THE AGES AND URANIUM CONTENTS OF ZIRCONS FROM KIMBERLITES AND ASSOCIATED ROCKS

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Preliminary results (Davis, Krogh and Erlank, 1976) showed that zircons from kimberlites of the Kimberley area, South Africa, all had nearly the same age of 90 m.y. Additional age determinations have been made on zircons from pipes from South Africa, Lesotho, Botswana, Namibia, Zaire, Angola and Swaziland. Samples from Brazil and from Malaita in the Solomon Islands have also been analyzed. The ages and uranium contents of the zircons analyzed to date are given in the accompanying table.

Zircons are radioactive clocks, recording the time that has elapsed since the onset of accumulation of the Pb isotopes that are the products of the radioactive decay of U. Zircons are rare in kimberlites but are concentrated at the same time as diamonds because of their high density and X-ray fluorescence. They form rounded to sub-rounded crystals as large as 1 cm in diameter. They are considered to belong to the deep-seated suite of discrete nodules (Kresten, Fels and Berggren, 1975) and are believed to have originated in magmas which may have come from the low velocity zone (Boyd and Nixon, 1973). The occurrence of zircon as an inclusion in a diamond (Meyer and Svisero, 1973) provides additional evidence for a deep-seated origin. No matter how long ago the zircons crystallized, at the temperatures of 1100°C or more estimated for the pyroxene discrete nodules Pb would be lost by diffusion and could not accumulate to start the clock. The ages of the zircons mark the times of sudden lowering of temperature at eruption.

The zircons were decomposed by the low-contamination method of Krogh (1973). A mixed tracer of ^{205}Pb and ^{235}U was used (Krogh and Davis, 1975). Isotope ratios were measured at the Department of Terrestrial Magnetism on the automated 9-inch mass-spectrometer. The contents of Pb and U isotopes were calculated from the ratios after correction for a small laboratory blank (0.1 ng Pb, 0.05 ng U) and correction for the presence of common lead (from submicroscopic inclusions and fractures). The latter correction causes a large uncertainty in the ^{207}Pb concentration with the result that the ^{207}Pb-^{235}U and the derived ^{207}Pb-^{206}Pb ages have little significance for such young, low-U zircons. The ^{206}Pb-^{238}U ages given in the table have an analytical error of $\pm$ 1.5% that is independent of sample weight because of the use of a mixed tracer. The concentrations of U are dependent on the weights and may be in error by as much as $\pm$ 7%.

DISCUSSION OF RESULTS: Knowledge of the ages of emplacement of the kimberlites provides a better understanding of the sequence and types of tectonic activity in southern Africa. About 90 m.y. ago zircon-bearing pipes erupted through the Precambrian Transvaal Craton and its covering strata, having come from or penetrated a part of the mantle in which diamonds were stable. The zircon samples analyzed come from near the periphery of the craton, particularly in the southern part, with one sample from Botswana to the north. They are characterized by very low U concentrations. Outside of the craton in the Orange River Belt, the pipes are consistently younger, as young as 50 m.y. in Namaqualand. All of these young occurrences to the south of the craton are barren of diamonds--evidence that they may have originated in the mantle at depths above the diamond stability field. The Namaqualand zircons contain 10 to 20 times as much U as those from the Transvaal. Carbonatites and alkalic intrusives are found in this region.

Zircons were separated from two granulite xenoliths from Lesotho. These rocks appear to be fragments of Precambrian crustal wall rock that were picked up by the ascending kimberlite. The ages shown are extrapolated from the discordant U-Pb ages. In spite of having been entrained in the kimberlite, both of the zircon samples have retained a memory of Precambrian crystallization and therefore have not been subjected to very high temperature for long. A zircon from a peridotite nodule from Bultfontein was analyzed in hopes that its age might reflect a time of crystallization prior to eruption. Instead the age turned out to be close to but somewhat younger than the average for discrete zircons from the Kimberley area. Ambient temperatures in the mantle are higher than in the crustal basement: apparently the zircon from the mantle-derived peridotite was unable to retain any radiogenic Pb prior to or in the early stages of eruption. The 650 m.y. zircons from Dokolwayo, Swaziland, contain liquid inclusions, are high in U and generally appear to have originated in an upper level crustal pegmatite rather than in the mantle.

