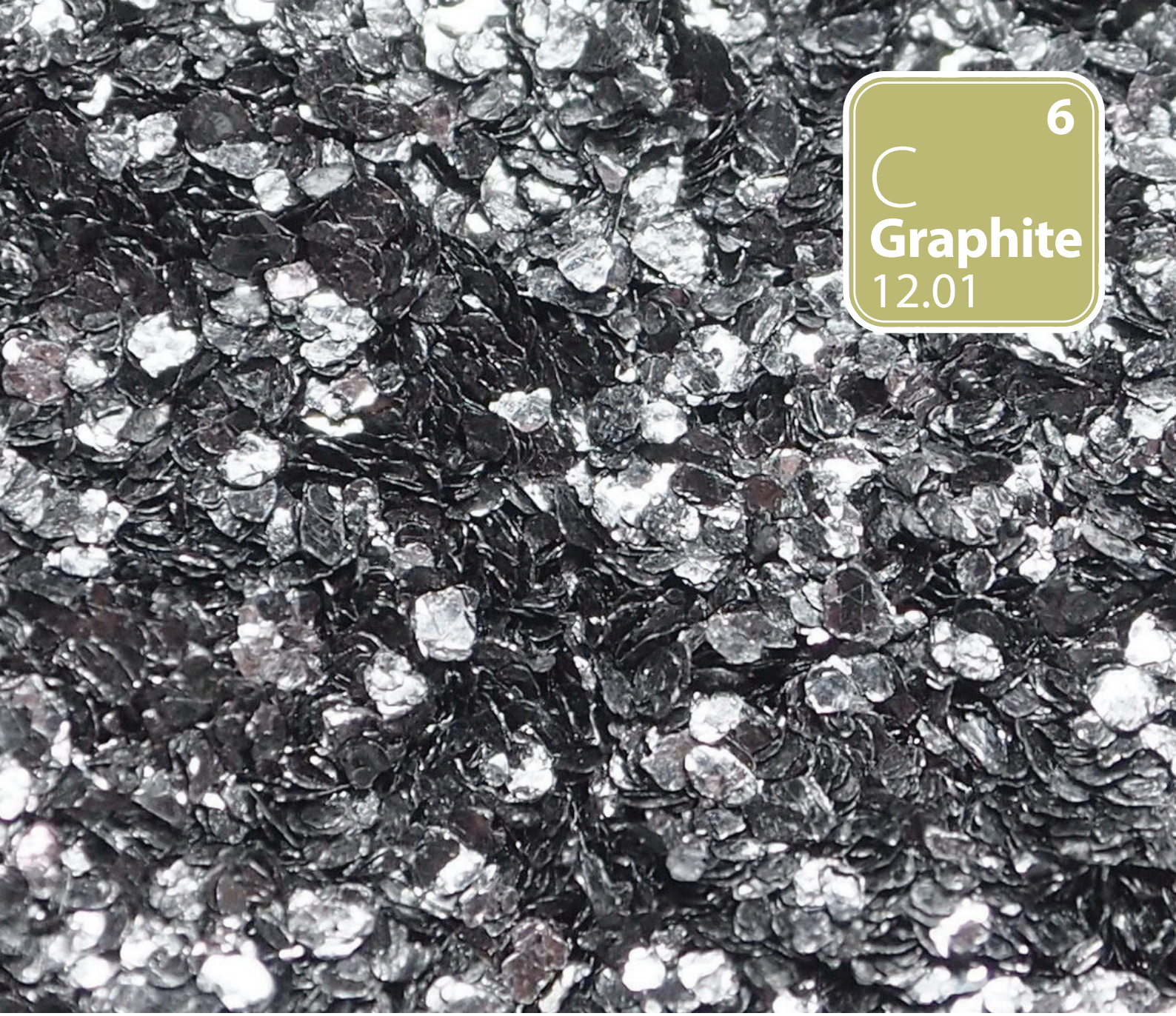

GRAPHITE

Critical mineral potential of South Australia

Alicia Caruso, Carmen Krapf and Adrian Fabris

SOUTH AUSTRALIA

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Acknowledgement of Country
As guests on Aboriginal land, the Department for Energy and Mining (DEM) acknowledges everything this department does impacts on Aboriginal country, the sea, the sky, its people, and the spiritual and cultural connections which have existed since the first sunrise. Our responsibility is to share our collective knowledge, recognise a difficult history, respect the relationships made over time, and create a stronger future. We are ready to walk, learn and work together.

