THE GEOLOGY OF THE ORAPA A/K1 KIMBERLITE, BOTSWANA: FURTHER INSIGHT INTO THE EMPLACEMENT OF KIMBERLITE PIPES.

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The A/K1 kimberlite pipe is the largest of a cluster of more than fifty kimberlite intrusions which have been located in the western part of Central District, Botswana. The kimberlite was discovered in 1967, and has been mined for diamonds since 1971.

Limited erosion since the pipes emplacement in the Cretaceous (Davis, 1977) has preserved much of the crater zone of the kimberlite. Mining and deep drilling have subsequently exposed much of the crater zone, thus affording the authors the unique opportunity to study this zone in detail.

At surface the pipe has an oval, bi-lobate shape and an area of 118.4 hectares. At depth (approximately 220 metres below surface) the kimberlite body separates into two independent diatremes (referred to as the southern and northern lobes respectively). Crater, diatreme and hypabyssal facies have been identified within the body. The kimberlite intruded through Archaean granitic basement, sedimentary rocks of the Palaeozoic Karoo sequence and the Jurassic Stormberg basalt lavas.

Detailed field mapping and petrographic examination suggest that the northern lobe was emplaced first, and that its deposits were disrupted and truncated by the formation of the southern crater. The preserved deposits of the northern lobe appear to be far less complicated than those of the southern lobe. These comprise competent, grossly layered pyroclastic kimberlite which grades downwards into monotonous diatreme facies tuffisitic kimberlite breccia. Deep drilling has revealed that the northern diatreme is a steep-sided body with a regular outline

In the southern lobe, diatreme facies tuffistic kimberlite breccia is sharply overlain by a heterolithic breccia at about 450 metres below surface. The latter contains little or no kimberlite-derived constituents, and is interpreted to represent an early talus deposit which resulted from spalling of exposed wall rock into a newly exposed crater. It thus marks an abrupt change from the diatreme to crater zones. This breccia was deposited on an irregular base which corresponds with a marked flaring of the kimberlite.

The crater facies deposits of the southern lobe have been divided into volcaniclastic and epiclastic subtypes. The volcaniclastic deposits overlie the basal heterolithic breccia, and are interleaved between later talus slope deposits. These volcaniclastic deposits are mostly green coloured, massive, poorly sorted, matrix-supported breccias, which are occasionally interspersed with well sorted, bedded and graded horizons. Petrographic examination indicates that they have suffered a considerable amount of clay alteration, but that they have not been oxidised to the same extent as the epiclastic deposits. In some layers delicate primary (magmatic) features are preserved, thereby indicating that the deposits could not have undergone vigourous re-sedimentation. The lithic clasts in these deposits are totally dominated by basalt, with only minor quantities of Karoo sedimentary and Archaean basement clasts being represented.

The epiclastic deposits can be separated into western talus deposits, eastern debris-flow deposits and central lacustrine deposits. The contrasting nature of the epiclastic deposits from the western and eastern areas of the crater impart a distinct asymmetry to it.

The western talus deposits comprise at least four distinct cones. The cores of these cones consist of very coarse breccias which are made up of angular blocks of basalt. The interstices between the basalt blocks contains minor kimberlite-derived minerals, and are largely cemented by carbonate. These breccias have steeply dipping (20 to 30 degrees) bounding surfaces near the crater margin, but the dips decrease as the fans flatten out towards the crater centre. One fan covers most of the southern crater floor 200 metres below surface. Closely associated with these breccias are steeply dipping (up to 30 degrees), well sorted, clast supported, bedded deposits composed mostly of kimberlite-derived materials. Palaeo-flow directions indicate that deposition took place inwards towards the crater centre. These deposits are interpreted to represent modified grain flows which resulted from the downward cascading of kimberlite debris, which probably originated from the tuff cone surrounding the crater rim.

The eastern epiclastic deposits unconformably overlie the volcaniclastic deposits. Near the margin they consist of channelised basalt-rich debris flow breccias, which grade laterally into finer grained mudflows. The bounding surfaces of the flows have much lower dip angles (10 to 20 degrees). Towards the centre of the crater the debris and mud flows are interdigitated with the lacustrine sediments.

The lacustrine sediments consist of kimberlitic shales and grits. They exhibit many soft-sediment deformation structures, whilst the presence of ripple marks, rain pit indentations and thin evaporitic layers reveal the ephemeral nature of the crater lake. These sediments also host a variety of plant and insect fossils (Rayner and McKay, 1986).

Deep drilling has revealed the presence of hypabyssal facies kimberlite at depth. This kimberlite is typical macrocrystic, spinel- and perovskite- bearing, monticellite kimberlite of the group-1 type. Very little coherent, magmatic kimberlite was intruded into the crater or diatreme zones of either lobe. A small dipping sill (about 1.5 metres thick) was located in the southwest of the southern lobe. Its volume is highly insignificant relative to the other crater deposits.

A synthesis of the geology of the A/K1 kimberlite indicates that there is a marked contrast between the northern and southern lobes. The northern lobe is a steep-sided diatreme which contains only primary pyroclastic kimberlite. The upper layered parts have all the attributes of hot pyroclastic flows. These flows grade downwards into diatreme facies, tuffisitic kimberlite breccia. The steep-sided, regular nature of the diatreme, as well as the abundance and large size (up to 9.6 metres diameter) of basement xenoliths in this kimberlite indicate deep-seated catastrophic eruption. The pyroclastic flows are envisaged to have formed in response to eruption column collapse.

The southern crater zone has a more flared appearance and is filled largely with re-sedimented kimberlite debris and wall rock fragments. Evidence suggests that the crater was formed by one or more catastrophic eruptions, which cleared a deep crater, exposed cliffs of wall rock and deposited a large amount of wall rock and kimberlitic debris on a tuff cone surrounding the crater. It is envisaged that piecemeal collapse of portions of the wall rock cliffs (probably mostly from the eastern side of the crater) produced the basal heterolithic breccias. This spalling induced catastrophic collapse of part of the still fresh tuff cone to produce the volcaniclastic deposits, largely through mass flow processes. This series of events rapidly filled the basal portion of the crater, thus preventing the further incorporation of clasts from the Karoo sedimentary sequence. After this, talus fans composed largely of spalling basalt clasts formed on the more stable western margins. Continued spalling would have undermined the kimberlite-dominated tuff cones, resulting in the emplacement of the steeply dipping grain flow deposits. Continued collapse of the eastern margins would introduce further debris flow deposits to the eastern and central portions of the crater. It is envisaged that a crater lake would have been established during this period resulting in the subaqueous deposition and subsequent oxidation of the epiclastic debris flows and lacustrine sediments.

The poor preservation of in-situ pyroclastic deposits in the crater inhibit an assessment of eruption mechanism, however the sedimentary history of the crater infilling suggest that relatively few eruptive events occurred after the commencement of the sedimentary infill. The nature of the northern lobe pyroclastic deposits and the underlying TKB suggest that they were emplaced by a high energy, gas-charged eruptive process.

References.

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