9th International Kimberlite Conference Extended Abstract No. 9IKC-A-00209, 2008

The Diamonds of South Australia

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In South Australia, diamonds are found in kimberlites and placer deposits. More than 150 individual kimberlites occurrences have been discovered in the Adelaide Fold Belt and on the adjacent Gawler Craton. Diamondiferous kimberlites, however, are restricted to the Eurelia area, ~20 km north of Orroroo (Fig.1, Scott-Smith et al. 1984). The placer deposits with the most diamonds recovered are the Springfield Basin (~200 diamonds, max. 0.34 ct.), located ~50 km northwest of Orroroo, and the historic Echunga Goldfield in the Adelaide Hills (≤50 diamonds, max. 5.3 ct.), ~30 km southeast of Adelaide (Fig.1). The physical and compositional characteristics of diamonds from kimberlites and placer deposits, and their mineral inclusions, were used to identify their mantle sources, and to define the provenances of the diamonds in the placer deposits.

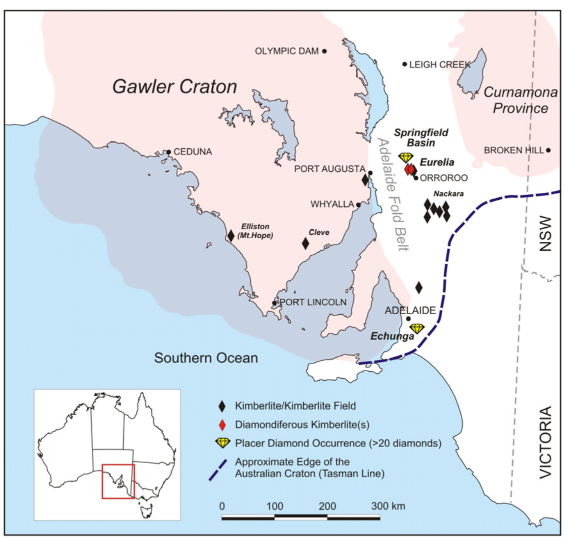

Fig.1 Location of diamond and kimberlite occurrences in South Australia

Diamonds from Kimberlites at Eurelia

From a set of 43 diamonds from three kimberlites in the Eurelia area (K2, K3, K7), one diamond contained inclusions of ferropericlase, which was associated with an inclusion of MgSi-perovskite. This provides evidence that part of the diamond population from Eurelia is of lower mantle origin (≥670 km). The bulk of the diamonds, including the diamond with lower mantle inclusions, are characterized by low concentrations (<100 ppm) of nitrogen impurities (Fig.2). High aggregation states of nitrogen of up to 100% B-centres in some of these low-nitrogen diamonds suggest high mantle residence temperatures and hence may reflect a sublithospheric origin. A diamond with an inclusion of olivine stoichiometry, which may have originally been incorporated as ringwoodite, is part of that group (Fig.2).

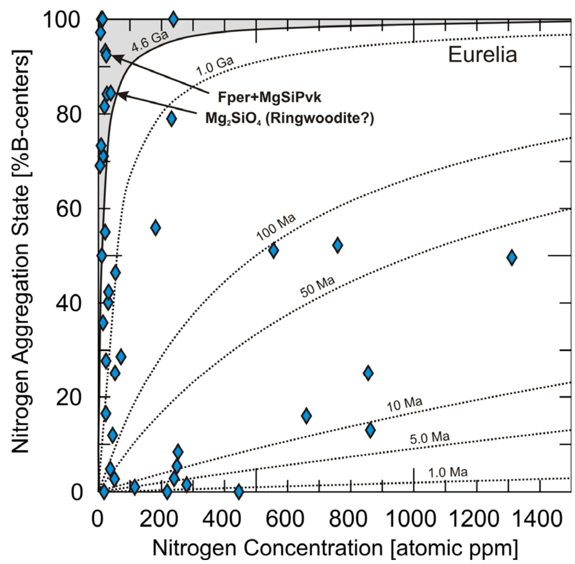

Fig.2 Nitrogen concentrations and aggregation states of diamonds from the Eurelia kimberlites. Isochrones are calculated for an ambient temperature of 1250°C. One diamond with 2560 ppm N is not shown.

Most of the diamonds with higher nitrogen concentrations (>100 ppm, max. 2560 ppm) have low nitrogen aggregation states (<10% B-centres), which indicates a lithospheric origin. Given the relatively high model geotherm of ~45 mW/m^2 surface heat flow for the lithosphere in this area, and maximum lithospheric temperatures of ~1250°C (Tappert et al., 2007), some of these diamonds must have formed just prior (<5 Ma) to kimberlite emplacement (Fig.2). The carbon stable isotope composition ($\delta^{13}C$) of diamonds from Eurelia ranges between -16 to -2‰, with a mean value of -6 ‰ (Fig.3), which is slightly lower than the mean for lithospheric diamonds worldwide (-4 to -5‰). A trend towards isotopically heavy carbon compositions ($\delta^{13}C$ ~0‰) for the diamonds with low-nitrogen contents and high nitrogen aggregation states (potentially sublithospheric diamonds), indicates that their carbon sources included subducted carbonates.

