Case History: the search for opal at Lightning Ridge

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SUMMARY

Opal at Lightning Ridge typically occurs at the interface between the electrically resistive Wallangulla Sandstone and the deeper conductive Finch clay facies. The best quality opal is generally found beneath thicker portions of the Wallangulla Sandstone and associated with local jointing, faults and breccia zones.

Electrical, electromagnetic, magnetic, induced polarisation and seismic reflection surveys have all been trialed by the New South Wales Department of Mineral Resources at Lightning Ridge. The electrical and electromagnetic methods appear to provide a means to define the conductive Finch clay facies (or "opal level"), the overlying and moderately resistive Wallangulla Sandstone and the highly resistive surface gravel and silcrete (or "shincracker") layers. Localised linear features appear to be well-defined in both TEM and high-definition ground magnetic data as electrically resistive and high frequency magnetic anomalies. Results indicate that an ultra-detailed airborne electromagnetic survey may assist in the future search for opal at Lightning Ridge.

Key words. Lightning Ridge, opal, resistivity surveys, electromagnetic surveys, magnetic surveys, TEM, SIROTEM, Wallangulla Sandstone, Finch clay facies.

HISTORY

In 1997-98, the estimated opal production in New South Wales was valued at approximately $56 million. Major opal fields occur at Lightning Ridge (Figure 1) and White Cliffs, respectively located in the central-northern and western parts of New South Wales. The miners at Lightning Ridge are finding it increasingly difficult to locate further occurrences of opal within or adjacent to the existing fields and have asked the New South Wales Department of Mineral Resources (NSWDMR) to assist in the search for opal.

Background

To help plan for the future needs of Lightning Ridge residents, the Walgett Shire Council in the early 1980s approached the NSWDMR to provide an estimate of the likely future for opal mining at Lightning Ridge. Findings of a study undertaken by the Department were published by Watkins (1985). One of the conclusions of the report recommended the trial of geophysical techniques to assist in the exploration for opal. The principal exploration tools employed by most miners were, and still remain, relatively as nine-inch auger drilling and three-foot diameter shaft sinking.

Figure 1 Location Map

Opal at Lightning Ridge is usually found at the top of the Finch clay facies within the Wallangulla Sandstone Member. Opal occurs as small roughly egg-shaped nodules, called nobbies, approximately 200 mm to 400 mm in size, or as sheet or vein deposits. Deposition of siliceous opaline material is usually associated with local jointing, structures and breccia zones and adjacent to the intersection of regional linear features (Watkins, 1985). Lineaments at Lightning Ridge can be observed on aerial photographs and Landsat images, and are postulated to be the conduits for movement of silica in fluids during the weathering process attributed to opal formation (Watkins, 1985).

The aim of the geophysical surveys was to detect both the Finch clay facies (the host for the opal) and the overlying Wallangulla Sandstone that are essential for the formation and deposition of opaline material at Lightning Ridge. The general thickness of cover (10 m to 15 m) and the thin (1 cm to 10 cm) nature of an opal seam, or sporadic occurrence of nobbies, meant direct detection of the siliceous-rich opal material was particularly difficult with geophysical methods.

In 1986 and 1990, transient electromagnetic (both standard and early-time SIROTEM), Schlumberger sounding, seismic reflection and induced polarisation surveys were conducted. All techniques were successful in detecting the Finch clay facies within the Wallangulla Sandstone Member. While an electrical resistivity contrast was anticipated between the sandstone and clay layers, it was not expected that the linear features described by Watkins (1985) would clearly show as resistive highs within the TEM sections. Although seismic reflection data resolved the claystone it was not pursued as the processing costs were high.

Since the release of the Department's findings in 1985 (Watkins, 1985) exploration and mining at Lightning Ridge has expanded. Now, some 15 years later, the 'easy' opal has been found and the miners are looking for more sophisticated techniques to assist in the search for opal.

Current Status
In June 1998, Leys and Robson presented a paper at the First Lightning Ridge Opal Symposium, where it was proposed to test modern geophysical surveys that were both relatively simple to acquire and to interpret by a claim holder. Subsequent field surveys were undertaken at Lightning Ridge in December 2000, using the semi-automatic ABEM LUND resistivity profiling equipment, a GEONICS EM-31 instrument and a rapid sampling Offenhauser magnetometer. The outcomes of this current survey are presented here.

