Photograph 17. Black opals from Lightning Ridge (enlarged). New South Wales is the world's principal supplier of high-quality black opal, with the Lightning Ridge field accounting for most of this production, and the White Cliffs field responsible for a lesser proportion. (Photographer D. Barnes)

Potential and Outlook

Australia is by far the largest producer of precious opal in the world, and most of that production is from New South Wales (Figure 19).

All significant opal occurrences in New South Wales, and Australia, occur in the Great Australian Basin (GAB), where the opal is hosted by deeply weathered Cretaceous sedimentary rocks. It is considered that the entire area of Cretaceous rocks exposed between Collarenebri, White Cliffs and Tibooburra has potential to host precious opal (Table 26).

Almost all of New South Wales' precious opal comes from the Lightning Ridge area. Although opal was originally discovered at White Cliffs and a large amount of opal was won, the White Cliffs field currently makes only a minor contribution to total New South Wales opal production.

The value of opal produced in New South Wales for 2002–03 was estimated to be A$35 million, based on Australian Customs figures for worked black opal exports (Photograph 17). The total of all opals exported from Australia in 2000 was over A$79 million (Australian Bureau of Statistics). The major markets for opal exports are Japan, Hong Kong, the USA and Germany, with lesser but significant exports to New Zealand, Singapore, Switzerland, Republic of Korea, Taiwan and Thailand.

All recent significant new finds of opal in New South Wales have been made by miners using simple methods — commonly following lineaments such as lines of large trees (indicating faults) followed by auger drilling and shaft sinking. Opal exploration has been carried out by small companies in several areas of the state with limited success.