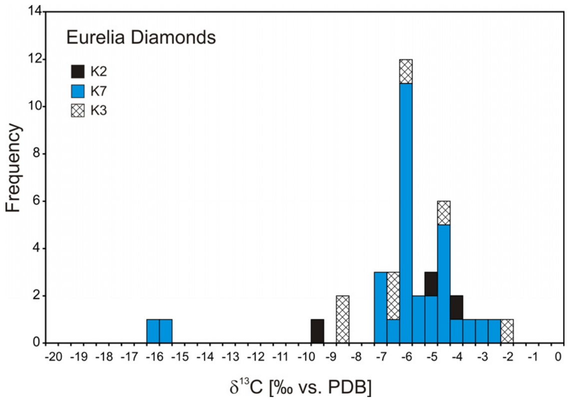

Fig.3 Carbon stable isotope compositions ($\delta^{13}C$) of diamonds from kimberlites in the Eurelia area.

The sublithospheric diamonds from the Jurassic kimberlites at Eurelia can be correlated with sublithospheric diamonds in similar aged (Jurassic-Cretaceous) kimberlites in other, former parts of the supercontinent Gondwana, including Southern Africa and South America (Fig.4).

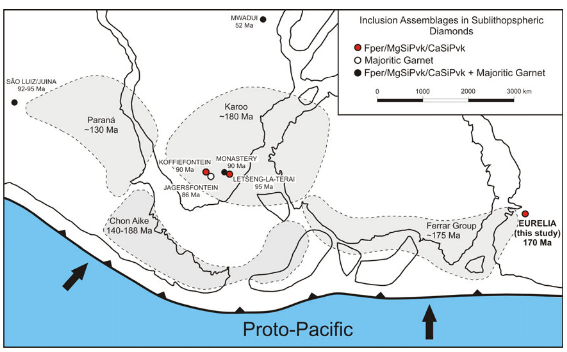

Fig.4 A reconstruction of the southern part of Gondwana before break-up, showing the locations of kimberlites with sublithospheric diamonds.

Within the southern part of Gondwana, kimberlites with sublithospheric diamond populations were emplaced in approximately equal distance (1500-2000 km) from the active subduction margin. In combination with crustal signatures in some of the sublithospheric diamond populations of these kimberlites, this provides evidence that deeply subducted remnants of the proto-Pacific plate are the ultimate source of the sublithospheric diamonds.

Springfield Basin Diamonds

In the Springfield Basin, diamonds and indicator minerals were recovered from conglomerates, which are estimated to be Late Permian in age. The physical characteristics (shapes, colors, surface textures) of 122 studied diamonds from the Springfield Basin closely resemble those of the diamonds from the Eurelia kimberlites. The comparison of the nitrogen characteristics also shows close similarities between the Springfield Basin and the Eurelia diamonds (Fig.2,5).

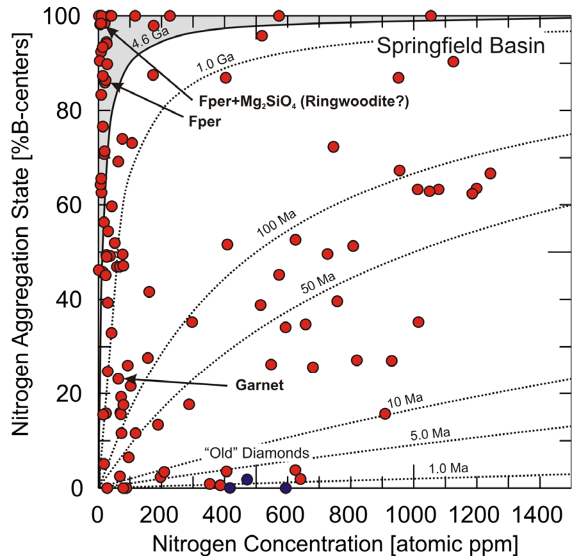

Fig.5 Nitrogen characteristics and mineral inclusion content of diamonds from the Springfield Basin. Two diamonds with 1511 and 1820 ppm are not shown.

The majority of the diamonds in the Springfield Basin, like the diamonds from Eurelia, have low nitrogen concentrations of <100 ppm, which, in part, are associated with high nitrogen aggregation states. Seven diamonds were classified as Type II (nitrogen-free). Diamonds with higher nitrogen concentrations (max. 1820 ppm) and variable nitrogen aggregation are also present in the Springfield Basin. In addition, the Springfield Basin diamonds are characterized by carbon isotope values that are similar to the Eurelia diamonds, with a mean $\delta^{13}C$ value of -6.5‰ and an isotopic range of -20 to -2‰ (Fig.6).

