Integrated Interpretation to Build a Geological Model from Ship Shoal to Keathley Canyon through Green Canyon*

Laura Bornatici[1]

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[1]WesternGeco / Schlumberger (laura.bornatici@gmail.com)

Abstract

Properly imaging salt canopies can be a challenge for seismic interpretation; however, integrating different methodologies can result in interpretation that is more complete and reliable. In this study, we interpret regional gravity and magnetic data, together with seismic, Marine MagnetoTelluric (MMT) data, simultaneous joint inversion results (SJI) and well logs to build a possible geological model that will explain the differences in seismic data quality between Ship Shoal and Eugene Island (E-Dragon), versus Green Canyon and Walker Ridge (E-Octopus).

Observations have highlighted decreasing seismic data quality moving from North to South in central part of northern Gulf of Mexico; most likely a result of an increase in salt thickness and complexity. Integrated analysis of geological and geophysical data consistently supports our hypothesis where the autochthonous salt flowed from North to South and was trapped in a basement low corresponding to a negative anomaly on both gravity and magnetic data. The large volume of para-autochthnous salt was mobilized by gravity. In addition, the formation of huge canopies was facilitated by a ramp (visible on seismic WAZ RTM data) at the oceanic-continental boundary presumably due to the higher sediment loading in the North than in the South.

In this area, seismic data alone may be insufficient to support a reliable interpretation. The present poster shows an example where 3D inversion of MMT data helped to interpret the base of salt which was ambiguous on seismic data.

Selected Reference

Mount, V.S., K.I. Mahon, and S.H. Mentemeir, 2010, Structural restoration and basin modeling in North-Central Gulf of Mexico deepwater subsalt plays: Gulf Coast Association of Geological Societies Transactions, v. 60, p. 503-510.

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Laura Bornatici, WesternGeco / Schlumberger

Introduction

Imaging subsalt with only seismic data may be a challenge. However, integrating different methodologies can result in interpretation that is more complete and reliable. In the present study, we interpret seismic and non-seismic data to build a more plausible geological model that will help explain the degradation of seismic data from North to South in the central part of North Gulf of Mexico (Fig. 1).

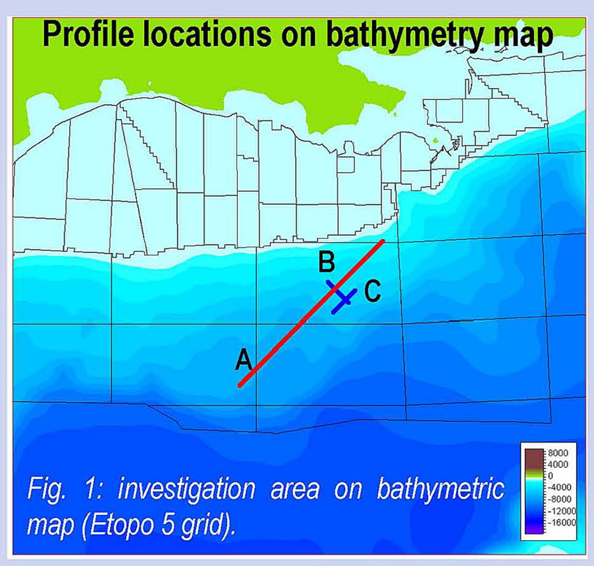


Fig. 1: investigation area on bathymetric map (Etopo 5 grid).

Workflow

1. Problem identification: Quality of seismic image degrades from North to South.
2. Process: Use gravity, magnetic and Marine MagnetoTelluric (MMT) data to improve the regional subsalt geological model.
3. Process test: Does the interpreted model fit all geophysical data?
4. Conclusions : What did we achieve?

1. Problem identification

It is well known that seismic data quality dramatically decreases moving from North (Ship Shoal and Eugene Island) to South (Green Canyon and Walker Ridge) in the north-central Gulf of Mexico (Fig. 2). This is partially related to the salt movement and related geometries within the two areas:

- in the North the salt is limited to small isolated diapirs.
- in the South the quantity of allochthonous salt is much larger, therefore forming huge complex canopies, sutures, and inter-bedded sediments.

