Source Body Migration, an Approximate Inversion Method for Full Tensor Gravity Gradiometer Data

James Brewster, Alan Morgan, and John Mims*

Bell Geospace Inc., 400 N. Sam Houston Pkwy E., Ste. 325, Houston, Texas 77060

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*Author change versus original submission.

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EXTENDED ABSTRACT

Due to the development of airborne gravity gradiometry technology, the past two decades have seen a resurgence in the use of gravity, one of the first geophysical exploration methods. The gravity field of a prospect can now be surveyed rapidly and with wide bandwidth.

Although qualitative interpretation of gravity data is possible, a quantitative interpretation requires some form of inversion, which is defined as any method that converts the survey observations to an estimate of the underlying source mass distribution.

Rigorous inversion methods require the solution of large optimization problems. A task that is computationally expensive and can require advanced mathematical knowledge to interpret correctly. Therefore there is a need for an inversion method that is fast, scales well, and is relatively easy to interpret. Because of this we have developed Source Body Migration as an approximate inversion method for full tensor gravity gradiometry data.

Source Body Migration fits a set of constant density source bodies to the gravity gradient observations. This is done by the iterative application of potential field migration, a 3D imaging method for potential field data.

After a brief explanation of Source Body Migration, its application will be demonstrated using data from a full tensor gradiometer survey of the Vinton salt structure in coastal Louisiana.

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SUPPLEMENTAL NOTES FOR SLIDES

Slide 3 (PDF page 6)

Schematic of the instrument.

Gradient is measured by taking the difference of the gravity field between 2 accelerometers 10 cm apart.

3 instruments (GGIs) to get Full Tensor.

Slide 4 (PDF page 7)

The FTG measures all 5 independent components of the gravity gradient tensor.

Slide 5 (PDF page 8)

Bell Geospace FTG survey over the Vinton salt structure, onshore Louisiana.

Tzz clearly shows the central, positive anomaly due to cap rock and shallow salt.

This is surrounded by a large, negative anomaly due to deeper salt.

Slide 6 (PDF page 9)

Google Earth image shows wells drilled around the edge of the central Tzz high.

Slide 9 (PDF page 12)

Shallow high density and deep low density well imaged.

In unconstrained output density contrast exceeds realistic limits in some locations.

Slide 10 (PDF page 13)

Density contrast vs. depth rules taken from known rock properties.

Non-uniqueness of gravity modelling means that any voxel can be replaced by a lower density sphere of voxels.

This makes no change in the expected gravity field.

Slide 12 (PDF page 15)

Largest negative density contrast seen at 4000 m depth.

Slide 14 (PDF page 17)

The forward modelled field of the salt model is subtracted from the FTG observations.

Source Body Migration now produces less density contrast.

This is the estimated deviation from the model.

Slide 15 (PDF page 18)

Negative contrast at 4000 m depth is no longer present.

Bodies fit at 2000 m indicate that the model should be extended further to the northeast.

Slide 17 (PDF page 20)

Bell Geospace data library in the Gulf of Mexico.

Full resolution available under license.

Slide 18 (PDF page 21)

Plan slices of Gulf of Mexico density.

Note at 3000 m gaps in the results over the Sigsbee Escarpment – as there should be.

EXPLORE THE FUTURE
LOOKING BACK THINKING FORWARD...
Corpus Christi, Texas – Sept. 18-20, 2016

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Outline

- The FTG gravity gradiometer

- Source Body Migration

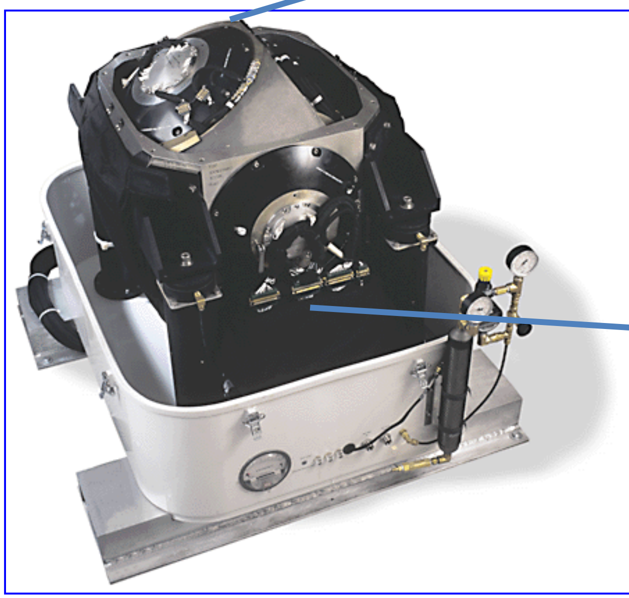
- Application to survey in onshore Louisiana
  – Without density constraints
  – With density constraints
  – After subtracting source model

