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The Cummins Range carbonatite, discovered by CRAE in 1978, lies on the southern margin of the Kimberley craton at the junction of the Proterozoic Halls Creek and King Leopold Mobile Zones (latitude  $19^{\circ}$  07'S, longitude  $127^{\circ}$  10'E). The carbonatite complex intrudes Precambrian metasediments and granite gneisses as a zoned, vertical stock. In plan, the complex has the shape of an asymmetrical rhomb with dimensions of 1.7 x 1.8km and a surface area of 18.6 ha. The complex is deeply weathered and exposure is very poor, being limited to a few isolated low mounds of silicified limonitic collapse breccia in the centre of the intrusive. Elsewhere the complex is very poor, the complex is deeply a blanket of aeolian sand 0.5 - 15m thick. Although surface expression is very poor, the complex is easily recognised by a marked 4900nT bullseye magnetic anomaly.

The margins of the complex have not been intersected with drilling but airborne and ground magnetic data indicate that the contacts are sharp and vertical to steeply dipping with strike directions of 040° or 140°, parallel to the two Proterozoic Mobile Zones. This suggests that the emplacement of the complex was controlled by major basement fractures.

The complex is of late Proterozoic age. An age of  $905 \pm 2$  Ma has been obtained from the Rb-Sr method on phlogopite - whole rock and phlogopite-apatite separates with an initial 87Sr/86Sr ratio of  $0.7030\pm0.0002$  (Sun and others, this volume). This date is in agreement with the  $854\pm57$  Ma age obtained by the K-Ar method on pyroxenes, but differs from the  $1012\pm3$  Ma age obtained by U-Pb dating of zircons (Pidgeon and others, this volume). The U content of these zircons is very low but the 208Pb and Th contents were high, distinguishing them from zircons in kimberlites and basic metamorphic rocks.

Drilling has revealed that the intrusion consists of three broadly concentric zones. A small central carbonatite plug is surrounded by an inner zone of carbonated, mica-rich, altered pyroxenite, now largely composed of amphibole, which passes into an outer zone of unaltered pyroxenite. The exception to this concentric pattern is a 300 x 500m satellite body of carbonated, mica and amphibole-rich rock on the eastern side of the complex. This satellite body may also have at its core a small carbonatite plug, thus explaining the anomalous alteration pattern. The inner, strongly altered and carbonated zone with abundant amphibole is cut by numerous carbonatite intrusions. The carbonatite intrusives are steeply dipping and have a discontinuous ring-dyke or cone-sheet morphology with variable thickness up to 60m. The altered pyroxenite (amphibolite) passes outwards into unaltered pyroxenite as the density of ring dykes and cone sheets decreases. The unaltered pyroxenite occupies more than half of the complex and may, in fact, be a composite body. Two other major rock types have been recognised within the complex: a silicified, limonite-rich collapse breccia and chlorite schist. The breccia is interpreted as being the weathering product of the central carbonatite plug and of the larger carbonatite dykes. The chlorite schist is thought to represent Precambrian basement rafted into the complex during intrusion.

The carbonatites include both sovite and beforsite. They range from massive to laminated, coarse grained, equigranular textured types containing abundant apatite and variable amounts of phlogopite, magnetite and clinopyroxene to finer grained, more recrystallised types with marked foliation and lineation containing abundant alkali amphibole and chlorite. Sulphide-rich vugs and veins up to several centimetres wide containing pyrite, pyrrhotite, chalcopyrite and occasionally, barite and fluorite are common. Other phases occurring as accessories in the carbonatite plug and dykes include zircon, sphene, baddeleyite, monazite, aeschynite, pyrochlore, columbite and allanite. The carbonated, altered, mica-and amphibole-rich pyroxenite varies greatly in its mineralogy, grain size and texture. It commonly consists of granular, pale green clinopyroxene (mainly diopside) and coarse mica (dark, turbid biotite cores enclosed by phloopite) rimmed and replaced to varying extents by lineated, fibrous alkali amphibole (dominantly richterite), chlorite and calcite intergrown with the same suite of accessory minerals found in the carbonatite. Additional accessory minerals are ilmenite, bastnaesite and thorianite. The relative proportions of mineral phases and degree of carbonate alteration vary greatly. The calc-alteration is first recognised by amphibole. This advances to a stage where microveins of carbonate form in cleavage planes of the mafic minerals, interstitial carbonate becomes commoner and pyroxene is replaced by amphibole and chlorite. As alteration intensifies, pyroxene is completely replaced by amphibole and chlorite, the density of microveining increases and the original pyroxenite textures are destroyed by the dominance of interstitial carbonate which constitutes most of the matrix. In extremely altered rocks, the concentration of carbonate increases to a level where the rock is classified as a carbonatite.

