EA A New Crustal Model of the Gulf of Mexico – From Seismic and Potential Fields Data*

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Abstract

TGS acquired a dense grid of ship-borne 2D seismic, gravity and magnetic surveys (Gigante) over the Mexican Gulf of Mexico (MGOM). TGS and Bain Geophysical Services (BainGeo) have collaborated to create the "Gigante Crustal Study" covering offshore Mexico and the wider Gulf of Mexico. This work combines the Gigante survey data with TGS seismic data in the USA GOM and public domain data sets to give coverage over the entire GOM. This presentation will show how our results better illustrate the deep crustal structure of the GOM and their implications for understanding the early evolution of the GOM.

Data Available to the Study

Seismic data used in this project includes the Gigante 2D seismic survey in the MGOM and other TGS 2D and 3D surveys in the USA sector. Processing details for these surveys can be found at tgs.com. Interpretation of 10 regional horizons from basement to seafloor was completed throughout the Gigante survey, tied to key PEMEX wells (O'Reilly et al., 2017). This interpretation was extended to the USA seismic data. Gigante multibeam bathymetric data was used to determine the 3-D Bouguer / terrain correction to the gravity data in the MGOM. Public domain bathymetry data was used to compute the full 3-D Bouguer correction for gravity data beyond the MGOM.

Gravity and Magnetic data were acquired together with the seismic over the Gigante survey area. The Gigante ship-borne data were merged with public domain gravity data (Sandwell et al., 2014) and magnetic data (Quesnel et al., 2009; Meyer et al., 2017) to create maps for the entire GOM area. Refraction seismic data (Marton and Buffler, 1994; Eddy et al., 2014) were used to calibrate gravity inversion to determine depth to Moho.

Methodology

Depth to Magnetic Basement - theory and calculation

What we interpret as basement can differ depending on the method used: seismic (acoustic) basement, gravity (high-density) basement and magnetic (crystalline) basement. For example, in the GOM, deep carbonates can very easily complicate the interpretation of both the acoustic basement and high-density basement, while the crystalline basement from magnetics is not impacted by these large velocity/density changes. Similarly, whereas the density and velocity of deep sediments approach those of basement, the magnetic susceptibility contrast at basement generally remains very high. Generally, magnetic basement is considered more reliable.

Old methods of estimating depth to magnetic basement (which assumed an infinitely thick magnetic crust) could be as much as 50% in error. Modern methods of estimating depth to magnetic basement in oceanic crust and in stretched continental crust differ from legacy methods by including an assessment of the thickness of the magnetic crust. This greatly improves the accuracy of the depth results (Flanagan and Bain, 2012a; Flanagan and Bain, 2012b; Flanagan and Bain 2013).

Depth to magnetic basement solutions were computed using labor-intensive interpretation of the magnetic field gradients extracted from the grid, and later applied to the entire Gigante magnetic data set (186,425 line km). These methods that incorporate the depth-extent (or thickness/depth) parameter are used to derive the first pass, or base line depth to basement result. Then, other methods are carefully applied and screened, and used to infill the picture.

Determine Thickness of Crust and Depth to Moho by constrained Gravity Modelling and Inversion

Total Sediment Thickness in the MGOM was determined as the thickness between the Gigante multibeam bathymetry seabed map and the depth to magnetic basement (see above; Figure 1). Total Sediment Thickness beyond the MGOM was taken from public domain data sources (Laske et al., 2013). Sediment density used a 3-D density cube derived from the Gigante velocity model for MGOM, and sediment density functions for the remainder of the model. Salt thicknesses (from TGS seismic) were used in both MGOM and USA GOM to account for the distinctive gravity effects of large, often allochthonous salt bodies.

Bathymetric data was used to correct the Bouguer gravity data. Inversion of the Bouguer gravity field yields the depth to Moho, crustal thickness, and an estimate of the limit of oceanic crust (LOC) or continental / oceanic crustal boundary (COB). Recent improvements to gravity inversion methods allow the incorporation of a thermal gravity correction (Greenhalgh and Kusznir (2007), Chappell and Kusznir (2008)), which recognizes that stretching the lithosphere induces a long wavelength change in the gravity field caused by thermal effects altering the deep density field.". Additional improvements allow the inversion to simultaneously invert for structure, while also endeavoring to satisfy multiple Moho depth control points, thus improving the crustal thickness result over previous inversion methods.

Results

Moho depths of between 13 – 40 km over the entire marine GOM were determined by the calibrated and constrained gravity inversion. A crustal thickness map was made by combination of the Depth to Moho map and the Depth to Magnetic Basement (Ultra Thin Crust model) map. Results from the crustal thickness map show very thin crust (2 – 5 km thickness) in the area immediately east of the interpreted transform fault variously called Western Main Transform (Marton and Buffler, 1994) or Western Gulf Transform (Pindell et al., 2015).

