Government of **Western Australia**
Department of **Mines, Industry Regulation and Safety**

RECORD 2019/5

MESOZOIC COAL RESOURCES OF THE NORTHERN PERTH BASIN: EXPLORATION AND EVALUATION HISTORY

by
AS Millar

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Cover image: Sunset over the Yalgoo Mineral Field. Photograph by T Ivanic, DMIRS

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Mesozoic coal resources of the northern Perth Basin: exploration and evaluation history

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Abstract

This Record is a review of historical exploration and resource evaluation of Mesozoic coal in the northern Perth Basin and accompanies a data package in which all available open-file data are compiled.

Mesozoic coal was first intersected by West Australian Petroleum Pty Limited (WAPET) in petroleum exploration wells Eneabba 1 (drilled in 1961) and Bookara 3 (drilled in 1967). Ongoing exploration has since delineated the deposits (from north to south) of Bookara, Eneabba, Brazier, Gairdner Range – Cowla Peak and Wongonderrah.

Coal in the Cattamarra Coal Measures, the principal coal-bearing unit within the Mesozoic of the northern Perth Basin, is interpreted as having been deposited in a telmatic, wet, forest swamp of a brackish to upper–lower delta plain, with minor marine influence during peat deposition. All of the defined Mesozoic coal resources are on the Greenough Shelf and Cadda Terrace, and almost all coal exploration has been within these structural units and the adjacent Beagle Ridge, with only minor coal-targeted exploration elsewhere.

Coal rank varies throughout the deposits, generally in the range of sub-bituminous B to sub-bituminous A, with some areas of the Gairdner block of the Gairdner Range – Cowla Peak deposit reaching high-volatile bituminous C. The coal is high in vitrinite and inertinite and typically low in liptinite. Vitrinite reflectance values range from 0.3% at Bookara and Eneabba up to 0.5% for the Gairdner Range – Cowla Peak deposit.

In the Eneabba area, exploration in the 1970s, followed by an extensive evaluation program by Gold Fields Exploration Pty Limited during the early 1980s, delineated a deposit then estimated to contain about 153 Mt of coal to a maximum depth of 195 m or 123 Mt to a depth of 130 m. More recent work by Aviva Corporation (including renaming as the Central West Coal project) led to estimated total Reserves of 89.3 Mt within a 130 m-deep pit at a strip ratio of 7.2 m^3/run-of-mine tonne to the floor of the Eneabba Main seam split G (reported according to the 2004 JORC Code). In February 2011, the Environmental Protection Agency recommended that the Minister for Environment not approve the Central West Coal Pty Ltd proposal to mine and supply coal to the proposed nearby Coolimba power station of 450 MW.

In the Gairdner Range – Cowla Peak area, various joint ventures led by CRA Exploration Pty Limited during the 1970s and 1980s outlined in excess of 500 Mt of coal over five adjacent deposits — of which about 90 Mt was considered extractable by opencut mining. However, approximately half of the defined 'in situ resource' of the project falls within the current boundary of the Mount Lesueur National Park, which was gazetted in 1992.

In the Bookara area, exploration for coal on the Greenough Shelf commenced in the early 1980s but with limited success. Exploration for coal seam methane by Eneabba Gas Limited commenced in 2004, with initial results indicating low coal rank and very low to non-existent gas content. Re-evaluation in 2012 delineated a coal Resource suitable for underground coal gasification of 205 Mt under the JORC Code (2004).

KEYWORDS: coal, coal analysis, coal classification, coal deposits, coal measures, coal rank, coal resources, exploration history, Mesozoic, Perth Basin

Introduction

The first reported coal discovered by Europeans in Western Australia was in the Irwin River in 1846 (Le Blanc Smith and Mory, 1995), and is now known as the Irwin River Coal Measures, which is Permian in age. Mesozoic coal, however, was first intersected in 1961 in petroleum exploration well Eneabba 1, drilled by West Australian Petroleum Pty Limited (WAPET; Pudovskis, 1962). Johnstone (1964a) reported 12 m of coal between 1942.5 and 1963.2 m, which was interpreted from wireline logs but not cored. Denman (1978) considered the interpretation unreliable and reinterpreted the section as containing 11.5 m of coal in five seams ranging from 1 to 3.3 m in thickness. The coal was considered high quality with weak coking properties, which encouraged WAPET to explore known outcrops of the 'Cockleshell Gully Formation' (name now obsolete) in the Hill River area.

This Record collates the exploration and evaluation history of the Mesozoic coal resources in the northern Perth Basin. Information sources include both published and unpublished data. Published information has been obtained from Geological Survey of Western Australia (GSWA) Reports, Records, Bulletins and geological maps. Other published sources include scientific journal papers, conference proceedings, and company annual and quarterly reporting.

Unpublished information was obtained from statutory exploration reports submitted to the Department of Mines, Industry Regulation and Safety (DMIRS) by mining and exploration companies and held within the

Western Australian mineral exploration index (WAMEX) database and the Western Australian petroleum and geothermal information management system (WAPIMS). This information was supplemented by reports and media releases to the Australian Securities Exchange (ASX) and university theses.

Due to the fluctuating nature of the extent of prospective areas and deposit boundaries over time, and the varying names used to refer to prospects and deposits by different companies, for reporting accuracy, prospects and deposits discussed within the text are consistent with those used in the original reference. Drillhole details were extracted from open-file reports where available. Drillhole collar coordinates that are reported for historical drilling were converted to GDA94 using the GDAit transformation software. Where collar coordinates were not available and only locations displayed on maps, the best-quality maps have been georeferenced in GDA94 in ArcGIS and the collar locations digitized. The scale and quality of the original maps varies greatly, both over time and between companies, and consequently the accuracy of the collar locations is also highly variable. Drillhole locations and details are available from the DMIRS Data and Software Centre at <www.dmp.wa.gov.au/datacentre> as a data package associated with this Record.

Geological descriptions of deposits and reported coal intersections have, in most cases, been taken directly from the explorers' original reporting. Unless otherwise specifically stated, resource figures do not comply with reporting requirements of the Joint Ore Reserves Committee, Australian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC Code), most recently revised in 2012. If resources were originally reported as complying with an earlier version of the JORC Code, then that particular JORC Code version is stated. Further information is provided in the chapter on resources.

Structural setting

The Perth Basin is a north–south trough, essentially a half-graben, in the southwest of Western Australia, containing a Silurian to Holocene sedimentary succession up to 15 km thick. The basin is bounded to the east by the Darling Fault and extends offshore to the continental–oceanic boundary (Fig. 1; Playford et al., 1976; Mory and Iasky, 1996; Thomas, 2014).

Mory and Iasky (1996) divided the onshore northern Perth Basin into 13 structural units: the Dandaragan and Coomallo Troughs, Beagle Ridge, Allanooka High, Greenough Shelf, and the Barberton, Beharra Springs, Cadda, Dongara, Donkey Creek, Irwin and Yarra Yarra Terraces. The Coolcalalaya Sub-basin is also included in the northern Perth Basin; however, it lies to the north of the current study area. Tyler and Hocking (2002) subdivided the Allanooka High into the Wicherina and Allanooka Terraces and the Bookara Shelf (Fig. 1). All of the defined Mesozoic coal resources are located on the Greenough Shelf and Cadda Terrace, and almost all of the coal exploration has occurred within these structural units and the adjacent Beagle Ridge, with only minor coal-targeted exploration elsewhere. Minor exploration for coal has occurred on structural units adjacent to these, including the Dongara Terrace and the Yarra Yarra Terrace, with no coal of economic interest being intersected. Numerous petroleum wells have intersected the Cattamarra Coal Measures although at depths beyond any current economic interest. The Cattamarra Coal Measures is also a known source rock for gas, and possibly oil, within the northern Perth Basin (Crostella, 1995; Ghori, 2015).

The descriptions below are largely based on those of Mory and Iasky (1996) and a recent review of the structure of the Perth Basin by Thomas (2014).

The Greenough Shelf (Mory and Iasky, 1996; Tyler and Hocking, 2002) is defined as an area of shallow basement between the Dongara Terrace to the south, the Allanooka Terrace to the east and the outcropping Northampton Inlier to the north, and is bounded by the Allanooka Fault to the south and the Mountain Bridge Fault to the east. The shelf contains up to 1500 m of Mesozoic and Permian sedimentary rocks overlying granitic and gneissic metasedimentary rocks.

The Cadda Terrace (Hocking, 1994) is bounded to the west by the Beagle Fault and to the east by the Coomallo Fault. The terrace is characterized by a complex pattern of en echelon faults that progressively downthrow the sequence from the Beagle Ridge, with the interpreted depth to basement increasing to the east from 2000 to 8000 m. The southern boundary of the Cadda Terrace is poorly defined as it is covered by post-breakup Cretaceous rocks.

The Beagle Ridge (Playford and Willmott, 1958) is a prominent north-northwesterly trending horst, bounded to the east by the Beagle Fault System and to the west by what is commonly interpreted as the southwards continuation of the Geraldton Fault. The northern boundary of the ridge is interpreted as the Abrolhos Transfer Fault ('Abrolhos transfer' of Mory and Iasky, 1996), and the Cervantes Transfer Fault defines the southern boundary (Crostella and Backhouse, 2000; Thomas, 2014). The ridge has 1000–3000 m of Permian to middle Jurassic sedimentary cover, with the Permian and at least part of the Mesozoic sections thinning onto the ridge.

Stratigraphy

The onshore Perth Basin contains mainly continental clastic rocks, ranging in age from Permian to Holocene, deposited in a developing rift system that culminated with the breakup of Gondwana in the Early Neocomian (Owad-Jones and Ellis, 2000).

The stratigraphy of the northern Perth Basin is summarized in Figure 2. Detailed descriptions and interpretations of depositional environments are discussed in Playford et al. (1976), Mory (1994a,b, 1995, 1996) and Mory and Iasky (1996).

Pre-Permian sedimentary rocks are present in the north of the Perth Basin adjacent to the Northampton Inlier and in the Coolcalalaya Sub-basin. Permian sedimentary rocks are exposed on the Irwin Terrace with limited outcrop along the Greenough River. Permian sedimentary rocks in the subsurface are thought to occur over most of the northern Perth Basin (Mory and Iasky, 1996).

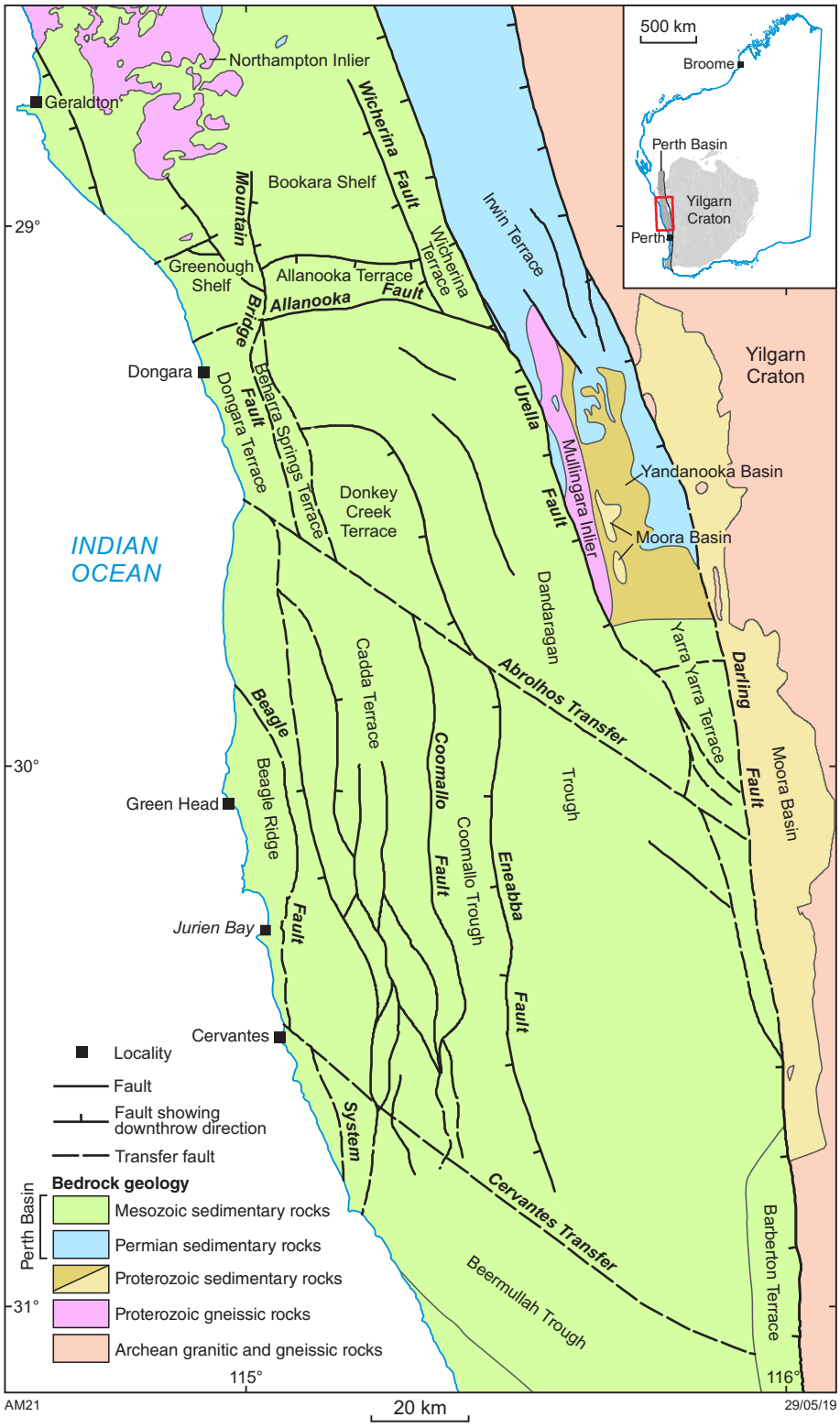

Figure 1. Main tectonic elements of the onshore northern Perth Basin after 1:500 000 tectonic units of Western Australia, 2017 (GSWA, 2017)

The lowermost Mesozoic unit encountered is the Kockatea Shale, intersected in a number of petroleum exploration wells and tentatively identified in several coal exploration holes on the Greenough Shelf. Several holes drilled on the Greenough Shelf and the Allanooka Terrace, both for petroleum and coal, report sandstone units beneath the Kockatea Shale. Historically designated the 'basal Triassic sandstone' (now obsolete), these are now interpreted to be late Permian in age. The Kockatea Shale is conformably overlain by the Woodada Formation, which is, in turn, conformably overlain by the Lesueur Sandstone.

The Lesueur Sandstone consists of coarse- to very coarse-grained feldspathic and pebbly sandstone with minor siltstone and conglomerate, lying conformably between the Woodada Formation and the overlying Eneabba Formation. In the north, on the Greenough and Bookara Shelves and the Allanooka Terrace, the Lesueur Sandstone is either absent or thin. The unit thickens to the southeast reaching almost 3000 m in Barberton 1 well, about 30 km south-southwest of the town of Moora (Mory and Iasky, 1996).

Jurassic sediments are widespread in the northern Perth Basin. The Eneabba Formation (Eneabba Member of the 'Cockleshell Gully Formation' — Playford and Low, 1972; Playford et al., 1976) lies, apparently conformably, between the Lesueur Sandstone and the Cattamarra Coal Measures. In the north, the Eneabba Formation is absent or lies disconformably on the Kockatea Shale. The Eneabba Formation consists of fine- to coarse-grained sandstone interbedded with multicoloured siltstone and claystone, with minor grey carbonaceous shale and thin coal (Mory and Iasky, 1996). Cored intersections of multicoloured siltstone and claystone from interpreted Eneabba Formation and upper Lesueur Sandstone equivalents in the southern Perth Basin (GSWA Harvey 1 well) are interpreted as paleosols, with the irregularly interbedded sandstones representing channel deposits within an alluvial plain (Millar and Reeve, 2014).

The Cattamarra Coal Measures is the principal coal-bearing unit within the Mesozoic of the northern Perth Basin, with minor coal occurrences in the Yarragadee Formation. The Cattamarra Coal Measures was originally named the 'Cattamarra Coal Member' by Wilmott (1964) for the coal-bearing unit within the Lower Jurassic 'Cockleshell Gully Formation' of Playford, Wilmott and McKellar (McWhae et al., 1958). The name was changed, first to 'Cattamarra Coal Measures Member' (Playford and Low, 1972) and then to 'Cattamarra Member' (Cockbain and Hocking, 1989). The name 'Cockleshell Gully Formation' was abandoned and formally replaced by the Cattamarra Coal Measures and the Eneabba Formation by Mory (1994a,b); however, the abandoned terminology persists in some reporting and the historical 'Cockleshell Gully Formation' is not subdivided in many old reports. The Cattamarra Coal Measures consist of fine- to coarse-grained sandstone interbedded with carbonaceous mudstone and seams of coal. Palynology (Sappal and Islam, 1992; Suwarna, 1993, 1999; Sappal and Suwarna, 1997), along with the common association of bioturbation of sediments and elevated sulfur levels in the coal, suggests that the depositional environment can be interpreted as lower deltaic with marine influence (Kristensen and Wilson, 1986). More detail on the stratigraphy of the main coal deposits is discussed in the section on the individual deposit geology and coal quality.

The Cadda Formation lies conformably between the Cattamarra Coal Measures and the overlying Yarragadee Formation, and consists of shale, siltstone and medium- to coarse-grained sandstone, grading in places into shelly limestone. The unit is regarded as a shallow-marine to paralic deposit (Mory and Iasky, 1996) representing a short-lived Middle Jurassic marine transgression.

The Yarragadee Formation is widespread throughout the northern Perth Basin and overlies the Bookara deposit located on the Greenough Shelf, but has been largely eroded from the Eneabba, Gairdner Range – Cowla Peak and Wongonderrah deposits. The Yarragadee Formation, consisting of interbedded fine- to coarse-grained feldspathic sandstone, siltstone and claystone with minor conglomerate and coal, lies conformably between the Cadda Formation and the overlying Parmelia Group of latest Jurassic to Early Cretaceous age. The Parmelia Group is restricted to the east and southeast of the area and is unconformably overlain by the post-breakup Warnbro and Coolyena Groups.

Exploration history

Following the initial coal discovery in Eneabba 1, the area was re-examined by WAPET and a temporary reserve (TR 2317H) was taken out in 1961 (Johnstone, 1964a). WAPET completed stratigraphic and shallow test drilling in two programs of drilling, the Hill River program of nine holes (Burdett, 1962a,b, 1963a) and the Mintaja program consisting of 22 holes (Johnstone, 1964a,b). Final results indicated the shallow coal was of poor quality and was structurally complex, and WAPET relinquished the temporary reserve in November 1963.

No further exploration occurred in the area until the early 1970s, following the discovery of shallow coal near Eneabba, and a reinvestigation in the late 1970s and early 1980s of the areas previously explored by WAPET to the south in the Gairdner Range and Hill River areas. Exploration targeting coal on the Greenough Shelf commenced in 1980, subsequent to the reporting of Jurassic coal in petroleum well Bookara 3 drilled in 1967. The general locations of the main prospects referred to in this Record are shown on Figure 3. In some reports, prospects are grouped or cover a broader area; for example, the use of the name Hill River area can cover prospects from west of Eneabba in the north to the Wongonderrah area in the south, as well as a specific project area.

The following exploration history has been broadly divided into the main prospect areas and into general chronological order, where possible. The combining of some prospects into larger projects for evaluation or through joint ventures and the relinquishment of tenements has meant this general structure has not always been possible. The locations of the major named exploration prospects and reported drillholes overlain on 1:500 000-scale geology are shown on Figure 4.

