Photograph 4. Rough diamonds from New South Wales (enlarged). The state was formerly the largest producer of diamonds in Australia, which were obtained mainly from alluvial deposits near Copeton and Bingara in the New England region. There is good potential for additional diamond resources in New South Wales. (Photographer D. Barnes)

Potential and Outlook

Production of diamonds (Photograph 4) in New South Wales has been estimated to be over half a million carats, with most production in the late 1800s and early 1900s. There is excellent potential for primary (hard-rock) diamond deposits and for the delineation of more alluvial deposits (Figure 7). There are clear indications that alluvial diamonds, which have been found in significant quantities, were locally derived, and there are intrusions that contain diamonds.

Despite a moderate level of exploration in the state over many years, economically viable source rocks have not yet been found. The lack of success may reflect the prevailing exploration concepts used rather than the potential for economic discoveries.

Diamond exploration is notoriously difficult, owing mainly to the very low concentrations of diamonds that may be present, even in economic deposits. Diamond explorers have to look for 'indicator minerals', which accompany diamonds, rather than actual diamonds, at least until targets have been identified. Once targets have been identified, samples need to be in the order of 50 cubic metres to reliably establish the presence or absence of diamond. Generally, the recovery of any diamonds, micro or macro, is highly encouraging.

In New South Wales explorers have recovered diamonds, in many cases macro diamonds, from samples as small as 20 kg, from up to 25 diatremes across the state. Many of these highly positive results have not been followed up with bulk sampling.

Experience elsewhere in the world shows that up to 150 possible targets may need to be bulk sampled before an economic deposit is identified. However, in

