3D Gravity Modeling of Osage County, Oklahoma, with 3D Geology Interpretation

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Free-air gravity map of Oklahoma, the study area is in the inset box.

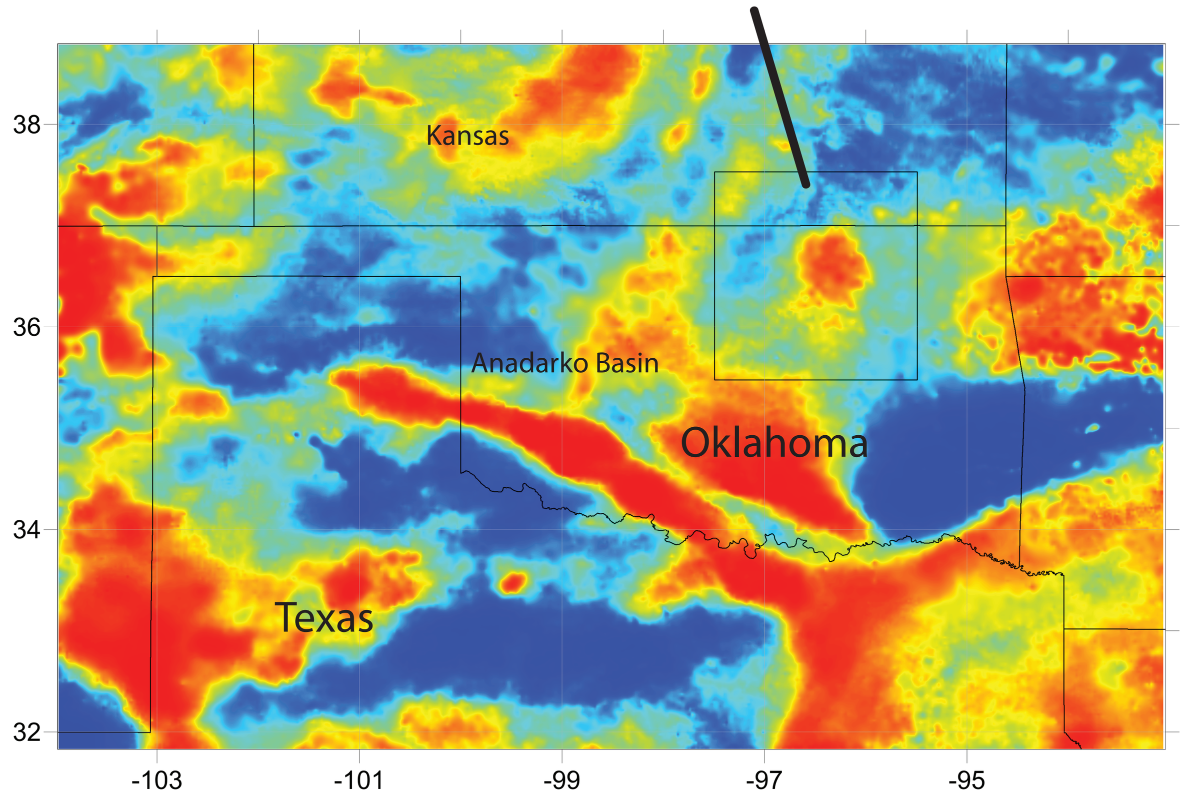


Figure 1. Index map.