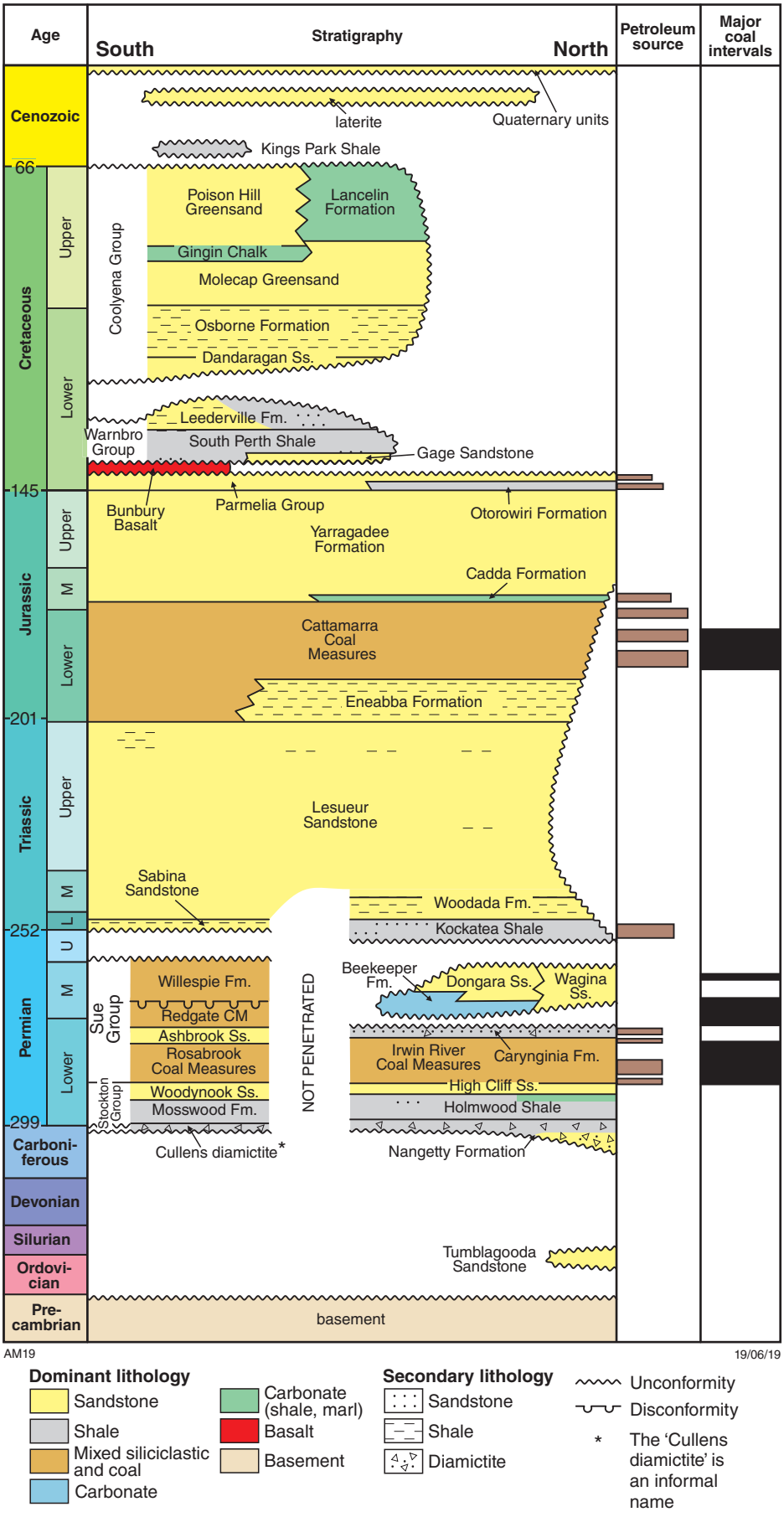

Figure 2. Stratigraphy of the Perth Basin displaying major coal-bearing intervals and the relative potential of different stratigraphic units as petroleum sources. Abbreviation: CM, coal measures

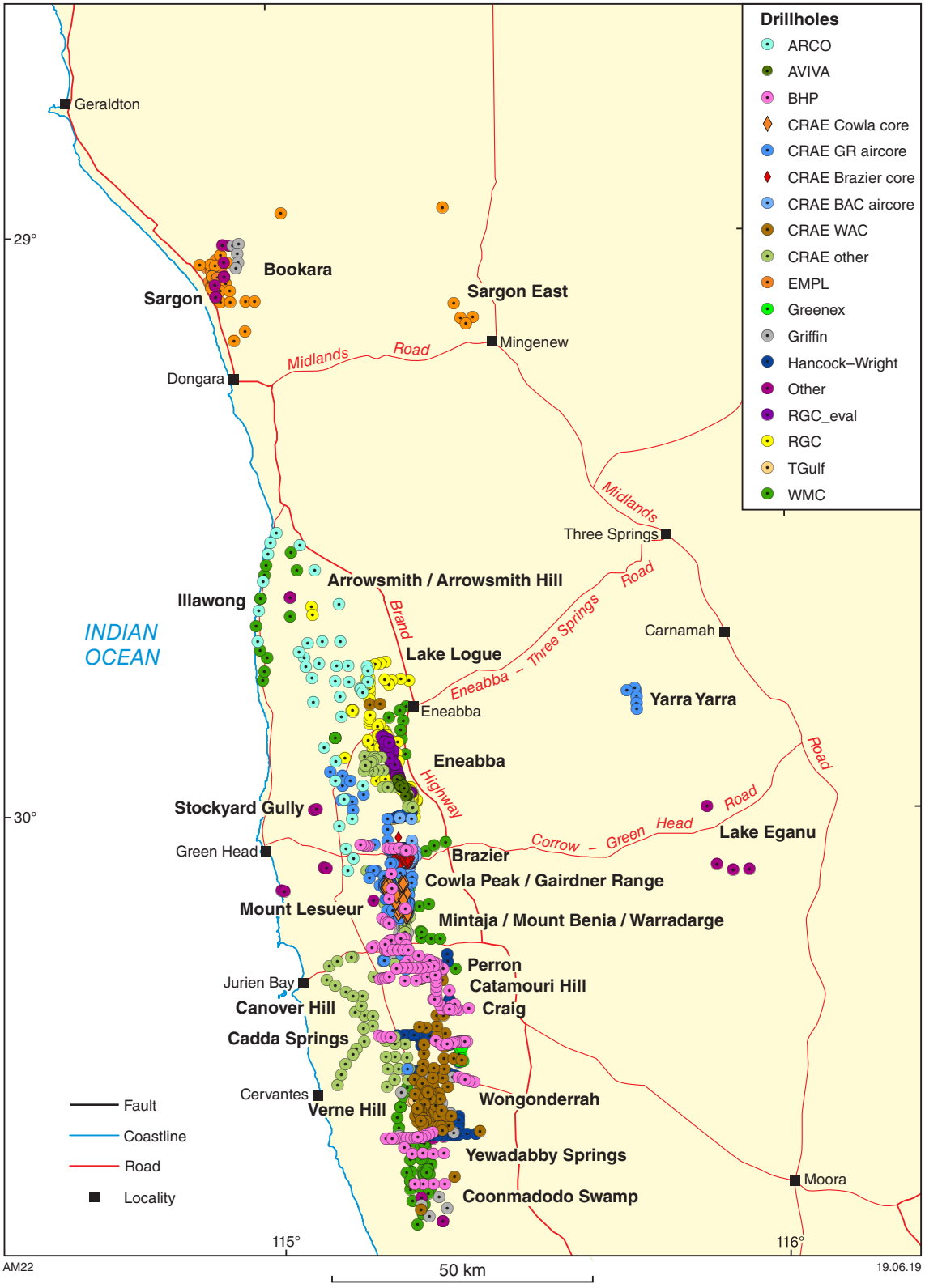

Figure 3. **Location of the main exploration prospects referred to in the Record and drillhole locations coloured by company. Abbreviations: BHP, Broken Hill Pty Ltd; EMPL, Eneabba Mining Pty Ltd; Greenex, Greenbushes Tin NL; Hancock–Wright, Hancock and Wright Prospecting; RGC, Renison Goldfields Consolidated early exploration holes; RGC_Eval, Renison Goldfields Consolidated evaluation holes; Tgulf, Texasgulf Australia Ltd; WMC, Western Mining Corporation. GR, BAC and WAC refer to the series names of holes drilled by CRA Exploration**

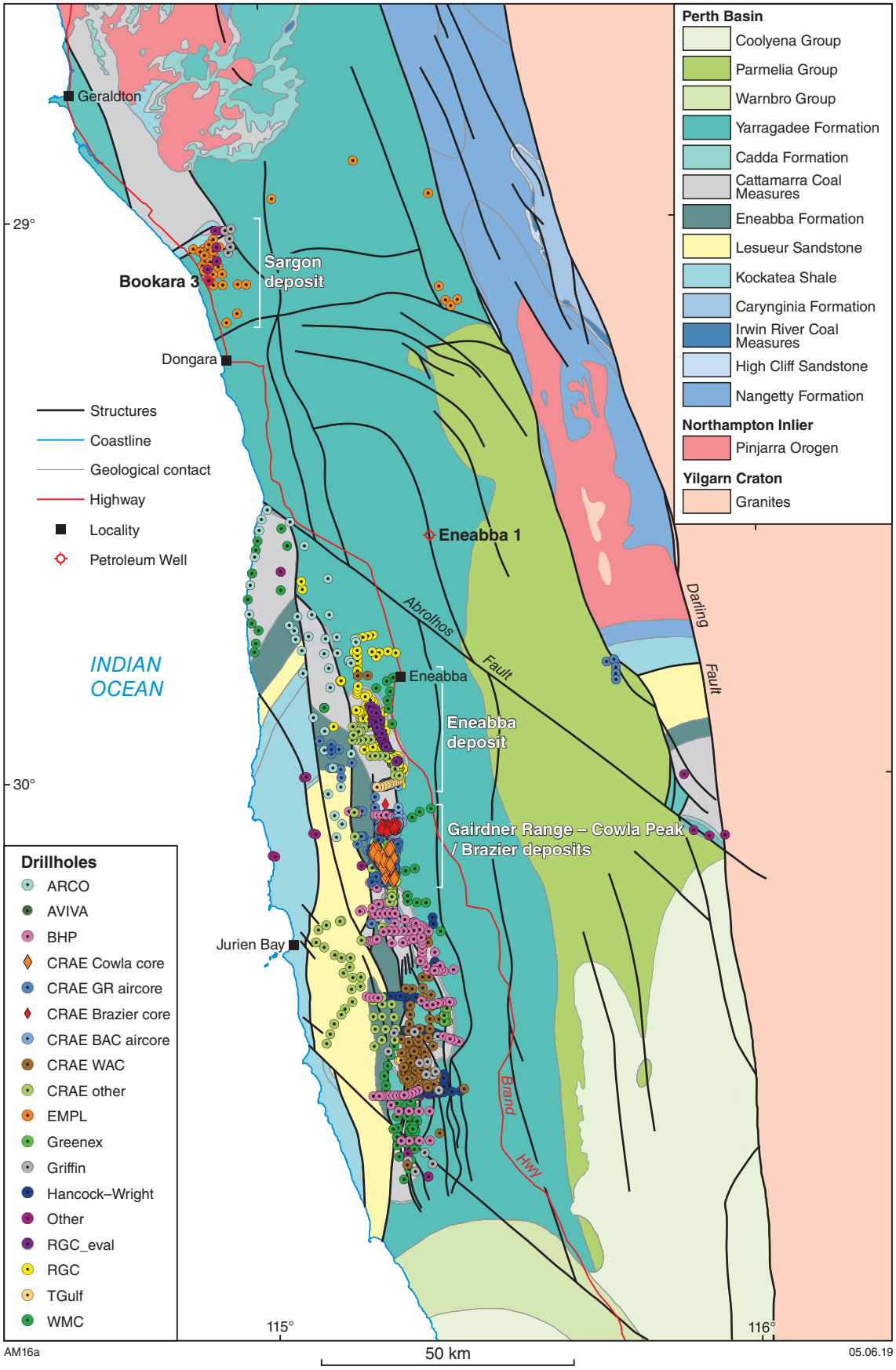

Figure 4. Distribution of drilling and location of defined coal deposits within the northern Perth Basin, with 1:500 000 State interpreted bedrock geology of Western Australia base map (GSWA, 2016)

Eneabba area

Taylor Woodrow International Ltd (TWI) commenced exploration in the Eneabba area in late 1970, following a report of coal in a farmer's water bore. Initially, a series of prospecting areas was pegged covering the area of greatest potential. Following the intersection of a thick coal seam in bore No. 12, coal mining leases were applied for and TWI completed an exploration program consisting of about 130 holes (Moorcroft 1971; Moorcroft and Boehm, 1971a,b). The drilling was mainly openhole with selective coring and geophysical logging. Results indicated a substantial resource of sub-bituminous coal over a strike length of approximately 5 km to depths of around 100 m. Early reporting (Moorcroft, 1971) lacks detail, leading to very poor clarity relating to drillhole nomenclature and locations.

Australian Anglo American Ltd obtained an option to participate with TWI in 1971 and, following a review of the previous work, commenced a program of six inch-diameter core drilling, evenly spaced along the coal strike to confirm the TWI work. The program of eight holes was completed during December 1971 to January 1972 and included a comprehensive analysis program leading to the estimation of an 'in situ reserve' of the order of 38 Mt of sub-bituminous coal to a depth of 91 m (300 ft). Australian Anglo American withdrew from the project prior to the completion of the final report (Powell, 1972).

Minimal further work appears to have been completed until Gold Fields Exploration Pty Limited (GFEL) commenced exploration in 1979. GFEL completed the exploration on behalf of Circular Quay Holdings Pty Limited, a wholly owned subsidiary of Renison Goldfields Consolidated Limited (name changed to Renison Goldfields Consolidated Limited in December 1995, merging with Westralian Sands Limited in 1998, and adopting the name Iluka Resources Limited in 1999).

Circular Quay Holdings signed an option agreement on 14 September 1980 with landowners Sword Nominees Pty Ltd and JA Griffiths for 188 coal mining leases covering the then defined Eneabba coal deposit. This total comprised 74 coal mining leases held by Sword and Griffith, and 114 held in the name of Amax Iron Ore Corporation, with the Amax-held coal mining leases being transferred to Sword and Griffith (Morgan, 1981).

Subsequent to the signing of the agreement, GFEL pegged on behalf of Circular Quay Holdings an additional 225 coal mining leases, mostly north of the known deposit. The land tenure situation was further complicated by the existence of mineral claims for heavy mineral sands overlapping with the coal mining leases. The original mineral claims for heavy minerals were granted to a depth of 25 m from the surface.

GFEL considered that the TWI evaluation had clearly shown that the deposit was impacted by faulting and that strike extensions to both the north and south were possible. They considered the data from earlier drilling programs 'unreliable in detail', that there were gaps in the drilling pattern, and variations in coal quality within the seams could not be reliably determined (Wells and Moore, 1980).

Trials of several surface geophysical methods were commenced by GFEL in 1979, followed by an all cored-hole exploration drilling program (EC/ECD series holes) in early 1980. This program was to establish correlations and obtain reliable coal quality data with the intention of shifting to openhole drilling plus geophysical logging once the correlations were clear (Morgan, 1981). Reporting indicates it soon became apparent that both the correlations and sedimentary features were more complex than anticipated, and the majority of holes were cored in the main evaluation program.

Having indicated that the coal did not extend significantly to the south, further work was concentrated in the northern area. The area of known coal was increased by progressively stepping out both northwards and eastwards from the already defined TWI area. The exploration program extended the area of known coal from 8.5 to 13 km strike length and significantly increased the resources. Once it became clear from the exploration drilling that a possible shallow economic coal resource was present at Eneabba, a program of grid drilling was initiated to define the structure and provide samples for test work.

During 1981, up to three drill rigs working simultaneously drilled 76 Eneabba Reserve Assessment (ERA series) drillholes representing 6967 m of drilling. It is reported that all the EC/ECD and ERA holes were surveyed (ERM Consultants Pty Ltd, 1982) although only limited data have been located.

By the end of November 1981, GFEL had drilled 139 holes (including exploration and reserve drilling) totalling 14 550 m in and immediately around the defined coal area. The drilling density was considered sufficient for seam correlation, definition of the structure for 'reserve calculation' purposes, and for analytical testing. The deposit was estimated to contain about 153 Mt of coal to a maximum depth of 195 m, or 123 Mt to a depth of 130 m (Morgan, 1981).

In addition to the exploration and evaluation drilling of the main Eneabba project, GFEL also completed exploration to locate extensions of the deposit and the equivalent stratigraphic horizon. A summary of that work is presented by Agg (1982c). Although coal was intersected in a number of holes, no extensions were located. In the northern areas, the results indicated that the main coal interval is deep, or that seams are thinned and split. In the south, the overlying Cenozoic is thicker and the structure in the Mesozoic interval was interpreted as more complex.

There is no reported coal exploration or evaluation activity over the area between 1982 and 2004. When Renison Goldfields acquired the mineral sands tenements in 1988, the coal and mineral sands tenements were combined into the current State Agreement mining lease M70/267SA, with Sword retaining the rights to the coal (Aviva Corporation Ltd, 2004b).

In May 2004, Aviva Corporation Ltd signed an option agreement to purchase the now named Central West Coal project from Sword Nominees Pty Ltd (Aviva Corporation Ltd, 2004b). The option agreements over the coal rights (Sword) and holder of existing tenements (Iluka) were finalized in September 2006 (Aviva Corporation Ltd, 2006b).

Aviva obtained available historical exploration data and development studies for the deposit as part of the agreement. All the drillhole data were transferred from hardcopy to a digital database and consultants McElroy Bryan Geological Services Pty Ltd verified the new database. An audit of the core shed at Eneabba found all holes present. As part of a scoping study, consultants Minserve Group prepared a resource statement (based on the 1999 JORC Code) based upon a coal resource estimate completed by McElroy Bryan (Aviva Corporation Ltd, 2004a,b), announcing a total coal Resource of 79.6 Mt (see Resources section for further information on all resource details).

Aviva commenced an infill program in April 2005 to better define the main seam subcrop, collect samples for limit of oxidation analysis and explore for deposit extensions (Aviva Corporation Ltd, 2005). This was followed in June 2006 by a 70-hole drilling program to upgrade the resource to a measured status, progress mining studies, collect a bulk sample and extend the resource limits (Aviva Corporation Ltd, 2006a).

Following trials in August 2006, Curtin University commenced a seismic acquisition research project in January 2007 to test for up-dip resource blocks to the west of the main deposit. The seismic project was apparently successful (Aviva Corporation Ltd, 2007a); however, no data or results for any of this work have been submitted to DMIRS.

In 2007, Aviva announced total reserves, prepared by the Minserve Group, of 72 Mt within a 130 m-deep pit at a strip ratio of 7.2 m^3/run-of-mine (ROM) tonne (Aviva Corporation Ltd, 2007b). Throughout 2007–08, Aviva continued mine planning, extension drilling and hydrogeological drilling (Aviva Corporation Ltd, 2008a,b). In September 2008, Aviva purchased M70/492 from Australian Gold Resources Pty Ltd, providing a southerly extension of the resource (Aviva Corporation Ltd, 2008c).

Aviva completed 204 drillholes testing the resource between 2004 and 2008 (McElroy Bryan Geological Services Pty Ltd, 2008), although only about 70 of these are contained in reports to DMIRS. It is assumed the remaining drilling is within the Iluka State Agreement mining lease, M70/267SA where reporting to DMIRS is not compulsory.

In April 2009, Aviva released the project Public Environmental Review documents for public review (Aviva Corporation Ltd, 2009a). In October 2009, Synergy informed Aviva that it was not the preferred tenderer for the 2009 electricity supply procurement program (Aviva Corporation Ltd, 2009b; Central West Coal Pty Ltd, 2009; note that the Aviva ASX and media release is incorrectly dated 29 October 2010), hence removing the potential market for electricity produced from the Coolimba Power project associated with any mine development.

