Continent-Ocean Transition at the Northern Margin of the South China Sea*

Jinwei Gao[1], Shiguo Wu[1], Kirk McIntosh[2], Lijun Mi[3], and Bochu Yao[4]

Search and Discovery Article #30451 (2016)**
Posted May 2, 2016

*Adapted from oral presentation given at AAPG International Conference & Exhibition, Melbourne, Australia, September 13-15, 2015

[1]Sanya Institute of Deep-sea Science and Engineering, Chinese Academy of Sciences, Sanya, Hainan, China (gaojinwei2013@gmail.com)
[2]Institute for Geophysics, University of Texas at Austin, Austin, TX (kirk@ig.utexas.edu)
[3]Exploration Department, China National Offshore Oil Corporation Ltd., Beijing, China
[4]Guangzhou Marine Geological Survey Bureau, Ministry of Land and Resources, Guangzhou, Guangdong, China.

Abstract

The northern margin of the South China Sea (SCS) has particular structural and stratigraphic characteristics that are somewhat different than those described in typical passive margin models. The differences are due to poly-phase tectonic movements and magmatic activity resulting from interaction of Eurasian plate, Philippine Sea plate and the Indian-Australia plate. Based on several crustal-scale multi-channel seismic reflection profiles and satellite gravity data across the northern SCS margin, this article analyzes the structures, volcanoes, and deep crust of the continent-ocean transition zone (COT) at the northern margin of the SCS to study the patterns and model of extension there. Results show that the COT is limited landward by basin-bounding faults near shelf-slope break zone, and bounded by seaward-dipping normal faults near the oceanic basin in our seismic lines. The shallow anatomy of the COT is characterized by rift depression and structural highs with igneous rock and may include a volcanic zone or a zone of tilted fault blocks at the distal edge. Gravity modeling revealed that a High-Velocity Layer (HVL) with a thickness of 0.8–6 km is commonly present in the slope below the lower crust in the mid-northern margin of the SCS. Our study shows that the HVL is only located in the eastern portion of the northern SCS margin, based on the available geophysical data. We infer from this that the presence of an HVL is not required in the COT at the northern SCS margin. The magmatic intrusions and HVL may be related to partial melting caused by decompression of passive, upwelling asthenosphere which resulted primarily in post-rifting underplating and magmatic emplacement or modification of the crust. Based on this study we propose that an intermediate mode of rifting was active in the mid-northern margin of the SCS with characteristics that are closer to those of the magma-poor margins than those of volcanic margins.

Selected References

Barckhausen, U., M. Engels, D. Franke, S. Ladage, and M. Pubellier, 2014, Evolution of the South China Sea: Revised ages for breakup and seafloor spreading: Marine and Petroleum Geology, v.58, p. 599–611.

Geoffroy, L., 2005, Volcanic passive margins: Comptes rendus-Geoscience, v. 337/16, p. 1395-1408.

Li, C.F., X. Xu, J. Lin, Z. Sun, et al., 2014, Ages and magnetic structures of the South China Sea constrained by deep tow magnetic surveys and IODP Expedition 349: Geochemistry, Geophysics, Geosystems. v. 15, p. 4958-4983.

Li, J.B., W.W. Ding, Z.Y. Wu, J. Zhang, and C.Z. Dong, 2012, The propagation of seafloor spreading in the Southwest Sub-basin, South China Sea: Chinese Science Bulletin, v. 57/20, p. 1896–1905.

Li, L., P. Clift, and H.T. Nguyen, 2013, The sedimentary, magmatic and tectonic evolution of the southwestern South China Sea revealed by seismic stratigraphic analysis: Marine Geophysical Research, v. 34, p. 341–365.

Li, S.Z., M. Santosh, and B.M. Jahn, 2012, Evolution of Asian continent and its continental margins: Journal of Asian Earth Sciences, v. 47, p. 1–4.

Rosenbaum, G., R.F. Weinberg, and K. Regenauer-Lieb, 2008, The geodynamics of lithospheric extension: Tectonophysics, v. 458, p. 1-8.

Sawyer, D.S., M.F. Coffin, T.J. Reston, J.M. Stock, and J.R. Hopper, 2007, COBBOOM: The continental breakup and birth of oceans mission:. Scientific Drilling, no. 5 (September), p. 13-25.

Wang, T.K., M.-K. Chen, C.-S. Lee, and K. Xia, 2006, Seismic imaging of the transitional crust across the northeastern margin of the South China Sea: Tectonophysics, v. 412, p. 237-245.

Zhu, J.J.,X.L. Qiu, H. Kopp, H.L. Xu, Z.X. Sun, A.G. Ruan, J.L. Sun, and X.D. Wei, 2012, Shallow anatomy of a continent-ocean transition zone in the northern South China Sea from multichannel seismic data: Tectonophysics, v. 554-557, p. 18–29.

Zhu, W., and C. Lei, 2013, Refining the model of South China Sea's tectonic evolution: Evidence from Yinggehai-Song Hong and Qiongdongnan basins: Marine Geophysical Research, v. 34/3-4, p. 325-339.