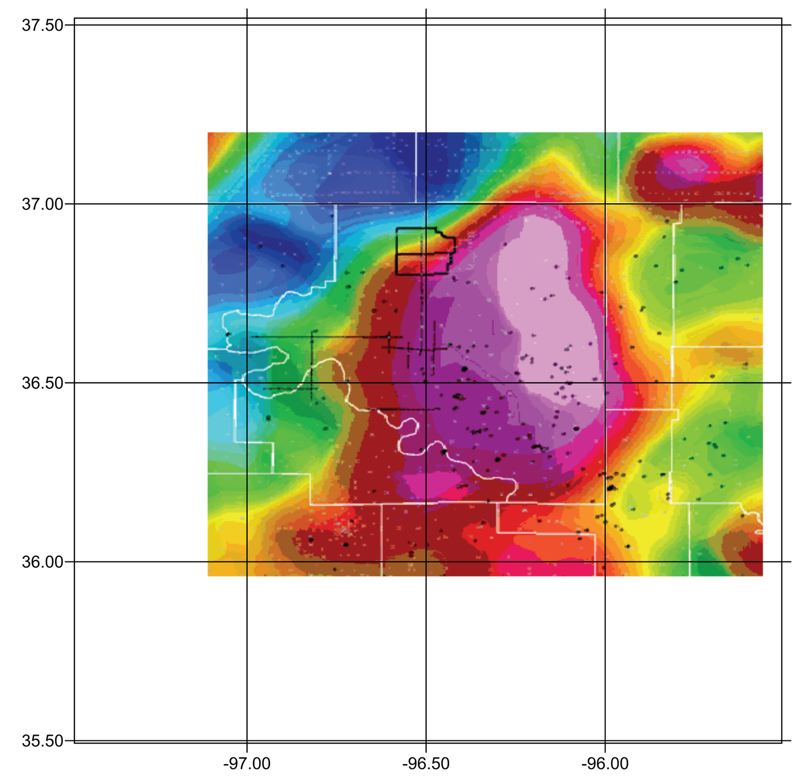


Figure 2. Residual Bouguer gravity.

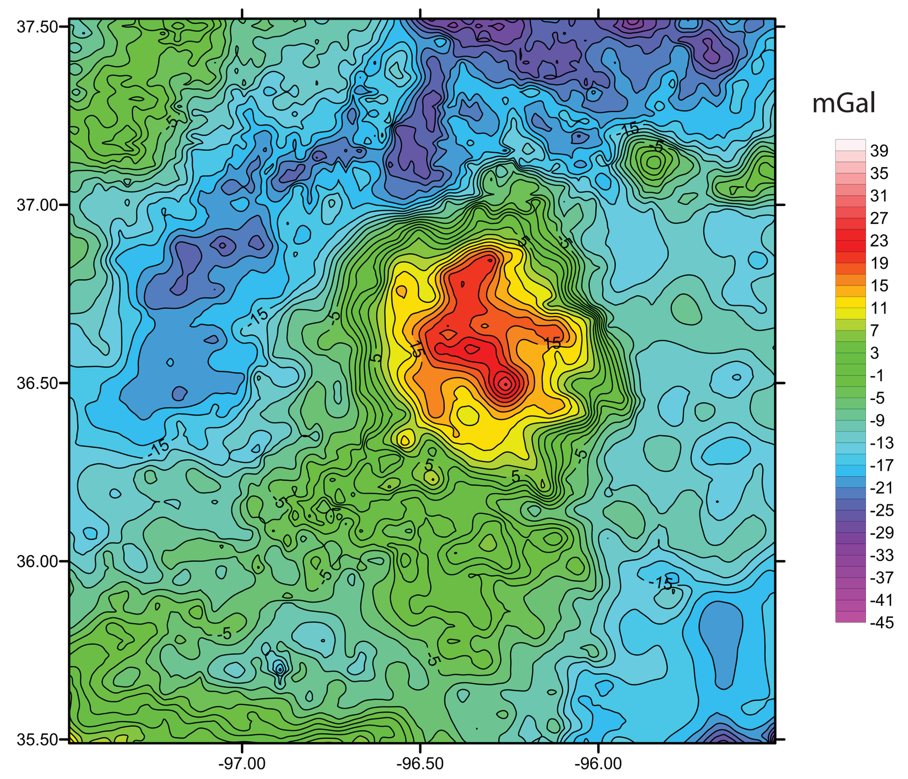
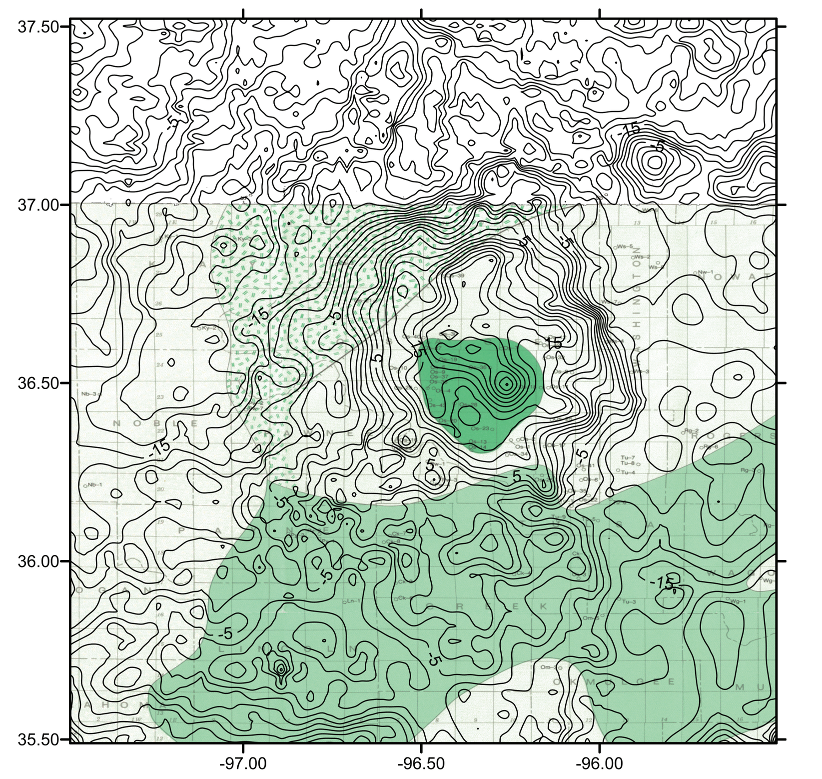


