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WESTERN AUSTRALIAN DIAMONDS

Abstract:

The position of Australia as Number One diamond producing country is based on the discovery of one diamondiferous lamproite pipe near Lake Argyle, Western Australia. The geological setting and the differences existing between lamproite and kimberlite are explained. The characteristics of diamonds from this deposit and also from some other Australian deposits are scrutinized. An hypothesis which tries to explain observed differences with diamonds from other countries is put forward.

Introduction:

Towards the end of last century, diamonds have been found in Australia. These finds were connected to gold and tin mining activities and to some extent to precious stones diggings.

Starting with the first discoveries of diamonds in the alluvial deposits of Bingara and Copeton in New South Wales, diamonds have been found since, in almost every state of this huge country (see map Fig.3).

About one hundred years later a whole series of diamondiferous igneous rocks is discovered in Western Australia in an area called "Kimberley". It's a first for Australia where never before diamonds had been found in but alluvial deposits, and it's also a première on a global scale since never before diamonds had been found in magmatic rocks other than "kimberlites".

The diamondiferous lamproite occurs in the western part of the Kimberleys close to a town called Ellendale where approximately forty pipes have been identified so far.

In East-Kimberley fewer pipes have been located, but it is mainly in this area, close to Lake Argyle, that Australia's reputation as a diamond producing nation has substantiated.

Fig.1: *An exceptional pink Argyle diamond (6.52ct).*

Fig.2: *Aereal view of the Argyle (AK1) mine with annex treatment plant.*

Fig.3: *Map of Australia indicating the most important diamond deposits. The dotted area indicates the position of the Kimberley 'craton' in Western Australia.*

Kimberley No.2:

In the north of Western Australia an area has been named the 'Kimberley' in honour of the same Lord Kimberley that had been commemorated already elsewhere...

In this dry and semi-tropical environment 3 diamondiferous outcrops exist:

* **in the North:** some kimberlites containing low amounts of diamonds with associated alluvial deposits, possiby of lesser economical importance.

* **in the Southwest:** around Ellendale an important number of lamproites and kimberlites and some associated alluvial deposits exist. Deposit economically important.

* **in the East:** some lamproite pipes and alluvial deposits exist South of Lake Argyle. It is here that the most important diamond mine is located: the famous'AK1'.

The Southwest of Kimberley:

Around the town of Ellendale 46 lamproite and kimberlite pipes have been discovered, some having exceptional dimensions, such as the Fitzroy/Calwynyardah pipe measuring 128 ha (BRUTON,E.,1981; ATKINSON et al,1984).

The majority of these rocks do not contain diamonds, or in such low amounts that they are only of a scientifical interest. In this area also some alluvial deposits are encountered.

At present, none of the outcrops are mined. They are, however, thoroughly studied to establish the feasability of a possible mining operation. Because of the low grade of the Ellendale deposits, they would ordinarily be considered of a marginal interest.

Since they contain, however, more than 60% of gem quality, any decision is harder in the make. In these low grade/high value deposits, the feasability of the exploitation depends heavily on the quality rather than on the quantity of the mined diamonds.

In the beginning of the 80's some smaller parcels of Ellendale diamonds have been sold on the Antwerp diamond market, creating a "cash-flow" and supplying the mining company with some hardly needed figures on which to base a decision. The diamonds in these trial-runs can be considered to be "spin-off" of the exploration program rather than as the result of "real" mining activities.

Fig. 4: *Map showing the geological structure of the northern part of Western Australia. The dotted area represents the Kimberley Craton with adjacent the King Leopold' and the Halls Creek Mobile Belt.*
The lamproite and kimberlite pipes are only symbolically indicated and the symbols used do not reflect the real number of intrusions.

East-Kimberley:

ARGYLE AK1

In East-Kimberley, south of Lake Argyle, a series of diamondiferous lamproite pipes and some associated alluvial deposits have been identified. One of these, the famous AK1 pipe has been discovered in 1979, is currently being mined and contains proven ore reserves to allow at least 25 years of operation.

Since 1986 this mine is operated at full speed and produces on its own, 29 million carats per year, accounting for one third of the total world production!(see Table 1). The very low 7$ per carat average for the AK1 rough indicates that the mine is producing mainly diamonds of industrial grade(95%).

