The use of airborne TEM for detection of various seafloor topographic features – multiple quasi-parallel ridges (Yatala Shoals), a mini-mountain peak (South Page) and a submerged bank (Threshold Bank) in Backstairs Passage, South Australia

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SUMMARY

Two helicopter TEM systems (HoistEM and RepTEM) were flown over waters in Backstairs Passage, South Australia, in 2003 and 2010 respectively to test the bathymetric accuracy and hence the ability to resolve seafloor structure in shallow and deeper waters (extending to ~40m depth) that contain interesting seafloor topography. The topography that forms a rock peak (South Page) in the form of a mini-mountain that barely rises above the water surface was accurately delineated along its ridge from the start of its base (where the seafloor is relatively flat) in ~ 30 m water depth to its quasi-submerged peak. A much smaller submerged peak (Threshold Bank) of ~ 9 m peak height located in waters of 35 to 40 m depth was also accurately delineated. These observations when checked against known water depths showed that the two airborne TEM systems were operating correctly. The third component of the survey was flown over a series of quasi-parallel seafloor ridges (resembling large sand waves rising up to ~ 20 m from the seafloor) that branch out and gradually decrease in height as the ridges spread out across the seafloor. These features provide an interesting topography because the interpreted water depths obtained from 1D inversion of TEM data highlight the effect of the EM footprint in resolving both the separation between the ridges and the height of individual ridges, and possibly also the limitations of assuming a 1D model in areas where the topography is quasi-2D.

Key words: AEM, seafloor topography, EM footprint, Yatala Shoals, bathymetry.

INTRODUCTION

Airborne electromagnetic (AEM) methods that are traditionally used for mineral exploration can also be used as a rapid reconnaissance technique for bathymetric mapping in shallow coastal waters. Previous studies (e.g. Vrbancich and Fullagar, 2007) have focused on areas where the seafloor topography is relatively featureless, i.e. can be reasonably considered as 1D. The seafloor topography in the area of Backstairs Passage, located between the Fleurieu Peninsula and Kangaroo Island, about 100 km SW of Adelaide, South Australia (Figure 1) contains two unique features that present as interesting 2D or 3D targets that are accessible from the coastline using a helicopter AEM system. A large rock feature (The Pages, 35.77º S, 138.29º E) split into two sections (North Page and South Page) rises steeply to the sea surface, approximately 40 m from the seafloor, and resembles a scaled-down mini-mountain, Figure 1. (A submerged feature, Threshold Bank (35.91º S, 138.25º E) lying in deeper waters, 35- 40 m, is also included in this study.) The second principal topographical feature is a series of ridges, resembling the structure of sandwaves centred around Yatala Shoals (35.74º S, 138.18º E), which fan out northwards and decrease in height as they spread across the seafloor. Two AEM surveys (2003, 2010) were carried to determine the water depth over these features using layered-earth (1D) inversion of AEM data and to examine how the effect of the EM footprint limits the resolution of the seafloor topography. A second factor which may affect the topographical resolution, the applicability of using 1D inversion in a 2D/3D environment, presently lies outside the scope of this preliminary study.

The AEM-bathymetry (i.e., the water depth derived from inversion of AEM data) of waters surrounding South Page accurately delineates the seafloor topography, as defined from known bathymetry. The ridges (peaks) in Yatala Shoals appear well resolved where the separation is about 300 m or greater. Ridges with narrower separations are unresolved or only partially resolved – in these cases the effect of the EM footprint is similar to that of a low pass filter with the seafloor topography profiles showing broader peak structure with lower peak amplitude, i.e., overestimating the water depth.

METHOD AND RESULTS

The Yatala Shoals, South Page and Threshold Bank areas were surveyed with the HoistEM central loop time-domain helicopter AEM system in March 2003, the same system used to survey Sydney Harbour (refer to Vrbancich and Fullagar, 2007, for details of the HoistEM system). The same area was later resurveyed in July 2010 using a similar AEM system (RepTEM, Geosolutions Pty Ltd). Both systems gave similar water depth profiles based on 1D inversion with the exception that the HoistEM system yielded data that required correction prior to inversion (Vrbancich and Fullagar, 2007) whereas the RepTEM system did not require any corrections to the data (Vrbancich, 2011). Only the HoistEM results are presented here. Layered-earth (1D) inversion using a model of two relatively conductive layers (water/sediment) overlying a relatively resistive basement (underlying consolidated sediment) was carried out using program *Amity* (Fullagar Geophysics Pty Ltd). Prevailing conditions did not permit the use of a vessel to take seawater conductivity soundings.

