Geoscientists without borders in South Australia: exploring for and understanding groundwater with geophysics

Professor Graham Heinson, Dr Michael Hatch, Mr Kent Inverarity
Department of Geology and Geophysics, School of Earth and Environmental Scientists
University of Adelaide, SA 5005
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Overview

Phase 1 of this project consisted of an extensive magnetotellurics (MT) survey in the area around the Aboriginal settlement of Nepabunna in northern South Australia in June 2010. The purpose of this survey was to see whether MT could be used to help define zones in the subsurface associated with water in fractured rock aquifers, focusing on the use of phase tensors (Caldwell et al., 2004) to image electrical anisotropy. In these environments anisotropy may be related to fracture alignment in the earth that may indicate the location of these fractured rock aquifers. The upshot of this work was that the MT method, specifically the use of phase tensors, was a promising avenue for research in fractured rock and/or fault defined water bearing systems. Unfortunately at Nepabunna our data were corrupted by powerline noise, despite its remote location. As the powerlines are providing electricity to the existing wells, most of the noise occurred in the most prospective areas. The results of this project have been reported in The Leading Edge (Inverarity et al., 2011).

On completion of phase 1 (the Nepabunna MT project) we intended to continue to the 2nd and final phase of this project by performing similar surveys in another remote Aboriginal settlement, this time in the Anangu Pitjantjatjara Yankkunytjatjara (APY) lands of far northwestern South Australia (SA). This area has the potential to be an excellent test bed for the methodologies that our group are developing and is in need of improved water supplies, as well as a better understanding of how water is distributed, so that it can be allocated correctly. Unfortunately the approval process for working in the APY lands is complicated and time consuming. It appeared that we were going to be able to collect another set of data in September of this year; unfortunately our permits were delayed. As the southern hemisphere summer was approaching and the possibilities for successful completion of our program before the onset of scorching summer temperatures neared, we decided that it was nearly impossible for our group to complete the intended program in a reasonable time frame.

Between the completion of the Nepabunna work and the intended start of phase 2 of this project, our group has been working on similar projects in the southern Great Artesian Basin (GAB) to characterise artesian “mound springs” both in the near-surface, as well as at depth. These mound springs have been used as water sources for thousands of years by Aboriginal groups (Harris, 2002) and then by early settlers (Harris, 2002) as they are the only sources of permanent surface water over much of the southern GAB, which is one of the driest areas in Australia. There is a great deal of interest in understanding the development of these springs as they have great cultural significance to Aboriginal groups living in the GAB, but the artesian aquifers they tap are also potential water sources for new mines (and have been over-exploited historically by the livestock industry). Additionally, they are of great interest to ecologists, as these springs are very important as oases for many native creatures (Ponder, 1986). This work was completed together with other institutions as part of a federally funded project titled "Allocating Water and Maintaining Springs in the Great Artesian Basin".

For our GAB work, we examined a number of mound spring systems in the southeastern corner of the Great Artesian Basin to determine the geophysical response at a number of scales and depths of investigation. For the main project, at Wabma Kadarbu Conservation Park, we ran surveys that covered much of the main spring area with shallow terrain conductivity, shallow TEM (Zonge's NanoTEM system), resistivity/induced polarization, self potential, and MT. The results of this project have been evaluated and reported on, and will be presented in a number of papers in the near future. We have collected numerous sets of data at the Beresford Spring system as well. Some of the results from both of these areas are summarised later in this report.

Our plan to finish project

At this time we are not able to finish this project as originally outlined, due to difficulties in obtaining timely permission to work in the APY lands. Nevertheless, due to the to the cultural significance of the mound springs and the artesian water associated with them, we intend to complete our GWB commitment by continuing to test the methodology that we have been developing at Nepabunna and in our original work in the GAB to another spring system in the GAB. At this time we are focussing on the Freeling Spring system, which is hypothesised to be a hybrid between a "typical" GAB system and a more localised hard rock/basement aquifer system, similar to what was examined at Nepabunna. Our intention is to collect these data during November of this year, getting in and done before the weather gets too hot.

In the future, after this project officially ends, we look forward to continuing this work by applying these methods over a wider range of similar targets across arid parts of southern Australia and other deserts, as we feel that it has great potential for understanding various mechanisms in both the near surface and deeper environments that govern the location of water and how it flows in these challenging environments.

Results from the GAB

Figure 1 overlays the results from four of the data sets collected over one of the spring systems (the Little Bubbler) at Wabma Kadarbu. In this figure, there is good correlation between resistivity highs in the terrain conductivity data and the TEM data, voltage highs in the SP data, and known locations of spring systems on this transect. Three dune systems are noted on this line. The dune system associated with the Little Bubbler spring shows a well defined resistivity high in the terrain conductivity data, well defined spring structure in the TEM section, and a relatively well defined high in the SP response data. Another dune system is noted north of 5650 m, which is associated with a small spring system near the line. This spring is associated with a resistivity high in the terrain conductivity data, along with a high in the SP response.

