ORIGIN OF THE CASUARINA ALLUVIAL DIAMONDS, WESTERN AUSTRALIA

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The Casuarina area lies to the east of the North Kimberley Kimberlite Province (Jaques et al., 1986), and was intensively explored for diamondiferous kimberlite pipes during the period 1980 - 1984. The regional geology consists of shallowly south-dipping and gently folded sediments and basic volcanics of the Lower Proterozoic Kimberley Group, elsewhere intruded by kimberlite (Skerring, Hadfields, etc.), lamproite (Pteropus Creek) and dolerite, and in places veneered by Tertiary laterite. Regional metamorphism approaches lower greenschist facies. There are no known kimberlite or lamproite intrusions within the Casuarina area.

Diamond exploration consisted of a number of phases of sampling, which followed-up results from aeromagnetic and photo-interpretation studies as well as from regional stream sediment surveys. Within the 600 square kilometres of the Casuarina area (Fig. 1), approximately 350 separate sites were sampled, using sample sizes from 8 kilogrammes up to 50 tonnes. The samples characteristically contained very small amounts of heavy minerals. A total of 154 diamonds aggregating 12.88 carats and 49 picroilmenites was recovered, as well as anomalous minerals such as zircons regarded as kimberlitic, manganese-rich ilmenite, xenotime and tektites. All the diamonds were found in stream samples, sometimes, but not always, associated with picroilmenite.

It is assumed, with some justification, that the diamonds were brought up from the mantle by kimberlite or lamproite intrusions. Erosion has removed the diamonds and deposited them ultimately in the creeks in the Casuarina area. The question is, do the diamonds come from outcropping intrusions near or within the Casuarina area, or do they have a more complicated history involving several cycles of erosion and deposition?

Geomorphological studies of the Kimberley region have identified a northward tilted high level dissected peneplain surface of presumed Mesozoic age, developed on Proterozoic formations, and which in the north is blanketed by lateritised alluvial deposits (boulder conglomerates, sands, clays) of presumed early Tertiary age. Palaeocurrents in Tertiary alluvium are directed northward to northeastward, a similar direction to the present day consequent streams. This evidence allows the possibility that a primary source of the Casuarina diamonds lies many kilometres to the southwest, and that the lateritised and ferricreted Tertiary gravels may be a secondary source.

The more recent geomorphological history of the Casuarina area is dominated by gentle doming and scarp retreat. The diamond bearing streams all occur on or immediately above Warton Sandstone bedrock. The overlying Elgee Siltstone is not resistant to erosion, and the southward retreat of the Elgee siltstone scarp, capped by Pentecost Sandstone, has allowed the major drainage to be captured and successively occupy the present positions of Cape Whisky, Elsie, Island, Brown and Casuarina Creeks. Thus, any diamond source in the catchment area may have contributed diamonds to these now-smaller drainages, at different times in the past.

The stream bedload in modern drainages is bimodal, consisting of sandstone-boulders and sand. During normal wet season runoff, only the top of sand and gravel bars moves about or is winnowed. It is apparent that the threshold of stream energy, above which the boulders start to move, may occur only once every several decades or more. A small increase in stream energy would cause virtually all the boulders to start moving, destroying the trapsite and redistributing any diamond-bearing concentrate. This may provide an explanation for the small amounts of concentrate in the samples and the perceived concentration of diamonds in the tops of gravel traps.

Studies of the diamonds themselves have not produced definite conclusions as to their origin. The diamonds range in size from 0.5092 carats down to 0.0042 carats. There is a clustering of diamonds around the 0.03 carats weight. This skewed distribution and the lack of large stones suggests a mature alluvial diamond population. Although few of the diamonds exhibit features that can be ascribed to transporation, this may not be unexpected considering their small size.