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Graphite

Critical Mineral potential of South Australia

Alicia Caruso, Carmen Krapf and Adrian Fabris

Geological Survey of South Australia,
Department for Energy and Mining

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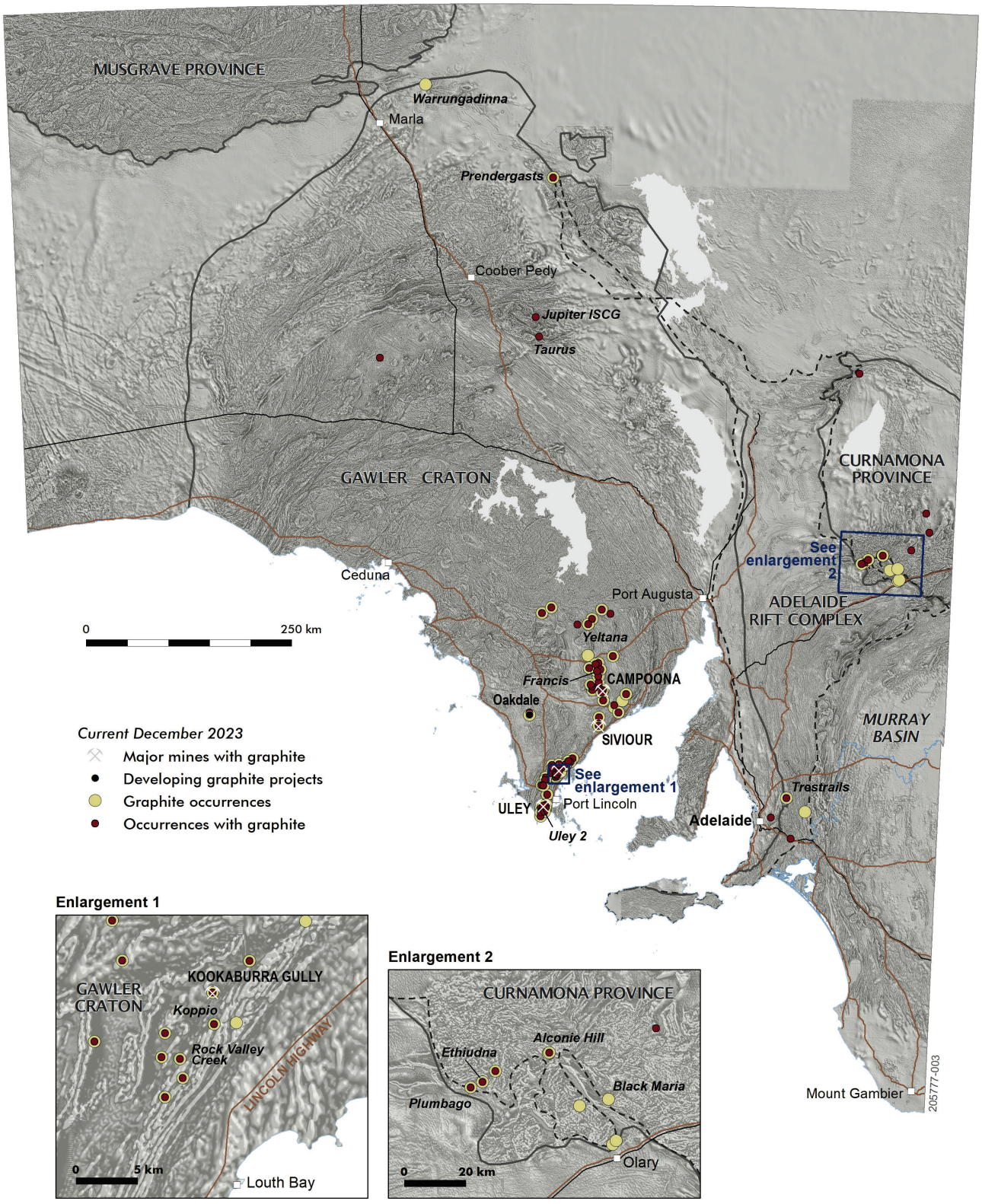