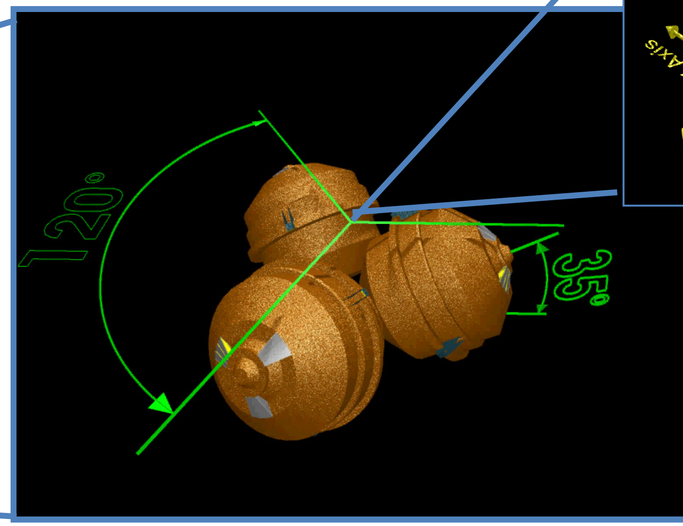
The FTG Gravity Gradiometer

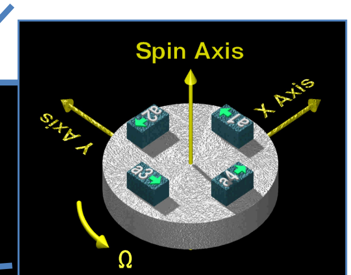
~ 1 Meter in each dimension

Inertially stabilized platform

Difference between accelerometers removes host vehicle effect

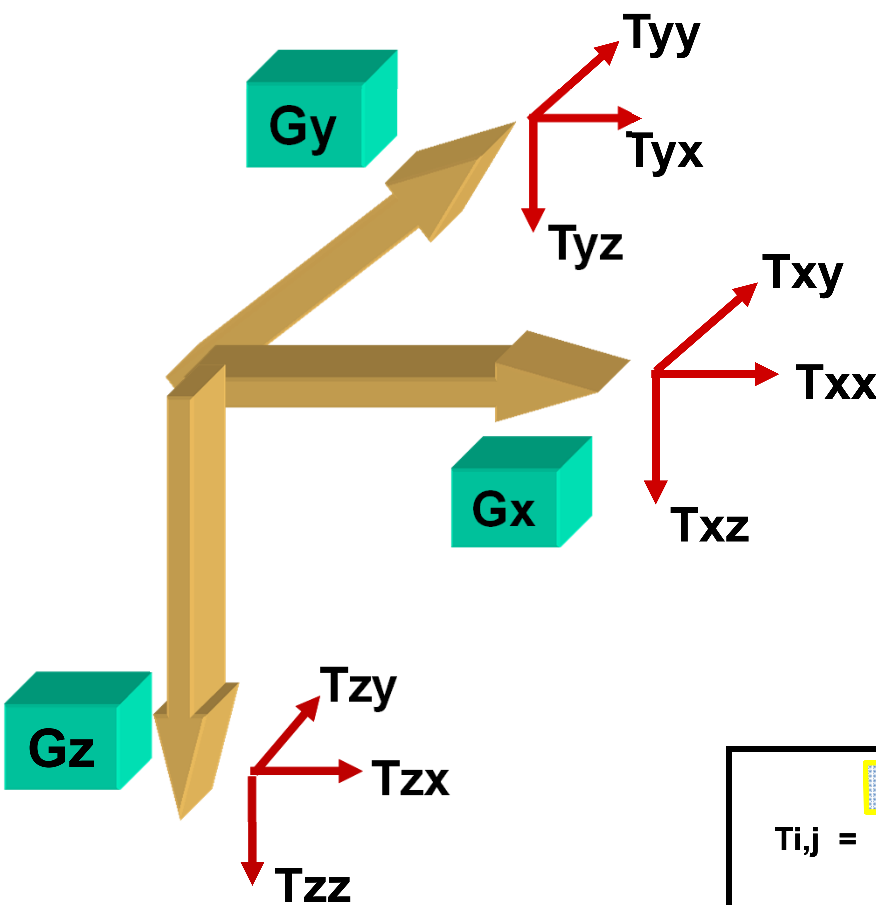




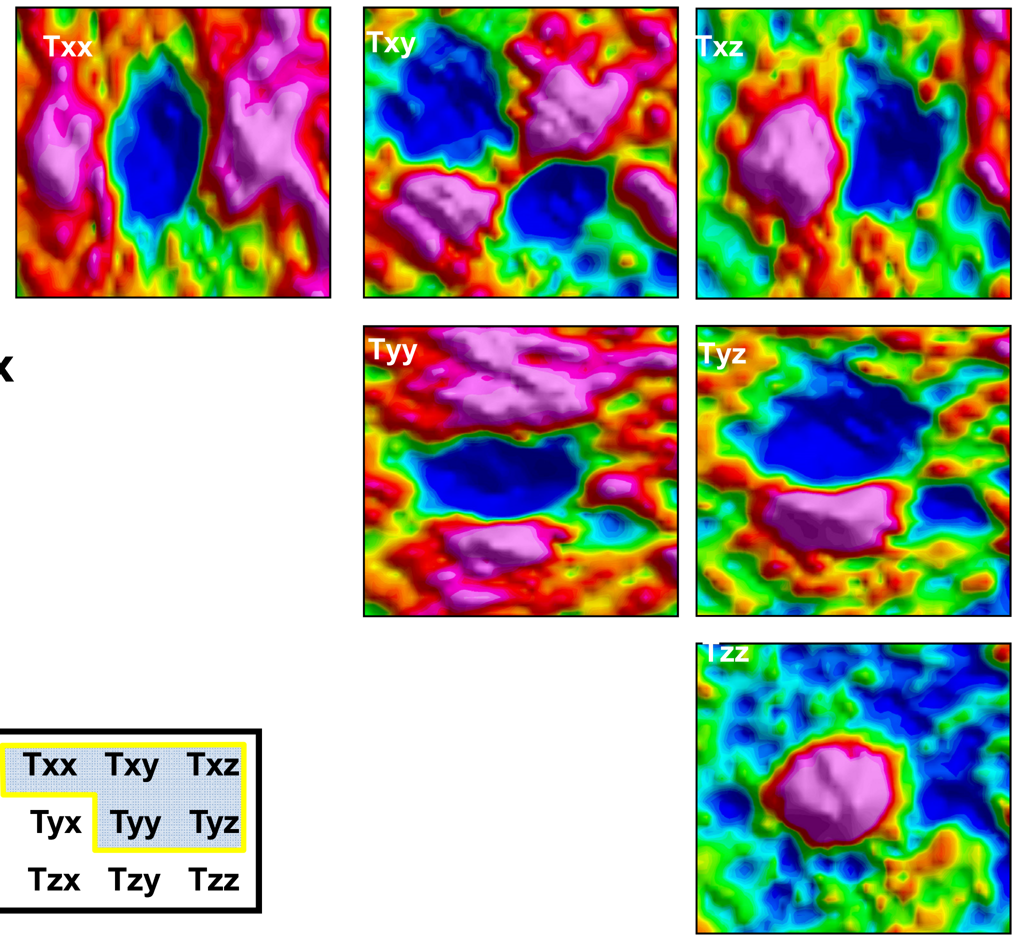


3 "GGIs" allow Full Tensor Measurement

The Gradient Tensor

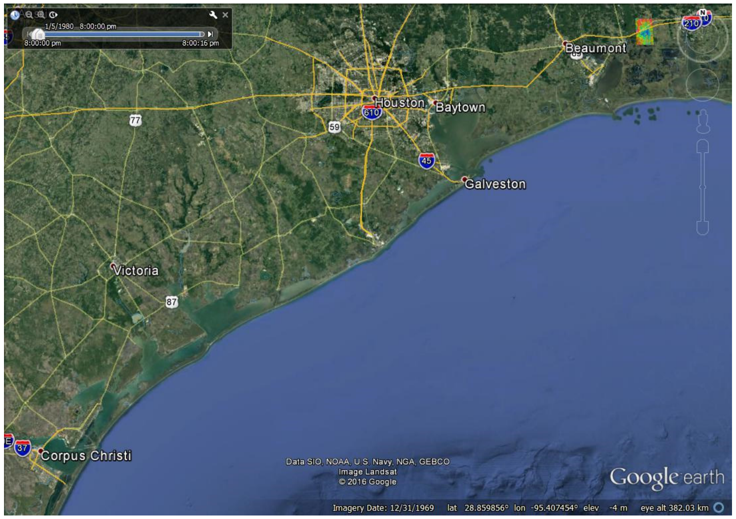


Observations from Vinton Dome salt body, Louisiana, USA



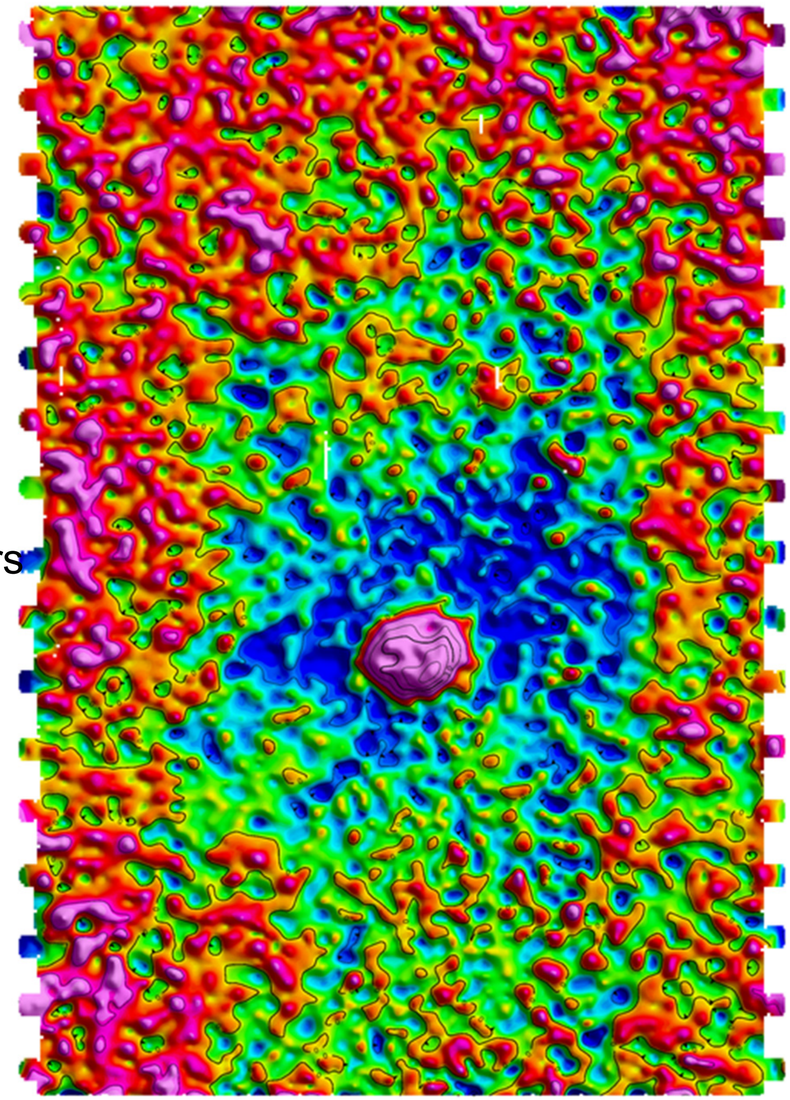