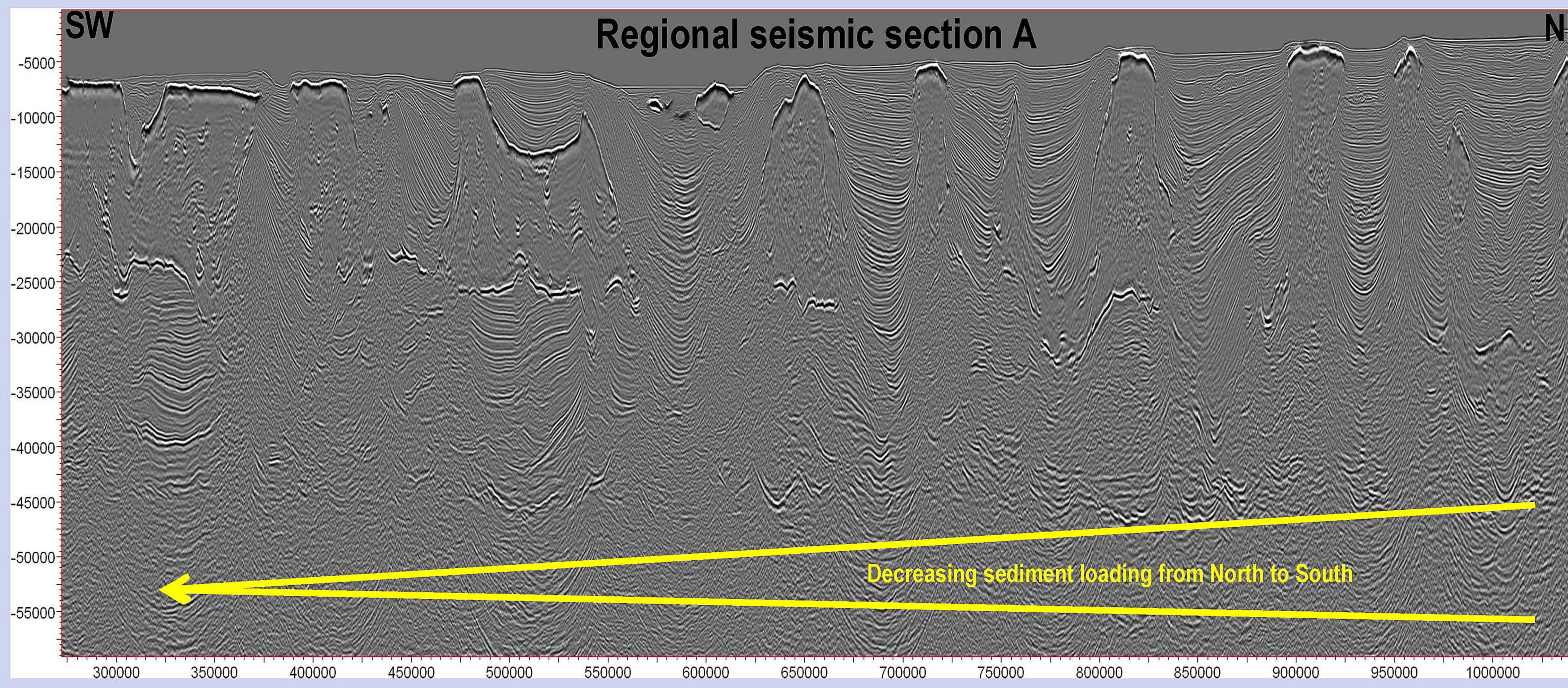
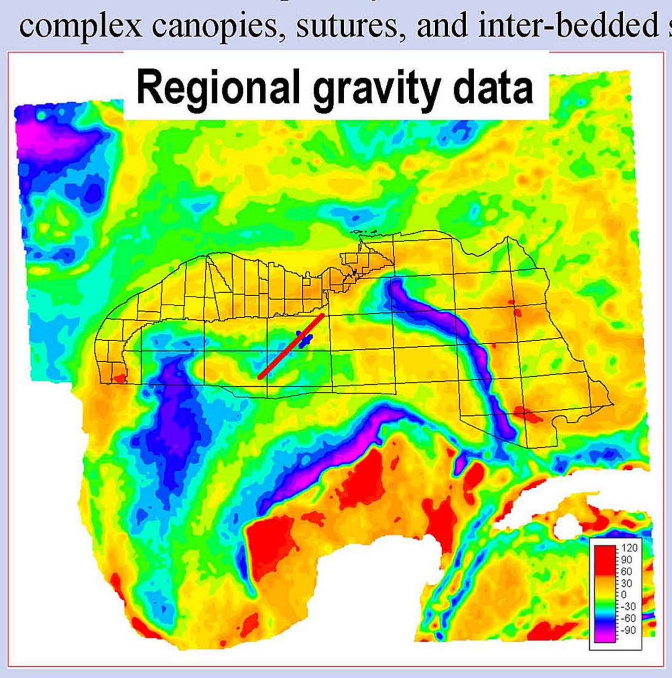


Fig. 2: SW-NE regional seismic profile from Keathley Canyon to Green Canyon.



