MAGNETOTELLURIC ANALYSIS OF THE MIDCONTINENTAL RIFT IN IOWA

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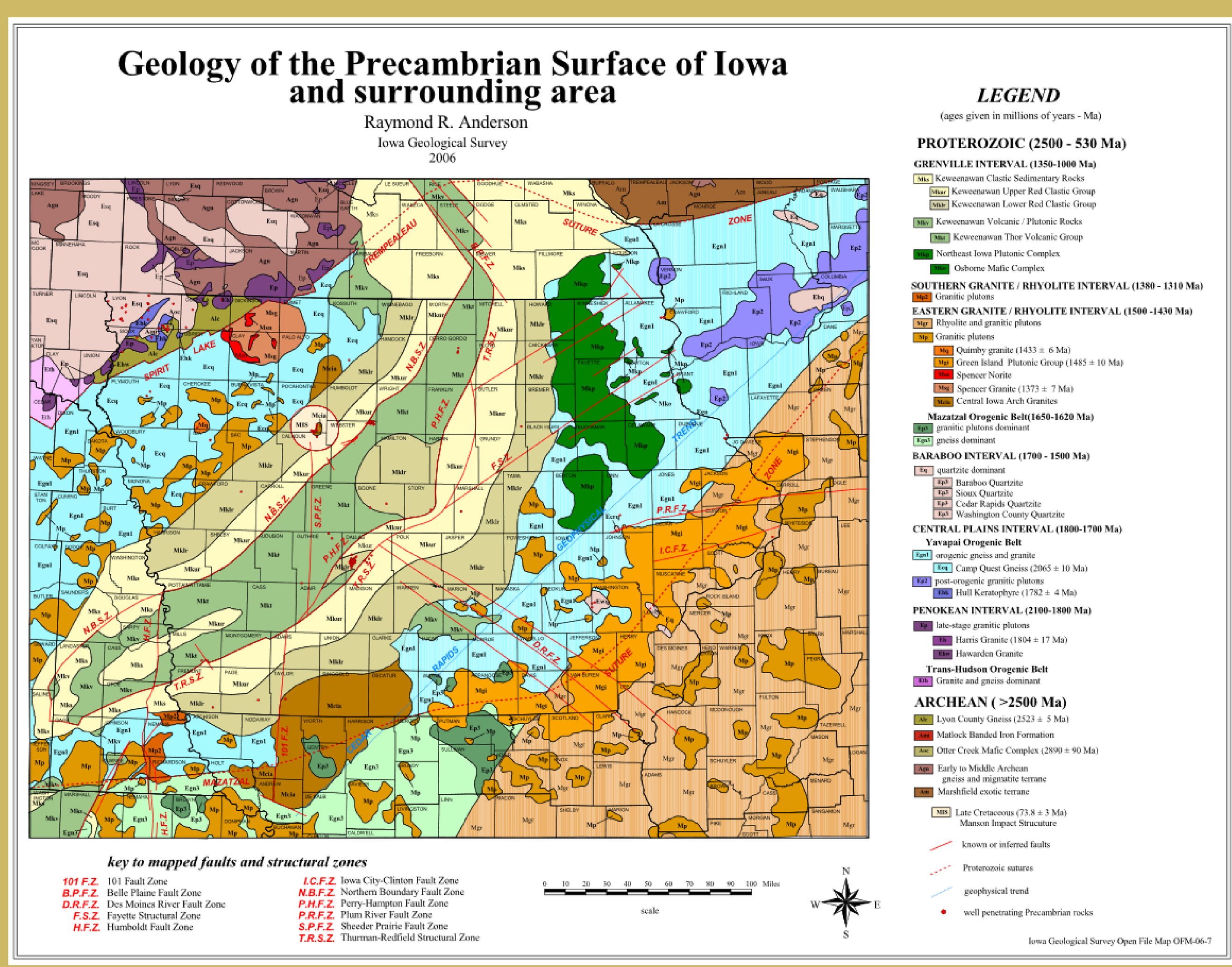
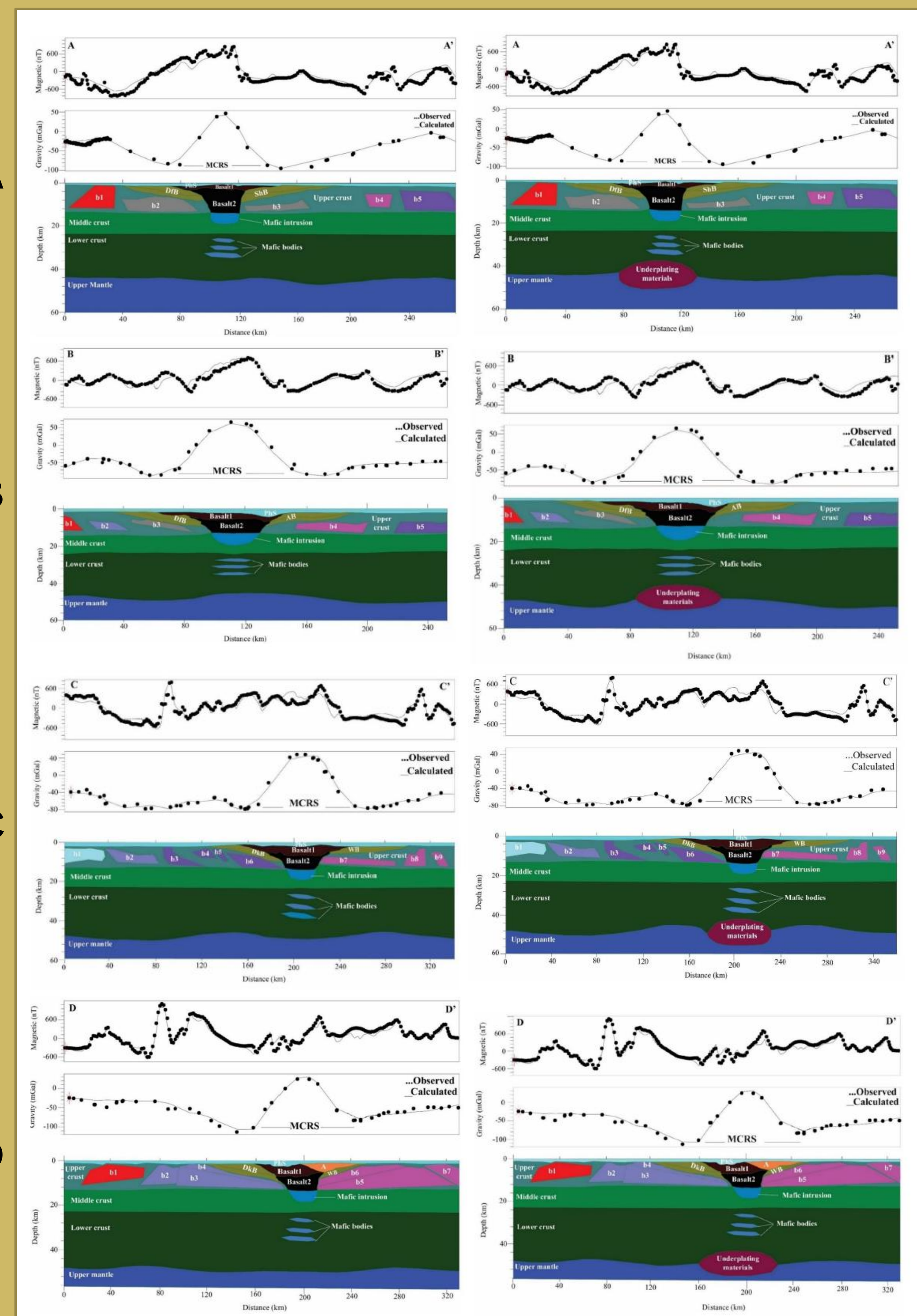
ABSTRACT