Interpretation of the MT data resistivity section shown in Figure 1d is more ambiguous in the near-surface than the other data sets shown. This is not surprising as the frequency range for the MT data collected here is not high enough to discriminate near surface variation very well. There is a small resistivity high in the top 20 m that appears to correlate with the location of the Little Bubbler spring. There is no indication in the resistivity data of the small spring at the north end of the line.

The change in resistivity layering at approximately 30 m from the surface is similar to what is seen in the TEM data in Figure 1b. Examination of the deeper part of the MT plot shows that there is an increase in resistivity at approximately 100 m. Close examination of the data suggests that the depth to this contact is not well defined in the MT data. Based on nearby borehole information this resistivity change is likely to be the contact between the Bulldog Shale and the underlying Cadna-owie Sandstone, which contains the artesian aquifer.

Interpretation of the MT is more interesting when the data are looked at as phase tensors (Caldwell et al., 2004). Phase tensor data shown in Figure 2 were collected over a different line at Wabma Kadarbu, which starts at Blanche Cup (station wkc2350), one of the larger springs at Wabma Kadarbu), and continues for 2 km to the northeast over, ending well off the known spring structures in this area (station wkc1100). The data shown in Figure 2b were collected at Beresford Spring, a complex located about 30 km to the northwest. MT data were collected to the north and south of the main spring, approximately 1.3 km to the north of the system and 1.8 km to the south. The main spring is located at station bwa2890. Below approximately 0.5 hertz both datasets show similar responses, suggesting alignment with known, large fault structures in the area. At both sites most of the higher frequency ellipses are nearly circular to slightly elliptical, indicating that there is little or no preferred direction for induction; the ground at these depths is relatively 1D. Interestingly, in Figure 1b at site bwa2890 (adjacent to Beresford Spring) the higher frequency phase tensor ellipse is again oriented NE/SW, parallel to the regional orientation. At Wabma, the ellipse data over Blanche Cup (wkc2350) shows little or no ellipticity, whereas the phase ellipse at station wkc1100, near the edge of the spring system, is more elliptical than surrounding stations. It is also more elliptical than similar sites, in similar positions at Beresford. These results suggest that there may be differences in the underlying structure at both sites that may explain why the spring system at Wabma Kadarbu is spread over a wider area than the spring systems at Beresford, which are arranged more linearly, and approximately parallel to known deeper fault systems. We believe the differences between these phase tensor responses may indicate the locations of faults which connect the aquifers at depth with the spring complexes in the near surface.