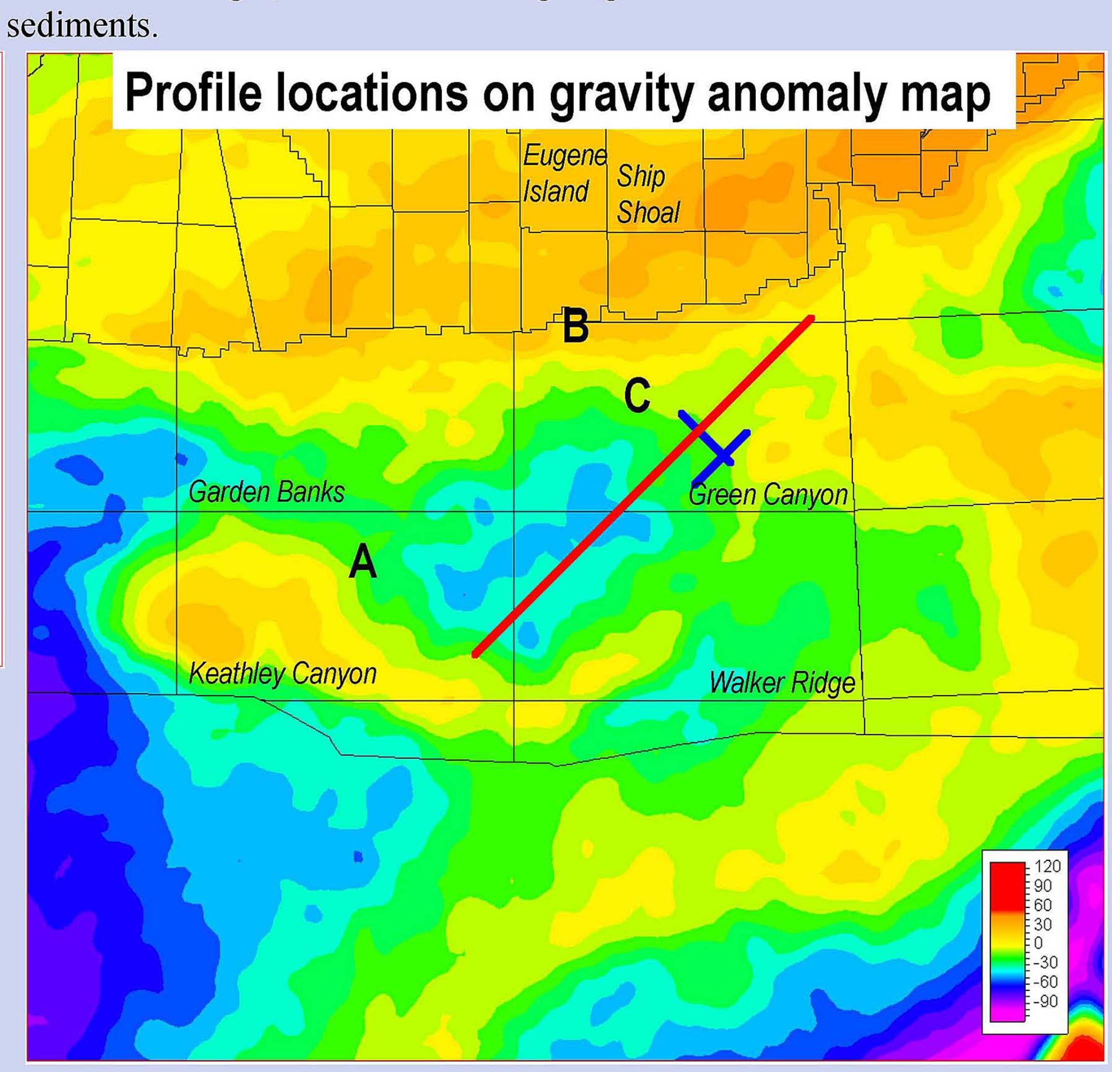
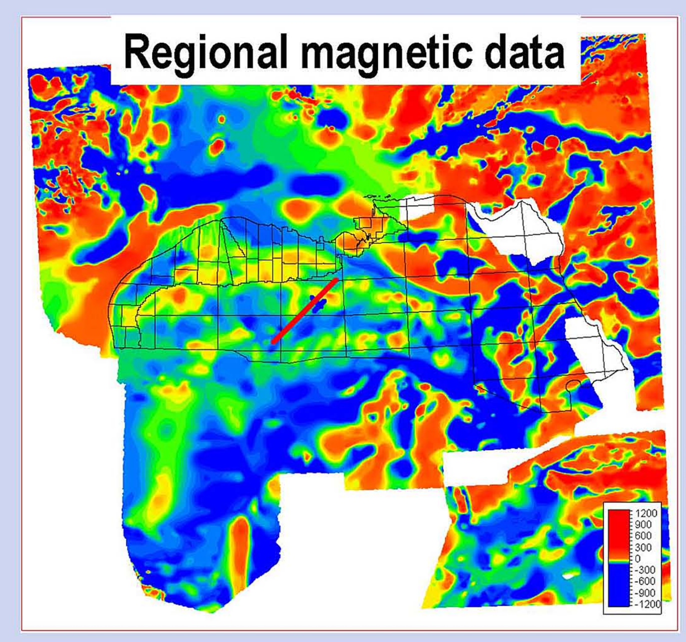