The option over the coal rights expired on 20 November 2009 and Aviva chose not to extend, although it and Sword, the owners of the coal rights, considered that a package comprising mining title, mine information and environmental approvals was required to maximize value and that both parties would work to achieve this (Aviva Corporation Ltd, 2009c, 2010).

In February 2011, the Environmental Protection Agency (EPA) recommended that the Minister for Environment not approve Central West Coal Pty Ltd's (a subsidiary of Aviva Corporation Ltd) proposal to mine and supply coal to the proposed Coolimba Power project (Aviva Corporation Ltd, 2011; EPA, 2011a,b).

In February 2013, Aviva completed the sale of its 100% subsidiary Coolimba Power Pty Ltd to Mid West Energy, a fully owned subsidiary of private company WestGen Pty Ltd (Aviva Corporation Ltd, 2013). Coolimba Power held the Coolimba project approvals and coal intellectual property that were developed as a part of the process to proceed with the Coolimba project. It is understood that the coal rights remain with Sword Nominees. Drillhole locations and the outline of the defined Eneabba coal deposit are shown on Figure 5.

Around the time of the discovery of shallow coal at Eneabba, other companies were also exploring in the Eneabba area (Figs 4, 5). Ashburton Oil NL drilled stratigraphic holes Woodada 1 (905 ft/275.8 m) and 1A (300 ft/91.4 m) within coal mining lease 582 during June to August 1971 (Ashburton Oil NL, 1971; note that this stratigraphic hole should not be confused with petroleum exploration well Woodada 1, drilled to a depth of 2546 m by Hughes and Hughes Australia Pty Ltd in 1980, and located approximately 21 km to the southeast of Ashburton's Woodada 1). Ashburton's Woodada 1 intersected the 'coal measures member of the Cockleshell Gully Formation' (Cattamarra Coal Measures) from 90 to 866 ft (27 to 264 m) terminating in the 'multicoloured member' (Eneabba Formation). Several coal seams were intersected and two cores were recovered that contained coal material. Woodada 1A was drilled adjacent to Woodada 1, coring 10 intervals. Coal analysis from these holes indicated a moderate ash, moderate sulfur, sub-bituminous coal. Reporting of the drilling is incomplete and what is available lacks detail (Ashburton Oil NL, 1971).

Ashburton also drilled four holes targeting coal in the Lake Eganu – Pinjarrega Lake area (Ashburton Oil NL, 1972). The target was shallow Cattamarra Coal Measures on the southern end of the Yarra Yarra Terrace, in a follow-up to the intersection of the lower Jurassic sequence in WAPET Eganu 1 (Burdett, 1963b). Once again the reporting is incomplete, with only Lake Eganu 1 intersecting thin coal seams of possible early Jurassic age. Traces of coal were also intersected in Lake Eganu 4, although this was interpreted as being within the Yarragadee Formation.

In August 1977, ARCO Australia Limited commenced pegging of coal mining leases in the Arrowsmith Hill – Eneabba area (Fig. 3). They were targeting shallow Cattamarra Coal Measures west of the Eneabba deposit following an ARCO review of WAPET's geophysical data and the limited available drilling data (ARCO Australia Limited, 1977). Forty-one openholes, drilled to a maximum depth of 150 m with associated wireline logging, were completed in early 1978 (ARCO Australia Limited, 1978). A total of 64 samples was collected for palynological determination and the results suggested that only four holes intersected Cattamarra Coal Measures. Coaly material was encountered in 26 of the holes, although ARCO concluded that all but one occurrence represented coalified wood of detrital origin and was of low rank.

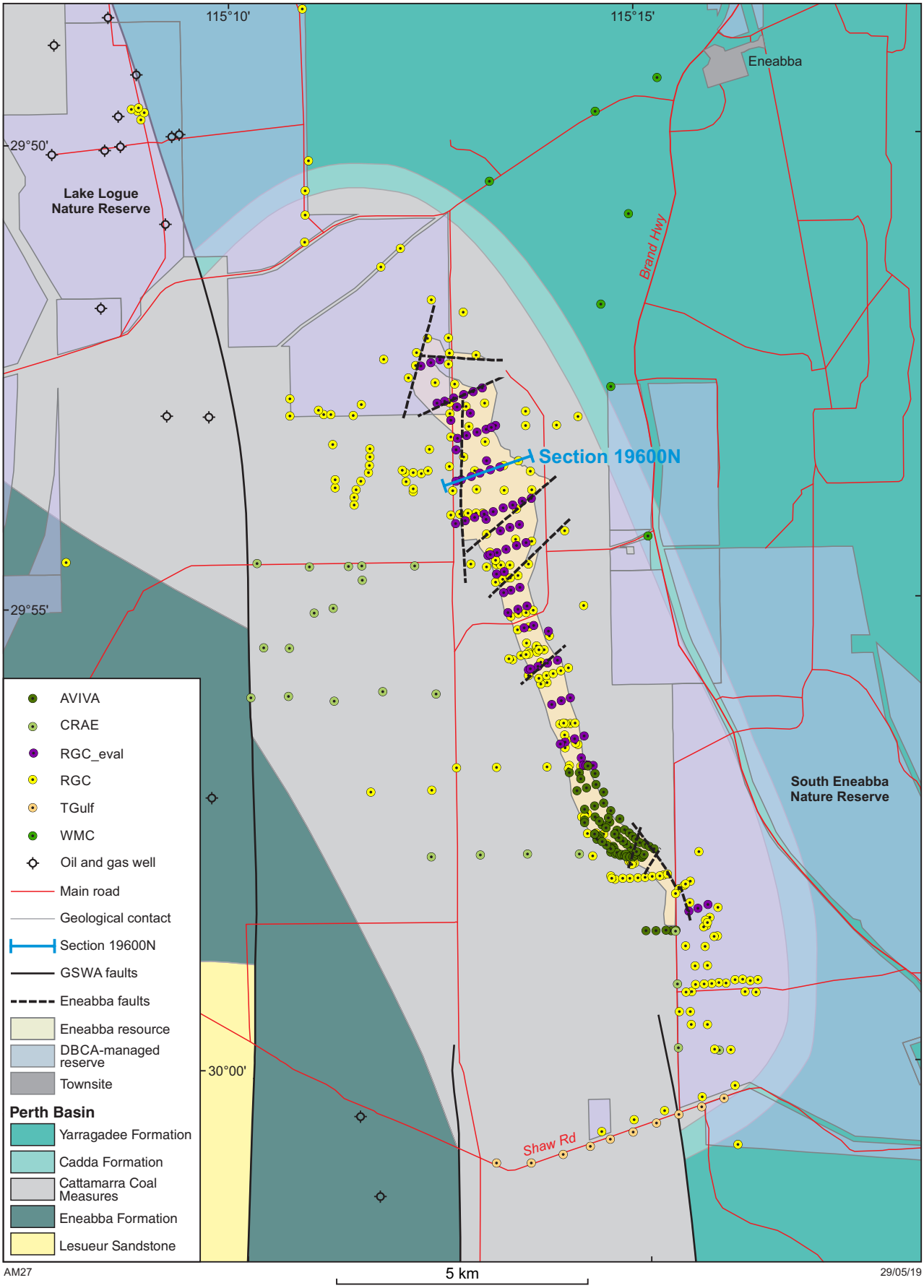

Figure 5. **Eneabba or Central West coal deposit outline and local faults (Central West Coal Pty Ltd, 2009) with drillhole distribution, overlying 1:500 000 State interpreted bedrock geology of Western Australia (GSWA, 2016). The position of a cross-section through the Eneabba deposit along local grid reference 19600N is also indicated on the map. Abbreviation: DBCA, Department of Biodiversity, Conservation and Attractions**

Western Mining Corporation Limited (WMC) held an extensive portfolio of tenements over the period 1981 to 1991, including Illawong and Stockyard Gully in the northwest, the Eneabba area, Gairdner Range – Catamouri Hill areas and Yewadabby Spring in the south (Fig. 3). During this period, WMC drilled about 100 holes, just over half at the Yewadabby Spring project. This work is discussed under the general Hill River area exploration.

WMC pegged 171 coal mining leases in the Illawong area during 1980, which remained as applications awaiting compensation agreements until September 1983 when the applications were withdrawn. At the same time, a reduced area of 123 km^2 was applied for as an exploration licence under the *Mining Act 1978*. In late 1984, after failure to obtain compensation agreements with landowners, WMC restricted their applications to below 30 m depth and the applications were then approved. Drilling (IR01–12) and associated palynology defined an area of shallow Cattamarra Coal Measures dipping at a relatively low angle to the north, bounded to the east by the Beagle Ridge and the coast in the west (Fig. 4). Intersected coal seams were interpreted as thin and discontinuous (Western Mining Corporation Limited, 1983c; ARCO Australia Limited, 1977; Meyer, 1986a).

Also in 1980, WMC applied for 86 coal mining leases in the Stockyard Gully area to explore for both Jurassic and Permian coal in the area of Beagle Ridge. Three holes were drilled in April 1982 (SGR1, 1A and 1B) all at the same location. The first two were abandoned at shallow depth, with the third reaching a depth of 102 m. No coal was intersected and samples taken for palynology were barren. As part of this program, WMC also completed downhole geophysical logging of GSWA hydrological bore Eneabba Line 11C. The coal mining lease applications were subsequently withdrawn in late 1983, prior to being granted (Western Mining Corporation Limited, 1983a; Meyer, 1984).

WMC applied for exploration licence 70/27 in May 1983, replacing 42 coal mining lease applications, to explore for Jurassic coal adjacent to the Eneabba deposit on the east side of Beagle Ridge. Six shallow holes each to 66 m (ER1–6) were drilled to test the pre-Cenozoic stratigraphy followed by a single deep hole (ER7, 501 m) to test the Jurassic sequence (Western Mining Corporation Limited, 1983b; Meyer, 1983). An extensive suite of downhole geophysical logs was obtained in ER7. Geophysical logging of nearby GSWA hydrological bores EL8B and EL9A was also undertaken, and carbonaceous samples collected from EL8 were submitted to determine vitrinite reflectance.

Only two coal seams were intersected in ER7, the thickest being 1.3 m at 460.4 m depth. The hole was drilled 4 km northeast of the Eneabba deposit and was expected to intersect the down-dip extension of the deposit; however, based on palynology the entire pre-Cenozoic section below 29.6 m was designated as Cadda Formation. WMC concluded that the 470 m of Cadda Formation equivalent in ER7 and the 200–400 m of Cattamarra Coal Measures in hydrogeological bore GSWA EL8A suggested significant faulting between the Eneabba deposit, ER7 and EL8A — thus limiting the shallow coal potential (Meyer, 1983). This unexpected thick Cadda Formation is atypical and the interpretation should be revisited.

The joint venture between Western Coal and Uranium NL and CRA Exploration Pty Limited also explored areas west of Eneabba (Cooper and Scott prospects). These are discussed under the Hill River area exploration as they were reported together with other prospects in that area.

Hill River area

Historical exploration in the Hill River area has covered prospects from west of Eneabba in the north to the Wongonderrah area in the south, in addition to the specific evaluation area known as the Hill River project. This section of the report covers the broad exploration area with the evaluation area discussed in the following section on the Gairdner Range – Cowla Peak and Brazier deposits.

Griffin Coal Mining Company Limited carried out a nine-hole drilling program for a total of 742 m during June–July 1973 (GJ1–9) in the broader Hill River area (Griffin Coal Mining Company Limited, 1973). Two holes were drilled on private property south of Jurien Road adjacent to a dam in which a coal seam had been encountered during construction. The remaining holes were drilled farther north, also on private property, near the WAPET Hill River – Mintaja drilling. Based on the reporting, it appears that Griffin, although aware of the 1960s WAPET drilling, did not know any of the results. Thin coal seams were intersected during the drilling, although Griffin considered the results as 'not encouraging'.

Other holes were drilled to the south of the Hill River with no significant coal intersections recorded. In conjunction with a mineral sands exploration program and following reports of shallow coal in a water bore, five holes (H1–5) were drilled in an area south of Bibby Road in the Wongonderrah area. Palynology indicated that drilling stopped within the Cadda Formation and therefore was not deep enough to intersect the coal sequence.

In a joint venture with International Nickel Australia Limited, Griffin carried out a four-hole (GCR1–4) trial drilling project in the Coonmadodo–Cooljarloo area during early 1976 (Utting et al., 1976). These four holes, numbered C1–4 by Griffin, appear on later WMC maps (Western Mining Corporation Limited, 1984b) as Griffin 1–4. The drilling encountered only minor coal with the maximum intersection of 36 cm. Palynology indicated that only hole GCR1 (C1) intersected Cattamarra Coal Measures with the other three terminating in the Yarragadee Formation.

A further series of holes designated as Griffin holes G1–12 appears on Broken Hill Pty Ltd (BHP; Kerber, 1979) and WMC maps (Western Mining Corporation Limited, 1984b), although no reporting of this drilling has been located in WAMEX. Holes designated G8–12 by BHP are located in the same general area as reported Griffin holes H1–5 and are possibly the same holes.

Dampier Mining Co. Ltd, later known as BHP Minerals, carried out an extensive drilling program between Coorow–Greenhead Road in the north, and the Coonmadodo area in the south, between early 1972 and 1979 (Kerber, 1979). The first program of 37 holes (HRD1–35) was undertaken in early 1972 and was restricted to road reserves while access negotiation with landowners occurred.

No further drilling was undertaken until March 1977 when 101 holes (HRD41–142) were drilled, a single hole (HRD143) was drilled in 1978 and a further 30 holes (HRD144–174) in February 1979. It is uncertain if holes HRD36–40 were drilled as there is no record of these. Geophysical logging of holes was attempted with variable success due to equipment failures and difficult ground conditions, and was not attempted on the most southern series of holes.

The drillhole location plan accompanying the BHP exploration report (Kerber, 1979) is of poor quality, although the logs for many holes include a written descriptive location and numerous collar locations are also shown on later CRA Exploration and WMC drilling plans.

Results of the program were mixed; potentially economic intervals of 5.7 m and 5.9 m were intersected in adjacent holes HRD7 and HRD8, and intersections of 3 m or greater were made in holes HRD24, HRD48 and HRD70. Dampier/BHP concluded that the coal seams were too thin and variable for economic mining and all leases were relinquished and applications withdrawn.

During 1977, farmers Hamilton, Isbister and White held a prospecting area (PA 70/1549) in the area previously explored by WAPET, which had drilled Hill River 2 and 2A and Mintaja 7A–C (Hamilton, 1978).

Hamilton and partners drilled 11 holes (FPA1–11) near previous BHP drilling, intersecting about 10 m of coal in FPA1 and about 6 m in FPA2, drilled approximately 140 m away. These intersections equate to the main coal unit in the area termed the Warradarge block by CRA Exploration. The Hamilton reporting is poor, consisting of a letter to the then Director of Mines in January 1978. The location of the holes is, however, displayed on a drillhole location map by Greenbushes Tin NL (Greenex; Carson, 1979), which explored in the same area as discussed below.

An area previously partially covered by the BHP leases between Jurien and Greenhead Roads was re-pegged in 1978 by Cowla Peak Mining (Hamilton–Isbister–White; Ellis, 1982) and exploration was carried out in this area in 1979 by Greenbushes Tin, and Square Gold and Minerals Ltd, under agreement with Cowla Peak Mining. It appears that Square Gold drilled the deposit although did not step out more than 200 m from the area originally drilled by WAPET and BHP (Ellis, 1982). No record of the Square Gold drilling has been located.

Greenex completed two programs, the first a 36-hole rotary air blast (RAB) program in February 1979 (Whitfield, 1979) covering the area previously drilled by WAPET and Hamilton, and a follow-up program of five reverse circulation (RC) holes reported in May 1979 (Carson, 1979). Greenex drilled a further 15 RC holes during 1980, including 10 within the Badgingarra National Park (Joass, 1980a). Although coal was intersected, it was not considered significant. Three of the 1980 holes intersected artesian water, one approximately 2 km south of their coal drilling on the Warradarge farmland, the other two within the Badgingarra National Park (Joass, 1980b).

Early in 1978, reconnaissance geological mapping and the drilling of a single rotary hole (WW1) south of previous drilling by Griffin was completed on PA 70/1546 at Wooka Wooka Well (Coonmadodo area) held by TRB Goyder (Wilkinson, 1978). The hole was drilled to 82.5 m and intersected 38 m of Quaternary Bassendean Sand overlying a sequence of carbonaceous clays interbedded with coarse-grained sandstones. Only thin stringers of coal were intersected, and palynology of a bottom-of-hole sample indicates the carbonaceous material belonged to the lower part of the Yarragadee Formation.

Following a preliminary assessment of previous exploration in 1978, two holes, FM1–2, were drilled in early 1979 on behalf of a joint venture lead by Forsayth Mineral Exploration NL (Atkinson, 1979). The drilling was completed within 2 of 19 scattered coal mining leases the joint venture held in the Wongonderrah area. Thin coal seams were intersected at shallow depths in both holes and palynology indicated that sequence intersected the Cattamarra Coal Measures. These holes lie near the western boundary of the area later evaluated by the Western Ventures NL – CRA Exploration joint venture and known as the Wongonderrah deposit.

Forsayth also report that Mogul Mining NL completed a drilling program of five rotary holes in early 1978 in the West Cataby (Wongonderrah) area, which intersected several coal seams between 1 and 2.5 m thick, and that analyses of samples recovered from this program reportedly contained energy values of 18–21 MJ/kg. The reported energy values were similar to those in Collie but with higher ash and sulfur values (reporting basis unknown). No coal exploration reports from Mogul Mining are present in WAMEX; however, holes designated as being drilled by Mogul appear on later maps by WMC, Western Ventures and CRA Exploration.

Exploration by Texasgulf Australia Ltd is mentioned in reports by Forsayth (Atkinson, 1979) and several series of drillholes (TGR1–21, TGC1–15 and TGD1) are shown on maps by Western Ventures (Wilkinson, 1985). Although no reports from Texasgulf have been located in WAMEX, some information on drilling depths and coal intersections is given on the Western Ventures maps. The date of the drilling is thought to be in the mid to late 1970s.

Exploration by Hancock and Wright Prospecting is also noted in a number of reports from the late 1970s and early 1980s. Western Ventures include on their drillhole location maps several series of holes identified as being completed by Hancock and Wright Prospecting (HA01–75, HP1–33 and HD1–4); however, no further details are available as no reports are available in WAMEX.

WMC initially applied for 102 coal mining leases in an area east of the Western Ventures – CRA Exploration leases extending from Coorow–Greenhead Road in the north to Cowalla Road in the south, replaced by a single exploration licence application, E70/123, in September 1983 and designated the Catamouri Hill project. WMC drilled 13 holes in March 1982 (Western Mining Corporation Limited, 1983e) followed by one hole in June 1983 (Western Mining Corporation Limited, 1984a). The initial series of holes was drilled to determine pre-Cenozoic stratigraphy. Holes were drilled to a maximum of 66 m and 70 samples were collected for palynology along with three hand-selected cuttings of coal. The final hole, CHR14, was drilled to 428 m, geophysical logging was completed and further palynology and coal samples collected. Note that the location of CHR14 differs between the Australian Map Grid (AMG) coordinates given and that shown on the location map of Western Mining Corporation Limited

(1984a). The AMG84 easting is given as 331450E although this may contain a typographical error and should be 334150E, a location that is approximately 150 m from that shown on the drilling location plan; whereas the difference between the typed location and that shown on the plan is about 2700 m.

The WMC Yewadabby Spring project initially covered 112 coal mining lease applications made in June 1980. This prospect, the most southern of seven areas pegged at the time, was considered to have potential for hosting shallow Jurassic coal and followed on from earlier work by Dampier/BHP and Griffin. In September 1983, 38 of the coal mining leases were relinquished and an exploration licence, E70/119, applied for over the remaining coal mining leases. These coal mining leases were withdrawn in February 1984, with the exploration licence being granted in January 1986. A second exploration licence, E70/353 to the east, was applied for in February 1986 and approved in August 1986.