The unaltered pyroxenite is also characterised by variable mineralogy, grain size and texture. The pyroxenite ranges from clinopyroxenite to micaceous clinopyroxenite composed of granular, dominantly diopsidic pyroxene, mica (dominantly phlogopite), magnetite, apatite, calcite and dolomite with accessory baddeleyite, sphene, ilmenite, monazite, zircon, zirconolite, pyrite, pyrrhotite and chalcopyrite. The accessory minerals tend to be more abundant in the pegmatitic phases of the pyroxenite.

The pyroxenes show a wide compositional range from diopside through salite, ferro-augite, augite and aegirine; all are characterised by low Al and very low Cr contents. The micas lie in the range Mg 85 - 45, have moderate Ti and Al contents  $(1-2\% TiO_2, 10-14\% Al_2O_3)$ , very low Cr and low Ba, Na and F (up to 0.5\% BaO, 1% Na2O, 3\% F). In weathered zones the micas become hydrated, and are hydrobiotites or, less commonly, vermiculites. The amphiboles are alkali-rich, ranging from sodic-calcic (richterite) compositions with moderate Al contents  $(6-8\% Al_2O_3)$  to strongly pleochroic, mauve coloured, sodic amphibole (magnesioriebeckite) with lower Mg/(Mg + Fe), very low Al and higher F contents. The carbonate phases range in composition from calcite through magnesian calcite to dolomite with Fe and Mn dolomite occurring as minor phases. The pyrochlore is commonly uraniferous and, in some samples, Ba-rich.

The Cummins Range complex exhibits a wide range of bulk compositions which reflect the varying modal proportions of specific phases such as apatite. The silicate rocks of the Cummins Range complex have a range of aggaitic indices (0.88-2.1) and  $K_20$ contents commonly exceed Na<sub>2</sub>O. Like carbonatites elsewhere the Cummins Range rocks are strongly enriched in P, Sr, Zr, Nb, Ta, Th, U and LREE. Zr and Nb contents, for example, range from 700 and 200 ppm respectively in the pyroxenite to 5000 ppm Zr and 1400 ppm Nb in baddeleyite-rich zones, whereas some of the coarser grained carbonatites contain less than 10 ppm Zr. Rb abundances are low in all Cummins Range rocks whereas Sr varies with the modal proportion of apatite, reaching 1.27% SrO in an apatite-rich carbonatite. Sr and Nd isotopic data indicate that the Cummins Range carbonatite was derived from mantle sources with near-chondritic Rb/Sr and Sm/Nd ratios (Sun and others, this volume), and it is suggested that the Cummins Range carbonatite may be related to the Bow Hill lamprophyre dyke swarm in the East Kimberley region (Fielding and Jacques, this volume), which is of comparable age.

The oxidised zone over the complex is of particular interest because it hosts LREE, Nb, U and P mineralisation. Weathering has involved leaching, dissolution and silicification of carbonates and alteration of the silicate minerals to clays. These processes have resulted in the physical concentration of resistant minerals such as monazite, apatite, zircon and pyrochlore to levels many times greater than in the primary rock types. Element concentrations in the enriched zone can reach 3.8% Ce, 3.1% La, 431 ppm Eu, 0.39% Nb, 350 ppm Y and 120 ppm U. This style of physical concentration has also been noted at the Sukulu carbonatite, Uganda (Reedman, 1984) at Mrima Hill, Kenya (Deans, 1966) and at Magnet Cove, Arkansas (Rose et al. 1958). Secondary monazite may also be present.

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