PREVIOUS SURVEYS

The results of the resistivity and electromagnetic (SIROTEM) surveys carried out during 1986 and 1990 identified a three-layer electrical model. A thin top layer (less than 1 m or 2 m) of highly resistive gravels and/or silcrete (locally known as "shincracker") over a thicker (approximately 10 m to 20 m) less-resistive sandstone, in turn overlying a low-resistivity clay layer (the opal-hosting Finch clay facies). The two lower layers form part of the Wallangulla Sandstone Member.

Small (25 metre) coincident loop, standard time, transient electromagnetic data provided the best resolution of the electrical layers (Leys, 1990). Resistivity profiling and sounding were also definitive (Leys, 1987a&b).

2000 SURVEYS

In December 2000, the Lightning Ridge Miners Association suggested a number of areas for possible investigation. The first, known as Crusty's Prospect, was chosen for a detailed study. That prospect is approximately 23 km northwest of Lightning Ridge along the Old Goodooga Road. A second area, over the Grawin–Glengarry Prospect at Mulga Rush, was chosen for a more limited study. This second prospect is approximately 40 km southwest of Lightning Ridge

Crusty's Prospect
Ground magnetic, EM-31 and resistivity profile data were acquired over two opal mining claims, covering an area of 100 m x 50 m (Figure 2a).

Resistivity Survey
A series of six east–west lines at 10 m intervals were read centred over the prospect (Figure 2a). An ABEM SAS4000 Terrameter, LUND automatic switching box and four 50 m cables with electrode take-out positions every 2 m, were used to facilitate the survey. Mild steel (8 mm and 10 mm diameter) tent pegs were used as electrodes. These were positioned at every 4 m along the four adjoining cables to provide a total coverage length of 160 m. Additional electrodes were placed along the inner two cables to provide a minimum electrode spacing of 2 m within the centre of the spread. The Wenner-alpha array was selected as the most appropriate profiling technique. The instrument then automatically acquired 10 electrode a-spacings (2, 4, 6, 8, 12, 16, 24, 32, 40 and 48 m) along each line to yield an effective coverage length of 100 m at 7 a-spacings, (70 m at 8 a-spacings, 45 m at 9 a-spacings and 20 m at 10 a-spacings). The more tightly spaced central electrode configuration was used in an attempt to more closely define the near surface, while the wider outer electrode separation was used to gain sufficient depth penetration over the prospect. Very dry and hot conditions during the survey continually affected electrical contact at each of the electrodes. Constant watering was employed to try and maintain good contact and data quality. However, rogue high values and some negative values were encountered.

The resistivity data were inverted using RES2DINV, a rapid 2-D resistivity and IP least-squares inversion package distributed by ABEM. The program uses a non-linear, least-squares inversion technique based on a quasi-Newton method (Loke and Barker, 1996). Both finite element and finite difference forward modelling techniques can be used to calculate the apparent resistivity values with the field data being used as a starting model. Given good quality resistivity data, the program usually converges to a suitable solution within three iterations. The program also supports a variety of array configurations.

Both the field results and the resultant 2-D models are presented in Figures 2e and 2f. The results generally show three flat lying resistivity zones. The uppermost and highest resistivity layer is generally thin (<5 m) and coincident with dry soil, gravels and silcrete, and is based on data for the top of adjacent drillholes. Below this layer the resistivity values become lower and a thin zone is interpreted as the Wallangulla Sandstone. At greater depths (approximately 10 m to 15 m) a lower resistivity layer is interpreted as the Finch clay facies — the "opal level".

The six resistivity pseudosections in Figure 2e show consistent trends. As expected, the near-surface resistive layer shows a large amount of variation as the sub-surface changes between silcrete and gravel. On the eastern half of the pseudosections, and with larger a-spacings there is a broad lower resistivity zone. From limited drillhole support this zone appears to be due to the Finch clay facies at about 10 m. On the western side of the pseudosections, the generally higher resistivity values most likely indicate a thinner or less extensive claystone lens within the sandstone.