Figure 1. Occurrences of graphite and occurrences with associated graphite in South Australia. (205777-003 PDF 1.7 MB)

Graphite

Alicia Caruso, Carmen Krapf and Adrian Fabris

USES

The properties of graphite (element symbol ‘C’), namely being a good conductor of both electricity and heat, make it suitable for a variety of industrial applications. Traditionally graphite has been used in electronic and electrical applications, metallurgy, the production of glass, mechanical and nuclear applications (Simandl et al. 2015). More recently it is used in the production of large-scale fuel cells, batteries and derivative products such as graphene with demand of graphite expected to rise (Simandl et al. 2015; Keeling 2017; Robinson et al. 2017).

ECONOMIC DEPOSIT TYPES

Synthetic and natural graphite supply primarily separate markets, however an overlap in these markets is increasing due to price and product purity factors (Keeling 2017). Natural graphite deposits are likely formed by the maturation and metamorphism of organic material, or by the precipitation from C-O-H fluids (metamorphic or metasomatic in origin) due to changes in pressure-temperature conditions or fluid chemistry (Simandl et al. 2015). Synthetic graphite is typically engineered through high-temperature treatment of amorphous carbon materials and is more expensive to produce than natural graphite.

The three main deposit types of natural graphite are generally grouped and described in relation to their commercial products, those being:

- microcrystalline (amorphous) graphite;
- flake graphite and;
- vein graphite.

Detailed descriptions for each type of graphite and their exploration features are summarised by Simandl and Kenan (1998a, 1998b, 1998c) and Simandl et al. (2015).

MICROCRYSTALLINE GRAPHITE

Microcrystalline, or amorphous graphite, forms through contact or regional metamorphism of coal seams or other highly carbonaceous sedimentary rocks in sub-greenschist to greenschist facies conditions (Simandl and Kenan 1998b; Taylor 2006). They are typically stratiform or lens-shaped but can be deformed by folding and faulting with exposures potentially extending from hundreds of metres to kilometres (Simandl and Kenan 1998b). The ore can have a massive or schistose texture (Simandl and Kenan 1998b; Keeling 2017). This type of graphite is typically amorphous and can be intergrown with fine-grained impurities (Simandl et al. 2015).

Economic deposits typically contain more than 1 Mt of ore with grades ranging from 75–85% graphitic carbon (Robinson et al. 2017). The largest deposit of this type is the Jixi (Liu Mao) deposit in China containing 300 Mt @ 85% C followed by 87 Mt @ 88% C at Kureyka in Russia (Robinson et al. 2017).

FLAKE GRAPHITE

Flake graphite is mainly associated with high-grade metamorphic rocks where organic carbon was subjected to upper amphibolite to granulite facies metamorphism (Simandl et al. 2015; Keeling 2017). Pressure, duration of the metamorphic conditions and shear strain influence the size of the graphite flakes and the degree of crystallisation (Buseck and Huang 1985; Beyssac et al. 2002; Keeling 2017). Generally, the flake size of most economic value is approximately 1 cm, however, it can range from 40 µm to 4 cm (Robinson et al. 2017). Economic deposits generally contain more than 200,000 tonnes of ore with grades ranging from 5–30% C (Robinson et al. 2017). High grades are usually associated with rocks located at the contact between marbles and paragneisses, some feldspathic intrusions, pegmatites and iron formations can also contain disseminated flake graphite

(Simandl and Kenan 1998a). This type of graphite is typically the focus for exploration in industrialised countries as it can be mined in open pits, reducing potential labour and mining costs (Simandl et al. 2015).

Notable deposits in Canada include Bisset Creek containing 69.8 Mt @ 1.75% graphitic carbon and an inferred resource of 24 Mt @ 1.65% graphitic carbon and Lack-Knife containing 9.576 Mt @ 14.77% graphitic carbon and an inferred resource of 3.102 Mt @ 13.25% graphitic carbon (Simandl et al. 2015). However, the largest known flake graphite deposit is Zavalyevskiy in Ukraine with 6.4 Mt @ 5–7% graphite (Robinson et al. 2017).

