Z-99 Imaging structure using AMT for hydrological modelling in the western USA

D. K. MCPHEE[1], L. PELLERIN[2], B. CHUCHEL[1], G. L. DIXON[3]
[1]*U.S. Geological Survey*
[2]*Green Engineering, Inc. 2215 Curtis St., Berkeley, CA 94702 USA*
[3]*Consultant*

Summary

Inversion of audiomagnetotelluric (AMT) sounding data collected in Spring Valley, Nevada, USA shows significant two-dimensional (2D) structure within the upper kilometre of the valley and helps define the shallow basement surface. The depth-to-basement profile provided by the AMT inversion is in good agreement with an independent determination made from gravity measurements. The survey was conducted as a test to determine the applicability of the AMT method to mapping basin structure to depths of 1 km or more. The results exceeded expectation and future surveys are planned to support the development of a hydrological model of eastern Nevada.

Introduction

The Basin and Range province is an arid, mountainous, sparsely populated region of the western USA. Growing development in cities such as Las Vegas, Nevada places increasing demands on the water resources of the area, and geophysical investigations are underway to define the subsurface structure and depth of valleys in eastern Nevada (Figure 1) that may have groundwater potential. The AMT method was tested to see if it is a feasible approach to map the structure and significantly contribute to the regional hydrological model in a typical Basin and Range setting. Faults and stratigraphy are important targets and estimates of depth to basement are valuable for assessing ground water potential.

Survey Description

We collected AMT data along two profiles in the southern part of Spring Valley (Figure 1) in the fall of 2004, using the Geometrics StrataGem EH4 system©, a four-channel, natural and controlled-source tensor system recording in the range of 10 to 92,000 Hz (Geometrics, 2000). To augment the low signal in the natural field, an unpolarized transmitter comprised of two horizontal-magnetic dipoles was used from 1,000 to 70,000 Hz. Profile A extends from the Fortification Range on the west across southern Spring Valley to the Limestone Hills in the east along a 12.6 km line with soundings recorded every 200 m. Profile B is a 2 km long, roughly E-W trending line located at the northern margin of the Fortification Range with sounding spacings of 200-400 m.

The AMT data were recorded in both modes: the electrical (E) field parallel and perpendicular to the regional geological NS strike direction. The electric dipole array was in an ‘X’ configuration with dipole length of 20 m. Through experimentation we found that the optimal transmitter distance was 200 to 300 m from the receiver array and we were able to acquire two stations for each transmitter location.

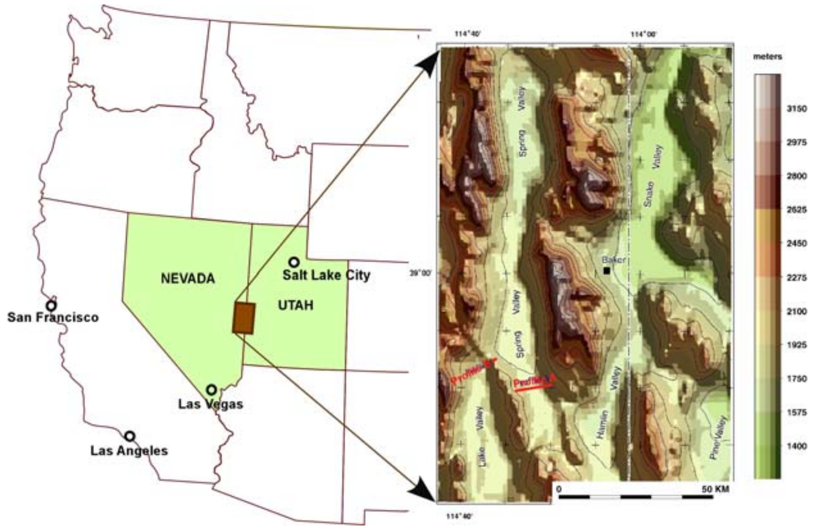

Figure 1. Location map of the western United States showing the survey lines, in red, on the inset map, which shows typical topography for the region.

