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Short Note: Early seismic refraction and gravity exploration over the Blendvale MVT lead-zinc deposit, Western Australia

Robert J. Whiteley   Laric V. Hawkins*

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INTRODUCTION

The area around the Blendvale Mississippi Valley-type (MVT) lead-zinc deposit at Pillara, Western Australia, has presented many exploration challenges over the past 30 years. This region of the Lennard Shelf was initially explored for MVT deposits using systematic grid drilling that led to the discovery of Blendvale and other deposits. However, the relatively high cost of this approach for deeper exploration prompted extensive testing and application of various geophysical methods over an extended period (Scott et al., 1994). Recently, Fullagar et al. (2004) presented a 3D gravity interpretation of the upper surface of the dolomitic limestone containing the Blendvale deposit. Accurate location of this interface is important to exploration of this ancient reef complex. This gravity interpretation exploited the large density contrast between the overlying shales and siltstones and the limestone, and was constrained by 561 boreholes that intersected the upper limestone surface. Fullagar et al. (2004) recognised that seismic methods are applicable to the problem of mapping this surface, but no seismic interpretations over this deposit were presented or discussed.

Early Blendvale area geophysical exploration during the 1980s, with IP, gravity, and seismic refraction, has been summarised by Isles et al. (1987). These authors also presented a Mini Sosie seismic reflection section over the deeper limestone about 1500 m north of Blendvale that was obtained sometime after the 1980s exploration phase, but no interpretations of the initial seismic refraction or gravity data were presented.

In order to establish fully the early exploration picture this note presents the initial seismic refraction interpretation over the Blendvale deposit and compares this with the initial gravity interpretation.

SEISMIC EXPLORATION

During the early geophysical exploration and testing phases, a single seismic refraction profile was completed across the Blendvale deposit to test the ability of this method to define the limestone interface at which a large seismic velocity contrast was expected. Secondary objectives were to define the lateral limits of the reef and to locate any seismic low-velocity zones that could represent mineralised breccia zones, similar to those in which the Blendvale deposit occurs.

Coffey Geosciences Pty. Ltd., 8/12 Mars Rd, Lane Cove West NSW, Australia, 1670
Phone: 9911 1000
Facsimile: 9911 1001
Email: bob_whiteley@coffey.com.au

*   *(deceased)*

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This refraction line (Line AA in Fig. 4 of Isles et al., 1987) traversed the Blendvale deposit in a NW-SE direction, approximately orthogonal to the strike of the reef complex. The refraction line was 9.0 km in length and extended onto the shale/siltstone sequence at its margins. The Blendvale deposit, itself, is shown on Figure 2 of Fullagar et al. (2004), approximately at (7 972 200 N, 793 000 E).

The seismic refraction data were acquired with 24 channel analogue equipment, using a 60 m geophone interval, 5 shot points per spread and reversed shooting to maximum offsets of 650 m. The shots were explosive charges in shallow drillholes.

The authors assessed and interpreted this refraction data using the manual Reciprocal Method (Hawkins, 1961). Data quality was generally very good over the limestone but somewhat variable over the shales and siltstones at its margins, as discussed below. We were provided with the location of the Blendvale deposit, and one calibration borehole that intersected the buried limestone interface.

GRAVITY EXPLORATION

Following the seismic interpretation, a gravity profile was completed along the seismic line and independently interpreted by Encom Pty. Ltd. A nominal station spacing of 200 m was used in this gravity survey. The resulting Bouguer gravity profile was quantitatively interpreted using available 2D gravity modelling software. The interpretation was constrained by the single borehole (BH on Figure 1), and by measured rock densities on a few shale and limestone samples from this hole.

INTERPRETATION

Figure 1 shows the interpreted seismic refraction and gravity sections over the main part of Line AA with the Bouguer gravity profile that was also shown in Figure 4 of Isles et al. (1987). The interpreted gravity section was obtained using a density contrast between the shales and siltstones and the limestone of 0.35 $t.m^{-3}$, which is close to the 0.30 $t.m^{-3}$ obtained by Fullagar et al. (2004) using extensive borehole data. On this profile, the gravity high over the reef has an amplitude of about 5.5 milliGal (0.55 gu), and the anomaly is asymmetric due mainly to the proximity of the granitic basement on the eastern side (Fullagar et al., 2004, Figure 1). Another contributor to this asymmetry is the complexity of the western margin, as discussed below.

Ignoring the thin surface soil layer, two layers were interpreted from the seismic refraction data as shown on Figure 1. In the upper layer, representing the weathered shales and siltstones, velocities range from 2500 to 3200 m/s. The lower layer has a much higher seismic velocity and is more laterally variable. Over the large gravity high representing the limestone reef, the lower-layer velocity ranges from 5400 to 7900 m/s. These velocities decrease abruptly to between 3600 and 4500 m/s over the shale/siltstone sequence, and this velocity change clearly defines the lateral limits of the reef at the bedrock interface. A wide low-velocity zone (2000–2500 m/s) occurs on the eastern margin between 5000 mE and 6000 mE, presumably corresponding to the major basement fault interpreted by Fullagar et al. (2004, Figure 5) in the same region. The other low-velocity zone (2000–2500 m/s) over the limestone occurs in the vicinity of the Blendvale deposit, and is associated with the known brecciation near the western margin of the limestone.