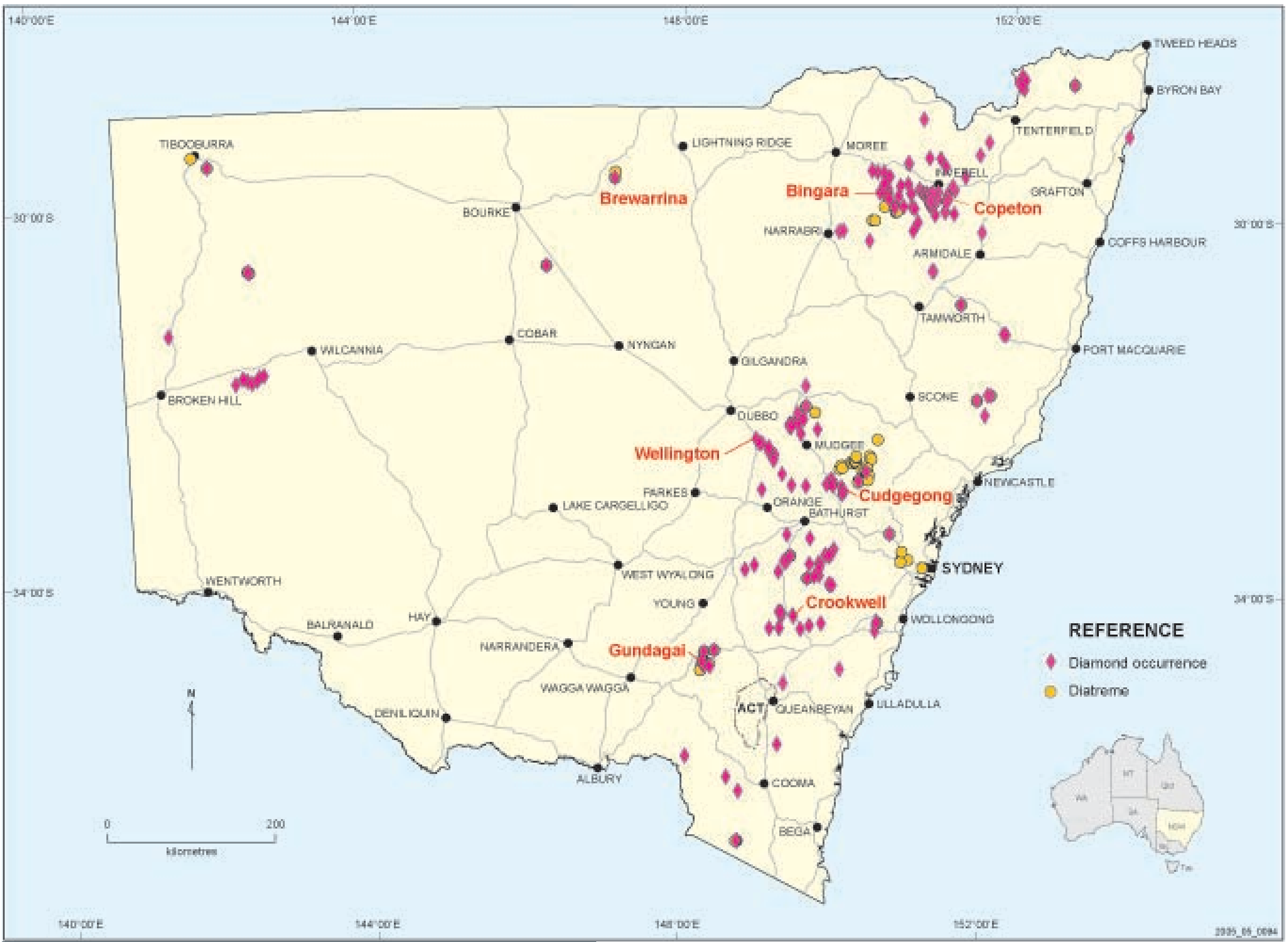

Figure 7. Diamond occurrences in New South Wales

New South Wales only one or two diatremes in any one province have been bulk sampled. Numerous diatremes remain untested.

The reasons for the lack of success of previous exploration are related to the adherence by many explorers to what is called the 'standard model' for diamond formation and occurrence. In the standard model, which is based on South African occurrences (and is often referred to as the South African diamond model), the setting of primary diamond deposits is ancient craton, thick lithosphere, and host rocks of kimberlitic or lamproitic pipes. However, New South Wales lacks most of these key elements, and the widespread occurrence of diamonds here is anomalous in terms of the standard model. Even at Broken Hill, the craton is not sufficiently old in terms of the standard model.

Many diamond explorers in New South Wales have been discouraged because the rocks from which positive indications have been obtained are not kimberlite or lamproite, but alkali basaltic rocks.

In the late 1990s, the Geological Survey of New South Wales developed a new model, 'the subduction model' (Barron et al. 1994; Barron et al. 1996; Barron et al. 1998), for diamond formation and occurrence in anomalous settings such as eastern Australia. The model explains the formation of off-craton primary diamond deposits, and extends standard diamond exploration techniques. Subduction model primary host rocks are alkali basaltic rocks such as nephelinite or basanite.

Various aspects of the diamonds found in the state — their hardness, isotopic character, specific gravity, morphology, internal features and inclusions, age data, associated minerals and host rocks — conform to the predictions of the subduction model. The subduction model predicts that the source rock in a subduction terrane, such as eastern New South Wales, is diamond eclogite in static, subducted oceanic crust or doubled crust, at 20–22 kbar. The nephelinitic or basanitic diatremes from which primary diamonds have been recovered in the state originate from similar depths.

The model allows for standard exploration techniques to be used, coupled with additional indicator minerals and new discrimination techniques. Recent data on garnet chemistry indicates that many more populations of garnets can be anomalous than predicted by the standard model.

The model also explains the occurrence of diamonds in Phanerozoic subduction terranes in other parts of the world, such as western North America and Kalimantan.

The subduction model has found only limited acceptance amongst major diamond exploration companies, mainly because of entrenched adherence to the standard model. This situation would change once an economic deposit was found, as happened with the discovery of the Argyle deposit, which was not predicted by the standard model.

In several areas in New South Wales there are numerous prospective diatremes (pipes), e.g. the northwestern Sydney Basin, the Kayrunnera area north of Broken Hill, the Brewarrina area, and the northern Tamworth Belt. In some of these areas, diamonds occur in nearby alluvial deposits, and have been recovered from one or more diatreme(s). Numerous diatremes remain untested.

Some previous exploration has been based on palaeodrainage models that are now thought to be flawed (Ray et al. 2003; Temby 2004; Temby & Ray 2004). Older palaeochannels that have not previously been explored for alluvial diamonds or used to locate potential hard-rock sources have now been identified in a number of areas, including Copeton, Bingara and Cudgegong.

The diamonds from alluvial deposits in the state were previously considered difficult to cut because of their hardness and the presence of internal deformation twins. However, these are now desirable features, and a high proportion of the diamonds that were produced would now be regarded as gem quality. If economic occurrences are located in the state, the average value of the stones would probably be high.

Areas with significant potential for diamond exploration include Copeton, Bingara, Cudgegong, Wellington, Crookwell, Gundagai, Balranald, Dolo Hills (near Broken Hill) and Brewarrina (Temby 2004). Targets have been identified in those areas, including untested magnetic anomalies in areas with known occurrences and potential source rocks, and unexplored diamond or diamond indicator mineral-bearing palaeodrainage systems.

Nature and Occurrence

Diamond is an isometric form of the element carbon, and is the hardest known naturally occurring substance. Because of its hardness and other properties it is one of the world's most important industrial minerals, especially for abrasive and cutting applications. Because of its hardness, rarity and beauty it is one of the most valuable gems. Per unit weight or volume, it is by far the most valuable industrial mineral.