	Txx	Txy	Txz
Ti,j =	Tyx	Tyy	Tyz
	Tzx	Tzy	Tzz

Vinton Dome FTG Survey



10 E contours

equal color scale



Tzz

17 km

250 m line spacing

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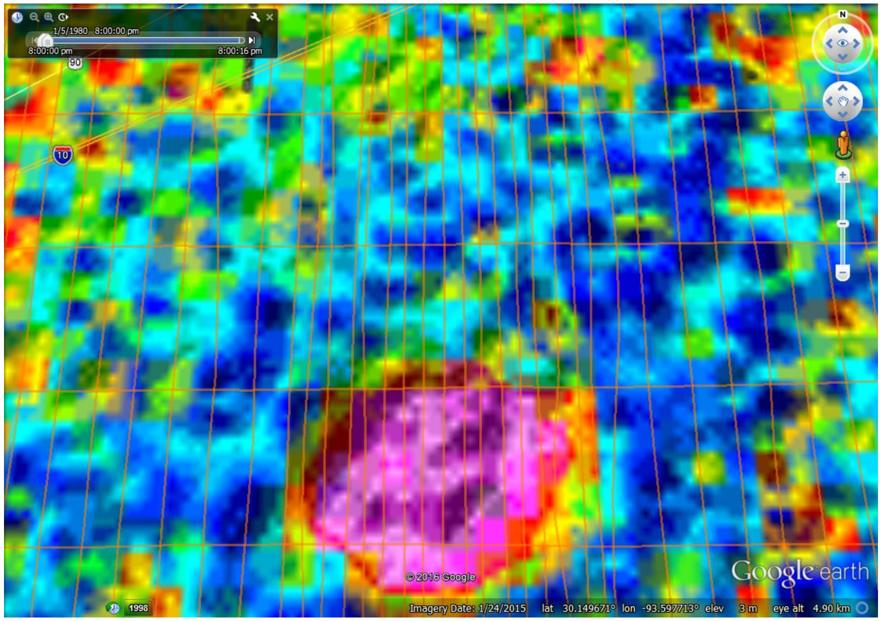
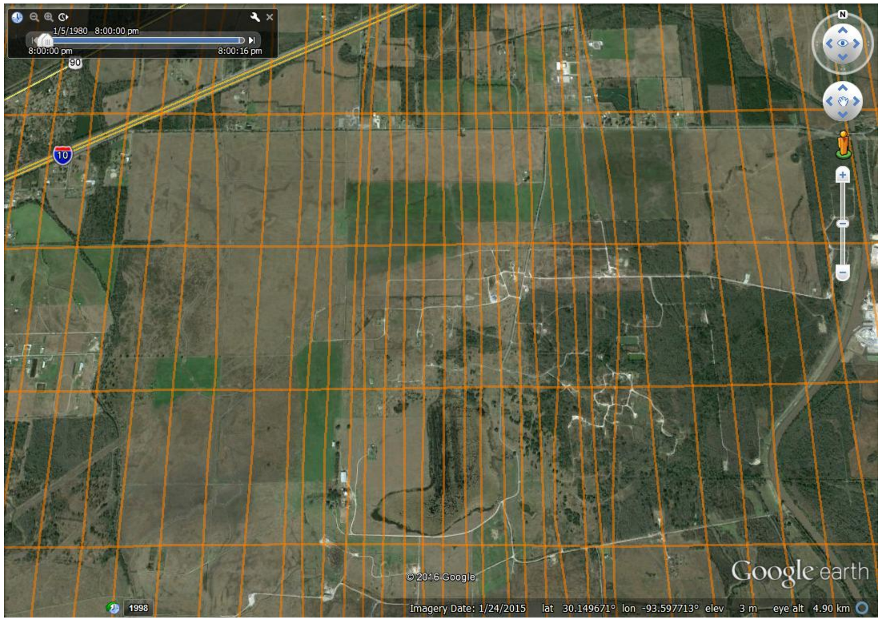
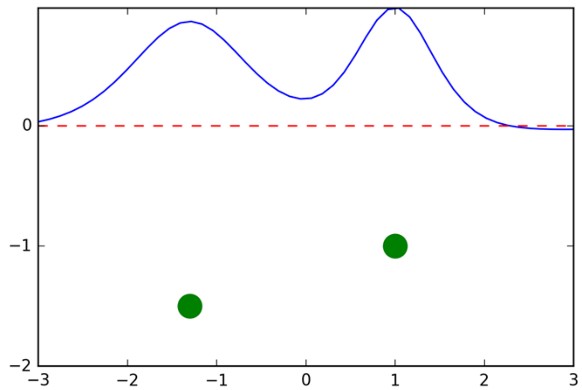
Vinton Dome FTG Survey



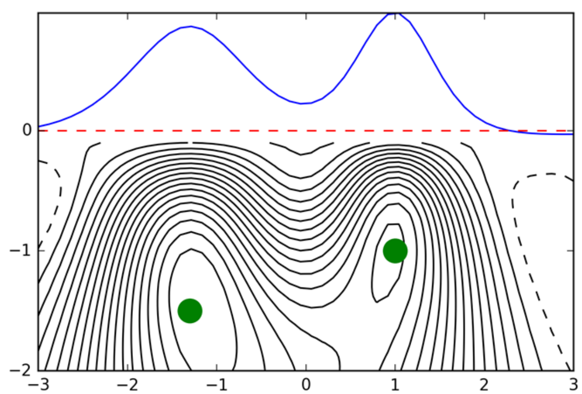


Tzz

Potential Field Migration



A method of rapidly generating 3D density images from potential field data



Role reversal:

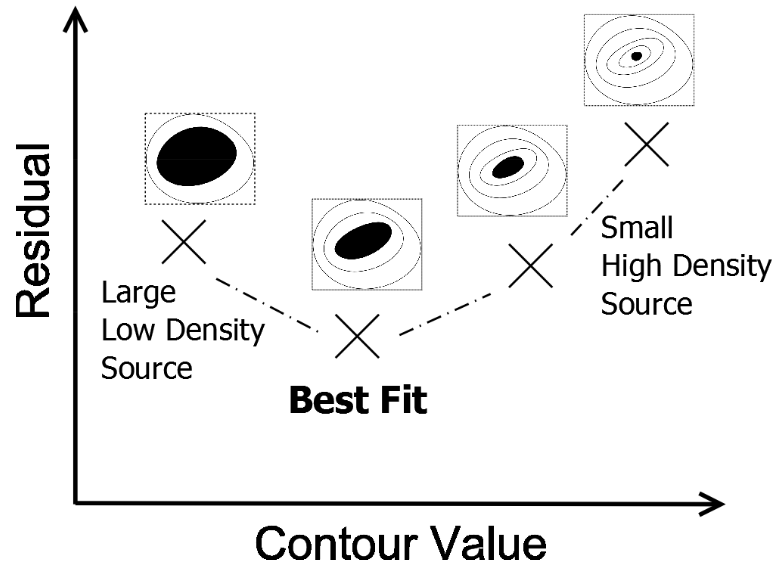
- Observations become sources

Filtered by continuation

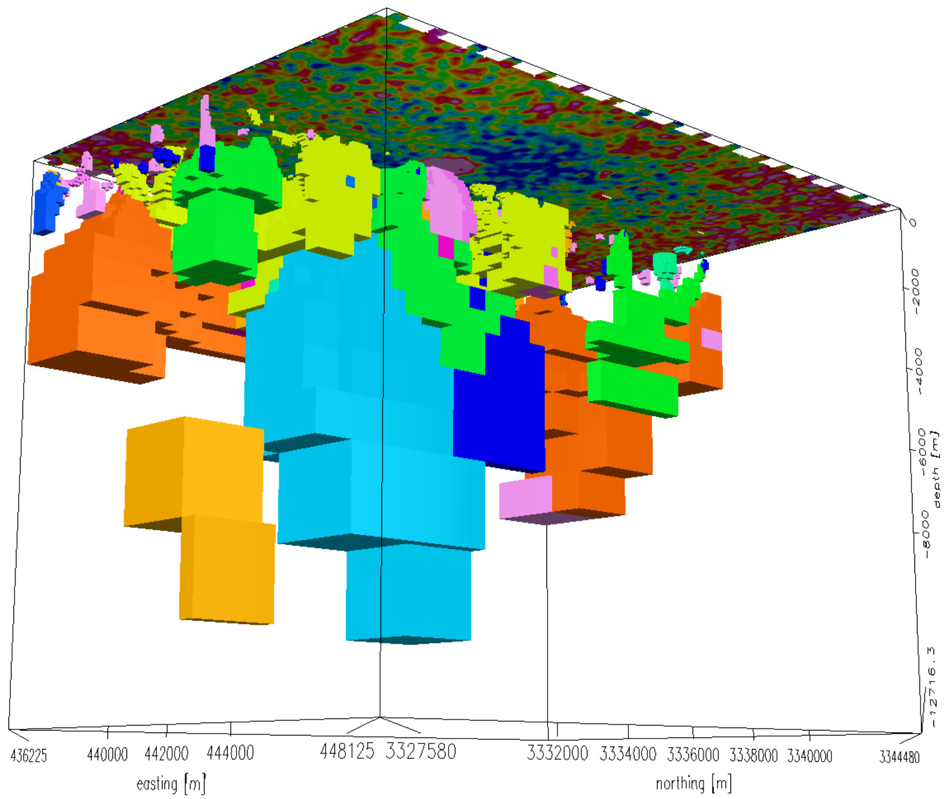
Rescaled by factor of z^2

Source Body Migration

- Fills 3D contours of migration density field with sources of uniform density
- Best-fit choice of contour found
- Iteratative
  - Subtract field and repeat
- All 5 gravity gradient tensor components used