Twenty holes (YSR1–20) drilled to a maximum depth of 78 m and a transient electromagnetic (TEM) survey were completed during 1981–82, from which samples were obtained for palynology and coal analysis (Western Mining Corporation Limited, 1983d). A single hole (YS21) was drilled the following year (Western Mining Corporation Limited, 1984b) and no work was reported during 1983–84 (Western Mining Corporation Limited, 1985). From 1984 to 1988, WMC completed a further TEM survey and drilled five holes (YS22–26), along with associated palynology and coal analysis (Meyer, 1986b, 1987, 1988). During the 1988–89 period, 14 aircore (YS27–40) and one diamond hole (YSD1) were drilled, geophysical logs were acquired and coal analysis performed on samples from these holes (Meyer, 1989a). WMC commenced compulsory relinquishments in 1988 (50% of E70/119; Meyer, 1989b) and 1989 (50% of E70/353; Meyer, 1989c) and no work was completed in 1989–90, although further relinquishments continued (50% of E70/119; Meyer, 1990a) and final relinquishment of E70/353 (Meyer, 1990b). A final drilling program of 16 holes was completed in 1990–91 and complete relinquishment of all tenements occurred in January 1991 (Meyer, 1991). WMC defined a small deposit named the Karinga coal deposit with a cumulative coal thickness of 6.6 – 6.7 m in 10 seams over an interval of about 80 m. The maximum individual true seam thickness was only 1.7 m, dipping at 30–35° to the west. From the limited coal analysis presented, this coal would classify as a low to moderate ash, low sulfur, sub-bituminous coal. No further information on this deposit has been reported.

There are indications that additional WMC drilling may have occurred. Plan 1180-8 within WMC report A35978 (Western Mining Corporation Limited 1983e, p. 43) shows the location of three holes designated WMC1–3 in the Gairdner Range – Mintaja area adjacent to WAPET shot hole Hill River F/32 and southeast of WAPET Mintaja holes 8 and 8A–D. These holes lie between the northern (Brazier) and southern (Gairdner Range – Mintaja) coal areas of CRA Exploration and therefore would have intersected the sequence below the main coal interval. There is no further information available on these holes.

Plan 1180-16 within WMC report A35978 (Western Mining Corporation Limited, 1983e, p. 42) shows a hole designated Perrin 1, located on private property approximately 450 m northeast of the intersection of Yerramullah and Cowalla Roads. No further information on this hole has been located.

In 1982, the Hill River project joint venture between Western Coal and Uranium and CRA Exploration was formed with Western Coal and Uranium as manager (Wilkinson and Thompson, 1983). The joint venture consisted of 366 coal mining leases and 19 mining leases covering seven prospects from the Scott and Cooper targets in the north, to the Wongonderrah and Wedge targets in the south, including the central Brazier area, which was later evaluated along with Cowla Peak – Gairdner Range deposits.

Initial exploration during 1982 concentrated on the Wongonderrah target area where previous exploration had identified several significant coal intersections. Three holes (TH1–3) were drilled to test the aircore drilling method and the suitability of wireline logging, followed by a program of 44 aircore holes (WAC1–44), including downhole geophysics when hole conditions allowed. Samples were collected for coal analysis and palynology. Nine coal seams were identified and these could be correlated throughout the area of drilling. The maximum individual seam thickness was 2.3 m and a maximum aggregated thickness in one hole was 7.0 m in seven seams.

In 1983, Western Coal and Uranium completed a two-stage drilling program covering the Cooper target area (CAC1–23) west of the Eneabba deposit, five holes in the Peron area (PAC1–5) southeast of Jurien, and six holes in the Brazier–Warradarge area (BAC1–6) north of CRA Exploration's Cowla Peak – Gairdner Range prospect (Wilkinson, 1984b). Drillhole PAC1 is also reported in Western Ventures (1984).

In 1984, the joint venture, then managed under the Western Ventures name, completed 30 aircore holes in the Scott area in the north (SAC1–2), the Brazier–Warradarge area (BAC7–13), the Craig target (RAC1–18), and the most southern Wedge prospect (WE1 and WTA1–2; Wilkinson, 1985). The program included downhole geophysical logging, coal analysis, collar survey and palynology sampling. By 1984, all titles were held as exploration licences (E70/27–29, 32 and 144–146).

Exploration in 1985 (E70/29, 144, 165 and 222, and P70/46–52 and 178) included three aircore holes on the Wongonderrah prospect (WAC45–47), and 23 aircore holes (BAC14–35) and one diamond core hole (WD1) on the Brazier–Warradarge prospect. Geophysical logging was completed where hole conditions permitted, and collar surveys were completed for the Brazier–Warradarge prospect holes. Other work carried out included an electromagnetic (EM-34) survey, and coal and palynology analysis (Wilkinson, 1986a).

Western Ventures changed its name to First Investors Resources NL during 1986 and reporting was split into the southern Wongonderrah prospect titles E70/29 and E70/165 (Wilkinson, 1986d) and the northern Brazier prospect (Wilkinson, 1986c), comprising two exploration licences, E70/144 (Brazier) and E70/222 (Brazier East). Discussion on the exploration and evaluation for the Brazier prospects from 1986 onwards is included with the following section on the Cowla Peak – Gairdner Range prospects as the post-1986 work was completed in conjunction with evaluation work on those prospects.

At Wongonderrah, 15 aircore holes (WAC 48–62) and one diamond core hole (WOCH1) were completed in 1986 (Wilkinson, 1986d). Drilling confirmed that the coal seams thin and pinch out rapidly in all directions and then reform. Cored hole WOCH1 was drilled between aircore holes and failed to intersect the full coal sequence encountered in the aircore holes. Analytical results from coal sampling in 1986 had not been received by the time the annual report was submitted and therefore not included. E70/165 was surrendered in January 1987 and E70/29 expired in January 1988.

Western Coal and Uranium, as they were named at the time, drilled a single aircore hole in 1983 within their West Cataby prospect, E70/15 south of Wongonderrah; a title not part of the CRA Exploration joint venture (Wilkinson, 1984a). The exact location of the drillhole, CW1, is not given in the report but was located about 400 m south-southwest of an unnamed hole with a reported aggregate thickness of 3.5 m of coal. The drillhole (CW1) intersected 72 m of poorly consolidated sandstone interpreted as Yarragadee Formation. Also in 1983, Western Coal and Uranium drilled a 198 m-deep aircore hole (PAC1) in P70/29 (Western Ventures NL, 1984) on the edge of the Badgingarra National Park in an area previously tested by Greenex (Joass, 1980a).

During 1985, the now Western Ventures completed a drilling program (Western Ventures NL, 1985) in the Wedge and south Wongonderrah prospects (P70/46–52), an area previously explored by the Griffin / International Nickel joint venture (Utting et al., 1976), Dampier/BHP (Kerber, 1979), Goyder (Wilkinson, 1978) and Mogul. Drillhole WTA1, drilled to 150 m, intersected minor coal and WTA2, drilled to 78 m, intersected mainly sandstone with minor detrital coal, both interpreted at the time as being within the Cattamarra Coal Measures, although a later reassessment indicated WTA2 terminated in the Yarragadee Formation.

Gairdner Range / Cowla Peak / Brazier area

CRA Exploration formed a joint venture (90%) with Cowla Peak Mining in 1981, comprising 50 coal mining leases and coal mining lease applications covering 65 km^2 in the Gairdner Range – Mintaja Hills area (note the geographical location in the area is Cowalla Peak; however, the company name was Cowla Peak). In addition, CRA Exploration held a further 650 km^2 under coal mining lease and exploration licence titles in their own right, and an additional 480 km^2 in the 50% joint venture with Western Coal and Uranium. Western Coal and Uranium changed their name to Western Ventures in February 1984, then First Investors Resources in May 1986 and to Melrose Mining NL in 1987.

CRA Exploration commenced exploration on 19 of the coal mining leases of the Cowla Peak project in 1981 (Fig. 3), drilling 27 mud-rotary (CPRH1–27) and one cored hole (CPCH1) in the area known as the Warradarge prospect (Ellis, 1982). Eight coal zones were identified (designated B to I) within a 250 m interval of the Cattamarra Coal Measures, with five coal seams considered of economic interest. Geophysical logging enabled a seam-by-seam correlation across the area drilled. A comprehensive suite of coal analysis was completed on core from CPCH1. This hole should be considered as the reference hole for the area and the core is now held in the DMIRS Perth Core Library.

In 1982, a single diamond hole was drilled to 200 m (CPCH2) and 19 aircore holes (GR2–19, 21) were completed (with a total of 2483 m drilled) on the Cowla Peak project along with downhole and surface geophysics, photo interpretation, surveying and photogrammetry (Kristensen, 1983). It should be noted that Kristensen (1983) mentioned that there was an error in the plotting of the AMG grid on contour maps, which was considered to be due to a lack of sufficient ground control in the 1970 photography used. The discrepancy was finally overcome in 1985–86; however, the plotted location of all drillholes on maps prior to 1986 should be treated with caution.

The 1982 exploration program discovered two new deposits, Cowla Peak north and west, and based upon coal analysis parameters such as moisture, carbon content and specific energy, a westwards increase in coal rank was indicated. The program allowed for a better definition of the structure of the project area along with seam correlation and splitting. The drilling significantly added to the known resource, largely in the main ‘G seam’. CRA Exploration estimated that the deposit it had explored to that date contained in excess of 160 Mt of sub-bituminous coal with approximately 40 Mt at depths of less than 100 m (Kristensen, 1983).

In conjunction with the Cowla Peak project joint venture, CRA Exploration also carried out exploration on 21 adjacent Mount Lesueur coal mining leases pegged in 1981 and held in their own right. Three aircore holes (GR1 20 and 22), two mud-rotary holes (GRRH1–2) and one cored hole (CPCH5) were drilled in 1982 and 1983. Downhole geophysical logging and coal sample analysis was completed for all holes (Ellis, 1984a).

The 1983 joint venture program consisted of 17 aircore holes (GR29–45) and seven diamond core holes (CPCH3, 4 and 6–9) (Kristensen, 1984). Following this program, CRA Exploration reported it had designated six separate fault/resource blocks — Gairdner Range, Mintaja, Cadda, Mount Benia, Munbinea and Warradarge (the latter two previously named Cowla Peak north and Cowla Peak south). The company considered it had a better definition of seam splitting and had increased delineated resources to about 180 Mt for the Mintaja and Cadda blocks, and intersected significant coal in the Gairdner block in the northwest.

The ongoing issue with the error in topographic maps is again mentioned in the 1984 report, with errors up to 60 m noted with a recommendation to fly aerial photography (Kristensen, 1984).

Exploration continued within both the joint venture title (GR72–78) and the area to the west (GR46–71 and 90) in 1984 (Kristensen, 1985a,b). Drilling tested more outlying prospects, validated structural interpretations and firmed up the known resources, adding about 40 Mt with the inclusion of the Gairdner block. Exploratory drilling west of the Lesueur Fault only intersected the sequence beneath the coal measures.

In 1985, drilling of a series of 84 RAB holes designated GRAH began to better define structure at depth and the degree of oxidation in areas of subcrop, along with aircore holes (GR 104, 106, 107–109 and 113–115) to prove up additional resources (Kristensen, 1986a). Within the Gairdner block, 33 RAB holes, four aircore holes and four diamond core holes (CPCH10–14) were completed to obtain coal samples for quality testing (Kristensen, 1986b). Exploration and evaluation continued in 1986, testing structural boundaries and obtaining core for coal quality and geotechnical analysis, drilling a combined total of 68 aircore and 16 diamond core holes (Park, 1987a,b).

At the northern Brazier prospect, the 1986 exploration program included 59 aircore holes (BAC36–94) and seven diamond core holes (BCH1–7) with associated geophysical logging and coal analysis with the aim of preparing a coal resource estimate (Wilkinson, 1986c). The 1986 drilling program accurately defined the position of the subcrop of the coal seams and the limit of fresh coal over a strike length of about 3.8 km.

No new drilling was completed in 1987, with work concentrating on the compilation of a digital database, analysis of coal samples from the 1986 drilling, detailed geotechnical assessment and preliminary mining studies, which were recorded in a single report (Kristensen, 1989). Resources for the Cowla Peak – Gairdner Range area were estimated at about 270 Mt, of which about 30 Mt was considered suitable for opencut mining.

In 1987, the Brazier prospect reporting was completed on individual tenements due to compulsory partial relinquishment requirements. No new drilling was completed at the East Brazier prospect (E70/222) and analysis of the previous year's program was reported. Work concentrated on geological modelling and resource estimation (Kristensen, 1988), with CRA Exploration reporting about 12 Mt of in situ coal to a depth of 150 m, with an energy content of about 17 MJ/kg and total moisture range of 27–30%. CRA Exploration purchased the Brazier tenements from First Investors Resources / Melrose in 1987, which was formally registered in December 1988.

A partial relinquishment for Brazier E70/144 in 1987 resulted in the removal of areas with limited or no coal potential (Park, 1989e). The program on the retained portion of the western Brazier prospect, E70/144 included the drilling of a fully cored hole for geotechnical and hydrogeological studies (BCH8). Reporting included coal analysis of the previous year's drilling, geological modelling and resource estimation (Park, 1989a). CRA Exploration reported an estimate of 38.3 Mt of in situ coal to a depth of 150 m, with an energy content of about 17.5 MJ/kg, total moisture of 26% and an ash value of 13% for the combined E70/144 and E70/222 tenement areas.

During 1988, an intensive evaluation program covering the combined 'Hill River project' areas including Cowla Peak, Mount Lesueur, Gairdner Range, Brazier and Brazier East prospects was completed (Millar, 1989). In total about 32 375 m were drilled, comprising 474 aircore holes (BAC95–298 and GR187–455), 43 fully cored diamond holes and 11 large-diameter holes (CPCH31–63 and BCH9–29) of which nine were 400 mm in diameter, providing a bulk sample of about 15 t of coal. Drillholes were geophysically logged and coal seams sampled on a ply-by-ply basis for standard analytical testing (Millar, 1989). The drillhole locations overlying prospect geology are shown in Figure 6.

During 1989, analytical work continued on samples from the 1988 drilling and further work was completed on the geological interpretation using the 1988 close-spaced drilling data. A detailed mining study was also completed (Kristensen, 1991a). Twelve fully cored PQ3 holes were drilled, six to test variations in analytical results of the existing drilling (BCH30–31 and CPCH65–68) and the remainder (BCH32–34 and CPCH64, 69 and 70) to infill gaps in the analytical grid drilling or replace holes with excessive core losses.

During 1990, no on-ground work was completed and the work program included a review of deposit geology, studies on the estimation of product coal moisture, a review of geotechnical conditions and detailed mining studies (Kristensen, 1991b).

In September 1990, CRA Exploration was granted combined reporting status for two groups of tenements, the first known as Hill River Group 1, comprising the tenements covering the areas with defined resources known as Brazier (mining leases), Cowla Peak (coal mining leases) and a group of coal mining leases west of the defined resources known as the Mount Lesueur tenements. The second group, Hill River Group 2 tenements, comprised exploration licences, mining leases and mining lease applications to the southwest and south of the defined resource. Mining leases M70/614–618 were part of the 1989 surrendered portion of E70/81 discussed later.

Reported activity in the Group 1 tenements during 1991 included a review of resource estimates along with a review of the geology, resources and mining potential of the southeastern Warradarge block (Kristensen, 1993a). The review of in situ resources showed that about half, or 265 Mt of the defined total 525 Mt, of the Hill River project resources lie within the boundaries of the then proposed Mount Lesueur National Park. The park was gazetted in 1992.

During 1992 and 1993, no additional exploration or evaluation occurred within the Group 1 tenements. Work concentrated on environmental studies, including rehabilitation of areas previously disturbed by exploration and farming activities, fire management and a review of the conservation value of Victoria Location 10351, known as the 'CRA Farm' (Kristensen, 1993b, 1994a).

In 1994, one of the Cowla Peak joint venture partners, Warradarge Resources Pty Ltd excavated a 500 kg bulk sample from a shallow coal seam on the CRA Farm. The bulk sample was excavated on pasture in the Warradarge block from the subcrop of the main coal interval, with a pit excavated on the site of hole CPRH27 drilled in 1981. A location plan is presented in the annual report (Kristensen, 1994b). The exercise was only partially successful because of equipment limitations, resulting in the recovery of only one sample from the split G2. Activities related to environmental studies continued, including rare flora surveys, rehabilitation works and monitoring of regrowth. Coal mining leases lying within the boundaries of the Lesueur National Park were surrendered over the period from 1997 to 2003.

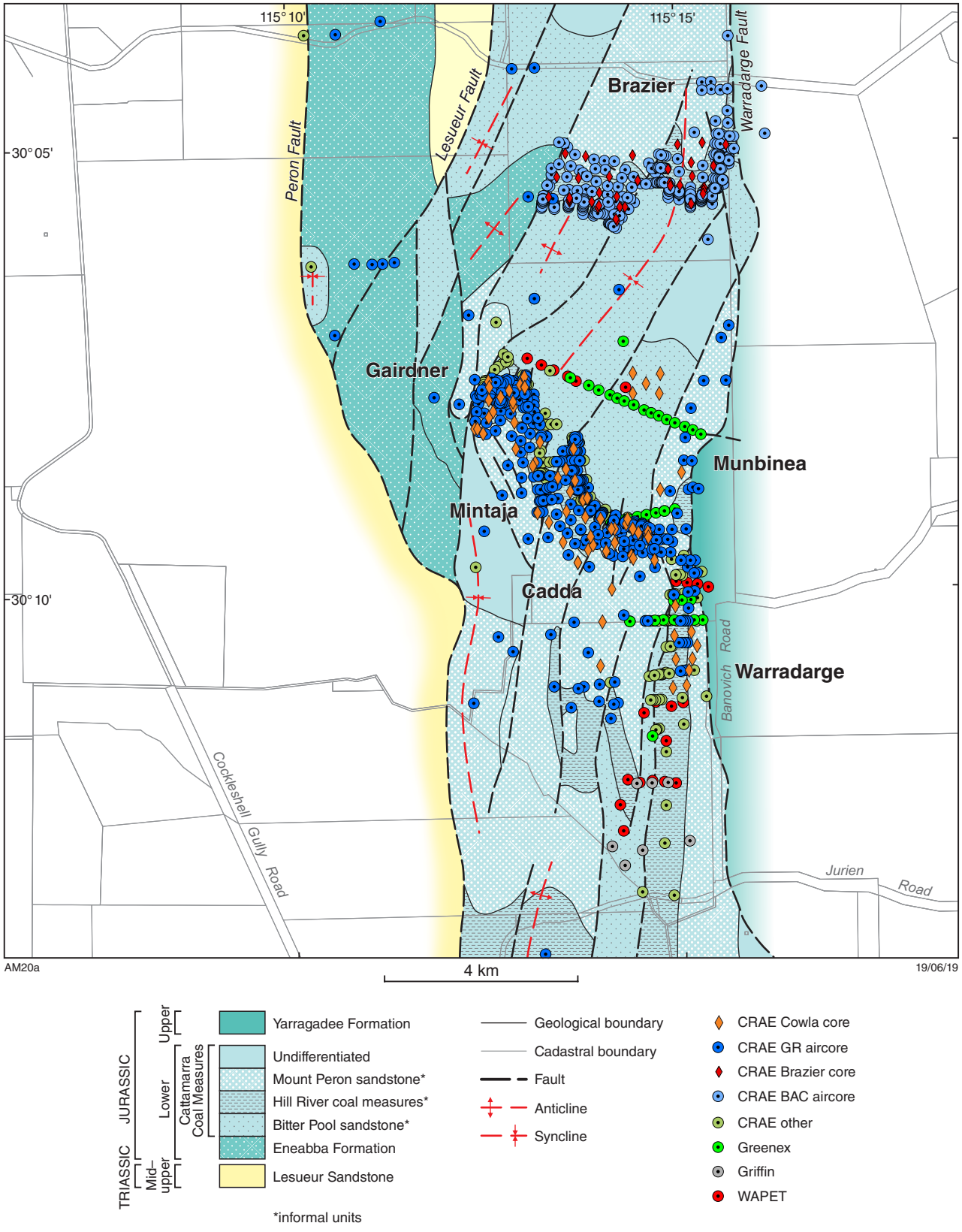

Figure 6. Location of the defined resources (prospect names) for the Cowla Peak – Gairdner Range and Brazier coal deposits (Hill River project) referred to in this Record, with drillhole locations overlying deposit geology from Kristensen (1991b). Geology to the east and west of the prospects was not shown in the original figure

From 1990 to 1994, no on-ground exploration was completed in the Group 2 tenements. During 1990, a photogeological review was completed (Kristensen, 1993c), and in 1991 a review of potential resources within the Group 2 tenements was undertaken (Kristensen, 1993d). No technical work was completed from 1992 to 1994 (Botje and Kristensen, 1993; Kristensen, 1994c, 1995).

