The geology and magnetic characteristics of precious opal deposits, southwest Queensland


Precious opal in southwest Queensland is found within a weathered profile developed in sedimentary rocks of the Cretaceous Winton Formation. This kaolinitic profile is the product of two periods of deep chemical weathering. The first weathering event is Maastrichtian to Early Eocene, and formed a tri-layered profile (Morney profile) in excess of 90 m in thickness. At this time ironstone was chemically precipitated within the basal layer. A period of sedimentation along river systems, with fragmentation and minor erosion of this profile along interfluves, was followed by a second weathering event about the Late Oligocene. A morphologically distinct profile formed (Canaway profile), consisting of an indurated crust and mottled zone, which grades down into a varying thickness of the residual older profile. During the second weathering event silica migrated as an aqueous sol, and was precipitated within voids in ironstone host rocks. The geomorphological properties of Queensland boulder opal are described in relation to the weathering history and bedding characteristics of the opal deposits.

Rocks which contain scattered opal deposits are poorly exposed in scarp-bounded mesas and flat-topped landforms, or are concealed below a pedimented land surface. Ironstone host rocks are remanently magnetised, and an exploration method based on ground magnetic surveying, using portable and vehicle-borne magnetometers, is discussed.

Introduction

Precious opal deposits in Queensland are scattered throughout a 300 km-wide belt, which extends northwest from the Queensland/New South Wales State border for about 900 km to the vicinity of Winton township (Fig. 1). Approximately sixty opal fields, mines and prospects have been worked, and some production is currently in progress, particularly in the Eromanga and Quilpie districts. Not all of the mines and prospects are named in Figure 1 owing to the scale used, and also because the locations of many open-cut workings post-date the most recent geological maps of the region.

All opal deposits in western Queensland lie within the central part of the Eromanga Basin. The deposits are in chemically weathered sedimentary rocks of the Late Cretaceous Winton Formation, which is the youngest unit of the Eromanga Basin sequence. The distribution of the Winton Formation, and opal-bearing weathered rocks, is given in Figure 1.

Previous geological mapping in this part of the Eromanga Basin established that opal was a product of deep chemical weathering of the Winton Formation, and its occurrence was related by Ingram (1969) to the distribution of kaolinitic weathered profiles. However, subsequent geological and geomorphological investigations, which involved detailed mapping, geochemistry and clay mineralogy of the Winton Formation, have shown that the Cainozoic weathering history of the region is more complicated than was previously thought. Three weathered profiles are recognised, and the one which contains sporadic occurrences of precious opal is believed to be the product of more than one weathering event.

The objectives of this paper are to elucidate the weathering history and geological occurrence of the southwest Queensland opal deposits. In addition the distinctive gemmological properties of opal from this region is discussed in relation to sedimentary structures in which opal deposits are found. Finally, a review is made of potential exploration techniques, particularly ground magnetic surveying, which could be of assistance in the search for new opal deposits.

Mining activity

The history of the opal mining activity in western Queensland was reviewed by Connah (1966). Early activity commenced about 1880 and virtually ceased by 1900, when a severe drought and shortage of food for horses resulted in the abandoning of the workings. Jackson (1902) visited numerous workings in the Eromanga Mineral Field in 1901 and found them almost deserted. Mining activity almost ceased in the region—except for the Hayricks mine and nearby localities, where production continued until about 1963. Elsewhere, production was a result of the activities of fossickers who worked known deposits only during favourable seasons (Connah, 1966).

Open-cast mining commenced in the mid 1960's. Success with this method led to the mining of many formerly abandoned workings using bulldozers, and activity reached a peak in about 1973, when about 20 bulldozers were working in the northwest part of the Eromanga Mineral Field. Most of the operations were engaged in extending the deposits discovered in the last century.

