VOLCANOLOGY OF THE ELLENDALE DIATREMES

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INTRODUCTION

More than 100 Miocene lamproites occur in the West Kimberley (Jaques et al, 1984), and are spread over a 7500 sq km triangular area from Ellendale to Noonkanbah to beyond Fitzroy Crossing. A few are emplaced into Lower Proterozoic granites and metamorphics of the King Leopold Mobile Zone; the majority intrude Phanerozoic sediments of the Lennard Shelf and Fitzroy Trough, at the north eastern margin of the Canning Basin. Forty eight lamproites occur in the Ellendale Field on the Lennard Shelf (Atkinson et al, 1984), 43 of them aligned with the Oscar Fault (one of the major step faults bounding the Fitzroy Trough) in an elongate belt 40 km long by 10 km across and trending at 305°. The Fitzroy Trough started forming in the Ordovician, with major graben development in the Devonian. Sedimentation continued until the Triassic, during which the early structures were reactivated with strong right lateral and vertical movements on the graben step faults.

DESCRIPTION OF THE DIATREMES

The lamproites range from leucite lamproite, containing variable amounts of phlogopite, diopside, richterite and usually less than 5% modal olivine, to olivine lamproite with no leucite, variable amounts of phlogopite, diopside and richterite and typically about 30% modal olivine. The leucite lamproites typically contain 50 - 55 wt % SiO_2 and would be relatively viscous, compared to the olivine lamproites with usually 35% - 42% wt % SiO_2. H_2O+ contents are high, ranging from 2 wt % to 7 wt % from leucite to olivine lamproite, and CO_2 contents are low usually less than 0.25 wt %. Of the 46 Ellendale occurrences 14 are classifiable as olivine lamproites, 28 are leucite lamproites and 4 are transitional rock types with modal olivine contents of ±20% and appreciable quantities of leucite also present.

