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Volcanology of selected kimberlites from the Lulo kimberlite field, Angola

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Introduction

The area under study is the Lulo Kimberlite Field in the province of Lunda Norte, Angola, which is located 630km east of the capital, Luanda. This 3000 km^2 concession is one of the world's most abundant alluvial diamond fields, producing high value Type IIa diamonds, as well as hosting a significant number of kimberlite pipes. Within Angola, there are hundreds of known kimberlite bodies of which, it is estimated, far fewer than 50% have been studied and fewer than 5% have economic diamond grades (Pereira et al. 2003). With ongoing exploitation of predominantly high-grade alluvial deposits, depletion of the diamond reserves demands continual and improved exploration of primary sources. Alluvial diamond mining within the Lulo Field has yielded large, high value alluvial diamonds along the Cacuilo River. These diamonds are euhedral in morphology and show sharp edges with little abrasive signs of travel, indicating that their primary kimberlite source is likely nearby. With more than 560 geophysical anomalies having been identified in the Lulo Field, 159 have been drilled, with 138 shown to be kimberlitic (Lucapa Diamond Company, 2024). The area is therefore considered highly prospective for potential economic diamond deposits and the likely source of the alluvial diamonds. The primary objective here is to provide a reconnaissance survey of volcaniclastic kimberlites within pipes across the Lulo field to aid in classification of the eruptive style with implications for diamond grade evaluation of the pipes.

Within the Lulo field, there are 141 confirmed kimberlite targets. For this study, 52 of these kimberlite targets were sampled from which 142 thin sections and representative bulk rock samples were obtained through collaboration with Lucapa diamonds. Each one of the 142 thin sections were described using a petrographic microscope and classified following the scheme of Scott Smith et al. (2018) and Webb & Hetman (2021). Petrographic analyses of the thin sections allowed for the classification of the kimberlites, at the most primary form of subdivision, as either coherent or magmaclastic (Webb & Hetman, 2021).Within the magmaclastic subsection, predominantly Fort á la Corne-type Pyroclastic Kimberlites (FPK) and Resedimented Volcaniclastic Kimberlites (RVK) are observed. Here, representative samples of the main volcaniclastic types are described.

Fort á la Corne-type Pyroclastic Kimberlites (FPK)

Representative samples of FPK's within the Lulo Field display a fragmental, volcaniclastic texture whereby the primary volcaniclastic textures have been preserved. However, olivine grains are completely serpentinized in all cases. Magmaclasts range in size from fine to coarse (~0.1 – 8 mm) showing regular/rounded to curvilinear/curved edged morphology and exhibit sharp margins. Cored and uncored varieties exist. Cored varieties exhibit predominantly olivine central kernels (Figure 1a), and less commonly xenoliths (Figure 1b). These central kernels are surrounded by kimberlitic rims, generally ~0.1 – 0.2 mm in width, and consist of an ultra-fine-grained (~0.125 mm) poorly-crystalline groundmass consisting of oxides, serpentine, and calcite. In the larger uncored magmaclast varieties (Figure 1c), the groundmass is poorly crystalline with multiple microcrysts of predominantly euhedral olivine and spinel along with less common perovskite and phlogopite.

Olivine, including both macrocrystic and microcrystic grains throughout the sample, are present in variable proportions of 25 to 53 vol % and the samples can be described as xenolith-poor with 1 to 13 vol% xenoliths. Magmaclasts are clast supported, within a predominantly ultra-fine-grained crystalline cement of serpentine and calcite (Figure 1d). These samples are interpreted as FPK's due to their clast-supported nature, the presence of calcite, and variable abundance/size distribution of olivine representing the process of sorting commonly seen as a product of an FPK eruption style. Furthermore, the high proportion of magmaclasts that are amoeboidal – curvilinear in morphology with sharp outlines/margins is also indicative of FPKs.