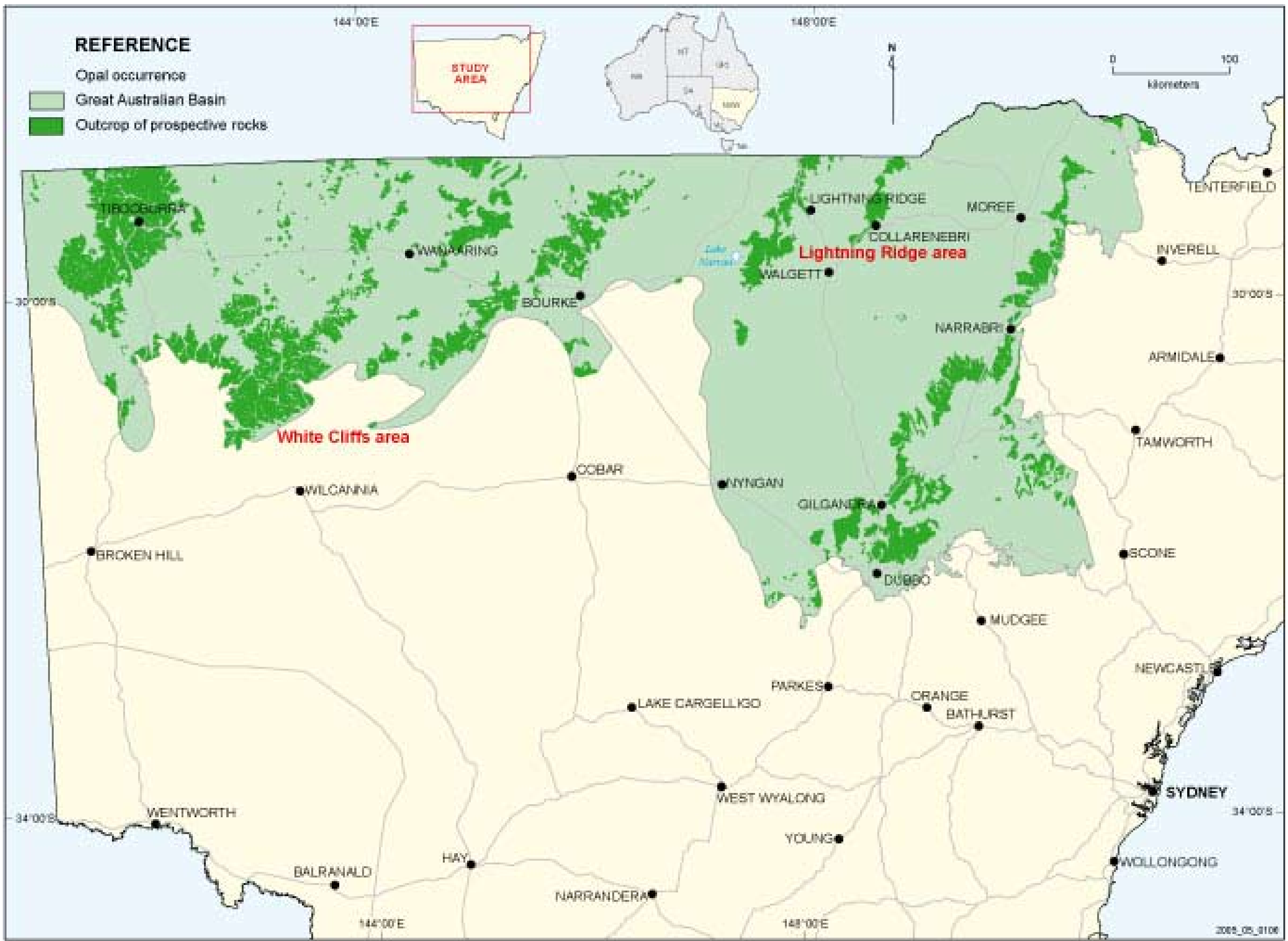

Figure 19. Opal occurrences and prospective Cretaceous rocks in the New South Wales portion of the Great Australian Basin

Despite there being various theories on the origin of opal there is general agreement about 'surface indicators' such as the presence of faults (indicated by lineaments), breccia pipes ('blows') and the presence of outcropping weathered Cretaceous sedimentary rocks. Structural features (such as faults and breccia pipes) are important controls but to date opal deposits have been found to have no recognised geochemical haloes. Most miners explore out from known opal fields. However, some exploration is undertaken in previously untested remote areas of Cretaceous sedimentary rocks away from the known opal-producing centres, in areas with no facilities and very little water.

At Lightning Ridge there is much scope for further opal finds, with the entire ridge of outcropping Cretaceous rock extending from the Queensland border to south of Narran Lake. The Geological Survey of New South Wales has been conducting geophysical surveys and geological investigations in the Lightning Ridge area to enhance the explor-ation potential of the area. The results of these investigations have been reported by Burton (2002) and Moore et al. (2003).

The potential for further discovery of opal in the White Cliffs area is also high. However, with the focus of opal mining in the Lightning Ridge area and the small amount of activity in the established White Cliffs fields, the potential of the White Cliffs area will remain untapped for some time to come.

Nature and Occurrence

Opal is a hydrated form of silica, with a variable proportion of the water being chemically bonded ($SiO_2.nH_2O$) (Table 26).

Opal is made up of microscopic spheres of silica up to 0.0005 mm in diameter (Darragh et al. 1966). The colour of opal is derived from the way light is diffracted by the silica spheres.

Table 26. Main properties of opal	
Mineral	Opal
Formula	$SiO_2.nH_2O$
Colour	Colourless, milky white, yellow, red, green, blue or black
Specific Gravity	1.98–2.2
Hardness	5.5–6.5

Source: Behr et al. (2000)

In **precious opal**, the spheres are of uniform diameter and are stacked in a regular pattern. In that case, the smaller the spheres the bluer the colour of the stone, whereas the larger the spheres the redder the colour of the stone (Darragh et al. 1966).

The background or body colour for the colour play in precious opal may be colourless, milky white, pale to dark grey, or black (Holmes et al. 1982). A harlequin pattern consists of an irregular patchwork of varying colours. A pinfire pattern consists of closely spaced pinpoints or specks of colour. A flash pattern shows broad irregular flashes which change or disappear as the stone is rotated. In transparent and translucent stones, no particular pattern is evident and the play of colour is described as 'flame' (MacNevin & Holmes 1980).

Common opal or **potch** is generally opaque. The silica spheres are of unequal diameter and/or are stacked in a haphazard way such that there is no uniform diffraction of light and hence no regular colour banding. Potch is intimately associated with precious opal, which may occur as bands within it (Holmes et al. 1982).

There are many varieties of opal. Important varieties are described briefly below.

Black opal —

is the most sought-after type of precious opal as the very dark body colour enhances the depth of colour (Photograph 17) and the colour play is seen to best advantage (Holmes et al. 1982). Lightning Ridge is the world's major producer of black opal.

Light opal —

has a background colour ranging from clear to milky. The clear varieties are known as crystal or jelly opal.

