

IN THE PINK: ARGYLE'S DIAMOND GIFT TO AUSTRALIA

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ABSTRACT

Through the generosity of Argyle Diamonds, an important part of Australia's rich mineral heritage will be preserved in perpetuity in an Australian public institution for the benefit of future generations. In a great gift to the nation, in 2003, Argyle donated several hundred pink diamonds to the mineralogical collection of the Western Australian Museum. This generous donation comprises twenty-eight parcels of faceted pink and other coloured stones from the Argyle (AKI) Mine in the Kimberley region of Western Australia. The collection represents the largest of its kind in any public museum in Australia. Part of the sponsorship agreement between Argyle and the Western Australian Museum is that the stones be placed on permanent display. Moreover, other institutions throughout Australia may apply to the Western Australian Museum to borrow material for temporary exhibition subject to appropriate insurance and security arrangements. In this way Argyle's bequest, representing a unique display resource, can at some time be enjoyed by all Australians.

Introduction

Argyle Diamonds mine, on average, around 30 million carats of diamonds per year from the AKI pipe in the East Kimberley region of Western Australia. The recovery represents about a quarter of the world's current total diamond production. Today, rough diamonds are sold directly to the world market by Rio Tinto Diamonds, acting as agents for Argyle Diamonds in Antwerp, Belgium.

Only about 5 per cent of the recovered diamonds from the AKI pipe are of **gem quality**, with a further 70 per cent classified as *near gem*. All of these stones are destined for the jewellery market, and diamonds ranging in colour from white (colourless), through *champagne* and *cognac* (yellow to brown diamonds), to the rare pinks are sold by the company. Pink diamonds are not unique to the Argyle Mine since they have been recovered in small amounts from deposits in other countries, such as South Africa, India, Brazil and Indonesia. However, Western Australia has become the primary source of pink diamonds for the world's markets.

Not-with-standing, less than 0.1 per cent of the total diamond extraction in Australia consists of pink diamonds. Because of the small number of diamonds of this colour available, they are in strong demand by the international diamond market and currently command very high prices. For this reason they make a significant contribution to Argyle's polished sales revenue. Although prices vary depending on current markets, past sales indicate that intensely coloured pink diamonds are commonly sold for more than A\$150,000 per carat, and sometimes very much greater.

Western Australian pink diamonds have stimulated many levels of interest. On an historical level, the discovery of diamonds in the Kimberleys in the 1970's marked a new era of exploration and research (not to mention wealth) in Australia. Moreover, because most of the diamonds were found in lamproites (an unusual rock type), the discovery caused a re-examination of diamond exploration in Australia, and around the world. On a cultural level, Argyle pink diamonds are something of an icon for the Australian community. Many would aspire to own one, others would be satisfied just to view one occasionally. On a scientific level, the rarity of natural pink diamonds makes them interesting targets for research. Research into the colouring agents, such as impurities and structural defects (colour centres), of diamonds continues. Finally, from a geological point of view, the complexity of the paragenesis of Argyle diamonds in the AK1 pipe has undoubtedly contributed to the wide range of coloured stones from this locality.

Herein lies a conflict, however, for the undoubted significance (historical, cultural, and scientific) of pink diamonds to Australia was, until recently, in stark contrast to the number of cut pink stones that were exhibited permanently in Australia's public cultural institutions. Prior to Argyle's donation, there was only one single cut pink diamond (of 0.30 ct), on display in an Australian public institution (Australian Museum in Sydney). The South Australian Museum in Adelaide exhibits a single, uncut pink diamond (1.50 ct), from the Bow River deposit in Western Australia, generously donated to them by Normandy Mining. And while there may be pink diamonds in private collections, or held for investment purposes in Australia, these remain invisible to the general community.

Australian pink diamonds are a limited resource. When the mining operations in the Kimberley eventually cease, this magnificent representative suite of unusual natural objects will still be preserved for posterity in a public collection in this country. Argyle's donation ensures that these items of cultural and scientific interest are protected, and remain accessible to the wider Australian community.