VEIN GRAPHITE

Vein graphite, also called 'lump' or 'chip' graphite, can be found in the same type of high-grade metamorphic terranes as flake graphite (Simandl et al. 2015) though it is present as veins, fracture fill or pipe-like body where carbon or carbon-rich fluids have migrated and precipitated (Keeling 2017). These deposits can also be found in skarn type mineral assemblages adjacent to igneous intrusions, within igneous intrusions or in zones that have experienced a retrograde overprint (Simandl and Kenan 1998c; Simandl et al. 2015). This deposit type is of a small scale, typically not exceeding 100,000 tonnes, with limited or unreliable data available for vein deposits (Simandl and Kenan 1998c; Robinson et al. 2017). Ore grades for this deposit type range from 40–90% C (Robinson et al. 2017).

Vein graphite is currently produced out of Sri Lanka at the Bogala mine where it is mined at significant depth of >600 m. Veins can be up to 3 m thick but limited resource information is published (Simandl et al. 2015; Robinson et al. 2017).

OCCURRENCES IN SOUTH AUSTRALIA

There are 75 graphite occurrences recorded across South Australia with 8 of these listed as deposits. Most of these deposits are on the Eyre Peninsula and hosted in Paleoproterozoic to Archean metasedimentary units. The largest is the Siviour deposit (MinDep no. 10711), with a resource of 123.6 Mt @ 6.9% TGC (Total Graphitic Carbon) (Renascor Resources 2023). The next largest resources are 6.3 Mt @ 11.1% TGC at Uley 2 (MinDep no. 11897) (Quantum Graphite 2022), Kookaburra Gully Extended (MinDep no. 11898) with 5.7 Mt @ 5.15% TGC, Kookaburra Gully (MinDep no. 311) with 2.94 Mt @ 11.45% TGC (Lincoln Minerals Limited 2023), Campoona Shaft (MinDep no. 476) with 2.232 Mt @ 12.1% TGC (Uranium SA Limited 2021) and Koppio (MinDep no. 312) with 2.08 Mt @ 10.47 % TGC. A major exploration target at Yeltana (MinDep no. 11798) is reported at 24.5–59 Mt @ 5.5–10.2% TGC (Alliance Resources Limited 2018). Other drill intersections include 15 m @ 20.7% TGC from 14–29 m at Francis (MinDep no. 9770) and Rock Valley Creek (MinDep no. 223) where a grab sample of ore material was 9–12% flake graphite @ 80–88% TGC. Several occurrences are known from the Olary region of the Curnamona Province, commonly associated with the Saltbush Group of the Willyama Supergroup.

Graphite production has been recorded from the Uley, Koppio and Prendergasts (MinDep no. 5954) deposits. The most significant is the Uley graphite mine (currently in care and maintenance) which contains graphite ore zones that are up to 12 m thick, and stratigraphically controlled within rocks equivalent to the Cook Gap Schist (Keeling 2000). Uley has had multiple generations of production from the 1920s until the 1980s (Keeling 2000). The earliest production recorded 77.45 t produced up to 1929 (Armstrong 1945), followed by 726 t of graphite produced from 1932–1951 (Betheras 1952a). More recent production from 1986–1993 produced approximately 1,000 t of graphite product (McNally 1997; Keeling 2000). Underground workings at Koppio led to production from 1943–46 of 100 t at an estimated grade of 12.2% C (Valentine 1994). Trenching at Prendergasts in 1928 recovered 18.3 t material at 20–25% C, but the graphite proved to be too fine for economic sale (Prendergast 1929; Betheras 1952b).