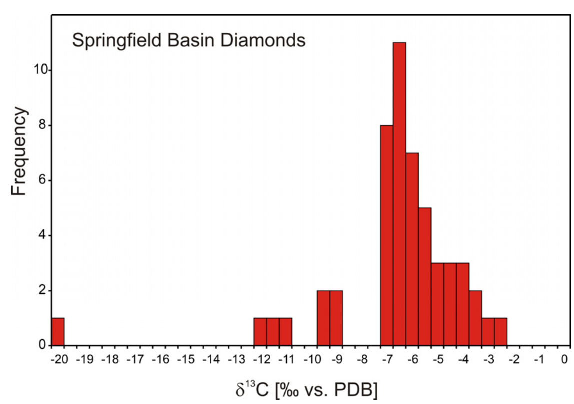

Fig.6 Carbon stable isotope compositions ($\delta^{13}C$) of diamonds from the Springfield Basin.

Two diamonds from the Springfield Basin contained ferropericlase inclusions. In one diamond, ferropericlase was accompanied by an inclusion of olivine stoichiometry. The nitrogen characteristics of the two host diamonds (low N content, high N aggregation, Fig.5) are similar to those of the ferropericlase bearing diamond from Eurelia (Fig.2). This not only reinforces the similarities between the two diamond sources, but it is also suggests the presence of a sublithospheric diamond population in the Springfield Basin. A single lherzolitic garnet inclusion was recovered from a third Springfield Basin diamond. The low nitrogen aggregation state of the host diamond (23% B-centres, Fig.5) is consistent with a lithospheric origin.

The similarities between the diamonds from the Springfield Basin and Eurelia indicate that the bulk of the Springfield Basin diamonds are derived from nearby kimberlites. These kimberlites must have sampled very similar mantle sources as the kimberlites in the Eurelia area, including sublithospheric sources. However, because of their younger ages (Jurassic), the known kimberlites in the Eurelia area may not be the direct sources of the diamonds in the Springfield Basin.

"Old" Inherited Diamonds (Springfield Basin & Echunga)

Despite the overall similarities between the Springfield Basin and the kimberlite-derived diamonds from the Eurelia area, there are three diamonds in the Springfield Basin sample set that are distinct. These diamonds are pale yellow; they also have well developed crystal shapes, large sizes, and a distinctive emerald green UV fluorescence. The relatively high levels of nitrogen in these diamonds (417-594 ppm) are poorly aggregated (0-2% B-centres, Fig.5). More importantly, all three diamonds exhibit brown radiation spots on their surfaces. In two cases these are associated with green radiation spots (Fig.7).

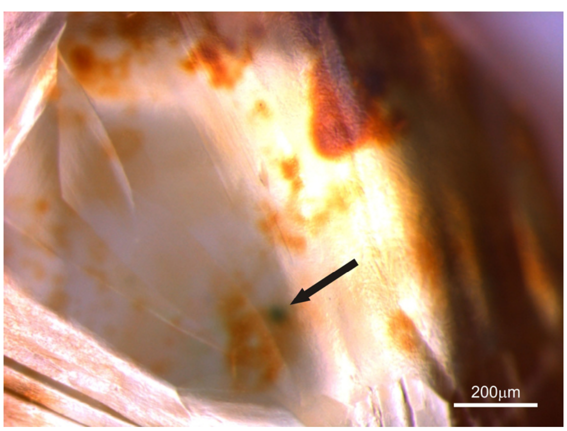

Fig.7 Photomicrograph showing clusters of brown and a single green irradiation spot (arrow) on an "old" diamond from the Springfield Basin.

In addition, abrasion textures and percussion marks are present on the surface of one of these diamonds. This provides evidence that the diamonds are not only significantly older than the bulk of the Springfield Basin diamonds, but also derived from distal kimberlitic sources.

Similarities exist between the "old" diamonds from the Springfield Basin and diamonds from the Echunga area (Adelaide Hills), where diamonds were recovered during gold mining operations between the 1850s and the 1900s (Gommers, 1988). The Echunga diamonds were generally large (up to 5.3 ct.) and of good quality. Only five diamonds, however, are still known to exist; three of which have been examined as part of this project. Like the "old" Springfield Basin diamonds, the three Echunga diamonds are yellow and exhibit signs of surficial transport in the form of percussion marks and abrasion features. Green and brown radiation spots are also present on the surface of the Echunga diamonds.

The close spatial association of the Echunga and "old" Springfield Basin diamonds with Permian glacigene sediments, or their reworked equivalents, suggests that the diamonds from both deposits were transported to South Australia by glaciers during extensive Late Carboniferous to Permian glaciation. The reconstruction of the direction of ice movement indicates that the diamonds were transported from intermediate, highly metamorphosed, sedimentary deposits in the Eastern part of Antarctica. Their primary kimberlitic sources may be located on the East Antarctic Craton. The physical characteristics of the Echunga and "old" Springfield Basin diamonds also provides a link to the placer diamonds in Eastern Australia, which were found to exhibit similar surface abrasion and radiation features (Davies et al. 1999).

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