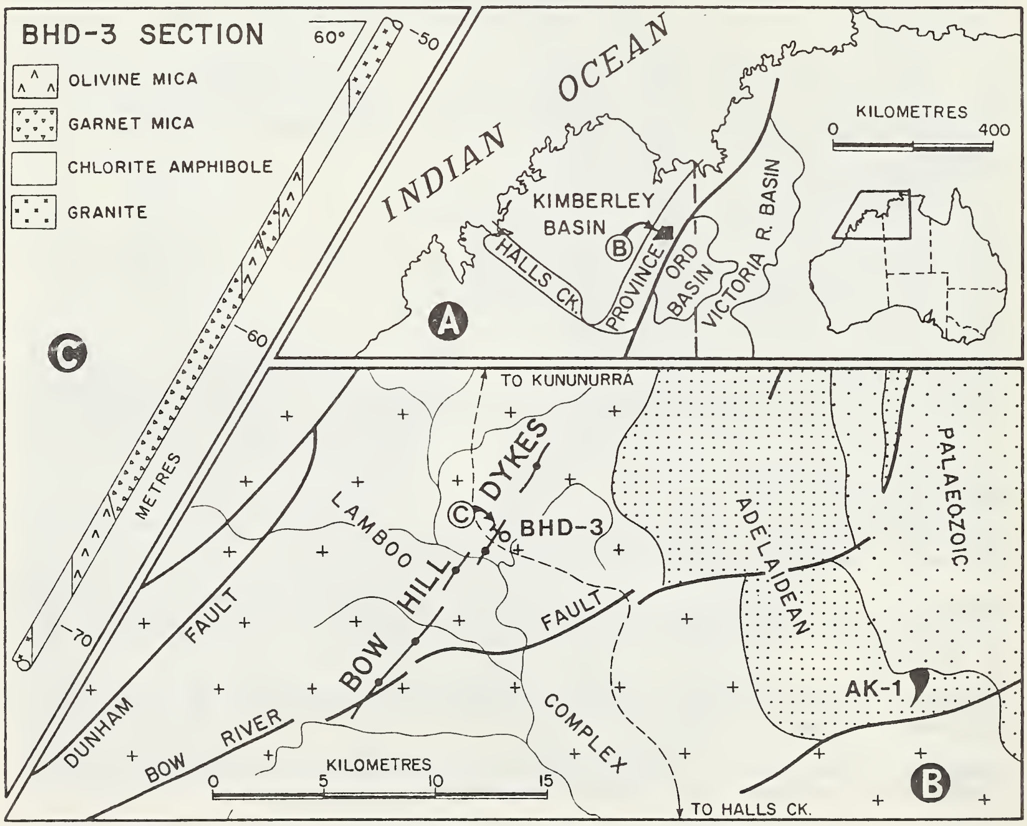

FIGURE I BOW HILL LAMPROPHYRE DYKES
Ⓐ GENERAL LOCATION & TECTONIC SETTING. Ⓑ LOCAL GEOLOGY. Ⓒ CORED SECTION 'BHD-3'.

consists of sericitisation of feldspar and replacement of mica in the granite by chlorite. Closer to the contact alteration is more intense with extensive development of alkali amphibole, in most cases pale magnesio-arfvedsonite. In the most strongly altered zones the granite is cut by numerous veinlets composed of strongly zoned clinopyroxene, alkali amphibole and alkali feldspar (see below), and alkali amphibole and chlorite are widespread.

Three main rock types are present in the dykes: 1) fine-grained ultramafic contact zone rocks at the margins of the dykes containing abundant chlorite, sodic amphibole, alkali feldspar and, commonly, alkali pyroxene; 2) ultramafic olivine-phlogopite lamprophyre, and 3) garnet-phlogopite pegmatite. The olivine-phlogopite lamprophyre consists of abundant coarse serpentinised olivine and large plates of pleochroic mica together with granular to prismatic clinopyroxene and lesser amounts of carbonate, apatite, dark red brown perovskite, spinel, trace rutile and Mn-ilmenite, and richteritic amphibole, commonly replacing pyroxene. The ultramafic olivine-phlogopite lamprophyre grades into and in places is cut by segregation veinlets containing abundant prismatic diopside strongly zoned to green aegirine-augite together with apatite, calcite, clinozoisite and sphene. These rocks are petrologically similar to those found at the contact and in veins some of which, in addition to the zoned pyroxene and epidote, contain abundant interstitial alkali feldspar. The garnet-phlogopite pegmatites, which are in places banded, occur both near the margins and in the inner portions of the dykes. The relative proportions of the garnet-phlogopite pegmatite and olivine-phlogopite lamprophyre are uncertain: drilling showed that in one dyke the pegmatite occupied the entire central portion of the dyke and and comprised nearly half of the dyke (Jaques et al 1986). The pegmatites are coarsely crystalline and composed of abundant phlogopite up to 4 mm long and large (up to 1 cm) anhedral, poikilitic garnet which displays spectacular zoning from dark red-brown melanite cores through to colourless andradite rims. Other phases present include diopsidic clinopyroxene, carbonate, apatite, clinozoisite, sphene, and richteritic amphibole.