This work also produces a more accurate derivation of the Limit of Oceanic Crust (LOC). The McKenzie and Bickle (1988) model can be used to provide an estimate of the oceanic crust (the blue area in Figure 1). Subtraction of the blue area from the total crust yields the separate area of continental crust (the green area in Figure 1). Thus, we can derive a semi-automated estimate of the limit of oceanic crust. The purple polygon in Figure 2 indicates the LOC predicted using just the public domain base of sediments as the top crust. The green polygon in Figure 2 shows the LOC predicted using the top of magnetic crust in the Gigante area as the top crust. The two polygons overlap in the USA sector, and diverge in the Alaminos Canyon and MGOM areas (where finer control from the Gigante data is available). The new LOC matches closely with the map of oceanic crust indicated from the Gigante seismic interpretation. Comparison of the LOC polygons derived in this work with those published by other authors (Figure 2) show some significant disparities, most notably in the area north and west of the Campeche Salt Province and along the Western Main Transform.

Conclusions

- Depth to magnetic basement determined throughout the MGOM
- Depth to magnetic basement mapping, combined with seismic basement maps, show the extent and architecture of the deep syn-rift grabens and half-grabens underlying the northern Campeche Salt Basin on stretched continental / transitional crust along the flanks of the mapped oceanic crust
- Gravity inversion (tightly integrated with depth to magnetic basement, regional seismic interpretation and public refraction control) is used to create a depth to Moho horizon and crustal thickness interpretation
- Gravity inversion and careful integration with seismic interpretation, supports an ultra-thin crustal model, with important implications for basin and thermal modeling
- 3-D gravity inversion provides an independent estimate of the Limit of Oceanic Crust.

Selected References

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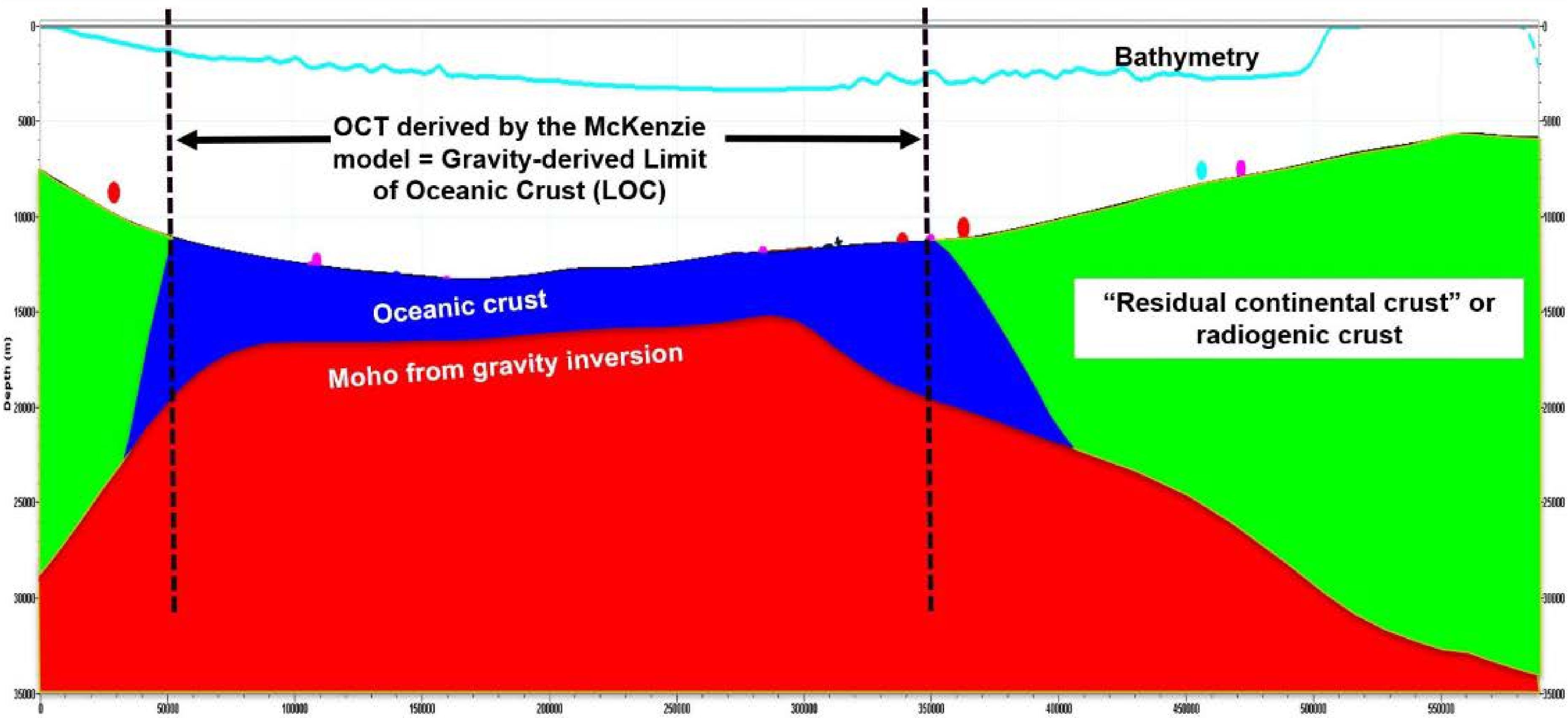