Fig. 3: Profile locations on regional gravity data map at two scales: 1) Gulf of Mexico above and 2) seismic survey right. Gravity data are Bouguer onshore and free air offshore (SEG gravity data on 4x4km grid). The area of huge salt canopies lies in a local low of gravity data, delimited in the North by a positive anomaly that mimics the shelf and in the South by a positive anomaly in the SW part of Keathley Canyon.



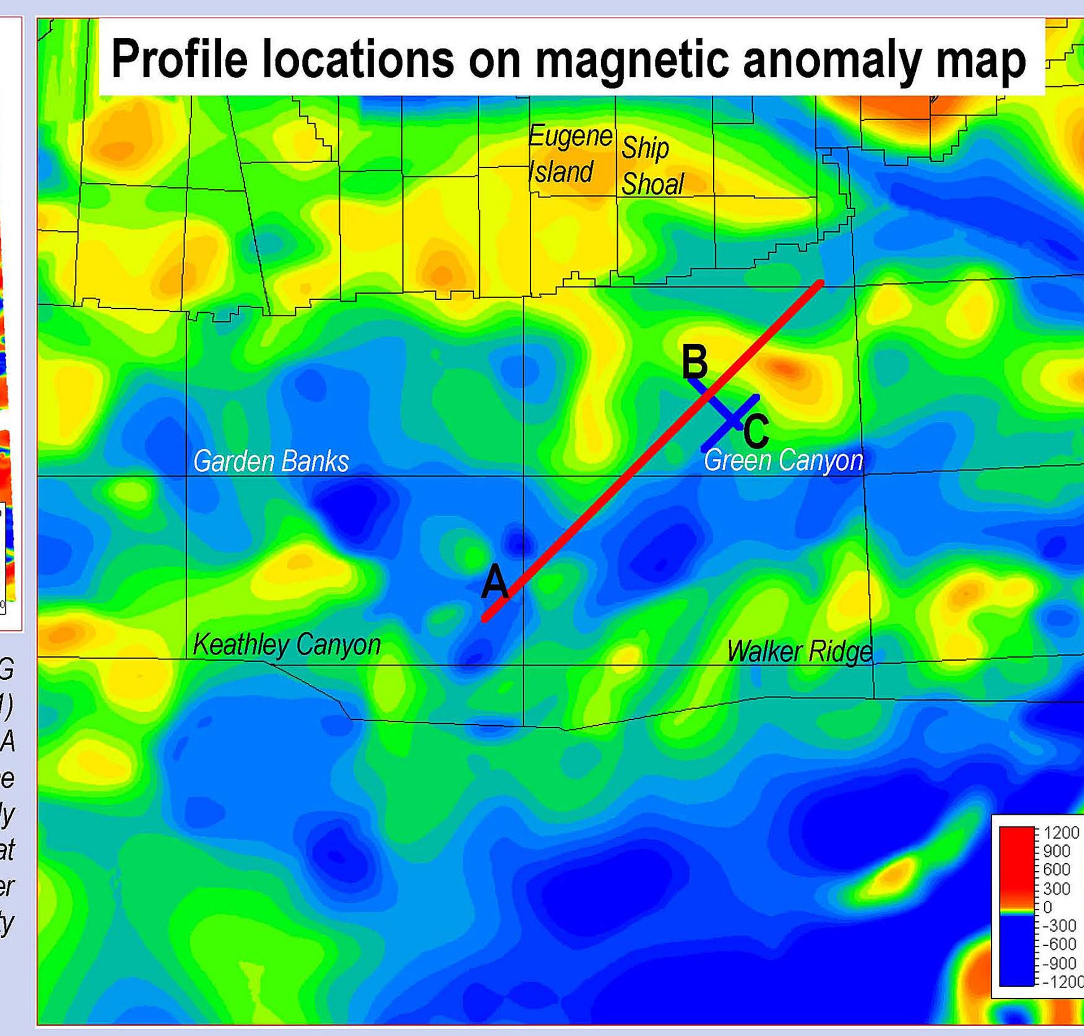


Fig. 4: Profile and seismic survey locations on DNAG magnetic anomaly map (2x2km grid) at two scales: 1) Gulf of Mexico above and 2) seismic survey right. A negative magnetic anomaly identifies the area of the salt canopies. Similarly with gravity data, this anomaly is delimited in the North by a positive anomaly that follows the shelf; the southern boundary is another positive anomaly that fits with Keathley Canyon gravity high.