Magnetic Survey
An ultra-detailed ground magnetic survey at an interline spacing of 5 m and a station interval of 1 m was carried out over the prospect area. An image of the gridded data is included as Figure 2b. The data were lightly filtered in an attempt to remove effects of surface noise due to maghemite. The magnetic low in the southwest of the area is most likely due to a large truck positioned 5 m to the south of the southernmost line. Apart from the maghemite effects, there is possible evidence of features with northeast and northwest trends. These intersect near the centre of the grid and may be due to local structures that are also postulated as favourable for opal occurrence.

Electromagnetic Survey
A Geonics EM-31 instrument, in vertical dipole mode, was used to survey the 100 m x 50 m prospect on a 5 m grid spacing. The quadrature (conductivity) and in-phase data are displayed as colour images in Figures 2c and 2d. Note that the quadrature data have been displayed as resistivity.

The EM-31 instrument operates at a frequency of 9.8 kHz. Consequently, the depth of investigation is rather limited (no more than 6 m), thus only reflecting predominantly near-surface conditions. For instance, the resistivity high traversing the northeast corner of the area is coincident with a small dry drainage feature most probably filled with sand and coarse gravel. The southern resistivity low coincides with a thinner surface covering, as observed in a drillhole which intersected a clay layer at about 3 m.

Grawin–Glengarry Prospect, Mulga Rush.
A 50 m x 50 m grid of ground magnetic and EM-31 data was acquired with a single resistivity profile.

<u>Resistivity Survey</u>
A single line of resistivity data was obtained and modelled using the ABEM Lund system. This line bisects the claim and runs grid east–west (Figures 3c and 3d) along an approximate line of drillholes. Survey specifications and data processing were similar to those described for Crusty's Prospect. The modelled resistivity depth section (Figure 3e) indicates a general decrease in resistivity with depth. It appears that the resistive surface layer and the Wallangulla Sandstone extend to about 10 m or 12 m. Below this, the resistivities are lower — particularly on the eastern half of the line — indicating the presence of a claystone. A deeper zone of low resistivity on the western portion of the line indicates a possible fault through the prospect (Figure 3). These results are consistent with the drillhole logs for the prospect. Note that the apparent resistivity values for both the observed and modelled sections yield slightly higher values than those presented for Crusty's Prospect.

<u>Magnetic Survey</u>
Similar ultra-detailed coverage of the prospect to that described for Crusty's Prospect is displayed in Figure 3a. The result shows a broad weak magnetic anomaly in the centre of the claim. There was no obvious superficial maghemite material in the vicinity of the prospect area.

<u>Electromagnetic Survey</u>
The prospect was similarly covered by EM-31 on a 5 m grid. The quadrature (displayed as resistivity values) and in-phase components are shown in Figures 3b and 3c. Note, the greatly increased apparent resistivity values and the reduced in-phase component values compared to Crusty's Prospect.

CONCLUSIONS

1. The opal bearing claystone and the overlying sandstone can be readily detected with both resistivity and TEM surveys.
2. With limited training, opal miners could operate the semi-automated ABEM Lund resistivity equipment and associated modelling software.
3. Near-surface magnetic noise effects can greatly affect a 50 m x 50 m prospect scale magnetic data coverage. However, there is some evidence that prospective local scale structures have been detected.
4. Due to the limited depth of penetration of EM-31 it is probably not suitable for use in the Lightning Ridge area.
5. The resistivity and electromagnetic data acquired by the Department indicate that a ultra-detailed airborne electromagnetic survey would probably detect the opal hosting clay layer and would thus greatly assist in the search for additional, opal-bearing environments.

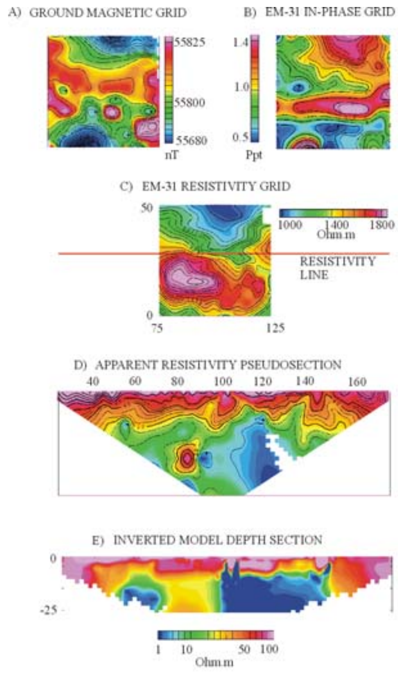

Figure 3 a) detailed ground magnetic data; b) EM-31 in-phase data; c) EM-31 resistivity data and resistivity survey line location; d) apparent resistivity pseudosection; and e) inverted resistivity model depth section