AAPG SEG International Conference & Exhibition 2015
13-16 September • Melbourne, Australia
PESA Incorporating PESA's Eastern Australasian Basins Symposium

Continent-ocean transition at the northern margin of the South China Sea

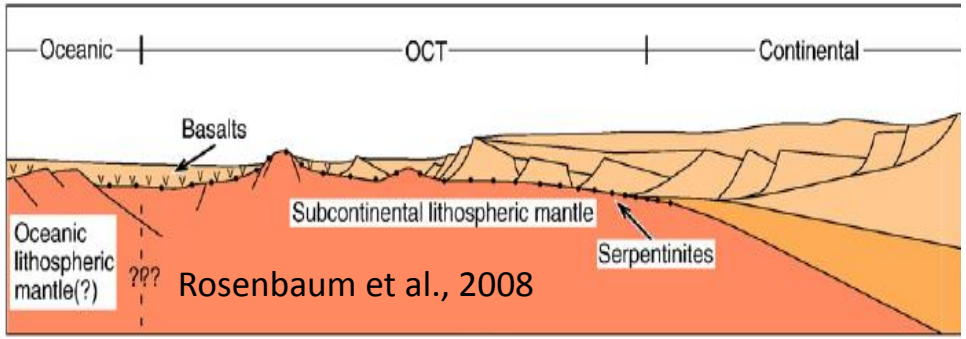
Jinwei Gao[1], Shiguo Wu[1], Kirk McIntosh[2], Lijun Mi[3], Bochu Yao[4]

1 Sanya Institute of Deep-sea Science and Engineering, Chinese Academy of Sciences, Sanya, China
2 Institute for Geophysics, University of Texas at Austin, Austin, Texas, USA
3 China National Offshore Oil Corporation Ltd., Beijing, China
4 Guangzhou Marine Geological Survey Bureau, Ministry of Land and Resources, Guangzhou, China

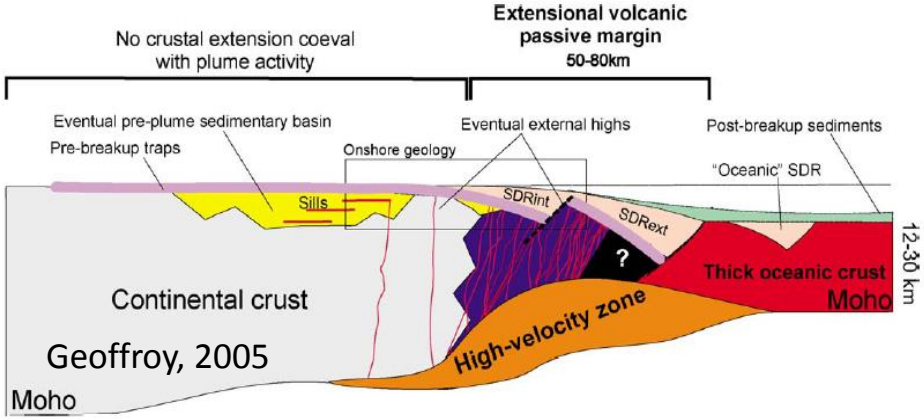
OUTLINES

- Introduction
- Geological settings
- Seismic profiles interpretation and gravity modeling
- Conclusions