DISCOVERY

Although alluvial diamonds were first found as early as 1851 on the Macquarie River near Bathurst, New South Wales, the discovery of commercial diamonds from a primary source in Australia is relatively recent. While there was an early discovery of alluvial diamonds at Nullagine in the Pilbara of Western Australia, by gold prospectors in 1895 (Groom, 1896; Simpson, 1951), systematic exploration of that area did not begin in earnest until 1965. In 1967, attention focused on the West Kimberley region where the geological setting and previous work elsewhere in the world had suggested good exploration prospects (Clifford, 1966; Deakin et al., 1989). Lamproites in the West Kimberley were first studied in the 1930's and their relationship to kimberlites was recognised (Wade & Prider, 1940). Until the 1960's, kimberlites were thought to be the only primary source of diamonds at the surface of the Earth; however Prider (1960) suggested the possibility that lamproite may also be diamond-bearing.

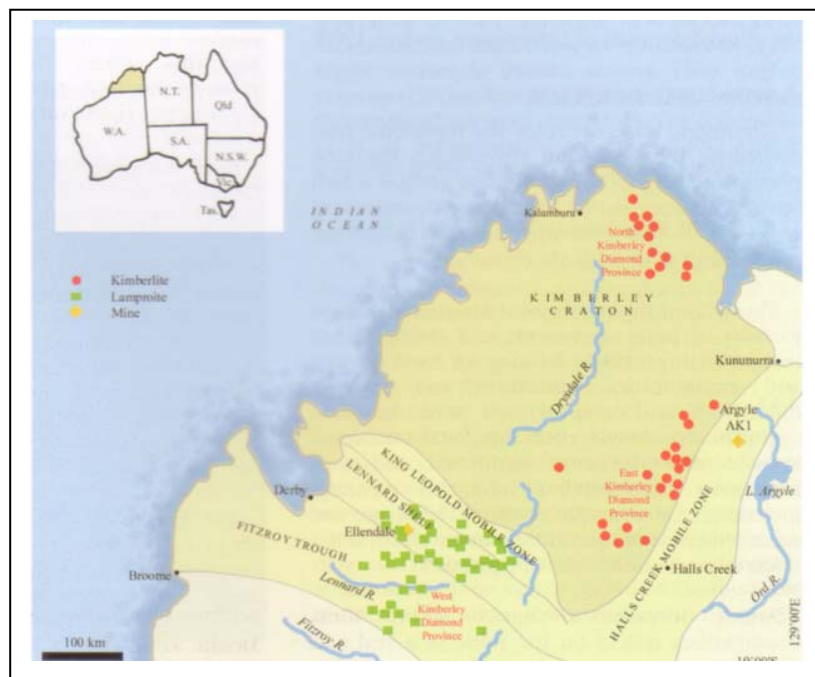


Fig. 1. Map of the Kimberley region of Western Australia showing the main geological structures, the three major diamond provinces, and the occurrences of lamproite and kimberlite pipes.

Early exploration by a number of companies in the Ellendale and Noonkanbah areas of the West Kimberley (Fig. 1) failed to locate diamonds. However, in 1969, following the discovery of a few alluvial diamonds along the Lennard River, in the West Kimberley, a consortium of companies then known as the Kalumburu Joint Venture (later the Ashton Joint Venture) began a systematic search for diamonds in this area. In 1976, CRA Exploration joined the Ashton Joint Venture as a major stakeholder. Shortly after, the company announced the discovery of diamonds and lamproite near Ellendale in the West Kimberley (Fig. 1).

Although the focus of diamond exploration remained in the West Kimberley, in the late 1970's the Ashton Joint Venture also sought diamonds, and the indicator minerals of potentially diamond-bearing rocks, in the stream gravels of the East Kimberley. In August 1979, after more than ten years of exploration in the Kimberley region by many companies, diamonds were found in stream gravels collected from Smoke Creek in the East Kimberley (Fig. 1). Further samples indicated that the upper part of the creek was a commercially viable alluvial diamond deposit. Moreover, these alluvial diamonds persisted for 20 km upstream to their source. On the 2nd of October 1979, the Argyle (AK1) lamproite pipe was discovered at the head of Smoke Creek, in the Matsu Range. Following further sampling, in 1980, a deposit of alluvial diamonds was found at Limestone Creek around 25 km from the AK1 pipe. This creek drained the area south of the AKI pipe and flowed south east towards the man-made Lake Argyle (Grice & Boxer, 1990; Shigley *et al.*, 2001 and references therein). The so-called Bow River Project, a joint venture between Gem Exploration and Minerals, and Freeport-MeMoran, began production from the alluvial deposits of Limestone Creek in 1988.