The Proterozoic Midcontinent Rift System (MCRS) formed 1.1 Gya as the result of a major tectonic event in the North American lithosphere. The 2,500 km MCRS spans from eastern Oklahoma to Lake Superior before curving southeast through Michigan, possibly stretching as far south as Alabama. Phanerozoic sedimentary cover prevents direct sampling of MCRS geology except within outcrops in the Lake Superior area and scattered drill holes. As a consequence, the MCRS is primarily characterized by extrapolations from outcrops and geophysical methods, including gravity, magnetic, broadband seismic, and seismic reflection profiles. Prominent gravity and magnetic anomalies define the rift due to its large volume of mafic rocks. Many questions remain about the origin of the MCRS. Some proposed theories include microplate interactions, mantle plumes, and passive rifting associated with the Grenville orogeny. In Iowa the rift cuts northeast to southwest through the state, which to date has only been investigated geophysically, with the most detailed being a gravity and magnetic study (Almaz, 2017) that investigated the lower crust and upper mantle structure of the rift. To further investigate this structure an analysis of EarthScope magnetotelluric (MT) data was undertaken. The data are long period (up to 20,000 seconds) collected from 41 stations with 70 km spacing, all located within Iowa and northeast Nebraska. The data were analyzed for dimensionality and geoelectric strike, then TE and TM mode data rotated for two-dimensional resistivity inversion along four profiles. A three-dimensional resistivity inversion was also completed using the ModEM software. The final two- and three-dimensional models will be compared here with previous gravity, magnetic, and broadband seismic tomographic models from the Earthscope seismic experiment within Iowa.



