



NSW DEPARTMENT OF
PRIMARY INDUSTRIES

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Potential and Outlook

New South Wales has moderate potential for graphite deposits. Most occurrences appear to have formed within the contact aureoles of granitoids emplaced in carbonaceous mudstones and siltstones. The most prospective area is the New England Orogen, near Tenterfield, where the Early Triassic Stanthorpe Monzogranite intruded the Late Permian Gilgurry Mudstone.

Prerequisites for the formation of significant graphite deposits include a prolonged heat source, carbonaceous or graphitic country rocks and a reasonably stable tectonic setting. Exploration should concentrate on areas in the New England and Lachlan orogens where carbonaceous or graphitic country rocks have been intruded by high-temperature granitoids. For example, there may be potential for small deposits of graphite in Ordovician black shales south of Goulburn, adjacent to Devonian granitoid plutons. Larger plutons are likely to be more prospective than smaller plutons and higher-temperature plutons are likely to be more prospective than lower-temperature plutons. A significant age difference between the pluton and the country rock is likely to promote brittle fracture of the intruded rock and hence increase potential for graphite accumulation (L. M. Barron pers. comm. 2003).

There may also be some potential for graphite occurrences in the high-grade metamorphic terrane in the Broken Hill region, where minor graphite occurrences are known.

Nature and Occurrence

Graphite is one of three forms of naturally occurring carbon, the others being charcoal and diamond. It is a black (to grey), lustrous mineral that crystallises in the hexagonal system, is soft ($H = 1-2$) and has a specific gravity of 2.1 to 2.2.

Plumbago and black lead are old names for graphite, owing to its lead-like appearance. Graphite is compressible and malleable, an excellent conductor of heat and electricity and is highly refractory — with a melting point of 3650°C . Thermal oxidation of natural graphite begins at about 300°C , and it is commonly stable and chemically unreactive at lower temperatures. Natural graphite is also typically resistant to chemical degradation, thermal shock, shrinkage and oxidation.

Three discrete commercial types of natural graphite are recognised: flake (also referred to as crystalline or disseminated flake); crystalline vein (or lump); and amorphous (microcrystalline) (Harben & Kužvart 1996).

- Flake graphite is the most important commercially. The name refers to graphite that occurs as thin disseminated flakes in metamorphic rocks.
- Crystalline vein graphite consists of coarse, platy or needle-like crystals in veins, mainly in Precambrian igneous and metamorphic rocks.
- Amorphous graphite is massive microcrystalline graphite, generally derived from thermally metamorphosed coal seams or carbonaceous sedimentary rocks.

Graphite (flake and crystalline) is graded according to carbon content and particle size, whereas amorphous graphite is classified mainly on the basis of its carbon content. High-purity graphite (up to 99.9% carbon) is also produced synthetically in electric furnaces from calcined petroleum coke.

World inferred resources of graphite currently exceed 750 Mt (Olson 2005). China and India are the largest producers, accounting for about 70% of the world's natural graphite production, about 800 000 tpa in 2004. Other important sources include Russia, Ukraine, Brazil, Mexico, Korea, Canada and Madagascar. Sri Lanka is the main producer of crystalline vein graphite.

Deposit Types

Graphite deposits of commercial interest occur widely in regionally or thermally metamorphosed sedimentary rocks and in hydrothermal and metasomatic deposits. Harben and Kužvart (1996) identified five deposit types.

1. Early magmatic deposits (rare)
2. Deposits formed by concentration and crystallisation of carbon (from coal or carbonaceous sedimentary rocks) during regional or contact metamorphism
3. Vein deposits
4. Contact metasomatic (skarn) deposits
5. Residual deposits.

Most of the world's production of flake graphite comes from deposits of disseminated graphite in regionally

metamorphosed rocks of Precambrian age. Marble, gneiss and schist are the most common host rocks and in many cases have been intruded by pegmatitic veins. The graphite was formed from organic material or bituminous and coaly materials in the original sediments. Deposits may be up to 35 m thick and several kilometres or more long. Mined flake graphite deposits commonly have grades of 10% to 12% graphite but grades of up to 60% have been reported in Madagascar. Madagascar has what are probably the largest resources of high-grade flake graphite in the world (Taylor 1994).

Mexico and South Korea are important sources of amorphous graphite. The largest known deposits of crystalline vein graphite occur in Sri Lanka. Contact metasomatic or hydrothermal deposits are mined in Canada and the USA. Such deposits are generally small and of relatively low grade and account for only a minor proportion of global production.

Main Australian Deposits

The only known commercially significant deposits in Australia are on the Eyre Peninsula in South Australia (Keeling 2000) and the Munglinup graphite deposit near Ravensthorpe in Western Australia (Fetherston 2002).