ABORIGINAL HERITAGE

The Argyle lease occupies the traditional land owned by the Gidja and Mirriuwung speaking people and neighbouring language groups, which have a presence dating back many thousands of years. Argyle has a strong, open and respectful relationship with each Aboriginal group.

The relationship with local Aboriginal groups extends to both agreements and arrangements that assist in providing a future for local families and communities, education and training initiatives, and employment and business opportunities. Argyle considers local traditional knowledge to be most significant, and it is frequently incorporated into the business including, for example, cultural heritage site management, a unique ethno-botany study, and a range of community relations projects.

Argyle foresees a legacy where local communities reflect on the mine as a real and practical cornerstone of sustainable development, having due regard for the environment, improved social wellbeing and generated economic prosperity.

GEOLOGICAL SETTING AND HOST ROCK

The Kimberley region of Western Australia comprises two main geological structures. A central basin consists of approximately flat-lying sediments and volcanics, 5 km thick, that were deposited between 1.9-1.6 billion years ago. The nature and age of the rocks beneath the Kimberley Basin have been the subject of considerable debate. This is because evidence of them comes from a small number of xenoliths in volcanic rocks, and indirect isotopic and geophysical techniques. Several authors have suggested that the Kimberley Basin is underlain by a stable Archaean Craton of igneous and metamorphic rocks with ages >2.5 billion years (Gellatly, 1971; Graham *et al.*, 1999). Plumb & Gemuts (1976), however, suggested that the Kimberley Basin was floored by rocks of the Halls Creek Group that are of Proterozoic age. This has been supported by more recent work indicating that the shallow basement is probably a Proterozoic granite terrain (Gunn & Meixner, 1998). The central Kimberley Basin is flanked along its south eastern margin by the Halls Creek Mobile Zone (East Kimberleys), and to the south west by the King Leopold Mobile Zone (West Kimberleys) (Fig. 1). These may be the remnants of a Proterozoic collision between the Kimberley Block and the rest of northern Australia. Both the Halls Creek and King Leopold Mobile Zones contain metasediments and metavolcanics of Palaeoproterozoic age, and the late Palaeoproterozoic intrusives and metamorphic rocks of the Lamboo Complex.

In all, three main diamond provinces have been found to date. The North Kimberley Province occurs east of Kalumburu (Fig. 1) in the Kimberley Basin. Here diamond-bearing kimberlites have been found in a typical cratonic setting. The other primary diamond occurrences (West Kimberley Diamond Province and East Kimberley Diamond Province) are in, or near, the mobile zones and almost exclusively in diamond-bearing lamproite pipes, although kimberlitic dykes in the East Kimberley also contain some diamonds (Jaques *et al.*, 1986). These intrusions occur along zones of faulting and extension.

The Argyle AK1 olivine lamproite pipe occurs about 120 km south-south west of Kununurra in the East Kimberley. Geologically, the pipe lies about 7 kms west of the Halls Creek Fault, marking the eastern boundary of the Halls Creek Mobile Zone (Boxer *et al.*, 1989). In the Halls Creek Mobile Zone the crystalline basement rocks are highly deformed by folding and faulting. These are superimposed in the north by northerly dipping sedimentary and volcanic rocks that were deposited 1.5 billion to 500 million years ago. The Argyle pipe intruded the older of these rocks about 1.1-1.2 billion years ago along a pre-existing fault (Pidgeon *et al.*, 1989). Considering its

great age, the AKI pipe is remarkably well preserved and the upper levels of what was once an active volcano can be observed today. The reason for this preservation is that resistant outcrops of the rocks into which the pipe was intruded have protected it from erosion. However, it may have been buried and exhumed over the vast expanse of time since its emplacement.

Prior to the discoveries in the Kimberley, diamonds had been found elsewhere in the world in kimberlite pipes. Both kimberlite and lamproite are igneous rocks of deep-seated origin belonging to the alkaline ultramafic suite (rocks rich in potassium and/or sodium, and low in silica). Kimberlites and lamproites have compositional and mineralogical differences that are probably related to variations in their depth of origin, and the degree of melting and the composition of the rocks that melted to produce them. Generally, lamproites (Fig. 2) are richer in silicon, titanium, potassium and phosphorus than kimberlite.