PROSPECTIVITY IN SOUTH AUSTRALIA

South Australia contains 66% of Australia's confirmed graphite resources (resources 10.7 Mt TGC, reserves 4.3 Mt TGC; Department for Energy and Mining 2023). The highly metamorphosed rocks of the eastern Eyre Peninsula are of most interest for flake graphite exploration. The Sleaford Orogeny led to the formation of disseminated flake graphite within the Sleaford Complex and the Kimban Orogeny resulted in a high metamorphic grade of the Paleoproterozoic metasedimentary rocks (Keeling 2017). The Hutchison Group is the host of the flake graphite deposits in this region, and carbon isotope data indicates an organic sedimentary source converted to graphite during high-grade metamorphism with stratigraphically controlled distribution (Keeling 2017). The Siviour deposit is hosted within the upper Katunga Dolomite and includes some retrograde alteration to serpentine and talc (Young 2015). The Kookaburra Gully deposit is hosted in high grade metamorphic schist and gneiss of the Hutchison Group.

Graphite has been identified within the Mount Woods Inlier during exploration for Iron Sulphide Copper-Gold (ISCG) deposits (Flint and Thompson 2017). At the Jupiter ISCG occurrence (MinDep no. 11183), graphite is associated with the margins of a metamafic unit and within surrounding, highly altered metasedimentary units. Graphite at Taurus (MinDep no. 9457) is within metasedimentary units and includes vein-style graphite of suspected metasomatic origin (Fabris and Michaelsen in prep.).

Some stratigraphic units within the Curnamona Province (e.g. Plumbago and Black Maria formations) are known to contain graphite, however, occurrences are typically small and associated with graphitic veinlets or graphitic schist host rocks (e.g. Ethiudna MinDep no.972; Black Maria MinDep no. 941). While most of these occurrences were not followed up due to their size or importance, sampling was done for recovery of marketable graphite at Alconie Hill (MinDep no. 946) in 1956, finding that there was 30% graphite within schists (Campana and King 1958). The Bimba Formation has been identified as containing minor flake graphite at Plumbago (MinDep no. 981) however, this cannot be verified with more recent information.

There are also historical mentions of occurrences that include graphite in the Mount Lofty Ranges within Precambrian rocks around Williamstown (e.g. Trestrails MinDep no. 3733).

A summary of the key deposit types associated with graphite and potential areas of interest within South Australia is shown in Table 1 and Figure 2.

Table 1. Summary of deposit types which can be enriched in graphite and regions of interest in South Australia with potential for these deposits.

Key deposit types	Regions of interest in South Australia
Principal sources:	
Microcrystalline graphite	• No specific regions of major sources identified in South Australia
Flake graphite	• Hutchison Group, eastern Eyre Peninsula (Keeling 2017) • Neoarchean rocks, metamorphosed to amphibolite-granulite facies, western Eyre Peninsula (Teale et al. 2006; Keeling 2017) • Saltbush Group and associated graphitic schists, Olary Domain, Curnamona Province
Minor sources:	
Microcrystalline graphite	• Graphitic black shales, northern Gawler Craton - e.g. Warrungadinna (MinDep no. 11649) • Olary Domain, Curnamona Province (Department for Energy and Mining 2023)
Flake graphite	• Precambrian rocks of the Mt Lofty Ranges and broader Adelaide Rift Complex (Department for Energy and Mining 2023) • Peake Metamorphics, Peake and Denison Inlier - e.g. Prendergasts
Vein graphite	• Highly altered metasedimentary lithologies, Mount Woods Complex within Mount Woods Inlier (Fabris and Michaelsen in prep.)