Details of estimated world natural diamond production in 2003 are shown in Table 7 (Taylor et al. 2005). World production was about 150 million carats. Although Australia dominates world production in volume, many other countries produce much more gem-grade stone. Natural diamond accounts for about 10% of all industrial diamond used, while synthetic diamond accounts for the remainder. Annual world production of synthetic diamond is estimated to be between 450 and 500 million carats.

Table 7. World natural diamond production 2003

Country	Production (carats)
Australia	31 013 000
Botswana	30 412 000
Democratic Republic of the Congo	29 000 000
Russia	24 000 000
South Africa	12 673 379
Canada	11 200 393
Angola	6 300 000
Namibia	1 454 852
Ghana	904 089
Guinea	660 000
Sierra Leone	506 819
Central African Republic	400 000
Brazil	400 000
Ivory Coast	307 000
Guyana	250 000
Tanzania	232 273
China	150 000
Liberia	60 000
Venezuela	34 790
Lesotho	2 099
Others	139 306
Total	**150 100 000**

Source: Taylor et al. (2005)
Note: 1 carat is 0.2 g

Until the early 1980s, all of the natural diamond produced in the world (excluding NSW) came from kimberlite pipes and derived placers in areas characterised by ancient, thick, cool lithosphere (cratons). This is the standard model setting for diamond formation. Diamonds were also known in placers with no apparent source, outside of ancient cratons. These deposits have now been explained by the subduction model.

The standard model was modified in the early 1980s to include deposits like the rich Argyle deposit in Western Australia. This deposit was discovered in the late 1970s in a lamproite pipe in a mobile zone at the margin of an ancient craton. The Argyle mine commenced production in the early 1980s, and since then has been producing approximately one third of the world's natural diamonds by volume.

New South Wales Occurrences

There are over 120 known diamond occurrences in New South Wales, several of which have significant recorded production (Ray et al. 2003; Temby 2004) (Figure 7). Until the discovery and mining of the Argyle deposit, New South Wales had the largest recorded diamond production in Australia. Production was entirely from alluvial deposits in the late 1800s and early 1900s. Most of this historical production was from deep leads in the Copeton and Bingara areas in New England (recorded production of about 170 000 carats and 35 000 carats, respectively) for which no hard-rock sources have been identified. Further production was associated with gold dredging in the Macquarie River (4000 carats), from deep leads in the Cudgegong area (2000 carats), and minor production from a number of other localities throughout the eastern highlands. It has been estimated that actual total production may have exceeded 500 000 carats.

With other occurrences stretching from far north Queensland to Victoria, the recorded occurrences form the eastern Australian diamond province which is over 3000 km long and up to 300 km wide.

Applications

Diamonds used as gems are assessed on the basis of the well-known 'four Cs': colour; clarity; carat weight; and cut. Generally, stones less than one carat have much lower value than those above one carat, and the lower classes of stone grade into near-gem and industrial. The near-gem material may be used for cheap jewellery.

Industrial grades of diamond are defined mainly in terms of grainsize, ranging down from larger stones, which have non-structural imperfections rendering them unsuitable for use as gems, to grits and powders. To date, synthetic diamonds have not been able to be manufactured economically in sizes larger than grit, and all of the coarser grades such as stones set in drilling bits and dies for wire drawing are natural diamonds. By far the major industrial use of diamond is in abrasive or cutting applications, but there are also important specialised applications which make use of its very high thermal conductivity and excellent electrical insulating properties. Emerging technologies are likely to expand the use of diamond in such forms as shaped composites and plasma coatings.

Economic Factors

Until about the early 1980s, marketing of gem diamonds was largely controlled by the Central Selling Organisation (CSO), a subsidiary of De Beers. The strong position of the CSO was subsequently eroded considerably through the decision of the Ashton joint venture (Argyle mine) to market its production independently; independent Russian marketing (at times under CSO control); and by expanding uncontrolled production and smuggling from areas such as Angola. Production from new Canadian mines is also marketed independently.

With a declining share of the world market, De Beers decided in late 2001 to abandon the cartel approach to marketing and became an independent player on world markets. The CSO was replaced by the Diamond Trading Company, which obtained its rough diamond supplies from De Beers Group Mines in Botswana, Namibia, Tanzania and South Africa.

Diamond can be synthesised in various ways. The most common methods currently in use involve subjecting carbon-bearing materials like graphite to high pressure and temperature. Intensive research is being undertaken into alternative methods of synthetic diamond production, for example, production of diamond coats on substrates by deposition from vapour (Olson 2005). These alternative methods of synthetic production may have a major impact if practicable. Many countries produce synthetic diamond, and the market has been oversupplied in recent years, leading to a decline in prices for many grades. Production of high-quality synthetic diamond is limited to a few countries, with most production coming from the USA, Ireland and South Africa, essentially under the control of either General Electric or De Beers.

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