Values of 5.0 and 1.25 S/m were assumed for the upper two layers respectively in the model for inversion. This value of seawater conductivity is relatively high and has been observed in the nearby Port Lincoln area following the warmer summer months during which time the coastal waters have warmed. The accuracy of the AEM bathymetry was appraised by comparison with known depths obtained from lidar soundings (Laser Airborne Depth Sounder survey, April-June 2000). The sections of available lidar bathymetry data relevant to the AEM survey are shown in Figure 1

South Page

Figure 2 shows two profiles (without smoothing, blue) of the seafloor topography at South Page; Figure 2b, near the peak of the mini-mount, and Figure 2a shows a deeper transect across the ridge that joins North Page and South Page as shown in Figure 2c. These two profiles depict the seafloor level to depths of about 30 to 35 m and show that the 1D inversion of AEM data, following data correction, can detect the seafloor topography fairly accurately.

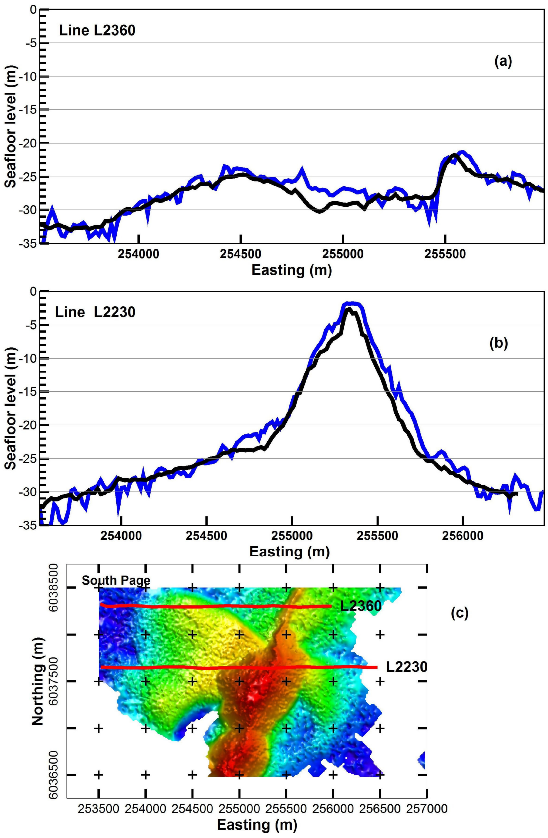

Figure 2. Water depth: lines L2360 (a) and L2230 (b); (c): lidar bathymetry of South Page, location of the two flight lines (red). (a), (b) - bathymetry: lidar (black), AEM (blue).

Threshold Bank

The deepest section of this survey is over Threshold Bank which, from north-west to south-east, gradually rises about 12 m from the seafloor and then falls sharply back to the seafloor “baseline”. An example of the seafloor profile (blue), for line L3315, is shown in Figure 3a, which detects the bank (250500 – 251300 mE) as well as finer features (~252100 mE, 6024800 mN, Figure 3b) further south east along the profile.

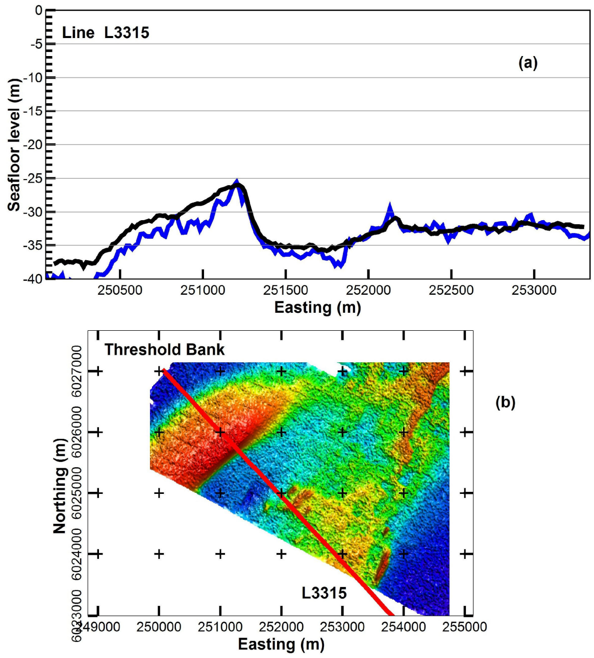

Figure 3. Water depth: line L3315 (a); (b): lidar bathymetry of Threshold Bank, location of the flight line (red). (a), (b) - bathymetry: lidar (black), AEM (blue).