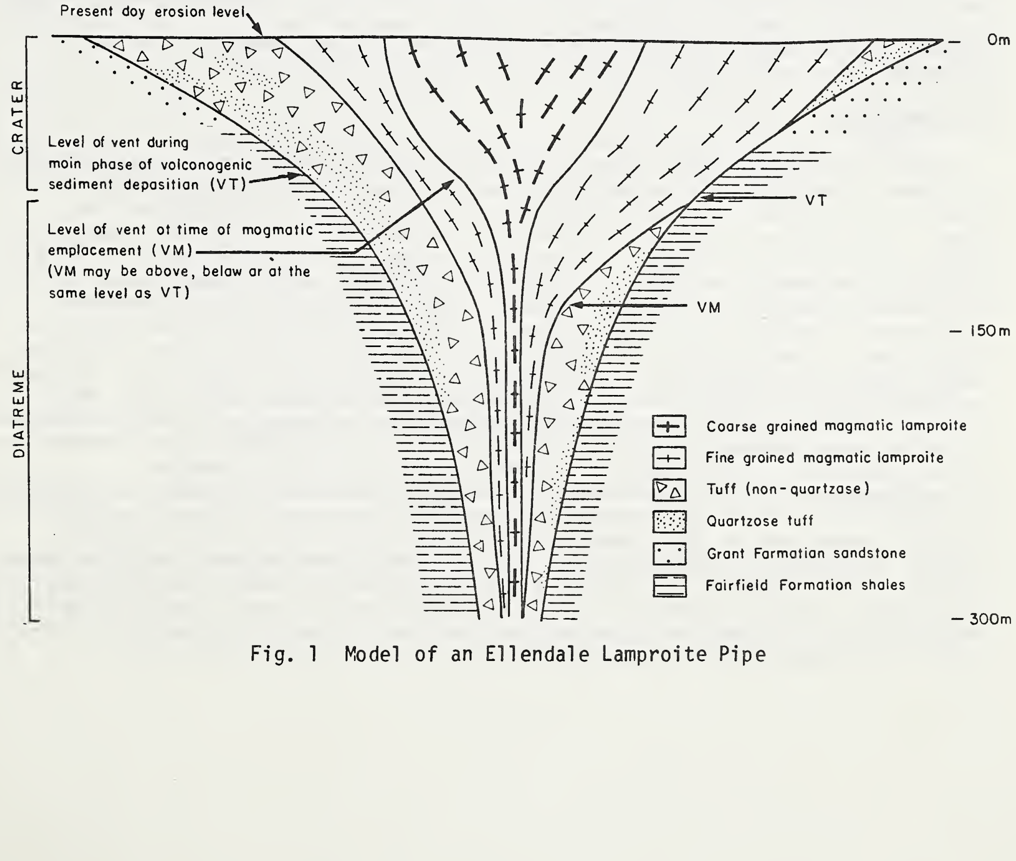

Fig. 1 Model of an Ellendale Lamproite Pipe

Most of the Ellendale diatremes are emplaced into Permian Grant Formation sandstone which overlies Devonian/Carboniferous shales of the Fairfield Formation. The Grant Formation is a good local aquifer. A zone of indurated sandstone often borders the diatremes and can form rocky hills up to 80m high, indicating the minimum amount of post-intrusion erosion that has taken place at Ellendale. Structurally the sandstone is undisturbed adjacent to the contact and preserves it regional subhorizontal disposition. In size the Ellendale diatremes range upwards from less than 1 ha (under 100 metres diameter) to 113 ha (more than 1 km across). About 1/3 of the bodies are larger than 10 ha. Many of the diatremes are elongate in plan view with long axis a little north of west. The typical Ellendale diatreme is champagne-glass shaped, having a narrow feeder vent corresponding to the stem of the glass, overlain by a broad, shallow crater (Fig. 1). In plan view individual bodies are essentially oval or circular but often assume complex shape through the coalescence of adjacent craters. The earliest volcanogenic beds within the crater sequence are often thinly bedded white mudstones and sandstones showing soft-rock deformation structures such as slump folding and microfaulting. Interbedded thin horizons containing juvenile lamproite clasts testify to their volcanogenic nature. They are overlain by varying thicknesses of quartz-rich tuffaceous sandstones and lapilli ash-tuffs. The content of juvenile lamproite lapilli increase upwards, as the quartz sand content decreases, but there are occasional oscillations. The upper (younger) part of the sequence is free of quartz sand and generally massive in texture with bedding evidence restricted to gross changes in grain size, imbrication of clasts, and vague colour differences. Country rock clasts are angular and predominantly composed of Fairfield Group shale, occasional limestone and lesser amounts of Grant Group sandstone. Fossil wood fragments occur, carbonised or silicified, and probably represent Miocene trees growing just outside the crater at the time of the eruptions. They testify to epiclastic deposition. Crystalline basement fragments are rare but include schist, metabasics and granite. This implies that the diatremes extend well down into the Fairfield Group, but the explosive volcanism did not generally reach down the 1000m to the basement.

Final stages in the volcanism show magma rising up the conduit into the centre of the craters where it spread out to form a lava lake or dome. The magmatic lamproite overlies the crater sediments, and may even overlap onto country rock. The base of the magmatic lamproite is highly vesicular and brecciated, and incorporates clasts from underlying crater sediments. The more viscous leucite lamproite shows streaky flow banding, passing downward with increasing brecciation into a lamproite breccia. The upper and central part of the magmatic section is coarser grained than the lower, the junction being a sharp intrusive contact at certain leucite lamproites and yet gradational at olivine lamproite pipes.