The diamonds can be classified into groups based on crystal form. A majority (61%) of the diamonds have a growth-modified octahedral habit. A smaller fraction (35%) have rounded dodecahedral to irregular and complex forms showing features characteristic of resorption and magmatic corrosion. Approximately 4% show highly pitted and striated cubic forms. Diamonds in the centre of the Casuarina area, that is the headwaters of

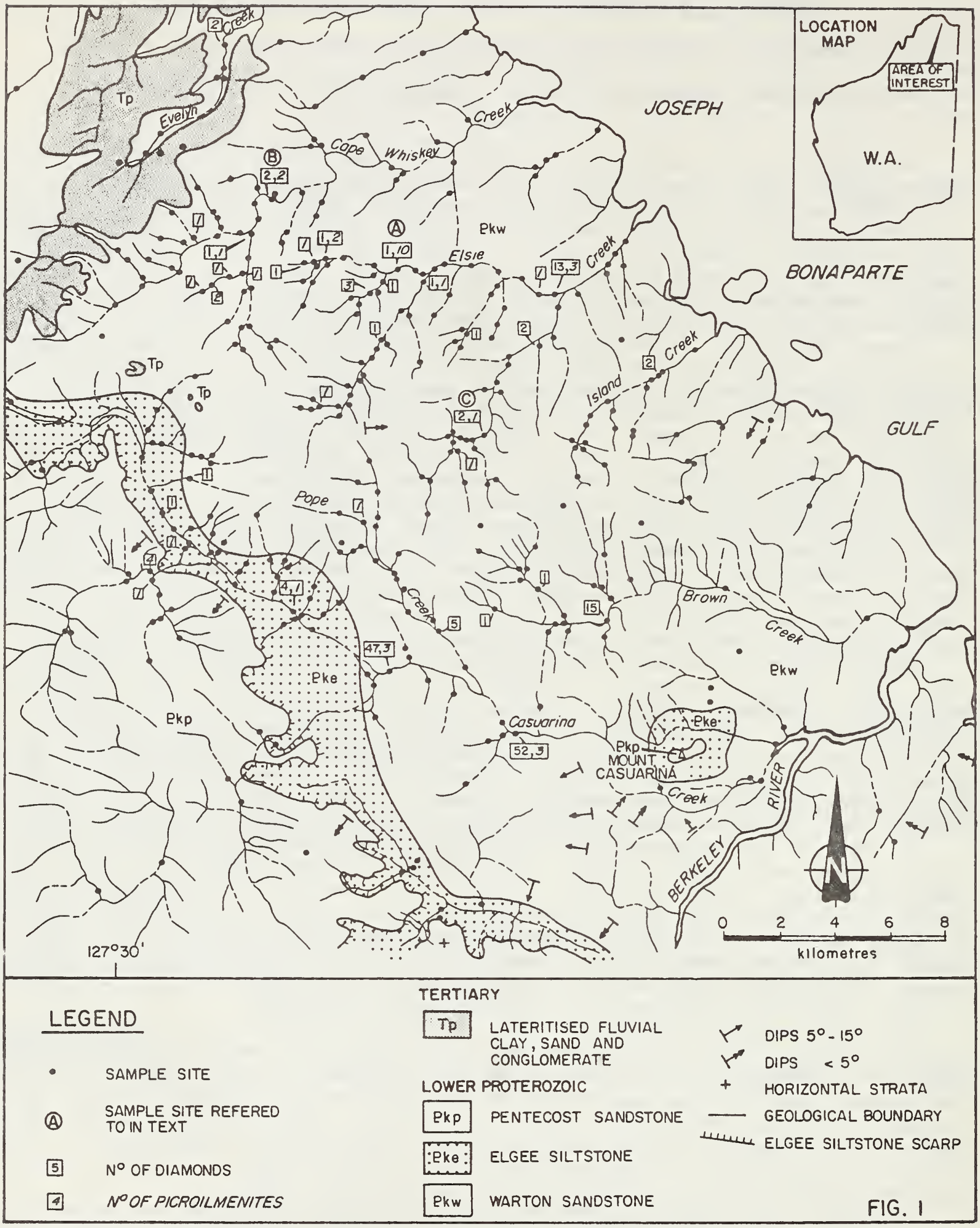

FIG. 1

Pope Creek, Brown Creek and the southern branch of Elsie Creek, are almost exclusively octahedral stones, whereas rounded dodecahedral stones are more common in the western part of the area. These two populations are believed to be distinct and real.

Diamonds can be classified according to their body colour. However, for 56% of the Casuarina diamonds, surface features mask any internal colouration. Of the remainder, 60% are brown, 32% are yellow and 7% are colourless. The distribution of these coloured stones appears to be random.

