A Geophysical Investigation into the Possible Structural Controls of Geothermal Waters in the Buckman Well Field, Southern Espanola Basin, New Mexico,

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Summer of Applied Geophysical Experience 2013

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Abstract:

A 2- Dimensional Magnetotelluric model of the Buckman Well Field located in the Espanola Basin of New Mexico was recently constructed using data obtained during the 2013 Summer of Applied Geophysical Experience field camp. MT data taken over a week period in 2013 was combined with data from previous years to create a model perpendicular to the local geomagnetic strike, which was then compared to recent geologic models of the same study area. Similarities in the models were observed in basin depth, and correlated to some degree with proposed structural features located along the Caja del Rio Plateau. The presence of a horst block feature in the region is still debatable yet features in the model may show fault related down-dropping of basement rock in the area consistent with the proposed horst block. This model alone is not enough to confirm or deny the presence of a horst structure but it can help to constrain and contribute to the validity of the recently created geologic models of the Buckman Wells area until further data is acquired.

Introduction:

A Magnetotelluric investigation of a region of the southern Espanola Basin was recently conducted in conjunction with other geophysical techniques at an area known as the Buckman Well Field in order to establish possible structural features in connection with geothermal water sources. The Espanola Basin is a north-south trending extensional basin lying in the northern portion of the Rio Grande Rift in Northern New Mexico. The Espanola is the middle of three relatively narrow, connected basins that make up the northern and middle portions of the RGR before it broadens out to the south. Many studies have been conducted within the basin to try and discover structural features of the RGR, and recently a central horst block feature has been proposed by Koning et al. 2013, as a possible mechanism for driving warm waters into the Buckman Wells area. The horst block remains controversial due to the inclusion of improperly collected MT stations in data used to create geologic cross-sections of the basin. A strong focus was made to attempt to connect structural features observed in MT models and gravity models, to the geologic cross-section located very close to the line of MT stations collected for this study. Some similar and interesting structural features were observed in the comparison of the models, although a complete determination of the existence of the horst block cannot be inferred upon from this data alone.

Methods:

Magnetotelluric data was collected using the Schlumberger MT24LF low frequency receiver, along with two horizontal magnetic sensors, one vertical magnetic sensor, and four copper-copper sulfate electrodes. Electrodes were laid out in cross-shaped or L-shaped arrangements depending on field location and were placed 100 m from the receiver and connected via cables. Care was taken to survey the electrode locations and ensure they were aligned to magnetic N-S and E-W. In the case of the L-shaped layout, electrodes were placed to the north and east of the receiver with two electrodes being placed at the corner near the receiver. For each electrode a hole roughly 50 cm deep was dug, each electrode was placed in a cup of bentonite mud, partially buried and then saturated with water before being fully buried. This procedure was conducted to ensure good contact with the subsurface and to try and eliminate the effects of wind and dry climate. The horizontal magnetic sensors were each buried in a 50 cm deep trench, one aligned to north and the other to east. The vertical magnetic sensor was buried in an approximately 150 cm deep hole and carefully leveled. The array was left in place and data was acquired over 24 to 48 hours depending on location. Once acquired the data from each station was converted from time domain into the frequency domain and input into WinGlink software for processing. A study line was chosen that offered the greatest number of stations, and was very close to being perpendicular to the geomagnetic strike of the region. Stations used in the study line were collected over a period of three years from 2011-2013 in order to extend the model as far as possible. Each station was analyzed separately and frequencies with high error were masked from the data; a D+ smoothing was also used to determine additional points to mask. One dimensional inversion models with between five and six layers were created and fit to the data using guidance from an Occam best fit curve. A variety of two dimensional models were created using a set of suggested initial parameters. Additional models were then created using static shift correction methods using both manual adjustments and the WinGlink software. Phase focused inversions were also created by increasing the apparent resistivity error floor to try and reduce its effect on the model. WinGlink inversion settings can be seen in Table 1.