Leases M70/614–618 were surrendered in June 1998 and E70/129 in September 1998, and there was no reporting during the period 1995–98. Lease E70/236 was extended from 1996 to 2002 and expired in March 2003, when it was converted to mining leases M70/1124–1125 in the name of Warradarge Resources.

Coal mining leases previously part of the Cowla Peak joint venture were converted to mining leases M70/1122 and 70/1123 in 2003, also under the name of Warradarge Resources, and later transferred to WA White Energy Pty Ltd in 2004. Warradarge Resources was owned by one of the partners in the Cowla Peak joint venture. These titles, covering the southeastern Warradarge prospect and the less well defined, small prospect in the south near Jurien Road, were given combined reporting status in 2003 (C32/2003). Data reviews and planning are the only activities reported over the period 2003–04 (White, 2003, 2004; Warradarge Resources Pty Ltd, 2005). WA White Energy report the drilling of six holes in 2005 (WA White Energy Pty Ltd, 2006), plus a single hole in adjacent tenement E70/2595 held by Mintaja Coal Pty Ltd (Coates, 2006a).

Jurien Energy Ltd agreed to purchase titles from WA White Energy and partners in October 2006 (Compston, 2007); however, formal registration did not occur until July 2014. The titles were then transferred to related entity Jurien Industrial Minerals Pty Ltd later in July 2014. A letter outlining resources within the Warradarge prospect is included in 2006 report (Compston, 2007); however, as the CRA Exploration evaluation was completed prior to the inclusion of coal reporting within the JORC Code, the resource quoted does not comply with the JORC Code.

No exploration activities were reported for these titles during 2007 (Bunge, 2008) or 2008 (Williams, 2009), and no reports were submitted in 2009 or 2010. Reporting from 2011 onwards remains confidential.

In 2014 and 2015, Jurien Industrial Minerals completed data reviews and the collation of historical drilling data; both reports remain confidential. M70/1125 was surrendered in 2015 (Provins, 2015b) and M70/1123–1124 were surrendered in 2016. The surrender report for M70/1123–1124 contains the collar locations of numerous historic drillholes (Provins, 2016b). Mining lease M70/1122 was retained and remains current.

Between 2006 and 2011, Jurien Energy / Jurien Industrial Minerals also held two titles to the east (E70/2715) and south (E70/2716) of the defined resource areas at Gairdner Range – Cowla Peak, in which coal was a target commodity along with mineral sands. All of the exploration activities reported relate to mineral sands.

From July 2011, Western Coal Pty Ltd held the licence E70/3968, which lies along the eastern boundary of the Cadda Shelf in the Hill River area. They completed a review of historical exploration, although no on-ground work was undertaken prior to relinquishment in September 2014 (Chen, 2012; Jun, 2013).

Mintaja Coal was granted E70/2595 in November 2003, adjacent to mining leases held by WA White Energy and straddling Jurien Road in an area previously explored by Dampier/BHP and CRA Exploration. Mintaja Coal held an agreement to explore on mining leases M70/1123–1125. The report submitted for 2003–04 (Coates, 2004) includes a review of the geology and historic drilling and is almost identical to the report submitted by Warradarge Resources (Warradarge Resources Pty Ltd, 2005) covering the adjacent mining leases.

The written report for 2004–05 (Coates, 2006a) indicates activity including drilling of holes MC001–004 and MC06 (note a change in the numbering format) plus a series of holes farther east designated MAC001–004, and two additional unnamed holes south of MAC001–004. Drilling details are incomplete and confusing, and it would appear that the holes mentioned in the text as MAC and the two unnamed holes are actually part of the WSAC series of holes, which are hand-drawn on an included location plan. Collar locations for holes MC01–06 are reported in the WA White Energy annual report (WA White Energy Pty Ltd, 2006), although no other details are presented. Exploration licence E70/2595 was transferred into the name of Westralian Iron Pty Ltd in May 2005, and then to AP Mining Pty Ltd in October 2005.

AP Mining reporting for 2006 (Coates, 2006b) included a review of previous work and the listing of drillholes MC1–7 and WSAC01–06, which all had surveyed collars (note the variation of hole numbering compared to previous reporting). During 2007, additional geological mapping and a heritage survey was completed (Tietjen, 2008a). AP Mining report the location of an unidentified drillhole encountered during their field mapping. From the location given in the report, this drillhole appears to be CPRH22, drilled by CRA Exploration in 1981 to a depth of 135 m and reported by Ellis (1982).

A partial surrender occurred in April 2008 (Tietjen, 2008b) and the exploration licence was extended for a further two years to November 2010. No 'on the ground' work was completed in 2008 (Milton, 2009) and drilling preparation and a flora survey were completed in 2009 (Milton, 2010).

In 2010, two aircore drillholes (10MC001 and 10MC002) were completed on old borrow pit sites adjacent to Banovich Road on the eastern edge of the tenement (Milton, 2011). Drillhole 10MC001 was drilled to 120 m and intersected a thin, slightly weathered coal seam from 25.2 – 25.4 m with sandstone and siltstone lithologies to the end of the hole. The second hole was terminated at 35 m in hard, siliceous, ferruginous sandstone. Palynology from 10MC001 indicated that the hole intersected the *Callialasporites turbatus* zone indicating the Cattamarra Coal Measures. A further two-year extension of the tenement was granted in November 2010.

No exploration was completed in 2011 (Smart, 2012) and following a review of the prospect in 2011–12, AP Mining recommended the tenement be relinquished (Smart, 2013). Following a fine for non-compliance with expenditure conditions, the tenement was forfeited in November 2012.

Brazier prospect post-1994

Australian Gold acquired rights to a number of the coal titles covering the Brazier deposit (M70/381–383, 543 and 639) and farther north (M70/490–492) from Melrose (previously First Investors Resources) and Rio Tinto (formerly CRA Ltd) over a period from 1995–99, although these were not formally registered in Australian Gold's name until early 2002 (Compston, 2002). Combined reporting status was granted in 1999 (C71/1999). There is no reporting on these titles for the period 1995–2001. No on-ground coal exploration is reported for 2001–02 (Compston, 2002) or 2003–04 (Compston, 2004), and no reporting covering the period 2002–03 has been submitted.

In 2003–04, Australian Gold completed a digital capture of historic project reports and maps. Drillhole plans and geological maps were re-drafted into digital format and digital coal quality data held by a consultant was recovered (Compston, 2004). There is a further gap in the reporting on this group of tenements until 2007–08, when the most recent open-file annual report was submitted (Ryan, 2008). This annual report includes details of drilling completed by Aviva within M70/492 of 39 aircore and two diamond core holes drilled to assist with the delineation of the southern extension of the Eneabba deposit (Central West coal deposit). Mining lease M70/492 was transferred to Aviva in 2010 and to Iluka in 2013.

A further gap in reporting occurs between 2007 and 2008 and between 2011 and 2012. The more recent reports are within the five-year confidentiality period.

Mining leases M70/490–491 were forfeited in February 2015 following the non-payment of fines relating to non-compliance with expenditure obligations. A final surrender report for M70/490–491 was submitted in June 2015 (Provins, 2015a). M70/383 was surrendered in February 2016 (Provins, 2016a). Only titles M70/381–382, 543 and 639 remain current. West Coal Pty Ltd was granted E70/4441, covering the main Gairdner Range – Mintaja coal deposits in August 2014, and reporting remains confidential. Most of this title lies within the Lesueur National Park.

Other CRA Exploration prospects

Throughout the 1980s, CRA Exploration continued exploring in areas away from the main deposits at Gairdner Range – Cowla Peak. The Verne Hill prospect, located approximately 13 km east of Cervantes, was applied for in May 1982 to test for Cattamarra Coal Measures beneath Quaternary cover. This lease, E70/13, was granted in March 1983 and surrendered in April 1985.

In 1983, 13 mud-rotary holes, CRAB6–18, were drilled and geophysically logged, and bottom-of-hole samples were submitted for palynology assessment (Ellis, 1984b). The majority of samples proved barren, although both Triassic and Lower Jurassic sediments were identified. In 1984, an INPUT (proprietary transient airborne electromagnetic [EM]) survey was flown to assist with drill target identification (Kristensen, 1985c). A single aircore stratigraphic hole (GR94) was drilled where the EM data and results of the previous year's drilling indicated possible coal measures. No coal was intersected and palynology indicated a Late Triassic age.

Exploration licence E70/3 covering the Mount Peron prospect, located 20 km east of the town of Green Head, was applied for in March 1982, granted in March 1983 and surrendered in January 1985. In 1983, one diamond core hole (MPCH1) and four aircore holes (GR25–28) were completed. Downhole geophysical logs were obtained in these holes and a single palynological sample was submitted from MPCH1. This sample led to an uncertain interpretation of the stratigraphy, which could be either the Cattamarra Coal Measures or the overlying Cadda Formation (Ellis, 1984c). The drilling and surface mapping indicated that the area was faulted and the indication from palynology, combined with a lack of limestone and absence of coal seams, suggested that the intersected section was within the upper part of the Cattamarra Coal Measures. A reassessment of the interpretation was made in 1985 (Kristensen, 1985d), which concluded that MPCH1 spans a sequence below the main coal zone; the upper section of the hole possibly includes part of the Bitter Pool claystone (informal) and is stratigraphically less than 200 m below the coal. With no prospects of economic coal, the area was relinquished.

CRA Exploration explored within the Cadda Springs prospect, E70/80, targeting the Cattamarra Coal Measures in the Hill River area about 10 km southeast of Jurien (Wilkinson, 1986b). The area was applied for in May 1982, granted in March 1986 and surrendered in October 1986. Work comprised an aeromagnetic survey, 13 mud-rotary holes (CRAB19–31), a single diamond hole (CCH1) and palynological sampling. Lithological and palynological data from samples collected from both the mud-rotary and diamond drilling indicated that the intersected sequence belonged to the Triassic Lesueur Sandstone.

Exploration licence E70/81 covering the Canover prospect, east of the town of Jurien and south of existing tenements of the Cowla Peak prospect, was applied for in May 1983 and granted in March 1986. The original area covered a number of earlier coal mining leases and mining lease applications that were withdrawn in favour of the exploration licence.

The 1986 report (Park, 1989b) covers the period from 1982 to 1985 and includes details on the drilling of holes CRAB1–4, 32 and 33, GR23, 24, 98–102 and CACH1, which were all drilled prior to granting of the exploration licence. Geophysical logs were obtained in the holes where possible. Palynology was completed on samples from CRAB3 and CRAB32, although very poor assemblages were recovered and the results were tentatively interpreted as Permian to Triassic. An airborne magnetic survey, airborne INPUT and a ground EM survey were completed over the area. Drillholes GR24, GR98 and GR99 intersected correlatable coal seams with a maximum thickness of 2.5 m in GR24, the southernmost hole. The following year, a single diamond hole, CACH2 was drilled in the area of the potential economic coal. The hole intersected only minor coal seams and was abandoned due to drilling problems (Park, 1989c). The western portion of the tenement underlain by Lesueur Sandstone (and therefore the Cattamarra Coal Measures are absent) was relinquished in June 1987.

In 1988 two fully cored holes, CACH3 and CACH5, and partially cored CACH4, a re-drill of CACH3 were completed (Park, 1989d). All three holes intersected the

Bitter Pool claystone, the unit directly below the main coal sequence, and encountered only minor coal seams. The results of this program suggested that the coal sequence was truncated to the south by faulting, significantly reducing the potential for economic coal.

During 1989, a water bore was drilled to fulfil a compensation agreement (Kristensen, 1991c). In 1990, the area underwent a second compulsory relinquishment with the surrendered portion replaced by mining lease applications, M70/614–618, which were granted in May 1991 (Kristensen, 1993c). These tenements were combined with a number of adjacent titles (E70/129, 236 and 806–808) and reported on as Hill River Group 2 tenements, covered in the previous section. The remaining exploration licence E70/81 expired in August 1991.

Bookara area

GFEL pegged and applied for tenements (coal mining leases) in the Bookara area (Fig. 3) approximately 20 km north of Dongara in 1980 (Agg, 1982a,b). The leases were to cover potentially shallow coal following reported intersections at depths of about 230 m in cuttings and log interpretations in WAPET petroleum well Bookara 3 (Bowering, 1967). Jurassic Chapman Group ('Cockleshell Gully' equivalent) and Champion Bay Group (Cadda Formation equivalent) had previously been mapped in the northeast of the area near Mount Hill.

Holes BC1 and BC1B were drilled adjacent to petroleum well Bookara 3, and BC3B, drilled some 4.2 km to the north-northeast, recorded 3.9 m of coal in two seams (1.3 m and 2.6 m). BC1B intersected the same two seams of about 1 m and 3 m thickness, respectively. Hole BC2, drilled approximately halfway between, was abandoned above the coal interval due to drilling difficulties.

Another three drillholes were completed in 1982, none intersecting coal. BC4 intersected interpreted Kockatea Shale overlying granite basement, and BC5 also terminated in shallow basement rocks below a thin sequence of post-Mesozoic sediment. The final hole, BC6, was drilled away from the area of shallow basement and was abandoned at 30 m in interpreted Yarragadee Formation.

Griffin, in joint venture with a small private company, completed a five-hole (DON 1–5) exploration program over part of the same area in 1983, being aware of the interpreted faulting between Bookara 3 and Mount Hill and the interpretation that Mount Hill was the expression of a horst block. The drilling was completed over a line from Mount Hill in the north to about 4.5 km to the southwest to test for shallow coal on the interpreted Mount Hill horst (Fewster and Denman, 1983).

DON 1 intersected undifferentiated 'Cockleshell Gully Formation' overlying basement. DON 2, located to the north of the horst, was abandoned within interpreted Chapman Group ('Cockleshell Gully Formation' equivalent). Drillholes DON 3–5 were located south of Mount Hill and were targeting a possible 'step down' in the faulted block. DON 3 and 4 intersected 120 m and 160 m, respectively, of Cattamarra Coal Measures containing some coal; the thickest seam was 1.7 m at 143 m depth in DON 4. The final hole, DON 5, was terminated at 121 m in carbonaceous shale that palynology confirmed as 'Cockleshell Gully Formation' below the Cadda Formation.

No further exploration for coal in the area was reported between 1983 and 2004. Over the period April 2004 to April 2005, Eneabba Gas Limited applied for a group of tenements to the northeast of Dongara, covering much of the area and beyond that previously explored by GFEL and Griffin during 1982–83. Titles were progressively approved between October and November 2005, and granted combined reporting status in April 2006 (C32/2006). The original title applications were for the purpose of coal seam methane (CSM) or coal seam gas (CSG) exploration (note that exploration for CSM or CSG is included in the *Petroleum and Geothermal Energy Resources Act 1967*, although the titles were applied for and granted under the *Mining Act 1978)*. In July 2006, the group of tenements was transferred into a subsidiary company, Eneabba Mining Pty Ltd (Westblade, 2006). Although Eneabba Mining reviewed and referenced petroleum exploration results in the area, the company does not appear to have reviewed the GFEL exploration, and the Griffin program results remained confidential at the time.

Eneabba Mining completed a four-hole, combined mud-rotary/diamond core program from December 2006 to January 2007 (Westblade, 2007) including downhole geophysical logging, and collected 13 samples for standard coal analysis, and gas content and composition testing. The analytical results from this program indicated that coal rank was low (sub-bituminous) and that the gas content was very low. Eneabba Mining concluded that seam thickness, depth and continuity could make the coal suitable for underground coal gasification (UCG).

During 2008, Eneabba Mining completed a 25-hole drilling program to define a coal Resource suitable for UCG, resulting in the reporting under the JORC Code (JORC, 2004) of a total coal Resource of 194 Mt within E70/2758 (Westblade, 2009).

A three-hole drilling program was completed during 2010 to assess the coal potential of the tenements on the Bookara Shelf and the Wicherina Terrace to the northeast and east of the defined coal resource (Westblade, 2010). Eneabba Mining interpreted that the Cattamarra Coal Measures was intersected in all three holes, although the coal was poorly developed. Minor coaly material was identified in drilling samples although the stratigraphic correlation with adjacent petroleum wells, using downhole logs, is poor and no palynology is available to positively identify the intersected units.

In mid-April 2010, Eneabba Gas signed a Memorandum of Understanding with Cougar Energy Limited for the development of the Sargon coal resources; this was formalized in June 2010 (Eneabba Gas Limited, 2010b) and terminated in June 2011 (Eneabba Gas Limited, 2011a,b).

Eneabba Mining drilled a single openhole with associated geophysical logging in 2012, primarily as a monitoring water bore but also to confirm the coal continuity. Resources were also updated to a total of 205 Mt, with the increase being entirely within the Inferred category (Eneabba Gas Limited, 2012; Westblade, 2013). Monitoring results were reported in 2013 (Westblade,

2014) and the final annual report received. Tenement E70/2758 was extended to November 2014. Eneabba Mining had commenced partially surrendering tenements from 2007 and final surrender of tenements from 2010 with the final title, E70/2758, being surrendered in August 2015.

Note that at the time of the Eneabba Mining evaluation program, the development of UCG was not covered by State legislation. Amendments allowing the in situ processing of a mineral resource were made to the *Mining Act 1978* in 2012 that would now allow for potential development of UCG.

Deposit geology and coal quality

Eneabba

At Eneabba, drilling has intersected an average thickness of the Cattamarra Coal Measures of around 570 m. The best-described interval is the stratigraphic section containing the three main coal units, which are characterized by cyclical upwards-fining sequences of sandstones, siltstones/mudstones, claystones and coal (Morgan, 1981). The lower and thickest known seam is the Eneabba Main seam. Approximately 50 m above the Eneabba Main seam is a thinner and less developed seam, the Eighty seam, and a farther 50 m above this is an interval containing four to five thin seams known as the Maxwell seam. Other thin seams have been intersected, mainly below the Eneabba Main seam, although these are generally discontinuous and poor quality. In the proposed mining area, the overall strike of the coal sequence is north-northwest, dipping to the east-northeast at 2.5 – 13.0°. Figure 7 is a simplified west-to-east section along local grid 19600 N in the northern part of the deposit.

The Eneabba Main seam averages 8.05 m in thickness and usually occurs as two or three splits, with the upper splits having better quality than the basal split. The two main splits are separated by a mudstone parting of up to 10 m.

The Eighty seam is relatively thin with an average thickness of 0.7 m and a maximum intersection of 1.95 m. The seam has been intersected over a wide area and is considered a useful marker occurring about 50 m above the Eneabba Main seam.

The Maxwell seam is characterized by four or five thin coal seams with an average total coal thickness of 1.74 m over a geological interval of about 8.5 m. Its areal distribution is relatively consistent and it is also a useful marker horizon. The average seam thickness is only 0.46 m although individual seams can exceed 1.5 m.