Yatala Shoals

The previous examples (together with equivalent examples from RepTEM data, not presented here) show that (i) AEM data derived from an imperfectly calibrated system (HoistEM, 2003), following correction, or (ii) from an AEM system which appears suitably calibrated (RepTEM, 2010) and does not require data correction, can be interpreted using 1D inversion to produce a reasonably accurate representation of the water depth, detecting smoothly varying topographic features. I present some examples from the Yatala Shoals region where the seafloor topography varies relatively sharply. The locations of blocks 1 to 4, within Yatala Shoals, are shown as 4 rectangular polygons in Figure 1 (marker “YS”) from south to north respectively.

Block 1: This area shows the dominant ridge (Figure 4c) heading from south-east (~244800 mE) to north-west and splitting into two sections at ~ 244700 mE, 6041100 mN. The western ridge following this split continues into block 2, and then breaks up into a series of minor ridges in blocks 3 and 4. Other secondary ridges located to the east of the main ridge in block 1 are not as high and track northwards. The EM footprint is expected to be about 200 m (Liu and Becker, 1990) at the inductive limit. In the case of finite transmitter frequency and earth conductivity, the currents induced in the earth will have a larger spatial extent than that at the inductive limit (Reid et al., 2006).

The main peak at ~244700 mE (Figure 4a) is resolved, however the shoulder to the west (~244580) and the separate peak further west (~244400 mE) are not resolved (gap separation is ~120m). The three main secondary ridges to the east of the main ridge (Figure 4a, ~245135, 245520 and 245850 mE) are partially resolved (gap separations ~340 m) with the peak height and structure being reduced and smoothed. The other ridges to the east of the main ridge are unresolved being separated from the other secondary peaks by about 150 – 170 m. Further north (~180 m, L1175, Figure 4b), after the split in the main ridge, the individual peaks (~ 244400, 244700 mE) are separated by ~320 m and are clearly resolved, however the EM footprint results in the narrow peak height and structure being noticeably underestimated and smoothed. The secondary peaks to the east of the main ridge in Figure 4b show similar features to Figure 4a.

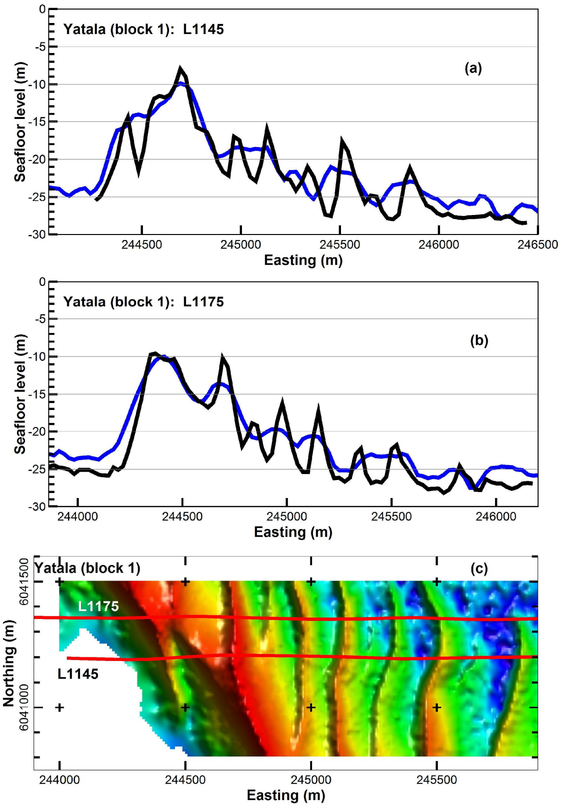

Figure 4. Water depth: lines L1145 (a) and L1175 (b); (c): lidar bathymetry Yatala Shoals (block 1), flight lines (red). (a), (b) - bathymetry: lidar (black), AEM (blue).