Results:

Initial 2D MT models indicated basement at between 3 and 4 km depth and showed the more gradational west-dipping slope of the eastern portion of the basement, see Figure 1. A curious linear feature extending from the central portion of the model to depths well beyond the assumed basin depth was observed and additional models were made to try and reduce this feature to determine its possible validity. Static shift corrections were moderately successful at reducing its size, but were still not deemed sufficient and so the focus was changed to phase inversions with some additional static shift corrections. This process improved the overall resolution of the assumed crystalline basement. The model was then compared a geologic cross-section of this region of the Espanola Basin created by Koning et al. 2013, see Figure 2. Although the cross-section is 1 km north of the modeled MT line, similarities in basement structure were observed, specifically the structural bowl shaped region of the basement. Gravity modeling also gave a very similar depth to basement prediction as that seen in the cross-section and the MT model. However the gravity data does not extend onto the plateau and so does not fully confirm the bowl feature. After careful measurement of local maps and comparison to MT stations a slight offset was seen between the bowl feature observed in MT data and the similar feature in the geologic cross-section. This difference was assumed to be due not only to the slight physical difference in each lines position but also the fact that the modeled MT line represents a projection of all points onto a central plane, which may cause some distortion. The deep feature was eventually determined to be possibly related to a fault zone observed in that area of the cross section, or possibly a 3D continuation of the changing basement structure (including the aforementioned bowl feature) along the roughly N-S trending, eastern edge of the Caja del Rio Plateau. A modeling error due to the closeness of two data stations on the projected model plane could have also been responsible. It has been observed that a projection of two geologically separated stations into a close spacing during modeling can erroneously cause features like that seen here. Other features seen in the model also correlated well to observed surface geology and the geologic cross-section, such as the resistive basalt flows of the Caja del Rio Plateau, and the approximately 1 km deep conductive unit. The basalt flows of the plateau appear in the MT model to extend to between 200 and 600 m depth, but are variable and without any known values to compare to, still questionable. The plateau is located in the eastern portion of the MT line and resistive units observed beneath it are far thicker than the resistive units seen in the west of the line; which overlies primarily basin fill. This shows that the basalt flows may in fact be the thick near-surface resistive units seen in the model, and thicknesses of 200- 600 m agrees well with the cross-section. At approximately 1200 m depth a conductive unit with a resistivity of around 5 Ohm/m is observed, most prevalently in the eastern portion of the model, but extending throughout the western portion as well. MT techniques are able to clearly resolve the top of a conductive unit but are less capable of resolving the top of a resistive unit beneath, therefore exact thickness of this regional conductor remains questionable. An estimate of 800 meters was made with well log data taken from the Yates #2 oil well located south of the MT line that observed an 800 m thick unit with similar resistivity. Koning et al 2013, predicts a nearly 800 m thick package of the Tesuque and Abiquiu formations in this area that are comprised of volcanic derived flows and sediments that could possibly have weathered to clays giving a 5 Ohm/m resistivity. However due to ambiguity of the conductors thickness, estimates of up to 2 km may be valid. Since many of the sediments in this region have volcanic provenance, the same explanation of weathering to clay could also explain a thicker conductive unit. Interestingly a drop down feature in the conductor is observed in the same region as the bowl feature in the basement. The cross-section shows a fault zone in this area as well as an uplifted horst block that is still highly debated; some apparent correlation between the drop in the conductor and the cross section are seen, but this still may be due to modeling error as it occurs directly under the two very close points in question.