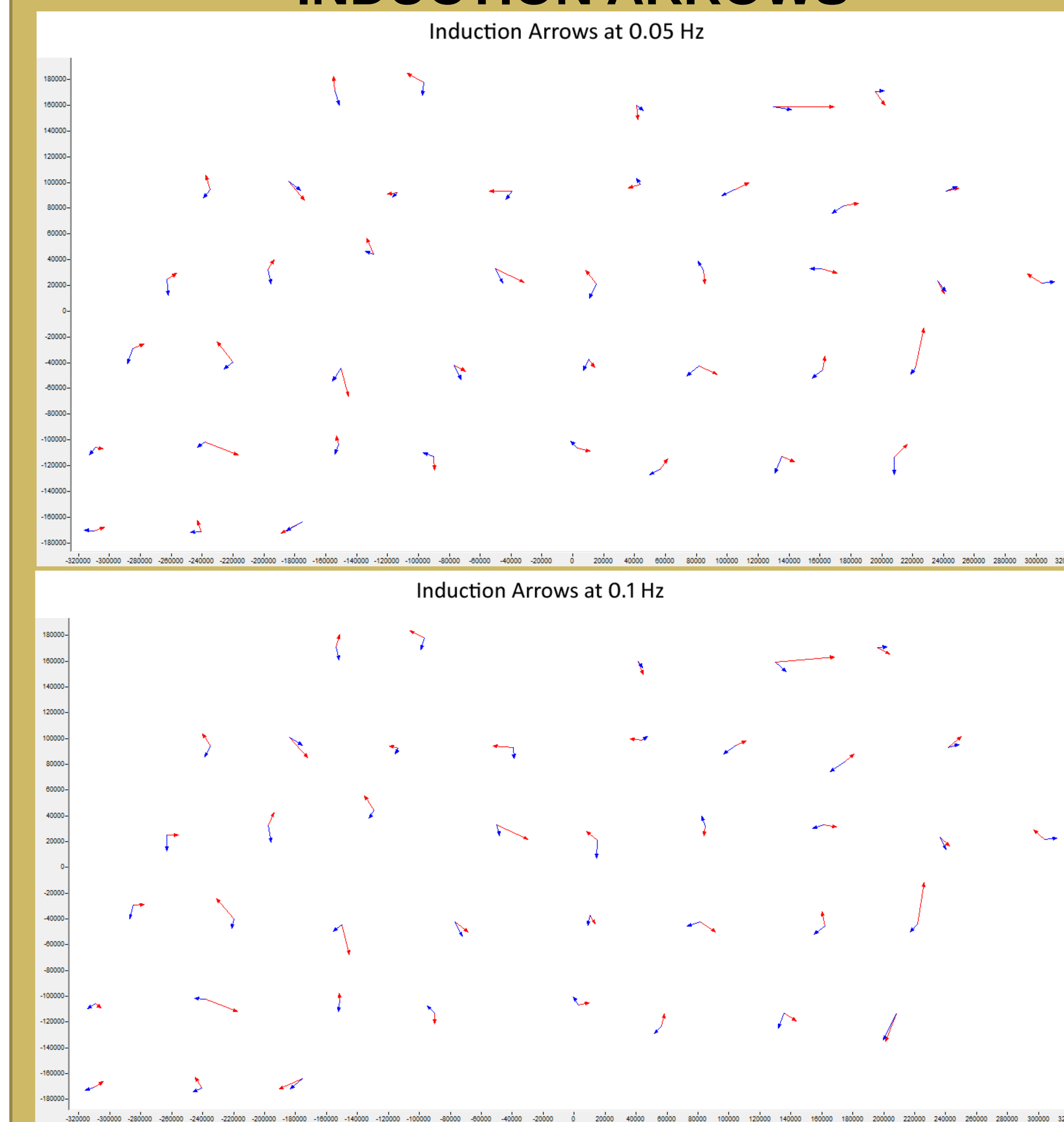
GRAVITY AND MAGNETIC MODELS

PROFILE



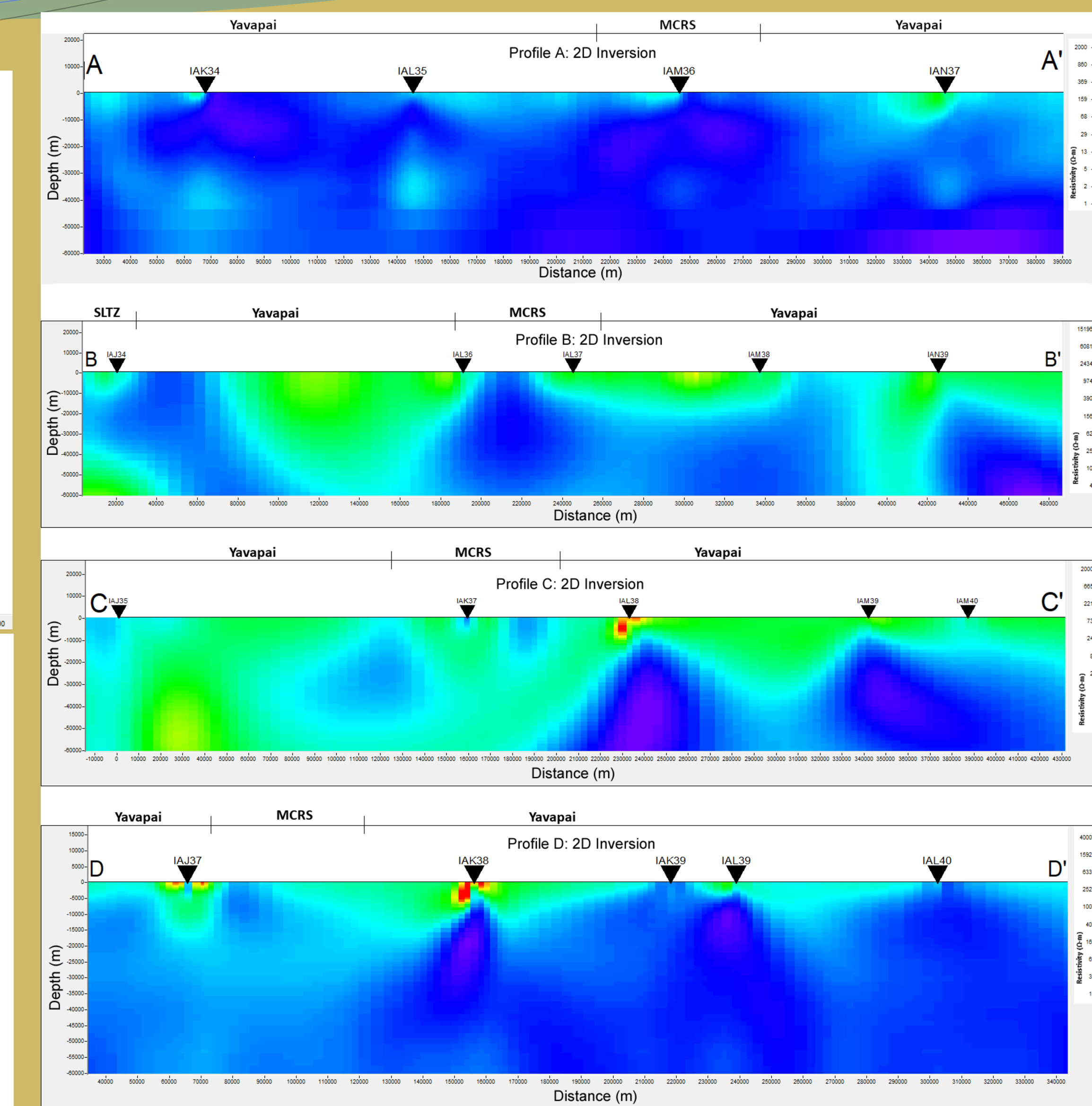
Gravity and magnetic models along profiles A, B, C, and D (adapted from Almaz, 2017).