In a very short period of time, the 'Argyle' name became quite 'popular' or even 'famous' to the diamond world.

Table 1:

	Annual production of ARGYLE-AK1	*Total World Production*
1985	approx. 7 million carats	approx. 66 mio. cts
1986	approx. 29 mio. cts	approx. 92 mio.cts
1987	approx. 30 mio.cts	approx. 93 mio.cts
1988	approx. 35 mio.cts	approx. 94 mio.cts

Geology:

In contrast to the kimberlites in other countries, the Western-Australian lamproites do not occur in the middle of a craton but rather in the adjacent Mobile Belts. The AK1 pipe occurs in the Halls Creek Mobile Belt. The Ellendale deposits are located partly in the King Leopold Mobile Belt and partly in the Fitroy Trough. The relationship between the deposits and the geological setting is shown. Interesting are the enormous age differences between the different rocks concerned.The sediments covering most of the old Kimberley Craton have been deposited there between 1,900 and 1,600 million years ago. The Halls Creek and probably also the King Leopold Mobile Belt have an age of some 1,900 million years.

The ARGYLE-AK1 intrusion has been dated to be 1,120 million years old. At that time the Halls Creek Mobile Belt was not longer active and can be considered cratonized at that time.

The Western Kimberley intrusions are much younger. In the proximity of Fitzroy town,some pipes have been dated to 185 million years. This is a very important era for diamond geology since in that time period most diamond-bearing rocks as well in Africa as in Brazil are formed. It is also in this era that the Atlantic Ocean developed.
Even younger than this are the Ellendale intrusions with no more than 25 million years of age, making it the Youngsters in diamond geology.

For a better understanding of this,the geological model of Steven HAGGERTY(1986) is introduced.

HAGGERTY (1986) proposes a lateral section through a craton with its adjacent Mobile Belts in order to explain the structural relations existing between the geological setting and the kimberlite and lamproite pipes (Fig. 5).

In the middle of the craton the thermal gradient is much lower than at the sides which explains why the graphite / diamond boundary is at much lower depth.

In kimberlite-K3 a predominance of ultrabasic (peridotitic) diamonds will be observed. This phenomenon is observed in most diamond-bearing kimberlites throughout the world.

When moving towards the periphery of the craton, diamonds in kimberlites become less peridotitic and more are derived from an eclogitic environment.

In kimberlite-K2 a predominance of eclogite-derived diamonds is already visible. This is for instance the case in Orapa (Botswana) or the Mir-pipe in the Soviet Union (Siberia).

Kimberlite-K1 which is located in an active Mobile Belt system, will contain no diamonds at all because of the thermally unfavourable environment.

The Lamproite-L (Argyle AK1) occurs in a cratonized Mobile Belt and, closely ressembles Kimberlite-K2 in the predominance of eclogitic diamonds.

Fig. 5 : HAGGERTY'S structural model (1986) relating the kimberlitic and lamproitic intrusions and the craton.

DIAMONDS FROM THE AUSTRALIAN KIMBERLEY

1. Diamonds from Western Kimberley (Ellendale)

Only a relatively small number of Ellendale diamonds have appeared on the Antwerp diamond market.
Inspection of these together with information available in the literature (ATKINSON et al., 1984, 1987; MADIGAN, R., 1983) reveal some of their characteristics.

In most Ellendale pipes, diamonds are (very) rare with grades up to 0.1 ct/t. The quality of these diamonds, however, is exceptional : up to 60 and 85 % of these are of gem quality.

At first sight, the Ellendale diamonds seem not to be different from diamonds from other (kimberlitic) deposits. Most diamonds have a yellow (cape) body colour, some are brown and very few are 'fancy' colours.

The shape of the diamonds and the state of the crystal surfaces indicate a transition through a rather hostile and corrosive environment. Most diamonds are rounded (fig. 6).

The surface of most diamonds is frosted, while others take on a remarkable polish. This natural "polishing" phenomenon is probably the result of interacting with CO_2 and H_2 gases present before the actual eruption.

Judging from the inclusion content, Ellendale diamonds show no marked predominance neither for peridotitic, nor for an eclogitic origin.