2. Process

Analysis and modeling of regional gravity and magnetic data suggests that the basement is deeper in the South (Figs. 3 and 4), and changes from continental to oceanic crust. As the paleo-oceanic crust cooled and subsided, the autochthonous salt moved down slope via gravity to a basement counter slope. If this hypothesis is correct, large volumes of transported salt (para-autochthonous) were trapped in this basin and further re-mobilized to form some of the canopies that are visible on seismic data.

3. Process test

A regional model of gravity data (Fig. 5) supports the hypothesis of a basement basin in correspondence with the salt canopy area. Constraining the density model where there is control from seismic and MMT data (Fig. 8) indicates that the oceanic-continental crust boundary divides the study area: *the good fit between observed and predicted data confirms that the assumed model is plausible*.

In particular our WAZ-RTM seismic data suggests the presence of a "step" at the oceanic-continental crust boundary (Fig. 9); this ramp is compatible with Hudec's interpretation (Fig. 7) and is presumably related to the higher sediment loading in the North than in the South (Fig. 6). Note that this ramp fits also with the modeled gravity data (even if less evident due to poor data resolution on a 4x4km grid, Fig. 8) and would have probably promoted the rise of the autochthonous salt to form the canopies.

4. Conclusions

Integrated analysis of geological and geophysical data in the northern central part of Gulf of Mexico consistently supports our hypothesis where the autochthonous salt flowed from North to South and was trapped in a basin corresponding to a negative anomaly on both gravity and magnetic data. The large volume of para-autochthonous salt was mobilized by gravity. In addition, the formation of the huge canopies was facilitated by a ramp (visible on seismic WAZ RTM data) at the oceanic-continental boundary presumably due to higher sediment loading in the North than in the South.

In this complex area, seismic data alone may be insufficient to support a reliable interpretation. Figure 10 shows an example where 3D inversion of MMT data helped to interpret the base of salt which was ambiguous on seismic data.