Boulder opal —

is a variety of precious opal found in veins or cavity fillings in dark, iron-stained sandstone or mudstone. Small boulders containing kernels of opal are known as '*Yowah nuts*' (Holmes et al. 1982). This type of opal is most commonly found in Queensland and South Australia, though a small occurrence of boulder opal has also been found at Lila Springs in New South Wales.

Matrix opal —

is precious opal saturating and cementing a sandstone or ironstone.

Fire opal —

is a transparent to translucent stone with an orange–red to red body colour which may or may not show a play of colour. This type of opal has been mined at several localities in Mexico.

Water opal —

shows brilliant flashes of colour in a clear, colourless (water-white) stone.

Hyalite (or Mullers Glass) —

is a perfectly clear, colourless opal.

Gilson opal is synthetic opal produced by precipitation of silica spheres. It has not been as popular as natural opal. Recently, synthetic opal has been produced in Russia using polymers.

Opal occurs in Slovakia, where it was mined from about 400 BC up until 1932 (Darragh et al. 1976). Hungary has also produced opal (Aracic 1999). Opal is also found in North and South America, sporadically along a belt extending from western Canada, Washington, Oregon, Idaho and Nevada through to Central America and Brazil (Darragh et al. 1976; Aracic 1999).

Deposit Types

The most significant opal deposits are in deeply weathered sedimentary rocks. All the significant Australian precious opal deposits occur in such a setting. Opal also occurs associated with volcanic rocks and it is within this latter environment that opal deposits are found in other parts of the world.

In the sedimentary-hosted deposits, opal occurs as nodules and seams in claystone and sandstone. It is also commonly found filling casts after fossils and as replacements of fossils as well as forming coatings on pebbles or within concretions. It may also fill casts after other minerals, such as the opal pineapples of White Cliffs (see later discussion). Nodular-type opal, or 'nobbies', are common in the Lightning Ridge area and its origin is still the subject of debate. It is speculated that they may be opal replacements after ball and pillow structures (Hiern 1964). Opal is also found filling ironstone concretions (boulder opal).

The most likely cause of opal formation in the major Australian opal fields is the weathering process. Surface kaolinisation of Cretaceous feldspathic sandstone and claystone of the Great Australian Basin led to the release of silica. The silica-enriched groundwaters percolated downward to be trapped at permeability boundaries, such as the base of sandstone units in contact with less-permeable claystone, as well as within various types of void. The silica-rich fluids then dried out forming a silica gel which precipitated silica spheres.

In the Lightning Ridge and White Cliffs areas, opal is considered to have formed during a Late Cretaceous–Early Tertiary weathering event (Watkins 1985; Burton & Mason 1996, 1998). However, Senior et al. (1977) inferred that boulder opal in southwestern Queensland formed between 15 Ma and 32 Ma ago in the Cannaway weathering event and MacNevin and Holmes (1980) noted 'a rare occurrence of common opal veins within Tertiary silcrete' north of White Cliffs. Hence, it is likely that opal has formed during more than one weathering event.

In the volcanic environment, opal has been formed through weathering and siliceous fluid deposition, much like the chalcedony and agate fillings. Such occurrences are found in such volcanic rocks in the northern New South Wales coast area.

Main Australian Deposits

Other than New South Wales, significant opal deposits also occur within South Australia and Queensland. The main South Australian fields are at Coober Pedy, Andamooka, Mintabie and Lambina.

In Queensland the main opal fields are Kynuna, Opalton, Kyabra, Yowah, Koroit, Toompine, Quilpie, Bulgroo, Yaraka and Jundah.

Minor opal occurrences have also been found in Western Australia (Aracic 1999).

New South Wales Occurrences

Opal mining in the Lightning Ridge area currently takes place in three opal–prospecting areas within the Narran–Warrambool Reserve, which covers an area of 5000 km² and incorporates Lightning Ridge township. In the Lightning Ridge area there are over 6000 registered claims. In the White Cliffs area there are about 450 mineral claims and about a dozen at Purnanga (about 60 km north of White Cliffs).

Most prospecting is carried out by the miners within designated Opal Prospecting Blocks and commonly consists of testing ground using nine-inch (23 cm) diameter auger drilling. Exploration for opal has also been carried out under Exploration Licences.

Lightning Ridge area

This area makes up the main Lightning Ridge mining centre, which consists of numerous individual fields, plus the outlying areas at Grawin, Glengarry, Sheepyard, Coocoran, Carters Rush and Mehi.