Two minor, local gravity lows occur on the gravity high arising from the buried reef; one coinciding with the Blendvale deposit near 3000 mE and the other near 4500 mE. It was tempting to ascribe such features to brecciation, which appears to be the case at Blendvale with coinciding local gravity lows and low seismic velocities, but this correlation was unreliable because of topographic undulations of the limestone surface. The gravity low near 4500 mE possibly represents an ancient sinkhole with no obvious brecciation or no low-velocity zone at this location.

DISCUSSION

At the time, the agreement between the gravity and seismic interpretations over the limestone, which varied between about 90 and 200 m depth, was considered good, taking into account the relatively wide spacing of the gravity stations and with only a single borehole to constrain the gravity interpretation. This result indicated that gravity would be a more cost-effective method than seismic refraction for further exploration over the deeper areas of the reef complex.

The agreement between the early seismic refraction and gravity interpretations over the shale/siltstone sequences on the margins was less satisfactory. On the eastern side, gravity interpretation has considerably underestimated the depth to the shale bedrock because

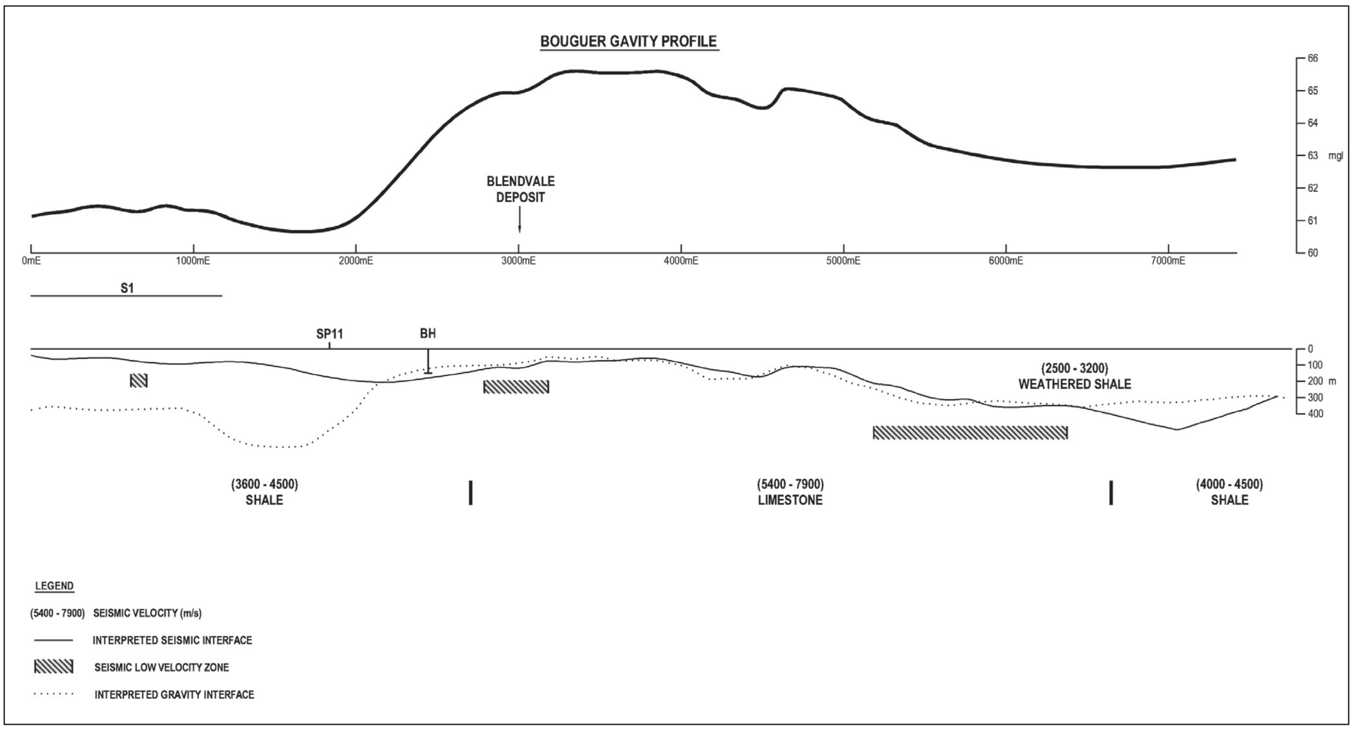

Fig. 1. Early gravity and seismic refraction interpretations over the Blendvale, MVT deposit.