The largest resources are on the Eyre Peninsula, where numerous occurrences of disseminated flake graphite are present. They occur within Proterozoic metasediments in a 200 km long zone on the eastern side of the Peninsula. The Uley deposit near Port Lincoln has been mined intermittently since the 1920s and has indicated resources of 2.87 Mt at 13% graphite (Keeling 2000). Total resources in excess of 350 Mt at 6–7% graphite have been inferred at the Uley deposit and five nearby deposits, which together make up the Mikkira Graphite Province.

New South Wales Occurrences

There are 14 recorded occurrences of graphite in New South Wales (Ray et al. 2003). They occur in two main areas in the New England Orogen: Undercliff Falls, north of Tenterfield; and Walcha, south of Armidale.

A total of fewer than 3000 tonnes has been mined in the past, nearly all from the Plumbago deposit in the Undercliff Falls area (Hamilton 1984; Brownlow 1989). In the Undercliff Falls area, there are nine separate graphite localities, including the Plumbago deposit. They occur in carbonaceous shales of the Late Permian Gilgurry Mudstone, which have been thermally metamorphosed

by the Early Triassic Stanthorpe Monzogranite. Deposits are typically of limited extent and the graphite is generally fine-grained and of low purity.

Graphite also occurs in two deposits about 35 km northeast of Walcha (Gilligan et al. 1992). These deposits occur within Early Permian granitoids associated with the Hillgrove Supersuite in which graphite is a minor but common mineral component. The deposits probably formed during Early Permian igneous activity that incorporated a pre-Permian (but unknown) source of organic carbon.

The Winterbourne graphite mine is developed in a north-trending micropegmatite dyke that intrudes granitic stocks of the Cheyenne Complex, Hillgrove Supersuite. The dyke is 2 m to 30 m wide and is exposed over a distance of about 250 m. It contains abundant segregations of fine-grained graphitic material. The Becks Point deposit consists of disseminated graphite in altered diorite adjacent to a probable lamprophyre dyke.

Ten tonnes of graphitic material were produced from graphitic shale in the South Komungla deposit near Goulburn, mostly between 1880 and 1930. Graphite has also been recorded at a number of other locations, including Cells Creek (north coast), Dundee, Grafton, Hillgrove, Tingha (New Valley), Broken Hill, Wagga Wagga, Pambula, Cordeaux River (probably anthracite), Eden and Mudgee. The potential for graphite in cindered (metamorphosed) coal seams in surface coal mines in the Hunter Valley is unknown, but unlikely to be significant.

Applications

The principal uses of natural graphite are in foundry facings, steelmaking, refractories, crucibles, pencils and lubricants (Harben 1999). Flake (80–99% carbon), amorphous (70–85% carbon), and highly crystalline graphite (90–99% carbon) are graded using carbon content and other criteria, including ash content and ash chemistry according to likely applications. Graphite is graded according to carbon content and particle size, whereas amorphous graphite is classified mainly on the basis of its carbon content.

Processing of natural and synthetic graphite to 2500°C produces high-purity graphite with up to 99.9% C and the ability to introduce selected promoter elements, such as boron and silicon into the graphite structure (Harben 1999; Crossley 2000). This enhances the consistency, lubricant properties and conductivity of the graphite. Crystalline graphite is preferred for making crucibles, while amorphous graphite is used in foundry facings, steelmaking and refractories.

The characteristically low coefficient of friction of natural graphite renders it highly suitable for coatings, pencils, powder metallurgy, refractories, lubricants and batteries. Low-quality graphite can now be used in high-technology applications, which were once the domain of synthetic material. Compared to synthetic graphite, natural graphite has a significant cost advantage.

Opportunities for recycling natural graphite are limited since it tends to be gradually consumed during use in such applications as refractories or brake linings. Used electrodes can be re-formed into electrodes or as a substitute for amorphous graphite. The use of recycled graphite refractories in such products as brake linings and thermal insulation is growing.

Economic Factors

Despite a decline in the usage of graphite in some applications, such as for electrodes and lubricants, overall demand for graphite is expected to grow significantly owing to the development of new applications in the high-technology field. These include alkaline and lithium ion batteries, fuel cells and chemicals.

The commercial production of electric cars using fuel cells would provide a major boost to natural graphite consumption, as one fuel cell may contain 9–14 kg of graphite (Crossley 2000). New applications, such as foil and membrane technology, are also anticipated to become important markets for graphite.

Demand for refractories, foundry materials and electrodes are linked to iron and steel production. In some of the larger markets, such as the USA, demand for synthetic graphite in steelmaking and other major applications has begun to adversely affect demand for natural graphite.

Demand for graphite in magnesite–carbon (Mag-carbon) brick production, as a replacement for asbestos in car brakes and alumina–graphite use in continuous casting is reasonably strong.

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