Below the Eneabba Main seam, the character of the sequence changes and for at least 20–30 m the lithologies are mainly clay rich with very fine-grained sandstone laminae. Discontinuous coal seams are common, generally <0.5 m thick and shaley. Bioturbation is common in the finer lithologies for 150 m below the Eneabba Main seam; however, bioturbation is very rare between the Eneabba Main and Maxwell seams. One hole, ERA72 (total depth 379 m) drilled to 350 m below the Eneabba Main seam, intersects a farther 50 m of interbedded coarse- to medium-grained sandstone with minor siltstone above a thicker, more monotonous mudstone and commonly coarse-grained sandstone.

Above the Maxwell seam is a mainly silty section with thickly laminated, intensely bioturbated siltstone and 1–2 m beds of fine- to medium-grained sandstone. Lying about 35 m above is an unnamed coaly interval about 10 m thick, with one or two thin coal seams. Above this horizon is mainly monotonous medium- to coarse-grained sandstones.

Eneabba coal is described as dull, black, sub-bituminous coal suitable for washing, which results in an appreciable reduction in moisture, ash and sulfur with good coal recovery (Morgan, 1981).

In 1982, Renison Goldfields engaged ERM Consultants to conduct a preliminary utilization study of the deposit specifically targeting mine development and an accompanying power station (ERM Consultants Pty Ltd, 1982). The work included a review of the resource data, including the adequacy of the data and the suitability of the coal for domestic power generation, and concluded that there were 'adequate in situ reserves for the 26 years economical life of a 700 MW power station' with more than 50% additional reserves indicated for the total life of such a power station.

Average in situ coal quality and basic coal properties are presented in the utilization study (ERM Consultants Pty Ltd, 1982); unfortunately, they mix the moisture basis of the reporting. Recalculating the given results to common moisture basis gives the results shown in Table 1. Typical ultimate analysis values on a dry ash-free basis are presented in Table 2. Indicative product, including dilution (roof, floor and partings), was estimated as shown in Table 3.

Based on these parameters, the coal classifies as sub-bituminous B (based on the ASTM classification [ASTM, 2018]) with moderate ash. Sulfur levels are high at 1.3 – 4.0% (air dried [ad]), with about half occurring as organic sulfur, indicating a marine influence on the depositional environment.

Only limited coal-quality data has been reported since the 2004 acquisition, re-evaluation and subsequent sale of the project by Aviva.

Gairdner Range – Cowla Peak and Brazier

By 1982, a composite thickness of about 550 m of what was still referred to as the 'Cockleshell Gully Formation' had been drilled in the Cowla Peak area, described by Kristensen (1983) as a typical regressive sequence with marine rocks overlain by coal measures that grade upwards into upper deltaic facies. Based on the descriptions given in Kristensen's report, this interval is interpreted to be only the upper section of the formation that is now named the Cattamarra Coal Measures.

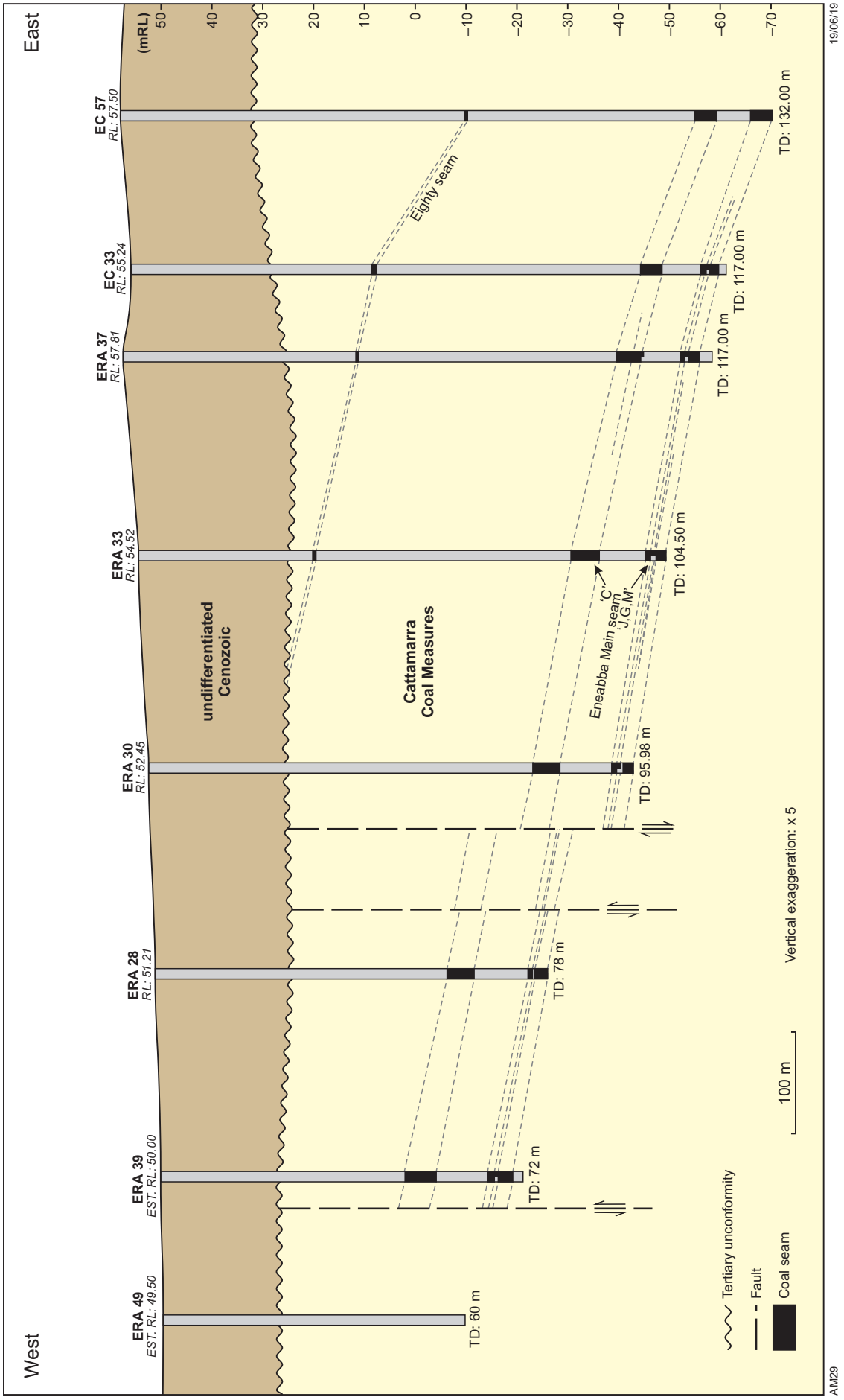

Figure 7. Cross-section through the northern Eneabba (Central West) coal deposit along local grid reference 19600N (for location of cross-section see Fig. 5), showing simplified geology and the locations of the Eneabba Main and Eighty seams (modified after Morgan, 1981). Abbreviations: EST, estimated; mRL, reduced level in metres (relative to sea level, above or below); TD, total depth

Table 1. Recalculated coal properties (30% moisture basis) for the Eneabba coal deposit after ERM Consultants Pty Ltd (1982)

	Moisture (%)	*Ash (%)*	*Volatile matter (%)*	*Fixed carbon (%)*	*Specific energy (GJ/t)*	*Total sulfur (%)*
30% Moisture	30	17.8	24.1	28.1	15	1.5
Air dried	17.8	20.9	28.3	33.0	17.6	1.8
Dry	–	25.4	34.4	40.1	21.4	2.2
Dry ash free	–	–	46.2	53.8	28.7	–

Table 2. Typical ultimate analysis of the Eneabba coal deposit (dry ash-free basis) after ERM Consultants Pty Ltd (1982). Oxygen by difference

	Carbon (%)	*Hydrogen (%)*	*Nitrogen (%)*	*Sulfur (%)*	*Oxygen (%)*
Ultimate analysis	71.9	4.61	1.16	2.79	19.54

Table 3. Indicative product coal quality values from the Eneabba coal deposit after ERM Consultants Pty Ltd (1982)

	Moisture (%)	*Ash (%)*	*Volatile matter (%)*	*Fixed carbon (%)*	*Specific energy (GJ/t)*	*Sulfur (%)*	*Chlorine (%)*
Indicative product	30.0	19.6	23.3	27.2	14.64	1.4	0.05

CRA Exploration recognized four informally named major units in the area, which are (in ascending stratigraphic order): the Bitter Pool claystone, the main coal-bearing sequence; the Hill River coal measures; the Mount Benia shale; and the Mount Peron sandstone. Figure 8 shows the geology and structural features as mapped and interpreted from drilling by CRA Exploration (Kristensen, 1991b). Figure 6 shows the location of the named deposits and drillhole locations overlying the project geology from Figure 8. Figure 9 is a schematic north–south cross-section displaying the lateral variations in the defined units within the coal measures.

The lower most unit, the Bitter Pool claystone, consists of mainly fine-grained sediments, predominantly massive, olive-green and brown claystone with thin limestone and calcareous beds and numerous pelecypod fossils. About 290 m of this unit was intersected in drillhole GR2. The depositional environment is interpreted to be shallow-marine grading upwards to estuarine and paralic. Thin coal seams may occur near the top, with the base of 'seam G' considered as the top of the Bitter Pool claystone. The unit subcrops over a large area in the central northern portion of the Cowla Peak – Gairdner Range prospect, where the topography is characterized by lowlands with poorly drained clayey soils.

Overlying the Bitter Pool claystone is the main coal-bearing sequence CRA Exploration informally named the Hill River coal measures, which covers the interval between and including 'seams C and G'. The unit varies in thickness from 70 to 100 m. The thick basal seam G is overlain by a prograding deltaic system and marks the appearance of fluvial point bar profiles in the sequence. Four fining upwards cycles are recognized, all with some coal development at the top (Fig. 10). Of these, seams C and D are the most persistent although absent in some areas, and are only potentially mineable in the southeastern Warradarge block (Kristensen, 1983).

Seam G has the characteristic uniform distribution of coal deposited in a paralic environment, where the watertable has a hydrostatic connection with the sea (Kristensen, 1983). The seam profile is recognizable not only throughout the Cowla Peak prospect but in the Eneabba area 30 km to the north. Even when the seam plies split and diverge to the south, the partings can be correlated with dirt bands within the coal.

The top one-metre ply of seam G diverges in the southerly portion of the prospect where it was originally named seam F and later renamed seam G1. The interseam sediment consists mainly of finely laminated, fissile clay and siltstone that is lensoidal and can exceed 40 m in thickness. The thickening of this unit is accompanied by the thinning of the plies of seam G. The overall thickening of the coal measures southwards is interpreted to be due to the Mount Benia shale, whereas the overlying sediments maintain a consistent thickness. Kristensen (1983) interpreted the Mount Benia shale as being a result of greater local subsidence resulting in less coal accumulation and increased clastic sedimentation, and that the increase in subsidence may have been due to differential compaction of underlying sediments rather than tectonism.

The Mount Peron sandstone overlies the coal measures and is a sequence of fluvial point bar deposits with no coal seam development, although detrital coal has been intersected throughout.

The dominant structure in the area is the Cockleshell anticline, outlined in early seismic surveys. The resulting dome-like structure is flanked by two faults with

displacements exceeding 1000 m (Figs 6, 8). The Lesueur and Peron Faults lie to the west and the Warradarge Fault to the east; both are normal faults with a downthrow to the east. Seam dips are low (<5°) except for the extreme easterly and westerly limbs where they increase to 13°.

The Brazier deposit lies to the north and is divided by two significant subparallel faults — both northeasterly trending, the easternmost of which is subparallel to and about 300 m west of the Warradarge Fault — dividing the deposit into three sub-blocks; Brazier West, Brazier East and east Brazier East. The seams strike east-southeast and dip at shallow angles to the north. The Gairdner Range – Mintaja – Cadda deposits lie to the south and are also divided by northeast–southwest-oriented faulting. The Warradarge deposit in the southeast dips east and is truncated by the Warradarge Fault.

The main coal unit, seam G, consists of six identifiable and correlatable seam splits (Figs 9, 10) designated G1–G6, which split and coalesce. In the Cowla Peak – Gairdner Range area, the partings are thinnest in the Cowla Peak north block. The upper parting thickens southwards and becomes the Mount Benia shale, separating the divergent coal ply seam G1. The middle parting averages 1 m thick and does not vary much except in Cowla Peak north. The lower parting thickens to the south and west with a maximum intersected thickness of 4 m. In the Brazier area, the coal occurs within two main sections, the upper G1–G4 seam split and the lower G5–G6 split. Seam G1–4 ranges in thickness from 7 m in the southwest to 8.5 m in the northeast of the deposit. In the southwest part of Brazier West, the subsections G2 and G3 diverge when a mudstone parting up to 0.8 m in thickness develops between them. The separation between subsections G4 and G5 decreases from 2.5 m to 1.5 m from the southeast to the northeast. The thickness of seam G5–6 averages 0.8 m.

Seam G was intersected by drillhole CPCH23 in the central Mintaja deposit. The combined downhole gamma, long-spaced density and caliper log traces (coal combination sonde [CCS]) acquired in CPCH23 are shown in Figure 11. The associated downhole caliper and short-spaced density or bed resolution density (BRD) log traces, along with a detailed seam profile and coal-quality values for the main seam G, are shown in Figure 12.

Overlying the main seam in CPCH23 is a sequence of sandstone irregularly interbedded with laminated mudstone and sandstone. The sandstones are fine- to medium-grained and finely bedded, including flaser bedding, and the mudstone–sandstone units are finely laminated. Both display variable bioturbation and the sequence is visibly weathered to a depth of 26.15 m. Immediately overlying the coal are several centimetres of sandstone interlaminated with coal.

In CPCH23, the splits G1/G2 are separated by a thin 3.5 cm coaly mudstone band but for practical purposes are combined into the upper 6 m unit. The G1/G2 seam is separated from the middle G3/G4 split by 1.2 m of mainly dark grey, laminated mudstone and siltstone and minor carbonaceous claystone. The G3/G4 seam in CPCH23 contains a 24 cm parting of carbonaceous claystone clearly shown on the geophysical logs. The lower most G5/G6 split lies about 3.7 m below an interval of laminated to finely interbedded siltstone and fine sandstone, and carbonaceous mudstone. Disturbed bedding, most likely from bioturbation, is noted along with siderite concretions. Seam split G5/G6 consists of coal with common finely interbedded carbonaceous shale and coaly shale. The increase in non-coal material is reflected in both the geophysical log signatures and the high ash values. Directly beneath the G5/G6 coal split is about 4 m of dark grey to black mudstone and carbonaceous mudstone with root traces and disturbed bedding, overlying a unit of grey, medium to coarse sandstone displaying low-angle, fine cross-bedding.

The coal-quality data displayed in Figure 12 shows the typical variation throughout the main G seam. In situ moisture does not vary much through the seam. The thickest split, G2, has the lowest ash and sulfur values and the highest contained energy. In general, the reported sulfur values decrease up the seam.

In summary, the coal is classified as sub-bituminous, with typical ranges of quality characteristics on an as-received basis shown in Table 4. The estimated average ROM coal quality on an as-received basis for the Hill River project is shown in Table 5.

Routine coal petrology on core samples throughout the exploration and evaluation programs has shown that the coal is high in vitrinite (70–80% mineral matter free [mmf]) and inertinite (15–25% mmf) and typically low in liptinite (4–6% mmf) and mineral matter content (4–20%). Vitrinite reflectance values range from 0.37 – 0.41% in the Brazier deposit to 0.38 – 0.51% for the Gairdner Range – Cowla Peak deposit. Suwarna (1993, 1999) carried out a detailed examination of the petrology and geochemistry and completed an interpretation of the depositional environments of the coal from the Cattamarra Coal Measures based upon cored samples from six drillholes from the Gairdner Range – Cowla Peak area. Based on lithotype, microlithotype and maceral analyses, the depositional environment is interpreted as a telmatic, wet, forest swamp of a brackish to upper–lower delta plain. Trace element analysis, especially boron content, indicates the presence of a marine influence during peat deposition, an interpretation supported by the relatively high proportion of organic sulfur present in the coal.

Coal rank varies throught the deposits generally in the range sub-bituminous B to sub-bituminous C (ASTM classification) with some areas of the Gairdner block reaching high-volatile C bituminous (Kristensen, 1991b).

Wongonderrah

Western Coal and Uranium exploration in the Wongonderrah area followed several earlier, although poorly reported work programs by Texasgulf, Hancock and Wright, and Griffin (Fig. 3). Generally, the geological descriptions available from open-file reports are limited and available drillhole details have been obtained from later exploration reports (Wilkinson, 1986a). Palynology indicates that the coal lies within the Cattamarra Coal Measures (Wilkinson and Thompson, 1983), and in a general sense, the coal-bearing sequence is considered to be equivalent to that at the Cowla Peak – Gairdner Range and Eneabba deposits to the north.

