EVENTS REFLECTED IN THE DIAMONDS OF SOME SOUTHERN AFRICAN KIMBERLITES

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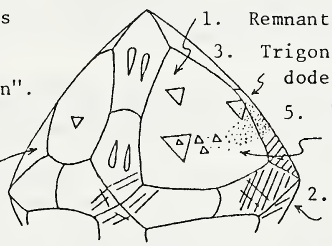
INTRODUCTION

Observations made of diamond samples (all of 0.15 to 0.35-carat diamonds, to facilitate comparisons) from fifteen Southern African kimberlite localities are reported.

THE SEQUENCE OF EVENTS IN EVIDENCE

Age relationships are apparent between many diamond features (Fig.1). The processes responsible for some of these features are tolerably well understood. For example, lamination lines have been shown to reflect plastic deformation (Urusovskaya and Orlov, 1964), the "rounded dodecahedral" form results from partial resorption (e.g. Moore and Lang, 1974) and various octahedral surface pits manifest etching at different combinations of temperature and oxygen fugacity (e.g. Yamaoka et al., 1980). In addition, the xenocrystic origin of kimberlitic diamonds has been confirmed by Richardson et al. (1984), who also demonstrated the very considerable interval which may elapse between diamond crystallization and incorporation into kimberlite. Thus, a sequence of events which have affected diamonds can be recognized. This sequence includes crystallization, residence at high T and P, plastic deformation, resorption (and associated etching), mechanical damage and further etching.

Fig. 1 : Age-relationships between features on an octahedron in combination with "rounded dodecahedron".



SAMPLE CHARACTERISTICS AND THEIR INTERPRETATION

The abundances of some features are given in the appended table. Grey/black diamonds are common at Palmietgat but are scarce, elsewhere, to a degree which is uniform within any particular kimberlite province. This distribution can reflect that present within the zone of mantle sampled by kimberlites. By contrast, the content of brown diamonds varies considerably within individual provinces (e.g. Kimberley, Jwaneng) and even within a composite pipe (e.g. Premier Mine). These variations suggest a secondary origin for the brown colour. They also require that associated kimberlites with differing proportions of brown diamonds were emplaced separately from wherever the differences originated.

Primary growth forms of diamond are the octahedron and, at lower temperatures, the cube (Bovenkerk, 1961). Octahedra dominate, to the virtual exclusion of cubes (as main form), at most localities. Of the three exceptions, two (Jwaneng) are a few kilometres apart while none are close to any of the octahedron-dominated (relative to cube) localities. Therefore, variations in cube content may reflect lateral variations within diamond-bearing mantle, rather than relatively shallow sampling by kimberlite.

The "rounded dodecahedron" (i.e. tetrahexahedroid) is always the predominant, main crystal form. Haggerty (1986) considers the resorption responsible for this form to occur during diamond residence in the mantle. That it actually occurs within transporting kimberlite magma is indicated, however, by the relatively unresorbed nature of any diamonds in xenoliths (e.g. Shee et al., 1982) by occurrences of pseudohemimorphic crystals (more resorbed at one side than the other) and by the range, in every sample, from nearly sharp-edged octahedra, through intermediate (combined) forms to pure "rounded dodecahedra". Thus, a model is favoured whereby the degree to which individual diamonds get resorbed is determined largely by the level (during kimberlite-magma ascent) at which they are liberated from enclosing xenoliths or xenocrysts. This model, unlike Haggerty's (op. cit.) hypothesis, also allows the widely differing proportions of preserved growth forms in closely associated kimberlites (e.g. Bultfontein compared with other Kimberley bodies) to be readily explained.

"Rounded dodecahedra" are as common in samples from dykes and diatreme root zones as in higher-level samples. The resorption must be practically complete before kimberlite magma becomes involved in diatreme formation.

The majority of the diamonds in most samples show evidence (lamination lines) of having undergone plastic deformation. Such deformation requires deviatoric stress, hence an essentially solid environment, and (De Vries, 1975) temperatures above 900°C which are coupled to high pressures. Only in the mantle are such conditions likely to be realized. Mantle-derived xenoliths in kimberlites could be deformed as a consequence (Mercier, 1979) of stress in aureoles about developing kimberlite conduits. Should diamond also be deformed in such aureoles, kimberlite magma would have to be responsible for the resorption which follows.

Lamination lines are much more common on brown than other diamonds. This suggests that plastic deformation is responsible for much of the brown colour. An additional factor (high temperature?) may also be involved as indicated by the data for Premier Mine (where brown diamonds are relatively scarce in the Brown Kimberlite, even though lamination lines are at least as common as in the other two kimberlites). It is possible that this factor operates subsequently to the deformation. Otherwise, associated kimberlites which contain differing proportions of brown diamonds will need to have been emplaced separately from the mantle.

