A Subsurface 3D Model of Basin Geometry and Fault Architecture at the Dixie Meadows Geothermal Prospect Based On Potential Field Geophysical Data*

Paul C. Schwering[1], Robert E. Karlin[1], Patricia H. Cashman[1], Ashton N. McGill[2], and Wendy M. Calvin[3]

Search and Discovery Article #120145 (2014)
Posted February 25, 2014

*Adapted from extended abstract prepared in conjunction with oral presentation at AAPG Hedberg Conference, 3D-Structural Geologic Interpretation: Earth, Mind and Machine, June 23-27, 2013, Reno, Nevada, AAPG©2013

[1]Department of Geological Sciences and Engineering, University of Nevada, Reno, NV, USA (p_schwering88@hotmail.com)
[2]ARANZ Geo Limited, Christchurch, New Zealand
[3]Great Basin Center for Geothermal Energy, University of Nevada, Reno, NV, USA

Abstract

The western Basin and Range province contains an abundance of geothermal systems that are structurally controlled; in many cases, the controlling faults have little or no surface expression (i.e., blind faults) (Coolbaugh et al., 2006). 3D characterization of these faults is a crucial step in exploration and potential development of these resources. The Dixie Meadows geothermal prospect is located ~150 km east-northeast of Reno, Nevada, USA (Figure 1A). It lies within an active, primarily north-northeast-trending, range-front fault zone between the Stillwater Range to the west and Dixie Valley to the east (Figure 1A). Geothermal surface expressions, consisting of advanced argillic alteration, fumaroles, and hot springs, are indicative of a potentially productive geothermal reservoir. Joint geophysical modeling of potential field data indicates that multiple normal faults of differing age and orientations, many of which are blind faults, are controlling geothermal fluid flow at depth.

Geological units (summarized in Figure 1B) exposed on the Stillwater Range footwall of the range-front fault zone consist primarily of Oligocene ash-flow tuffs. The tuffs unconformably overlie magnetized Jurassic volcanic rocks that are tectonically intercalated with older Mesozoic sedimentary and metasedimentary basement. These units are down-dropped on the Dixie Valley hanging wall, and are covered by unconsolidated erosional basin fill.

The relatively low density of the basin fill and relatively high magnetic susceptibility of the Jurassic volcanics are mappable with gravity and magnetic potential field techniques, respectively. This study comprises ~150 square kilometers of potential field data coverage from 80 aeromagnetic transects flown by the USGS in 2002 and from 516 gravity stations acquired in 2010 by Zonge Geosciences for Ormat Technologies (Figure 1B). Reduced-to-pole (RTP) magnetic data reveal a distinct relative magnetic low, indicating an apparent discontinuity of the Jurassic volcanics. Complete Bouguer anomaly (CBA) gravity data, reduced to 2.35 g/cc, in the basin contain strongly linear horizontal gradients, suggesting that subsurface faults are present.

In order to integrate and structurally assess the gravity and magnetic surveys, 2.5D joint forward modeling of both data sets was performed using Geosoft's GM-SYS Profile Modeling software. Basin geometry and faulting were modeled with the gravity data by using a 0.6 g/cc density contrast between basin fill and bedrock. A magnetic susceptibility of 0.006 CGS associated with Jurassic volcanics delineates faults in bedrock (Figure 2). Results from the joint modeling profiles are incorporated into a single 3D model of basin geometry and fault architecture using the Leapfrog Geothermal program by ARANZ Geo Limited.

Joint modeling presents evidence for normal faults within the Dixie Meadows basin. Modeling of the gravity data, supported by available well data, indicates a basin thickness of >1 km in the basin center, abruptly decreasing to within 500 m in a 1-2-km-wide zone (the intrabasin) on the basin margin adjacent to the range-front (Figure 2). Magnetic modeling reveals discontinuous Jurassic volcanic units that are down-dropped basinward (Figure 2). Jointly modeled on multiple profiles, the potential field data indicate 1) relatively small (<200 m) total fault offset on the range-front, 2) large offset (>600 m) on a blind piedmont fault zone sub-parallel to the range-front fault, and 3) intermediate offset on short, blind intrabasin faults (Figures 1B & 2).

Exposed range-front and geophysically delineated blind faults have multiple orientations (Figure 1B). Faults along the range-front fault zone R_1 dominantly strike north-northeast and dip east-southeast, but there are also north-striking, east-dipping, right-stepping segments. Fault zone R_1 is deflected east-northeast into R_2 on the north end of Figure 1B. Joint modeling in the piedmont fault zone detects a similar pattern; north-northeast-striking, east-southeast-dipping fault 1 appears truncated by east-northeast-striking, south-southeast-dipping fault 2. Intrabasin faults 3, 5, and 6 strike north-northeast and dip east-southeast, and fault 4 trends northwest and dips southwest. The varied orientations of normal faults imply multiple generations of extension, the timing of which is being evaluated.