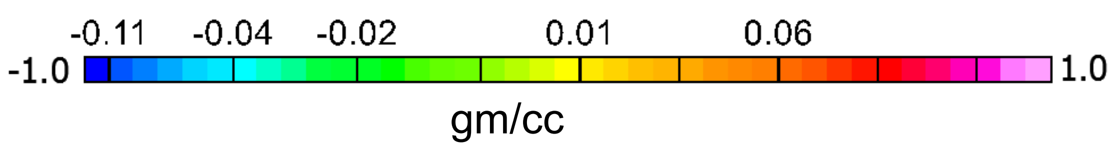


Unconstrained Image

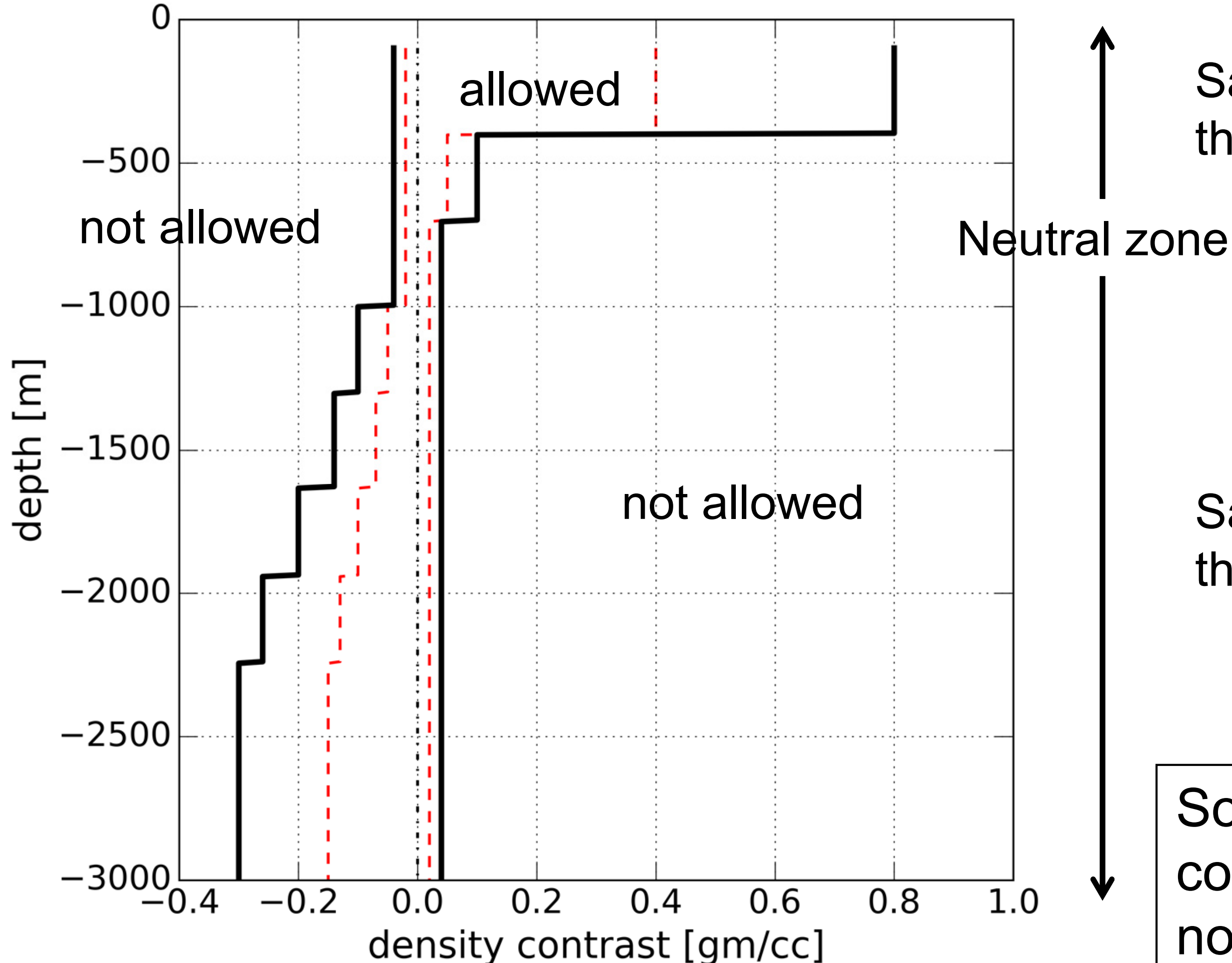


Best results have been found to be obtained if algorithm is run free of density constraints