VOLCANOGENESIS

At nearly all Ellendale pipes volcanic activity commenced with a phreatomagmatic phase when rising lamproite magma interacted explosively with copious amounts of groundwater from the rather unconsolidated sands/sandstones of the Permian Grant Group. A maar formed and then collapsed due to ejection of juvenile and especially country rock clasts, a diatreme developing underneath. Phreatomagmatic activity at surface led to deposition of many thin pyroclastic beds, mostly of base surge origin, both on the crater rim and within the maar. Continued activity led to repeated subsidence of the diatreme content and associated collapse of the crater rim. Flows of lahars from collapsing crater rim deposits and from sands exposed in the collapsing country rocks within the crater wall accumulated on the crater floor. The interbedded pyroclastic and epiclastic crater floor deposits subsided repeatedly within the diatreme. The explosive activity removed groundwater as steam and a cone of depression formed allowing downward extension of the diatreme (Lorenz, 1986a). When the diatreme had penetrated deep enough into dry mudstones of the Fairfield Formation phreatomagmatic activity ended because of lack of groundwater and magma could then rise non-explosively. The lamproite magma intruded the diatremes and formed lava lakes (olivine lamproites) or lava domes (leucite lamproites) within the initial maar crater. In a number of leucite lamproite pipes early phreatomagmatic eruptions were followed by rise into the maar crater of magma carrying only small microphenocrysts of phlogopite. This was followed by lamproite magma carrying large phlogopite phenocrysts implying that the respective magma batches rose from a stratified magma reservoir which could be the reason for fractionation and variation in diamond grade. The fractionation process did not separate all the diamond, neither did diamond resorb completely during residence time in the magma reservoir.

COMPARISONS WITH OTHER PHREATOMAGMATIC DIATREMES

With their volcanoclastic deposits and sequence of events the Ellendale pipes are comparable to many other small phreatomagmatic volcanoes. In the Quarternary Eifel volcanic fields many scoria cones are located in initial maars because magma continued to rise when lack of groundwater ended an initial phreatomagmatic phase. In many Cainozoic volcanic fields of Central and Western Europe initial phreatomagmatic maar-diatreme activity was followed by emplacement of a lava lake (Hocheifel and Hegau/Germany, Massif Central/France). In contrast to the basic and ultrabasic magmas which formed lava lakes or scoria cones in initial maars, intermediate and acid magmas formed lava domes in initial maars as e.g. trachyte and phonolite domes in the Massif Central or in the Eifel or many small dacite and rhyolite domes in the Permocarboniferous of Europe. In the initial maars at Ellendale the ultrabasic olivine lamproites formed lava lakes whereas the more viscous leucite lamproites formed lava domes. At Calwynyardah 50 km south of Ellendale phreatomagmatic activity lasted as long as the volcanic activity, with the result that only a maar formed. Restoration of the groundwater table allowed formation of a maar lake and accumulation of fossiliferous lake sediments. This evolution was similar to the present situation in the lakes of the Eifel and Massif Central or Victoria maars.

Concerning the lack of lithification of Permian Grant Group sediments, the volcanicity at many Ellendale pipes, at least initially, resembled areas of synsedimentary volcanism where maars and diatremes formed within unconsolidated sediments such as the Carboniferous Midland Valley (Scotland), the Tertiary Limagne graben (France), the Tertiary Hegau-Molasse trough (Germany) and the Permocarboniferous Saar-Nahe trough (Germany). In contrast to those areas the unconsolidated sediments of the Grant Group which formed the aquifer were not very thick, causing an early end to the phreatomagmatic activity followed by non-explosive rise of lamproite magma. The hydrogeological conditions at the site of the synsedimentary or early post-depositional Argyle pipe in the East Kimberley were more favourable for continuous supply of groundwater during eruptive activity, with result that this pipe is more evolved and only contains late magmatic lamproite dykes within the thick phreatomagmatic volcanoclastic deposits.

Kimberlite diatremes from southern Africa, mostly cut by erosion at much deeper levels, also erupted phreatomagmatically (Lorenz 1986b). In contrast to the Ellendale pipes most had much longer phreatomagmatic phases, as indicated by the larger diatreme size, implying that hydrogeological conditions were rather favourable in southern Africa. Due to erosion it is unknown if the late kimberlite dykes found in many diatremes have fed lava lakes in the respective maars or if most kimberlite diatremes ended in maars with accumulated lake sediments such as at Orapa and Mwadui.

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