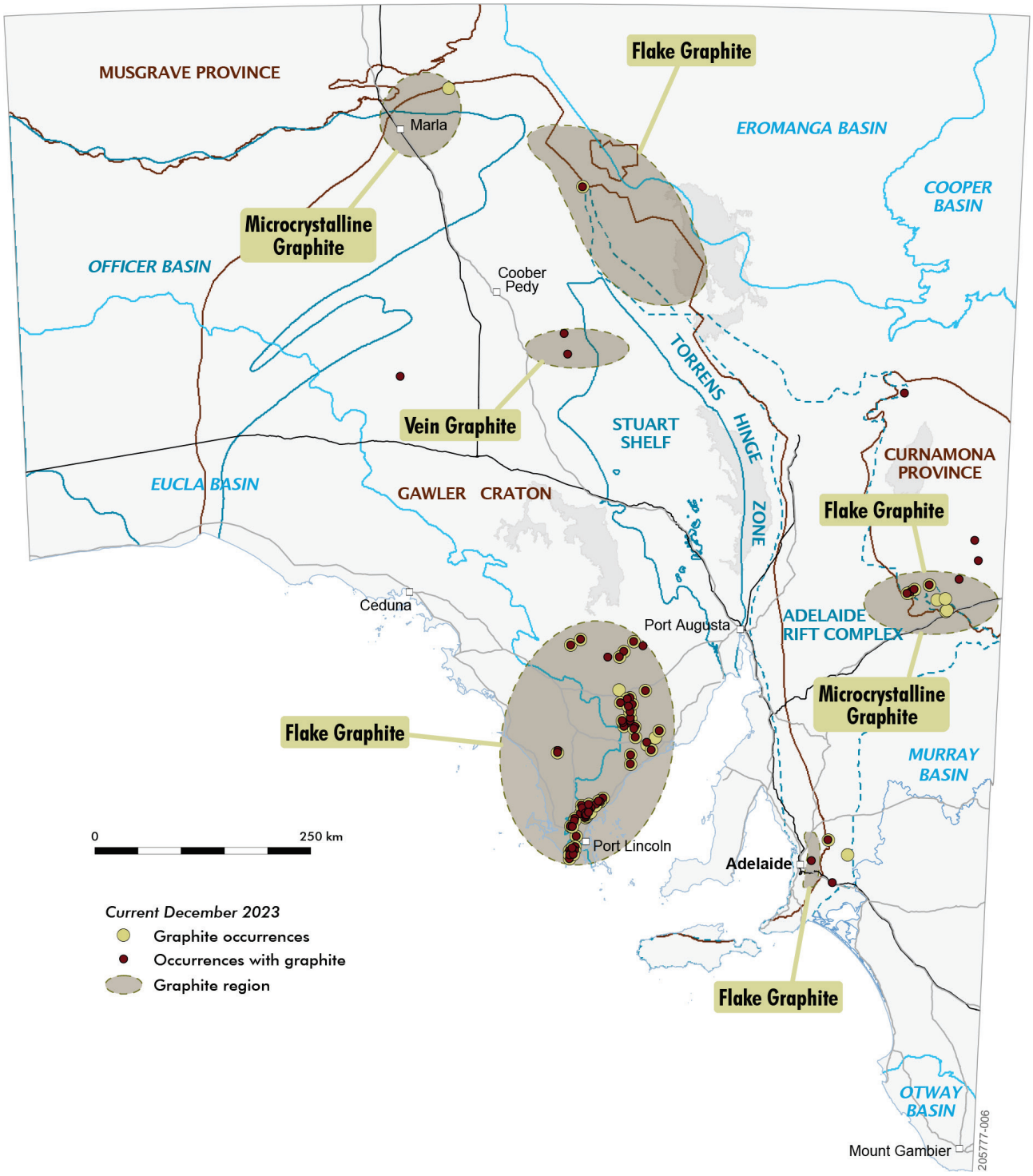

Figure 2. Location of South Australia's graphite occurrences and characteristic graphite forms. (205777-006 PDF 190 KB)

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RELATED LINKS

Graphite webpage
https://www.energymining.sa.gov.au/industry/minerals-and-mining/mineral-commodities/graphite

South Australian commodity resource information (SARIG)
http://map.sarig.sa.gov.au/MapViewer/StartUp/?siteParams=DashboardWidget%7CcommoditiesIndicators

Critical Minerals South Australia dashboard
https://www.energymining.sa.gov.au/industry/geological-survey/gssa-projects/critical-minerals-south-australia/south-australias-critical-minerals-dashboards

Critical Minerals South Australia project
https://www.energymining.sa.gov.au/industry/geological-survey/gssa-projects/critical-minerals-south-australia

South Australia's Mineral Deposit (MinDep) database
https://minerals.sarig.sa.gov.au/MineralDepositSearch.aspx

APPENDIX

OCCURRENCE DATA

Combined data available from South Australia's Mineral Deposit (MinDep) database as displayed in Figure 1 (as at December 2023).
Click to open attachments panel.