Figure 3. Observed Free-air gravity.



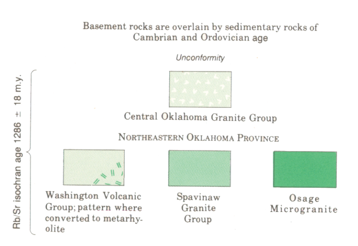


Figure 4. Free-air gravity over Precambrian basement geology.

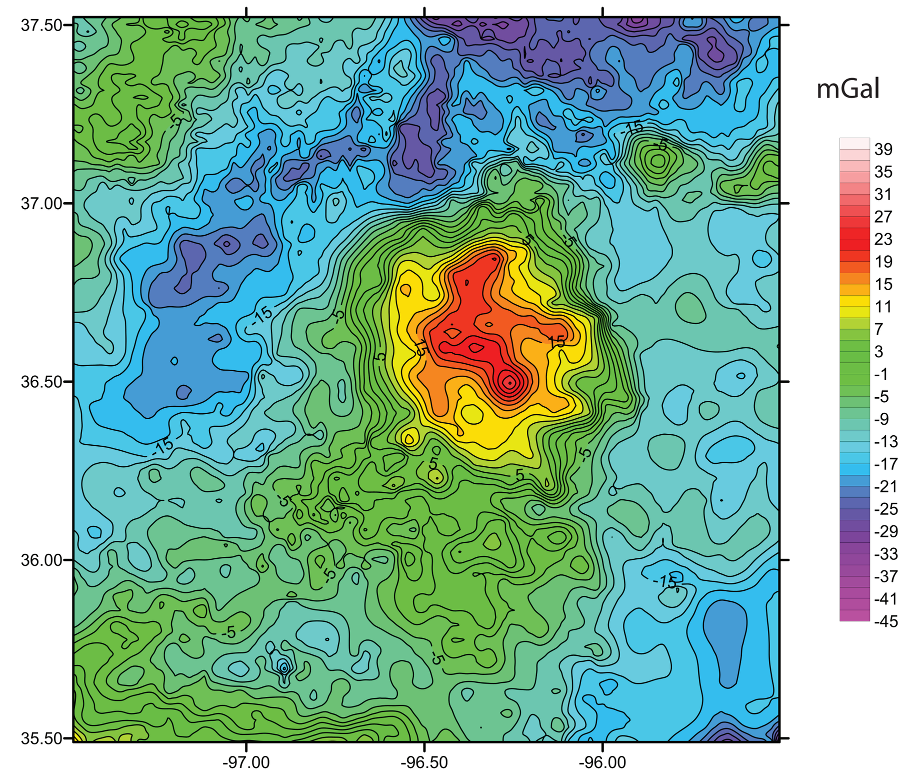


Figure 5. Observed Free-air gravity.