Diamonds can also be classified into groups based on combinations of features which appear to be characteristic of diamonds from known kimberlite intrusions. Although the Argyle diatreme is not a kimberlite and is 270 km to the south-southeast, it is richly diamondiferous and its diamonds show a characteristic set of features, including granular surfaces, rounded hexagonal to oval pits, and black inclusions. Of the Casuarina diamonds, however, only 6% can be classified as 'Argyle-like', and significantly have no green or brown spots. No diamonds were recognised as being similar to those from Ellendale.

The most remarkable and perhaps most significant feature of the Casuarina diamonds is the presence, on 75% of the stones, of green and/or brown spots. Vance et al. (1973) proposed that green spots are crystal lattice distortions in the surface skin (20 microns) of diamonds, caused by alpha particle radiation from contact with a radioactive mineral, and that brown spots are former green spots that have been annealed by heating to elevated temperatures. Green spotted Casuarina diamonds have been heated to temperatures above 540°C for 24 hours, and the spots turn brown, whilst temperatures below this appear to have no effect over periods of a few days.

Some of the Casuarina diamonds (6%) have both green and brown spots. It is also common for a single stone to have more than 25 discrete coloured spots. Colours range from green through dark green to nearly black, and from pale orange to dark brown. The colour of an individual spot is generally lightest on the outside, becoming darker towards the centre. However, there are some spots that exhibit distinct rings of colour intensity (bulls eyes). A few of the spots have what can only be described as tails, and in rare instances, the tails of green spots are brown. These green and brown spotted diamonds may have had a complex history involving residence at an alluvial site where extended periods of contact with small radioactive mineral grains produced some green spots. Subsequent heating, either by metamorphism, or proximity to an igneous intrusion, turned all the spots brown. Continued contact with radioactive grains produced a second crop of green spots. However, the large number of spots per diamond implies an unreasonably high concentration of radioactive minerals. Alternative and less well researched explanations of the spots include: a) the inclusion of radioactive particles in the diamond during crystal growth, b) explosive pressure release of fluid inclusions, c) ionic diffusion of elements, such as iron, into the diamond surface during intense lateritisation.

Magnesium-rich ilmenites are common in the kimberlites and some of the creeks of the North Kimberley Kimberlite Province, but rare in the Casuarina area. A total of 223 grains were analysed by electron microprobe, and the results subjected to cluster analysis. This work indicated a distinct correlation between cluster groups and particular drainages in the kimberlite province, consistent with there being a number of primary sources. Within the Casuarina area however, the small number of ilmenites found makes statistical treatment difficult. The most compelling evidence that these indicator minerals were derived from nearby primary sources is the presence of eight grains from one cluster group in sample A (Fig. 1), when only ten grains were found in that sample. When compared with the scatter of compositions that is present within the Casuarina area, it appears unlikely that this concentration was fortuitous.

There are too few ilmenite grains to indicate well-developed trains showing increasing wear with down-stream distance. A microscopic study of the picroilmenites demonstrated that most appear to be fresh to fresh-worn. Few worn grains occur. Two very fresh picroilmenites still retaining a substantial portion of a thick leucoxene skin were found, one each at sample sites B and C. These are believed to have come from a primary source within a few kilometres. Several polycrystalline aggregates have been found, which also implies only limited fluvial transport. These data strongly suggest that there are a number of small kimberlite dykes within the Casuarina area.

The results of all these studies suggest that there are kimberlitic intrusions within the Casuarina area. These are likely to be small dykes and have either no diamonds, or diamonds which may have similar features to those from Argyle. The majority of the diamonds, particularly the spotted stones, are probably not derived from a local primary source. The most likely source area lies some considerable distance to the southwest. The Drysdale River may once have continued its north-northeasterly course from the centre of the Kimberley Plateau, via the sand-choked and weakly diamond-bearing Beta Creek to the area now drained by Casuarina Creek, where extensive early Cenozoic gravels were deposited. The lack of abrasion of the diamonds, and the distribution of crystal forms appears not to support this explanation, however the other evidence, particularly the preponderance of spotted stones suggests that an unknown primary source of many Casuarina alluvial diamonds lies closer to the diamondiferous intrusions of the East or West Kimberley lamproite provinces.

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