Conclusion:

Models created from MT and gravity data show some correlation to the geologic cross-section created by Koning et al. 2013, and support the idea of a bowl shaped feature in the basement that may or may not be caused by the uplifting of a horst block, but still seems likely fault related. It has been proposed that the models of the Espanola basin created by Koning et al, are erroneous due to some faulty MT models, based on bad data collection procedures. This model was created specifically to be perpendicular to geomagnetic strike, and so, should be valid. Even minor errors and specific parameter choices within the modeling process still cannot totally invalidate features that were observed in every model made of the MT line. These features such as the west dipping grade of the eastern portion of the basin, the drop down or bowl feature observed in the basement as well as in the conductive unit, and the thicker near surface resistive areas in the east all appear to exist regardless of parameter choice. However it is noted that the process of Magnetotellurics can be highly subject to user error. Since a good cross-strike MT line was conducted in only one location we are not able to make any comparison to the modeled geologic cross-sections farther to the north and south of the MT line, but in this single case it appears that overall structural details tend to agree, and are also supported by gravity models. Exact basin depth is also questionable from just MT models alone due to the poor ability of resolving the exact boundary of a resistor beneath a conductor. However in conjunction with gravity data it seems that a depth of between 3500 and 4000 m is valid for the area. Gravity data collected independently from this project was used by Koning et al, to constrain the cross-sections and those depths also agree. This model in itself is insufficient to confirm or deny the presence of a horst block in the region beneath the plateau, but may suggest the presence of large faults with offsets of up to a few hundred meters. For future studies it would be beneficial to create other models of this same line, eliminating in turn each of the closely spaced stations or finding a better projection to determine the true source of the possibly erroneous linear feature observed extending to great depths in the MT model; and what effect it may have had on the presence or absence of the structural bowl feature. It is also recommended that more cross-strike MT lines are collected to the north and south of the modeled MT line in order to shed more light on the structure of the basement and the validity of the Koning et al 2013, cross sections.

Citations:

Koning, D.J., Grauch, V.J.S., Connell, S.D., Ferguson, J., McIntosh, W., Slate, J.S., Wan, E., and Baldridge, W.S., 2013, Structure and tectonic evolution of the eastern Española Basin, Rio Grande rift, north-central New Mexico, *in* Hudson, M.R., and Grauch, V.J.S. (Tien), eds., New Perspectives on Rio Grande Rift Basins: From Tectonics to Groundwater: Geological Society of America Special Paper 494, p. 185-219

Acknowledgements:

Thanks to Paul Bedrosian, Louise Pellerin, and George Jiracek for their advice and suggestions.

Figures:

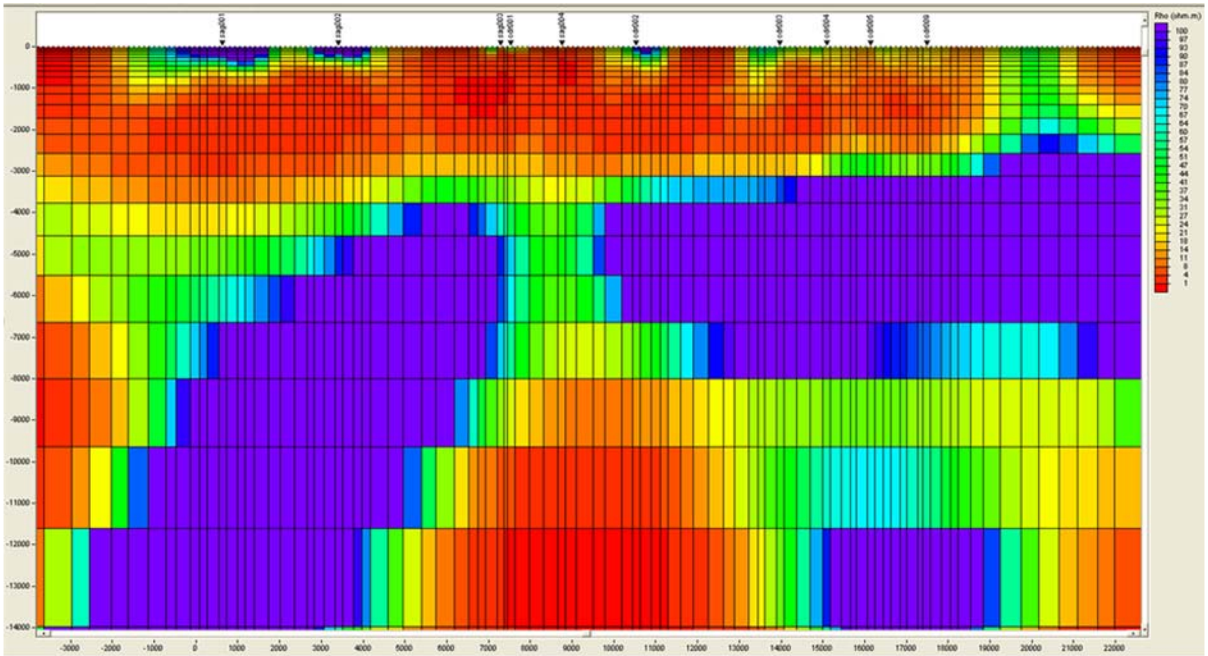

Figure 1: Initial model from suggested parameters

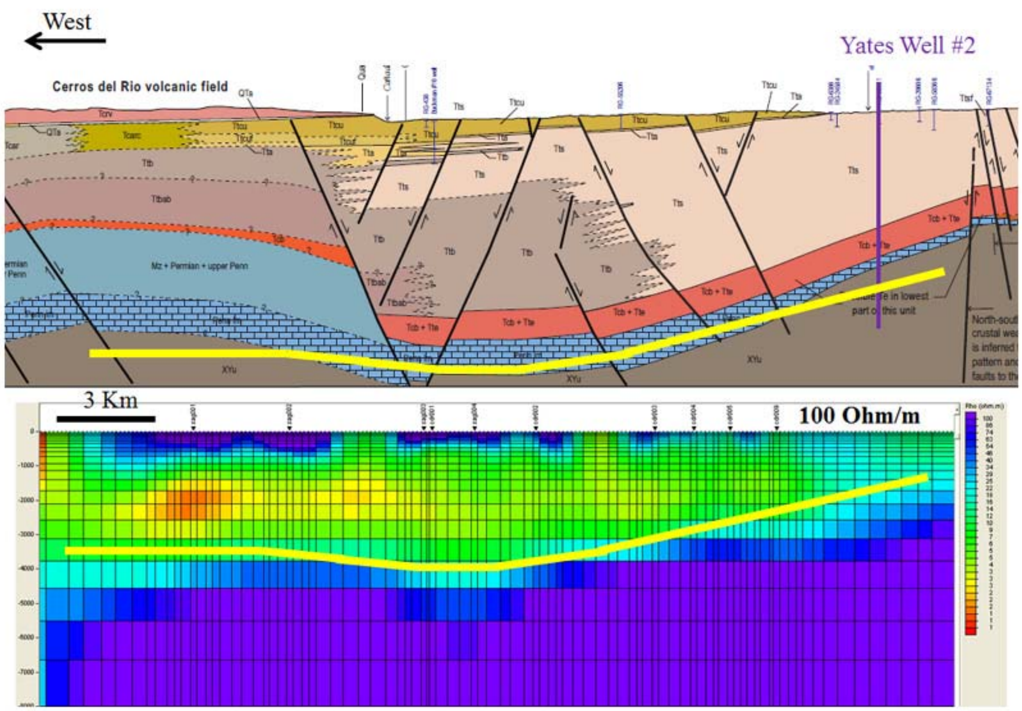

Figure 2: Possible alignment of bowl feature

Table 1: WinGlink 2D Inversion Settings

Inversion	TE & TM modes, ρ, ϕ
Minimum Frequency	.001 for all
Decades	5.00 for all
	used section data
Smooth Inversion	smoothest model
	std. grid Laplacian
	min. integral Laplacian
Static Shift	Invert for static shift
	variance constraint = 5.0%
	damping constraint = 10,000.00
Data Errors	TE & TM ρ=10.00
	TE & TM modes ϕ= 5.0
	Tzy = 0.01
Error Floor	Initial:
	ρ=5.00%
	ϕ= 2.5%
	Phase Model:
	ρ=30.00%
	ϕ= 2.5%