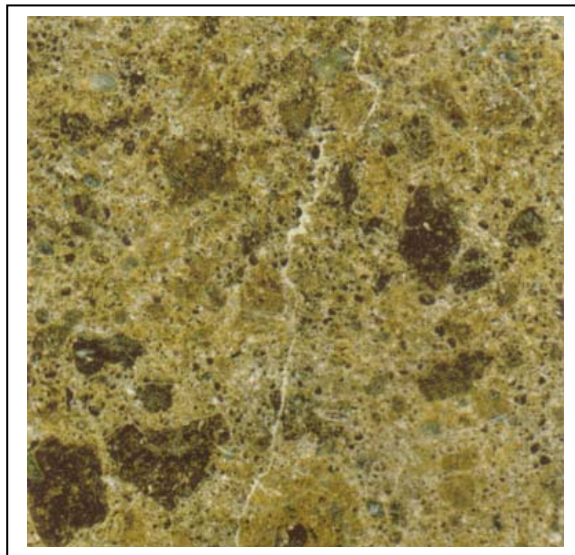


Fig. 2. Typical diamond-bearing olivine lamproite from Argyle's AKI Mine, East Kimberley (field of view approximately 2cm).

Thus lamproites are often rich in potassium silicates, including leucite, phlogopite, potassic richterite and sanidine, but also may contain forsteritic olivine and diopside. In contrast, kimberlites are rich in volatiles, or dissolved gases, with a high content of CO_2 , and a mineral assemblage that includes olivine with monticellite, phlogopite, perovskite, spinel, apatite, carbonate and/or serpentine. Not all kimberlites and lamproites are diamond-bearing. Indeed, diamond-bearing pipes are the exception rather than the rule, and of the lamproites in the Kimberley it is the olivine lamproites, not the leucite-bearing lamproites that contain economic quantities of diamond.

The emplacement of diamond-bearing rocks in Australia has occurred sporadically from 2000 to about 20 million years ago, with lamproites being the main diamond carriers (Jaques *et al.*, 1986). The Proterozoic Argyle pipe, erupted about 1180 million years ago, is the richest, and since then, weathering and erosion has distributed some of its diamonds into local economic alluvial deposits (Smoke Creek, Limestone Creek & Bow Creek deposits).

The Argyle lamproite carried up two generations of diamonds from the mantle. These diamonds formed at temperatures of between 1000 and 1500 °C (Jaques *et al.*, 1989; Jaques *et al.*, 1990), and at depths of 150-180 km. One generation of diamonds might have formed as far back as the Archaean. However, the majority of the Argyle diamonds formed around 1580 million years ago (Richardson, 1986), including the brown diamonds, which were stored for up to 400 million years, at temperatures around 1260°C, before transport to the surface (Taylor *et al.*, 1990).

COLOUR AND COLOURING AGENTS

The cause of colouration in pink (and other) diamonds is enigmatic and continues to be the subject of scientific research (e.g. see Chapman & Humble, 1991; Chapman *et al.*, 1996; Chapman & Noble, 1999; King *et al.*, 2002, and references therein). In the absence of evidence that colouration is due to some trace element contents of the pink diamonds (such as nitrogen or boron), currently it is thought that the cause of the colouration is similar to that producing brown colouration in diamonds. Essentially, colour is determined at the atomic level by lattice defects (colour centres) that can selectively absorb light in the visible region of the spectrum (Collins, 1982, and references therein).

In some pink diamonds colouration is unevenly distributed, occurring most intensely along bands parallel to octahedral {111} planes in the cubic structure. This has been interpreted (Collins, 1982) as having resulted from deformation of crystals during their geological history in the host rocks. Essentially, carbon atoms along the planes of stress are displaced along slip planes producing colour centres, although the structure of these is poorly known.

More recently, Chapman & Noble (1999) have studied colouration in pink and rare blue Argyle diamonds. Their research, using Electron Spin Resonance, Fourier-transform infrared spectroscopy, photo-luminescence and other techniques has revealed that pink colouration may be related to charge states in colour centres, and could involve nickel (Ni⁻) impurities in association with nitrogen (N⁺) defects.

For pink diamonds, Argyle recognises four main colour categories: pink (P), purplish pink (PP), brownish pink (BP) and pink 'champagne' (PC). These broad categories are graded further according to the intensity of their colour from 'very intense' (1) to 'very faint' (8), and on the basis of the diamonds clarity.