Here density contrast is limited only to the range +/- 1 gm/cc



Density Contrast Rules

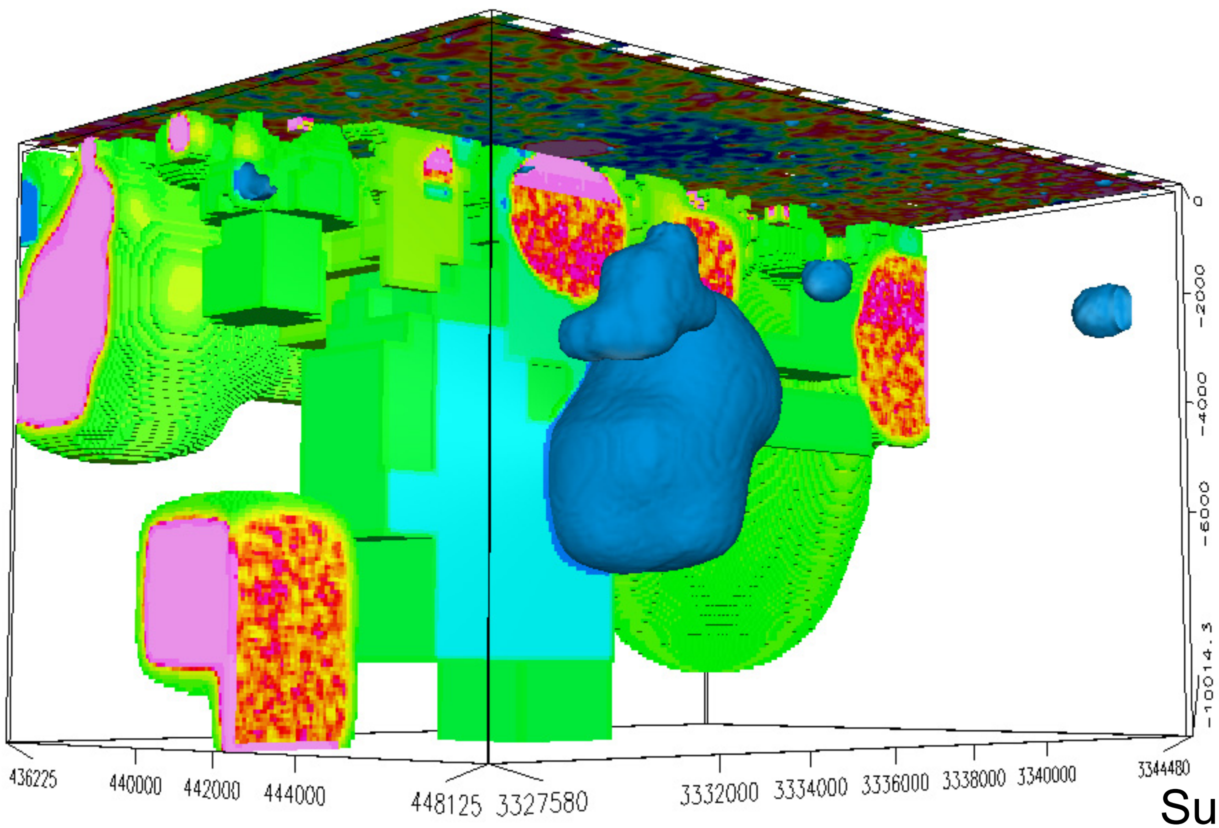


Salt more dense than matrix

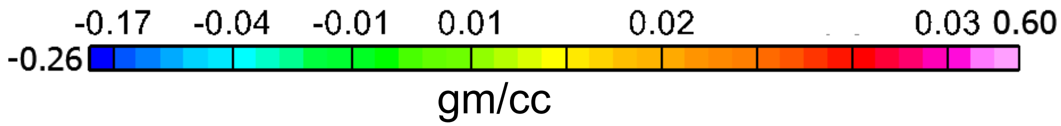
Salt less dense than matrix

Sources made to comply by exploiting non-uniqueness

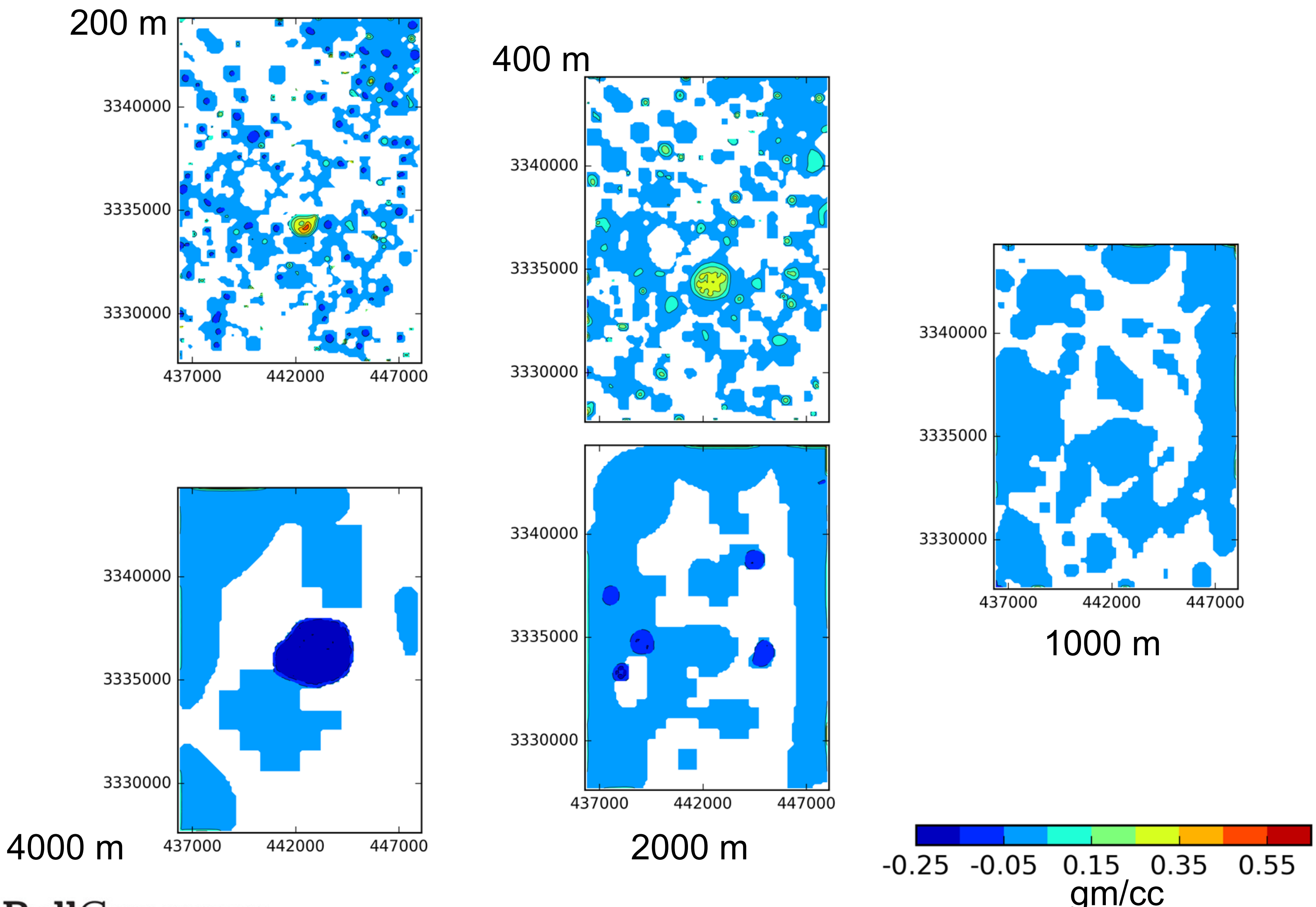