INDUCTION ARROWS



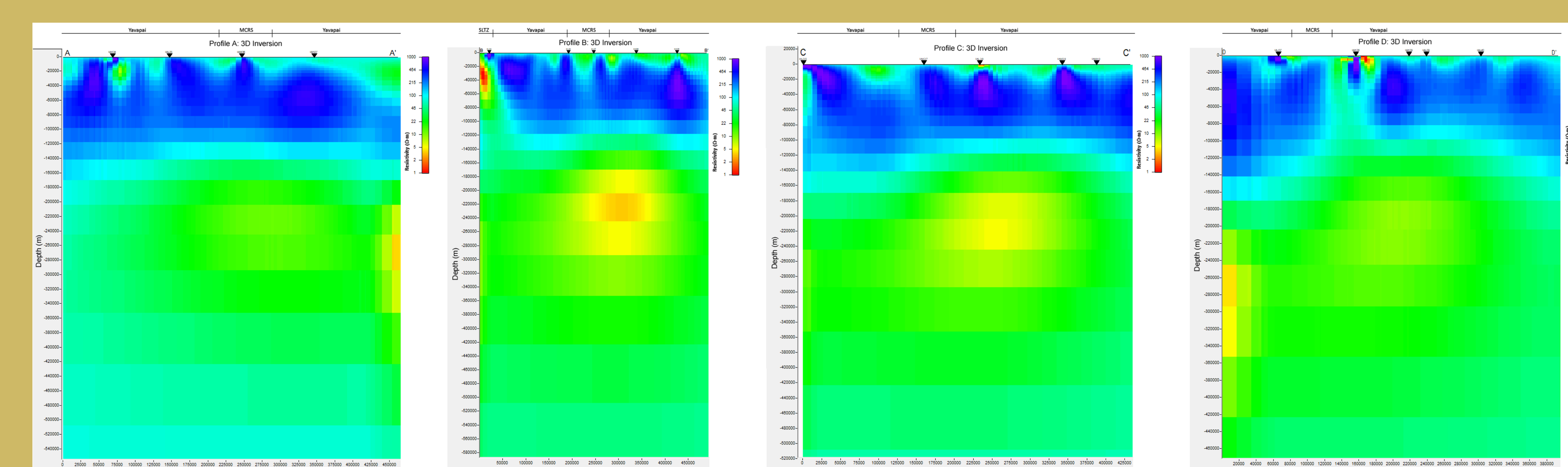
Induction arrows of the study area at 0.05 and 0.1 Hz. Red arrows are the real part, blue arrows are the imaginary part. Arrows are shown pointing away from conductors. Electrical properties of the subsurface of Iowa are highly variable.

2D INVERSIONS



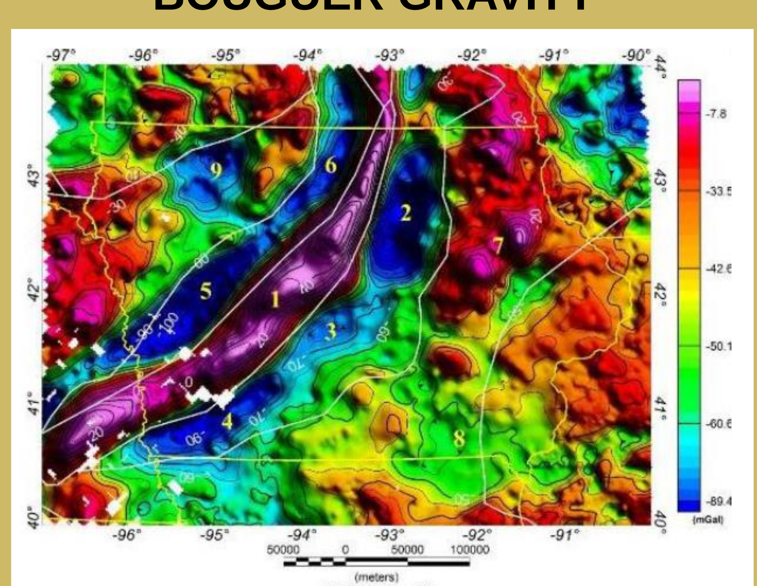
2-dimensional magnetotelluric inversion models along profiles A, B, C, and D using a robust inversion routine. These models are along the same profiles as the gravity/magnetic models.