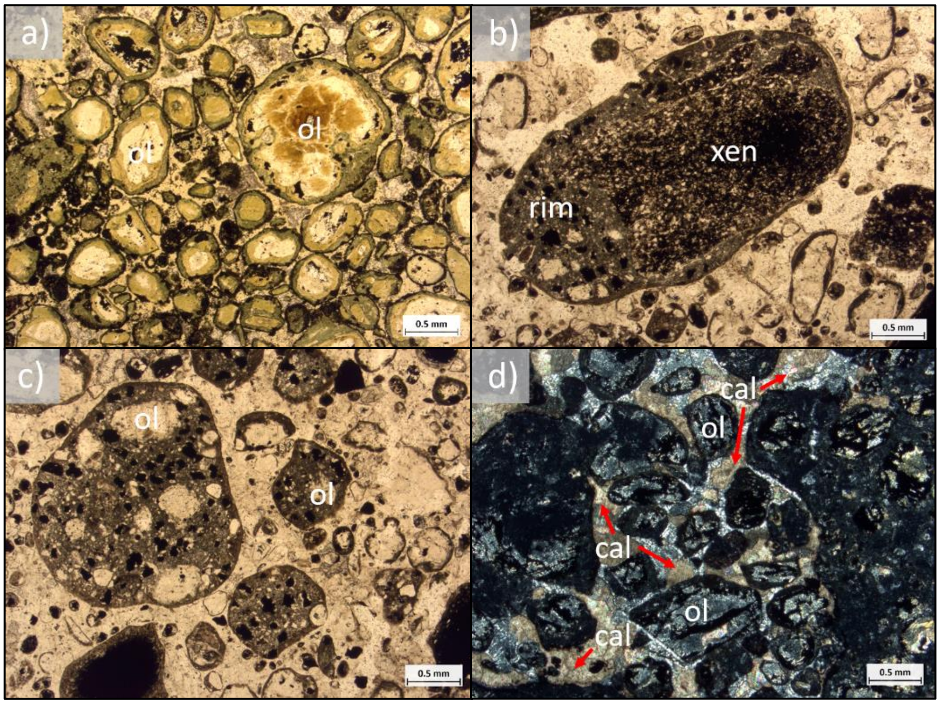

Figure 1: Photomicrographs in PPL of magmaclasts in LKP-001 (a) Olivine (ol) cored magmaclasts showing regular to irregular morphology that are single rimmed, complete, and symmetrical. Variable sizes are evident, in addition to a clast supported nature. Photomicrographs in PPL of magmaclasts in LKP-002 (b) Cored magmaclast variety with a xenolith as a central kernel (c) Uncored magmaclast variety with microcrysts of euhedral olivine (ol) and spinel (sp) showing the relative olivine (ol) size of equivalent-finer to that of the olivine (ol) surrounding the magmaclast. Photomicrographs in XPL in LKP-003 (d) Calcite interclast matrix.

Resedimented Volcaniclastic Kimberlites (RVK)

Representative samples of RVK's within the Lulo Field display a fragmental, clastic texture whereby the primary clastic textures have been preserved, however, olivine grains are completely serpentinized in all cases. Magmaclasts range in size from fine to very coarse (1 – 13 mm) showing regular/rounded to amoeboidal morphology (Figure 2a) and exhibit sharp margins. In the larger uncored magmaclast varieties, the groundmass is poorly crystalline with multiple microcrysts of predominantly euhedral olivine in addition to spinel, perovskite and less commonly phlogopite. Broken magmaclasts can be seen throughout RVK samples, as seen in Figure 2c. Less commonly, layered magmaclasts are observed with distinctly different groundmass assemblages and grain sizes (Figure 2d). Except for these layered magmaclasts, all magmaclasts show similar kimberlite mineralogy and grain size. Magmaclasts and clastic material (primarily quartz) are clast supported, within a predominantly crystalline cement of serpentine and calcite. Quartz is highly abundant within the interclast matrix (Figure 2b). The samples can be described as xenolith-poor (0 - 15 vol%).