Jackson (1902) estimated that the total value of production from 1891 to 1901 was approximately $130 000 ($260 000). At that time Queensland opal was regarded as inferior gemstone to the opal produced in the Lightning Ridge and White Cliffs opal fields of New South Wales. However, the distinctive bright green, blue and red colours set in the dark background of Queensland 'boulder' opal have in recent years become greatly prized and values have increased dramatically. Total recorded value of opal produced in Queensland between 1966 and 1974 is estimated at 1.3 million dollars (Gourlay and others, 1976). This figure is a conservative estimate as there has been an increasing trend of direct sales to overseas buyers, on which statistical information is incomplete or non-existent. Production in Queensland probably peaked in 1974 and the industry is now declining, owing to the depletion of opal from old workings which were re-opened by earthmoving machinery. Very few, if any, new deposits have been discovered despite the apparent geological potential of the region. Possibly this is because of the conservative attitudes of the miners who hesitate to explore unknown areas, and the miners' limited financial resources—which usually do not permit more than

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The geological occurrence of opal in southwest Queensland

Weathered rocks of the Winton Formation constitute two weathered profiles. Measured reference sections are established (Fig. 2), and are here informally named the Morney and Canaway profiles. Both profiles are composed of kaolinised sedimentary rocks, and consist of a sequence of weathered layers which grade from the land surface down to unweathered parent rock. The arrangement of the component layers serves to distinguish each profile. For example, the older Morney profile (Fig. 2) consists of three layers of roughly equal thickness forming a profile up to 90 m thick. The younger Canaway profile is somewhat thinner, and consists of four layers of unequal thickness in a profile up to 40 m thick.

In many areas the weathered profiles are concealed below younger quartzose sedimentary rocks (Cainozoic Eyre Formation and unnamed equivalents), and these in turn have been strongly silicified to form silcrete. The
distribution of the kaolinitic Morney and Canaway profiles and the silcrete profile is shown in Figure 1. Deposits of precious opal relate to the distribution of the Canaway profile.

Later Cainozoic erosion has truncated or completely destroyed these profiles in places, particularly along the axial zones of folds and in the vicinity of faults. Elsewhere the profiles form flat-topped landforms which are in part scarp-bounded, or crop out as low rubble-covered rises on an extensively pedimented surface.

Geological investigations have provided a maximum and minimum age for weathering in this region. The Winton Formation, the youngest formation in the Eromanga Basin, is Cenomanian based on palynology (Burger in Senior, 1977). The Morney and Canaway profiles extend as an unbroken mantle from the opal-bearing region eastwards into the Surat Basin. In the Roma-Amby area of this basin there are a number of small basalt flows which overlie these weathered rocks (the identity of the particular profile is unknown). Exon and others (1970) dated these basalts radiometrically, using the K/Ar method, at 23 m.y., and equated the underlying weathered rocks with those of the Winton Formation of the Eromanga Basin. Consequently the maximum and minimum constraints for weathering fall approximately within 75 m.y. (Cenomanian to Early Miocene).

The recognition of two kaolinitic profiles in the Eromanga Basin (Fig. 1) indicates that more than one weathering event may have occurred. It can be demonstrated that the simple trizonal form of the Morney profile...
merges laterally into the somewhat thinner four-layer Canaway profile. The crust and mottled zones of the Canaway profile may grade directly into unweathered rock, or more usually as illustrated in Figure 1 a variable thickness of kaolinitic weathered rock underlies and is a relict of the former Morney profile. Thus the crust and mottled zones have formed from and cut across the former tri-layered arrangement of the parent profile. This relationship was produced by variable erosion and fragmentation of the Morney profile, followed by cementation of the surficial fragmented layers. The convergence of the basal ferruginous zone with the indurated crust appears to be an important factor in opal formation. In places where the crust and basal ferruginous zones are in close proximity, the host ironstone bodies were favourably located within a fluctuating groundwater table which permitted the deposition and dehydration of siliceous material. Other factors are also important, however, and will be discussed later.

Idnurk & Senior (in press) studied the palaeomagnetic directions of the ferruginous components of these profiles and compared their results with the Late Cretaceous and Cainozoic apparent polar-wander curve for Australia (McElhinny and others, 1974). This investigation demonstrated conclusively that an age difference exists for the two profiles. The Morney profile was found to be Maastrichtian to Early Eocene, and the Canaway profile to be approximately Late Oligocene. The Canaway profile apparently formed along interfluves, and may have developed simultaneously with the surface silcrete across adjacent plains mantled with quartzose clastics. Silification was widespread, and was probably contemporaneous with the precipitation of silica within voids present in ironstone rocks in the Canaway profile. The concentration of precious opal in silicified quartzose rocks is a matter for conjecture, but may be related to the lack of suitable bedding structures, coupled with the high porosity and permeability of the sandstones. However, if the association between opal and silcrete development is correct, and if the opal is a product of rock weathering which formed the Canaway profile, it is likely that the opal is 15 to 32 m.y. old.