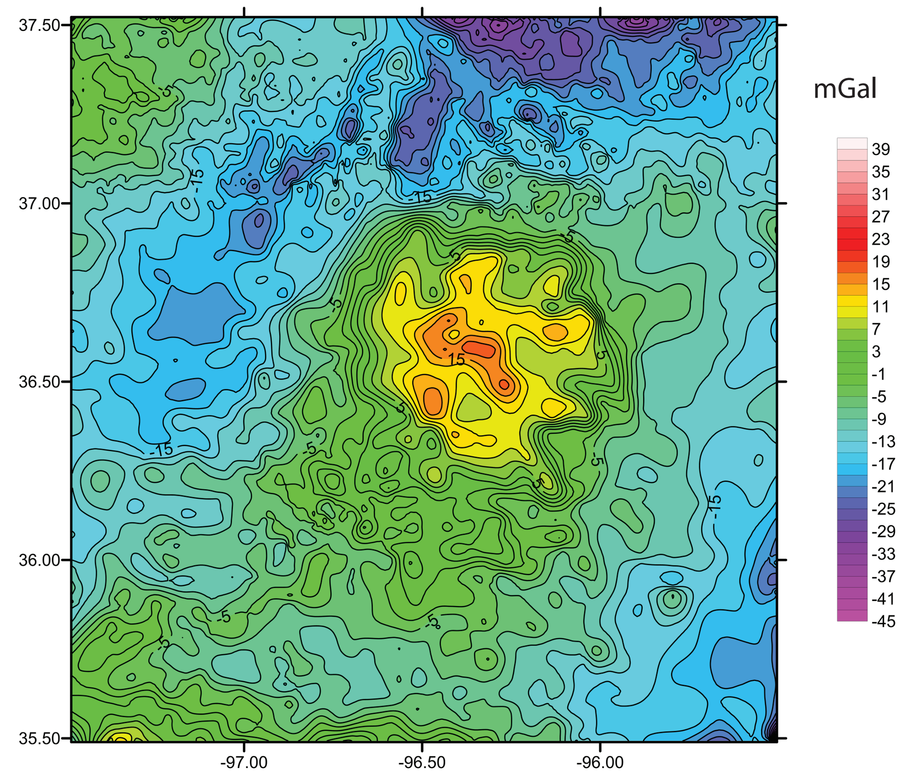


Figure 6. Estimated Free-air gravity anomaly from 3D geology model.