Microprobe analyses show the olivines are highly magnesian ($Mg_{92-92.8}$). The micas show a wide range of compositions from rare Ti-rich biotite cores (Mg_{62-66}, 6 wt % TiO_2) to more typical Al-rich phlogopite (13-15 wt % Al_2O_3, Mg_{89-76}) with variable TiO_2 contents (0.2-3.6 wt %) to thin rims of tetraferriphlogopite with low Ti and Al. The pyroxenes range from Na-Al-poor diopside microphenocrysts to aegirine-augite (up to 6 wt % Na_2O). The spinels range from titaniferous chromite with up to 55 wt % Cr_2O_3 through to more abundant Mg-poor titaniferous magnetite. Ilmenite is a late-formed accessory and contains up to 12 wt % MnO. The groundmass garnets show a wide range in composition and zoned from melanite-schorlomite cores with up to 14 wt % TiO_2 and appreciable Zr and Nb to andradite rims with less than 1 wt % TiO_2. The amphibole is pale to colourless richterite with up to 1.6 wt % K_2O.

Macrocryst minerals recovered from concentrates include chrome spinel, garnet, chrome diopside, and rare enstatite. The chrome spinels range in composition from magnesian aluminous chromite (up to 40 wt % Al_2O_3) through to magnesiochromite with up to 60 wt % Cr_2O_3. The garnets are dominantly chrome pyropes (^{2} 6 wt % Cr_2O_3) and calcic pyrope almandines belonging to Dawson and Stephens (1975) cluster groups 9 and 3. The chrome diopsides contain up to 1.8 wt % Cr_2O_3 and have moderate Al_2O_3 contents (1.5-3 wt %). No diamond was recovered in the bulk sampling program.

The Bow Hill dykes show a wide range in composition. The olivine phlogopite lamprophyres are ultrabasic (40-44 wt % SiO_2) and rich in MgO (20-22 wt %) with high Ni and Cr contents (900-1300 ppm). They are mildly peralkaline and contain a little nepheline, leucite and acmite in their CIPW norm. The garnet-phlogopite pegmatites are poorer in MgO (15-5 wt %) and richer in CaO (13-25 wt %) and Al_2O_3 (7-10 wt %). All have high K_2O/Na_2O ratios (5-20) with K_2O contents ranging up to 5.5 wt % in the olivine phlogopite lamprophyres.

The Bow Hill dykes, particularly the garnet-phlogopite pegmatites, are enriched in incompatible elements, particularly Ba, Rb, Ti, Nb, and F. Trace element abundance ranges in the olivine-phlogopite lamprophyres are: Ba = 2500-3000 ppm, Rb = 250-350 ppm, and Zr and Nb = 70-130 ppm, whereas comparable ranges in the garnet-phlogopite pegmatites are: Ba = 4500-5500 ppm, Sr = 500-3000 ppm, and Zr and Nb = 40-1000 ppm. F contents lie in the range 0.4 to 0.65 wt %. Features of the Bow Hill dykes are their very low Zr/Nb ratios and very high Rb/Sr ratios in the olivine phlogopites (both near 1). Zr contents decrease from olivine-phlogopite lamprophyre to the garnet-mica pegmatite, reflecting crystallisation of Zr-rich garnet. The Bow Hill dykes are strongly enriched in LREE (200-700x chondrites) and have highly fractionated REE patterns with very low abundances of Sc (10-25) and HREE (3-5x chondrites) similar to kimberlites.

Both kimberlites (Maude Creek, Devil's elbow) and lamproites (Argyle, Lissadell Road dykes) are known from the East Kimberley region (Atkinson et al 1984; Jaques et al 1986). The Bow Hill dykes display petrologic and geochemical differences to both, notably in the association of fenite and the presence of sodic amphibole and pyroxene, melanitic-andraditic garnet, sphene, and clinozoisite. The dykes have many of the petrologic features of ultramafic lamprophyres (Rock 1986), particularly aillikites rather than alnoites since melilite is lacking, but are not as silica undersaturated. They are also richer in MgO and K_2O and have higher K/Na ratios than is typical of most ultramafic lamprophyres, and therefore lie between micaceous kimberlite and ultramafic lamprophyre. The Bow Hill dykes, nevertheless, possess many of the features of ultramafic lamprophyres and, like them, are considered to have affinities with lamprophyre-carbonatite suites. In partiuclar, similarities in age and Nd isotopic composition (Bow Hill ε_{Nd} at 900 Ma = +2, Sun et al this volume) suggest that the Bow Hill dykes may be related to the Cummins Range carbonatite (Andrews et al this volume) which lies some 350km to the south at the intersection of the Halls Creek and King Leopold Mobile Zones. The distribution and form of the Bow Hill dykes i.e. en-echelon dykes parallel to major structures, indicates a strong structural control by earlier (early Proterozoic) left-lateral faults and suggests emplacement in a tensional environment. Such an environment may have been generated locally during reactivation of the older fundamental fractures or, alternatively, the reactivation might be associated with limited crustal extension at the eastern and northern margins of the Kimberley craton.

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