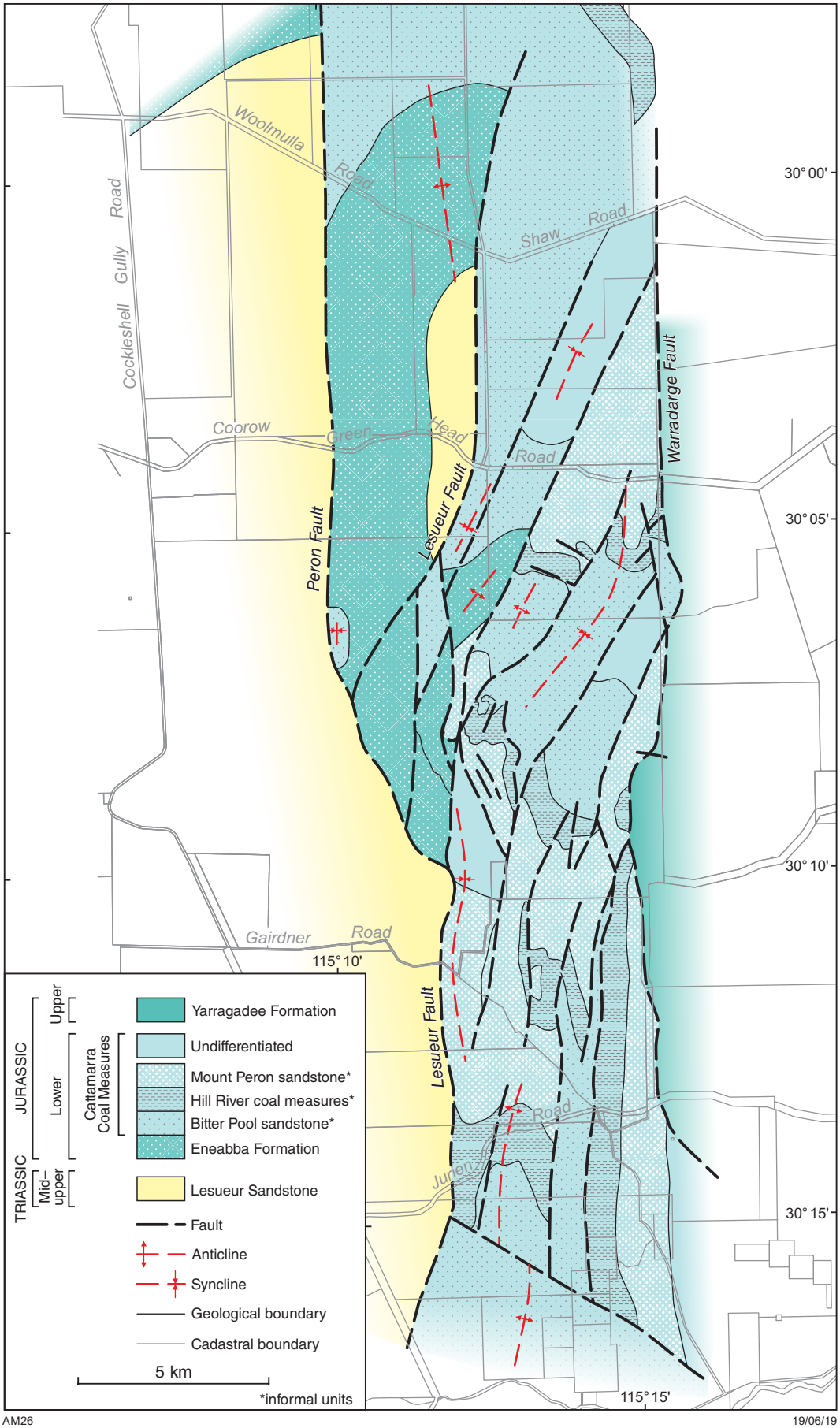

Figure 8. Geology of the Hill River area centred on theGairdner Range – Cowla Peak and Brazier prospects after Kristensen (1991b)

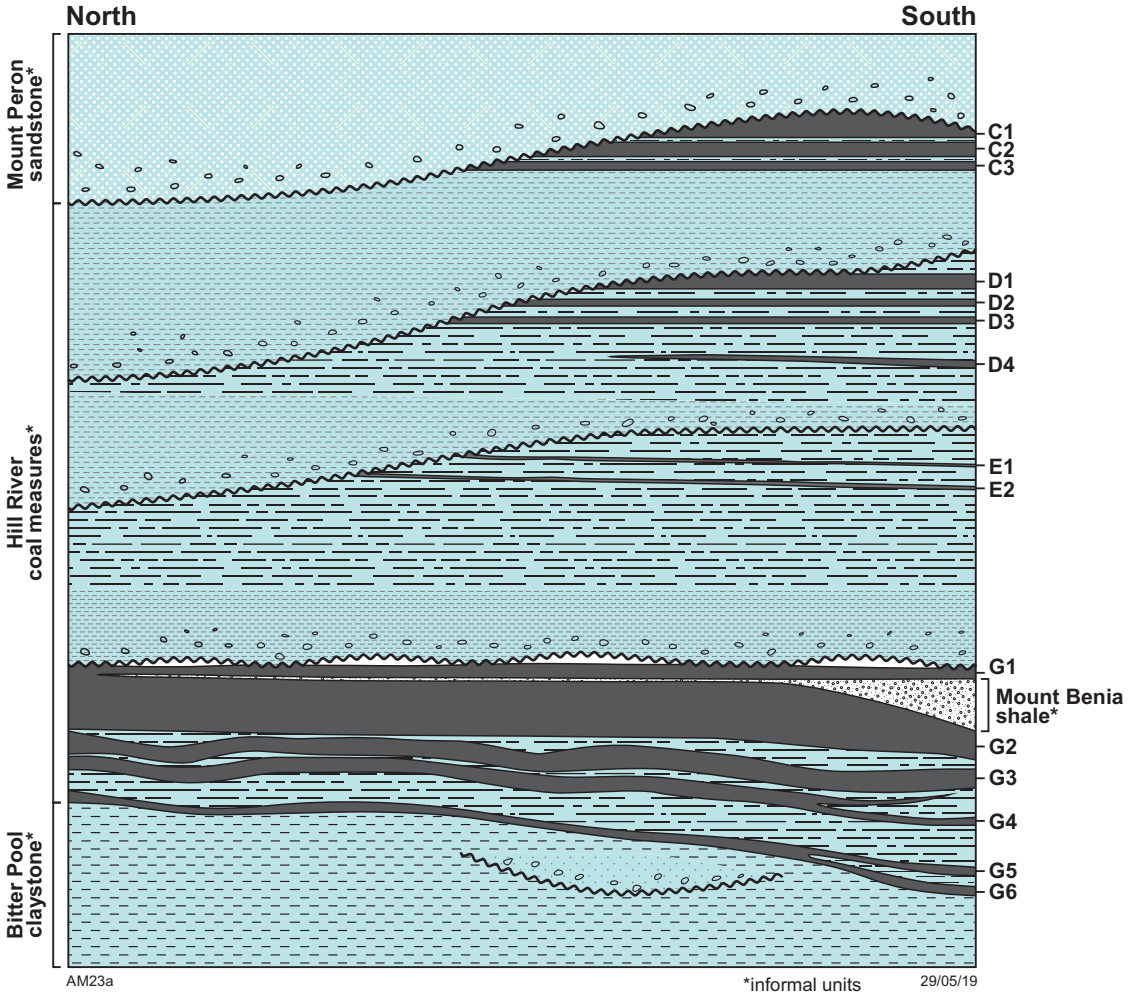

Figure 9. Schematic north–south geological section of the Hill River group of coal deposits, showing lateral variations in the local defined stratigraphy and splitting of coal seams C, D, E and G (modified from Kristensen, 1991b)

Drilling in 1982 intersected the main coal sequence, which comprises up to nine distinct seams up to 2.4 m thick that could be correlated using downhole geophysical logs over an area of about 8 x 1 km. Further drilling in the north of the area indicated the presence of fewer and thinner seams, and therefore correlation with the main area was not completed (Wilkinson and Thompson, 1983).

Wilkinson (1986d) reported that coal seams thin and pinch out rapidly both along and across strike. Core from WOCH 1 showed sedimentary structures such as herringbone cross-bedding, bioturbation and shell beds close to coal seams. Geological interpretation indicates that the coal at Wongonderrah was deposited in a coastal swamp environment subject to tidal influences, and this may explain the variations in coal thickness over short distances.

The limited available coal quality data indicates that the coal is similar in composition to those from the other main deposits at Cowla Peak – Gairdner Range although with higher ash values.

Bookara

The Cattamarra Coal Measures on the Greenough Shelf lie beneath a sequence of Cenozoic sandstone and limestone, unconformably overlying the Yarragadee Formation, which in turn conformably overlies the Cadda Formation.

Coal development on the Greenough Shelf occurs as four identifiable seams in a zone about 10 m thick, approximately 100 m below the top of the Cattamarra Coal Measures. In the Bookara area, these occur at depths between 160 and 410 m. The two upper seams, designated seam A and B by Eneabba Mining, are generally poorly developed being only 10–30 cm thick. The two lower seams (C and D) are better developed; seam C has a thickness of 1.2 – 1.5 m, with an average of 1.3 m, and seam D has a thickness of 1.3 – 3.0 m, with an average of 2.7 m (Turner, 2009). Both seams C and D develop splits in the south of the area. Although the Cattamarra Coal Measures occur on the adjacent Dongara and Allanooka Terraces and the Bookara Shelf, the coal seams are not as

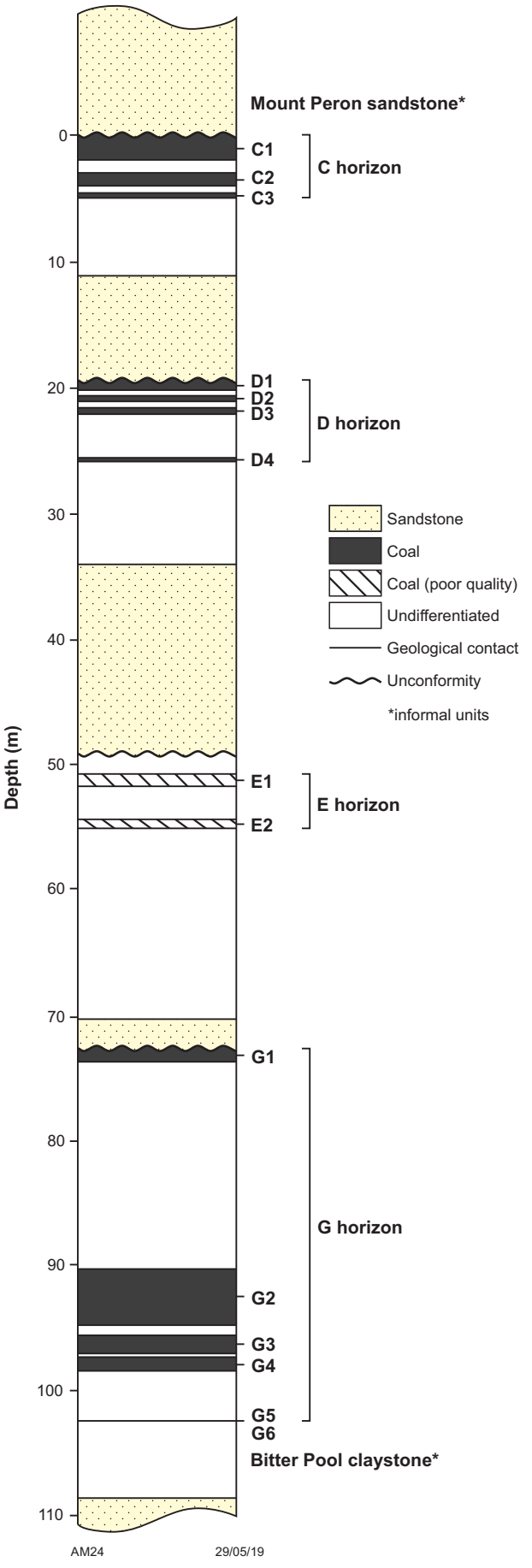

Figure 10. Typical stratigraphic section showing named coal units at Gairdner Range, modified after Kristensen (1991b)

well developed and generally too deep to be considered economic using current extraction techniques. Agg (1982a) noted that the 'Cockleshell Gully Formation' had an increasing number of calcareous bands towards the base, at least one of which becomes a limestone, and several probable marine fossils have been noted directly below the coal.

In 2007, Eneabba Mining drilled four holes to assess the rank, coal quality, methane content, permeability and porosity of the coal (Westblade, 2007). Analysis revealed that the coal rank was low (sub-bituminous) and the methane content was very low. Ply-by-ply and composite coal analytical data are presented in the Eneabba Mining 2007 and 2009 annual reports (Westblade, 2007, 2009). Typically, the coal is moderate to high ash (15–25% ad), moderate to high sulfur (1.5 – 3.5% ad), moderate energy (14–18 MJ/kg ad) and classifies as sub-bituminous. From the limited number of samples analysed, the organic sulfur levels are high, reflecting the likely marine influence on the original peat swamps. Petrography has been reported on only four samples, all in the south of the area (Westblade, 2007). These all report high vitrinite content of 60–85% (mmf), liptinite values of 5–12% (mmf) and inertinite of 11–27% (mmf), all typical of the Cattamarra Coal Measures. The dominant liptinites are sporinite followed by resinite. Mean maximum vitrinite reflectance values of 0.30% are reported.

In the Eneabba Mining resource report (Turner, 2009), coal quality data are reported at a 26% moisture content, and modelled results indicate an average ash value for seam C of 22.7% and specific energy of 14.9 MJ/kg. Seam D model values report average 19.1% ash and specific energy of 16.0 MJ/kg.

Resources

Unless otherwise specifically stated, resource figures in this Record do not comply with the reporting requirements of the current JORC Code (JORC, 2012). If resources were originally reported as complying with an edition of the JORC Code prior to 2012, then the edition year has been stated here.

Prior to September 1999, the estimation and reporting of coal resources and reserves in Australia was outlined by the Code for Reporting Identified Coal Resources and Reserves (fifth edition; Standing Committee on Coalfield Geology of New South Wales, 1986).

This code was ratified by the Government Geologists' Conference in April 1986 and appended to the JORC Code in February 1989. The JORC Code was subsequently revised in 1992 and 1996. In 1999, a significant revision occurred, which resulted in the inclusion of the reporting of coal resources and reserves into the JORC Code. This 1999 edition of the JORC Code referenced the 1999 edition of the Guidelines for the estimation and reporting of Australian black coal resources and reserves (Coalfield Geology Council of New South Wales and Queensland Resources Council, 1999). The guidelines were updated in 2003 as the Australian Guidelines for Estimating and Reporting of Inventory Coal, Coal Resources and Coal Reserves (the 2003 Guidelines; Coalfield Geology Council

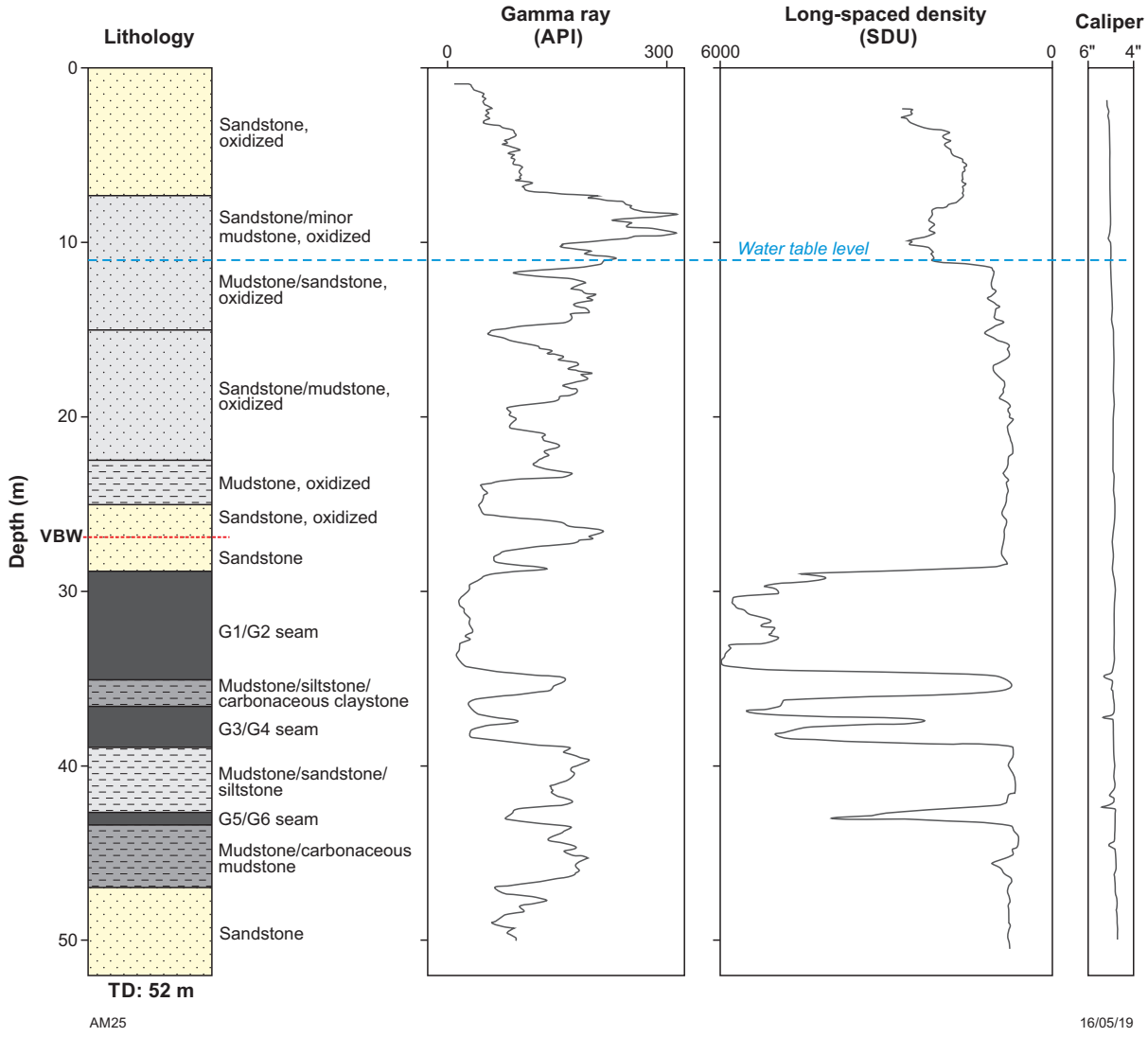

Figure 11. Simplified lithology log for central Mintaja drillhole CPCH 23, alongside downhole natural gamma, long-spaced density (uncalibrated) and caliper logs (modified after Park, 1987a). Abbreviations: API, American Petroleum Institute units; SDU, standard density units; VBW, visible base of weathering

Table 4. Coal characteristics (as-received basis) used to define coal quality in the Hill River project areas (Millar, 1989)

Moisture (%)	*Volatile matter (%)*	*Ash (%)*	*Sulfur (%)*	*Specific energy (MJ/kg)*
18–30	26–28	11–17	0.9 – 1.4	16–22

Table 5. Estimated average run-of-mine (ROM) coal quality (as-received basis) for the Hill River coal deposit (Kristensen, 1991b)

	Moisture (%)	*Ash (%)*	*Volatile matter (%)*	*Fixed carbon (%)*	*Specific energy (MJ/kg)*	*Sulfur (%)*
Estimated ROM	26.8	16.9	24.6	31.7	17.2	1.11

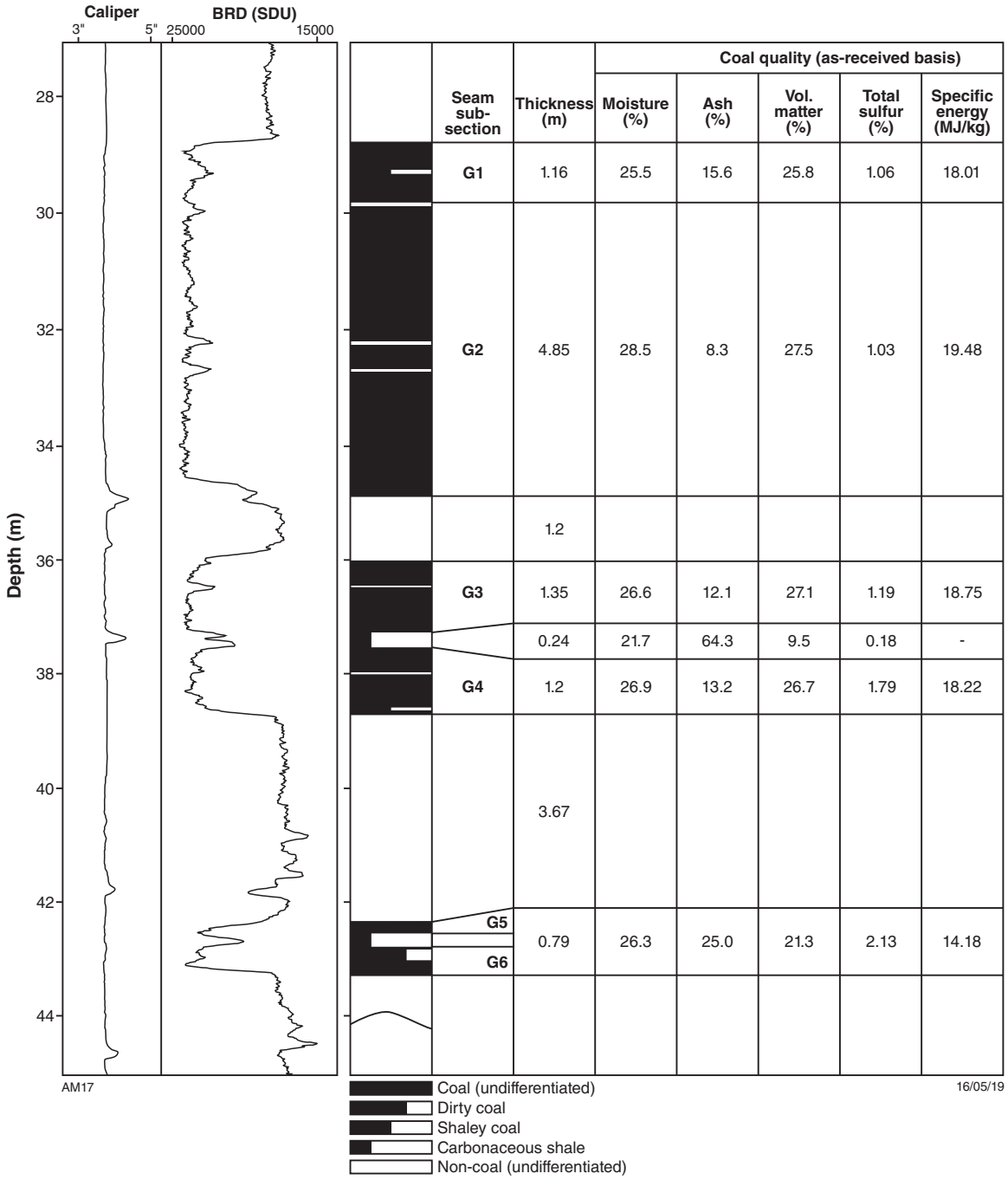

Figure 12. Detailed seam profile and coal-quality values for the main seam G from drillhole CPCH 23 displayed alongside the downhole bed resolution density (BRD; uncalibrated) and caliper logs. Modified after Park (1987a) and Kristensen (1991b)

Table 6. Summary of 2004 coal resource estimate for the Eneabba deposit (Aviva, 2004b), reported according to the 1999 JORC Code (JORC, 1999)

	JORC category			
	Measured	*Indicated*	*Inferred*	*Total*
Resource (Mt)	23.5	43.6	12.4	79.6

of New South Wales and Queensland Resources Council, 2003), and were referenced in the 2004 and 2012 editions of the JORC Code. The 'Coal Guidelines', as they are commonly referred to, underwent a significant revision in 2013–14 and were released as the Australian Guidelines for the Estimation and Classification of Coal Resources in 2014 (Coalfield Geology Council of New South Wales and Queensland Resources Council, 2014). The Coal Guidelines are not part of the JORC Code (2012); however, adherence to the processes and procedures outlined in the guidelines is recommended by the JORC Code (2012). A significant change in the latest guidelines was the removal of the often misused suggested distance between observation points, generally drillholes, to allocate resource categories. For further information on the Coal Guidelines and the JORC Code see Arnott (2013, 2015), Coalfield Geology Council of New South Wales and the Queensland Mining Council (2014), JORC (2012) and Stoker (2015).