During earlier geologic investigations (Ingram, 1969, 1971a & b; Senior, 1971) it was thought that all kaolinitic weathered rocks of the Winton Formation were potentially opal-bearing. The Morney profile (Fig. 2) with its three layers, contains suitable bedding structures, and in the basal zone the essential ironstone host rocks. The ironstone bodies, however, are non-opaline although they contain voids with characteristic concentric, radial or septarian patterns. Emplacement of opal within these voids was the result of partial erosion of the Morney profile and development of a silica and iron oxide-rich crust. The resultant Canaway profile has four zones. Truncation of the older profile brought potential ironstone host rocks closer to the weathering landsurface, and hence into a geochemical environment where silica was mobilised and precipitated.

The size and geometric arrangement of the voids within the ironstone appear to have affected the microstructure, and hence the intensity of the colour, of the opal. Within individual ironstone concretions, fissures tend to vertical rather than horizontal orientation, with some concentric and subradial arrangements. Large voids and fissures (> 1 cm wide) tend to contain non-precious varieties of white, grey, or blue opal. Most of the precious opal is within narrow, or attenuated, voids. Very fine hair-like cracks frequently contain high quality, though unusable, varieties of precious opal.

Commonly the opal displays rhythmic or cyclic layering, which appears to have formed where successive increments of opaline silica have settled under essentially hydrostatic conditions to produce a pronounced horizontal layering and colour banding. Commonly the void is incompletely filled and a free, level, opaline surface with a meniscus-like curve is present; as in Figure 3.

Accumulation of precious opal was a slow process in which successive cycles of saturation and dehydration are recorded by the varied colour laminations indicating sharp changes of particle sizes. This cyclic layering might be the product of seasonal or annual effects. Less commonly voids may receive a massive increment of uniformly sized silica at a particular stage and develop a thick layer of constant colour and pattern with an enhanced gemmological value.

Hardening of the opaline silica within a void was at times incomplete before a successive increment of opaline silica was introduced. Groundwater movements of this type distort the partially hardened gel and produced textures analogous to those seen in sediments. These structures include fold, fault and flow contortions on a micro-scale, and are usually discernible in parts of almost every specimen (Fig. 4). Breccia textures are less common, and consist of a suspension of contrasting coloured fragments of opal within later deposited material. These structures indicate that the precipitation of opaline silica was cyclic, and may have occurred over a longer period of time than the non-banded opal typical of the New South Wales and South Australian opal fields. Opal from southwest Queensland is thought to have a lower water content, because it is very stable after removal from the ground and is virtually free from shrinking and cracking caused by dehydration. This process is known as 'crazing'; it affects a proportion of the opal from all the fields in South Australia and New South Wales. Queensland opal has the disadvantage that it is
difficult to separate from the ironstone host, and its commercial value depends upon acceptability of ironstone inclusions or backings in the finished gems.

Sedimentary structure as a primary control in the deposition of precious opal has long been known. Jackson (1902) for example described 'sandstone opal' at the interface...
concretions. The miners distinguish four forms:
of it is found within ironstone-enriched layers, lenses and
linitic weathered rocks of the Winton Formation. Almost all
view of the surrounding geology in small drives and shafts,
stone or claystone. (1966) illustrates examples of this control in occurrences at
opal deposits within the Canaway profile are illustrated in
the advent of larger scale
mentary structures which control the location of precious
the term
relate to bedding irregularities which are floored by a
relatively impermeable layer of kaolinitic siltstone. mud•
between an upper sandstone and lower lutite bed. Connah
(1966) illustrates examples of this control in occurrences at
the Yowah Opal Field. However, owing to the restrictive
view of the surrounding geology in small drives and shafts,
the full spectrum of sedimentary traps was unknown until
the Yowah opal field (Fig. 7).
The host ironstone is dominantly of goethite limonite
and hematite which, either by itself or as a cement, ap-
parently imparts the degree of strength essential to sup-
port the voids during the fairly lengthy period in which
the opal is formed. Most other cavities produced by
weathering or tectonism in the Canaway profile
were apparently lost by compaction and settling of its relatively
poorly indurated components. Some opal may occur
independently of the ironstone host; examples include
infillings of voids, produced by leaching of organic material
such as fossil wood. There are rarer examples, of opal
veinlets within secondary minerals such as gypsum and
alunite. These occurrences are found infrequently at almost
every location examined. However, the bulk of commercial
opal in southwest Queensland is associated with various
forms of ironstone, which in itself is a unique and
distinguishing feature.