The interpreted model highlights a structurally controlled zone of geothermal activity in the subsurface. Joint modeling results indicate that faults 3 and 5 are blind fault splays. These faults are located near the intersection of faults 1 and 2, near the hot springs and fumaroles at the surface, and within a relative magnetic low anomaly (Figures 1B & 2). The thermal surface expressions and the magnetic low are laterally confined within faults R_1, 1, and 4. The magnetic low indicates a localized absence of Jurassic volcanics, conspicuously in the area of geothermal activity. Although a gap in the otherwise extensive Jurassic volcanics is possible, it is more likely that advanced-argillic hydrothermal alteration at depth has demagnetized the units and rendered them insensitive to magnetic measurements. Structurally, splaying faults 3 and 5 appear to promote geothermal fluid flow at depth, while faults R_1, 1, and 4 are lateral fluid-flow barriers. In broader context, the observed intersection of dominant north-northeast-striking faults with east-northeast-striking faults is a favorable geothermal structural setting, as has been found in other detailed studies (Faulds et al., 2004).

Joint modeling of potential-field geophysical data delineates a 3D system of otherwise undetectable blind faults that are critical in controlling hydrothermal fluid flow. This study provides a testable structural model for further exploration and potential development at Dixie Meadows and offers analogous insights and applications for defining blind structural controls of other prospective and known geothermal systems in the Basin and Range province.

References Cited

Coolbaugh, M.F., G.L. Raines, R.E. Zehner, L. Shevenell, and Williams, 2006, Prediction and discovery of new geothermal resources in the Great Basin: Multiple evidence of a large undiscovered resource base: Geothermal Resources Council Transactions, v. 30, p. 867-873.

Faulds, J.E., M. Coolbaugh, 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 Resources Council Transactions, v. 28, p. 649-654.