Block 2: Further north of block 1, there is a small split in the main peak (Figure 5a, c) between 244280 and 244450 mE (Figure 5a) with a gap of ~170 m that is unresolved. The two principal secondary peaks to the east of the main ridge (~244670, 244930 mE Figure 5a) separated from the main ridge by ~ 230 m and with an inter-peak separation of ~260 m are barely resolved. Approximately 1 km further north where the main ridge has again split into two (L1420, Figure 5b) the two peaks are separated by ~300 m and are well resolved, again with reduced peak height.

Block 3: Further north again, in Figures 6a,c, there are two principal ridges centred at ~ 243300 and 243700 mE, with each ridge beginning to be split into two. The gap separation between the nearest adjacent peaks of the two main peaks is ~ 290 m and is resolved, yet the split in each of the main ridges (~180 m centred around the western peak and ~150 m centred around the eastern peak) are essentially unresolved. Further north, the main ridge has broken up into a series of small ridges centred around 243000 mE (Figure 6b,c) with peak separations of about 100 to 150 m that are unresolved.

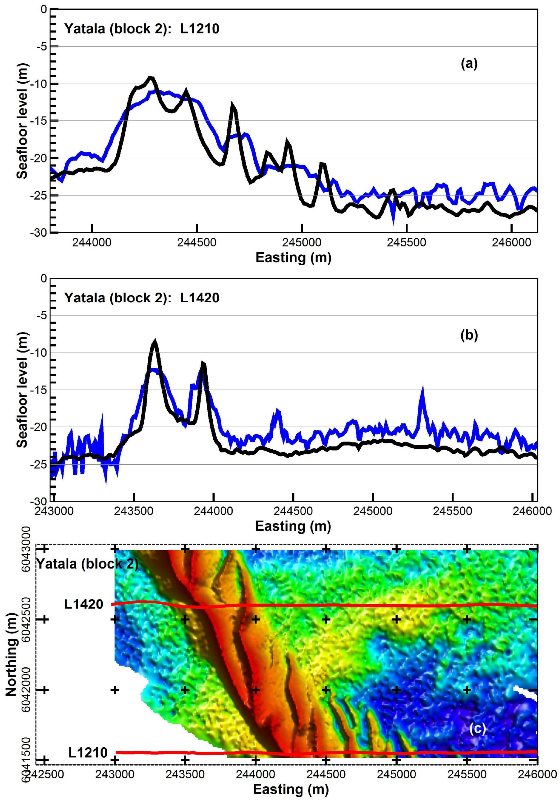

Figure 5. Water depth: lines L1210 (a) and L1420 (b); (c): lidar bathymetry Yatala Shoals (block 2), flight lines (red). (a), (b) - bathymetry: lidar (black), AEM (blue).

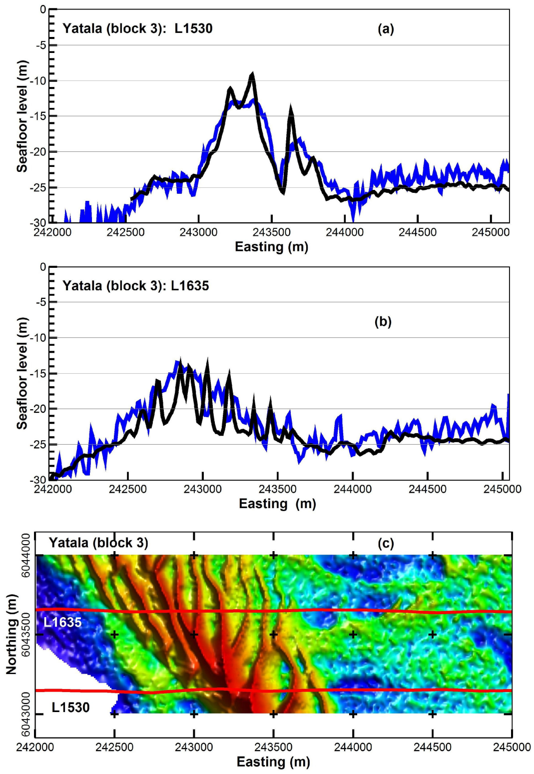

Figure 6. Water depth: lines L1530 (a) and L1635 (b); (c): lidar bathymetry Yatala Shoals (block 3), flight lines (red). (a), (b) - bathymetry: lidar (black), AEM (blue).