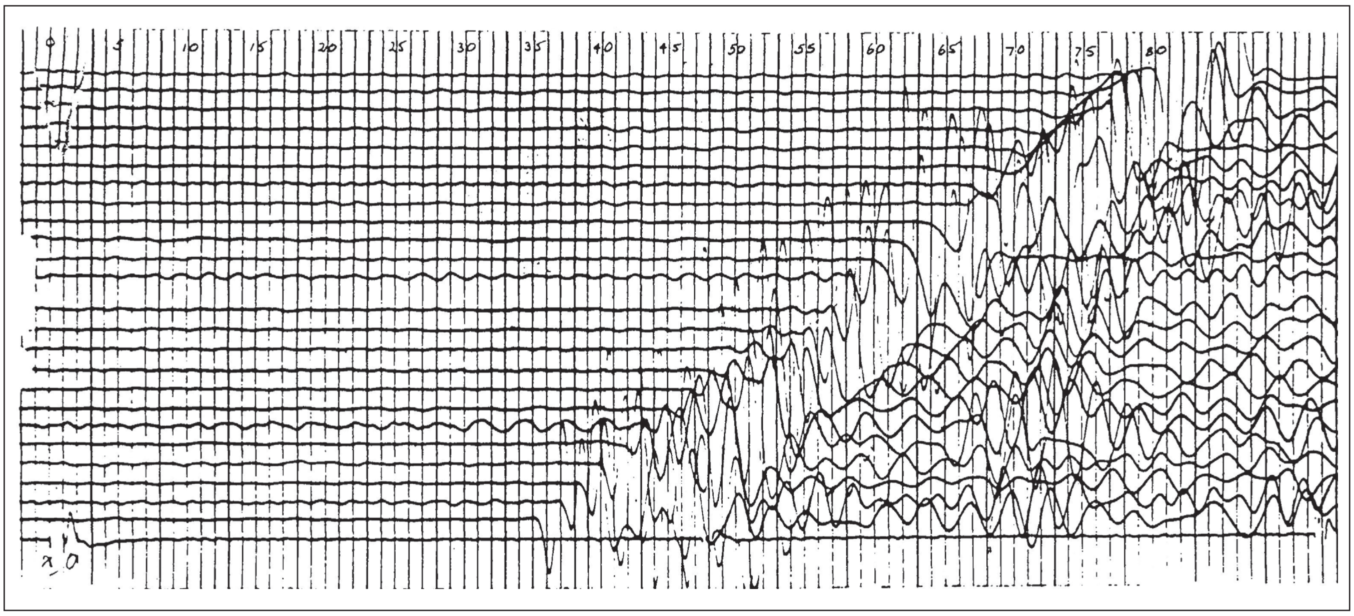

Fig. 2. Long-offset analogue seismic refraction record from SP11 over the western margin shales/siltstones.

of the limitation of the 2D interpretation methods used. The disagreement is even more substantial on the western margin, where the gravity interpretation appears to have greatly overestimated the depth to the shale bedrock. The explanation for this discrepancy was not apparent from either the gravity profile or from Fullagar et al. (2004), but it may be that the limestone wedges out in this region. Certainly, the western margin of the limestone is more complex than indicated on the gravity interpretation in Figure 1.

The seismic refraction data in this region is also more complicated than that over the limestone. Figure 2 shows one of the refraction records from S1 for the long-offset shot point at SP11 (Figure 1), which clearly shows a loss of visibility of the first arrival wavelets with increasing range, especially shingling (Sheriff, 1984). This effect was believed to be due to the presence of hard limestone or siliceous bands within the shale/siltstone sequence, and the refraction interpretation was considered less accurate in this area.

In summary, the combination of seismic refraction and gravity applied in the early 1980s exploration program at Blendvale showed that the limestone interface could be mapped with either method. Gravity was considered to be the more cost-effective geophysical method for exploration of the 50 square km of prospective, deeper reef area. Neither method is without its limitations, particularly near the margins with the surrounding shale/siltstone sequence where more complex geometries and hard bands in that sequence reduced the accuracy of early the geophysical interpretations.

ACKNOWLEDGMENTS

BHP Exploration commissioned this geophysical project and is gratefully acknowledged. These early exploration results were first presented, with permission, at Seismic Workshops held around Australia in the early 1980s, sponsored by Geometrics and presented by the authors.

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This publication marks the 20th anniversary of Laric Hawkins' death. The material was among the papers he left, which have since been archived by the University of New South Wales.

Laric Hawkins originally studied at the University of Sydney (where he was awarded a Blue for Fencing). Laric's particular gift to Geophysics came through his seminal 1961 paper on the Reciprocal Method, cited above. It is possible that this work came about from his experiences with the BMR in the 1950s, which included seismic refraction field work at the Maralinga nuclear test site, the Coronation Hill Uranium Mine and numerous engineering sites in the Australian Capital Territory. However, his contribution ranged much more widely. After joining the School of Mining Engineering and Applied Geology in 1958, he participated in US, Russian and French marine geophysical exercises in Australian and Pacific waters, at a time when the plate tectonics hypothesis was being pieced together. His teaching and supervision at the University of New South Wales have given us many fine geophysicists, of whom David Falvey and Jeff Weissel might be the most widely known.

The ASEG awarded Laric Hawkins the first ASEG Gold Medal, in 1985, and simultaneously inaugurated the Laric Hawkins Award; these are the two longest-standing honours bestowed by the ASEG.

RW/LT