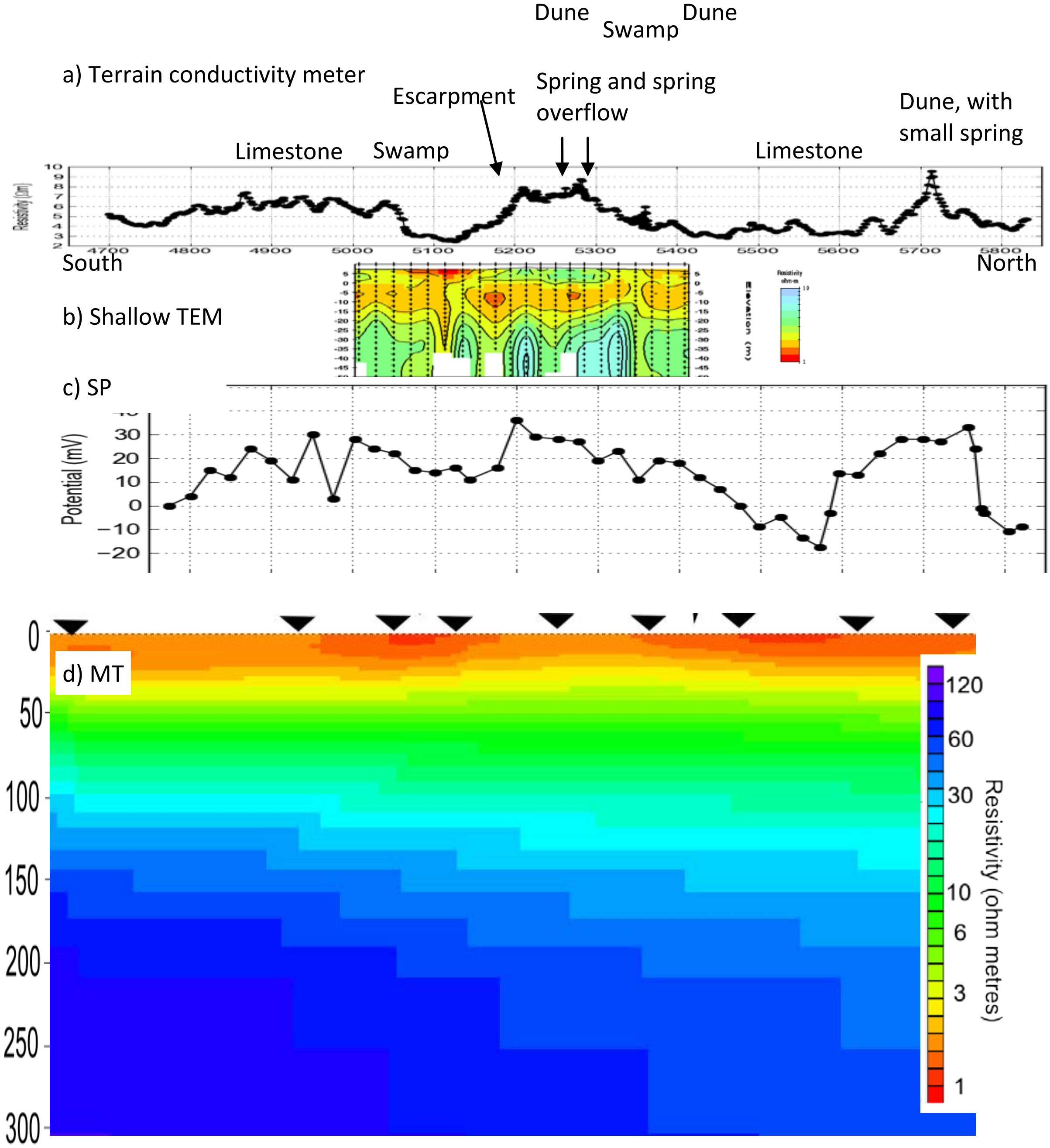

Figure 1. Comparison plot for data sets collected at Line A, Wabma Kadarbu. A) terrain conductivity data; b) shallow TEM data; c) SP data and d) MT resistivity data. On d) triangles indicate locations of MT measurement sites.

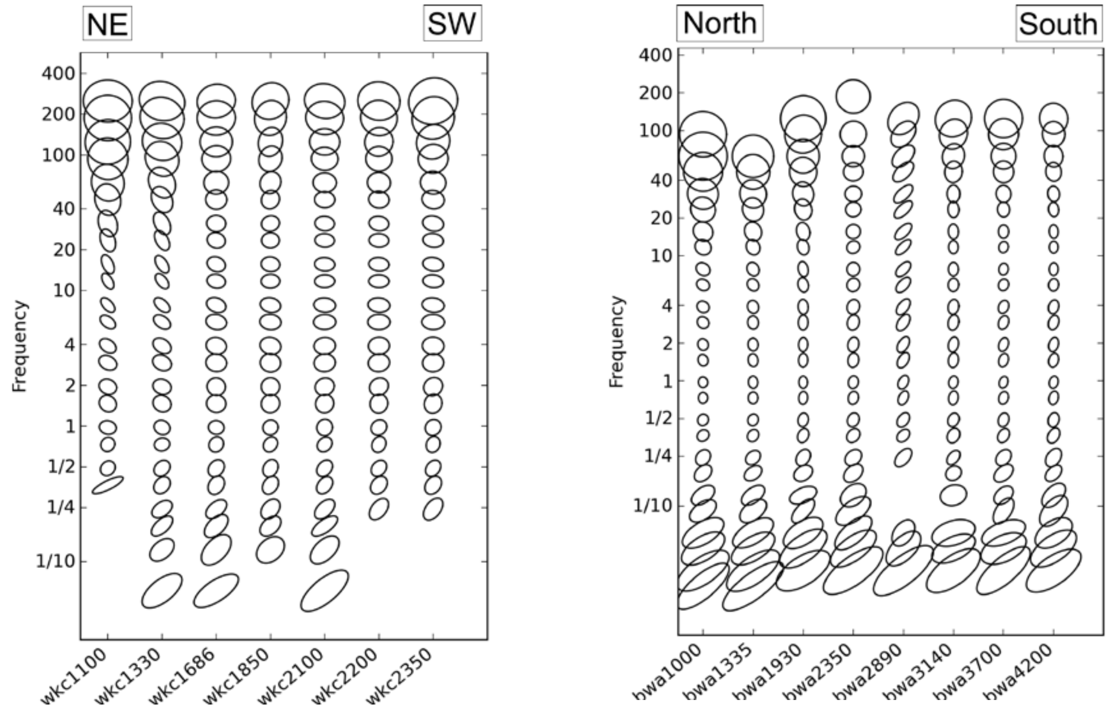

Figure 2. Phase tensor ellipse pseudosections along a) Line C at Wabma Kadarbu; and b) Line A at Beresford Spring. Note the difference in response at 20 Hz between Blanches Cup Spring (located at station WKC2350) in a), and the Beresford Spring (located at BWA2890) in b).

References

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