After Enforcing Density Rules



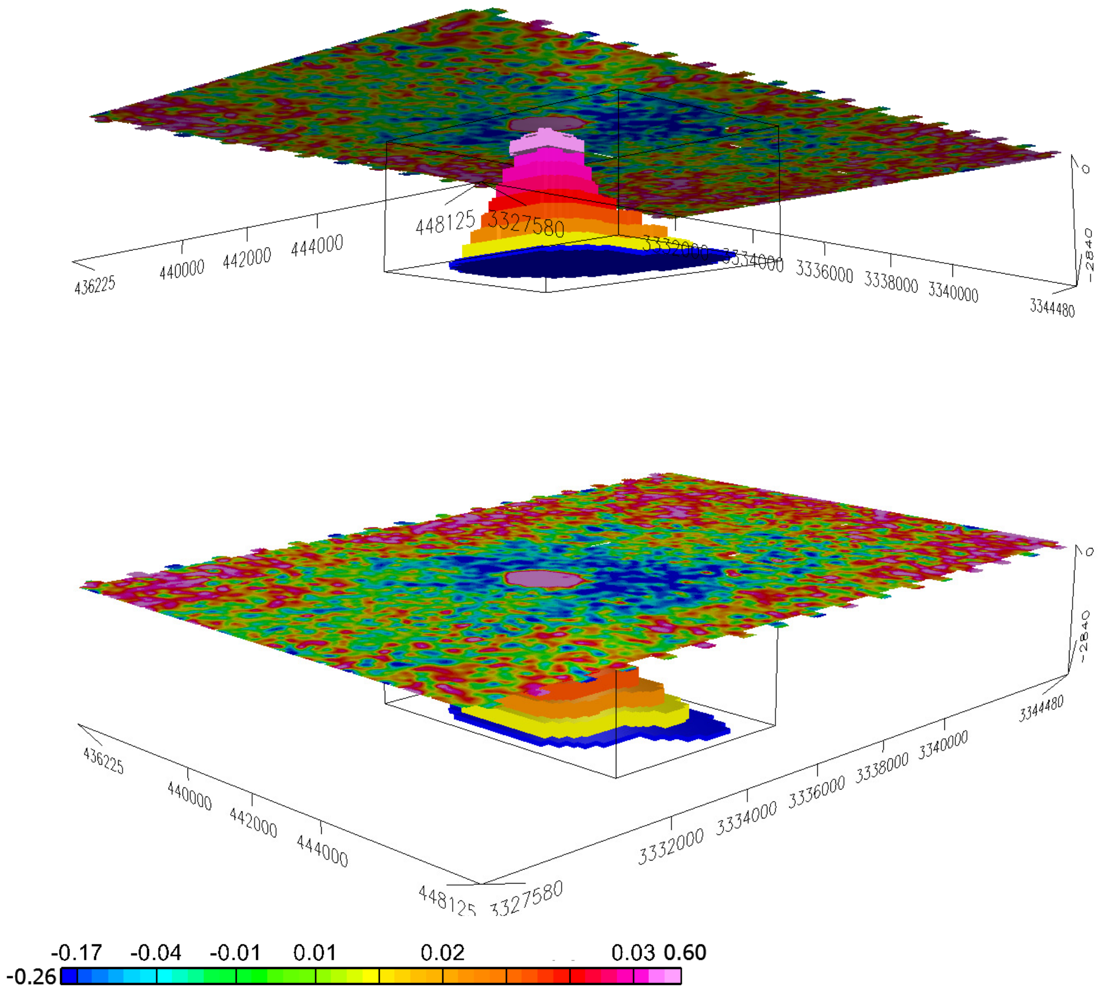
Surface represents
-0.1 gm/cc



Plan View Slices

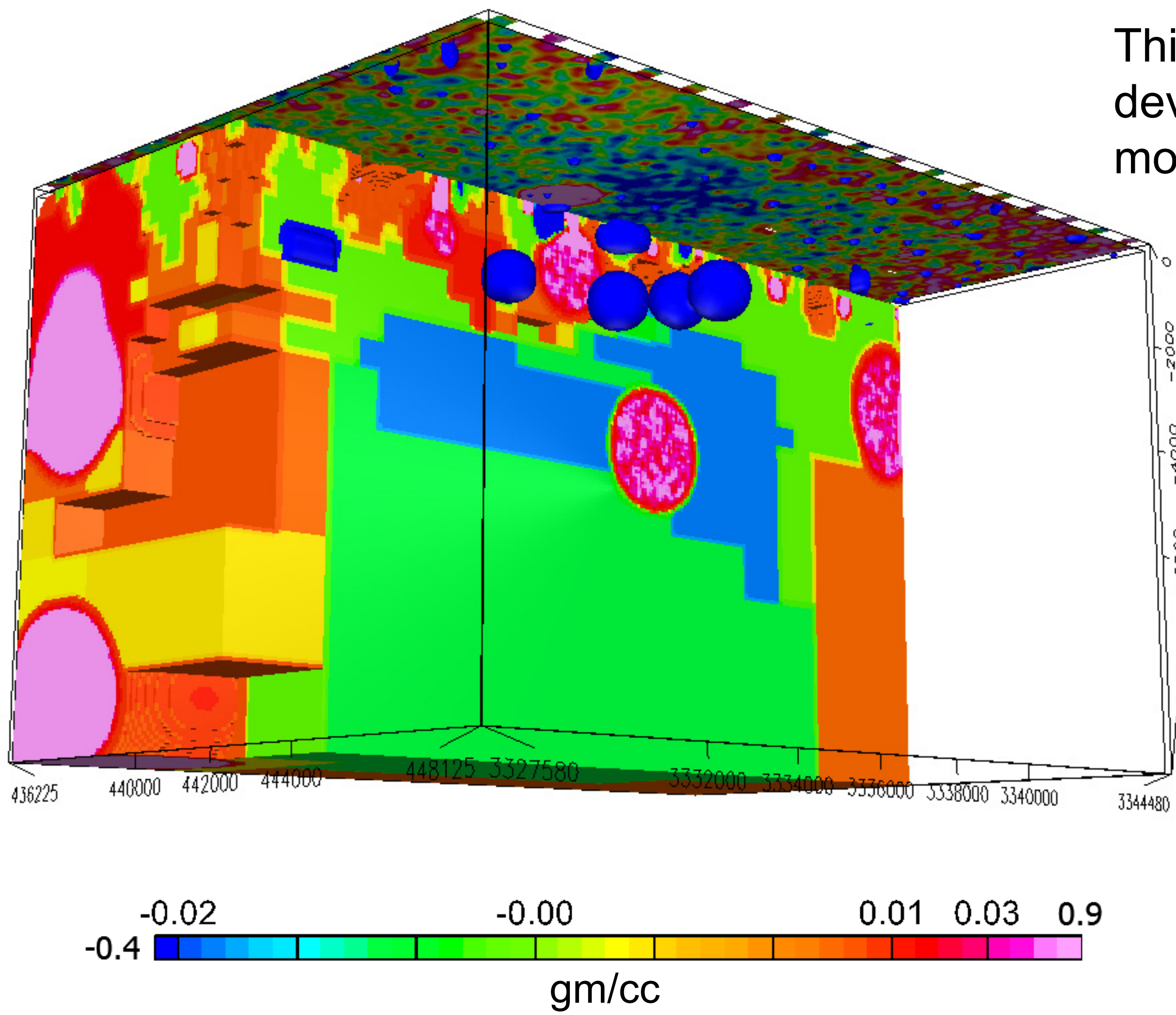


Source Model



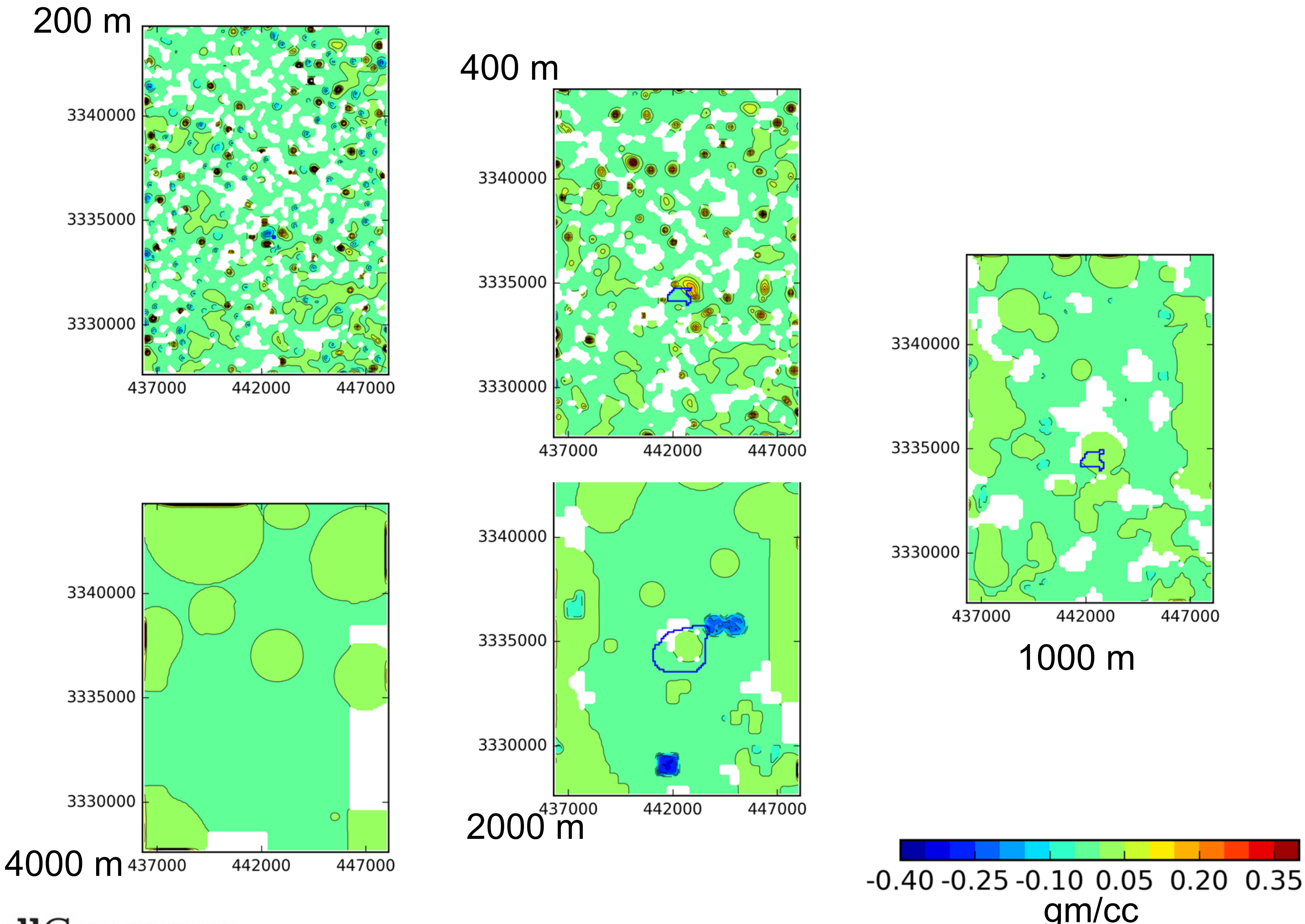
Model of salt structure published in thesis by Chris Ennen, University of Houston