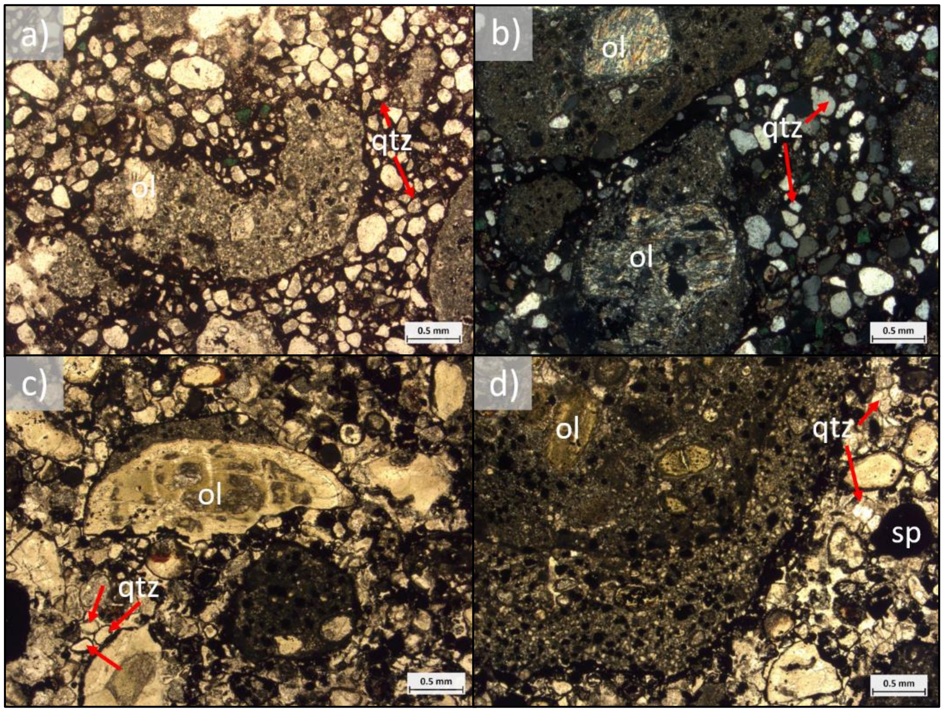

Figure 2: Photomicrographs in PPL and XPL of magmaclasts in LKP-004 (a) Magmaclast displaying amoeboidal morphology (b) Abundant quartz within the interclast matrix. Photomicrographs in PPL of magmaclasts in LKP-005 (c) Broken cored olivine (ol) magmaclast (d) Layered magmaclast showing two kimberlite melt phases.

Implications for diamond resource evaluation

The identification of the kimberlites as either FPK, RVK and HK, combined with sample depth, aids in constructing basic geological models to further understand the geological processes that occurred within the individual pipes. Within the FPK, the varying abundance and size distribution of olivine indicate the sorting, fragmentation, and dilution processes that occurred within the magma post-eruption. The presence of RVK reflects the subsequent mixing of surface material and one or more pyroclastic phases (produced in preceding pyroclastic eruptions). Diamond grade evaluation will be heavily dependent on the above-mentioned sorting processes and will thus vary based on grain size sorting and internal geology of the pipes.

Conclusion

Within the Lulo field, the types of kimberlite deposits found implies that the eruptive style in this region is similar to that of the Fort á la Corne Kimberlites in Canada. This has contributed to magma fragmentation, pipe formation and subsequent infilling – meaning multiple events have taken place within a single pipe. This implies that the geological processes are highly complex, needing additional research to compile a more accurate depiction of the internal geological structures within the pipes. In addition, due to the extensive separation of any entrained solids from the melt during eruption, as commonly seen amongst FPKs, diamond grade could be affected and consequently reduced – this, combined with the aforementioned grain size sorting will contribute to an overall understanding of diamond grade within the Lulo Field.

References

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