Structural Framework of the Soda Lake Geothermal Field: An Optimized Composite Model Based on Well Lithology, Gravity, and Seismic Data*

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General Comments

The Soda Lake geothermal field is a blind, fault-controlled system located ~80 km east of Reno, NV, in the west-central Great Basin. It was first drilled to assess its potential for geothermal electricity production ~40 years ago, and it has been producing electricity for over 20 years. More than 28 deep wells are at and near the production site. Numerous geophysical surveys have been carried out in the area, including gravity (Figure 1), ground magnetics, MT, CSAMT, and 3D-3C seismic. The purpose of this study is to integrate well lithology, gravity, and seismic reflection data in order to accurately model the subsurface structural framework of the hydrothermal system.

Soda Lake Field

Structure

The Soda Lake field lies within the Basin and Range structural province, a few tens of kilometers east of the Walker Lane. This region is rich in geothermal sites, and regional-scale constraints on their occurrence are reasonably well understood. Most geothermal systems in the west-central Great Basin are associated with north- to northeast-striking, moderately to steeply dipping normal faults that are roughly orthogonal to the present-day regional extension direction (Faulds et al., 2004). The most productive fields are commonly found near the tips of these primary structures, not at their culminations. Intense geothermal fluid flow – hot and strong enough to make an individual system prospective for electricity production – is commonly localized by smaller structures that accommodate or transfer strain between the primary structures. Accommodation zones generate regions of enhanced local fracture density and tend to have subdued surface expression. Understanding them is critical for modeling subsurface fluid flow, but they are commonly poorly exposed.

Substantial evidence indicates the primary faults at the Soda Lake geothermal field strike north to north-northeast, roughly perpendicular to the contemporary extension direction. Preliminary work with cuttings and seismic data supports this model; all evidence indicates the field lies within a graben, bounded on the west by a N-S-striking, east-dipping normal fault that dies off to the south, and on the east, by a NNE-striking, west-dipping normal fault that terminates to the north. Preliminary interpretation of well-log lithology, gravity and seismic data indicates that the field lies within an accommodation zone between these overlapping, antithetic faults.

While the regional-scale (1-5 km) structural setting at Soda Lake is understood, production-scale controls on fluid flow, such as the geometry of the lesser faults and the local stress regime, are still poorly characterized. A key challenge in assessment of the Soda Lake field is that it lies under hundreds of meters of unconsolidated basin fill, with few surface expressions of the fluids or the structures that guide their circulation. The Soda Lake geothermal system must be characterized remotely via information from wells and geophysical surveys.

3D Model

We developed a 3D model of the structural setting at Soda Lake, as follows:
1) re-logged archived drill cuttings (50,000+ feet or meters or what? chips)
2) obtained a coherent subsurface stratigraphy based on chip logging
3) checked and cross-correlated the stratigraphy observed in cuttings with borehole geophysics
4) worked iteratively where possible – with borehole geophysics and chip logs – to expand the stratigraphic interpretation throughout and beyond the well field
5) crafted a 3-unit density model of the subsurface based on this stratigraphic model
6) incorporated the well-log-based rock density model and the microgravity survey into Oasis GM-SYS
7) integrated the density-unit model to the gravity in 9 cross-sections (e.g., Figure 2)
8) compared these stratigraphically constrained gravity cross-sections with vertical slices pulled from the 3D-3C seismic dataset
9) used the gravity-based, 2D interpretations to prioritize fault picks in the seismic reflection dataset.

This latest structural/stratigraphic model of the Soda Lake geothermal field is comprehensive, constrained by many different types of data. It is intended to facilitate efforts to expand production at the power plant and to provide a template for successful future drilling. It may also aid interpretive efforts at other recognized geothermal fields and undeveloped geothermal sites, particularly those that are blind or hidden within the central parts of basins. The model will be used in conjunction with thermal gradient, MT, and CSAMT datasets to estimate optimal flow paths for geothermal fluids at the Soda Lake geothermal field.

Reference Cited

Faulds, J.E., M. Coobaugh, G. Blewitt, and C.D. Henry, 2004, Why is Nevada in hot water? Structural controls and tectonic model of geothermal systems in the northwestern Great Basin: Geothermal Council Transactions, p. 649-654.

