MODEL OF A KIMBERLITE PIPE

J.B. Hawthorne
Geology Department,
De Beers Consolidated Mines Limited
P.O. Box 616,
KIMBERLEY
South Africa.

Recent discoveries of kimberlites in Tanzania, Zambia and Botswana together with new evidence from pipes which are being mined in Angola and Zaire show that in central Africa there is widespread development of pipes which differ in several respects from those which are mined in South Africa. The occurrences in central Africa of which the Orapa pipe in Botswana is typical are often found to be overlain by large basins containing re-worked kimberlite. The inward dip of the pipe walls below these basins tends to be much shallower than that of the South African pipes, ranging from 30^{o} to 70^{o}. The basins are interpreted as being the remnants of ancient crater lakes of maar type kimberlite volcanoes, filled with reworked kimberlitic ejectamenta which formed epiclastic kimberlite deposits. The presence of crater sediments and the shallow inward dips of the pipe walls suggest that these pipes have undergone relatively little erosion since they were formed.

In South Africa crater sediments are found only in some of the kimberlite diatremes of the Bushmanland. Elsewhere, in the Karroo Kimberlite Province, in Lesotho and the Transvaal crater sediments in kimberlite pipes are not found.

Detailed studies of the shapes of eleven South African pipes have been undertaken.

It was found that at depths of 300m to 500m, pipes in the Kimberley area have smooth regular walls and near vertical axes. Below these depths the pipe walls become irregular, breccia zones and domes are developed and the pipe axes are no longer vertical. Further to the southeast as the thickness of present day Karroo rocks increases this transition is found to take place at greater depths.

A method of average slope measurement based on variations in the pipe area was devised and applied to the upper parts of the pipes. This enabled a comparison of the slope of various pipes to be made. It was found that the slopes of the regular upper parts of the pipes investigated were highly consistent, ranging between 79^{o} and 85^{o} and averaging 82^{o}.

AVERAGE INWARD DIPS OF PIPE WALLS

Pipe	Wallrock	Levels between which measurements were made	No. of levels used.	Av. Dip
Premier	Bushveld Felsite	170m-538m	5	84,5°
Finsch	Transvaal System Ironstone and Dolomite	9m-95m	2	82,0°
Dutoitspan	Karroo Dolerite & Shale, Ventersdorp Lava & Quartzites Archaen Granite Gneiss	0m-411m	4	79,0°
Koffyfontein	Karroo Dolerite, Shale	46m-244m	3	85,0°
Wesselton	Ventersdorp Lava, Quartzite	250m-470m	3	81,0°
Jagersfontein	Karroo Dolerite, Shale	238m-570m	5	81,0°
Bultfontein	Ventersdorp Lava, Quartzite Archaen Granite & Schists	296m-670m	3	83,5°
De Beers	Ventersdorp Lava, Quartzites	105m-300m	3	84,0°
Kimberley	Karroo Shale, Ventersdorp Lava, Quartzite	91m-294m	4	80,5°
West End	Transvaal System Dolomite	0m-165m	2	81,0°
Kao (Lesotho)	Stormberg Lava	0m-90m	2	85,0°
			Av.	82,4°

The differences in pipe profile described are thought to be due primarily to differences in the depth to which erosion has proceeded since the emplacement of the pipes.

In central Africa the depth of erosion has been considerably less than at most South African pipes suggesting a substantially different age or geomorphological history. In the Kimberley area this depth of erosion is estimated to be between 900 and 1900m. The estimate is based on the nature of the wall rock inclusions found in the pipes and on evidence obtained from studies of the depth of formation of kimberlite sills supplemented by geochemical and diagenetic studies of the wall rocks around the pipes.

Williams (1932) described many of the inclusions found within the pipes. In addition to deep seated inclusions he identified inclusions derived from the upper part of the Karroo System which is no longer preserved in the area. It is concluded from the character of the Karroo inclusions that the full sequence of the Karroo System including at least some of the Stormberg Lava was present when the pipes were intruded.

A number of kimberlite sills in the Kimberley area have been described (Hawthorne 1968). These sills are confined to the flat lying sedimentary rocks between the base of the Karroo System and the lowest dolerite sill which intrudes the Karroo rocks. Many are close to the present land surface. Mudge (1968) examined a large number of concordant masses of igneous rocks in flat lying sedimentary environments and concluded that the limiting depths of emplacement for these bodies was between 900m and 2300m below the surface. If the kimberlite sills were emplaced under similar controls then the surface around Kimberley has been lowered by a similar amount since then. If the pipes and sills were more or less contemporaneous this depth range also indicates the depth to which the pipes have been eroded.

In an attempt to reduce these fairly wide limits for the depth of erosion, the results of geochemical and diagenetic studies undertaken by the Southern Oil Exploration Corporation were investigated. Regional studies on the Karroo System have been carried out and samples of near surface lower Karroo sediments obtained from borehole cores in the vicinity of Kimberley and Koffiefontein have been examined. (De Swardt and Rowsell in prep.). The degree of crystallinity of illite, the residual to total carbon ("CR/CT") ratios and the bulk grain densities were measured. These measurements suggest a total depth of burial of 1900m for the lower Karroo in the vicinity of Kimberley. This figure represents the total thickness of Karroo rocks removed by erosion. The Karroo thickness at the time of pipe emplacement must have been less than this because of post-Stormberg pre-kimberlite erosion during a period of some 80 to 100 million years. This reduction of the Karroo thickness cannot be determined at present but for a graphic representation of the kimberlite pipe model an arbitrary reduction to 1400m is made. This figure is the average of the upper limit of sill formation (900m) and the total thickness of the Karroo System (1900m) in the Kimberley area.

The information on shape obtained by studying kimberlite pipes which appear to have been eroded to different depths has been incorporated into the accompanying diagram of a hypothetical pipe. This model serves as a means of identifying the relative depth to which a pipe has been eroded and of predicting changes in its character which may be found in depth.

REFERENCES

De Swardt, A.M.J. and Rowsell, D.	(In prep.)	Diagenesis in the Cape and Karroo Supergroups.
Hawthorne, J.B.	(1968)	Trans. Geol. Soc. S. Afr. 71: 291-311.
Mudge, M.R.	(1968)	Bull. geol. Soc. Amer. 79: 315-332.
Williams, A.F.	(1932)	The genesis of the diamond. 2 vols. Ernest Benn, Ltd., London, 636p.

MODEL OF A KIMBERLITE PIPE PLATE V