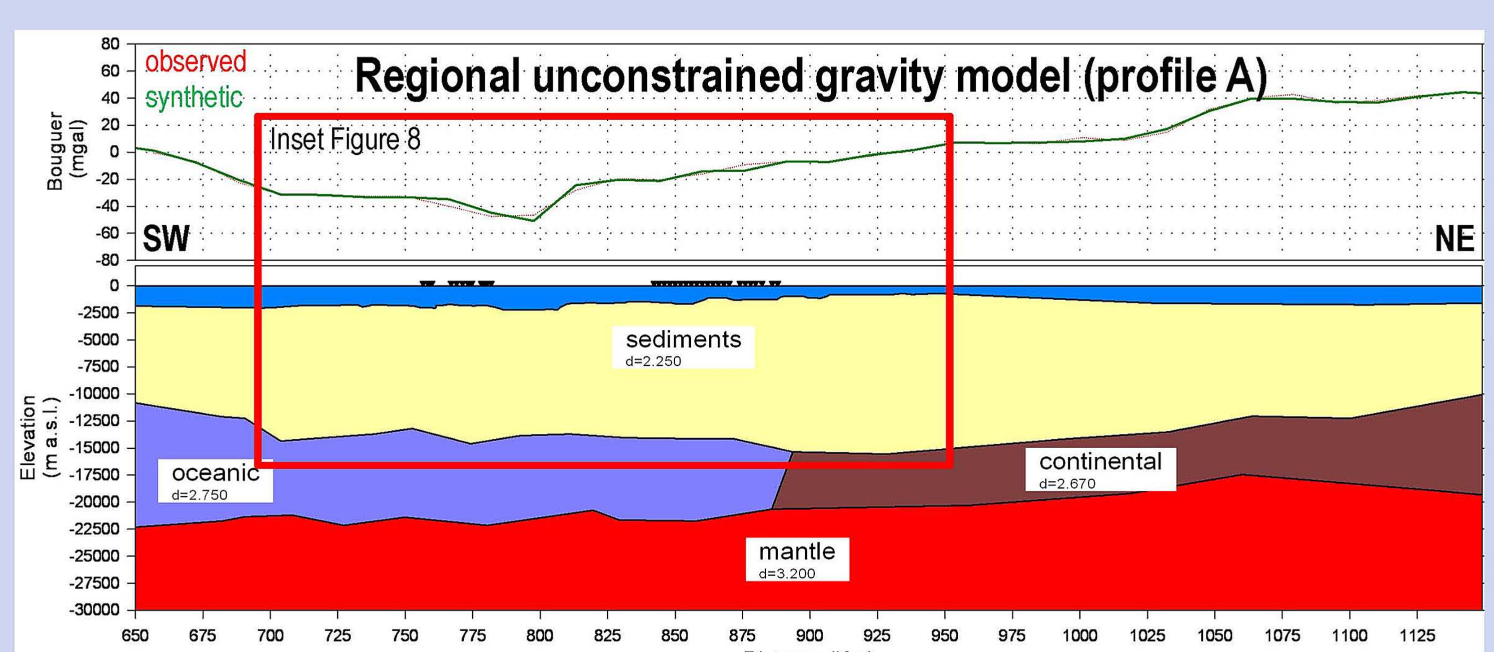


Fig. 5 (left): Gravity data model along a regional SW-NE profile. The upper panel shows the fit between observed (red) and predicted (green) Bouguer anomalies. The lower panel shows the density model along the profile at location shown in the map in the lower right corner. Note that in absence of more information the model is assumed to be the simplest one, including only sediments, basement and mantle. The horizontal scale is in km and the vertical one is in m a.s.l.

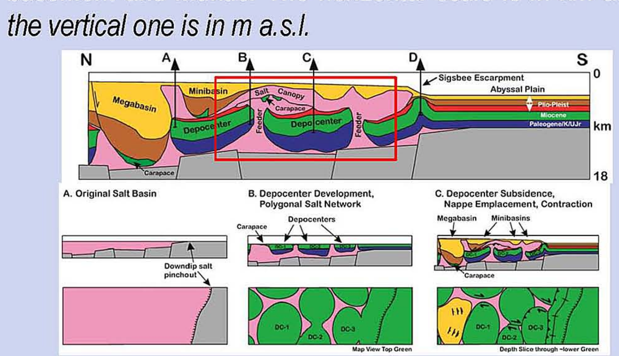


Fig. 6 (above): Van Mount (Van Mount et al. 2010) interpretation of mini-basin evolution

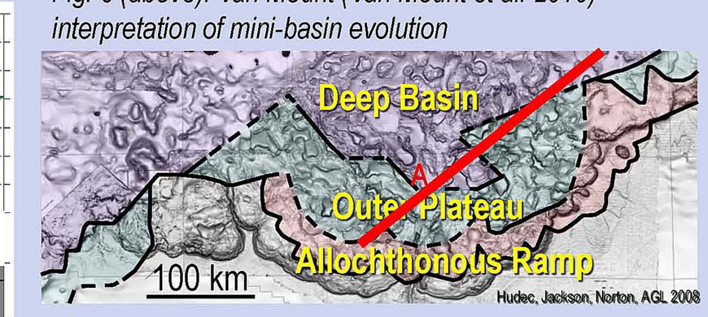


Fig. 7 (above): Approximate location of interpreted profile on Hudec's interpretation.