Breakage is very common in all of the samples examined in this study. This includes samples from dykes so most breakage must pre-date diatreme formation. Few breakage surfaces are modified by resorption but they are generally etched.

Two merging groups of late-stage etch features are developed upon "rounded dodecahedral" surfaces. The first group includes microdisk patterns, corrosion sculpture and shallow depressions, while the second group consists of frosting (coarse and fine). On crystals exhibiting the first group of features, any remnant octahedral faces exhibit only the trigons also produced during resorption. Frosting, on the other hand. extends onto octahedral faces as a myriad of hexagonal pits or trigonal pits in the "positive" orientation. Yamaoka et al. (op. cit.) demonstrates that cooler and/or more oxidizing conditions are required for these pits than for trigons and the resorption forms.

The first group of late-stage etch features is particularly common in samples from hypabyssal-facies and the deeper parts of some diatreme-facies kimberlites. Etch-pit development could have continued after emplacement during relatively slow cooling. Frosting tends to be more common in samples from diatreme-facies kimberlites. This can reflect brief etching associated with a sudden increase in fO_2 just prior to quenching. Both groups of late-stage etch features are relatively scarce in the sample from epiclastic kimberlite. Some samples from hypabyssal and diatreme-facies kimberlites are also poor in diamonds exhibiting either group of features.

CONCLUSIONS

Essentially the same sequence of events is evident in the diamonds of all the kimberlites considered. The frequencies of occurrence of certain features, e.g. grey/black colour, can reflect the situation in underlying mantle but this is not the case for brown colour or for the "rounded dodecahedral" form. Brown colour is associated with plastic deformation which probably occurred during the initial ascent of kimberlite magma. Such magma subsequently produced "rounded dodecahedra" by partial resorption of growth forms. The development of late-stage etch features extends to the final phases of kimberlite emplacement.

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Table giving the percentages of the diamonds which exhibit particular features. (N = number of diamonds. Facies T = diatreme, 1 = upper and 2 = lower portion, H = hypabyssal, R = root zone, D = dyke, Tr = transitional or mixed T/H, E = epiclastic).

			Colour			Main Form			Shape		Surface Texture					
		N	Yellow-col.	Brown	Grey/black	Octahedron	"Rnd. dodec."	Cube	Broken	Pseudohemi.	Lam. lines	Microdisks	Corrosion	Shallow dep.	Coarse frost	Fine frost	Facies
Dokolwayo		301	81	18	1	6	94	0	54	tr	55	2	1	4	24	30	T1
Dullstroom		72	79	19	1	4	94	0	75	0	51	6	1	11	6	0	HD
Palmietgat		299	9	11	46	2	95	1	76	tr	46	3	24	31	1	4	T2
Premier Brown K		300	70	30	1	4	95	0	70	1	73	0	5	16	13	21	T2
Grey K		300	36	63	1	11	86	0	67	3	65	5	9	25	3	6	T2
Black K		300	34	65	1	7	89	0	68	2	59	3	15	31	8	16	Tr
Helam		246	69	24	7	11	51	22	44	0	38	1	0	4	0	tr	HD
Kamfersdam		300	29	71	0	11	86	0	68	3	64	tr	1	2	tr	1	Tr
De Beers	Kimberley	161	63	37	0	7	89	0	60	1	63	3	6	28	12	10	HR
Dutoitspan E Plug	Kimberley	253	54	44	2	10	88	0	71	2	58	5	25	30	5	8	HR
Bultfontein	Kimberley	300	57	38	2	21	76	1	75	tr	54	tr	2	2	2	2	Tr
Wesselton W2	Kimberley	290	51	45	2	4	96	0	62	tr	57	2	12	34	0	1	HR
W3	Kimberley	300	47	51	2	3	95	0	73	0	61	1	43	50	1	1	HR
W5		94	69	31	0	4	95	0	69	1	51	0	2	3	0	0	T2
W7		160	44	55	1	4	95	0	69	0	54	1	5	11	2	18	Tr
Finsch K-F1	Postmas.	307	45	53	2	6	94	tr	62	tr	73	3	2	9	3	3	T1
K-F6	Postmas.	102	54	46	0	11	89	0	65	1	48	0	2	4	2	6	HD
Makganyene	Postmas.	332	44	54	2	2	98	0	51	1	62	12	1	11	1	tr	Tr
Peizer	Postmas.	108	19	81	0	6	94	0	64	0	69	4	10	45	5	10	HR
Jwaneng DK2		300	86	14	1	16	62	19	57	1	22	1	1	3	0	1	E
DK7		299	53	46	tr	32	55	8	66	4	36	2	1	1	1	2	Tr