Opal was discovered at Lightning Ridge in the late 1880s, with significant mining starting in the early nineteen hundreds. The Grawin field was discovered in 1908. Opal mining took place in the Coocoran area during the depression years (MacNevin & Holmes 1980). In 1988 Molyneux's Rush was discovered and, subsequently, other extensive deposits of opal were worked in the southern part of the Coocoran area. The most active fields in the Lightning Ridge area are in the Grawin–Glengarry–Sheepyard–Carters Rush area, with lesser production from the Coocoran and Lightning Ridge fields.

Within the Lightning Ridge area, opal occurs mainly within Cretaceous claystone lenses (Finch clay facies) within sandstone (Wallungulla Sandstone Member) of the Griman Creek Formation, Rolling Downs Group. The claystone is referred to by miners as 'opal dirt' and occurs at various stratigraphic positions or 'levels'. Opal mines range in depth from several metres to a maximum of about 30 m. Most mining is done via shafts, though some opal has been won through open cut methods. Extraction techniques vary in technological sophistication — from pick and shovel to mechanised shaft sinking (usually Calweld auger holes) and extraction of material via tippers and blowers.

Opal occurs as both 'nobbies' and in seams. Nobby opal occurs in the Lightning Ridge and Coocoran fields whereas at Grawin and the other southern fields the opal mainly occurs in seams. Opal has also been found replacing various types of fossils, which have significant value both for their gem potential and also for their scientific value. Opalised fossils include the disarticulated remains of crinoids, molluscs, crustaceans, fish, reptiles, plesiosaurs, dinosaurs, mammals and birds (Smith & Smith 1999). The different fossil types substantiate the inter-pretation that the Cretaceous rocks were deposited within a transitional shallow marine to freshwater, estuarine environment.

At Lightning Ridge, opal occurs in the near-surface environment within and at the top of a claystone or 'opal dirt' unit below a 5 m to 10 m thick porous sandstone unit. Many miners look for the presence of faults or breccia pipes, as these are considered to have controlled the movement of silica-rich groundwater during opal formation. Cretaceous-age palaeochannels also seem to have played an important role in localising opal deposits, particularly in the Coocoran Opal Field.

A silicified sandstone unit or 'steel-band' is often found at the base of the sandstone unit overlying deposits of opal in the claystone unit. The 'steel-band' ranges in thickness from several millimetres to about one metre and is considered by some to be a useful indicator for opal.

Recent studies on the origin of opal at Lightning Ridge have discovered large fossil bacteria and fungi communities in potch opal (Behr et al. 2000). Interpretation of the new data suggests that microbes may have played a role in the bioweathering of the host rocks (sandstone, claystone) to produce the silica to form the opal.

White Cliffs area

The White Cliffs area includes the fields around the town of White Cliffs plus workings at Gemville, Welshes Knob, Barclays Bunker, Pinnacles, Polpah, Morambie and Purnanga.

In the White Cliffs area, opal occurs within the deeply weathered Doncaster Member of the Wallumbilla Formation, Rolling Downs Group (stratigraphically below the rocks in the Lightning Ridge area). The sedimentary sequence was deposited within a shallow marine environment. Fossil remains, commonly opalised, within the sequence include pelecypods, ammonites, belemnites, gastropods and crinoids. Also found have been the well-preserved remains of a plesiosaur and an ichthyosaur.

Opal at White Cliffs generally occurs as seams and as fossil replacements and filling voids after fossils. Opal also occurs as coatings on glacially derived Devonian quartzite boulders (dropstones) in the Cretaceous sequence — a feature referred to as a 'painted lady'. A form of opal unique to White Cliffs is the 'opal pineapple'. These are opal fillings of a cavity formed after the dissolution of possibly either ikaite or glauberite (R. Pogson pers. comm. 2003).

At White Cliffs, the controls on opal localisation are subtle and not well understood. The rocks at White Cliffs are generally finer grained than those at Lightning Ridge and there is not a well-developed geometry of claystone lenses in sandstone as at Lightning Ridge. Opal occurrence may be controlled by local fracturing, which formed through tectonism and/or the weathering process.

Many miners look for faults, though, as is the case with Lightning Ridge, the importance of these structures in localising opal is yet to be demonstrated convincingly (Burton & Mason 1998).