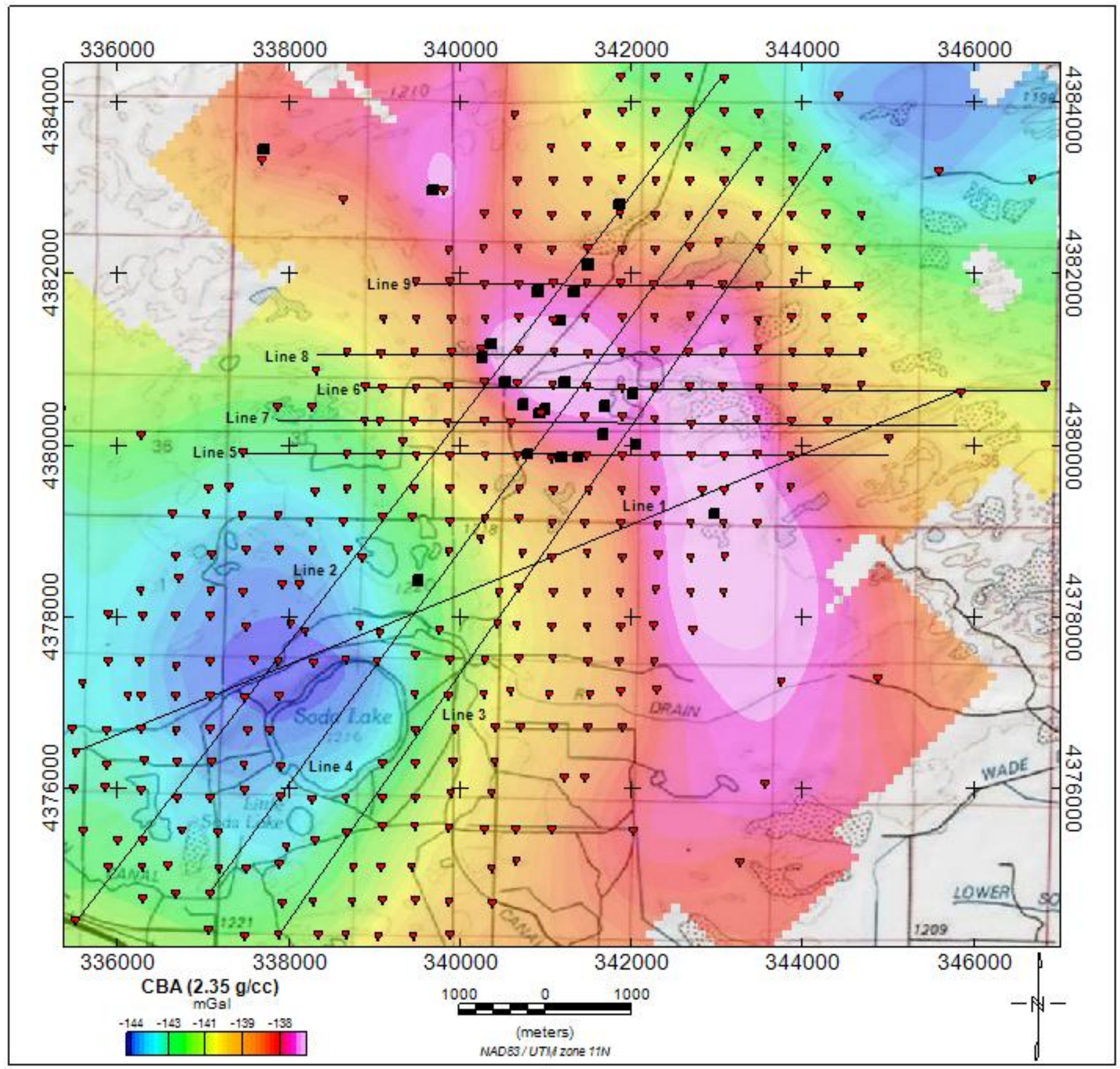

Figure 1: Color contour map of the complete Bouguer anomaly gravity data (reduced to 2.35 g/cc). Red inverted triangles are gravity stations. The Soda Lake geothermal field is at the center of the image. Black lines (Lines 1-9) depict gravity model profiles interpreted using Geosoft Oasis Montaj and GM-SYS geophysical modeling software, lithologically constrained by well data. Wells used to generate the rock density model are indicated with black squares.