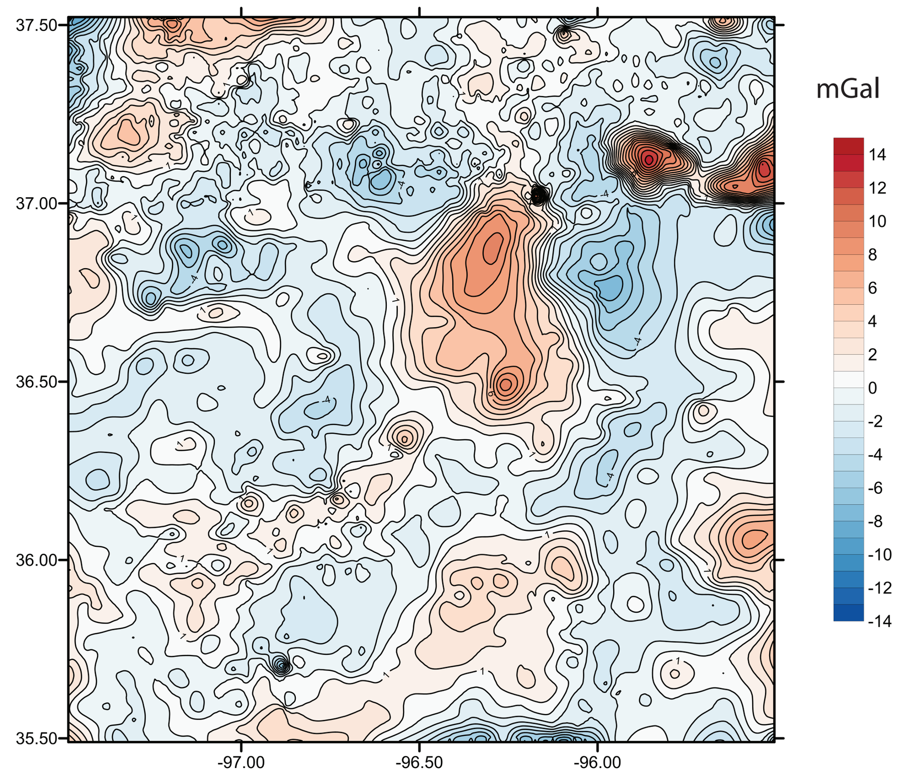


Figure 7. Residual Free-air anomaly, Gobs - Gest, (RFAA.) Anomaly

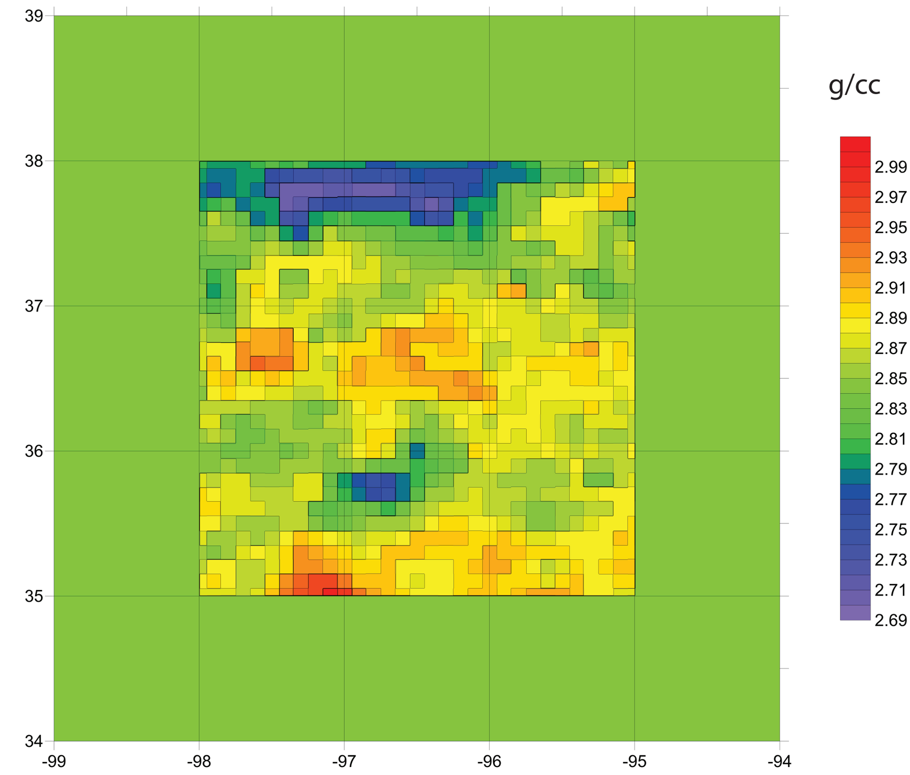


Figure 8. Density model used between -25 km and -45 km.