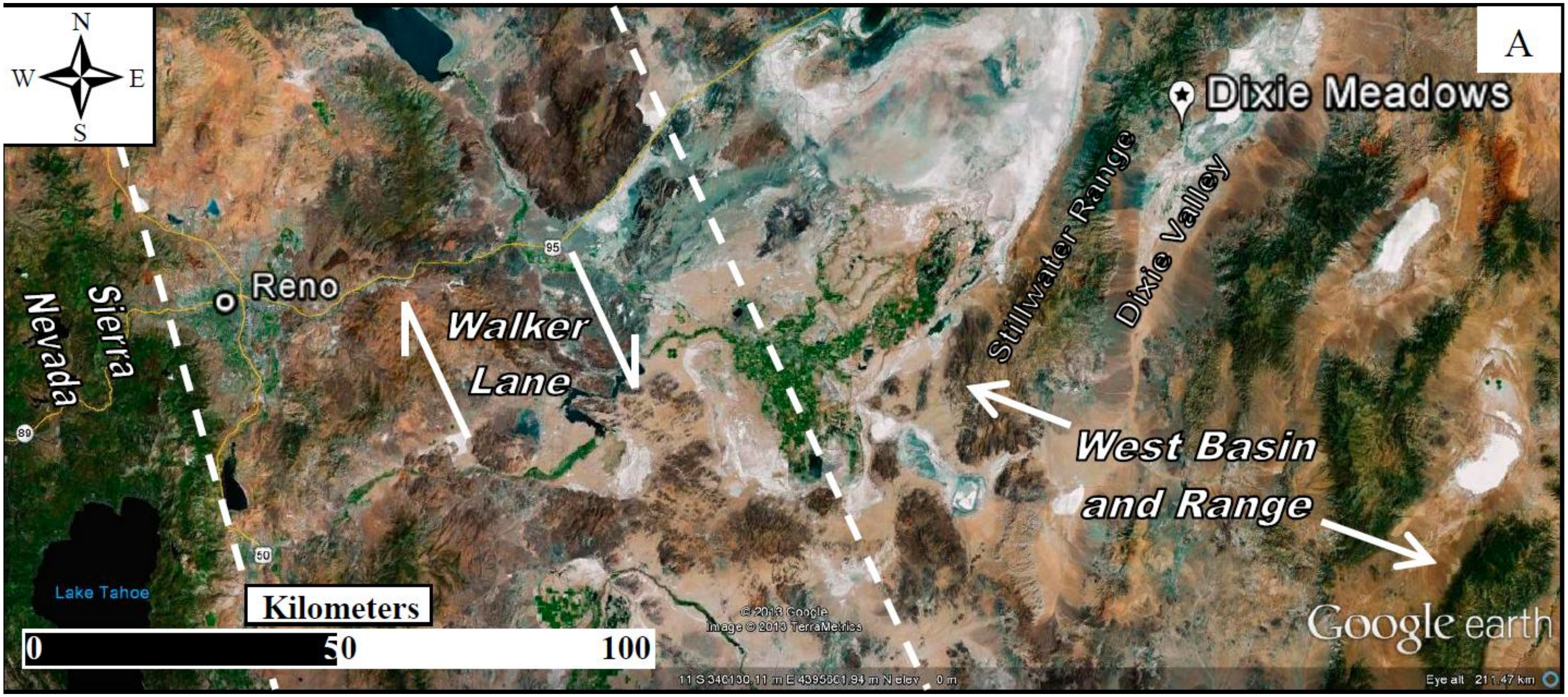

Figure 1. A. Index map showing the location of the Dixie Meadows study area and regional tectonic zones. From west to east are the relatively stable Sierra Nevada microplate, the Walker Lane zone of northwest-oriented dextral shear and the western Basin and Range province of west-northwest extension.

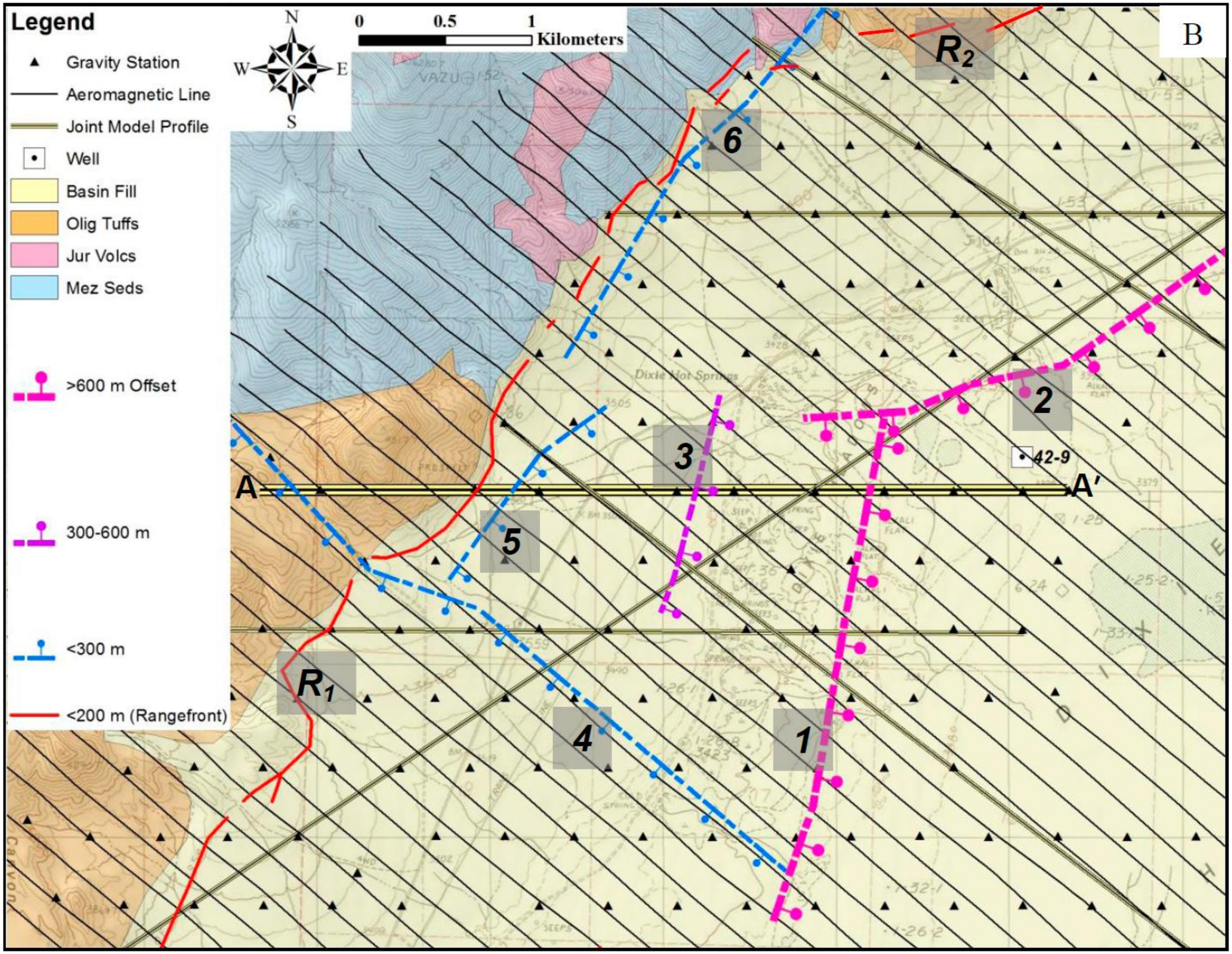

Figure 1. B. Summary geologic map of the geothermal area of interest in this study, featuring geophysical data coverage, model profile locations, geophysically delineated normal faults, and the surface traces of the range-front fault zone. Faults are labeled in grey boxes and are described in the text. Approximate fault offsets are determined from joint modeling results (i.e., Figure 2).