HAGGERTY'S model (1986) suggests a predominance of eclogitic diamonds in lamproites or kimberlites in a Mobile Belt environment. The divergence with the observation can be easily attributed to age differences between the Ellendale pipes and the Mobile Belt in which they occur.

What was an active Mobile Belt 1.600 million years ago, has been completely cratonized (shift towards the middle of the craton) 25 million years ago when the Ellendale intrusions took place.
At the time of this event, the position of Ellendale on the continental plate bears close ressemblance to a position in between kimberlite-K2 and kimberlite-K3 on the diagram.
This position is in perfect accordance with the syngenetical inclusion content.

2. Diamonds from Argyle - AK1

At first sight, an AK1 'run-of-mines' bears closer ressemblance to candy sugar rather than to diamonds.

Most of the stones are heavily included, with numerous black inclusions (the famous "carbon spots").

Shapes like octahedrons, maccles, cleavages and irregulars are common. Cubes are not encountered.

These characteristics can also be observed on diamonds from other deposits.

The crystal surfaces :

The corrosion pits on the octahedral crystal faces are different from the normal trigons.
Instead, hexagonal depressions produce a 'bee-hive' appearance (fig. 7).

ORLOV (1977) indicates that this kind of corrosion figures probably results from "laminar" corrosion rather than from corrosion around a dislocation which produces trigons.

ORLOV (1963) had already studied similar corrosion figures on some diamonds from the Urals (USSR).

It is quite remarkable that on AK1-diamonds both types of corrosion figures are visible, since inside the hexagonal depressions all kinds of trigons are visible.

'Surface grain lines' are also a common feature of AK1 diamonds. These lines indicate the presence of 'glide-planes' produced by plastic deformation. Strong corrosion along these lines resulted in deep corrosion channels that are frequently observed (fig. 8).

Fig. 7 : Hexagonal corrosion pits on an AK1-diamond

Fig. 8. : Corrosion channels along glide planes on an AK1-diamond

Hardness

Interesting and may be surprising is the fact that in comparison with diamonds from other deposits, AK1-diamonds, and perhaps all Australian diamonds, are noticeably harder. This hardness difference has been known to the Antwerp diamond polishers already since a long time, and they nicknamed diamonds from New-South Wales : "kan-nie-faire" (translated "can-not-make") (JORIS, A., 1986).

For some particular industrial applications, these diamonds have proven to be very interesting.
Argyle diamonds have the reputation to be very hard and very brittle at the same time.
This 'brittleness' resulting probably from the presence of glide planes along cleavages planes. The superior hardness is without any doubt a result of a reorientation of the 'was' (grain) of the diamond between the different glide planes. This produces a 'fragmentation' of the crystal (fig. 9).

Fig. 9 : 'Fragmentation' of an AK1-diamond by glide planes as seen with a cathodoluminescence apparatus. This phenomenon can also be observed with interferoscopy.

Specific gravity

Not only the hardness of AK1-diamonds is superior, also the specific gravity is high.

BARDET (1973) gives specific gravities as high as 3.578 for diamonds from Copeton (N.S. Wales).
He tries to relate this to a higher C^{13} content (C^{13} is the heavier carbon isotope). Our measurements of the specific gravity of AK1-diamonds both hydrostatically as well as electronically in almost - clean diamonds, confirm these high readings.

ATKINSON et al. (1987) reject a correlation between a high sg and a higher C^{13} content in AK1-diamonds.

Colour

About 80 % of AK1-diamonds are brownish, 15 % are yellowish and some percentages are colourless, and even fewer stones are of a fancy colour.

It is, however, exactly this category that has made the reputation of Argyle. The exceptional pink or purple Argyle diamonds are in a league of their own. The colour intensity is striking. Colours ranging from pure pinks to peach and even to purple pink are observed.

Contrary to the fact that most pinks from other deposits belong to type IIa (not containing Nitrogen as an impurity), the Argyle pinks just as well as most other diamonds from this deposit, belong to the type I_a (containing Nitrogen as an impurity).

Another remarkable fact is the uniqueness of its I.R.-spectrum. This points towards an accelerated 'ageing' of the Argyle diamonds (table 2).