3D INVERSION

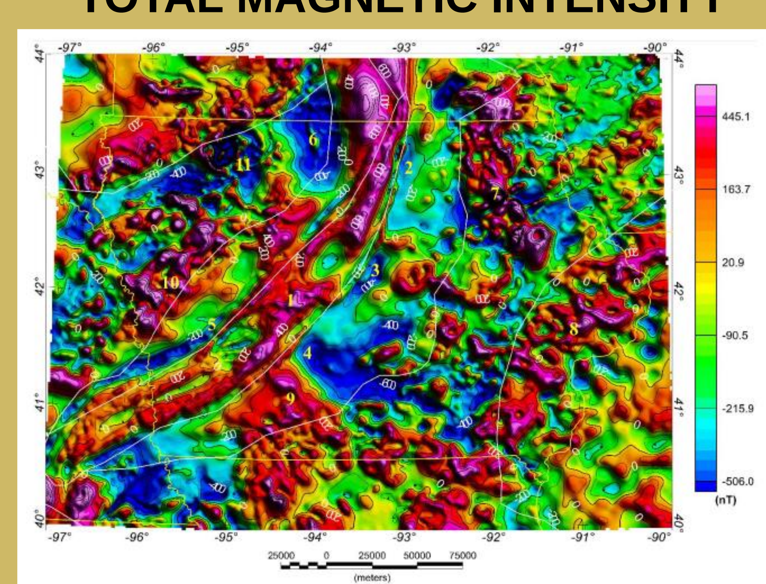


3-dimensional magnetotelluric inversion models along profiles A, B, C, and D using the ModEM magnetotelluric program. These slices are along the same profiles as the gravity/magnetic models and the 2D resistivity models. The low electrical resistivity regions mark the Asthenosphere, notice how the asthenosphere is shallow under the MCRS. The MCRS sedimentary basins are marked by low resistivities