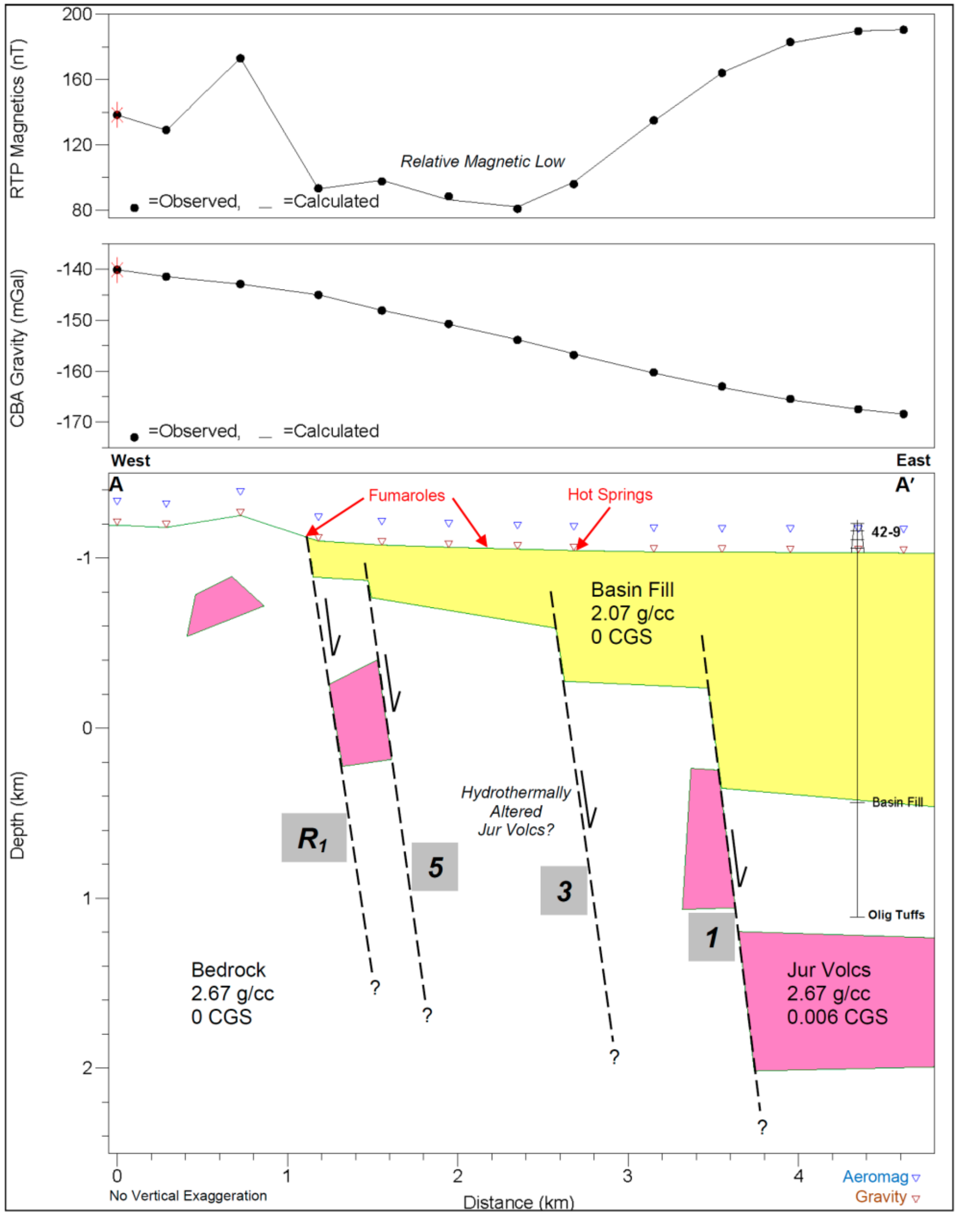

Figure 2. Sample model profile A-A′ (Figure 1B) displaying the magnetic data fit (top panel), gravity data fit (middle panel), and geologic model (bottom panel) highlighting normal fault offset of basin fill and Jurassic volcanic units. Note well 42-9 helps constrain depth to bedrock; the well bottoms-out in Oligocene tuffs. Approximate locations of geothermal surface expressions (red) are also shown for reference.