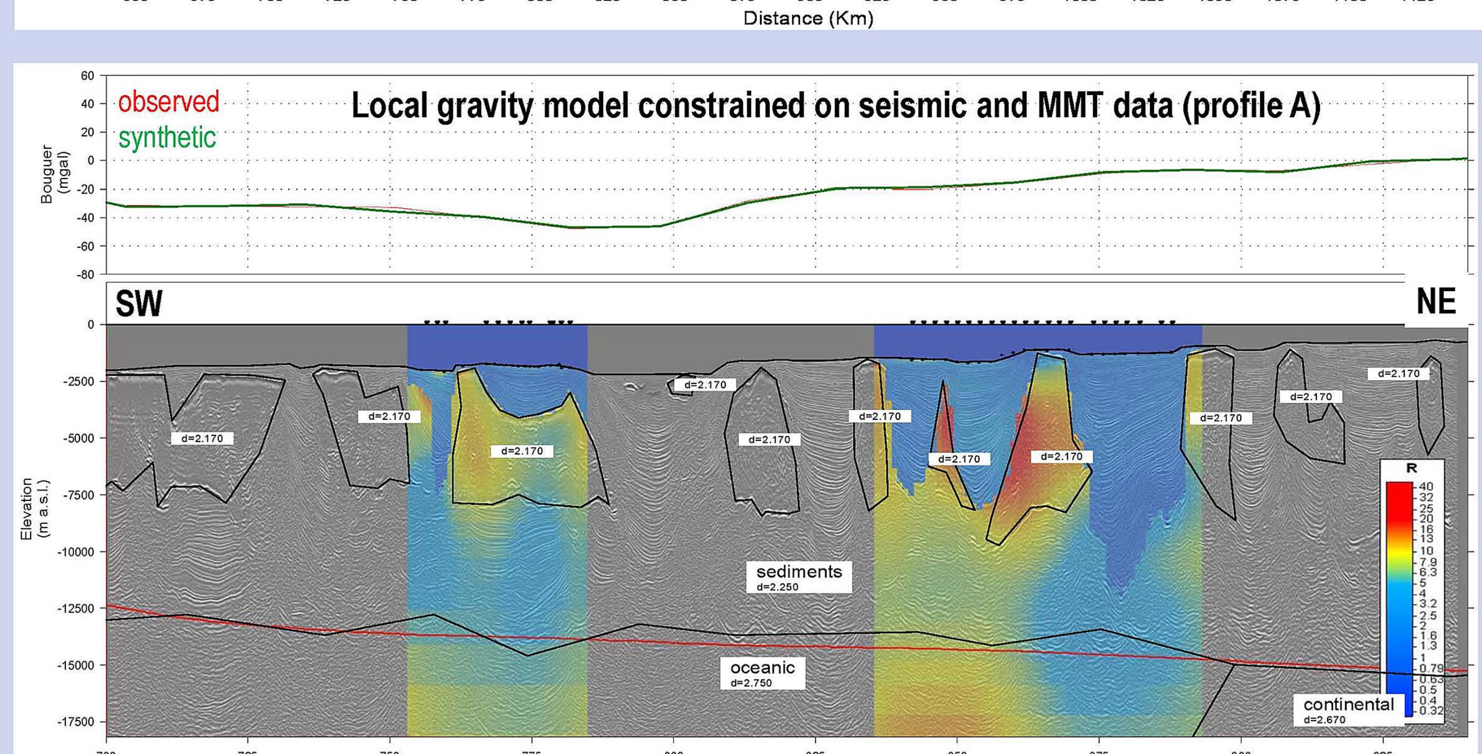


Fig. 8 (left): Gravity data model along the section of Fig. 5 profile where there is control from seismic and MMT data. The fit between observed and predicted Bouguer anomaly is good and is visualized in the upper panel. The density model (black line) shown in the lower panel is superimposed on seismic and co-rendered with resistivity model from the 3D inversion of MMT data. The red line on the model represents basement as interpreted from magnetic data by Bird. The horizontal scale is in km and the vertical one is in m a.s.l.