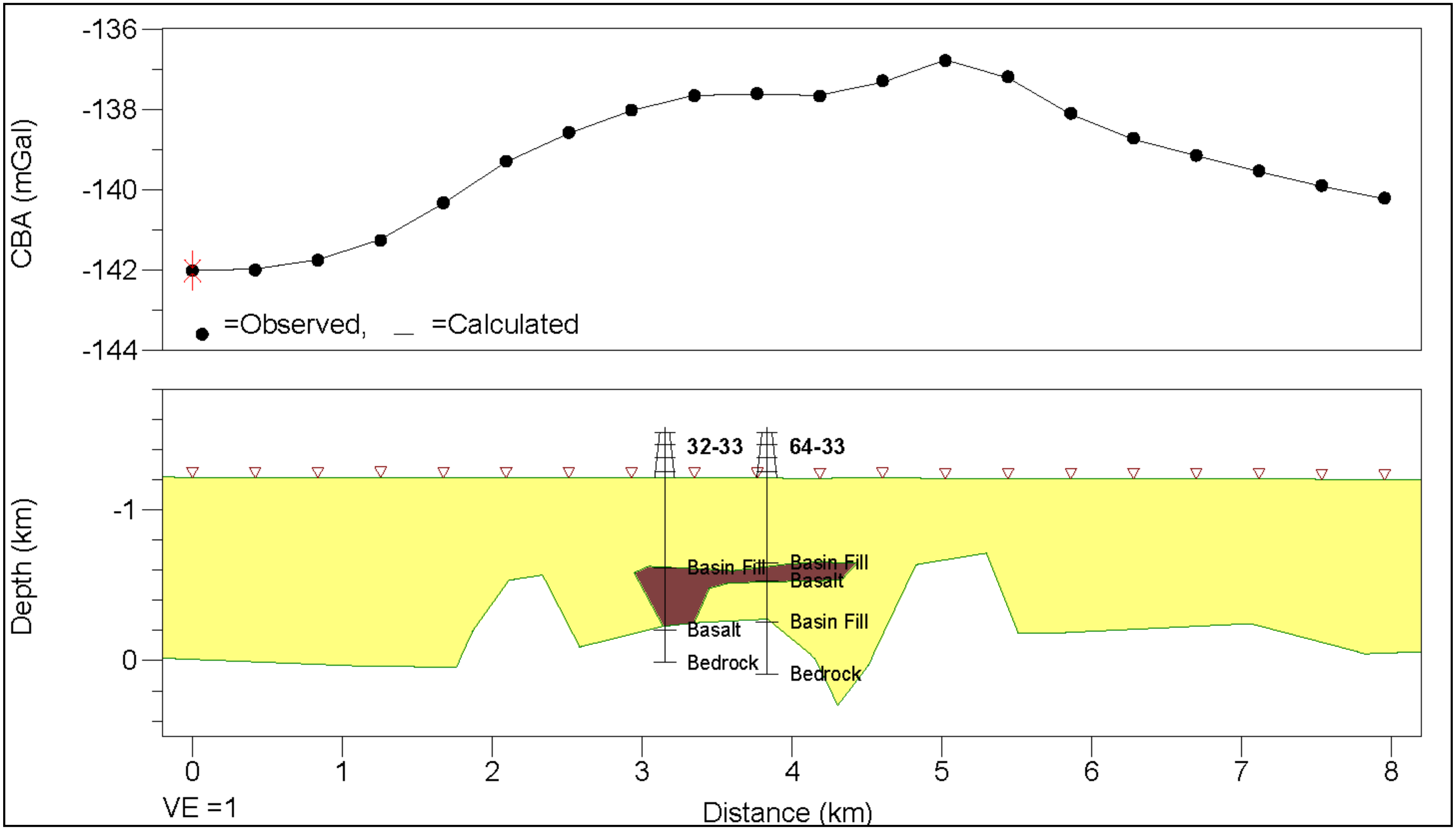

Figure 2: Line 7 cross-section (from Figure 1). Gravity fit displayed in top panel; geologic model in bottom panel. Well control indicated with derricks; gravity stations indicated with inverted pink triangles. Density blocks: Yellow= unconsolidated basin fill, 2.1 g/cc; brown = 5.1 Ma basalt body, 2.6 g/cc; white = bedrock, 2.67 g/cc.