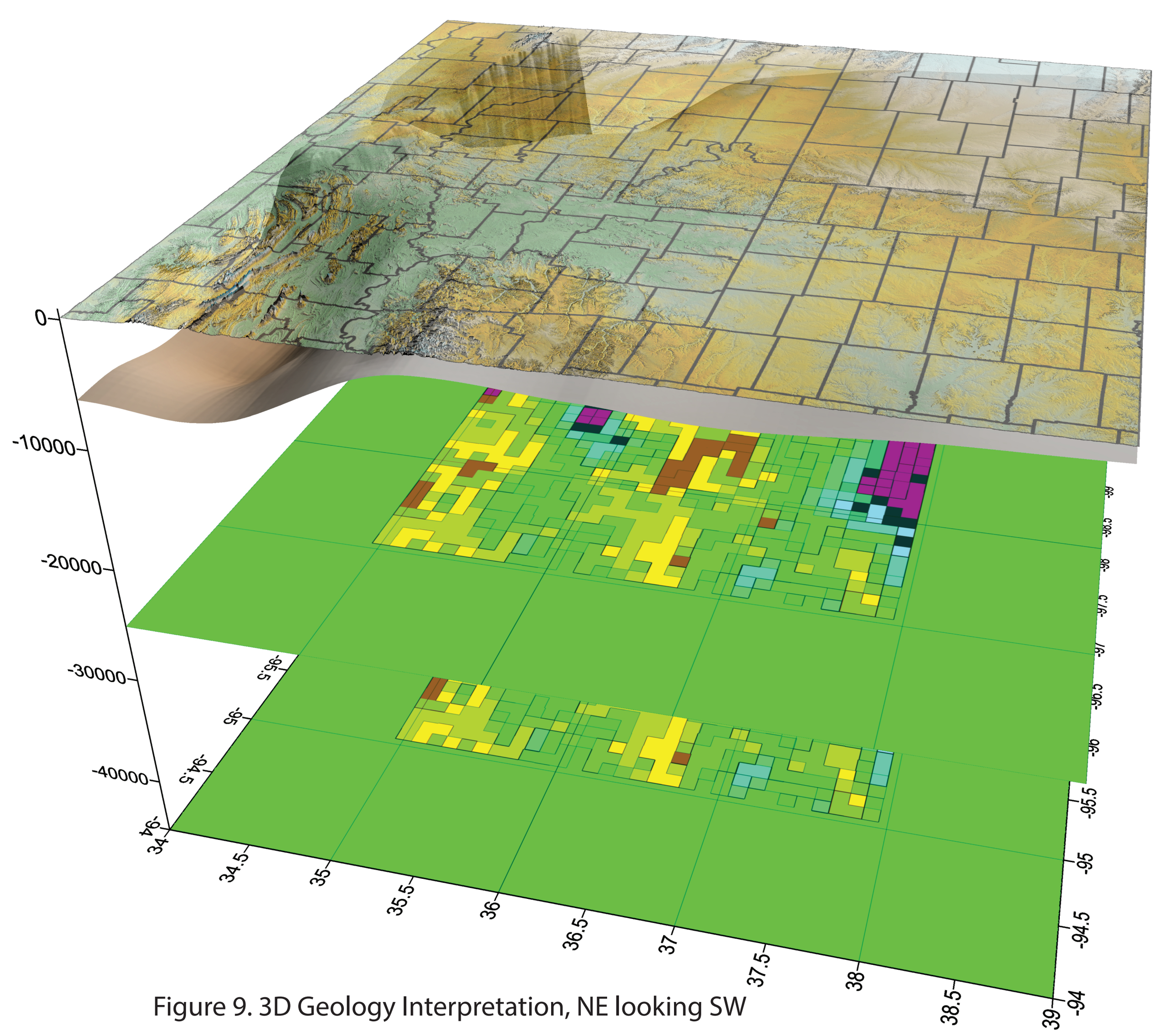


Figure 9. 3D Geology Interpretation, NE looking SW

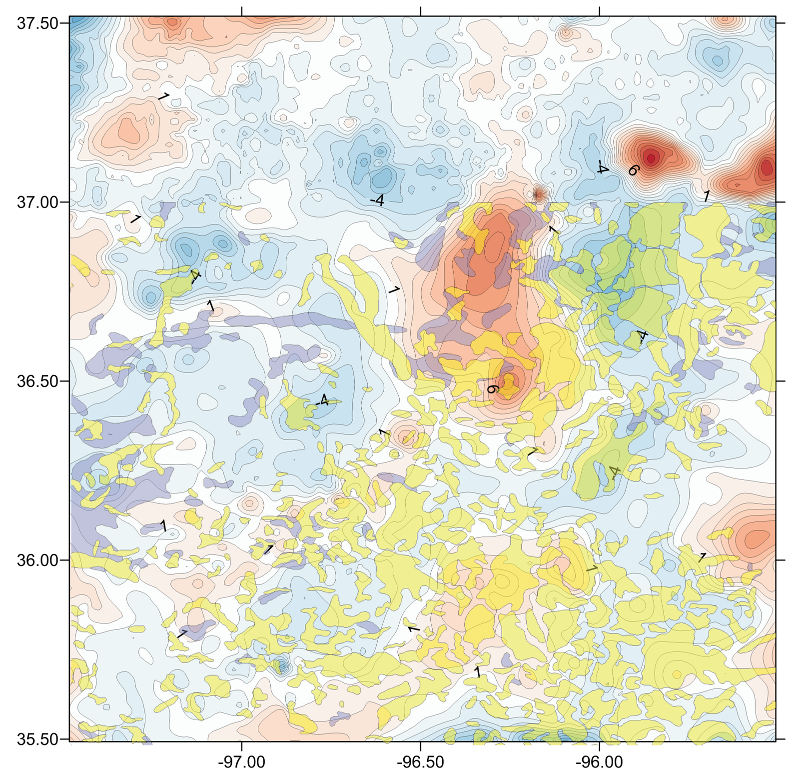


Figure 10. Red Fork sand and Mississippi Lime production zones. OGS, GM-38, Boyd, D., 2002