BOUGUER GRAVITY

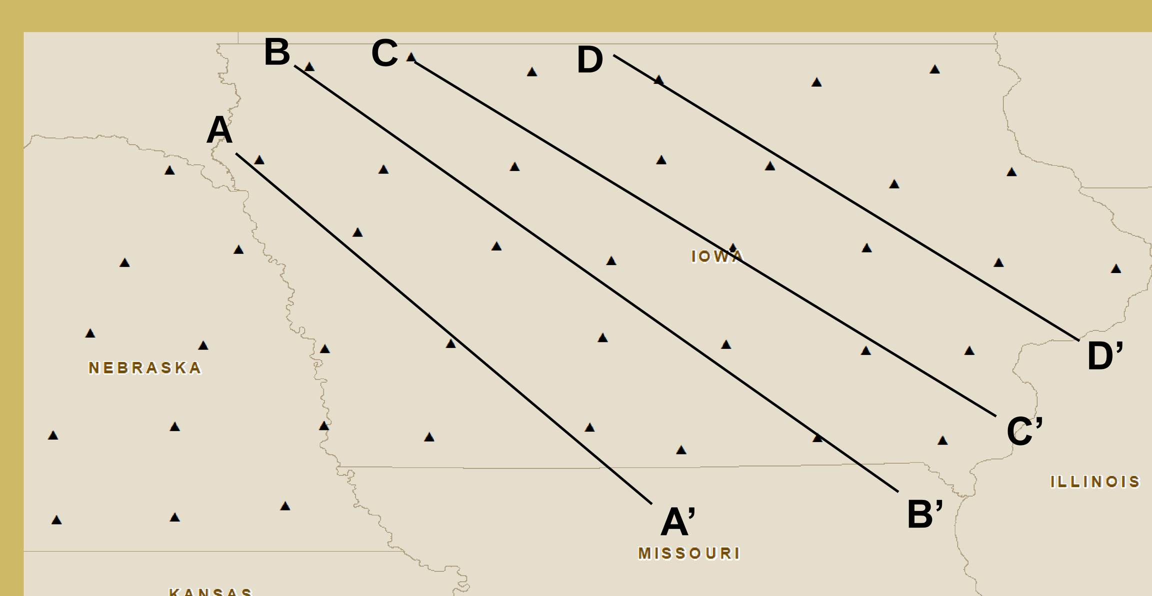


TOTAL MAGNETIC INTENSITY



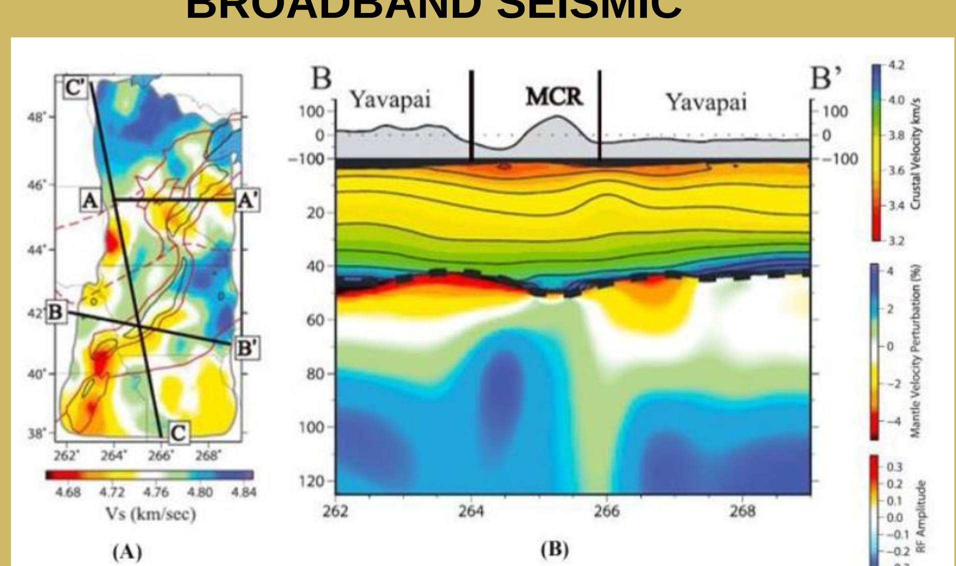
Bouguer gravity and total magnetic intensity maps of Iowa and the surrounding areas (adapted from Almaz, 2017). White lines are Precambrian boundaries. The MCRS (1) is a high density/high susceptibility feature with adjacent lows due to sedimentary basins (2-6).

MAGNETOTELLURIC STATIONS



Map of Earthscope USArray stations within Iowa and northeast Nebraska. The set consists of 42 stations with approximately 70 km spacing. MT data were collected using fluxgate magnetometers and non-polarizable lead-lead chloride electrodes. A sampling rate of 1 Hz was used to collect the long-period MT data (0.1-0.0001 Hz).

BROADBAND SEISMIC



(A) A depth slice at 120 km taken from a 3D seismic velocity model. (B) A cross section of profile B from a 3D seismic velocity model (adapted from Shen et al., 2013). Beneath the MCRS are anomalously thick crust and high mantle velocities.

CONCLUSIONS

Coarse site spacing and complex geology make two-dimensional MT inversion difficult. The RMS errors of 2D inversions wer1.56 (profile A), 2.64 (profile B), 1.85 (profile C), 2.82 (profile D), with large patches of resistivities of over 1000 Ohm-m. The ModEM program (Kelbert et al., 2014) was used to perform 3D inversions of the Earthscope MT data.. The 3D MT inversion resulted in a resistivity model with RMS error of 2.03. The lower resistivities and thinner lithosphere under the MCRS suggests that the effect of the Proterozoic rifting is still affecting the lithosphere structure under the MCRS. The low resistivities can be explained by the introduction of grain boundary conducting elements during the extraction of the large amounts of Fe and Mg during the rifting process. The slightly higher electrical resistivities above these low electrical resistivity regions may be due to the main region of Fe and Mg extraction leaving the remaining lithologies more resistive.

REFERENCES

Almaz, Moamen Mohamed. 2017. “Lithospheric Evaluation of the Mid-Continental Rift System in Iowa from a Gravity and Magnetic Analysis”. MSU Graduate Theses. 3063. http://bearworks.missouristate.edu/theses/3063

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Kelbert, A. Meqbel, N. Egbert, G.D., Tandon, K. 2014. ModEM: a modular system for inversion of electromagnetic geophysical data. Computers & Geosciences. 66. 40-53. http://dx.doi.org/10.1016/j.cageo.2014.01.010.

Shen, W., Ritzwoller, M. H., and Schulte-Pelkum, V., 2013, Crustal and uppermost mantle structure in the central U.S. encompassing the Midcontinent Rift: Journal of Geophysical Research, v. 118, p. 4325-4344.

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