Residual After Subtracting Model



This represents deviation from salt model

Plan Slices: Residual from Model



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Migration Vs. Inversion

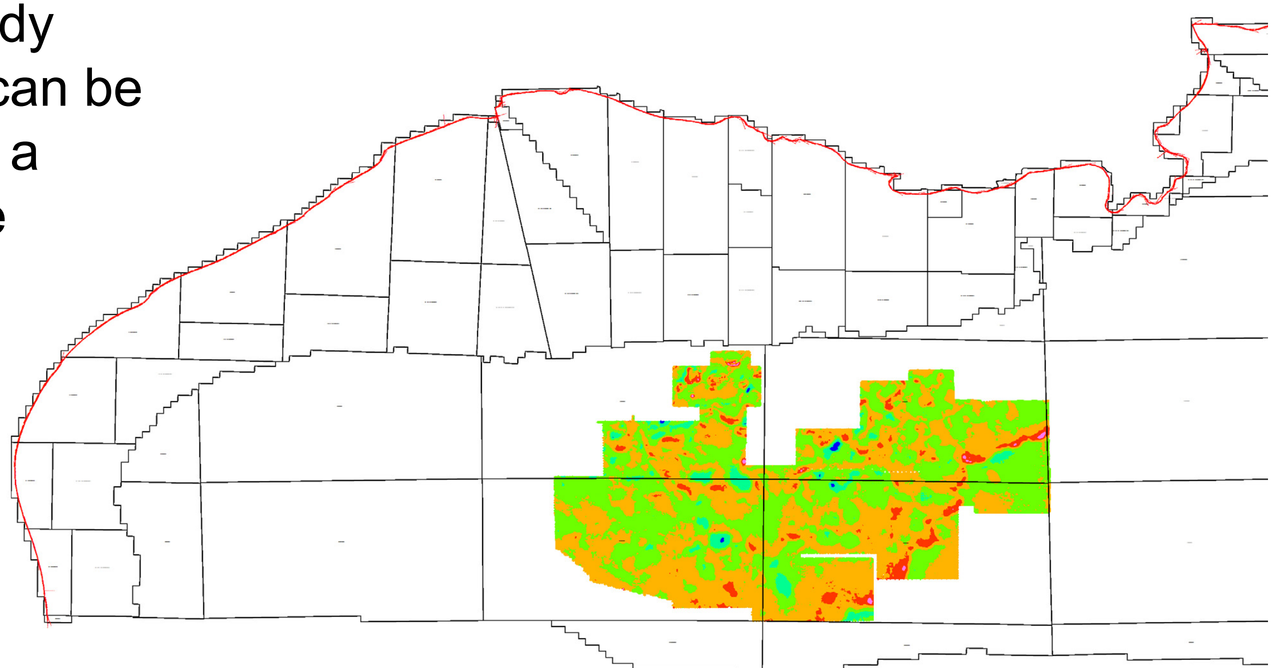
(Matrix to be solved 5×10^{11} terms) x (1,000,000 Voxel density Values) = (100,000 x 5 Observations)

Although development of inversion methods is very advanced, problem to be solved is very large.

There is still a place in the interpretation workflow for an alternative that is fast and stable

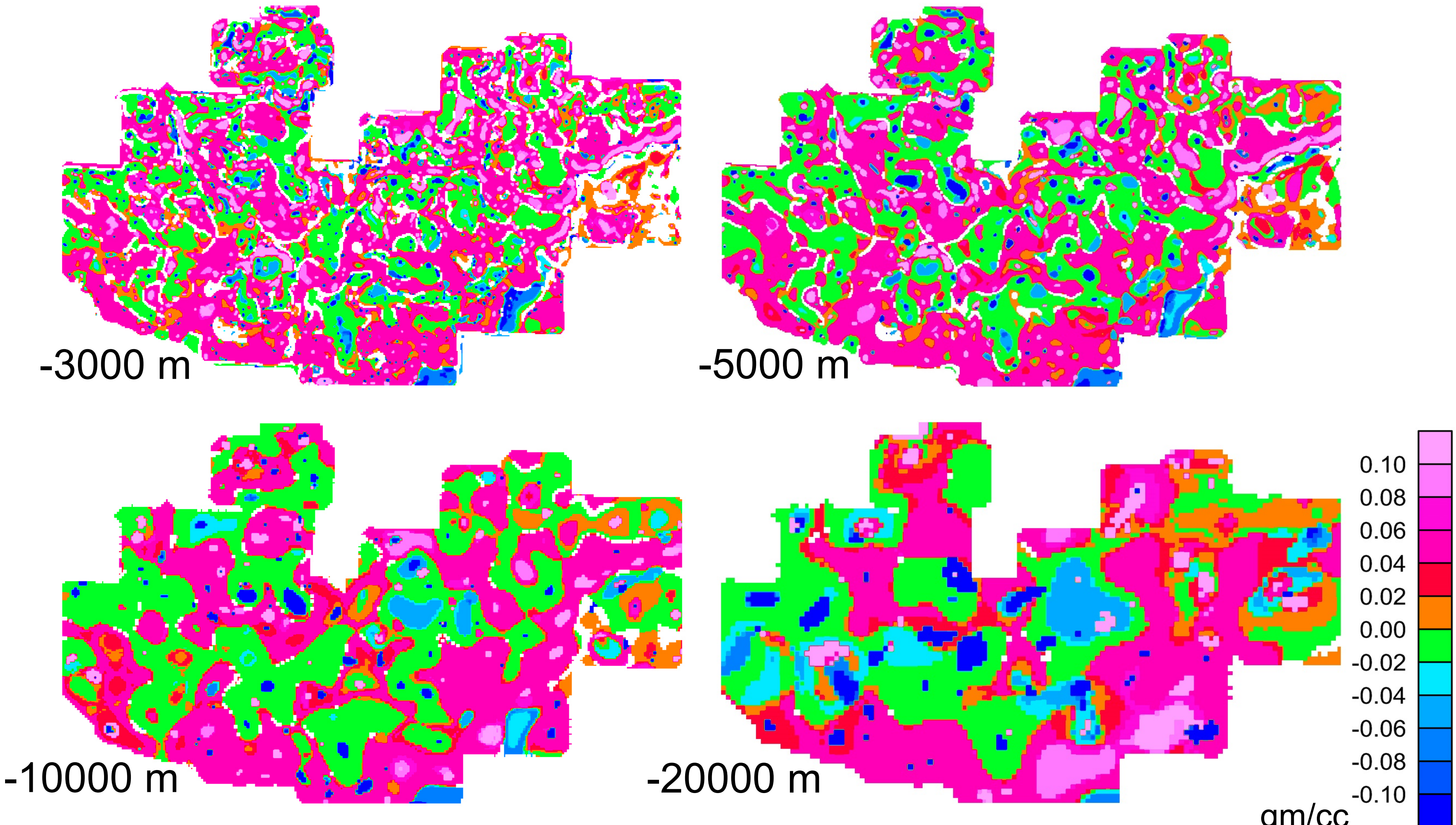
Gulf of Mexico

Example of how Source Body Migration can be applied on a large scale



Bell Geospace FTG data

Gulf of Mexico



Conclusion

- Source Body Migration has a place in the interpretation workflow as a method of rapidly producing 3D density images from FTG data

References

Murphy, Colm A., James Brewster, and James Robinson. "Evaluating Air-FTG® survey data: bringing value to the full picture." *Preview* 126 (2007): 24-28.

Zhdanov, Michael S., Xiaojun Liu, Glenn A. Wilson, and Le Wan. "Potential field migration for rapid imaging of gravity gradiometry data." *Geophysical Prospecting* 59, no. 6 (2011): 1052-1071.

Wan, Le, and Michael S. Zhdanov. "Iterative migration of gravity and gravity gradiometry data." In *2013 SEG Annual Meeting*. Society of Exploration Geophysicists, 2013.

Ennen, Christopher. "Mapping Gas-charged Fault Blocks Around the Vinton Salt Dome, Louisiana Using Gravity Gradiometry Data." (2012).