Survey Results

We computed our preferred two-dimensional, inverse models from the E-perpendicular mode data using the conjugate gradient, finite-difference method of Rodi and Mackie (2001) and a 100 ohm-m half-space starting model. Inverse models were also computed using both the E-parallel and E-perpendicular modes and an equivalent model resulted, with a slightly higher RMS fit indicating the two-dimensionality of the structure.

The choice of a starting model influences the depth to basement estimates. For the frequencies employed and the resistivity of the subsurface, the depth to bedrock was near the limit of the depth of investigation of the system. Various starting models were used to test the sensitivity of the model. A half-space starting model of 10 ohm-m did not produce a model with a resistive basement. Using starting half-space models of 100 and 1000 ohm-m did produce models that were consistent with depth to basement estimated from gravity data (Figures 2 and 3).

The model along Profile A (Figure 2) shows detailed structure revealed by the inversion model results within the alluvial basin. A clear transition between unsaturated (200-500 ohm-m) and saturated alluvium/volcanic rocks (20-50 ohm-m) is present at roughly 100 m depth. Highly-resistive (>1000 ohm-m) carbonate rocks are clearly defined at the east end of Profile A under the Limestone Hills, and the locations and inclination of several range-front and inter-basin faults, which lack surface expression, are delineated throughout the upper 1 km of section.

In addition to AMT data, gravity data collected at roughly one-mile spacing throughout Spring Valley and at 200 m spacing along Profiles A and B were inverted to produce depth to basement estimates using the three-dimensional inverse algorithm of Jachens and Moring (1990). This method assumes density values and inverts only on the depth to basement based on the density contrast between the basement and basin fill. Our AMT model along Profile A clearly defines the shape of and the depth to basement surface and correlates well with depth to basement estimates derived from the inversion of gravity data.

The model along Profile B (Figure 3) shows conductive features beneath the carbonate rocks that crop out nearby. The saturated alluvial valley fill and volcanic rocks are well defined along with the location of a range-front fault. In addition, a resistivity increase of ~100 ohm-m agrees with gravity-derived depth to basement estimates.