Geological controls of opalisation

Geological factors believed to have influenced opal
formation may be summarised as follows:
(a) A prolonged period of deep chemical weathering is
required to degrade the host rock mass, and initiate
hydrolysis of the silicate components. Amorphous silica is a
resulting product, and occurs either as a solution or a
colloidal suspension in groundwater.
(b) Appropriate sedimentary structures are needed to
provide partial lateral closures into which silica-laden water
will be directed and trapped by porosity and permeability
barriers.
(c) Within the sedimentary structures suitable voids are
necessary to serve as reservoirs in which the silica can precipitate and/or flocculate from virtually static siliceous
groundwater.
(d) Climatic conditions must provide periods of satura-
and dehydration of the rock, with considerable fluctua-
tions in groundwater levels. Within the sedimentary traps
dehydration would be brought about by a slow combination
of downward filtration and upward evaporation. Colloidal
spherical silica particles would be enlarged by both
aggregation and further deposition from solution. Gelat-
inisation and final hardening of the opaline silica take place
over a fairly lengthy period, working upwards from the base
of the voids.
(e) Precious opal, as distinct from the non-precious
varieties without a play of colours ('potch'), formed within
cavities where uniformly sized silica spheres were pre-
ceptititated and accumulated in a regularly close-packed,
three-dimensional symmetrical array, which resembles an
ultra coarse-crystal lattice. The mechanism controlling the
size of the silica spheres is almost certainly the intensity and
duration of the saturation and dehydration periods.
Uniformity of size could be a function of settling rates; the
means by which the close-packed structure is imposed is
still conjectural, although it has been accomplished by
various synthetic means in laboratory experiments
(Darragh & Perdrix, 1973).
The three-dimensional structure of precious opal was dis-
cussed by Jones and others (1964), and Sanders (1964),
using electron microscopy. Their work quickly led to the
identification of diffraction from the regular silica layers as
the cause of the play of spectrum colours seen in precious
opal (Darragh and others, 1966; Darragh & Gaskin, 1966).
Geological prospecting

At present all prospecting for opal is based either on intuition, or careful search for traces of opal in patches of ironstone lag gravel. Earthmoving machinery is then employed to expose any ironstone host rocks present. Frequently these methods are unsuccessful, and the large number of barren open cuts detracts from the profitability of the operation.

It may be possible to improve this situation. The gross distribution of the opal-bearing Canaway profile can be determined by aerial photograph interpretation; it is distinguished by flat-topped landforms which have distinct banding of vegetation across the crust-forming layer. Unfortunately the existing RC9 aerial photographs at approximately 1:80 000 scale have insufficient resolution to permit the geological mapping of the component layers of the profiles. Colour aerial photography, if available, would be of immense assistance—potential localities where the crust and ferruginous layers are in close vertical proximity could be identified for field examination.

As noted previously, most opal deposits lie in favourable sedimentary structures in the ferruginous layer. It is probable that palaeochannels and fault-bounded traps (Fig. 5) could be identified on large-scale colour aerial photographs, and might take the form of linear or curvilinear features, or sinous lines of dark-toned ferruginous gravel. Photographs at 1:25 000 scale would be required to identify linear features, which in all probability are less than 0.3 km long and 10 m wide. Intersecting linear features might prove to be potential sites worthy of field investigation because of the possibility of enhanced vertical permeability which could facilitate the ingress of siliceous groundwater. Shallow core-hole drilling, using the method described by Ingram (1969), might be employed to establish the presence of subsurface ferruginised layers, and to calculate the depth of any proposed open cut.

Ground magnetic surveying

The association of opal with distinct ironstone segregations, which for the most part conform to the bedding geometry of the parent profile, offers a means of prospecting for opal deposits. In general the limitations imposed by very flat terrain and poor outcrops severely restrict the direct geological appraisal of sedimentary structure. However, the relatively high remanent magnetisation of the ironstone (Idnurm & Senior, in press) indicated that field trials with equipment that measures local changes in the magnetic field might be useful in locating boulder opal.

