Citation: Bird, D. E., Coulibaly, K., Stieglitz, T., Jansen, J., and Marberry, K., 2025, Mojave Desert aquifer modeling via 3D gravity inversion: American Association of Petroleum Geologists & Society of Exploration Geophysicists, International Meeting for Applied Geoscience & Energy (IMAGE): GM 2.

Mojave Desert aquifer modeling via 3D gravity inversion

Dale E. Bird, Bird Geophysical; Kapo Coulibaly, Mojave Water Agency; Ted Stieglitz, John Jansen, and Kristen Marberry, Collier Geophysics*

ABSTRACT

The Mojave Block lies northeast and southwest of the respective San Andreas and Garlock Faults in southern California, encompassing the Eastern California shear zone, or the southern extension of Walker Lane (Figure 1). The groundwater basin in the block is the dominant water source for agricultural, domestic, and urban uses in the region. Understanding crystalline basement geometry and structures are critical factors for controlling estimates of aquifer thickness and groundwater flow.

We construct 3D gravity models of the Mojave Block, controlled by outcropping basement rocks, nearly 10,000 wells and three bedrock map interpretations, to produce a basement depth map. The standard Bouguer gravity correction density (2.67 g/cm^3) is backed out, then a new correction density is determined (2.72 g/cm^3) and applied via the "Nettleton method" (Nettleton, 1976). Outcrop polygons are extracted from surface geology shapefiles and integrated with topographic data to control the basement surface in these regions. Most of the wells are water wells with almost 500 penetrating the crystalline basement. Three previous bedrock interpretations of smaller areas within our study area are integrated into the 3D models. These control data, consisting of outcrops, wells and interpretation maps, are combined to build a constraining grid that limits the inversion algorithm's ability to adjust modeled horizons.

Our 3D model computations are performed in Seequent's *Oasis Montaj* GMSYS-3D potential fields modeling module. Forward and inverse solutions are computed in the Fourier domain, following equations presented by Blakely (1995). Sedimentary rock density is represented by an exponential decay function (Cordell, 1973) that follows layer densities converted from seismic refraction velocities (Ludwig et al., 1971; Biehler, 2002). We use crystalline crust layer densities from a Los Angeles Regional Seismic Experiment (LARSE-1) regional 2D gravity model (Romanyuk et al., 2007).

Our two-step workflow begins with a 3D gravity model that includes crustal and upper mantle layers. In this model we invert layer densities and horizons in the deepest part of the model: middle crust, lower crust, and upper mantle. We then subtract anomalies produced by these deep density contrasts from the observed Bouguer anomalies, i.e., long wavelength, high-amplitude anomalies. This method, known as gravity stripping, is an attempt to isolate anomalies produced by the basement surface in the model. Our second 3D gravity model includes only shallow layers: sedimentary basin and upper crystalline crust. Final inversions of this model make use of the stripped anomalies to invert the basement surface.

Two challenging aspects of this study are the quantity of model control data and the overall shallow depths to basement rocks. The inversion control data included many basement outcrop areas, thousands of wells – with hundreds of basement penetrations, and large portions of the study area covered by previous interpretations. Such extensive control limits the inversion algorithm's ability to adjust the basement surface. The sedimentary rock thickness in much of the study area is less than 500 feet, with small areas of thickness up to about 2000 feet. The final basement surface inversion therefore is able to only make modest adjustments. However, when cross-plotted against the basement well control, the coefficient of determination of the final basement (R^2) is 0.98; and the previous bedrock map interpretations were improved from: 0.68 to 0.98, 0.50 to 0.97, and 0.03 to 0.90. Our inversion results represent a uniform regional basin model that may be used to anchor planned detailed studies

Acknowledgements

We thank the Mojave Water Agency and Collier Geophysics for granting us permission to present this material. We also thank Seequent, creator of potential fields mapping, processing, and modeling software.

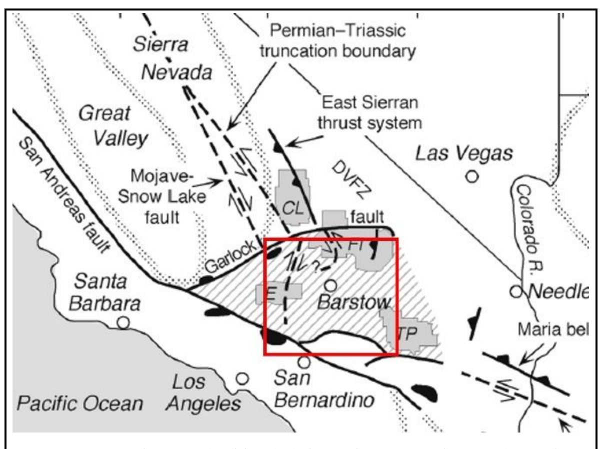

Figure 1: Study area (red box) (after Glazner et al., 2002). Mojave Block (diagonal gray lines), mapped and inferred faults (solid and dashed black lines), Death Valley Fault Zone (DVFZ), China Lake (CL), Fort Irwin Range (FI), Edwards AFB (E), and Twentynine Palms quadrangle (TP).

- Biehler, S., 2002, Seismic refraction studies, George Basin, San Bernadino County, CA, Appendix D: URS Corporation, 41 p.
- Blakely, R. J., 1995, *Potential theory in gravity & magnetic application*s: Cambridge University Press, 441 p.
- Cordell, L., 1973, Gravity analysis using an exponential density-depth function – San Jacinto Graben, California: Geophysics, v. 38, n. 4, p. 684-690.
- Glazner, A. F., Walker, J. D., Bartley, J. M., and Fletcher, J. M., 2002, Cenozoic evolution of the Mojave block of southern California: *in*, Glazner, A. F., Walker, J. D., and Bartley, J. M. (editors), *Geologic evolution of the Mojave Desert and southwestern Basin and Range*: Geological Society of America, Memoir, v. 195, p. 19-41.
- Ludwig, W. J., Nafe, J. E., and Drake, C. I., 1970, Seismic refraction: *in*, Maxwell, A. E. (editor), *The sea: ideas and observations on progress in the study of the seas*: Wiley-Interscience, v. 4, n. 1, p. 53-84.
- Nettleton, L. L., 1976, *Gravity and magnetics in oil prospecting*: McGraw-Hill, Inc., 464 p.
- Romanyuk, T., Mooney, W. D., and Detweiler, S., 2007, Two lithospheric profiles across southern California derived from gravity and seismic data: Journal of Geodynamics, v. 43, p. 274-307.