Block 4: Here, there is no single dominant ridge. The relatively small ridges separated by 120 to 200 m (Figures 7a,b) are unresolved, however, the subtle variations in the seafloor topography east of 243000 mE are detected.

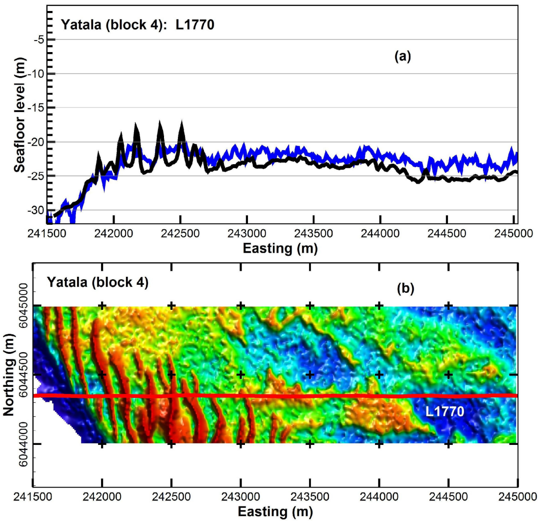

Figure 7. Water depth: line L1770 (a); (c): lidar bathymetry Yatala Shoals (block 4), flight line (red). (a) - bathymetry: lidar (black), AEM (blue).

CONCLUSIONS

An AEM survey using a helicopter time-domain system over coastal waters with varying seafloor topography provided water depths that were in good agreement with known depths, based on 1D layered-earth inversion of the data in areas where the variation in seafloor topography was comparable to or greater than the expected EM footprint. However, in other areas where the seafloor consisted of series of ridges resembling sandwaves, resolution of the ridges was unachievable in cases where the ridge separations were less than the expected EM footprint (< ~250 m). Practically, the water depth in areas of narrow ridges that lie within the EM footprint will be overestimated. Furthermore, these areas are not 1D and further analysis using 3D interpretation methods is warranted.

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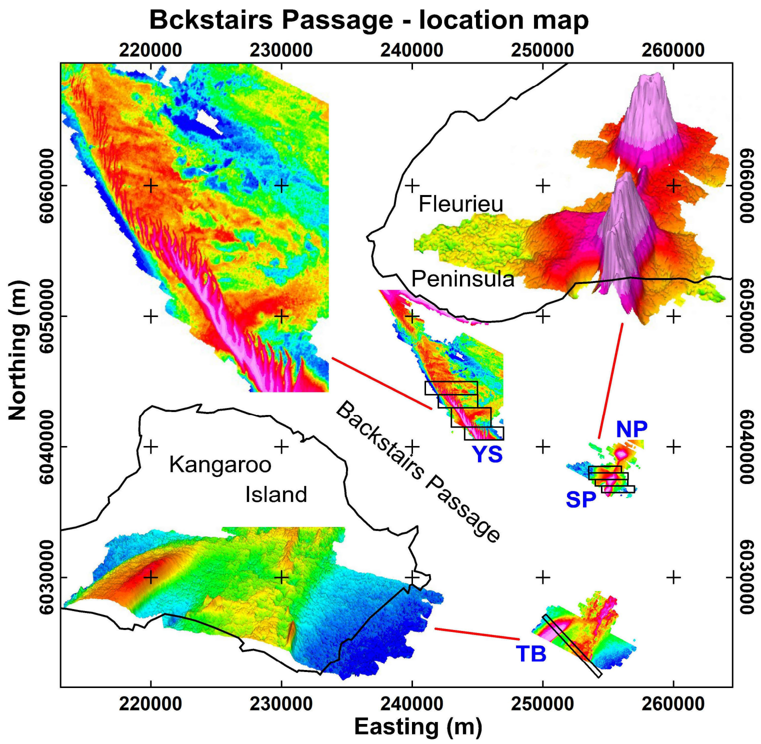

Figure 1. Location map: Backstairs Passage, South Australia. YS: Yatala Shoals; NP: North Page; SP: South Page; TB: Threshold Bank. Polygons at SP, YS and TB mark the AEM survey areas. The coloured images at these locations show the extent of the available lidar bathymetric data. Enlarged images: top right - NP, SP, vertical exaggeration: 50; top left – YS; bottom left – TB (vertical exaggeration: 70).