Horsfall & Senior (1976) carried out ground magnetic surveys at a number of opal prospects and mines in the Eromanga and Quilpie districts, including the Mayneside leases at Yeppara (Fig. 8), the Bull Creek Mine, and Bulgroo and Nickavilla prospects near Quilpie. Magnetic susceptibility and remanence measurements were also made on ironstone and country rock samples from these and other areas.

A Geometric G816 total-field magnetometer, with the sensor mounted on a 2.5 m long pole, was used to evaluate the sites. Readings were generally taken on square grids of 6.1m spacing, with follow-up traverses across anomalies of interest at 1 m to 1.5 m spacings. Corrections for diurnal variations were made at 15 minute intervals. These were generally small, and seldom exceeded 2nT.

Significant magnetic anomalies were detected at all the sites surveyed. At Mayneside anomaly amplitudes ranged up to 60nT, with most anomalies of the order of 35nT. Anomalies were generally larger at the Bull Creek.

Figure 8. Total magnetic intensity contours of an area at Mayneside’s leases, Yeppara district.
Minerals, where amplitudes sometimes exceeded 100nT. At most of the sites anomaly widths ranged between 5 and 20 m. Some anomalies have linear or ovate shapes which were interpreted as resulting from variations in concentrations of iron oxide within the weathered rocks. A trial excavation was sited at Mayneside (fig. 8), between a 450nT magnetic high and a 435nT low on the easternmost portion of the grid. An existing excavation to the east of this was barren of limestone, and coincides with an area of low magnetic intensity.

Ironstone concretions were first encountered in the trial excavation at a depth about 1 m below the surface. At the maximum depth of 3 m about one hundred ironstone concretions had been unearthed. Most of the ironstone boulders contained empty voids, although some had veins of non-precious opal.

Magnetic susceptibility and remanence measurements were made on oriented samples from the weathering profile at a number of areas. These showed that many of the ironstones had substantial remanent magnetisation in both normal and reversed directions, as well as a low magnetic susceptibility. The measurements further revealed a variable magnetic contrast between the ironstone and country rocks, which in some areas would be expected to be sufficiently marked for ironstone bodies to be detected.

Horsfall & Senior (1976) concluded that in some instances magnetic anomalies relate to subsurface ironstone occurrences, in others merely reflect zones of diffuse iron-oxide enrichment. Interpretation of anomalies was confused in places by (1) magnetic inhomogeneities within alluvium deposited after formation of the Canaway profile, (2) variations in the magnetic properties of the country rock, (3) variations in the depth of the ferruginous portion within the weathered profile, and (4) the effects of lightning strikes on the remanence of the country rock. They also concluded that some form of continuous magnetic recording was desirable for exploration of large, potentially opal-bearing regions.

Figure 9. Plane-borne magnetometer system.

As a result of these conclusions a further ground survey was carried out in the vicinity of the Bull Creek Mine, using a continuously recording vehicle-borne magnetometer system for reconnaissance, and a Geometrics G816 magnetometer for detailed follow-up surveys.

The vehicle-borne system was constructed at the University of NSW by installing a Varian 4937A total-field magnetometer with a sample time of 1 sec and a chart recorder, within a short-wheel base Landrover. The magnetometer sensor-head was mounted at the rear of the vehicle on an aluminium alloy boom to minimise the magnetic influences of the Landrover (Fig. 9). The boom arrangement was stabilised with guy ropes, and could be raised for rough traversing. The sensor was thermally insulated, and placed about 6 m behind the vehicle at a height of approximately 1.5 m. In this position a maximum heading error of about 25nT was recorded. This was considered sufficiently small for reconnaissance magnetic surveying.

Traversing with this system was accomplished at speeds of about 5 km/hour. Significant magnetic anomalies were flagged, coded, and positioned approximately on aerial photographs for later detailed follow-up magnetic surveys.

A total of about 200 line-kilometres of reconnaissance magnetic traversing was completed in this manner around the Bull Creek Mine. Some fifty significant magnetic anomalies, with amplitudes generally in excess of 50nT, were delineated and flagged. About 10 of these anomalies were investigated by detailed ground traversing and excavations were carried out at the sites of two of the anomalies. These follow-up surveys were done on rectangular grids, using a station spacing of 2.5 m, and a line separation of 5 m. Additional readings were taken at intermediate stations where necessary. Spot readings were also taken around the edges of grids, and if additional anomalies were found the grids were usually extended.