Eneabba

In 1981, GFEL reported the Eneabba deposit was estimated to contain about 153 Mt of coal to a maximum depth of 195 m, or 123 Mt to a depth of 130 m (Morgan, 1981). No updates were reported until 2004 when Aviva, as part of a scoping study, had consultant Minserve Group prepare a resource statement following the superseded 1999 JORC Code and based upon a coal resource estimate completed by McElroy Bryan (Table 6; Aviva, 2004a,b). The resource estimate included coal from the Eneabba Main seam (76.6 Mt) and the Eighty seam (E split; 3.0 Mt) to a depth of 130 m to the base of the Eneabba Main seam G split.

Aviva announced total reserves of 72 Mt within a 130 m-deep pit at a strip ratio of 7.2 m^3/ROM t, from a study completed by the Minserve Group (Table 7). The reserve was based on a resource model completed in March 2007 containing 86.7 Mt for the Eneabba Main seam. The geological database used in the resource estimate comprised 251 drillholes, including raw coal-quality data from 76 holes and product composite testing from 23 holes (Aviva, 2007b). This resource report has not been submitted with annual reports to WAMEX.

The resource model was updated in November 2008 by McElroy Bryan (McElroy Bryan Geological Services Pty Ltd, 2008) and Nolan (2009) to incorporate the latest drilling results, including the area to the south within M70/870. From this model, a Resource (JORC, 2004) to a depth of 130 m to the floor of the Eneabba Main seam split G, was reported as shown in Table 8.

Gairdner Range – Cowla Peak and Brazier

No resources meeting JORC reporting standards are available for the Cowla Peak – Gairdner Range and Brazier coal deposits (Fig. 13). Resources outlined in available reports are pre-1999, therefore prior to coal being included in the JORC Code; however, they are generally based on the Coalfield Guidelines (Standing Committee on Coalfield Geology of New South Wales, 1986).

Park (1987a) lists Indicated 'in situ coal resources' for the Mintaja, Cadda and Warradarge blocks of 36 Mt suitable for opencut mining, apparently following what was referenced as the New South Wales DMR 1984 code, this is in fact the Code for Calculating and Reporting Coal Reserves (5th Edition; Standing Committee on Coalfield Geology of New South Wales, 1986). An additional 12 Mt (Indicated) was reported for the Gairdner block (Park, 1987b, 1989a) and lists mineable coal reserves of 'measured status' for the Brazier deposit of 38.3 Mt in 1987.

The total in situ resource for the combined project as estimated in 1987 was about 450 Mt, and conceptual mining studies identified reserves of about 94 Mt suitable for extraction by opencut methods (Millar, 1989).

Kristensen (1989) states that based on a preliminary mining study, the Cowla Peak – Gairdner Range deposits contain a total resource of 270 Mt (250 Mt Measured and Indicated, 20 Mt Assumed), of which 30 Mt could be recovered by opencut mining methods at overburden ratios not exceeding 10 m^3 per tonne of coal mined.

Reporting for 1989, following the major evaluation programs in 1988 and 1989, contains an independent consultant's technical audit (McElroy Bryan) of the geological resources work completed by CRA Exploration, in which the consultants confirm the 'measured in situ coal resource' of 85.8 Mt estimated by CRA Exploration (Kristensen, 1991a). McElroy Bryan also report their own resources of 65.1 Mt to 100 m cover over the upper G1 seam and 88.6 Mt to 120 m cover over the upper G1 seam (Table 9). It is understood the CRA Exploration figure was estimated to a maximum coal depth of 120 m.

Wongonderrah

Although an area of potentially economic coal has been outlined, no resources have been reported for the Wongonderrah deposit.

Bookara

During 2008, Eneabba Mining completed a 25-hole drilling program within their Sargon project near Bookara to define a coal resource suitable for UCG, resulting in the reporting under the JORC Code (2004) of a total coal Resource of 194 Mt (Table 10) within E70/2758 (Eneabba Gas Limited 2009a; Turner, 2009; Fig. 14).

Xstract Mining Consultants Pty Ltd completed an independent review of the resource for Eneabba Gas in November 2009 (Eneabba Gas Limited, 2009b) with the key findings noting that other than a '…few terminology issues, Eneabba's October 2009 coal resource estimate report meets the minimum 2004 JORC Code requirements for coal resource reporting'. Xstract also noted '…that greater transparency in the data reported could enhance the acceptability of the reported estimate with minimum effort'.

Table 7. Eneabba coal deposit estimated reserves 2007. The reserve is based on 35° pit slopes and a maximum pit depth of 130 m. A cut-off cost of $1.50/GJ was applied for block rejection (Aviva, 2007b). Abbreviation: bcm/t, bulk cubic metres per tonne

Reserves	*Proven*	*Probable*	*Total*
ROM coal (Mt)	44.54	27.53	72.07
ROM energy (as-received) (MJ/kg)	14.87	14.50	14.73
ROM strip ratio (bcm/t)	6.99	7.42	7.16

Table 8. Eneabba coal deposit updated resource 2008 (McElroy Bryan Geological Services Pty Ltd, 2008), reported according to the 2004 JORC Code (JORC, 2004)

	JORC category			
	Measured	Indicated	Inferred	Total
Resource (Mt)	51.8	26.2	11.3	89.3

Table 9. Summary of 'coal resources' suitable for opencut mining for the combined Hill River coal project (Kristensen, 1991a, appendix 30)

	Resource block				
	Brazier East	*Brazier West*	*Gairdner*	*Mintaja/Cadda*	*Total*
100 m cover over seam G1 (Mt)	17.0	15.4	12.5	20.2	65.1
120 m cover over seam G1 (Mt)	22.7	23.6	17.8	24.5	88.6

Table 10. Sargon project resource summary (Eneabba Gas Limited, 2009a; Turner, 2009), reported according to the 2004 JORC Code (JORC, 2004)

	JORC category		
	Indicated	*Inferred*	*Total*
Resource (Mt)	74	119	194

Other points noted in a review of the Xenith report for this Record are:

- the poor-quality maps, which are hard to read and not presented at a suitable scale
- not all drillholes are shown on plans
- resource extrapolation has continued across significant faults
- there are no maps or discussion on spatial variability of coal quality
- there is no mention of broad economic criteria such as seam thickness, interburden thickness and seam depths, which may impact on the resource, other than basic limits of >1 m thickness and maximum ash of 40%
- there are several inferences to issues such as faulting 'lowering the confidence' and additional drilling being required, which would suggest that the entire resource may be more appropriately classified as Inferred
- resource tonnes have been converted to contained energy by simply multiplying by average specific energy and reporting an in situ energy value, which may be misleading.

SRK Consulting also completed an independent assessment of the resource as part of a broader study of the valuation of the Sargon project coal assets (Eneabba Gas Limited, 2010a; Williams, 2010). SRK considered the parameters used in the estimation to be valid and that the geochemical data on which the estimation was based are of a quality to meet JORC standards. As part of the review, SRK completed a basic interpretation of a number of seismic lines and concluded that there were at least five small-scale structural features that may affect the coal seam continuity in addition to major faults already identified. SRK recommended that a detailed interpretation be completed. SRK was of the opinion that the reporting could be improved and that combining the seam interpretations from the resource model and seismic data would be beneficial, and considered the resource as calculated by Xenith Consulting Pty Ltd to be conservative in terms of in situ resources.

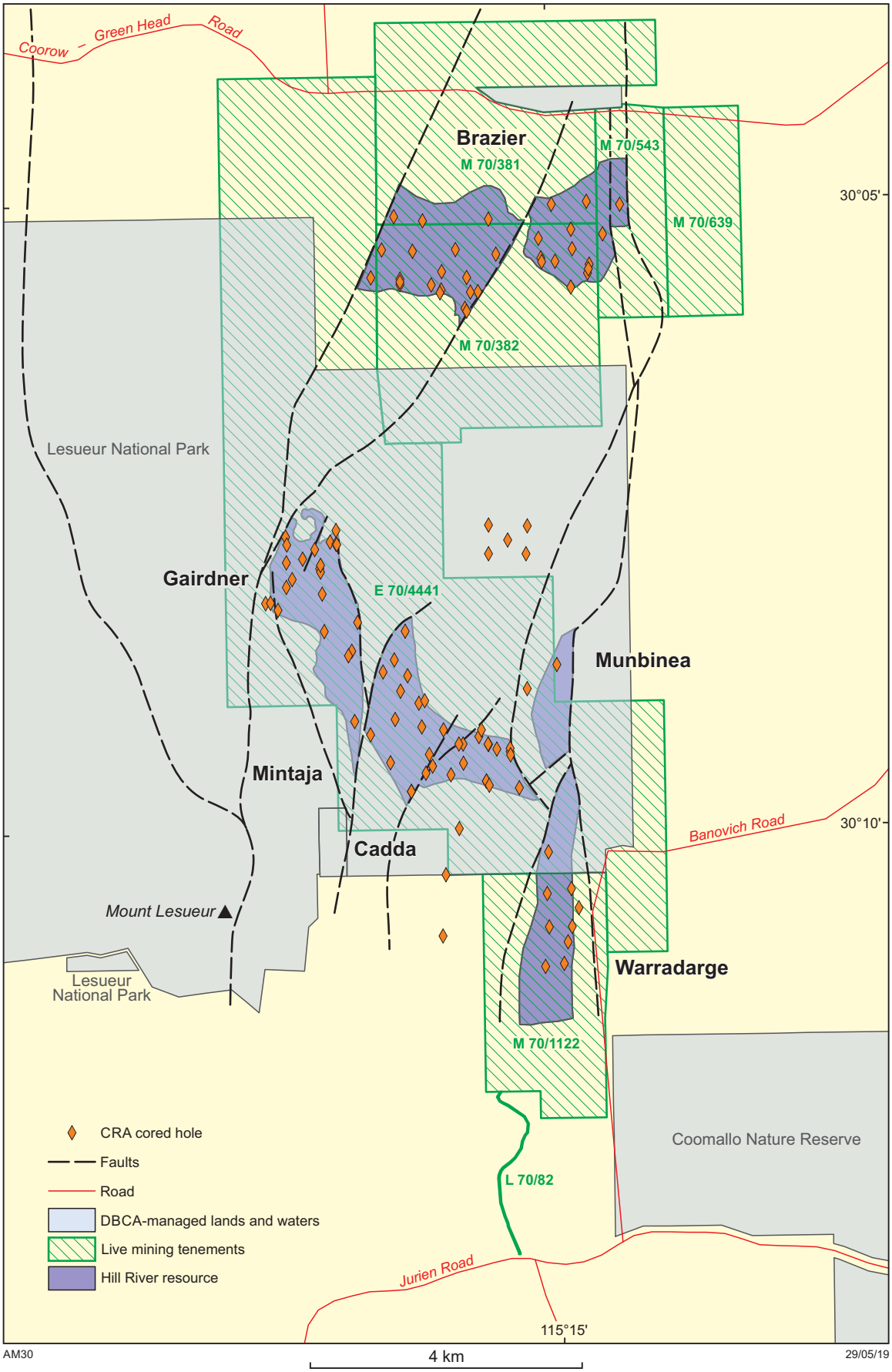

Figure 13. Location of the defined Hill River project coal resources and cored drillholes in relation to live mining tenements and the Lesueur National Park

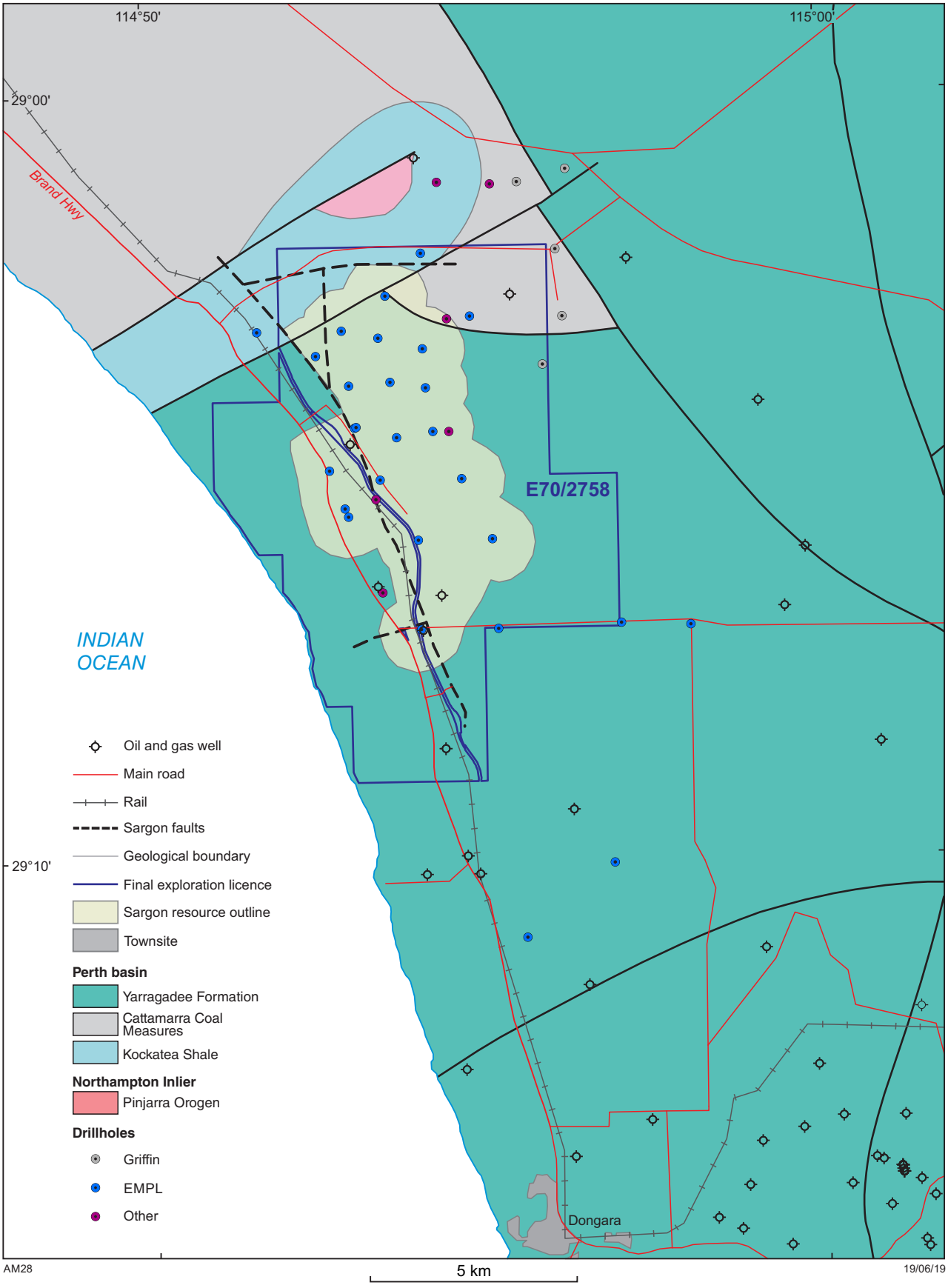

Figure 14. Location of the defined Sargon project coal resource (outline from Turner, 2009), showing drillhole distribution overlying 1:500 000 State interpreted bedrock geology of Western Australia (after GSWA, 2016)

Eneabba Gas, in an ASX release on 27 November 2012 (Eneabba Gas Limited, 2012), announced an increase in the Inferred resource of 11 Mt (Table 11). The revised resource estimate does not appear to have been completed by the previous consultant and no details of methodology used to calculate the additional resource are given in either the ASX announcement (Eneabba Gas Limited, 2012) or in the annual statutory report (Westblade, 2013).

Table 11. Sargon project revised resource summary (Eneabba Gas Limited, 2012), reported according to the 2004 JORC Code (JORC, 2004)

	JORC category		
	Indicated	*Inferred*	*Total*
Resource (Mt)	75	130	205

Summary

Mesozoic coal in the northern Perth Basin was first discovered during petroleum exploration drilling in the 1960s. Subsequent exploration has defined several major deposits: Bookara, Eneabba, Brazier, Gairdner Range – Cowla Peak and Wongonderrah, all of which are on the Greenough Shelf and Cadda Terrace.

The Cattamarra Coal Measures is the principal coal-bearing unit within the Mesozoic of the northern Perth Basin, and coal is interpreted as having been deposited in a telmatic, wet, forest swamp of a brackish to upper–lower delta plain, with minor marine influence during peat deposition. Coal rank throughout the deposits is variable, ranging from sub-bituminous B to sub-bituminous A. The coal is high in vitrinite and inertinite, and typically low in liptinite. Vitrinite reflectance values range from 0.3% at Bookara and Eneabba up to 0.5% for the Gairdner Range – Cowla Peak deposit.

In the Bookara area, coal exploration on the Greenough Shelf commenced in the early 1980s but with limited success. Eneabba Gas began exploring for CSM in 2004. Initial results indicated low coal rank and very low to non-existent gas content; however, re-evaluation in 2012 (under the 2004 JORC Code) determined a coal Resource suitable for UCG of 205 Mt.

In the Eneabba area, exploration in the 1970s, followed by an extensive evaluation program during the early 1980s, delineated a deposit then estimated to contain about 153 Mt of coal to a maximum depth of 195 m. More recent work revised the estimated total Reserves to 89.3 Mt within a 130 m-deep pit, at a strip ratio of 7.2 m^3/ROM tonne to the floor of the Eneabba Main seam split G (reported according to the 2004 JORC Code). Central West Coal Pty Ltd proposed to mine and supply coal from the Eneabba deposit to the proposed nearby Coolimba power station; however in February 2011, the EPA recommended against implementing this project.

Various joint ventures led by CRA Exploration during the 1970s and 1980s in the Gairdner Range – Cowla Peak area outlined in excess of 500 Mt of coal in five adjacent deposits. About 90 Mt was considered extractable by opencut mining; however, approximately half of the defined 'in situ resource' of the project is within the current boundary of the Mount Lesueur National Park.

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