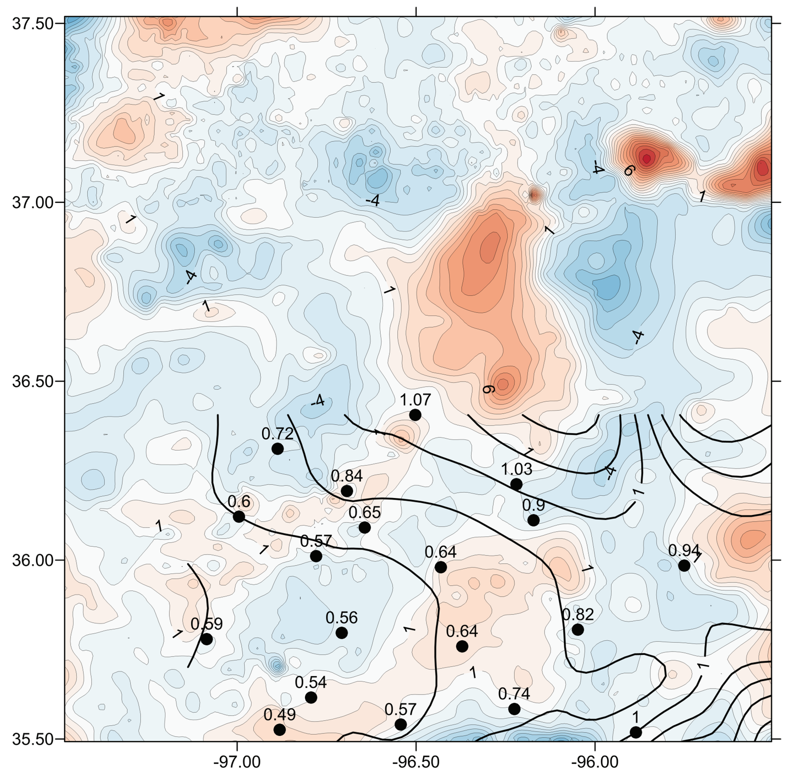


Figure 11. Vitrinite reflectance over residual Free-air anomaly.

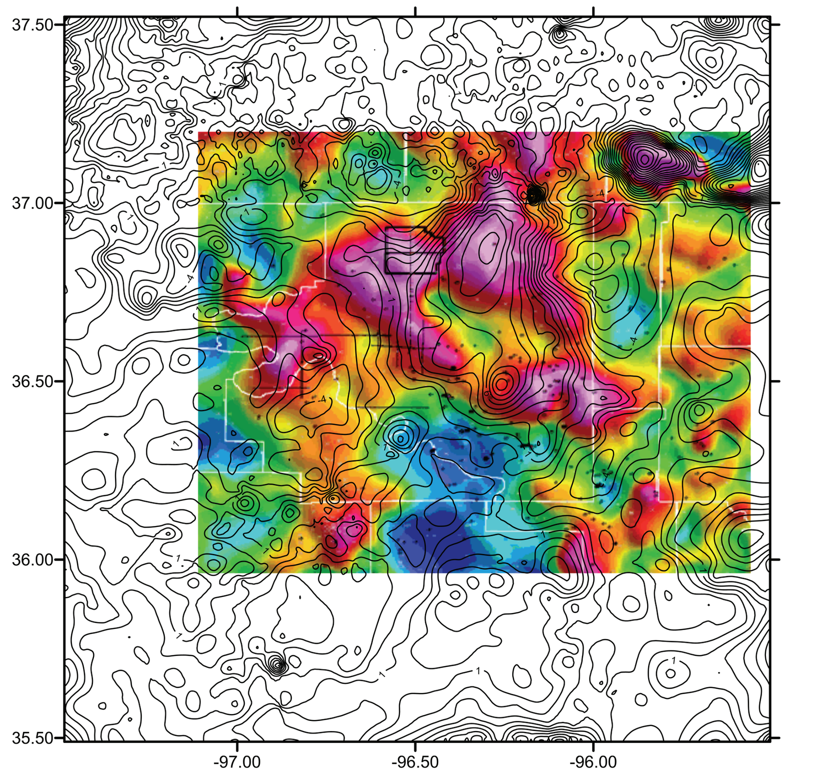


Figure 12. Residual Free-air anomaly over residual TMI anomaly.