Using this method, because of the closeness of the sensor to the magnetic sources, magnetic anomalies were about 20 percent greater than ordinary anomalies. Features of the significant magnetic anomalies in the Bull Creek area are:

(a) Anomaly amplitudes are generally in the region of 30nT to 100nT although some can attain amplitudes in excess of 150nT.

(b) Both normal and reversed anomalies occur, often in close proximity. The direction of the remanent component of the anomaly is significantly different from the direction of the induced anomaly, and much greater in intensity.

(c) Anomalies are mostly less than 30 m in width (some are less than 5 m in width), and have shapes consistent with anomalies produced by shallow tabular, ovate or dipolar magnetic sources.

(d) Anomalies tend to occur in clusters or in linear belts adjacent to existing workings, or around the edge of mesas which have little if any magnetic character.

(e) Precious opal traces were found in the vicinity of the magnetic anomalies.

Figure 10 shows a complex linear belt of magnetic anomalies which were discovered just to the west of the Bull Creek Mine. The four prominent anomalies (A31, A32, A33 and A34) are caused by magnetic sources with a strong remanent magnetisation. The largest anomalies (A31 and A32) have nearly identical amplitude, but are reversed in direction with respect to each other. Anomaly A34 has not been fully defined. Anomaly A33 to the north is similar in direction to anomaly A32, but smaller in size and about one-third the amplitude of the latter anomaly.

All of these anomalies are approximately in line with a series of very old pits and shafts some 30 m to the south of A31. Hard ground consisting of silicified kaolinitic rocks precluded testing of these anomalies by excavation.

Figure 11 shows a detailed survey on the eastern side of a mesa about 5 km east of the Bull Creek Mine. A number of intense anomalies were delineated at this site, some of which were tested by excavation. Several traces of precious opal were also discovered in this area. They are present in one of the few areas in which such indications have been found away from the Bull Creek Mine site area itself.

Magnetic anomaly A17 in the south of this area is a broad feature with an amplitude of about 30nT (Fig. 11). The source of this anomaly is essentially normally magnetised, and the anomaly was tested with a wide coestane (coestane 1). The excavation extended to a depth of about 1 m, and revealed a soft pink ferruginous sandstone beneath a thin dry, blocky surface layer. No boulders were encountered, although occasional sandstone concretions were noted. A
Figure 10. Magnetic anomalies A31 to A34, west Bull Creek area.
magnetic traverse along the centre of this costean at its maximum depth did not produce any anomalies, and anomaly A17 is believed to be due to variations in the iron content within the soft sandstone layer.

Magnetic anomalies A22 and A23 to the northwest of the area and immediately adjacent to the mesa are of greater intensity than anomaly A17. They are remanently magnetised in essentially opposite directions. Anomaly A22 was
tested by excavation along costean 2 and a cross-cut along costean 3. The smaller apparent dipole magnetic anomaly A23 was not tested by excavation. A22 has an amplitude of about 150 nT. Both remanent and induced components can be recognised in this anomaly.

The remanent component of the anomaly is considerably stronger than the induced component, and at about 90 degrees to the present geomagnetic field direction. The shape of the anomaly A22 is consistent with a shallow body with strong remanence.

Excavation of this anomaly along costeans 2 and 3 intersected a dark pink kaolinitic ferruginous sandstone from a depth of about 1 m below the surface, and continued to 3 m. From the sections revealed in the two costeans the sandstone body appeared ovate. Oriented samples of this sandstone were later tested in the laboratory and found to have high remanence values (Table 1).

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Table 1. Ferruginous sandstone samples from near the Bull Creek Mine.

* + indicates reverse magnetisation.

No opal of commercial grade was recovered from costeans sited by ground-magnetic methods. However, the number of costeans are few when compared with the total range of anomaly patterns which were delineated. Therefore the usefulness of this technique cannot be fully assessed at this stage, but the fact remains that the host ironstone has a discontinuous distribution and invariably a relatively high magnetic remanence. Laboratory measurements of excavated rock show that the contrast between the ironstone and country rocks is very variable, though in some areas the contrast is sufficiently strong to detect ironstone bodies with little difficulty. Further magnetic field surveying and excavations are warranted, to examine the complex anomaly patterns in more detail and their relationships with precious opal deposits. The association of opal with fault and bedding structures lends itself to detailed aerial photograph lineament interpretation, and to experimentation with geoelectric and shallow seismic techniques.

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