Figure 1. Definition of “Residual Continental Crust” and Limit of Oceanic Crust (LOC).

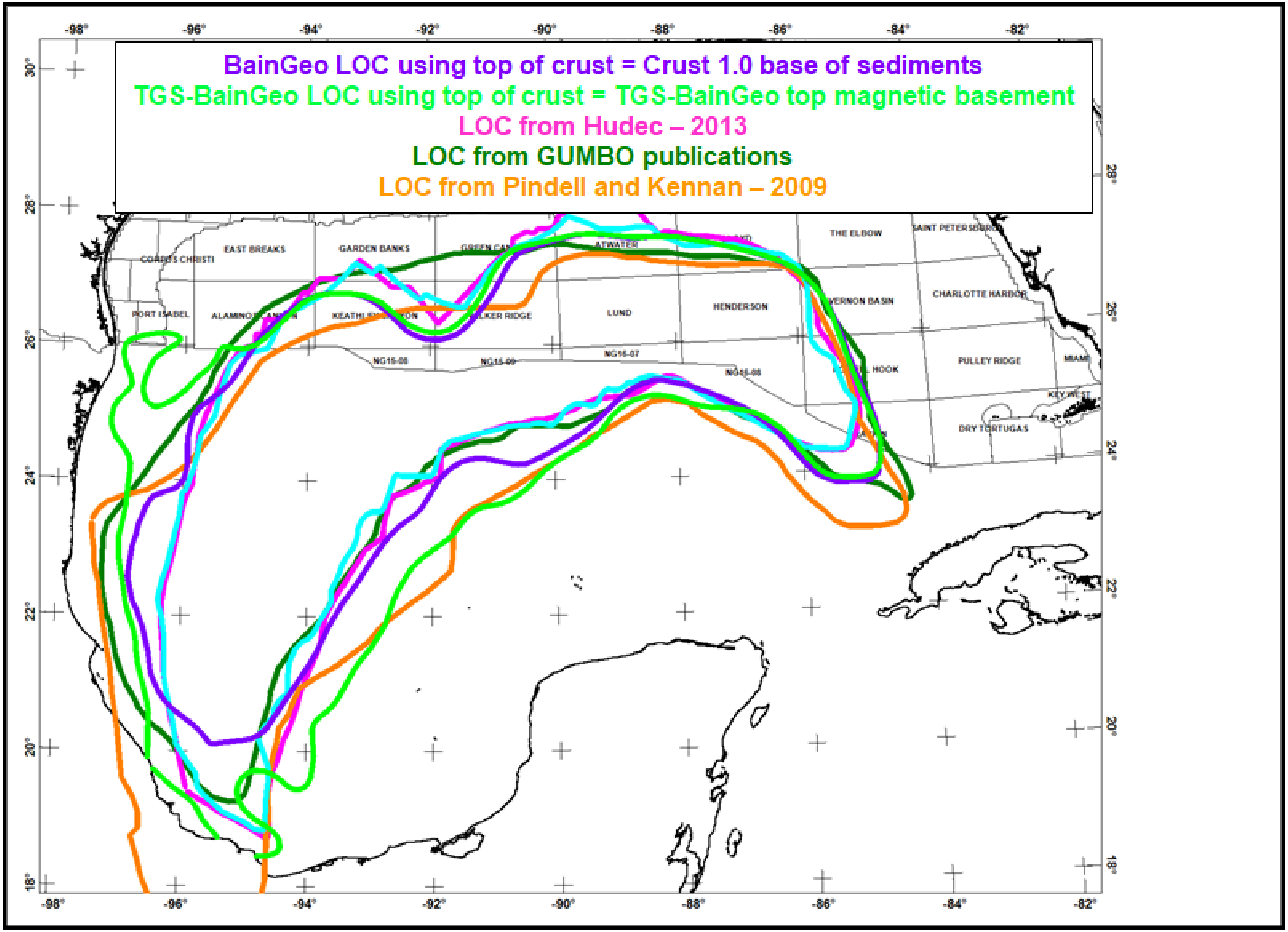

Figure 2. Limit of Oceanic Crust (LOC) – Comparison of this study with published LOC boundaries.