Summary

New exploration challenges in complex regions demand 3D gravity modeling using representative and causal 3D geology interpretations. We present a simple 3D gravity model of Osage County in northeastern Oklahoma, Figure 1, where there is a greater than 40 mGal, 100 km diameter circular gravity anomaly that cannot be effectively removed by traditional gravity processing techniques, Figure 2.

The goal of this particular gravity interpretation is to enhance the signal of the geology above the Precambrian basement by minimizing the signature of an expected deep-sourced gravity field reflected in the observed Free-air gravity. The modeled gravity is the result of a density inversion using spatially distributed observed Free-air gravity data at their observation locations and the gravity effect of a geology-constrained 3D interpretation, Figure 9, using observed and expected geology. Individual components of the 3D geology interpretation can be modified and updated at any time to address the residual gravity anomaly.

The observed Free-air gravity, Figure 3, and, Figure 5, is the result of the instantaneous "local" density distribution. Therefore, the modeled Free-air gravity, Figure 6, is built with geologically consistent and constrained 3D geology interpretation at sufficient detail representing the necessary complexity of the Earth, Figure 9, while allowing for ease of calculating the model gravity field and geology interpretation. The residual Free-air anomaly (RFAA) is the difference between the observed Free-air and the estimated Free-air gravity, Figure 7.

The Geology Interpretation

This Osage County geology interpretation assumes simple "layer cake" geology, Figure 9, starting from the topographic surface to 45 km below mean sea-level. The elevation of the Precambrian basement topography and geology are constrained by drill–hole intercepts and geology, Figure 4, after OGS Cir-84. The expected deep crust high-density distribution extends from 25 to 45 km depth and reflects the large gravity anomaly, Figure 8. The basic density structure of the geology interpretation is:

1. Sediment above Precambrian basement 2.55 g/cc
2. Precambrian basement 2.67 g/cc
3. Lower crust 2.85 to 3.00 g/cc

Results

The estimated Free-air gravity, Figure 6, is the result of a density inversion of a 3D geology interpretation. The difference between the observed and estimated Free-air gravity is the RFAA gravity, Figure 7. To evaluate the results, we examined the observed Free-air gravity, the estimated Free-air gravity and the RFAA, Figure 5 to Figure 12, along with the expected geology interpretation, Figure 9. The level of complexity of the RFAA in Figure 7, reflects the multiple sources of gravity signature that can only be addressed by building correspondingly more complex geologic interpretations of:

- Basement structures.
- Complex density structures within the sediments.
- Complex density structures within the upper and mid-crust.

To illustrate, the RFAA shows correlations to Lower Red Fork sand and Mississippi carbonate production zones, Figure 10, throughout the sedimentary section. Mid-crust high-density igneous intrusions may address some of the "small" scale "high" amplitude anomalies in the residual Free-air anomaly. To support this hypothesis vitrinite reflectance values are increasing and curving around the under-compensated residual gravity anomaly (B. Cardott, personal communication, 2011), Figure 11, and the RFAA correlation to the residual TMI anomaly, Figure 12.

Conclusions

We have presented results for a simple, first pass 3D gravity model using an initial simple 3D geology interpretation. The estimated 3D Residual Free-air anomaly shows geologically consistent gravity signatures. The residual can be addressed with updated geology interpretations. Each of the individual components of the Osage County, OK, geology interpretation was built to test one or more geologic hypotheses. By updating one of the components of the geology interpretation, the validity of that individual component can be tested. One updated geology interpretation may include a mid-crust igneous intrusion addressing the gravity high (red in color, under-compensated in the geology interpretation) near the center of the survey area, the high vitrinite reflectance values, and corresponding residual TMI anomalies.