Pink is a colour that results from the presence of innumerable 'grain lines' or structure defects associated with glide planes. In most cases, however, this defect produces brown colours. This is the most common colour observed in AK1-diamonds.
It is ironic that the phenomenon making that most of the Argyle diamonds (95 %) are considered to be of industrial quality can sometimes produce unique pink stones.

In some diamonds, patches or zones of pink are mixed with brown zones separated by glide planes. These patches take up the form of small rectangles and seem to be influencing the hardness of the diamond (fig. 9).

Inclusions :

Eclogitic inclusions are predominant in Argyle diamonds. About 70 % of the syngenetic inclusions have been classified of eclogitic origin, 30 % of a peridotitic origin.

The most common inclusion, however, is without any doubt the cleavage (crack), wether graphitised or not.

The location of the AK1 pipe and the properties of the diamonds it contains are in perfect harmony with lamproite L1 on HAGGERTY'S diagram.

Between the crystallization around 1,580 million years ago (HARRIS, 1988) and the intrusion of the AK1 pipe around 1,120 million years ago, the diamonds have transided for more than 460 million years in a corrosive, dynamically active Mobile Belt Zone. This might be the reason for phenomena like massive plastic deformation, heavy corrosion, cleavages and brown and pink colours that are characteristic features of AK1-diamonds.

Conclusions :

Diamonds from Australia and especially from Argyle have changed the diamond world.
Not only because of the enormous size of the production but also because of the characteristics of these diamonds and the special nature of the deposits.
Ellendale lamproite diamonds seem not to be too different from 'normal' kimberlitic diamonds. Thus the nature of the rock in which diamonds occur is not the decisive factor.
Argyle diamonds are very much different.
These differences have very little to do with differences in crystallization but rather with enormous differences in the geological events that followed.

Argyle diamonds have been subjected to gigantic oriented pressures during their transition in an active Mobile Belt system.

The ubiquitous corrosion figures, plastic deformation with cleavages and cracks, the higher hardness and specific gravity, the uniqueness of their I.R. spectrum, the great pinks make that Argyle diamonds deserve a special place in the mineralogy of diamond.

Conclusion :

Les diamants d'Australie et surtout les diamants d'Argyle ont bouleversé le monde diamantaire.

Non seulement par la masse de pierres qui est mise sur le marché, mais aussi à cause des caractéristiques de ces diamants et des gisements où on les retrouve. Les diamants d'Ellendale ne semblent pas être très différents des diamants kimberlitiques d'autres gisements. Ce n'est alors pas la nature de la roche qui est déterminant.

Les diamants d'Argyle, par contre, sont assez différents. Ses propriétés sont probablement introduites après la cristallisation des diamants par les pressions orientées présentes au moment de la transition dans la zone mobile encore actif.

Les traces de corrosion omniprésentes, les déformations plastiques, les clivages et félures, la dureté et le poids spécifique élevé, la nature extraordinaire de son spectre infrarouge, le grand nombre de pierres brunes et les uniques pierres roses en sont témoins et font que les diamants d'Argyle méritent une place spéciale dans la minéralogie du diamant. ■

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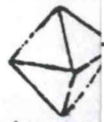
1,580 mil ——→ 1.126 millions d'années

CRYSTAL, Belt — LAMPROITE ERUPTION

Type I-(

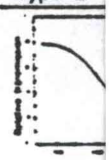


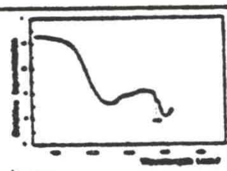
with Nit——— Frosted surface

ORGANISATION DES ATOMES D'AZOTE (N)

C C C activation energy of 7e V, this level of aggregation
C N C ed in at least 4,600 million years, which is
C C C he age of the earth itself. Since only 460 million
C C C en crystallization and eruption, an unknown, very
menon must have provoked this accelerated 'ageing'
atomes is NS, 1985).
Type Ib

SPECTRE VISUEL





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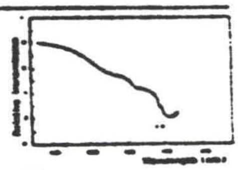

rose

colour

INCLUSIONS

70 % ec.
pyroxen

20 % pe
pyrope,

(Spectres UV/VIS: VAN ROYEN, 1988 a, b)