THE ARGYLE DIAMOND DISPLAY COLLECTION

The diamond collection donated to the Western Australian Museum consists of twenty-eight parcels containing more than 500 individual stones weighing 13.73 ct in total (Fig. 3). Four are rough pink diamonds (octahedral crystals) of different hues. Several hundred of the stones are Argyle's stock 'pink melee diamonds', each no more than a few points in weight from strongly coloured to faint pink diamonds. For comparison, two are white diamonds and two are champagne coloured diamonds at either end of the intensity scale (Fig. 3).

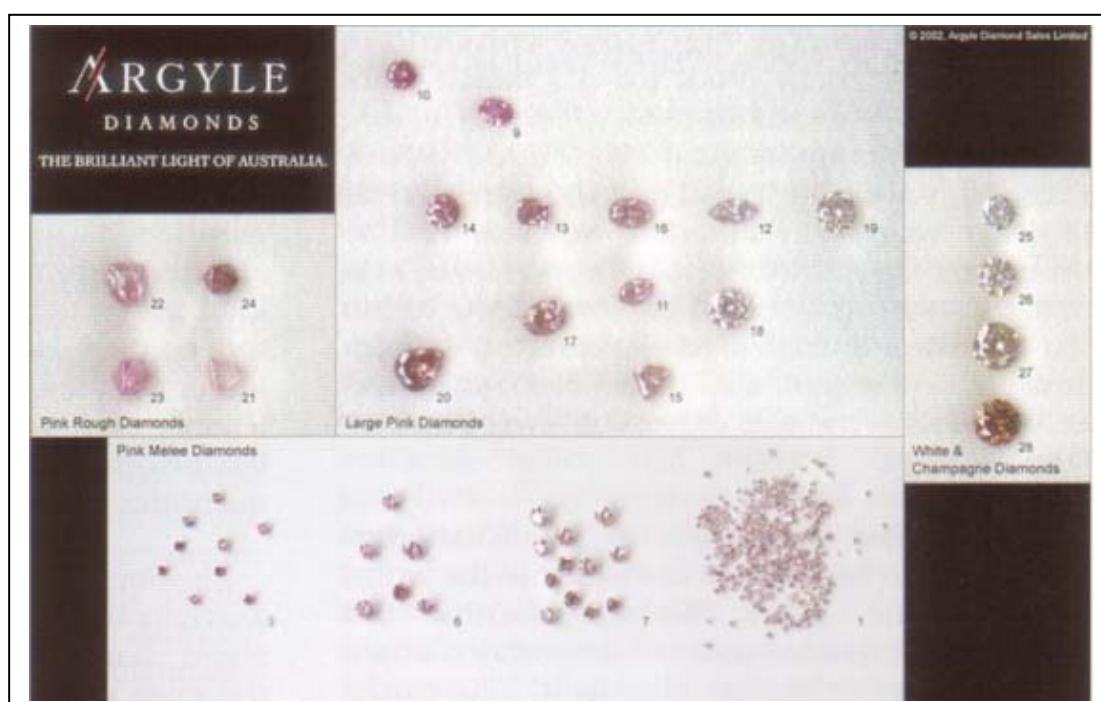


Fig. 3. The complete Argyle Diamond display collection held at the Western Australian Museum.

Twelve stones (12) are large pink diamonds of different hues. These range in individual weight from 0.16 to 0.58 ct and have been cut in a variety of shapes including brilliant, oval, marquise, emerald and triangular. The colours of the diamonds vary from light or pale pink to purplish pink. A few of the stones are brownish pink, and two are pink *champagne* in colour. The largest diamond is an intense brownish pink, pear-shaped diamond containing an inclusion, (Fig. 4).



Fig. 4. Five of the largest pink diamonds in the Argyle Diamonds display collection at the Western Australian Museum. The largest (centre) weighs 0.58 ct.

The current total market value of the stones is more than \$A200,000, although their actual value as a collection of pink and comparative diamonds far exceeds the sum of their individual parts.

SUMMARY

The Argyle Pink Diamond Collection, currently housed at the Western Australian Museum in Perth, is an exceptional gift to the nation, and represents an outstanding gemmological/geological display resource. It is hoped that over years of exhibition many Australians will view the collection (or part of it), and it will also be enjoyed by numerous visitors from overseas. The primary role of public Museums is to preserve collections in perpetuity for the benefit of future generations. Long after the Argyle Mine has closed, this collection will be enjoyed by future generations of Australians.

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