KIMBERLITIC OLIVINE.

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1. INTRODUCTION

This study is based on analyses from more than 1000 occurrences. In fresh hypabyssal-facies, macrocrystic Group I and Group II kimberlites (sensu stricto) olivine commonly represents 50 volume per cent of the rock. In rare cases, e.g. parts of sill and dyke complexes olivine accounts for up to 80 volume per cent. Several varieties of olivine occur (Skinner, 1989).

(1) Anhedral xenocrysts with a modal size of 2mm (size range <0.5mm to >20mm) derived from various sources, including disaggregated mantle peridotite, failed proto-kimberlites, LIHN megacryst suites and HILN megacryst suites; making up about 25 vol %.
(2) Subhedral to euhedral phenocrysts with a modal size of 0.3mm (size range <0.1mm to >5mm) representing early forming (within mantle) discrete crystals, crystal overgrowths (only in some kimberlites) and late forming (surficial) discrete crystals; making up about 25 vol %.
(3) Olivine as a constituent mineral of peridotite xenoliths.
(4) Olivine inclusions within peridotitic diamonds.

Distinction between anhedral xenocrysts and subhedral / euhedral phenocrysts is facilitated by several factors, such as; differences in morphology, grain size, internal textures (e.g. undulose extinction, kink-banding, etc.) inclusions of other minerals (large and very small) as well as differences in major and trace element compositions.

2. KIMBERLITE GENESIS

Since olivine crystallises throughout the history of the kimberlite magma, both in the upper mantle and at surface, the differences in the olivine populations provide valuable clues to interpretation of processes operating during the genesis at kimberlite in the upper mantle, during ascent and during emplacement of the kimberlite magma at surface.

2.1. Hotspot Magmas. It is assumed that kimberlites are initiated by hotspot activity and that hotspot magma originates by reheating of basalt which has accumulated at the core-mantle boundary (Hofmann and White, 1982). The basalt becomes bouyant, rises, and is trapped at the base of the lithosphere. Olivine of the <u>HILN</u> variety crystallises from this magma.

In the next stage of kimberlite genesis mantle peridotite is assimilated as a result of heat released by crystallisation of the basalt. Two sites of assimilation are distinguished; in the reduced, diamond-bearing lithosphere (RL) and in the underlying, oxidised, volatile-enriched lithosphere (VEL).

2.2. <u>Assimilation of reduced mantle peridotite.</u> Assimilation of reduced peridotite results in a simultaneous increase in the magnesium and nickel contents of the melt. Olivines that crystallise from this melt are thus relatively Mg and Ni-rich (LIHN) and are related to the Cr-poor megacryst suite. More extensive assimilation produces magmas which crystallise the Cr-rich megacryst suite. As yet olivines associated with this suite are unknown.

2.3. <u>Proto Kimberlite Melts.</u> True kimberlite melts form when the hotspot basalt assimilates VEL formed as a consequence of earlier subduction processes. Assimilation of volatiles produces a low viscosity proto kimberlite magma (PKM) which easily penetrates the lithosphere. Volatile-poor megacryst magmas are trapped in the lithosphere but may be incorporated by the ascending proto kimberlite.

2.4. <u>Early Ascent.</u> Rising batches of PKM cool and crystallise early phenocrysts of olivine. Some of these may fail and be sampled by later PKM's incorporating earlier olivine crystals of differing Mg-numbers.

2.5. <u>Peridotite Disaggregation.</u> After heat loss during early ascent, kimberlite can no longer entirely digest peridotite and partial assimilation (of opx, cpx and garnet) takes place leaving xenocrysts of olivine. These constitute the majority of the anhedral olivine xenocryst population.

2.6. <u>Magma Coalescence.</u> Ascending kimberlite magmas may pond at resistive interfaces within the lithosphere (e.g. at the base of the assumed Roberts Victor eclogite complex). At this level the final, successful kimberlite gathers together earlier failed kimberlite and/or megacryst magmas, disrupts and samples (as xenoliths) the resistive layer and ascends rapidly to surface.

The successful kimberlite will always be more oxidised and volatile-rich than failed kimberlite or megacryst magmas, since ascent requires a high volatile content; and the more volatile rich, the more oxidised a magma will be that interacts with VEL. Kimberlites sampling earlier PKM's will thus oxidise that magma. Olivine overgrowths with zoned Ni (<u>Skinner</u>, 1989) may grow in response to the change in oxygen fugacity.

2.7. <u>Mantle Ascent.</u> As the successful kimberlite ascends rapidly little olivine crystallisation takes place.

2.8. <u>Ascent through the Crust.</u> As the magma ascends through the upper crust (at 1.5 kbar = ± 5km) there is a dramatic change in the position of the CCO buffer relative to other oxygen fugacity buffers. This change may cause substantial degassing and result in rapid slowing of the rate of ascent of the magma and renewed crystallisation of olivine. Crystal growth will vary substantially depending essentially on the magma temperature. In some kimberlites (e.g. Bellsbank, Bobbejaan Fissure) very little early (mantle) olivine phenocrysts occur and the late (near-surface) phenocrysts are all fine grained (<0.1mm) due to rapid cooling.

2.9. Post Emplacement Effects. After emplacement and final crystallisation of olivine the residual magma cools and fractionates further. The residue becomes reactive towards olivine resulting in zoned reaction mantles on all grains.

3. GROUP 1 AND GROUP 2 KIMBERLITES

The different character of Group 1 and Group 2 kimberlites may be explained by differences in the proportions of reduced and oxidised lithosphere assimilated by their antecedent hotspot basalts.

Group 1 hotspot basalt is considered to be voluminous relative to Group 2 hotspot basalt, with the former penetrating the RL and producing many failed megacryst magmas while the latter assimilate proportionately more of the VEL. The lower proportion of megacryst magma in Group 2 kimberlites ensures that their magnesium number is higher than Group 1 kimberlites.

4. CONCLUSION

Even though olivine is the most abundant constituent of kimberlite (s.s.), it is possibly the least researched and understood mineral relative to other mantle - derived constituents. This is due to several factors, such as; its commonly altered state, difficulty in classification and limited use as an indicator mineral in diamond prospecting. Because of this the debate as to whether olivine macrocrysts are xenocrysts, phenocrysts or megacrysts continues. This study assists in resolving this dispute and also contributes to the understanding of the processes involved in kimberlite genesis.

REFERENCES

Hofmann, A.W. and White, W.M. (1982). Mantle plumes from ancient oceanic crust, Earth Planet. Sci. Lett. 57, 421-436.

Skinner, E.M.W. (1989) Contrasting Group I and Group II kimberlite petrology: towards a genetic model for kimberlites. In J. Ross, Man. ed., Kimberlites and Related Rocks, Their Composition, Occurence, Origin and Emplacement, Geol. Soc. Australia Spec. Publ. 14, p. 528-544.