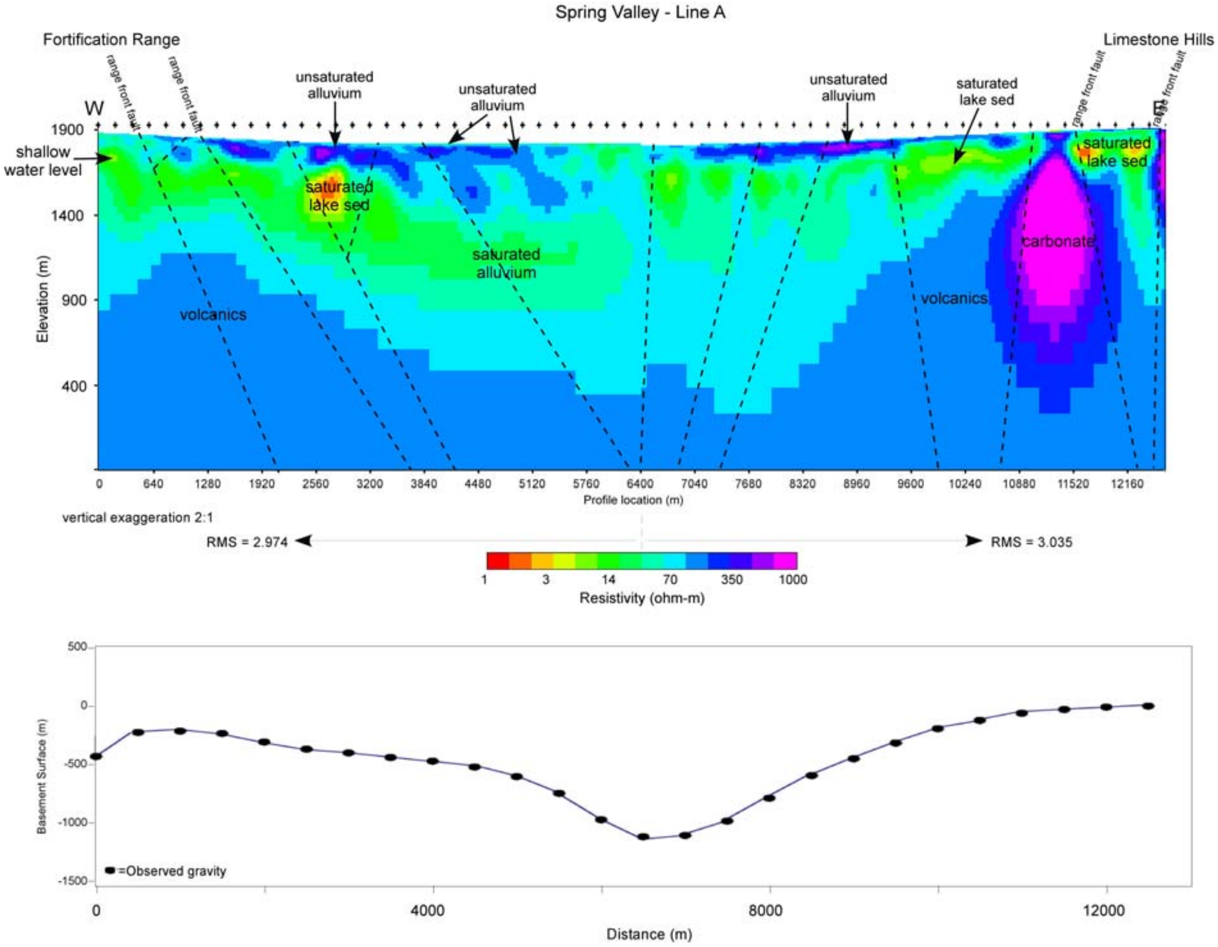

Figure 2. AMT model (above) and depth to basement derived from gravity data (below) along Line A across Spring Valley.

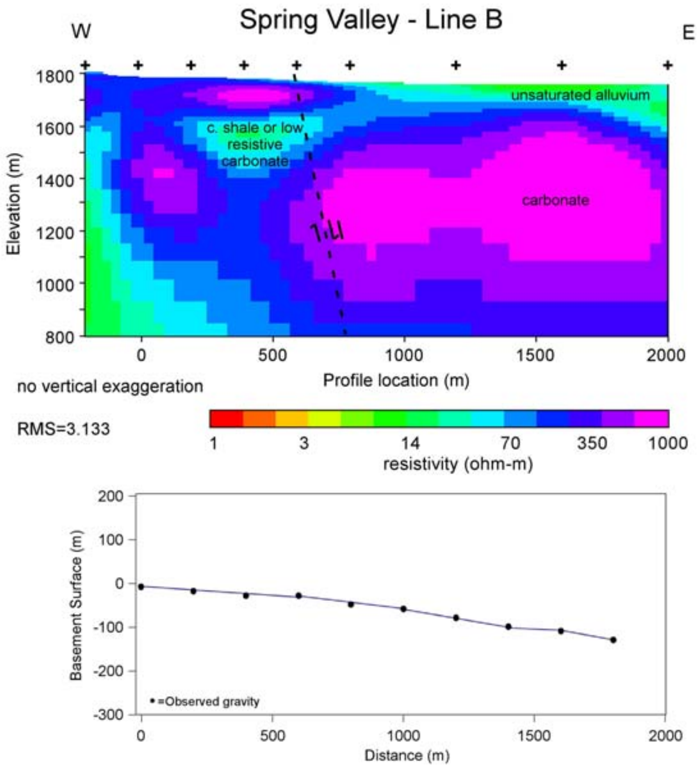

Figure 3. AMT model (above) and depth to basement derived from gravity data (below) along Line B.

Conclusions and Future Work

As these results show, the AMT method is a valuable tool for revealing subsurface structure and stratigraphy within Spring Valley to depths greater than 1 km. When compared to the basement-surface derived estimates from the inversion of gravity data, AMT proved successful at estimating the depth to bedrock, which is significant for future hydrologic modelling in Spring Valley. The combination of AMT and gravity enhances confidence in estimating the depth to bedrock. Due to the success of this test study, additional AMT and gravity surveys are planned to investigate the hydrologic connectivity between Spring Valley and surrounding valleys. Further AMT experiments near well sites are also scheduled for the summer of 2005 to prove ground truth to the resistivity and gravity images.

Acknowledgements

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