The zircons from Ramatseliso, Lesotho, have low U-contents in the range of kimberlitic zircons, but their older ages do not fit the South African age pattern as it has developed so far. The sample from Angola posed some analytical problems, possibly due to its low U-content. The suggested age of 134 m.y. is not in conflict with an Upper Jurassic stratigraphic age. At Muadui, Tanzania, where Cretaceous sediments occupy the crater of the diatreme, the age of the zircon is 189 m.y.

The ages of the zircons from Brazil range from 122 m.y. to 79 m.y., suggesting that Africa and South America, once parts of Gondwanaland, have similarities in their tectonic histories after separation. The ages of many Brazilian alkalic rocks (Herz, 1977) lend further support to this suggestion. Zircons from kimberlite pipes are often coated by soft chalky-white ZrO_2, possibly the result of a desilication reaction with carbonates. A 1 cm zircon from a Brazilian kimberlite had such a coating, nearly 1 mm thick, in which were embedded many small brown crystals of baddeleyite, the monoclinic form of ZrO_2 that is stable below 1170°C. Upon analysis, the baddeleyite was found to have the same age as the zircon, but it contained 10 times the U, too much to have come from any reasonable volume of zircon. The chemical environment in the kimberlite at the time of desilication must have been very high in U, as suggested by Kresten (1974).

One zircon from the Solomon Islands with an age of 34 m.y. indicates that kimberlite-like eruptions took place as recently as Oligocene in this region of Melanesia.

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	ppm U	m.y.	
TRANSVAAL CRATON			
Kimberley Pool, So. Africa	39.9	95.4	altered peridotite
Finsch, So. Africa	26.1	94.1	
Leicester, So. Africa	18.5	93.6	
Orapa, Botswana	14.4	93.1	
Roberts Victor, So. Africa	27.7	92.2	
De Beers, So. Africa	28.2	92.0	
Bultfontein, So. Africa	13.1	91.2	
Monastery, So. Africa	6.1	90.4	with ilmenite
Wesselton, So. Africa	18.6	90.3	
Mothae, Lesotho	8.6	87.1	
Kampfersdam, So. Africa	29.8	86.9	
Bultfontein, So. Africa	5.6	83.8	peridotite nodule
(duplicate)	6.0	81.7	
AROUND THE CRATON			
McKenzie's Post, So. Africa (1)	12.4	80.4	
McKenzie's Post, So. Africa (2)	129.4	79.7	
Rietfontein, Namibia	25.2	71.9	
(duplicate)	23.4	71.7	
Bokputs Camp, Namaqualand	197.1	67.9	
Lushof, Victoria West	64.9	67.7	
Platbakkies, Namaqualand	440.5	66.7	
Melkfontein, East Griqualand	109.4	63.4	carbonate tuff
Brakfontein, Namaqualand	338.1	54.1	
FROM THE LITHOSPHERE			
Kao, Lesotho	150.9	1500	altered granulite
Thaba Putsoa, Lesotho	61.9	1050	scapolite granulite
Dokolwayo, Swaziland	152.4	650	pegmatitic?
Ramatseliso, Lesotho (1)	17.9	150.8	
Ramatseliso, Lesotho (2)	12.0	148.6	
OTHER KIMBERLITES			
Val do Queve, Angola	3.1	(134?)	
Bakwanga, Zaire	38.0	71.3	
Nzega, Tanzania	6.3	53.2	
(duplicate)	6.7	52.2	
Mwadui, Tanzania	15.1	189.3	
BRAZIL			
Batovi 9 (1)	24.3	122.1	
Batovi 9 (2)	13.5	120.0	
Poco Verde, Minas Gerais	29.3	86.0	
Poco Verde, Minas Gerais	317.5	87.0	baddeleyite
Joana 5, Minas Gerais	17.1	80.1	
Joana 6	235.4	79.2	
Esperanca 1	47.5	79.6	
MELANESIA			
Malaita, Solomon Islands	4.8	33.9	