Other areas of sedimentary-hosted opal

Seam and boulder opal occurs at Lila Springs, about 20 km southeast of Enngonia (about 100 km north of Bourke). This area has recently been investigated by CIM Resources Ltd and Desertstone NL (Coenraads 1997). Previous exploration by Redfire Resources NL identified micro opal in drilling at two areas — one (the Lila Springs Prospect) about 10 km southwest of the Lila Springs workings and another (the Tuncoona Central Prospect) about 30 km southwest of the workings (Martin & Besley 1994).

Old shafts and open pits occur near Clarke's Bore on Nahweenah Station, approximately 55 km east-southeast of Hungerford (about 80 km north of Wanaaring). Samples of opal from those workings are kept in the Australian Museum (Jeffery 1998a, b). Drilling by Desertstone NL in that area encountered rare local developments of potch (Jeffery 1998a).

Near Youngarina Homestead, about 90 km southeast of Hungerford, there are old prospecting shafts. Drilling in that area found some potch (Cooper 1999). Drilling by Desertstone NL near Lismore Tank, about 20 km southwest of Youngarina homestead, also intersected potch (Jeffery 1997).

Redfire Resources NL identified opaline mineralisation, including potch and iridescent opal, in drilling at three areas north of Collarenebri — the Araluen prospect, about 50 km north of Collarenebri; the Weeona prospect, about 40 km north of Collarenebri; and the Coolabah prospect, about 10 km north of Collarenebri (Besley & Martin 1993).

MacNevin and Holmes (1980) noted that occurrences of opal in weathered Cretaceous rocks of the Great Australian Basin have been reported from near Milparinka and 56 km from Nyngan (between Mudall and Nymagee).

Volcanic-hosted opal occurrences

The following account of volcanic-hosted opal in New South Wales is based on that given by MacNevin and Holmes (1980).

Volcanic-hosted opal is found in the Tintenbar area, near Ballina, where it is found filling vesicles in basalt. It was discovered in 1901 but most of the production was between 1919 and 1922. It is mostly transparent, with some blue, green and yellow colours with occasional flashes of red, commonly in a harlequin pattern. Much of the material tended to craze either on exposure to the atmosphere or later, during the cutting process.

Volcanic opal is also found at Point Danger in a similar setting to that at Tintenbar. It is also found about 16 km south of Neville at Rocky Bridge Creek (southwest of Bathurst) within vesicular basalt of Tertiary age. The stones are small, being up to 15 mm across. Working of the deposit occurred between 1920 and 1926. Volcanic opal has also been found at Tooraweenah in the Warrumbungle Ranges; Nandewar Mountains; Hyandra Creek, about 21 km south of Dubbo; the Nightcap Range, near Nimbin; and near Comboyne.

Although some volcanic opal exhibits good colour properties, the stones are usually small and the deposits are not as extensive as the sedimentary deposits. Being hosted by volcanic material also means that the opals are more difficult to extract.

Applications

Opal is used solely as a gemstone in jewellery. It is exported either as unworked stones, worked unset stones, and stones set in precious metal. More recently, freeform, or uncut, opals have been popular. The following account on stone setting is after Holmes et al. (1982).

'Solids' (whole stones) are the most valuable. 'Doublets' are made by joining films or pieces of precious opal to a backing of dark common opal, black onyx, or black glass called *opalite*. This dark backing enhances the apparent colours of the opal film. 'Triplets' are made by adding a capping of rock crystal, perspex, or glass to a doublet. This capping also enhances the apparent colours and provides a protective cover. The slices of opal used for triplets are thinner than for doublets and thus triplets are generally less valuable.

The value of opal is determined by many factors: the range of colours in the colour play; the pattern of colours; and the fire of the colours are particularly important. In addition, it is essential that the stones are free from cracks (crazing) or flaws. The weight of opal is not as important as with other gems.

Economic Factors

The opal market and the value of the stones is dependent upon individual tastes and fashions in jewellery.

References

Aracic S. 1999. *Rediscover opals in Australia*. Stephen & Mary Aracic, Landmark Press, Drouin, Victoria, Australia.

Behr, H.J., Behr, K. & Watkins, J.J. 2000. Cretaceous microbes — producer of black opal at Lightning Ridge, NSW, Australia. *In:* Abstracts of the 15th Australian Geological Convention. Understanding Planet Earth: searching for a sustainable future, Sydney 2000, p. 28 *Geological Society of Australia, Abstracts* **59**.