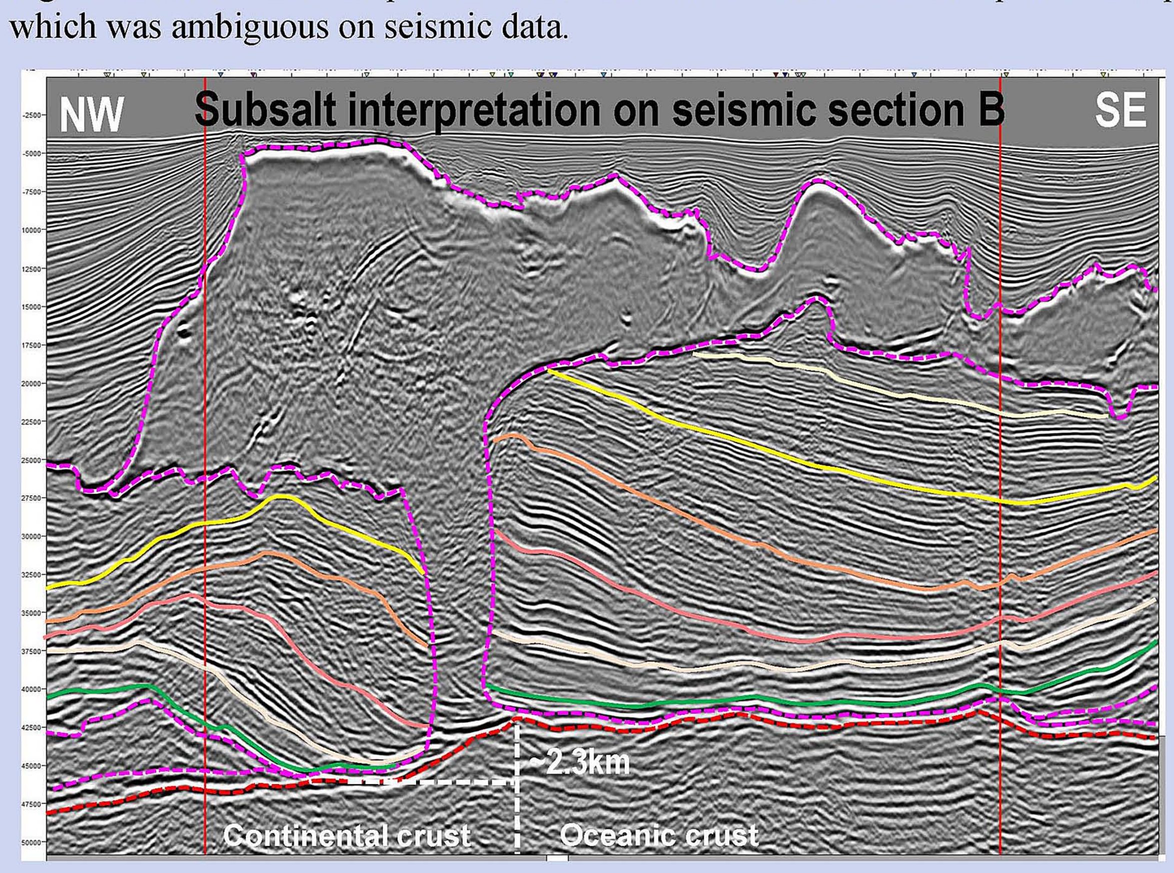


Fig. 9: WAZ-RTM data along a NW-SE section across a canopy. Key subsalt structural horizons and basement are superimposed. Note that a step of ~2.3km in basement depth is recognizable on the data at the interpreted oceanic-continental crust boundary.

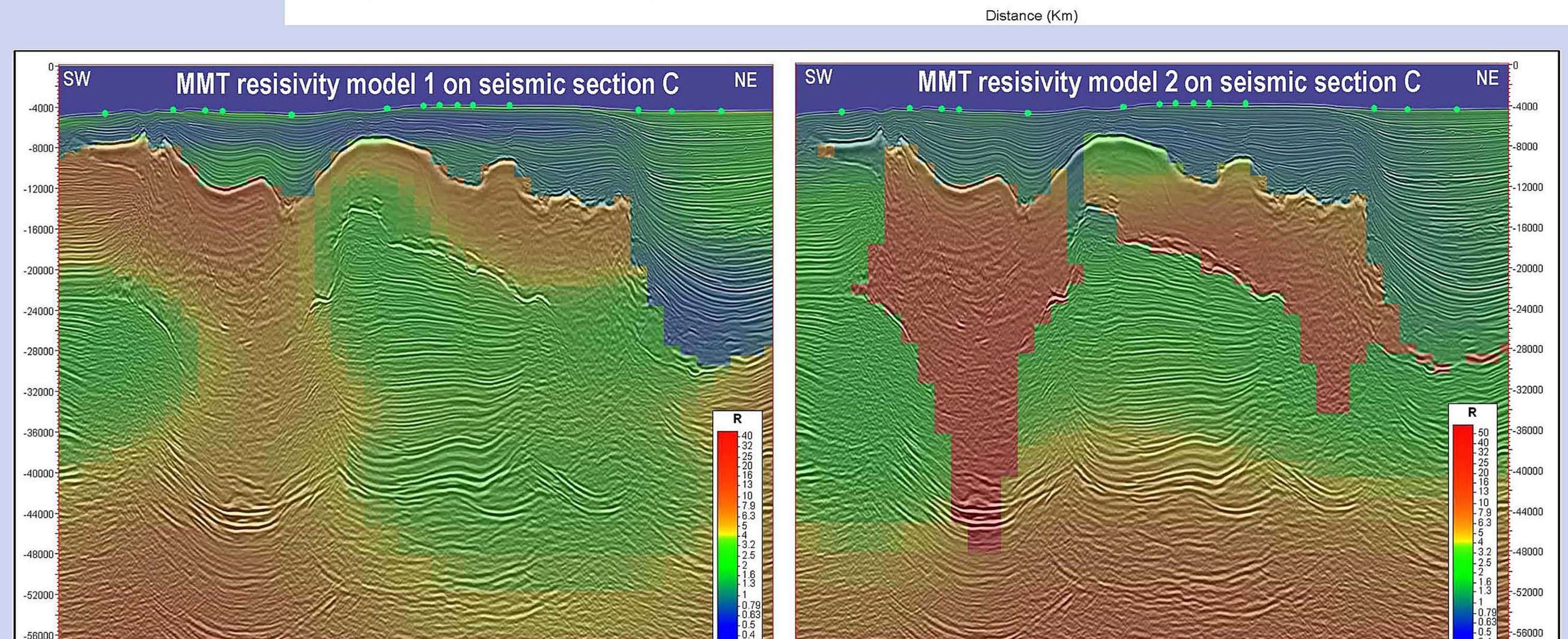


Fig. 10: Resistivity cross-sections from 3D inversion of MMT data, superimposed on seismic data. Model 1 (panel on the left) started from a salt-flood model: in the starting model the sediments above the salt were conductive, and everything below the top of salt as interpreted from seismic data was resistive. 3D inversion of MMT data inserted lower resistivity where sediments are expected. The panel on the right shows the resistivity cross-section obtained from a 3D MMT inversion starting from an a priori salt model, where the base of salt was interpreted integrating seismic and MMT data. The base of salt, questionable on seismic data, can be interpreted as a feeder with the support of electromagnetic data interpretation.

References

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