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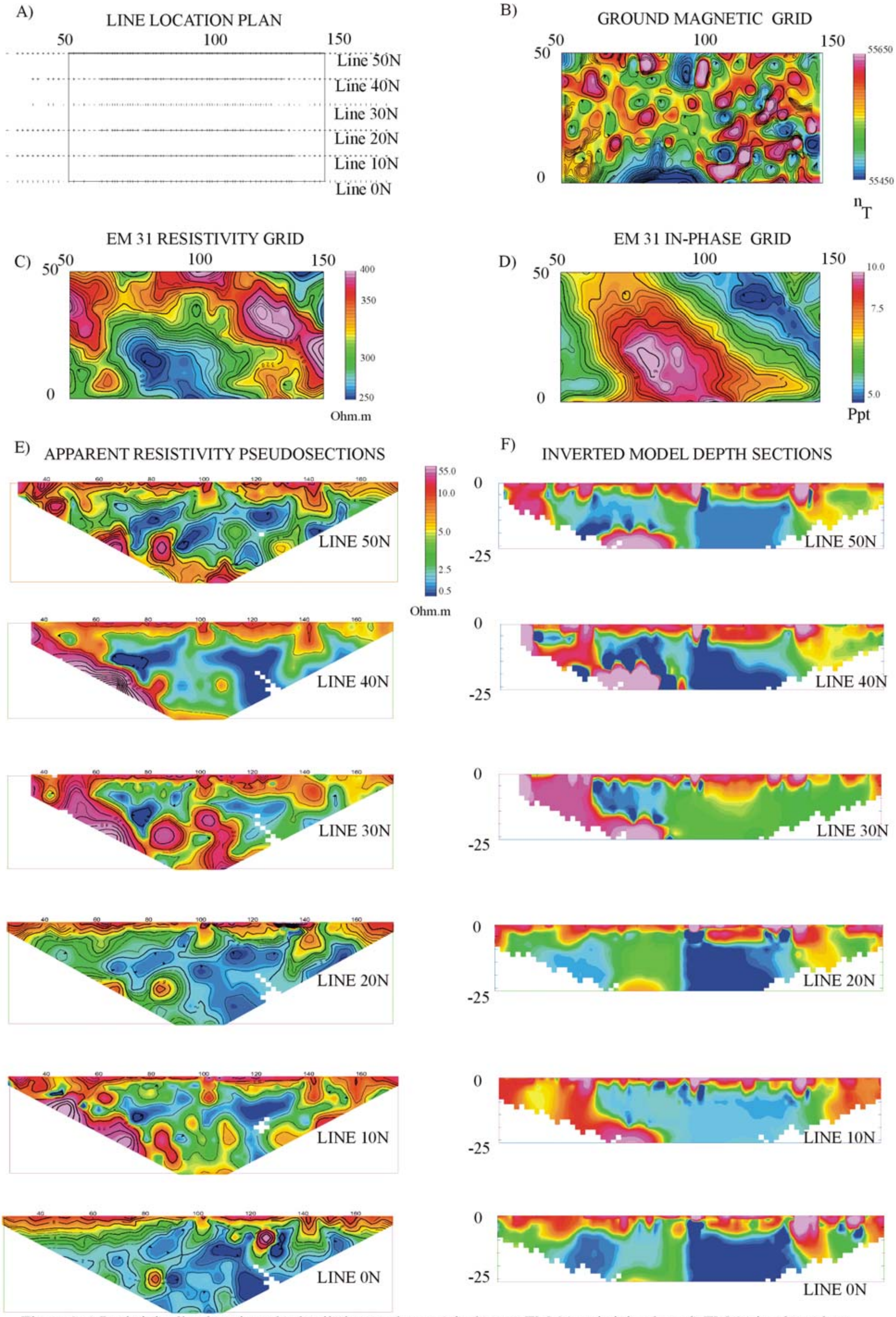

Figure 2 a) Resistivity line locations; b) detailed ground magnetic data; c) EM-31 resistivity data; d) EM-31 in-phase data; e) apparent resistivity pseudosections; and f) inverted resistivity model depth sections