Besley R.E. & Martin N.H. 1993. Redfire Resources NL, Australian Opal Joint Venture, Exploration Licences 3573 and 3574, Collarenebri, New South Wales, Third Annual Report to July 1993. Geological Survey of New South Wales, File GS**1993/228** (unpubl.).

Burton G.R. 2002. A geological investigation of the Coocoran South area, Lightning Ridge. Geological Survey of New South Wales, Report GS**2002/753** (unpubl.).

Burton G.R. & Mason A.J. 1996. A preliminary geological investigation of the opal deposits in the White Cliffs area. Geological Survey of New South Wales, Report GS**1996/127** (unpubl.).

Burton G.R. & Mason A.J. 1998. Controls on opal localisation in the White Cliffs area. *Geological Survey of New South Wales, Quarterly Notes* **107**, 1–11.

Coenraads R.R. 1997. The Bourke Opal Project at Lila Springs, EL 4562, Annual Report to the New South Wales Department of Mineral Resources for the period 27 July 1996 to 26 July 1997, Opal Mining and Exploration NL. Geological Survey of New South Wales, File GS**1997/324** (unpubl.).

Cooper M. 1999. Final Report Exploration Licence 5324. Geological Survey of New South Wales, File GS**2000/028** (unpubl.).

Darragh P.J., Gaskin A.J. & Sanders J.V. 1966. The nature and origin of opal. *The Australian Gemmologist* **66**, 5–9.

Darragh P.J., Gaskin A.J. & Sanders J.V. 1976. Opals. *Scientific American* **234**(4), 84–95.

Darragh P.J, Gaskin A.J., Terrell B.C. & Sanders J.V. 1965. Origin of precious opal. *Nature* **209** (5018), 13–16.

Hiern M.N. 1964. Report on Lightning Ridge Opal Field, New South Wales and the occurrence of precious opal. South Australian Geological Survey, Report Bk No. 58/29 (unpublished). *also* New South Wales Geological Survey, File GS**1964/008** (unpubl.).

Holmes G.G., Lishmund S.R. & Oakes G.M. 1982. A review of industrial minerals and rocks in New South Wales. *Geological Survey of New South Wales, Bulletin* **30**.

Jeffery R. 1997. Desertstone NL, Sixth Annual and Final Report on Exploration Licence 3818 Cobar, Wampra Project, New South Wales, for the period 17th April 1991 to 16th April 1997. Geological Survey of New South Wales, File GS**1998/167** (unpubl.).

Jeffery R. 1998a. Desertstone NL, Nahweenah Opal Project, New South Wales, Sixth Annual Report on Exploration Licence 4159, Cobar, for the period 18th December 1996 to 17th December 1997 and Final Report for the period 18th December 1991 to 17th December 1997. Geological Survey of New South Wales, File GS**1998/147** (unpubl.).

Jeffery R. 1998b. Desertstone NL, Brindingabba Opal Project, New South Wales, Annual Report and Final Report on Exploration Licence 4722, Cobar, for the period 22nd November 1994 to 21st November 1997. Geological Survey of New South Wales, File GS**1998/178** (unpubl.).

MacNevin A.A. & Holmes G.G. 1980. Gemstones. *Geological Survey of New South Wales, Mineral Industry* **18**, 2nd edition.

Martin N.H. & Besley R.E. 1994. Redfire Resources NL, Australian Opal Joint Venture, Exploration Licences 3575 and 3576, Bourke, New South Wales, Fourth Annual Report to July 1994. Geological Survey of New South Wales, File GS**1994/171** (unpubl.).

Moore M., Macnae J. & Burton G. 2003. Evaluation of multifrequency airborne EM for opal prospect definition at Lightning Ridge, NSW. Australian Society of Exploration Geophysicists 16th Geophysical Conference and Exhibition, February 2003, Adelaide.

Senior B.R., McColl D.H., Long B.E. & Whitely R.J. 1977. The geology and magnetic characteristics of precious opal deposits, southwest Queensland. *BMR Journal of Australian Geology & Geophysics* **2**, 241–251.

Smith E. & Smith R. 1999. *Black opal fossils of Lightning Ridge*. Kangaroo Press, East Roseville, New South Wales.

Watkins J.J. 1985. Future prospects for opal mining in the Lightning Ridge region. Geological Survey of New South Wales, Report GS**1985/119** (unpubl.).