Introduction



Rosenbaum et al., 2008



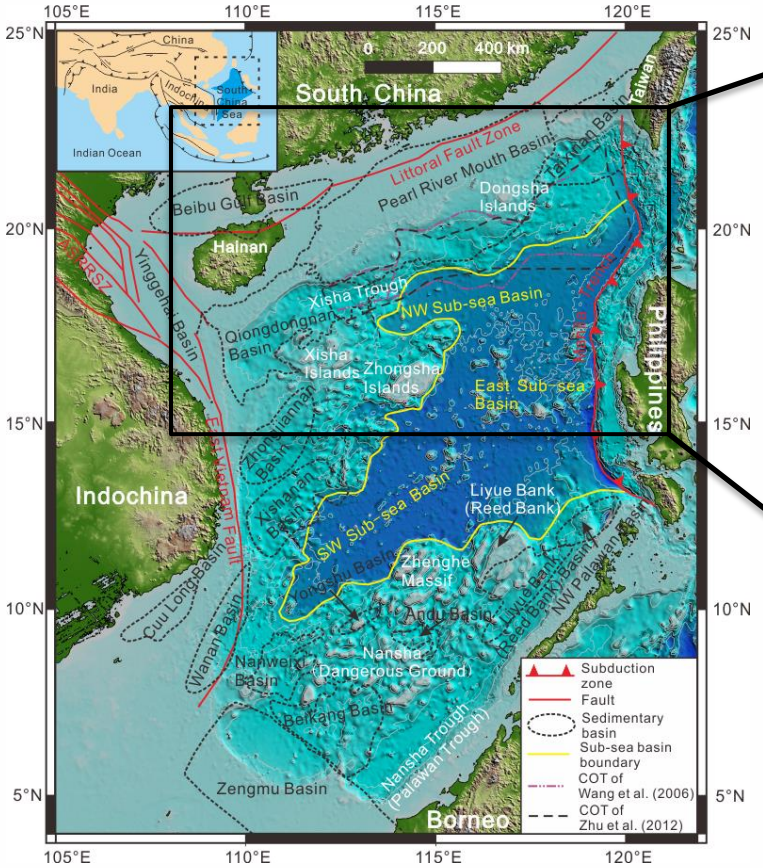
Geoffroy, 2005

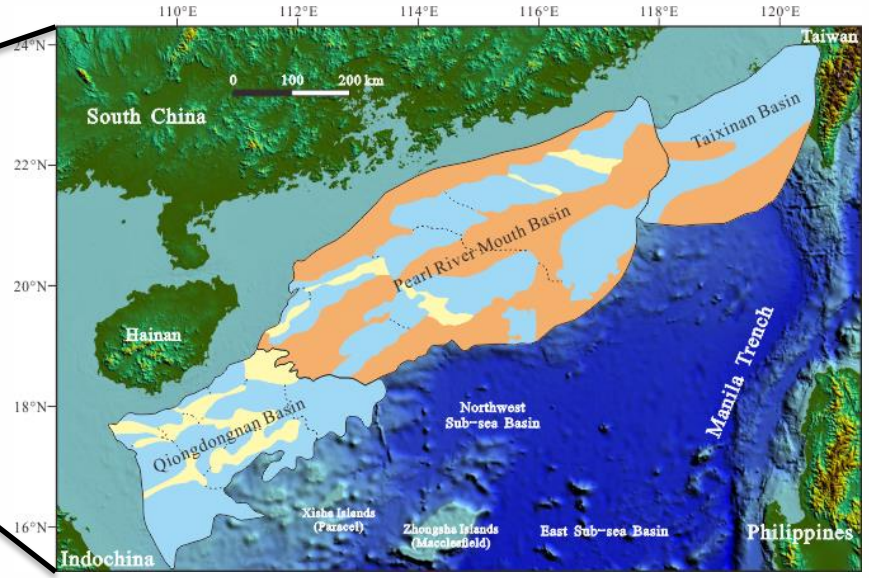
Two end member patterns of passive margins

COT zone in the magma-poor margins: detachment faults, tilted fault blocks, **serpentinized peridotite ridges**, and limited syn-rift magmatism;

COT zone in the Volcanic margins: seaward dipping reflectors (**SDRs**), the expression of subaerial lava flow, the presence of **sills** and **dykes** in the sediment and a high velocity layer (**HVL**).

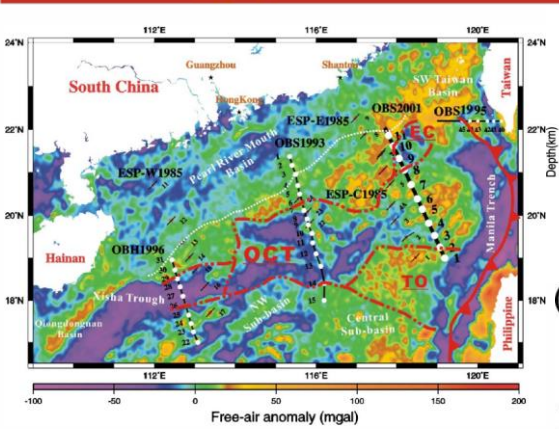
Geological settings



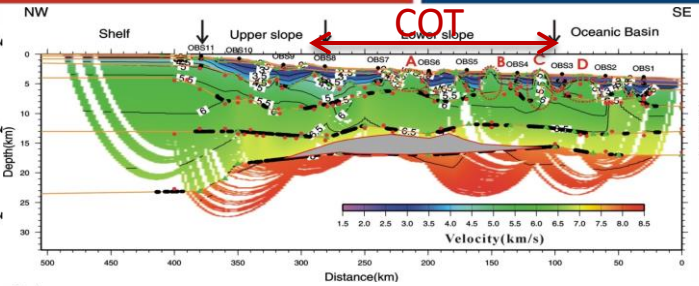


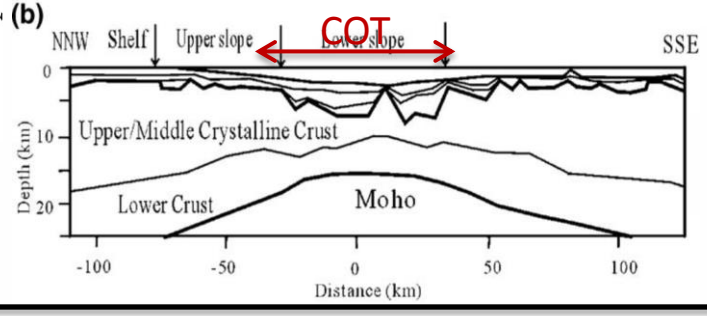
Rifting: started at 65Ma, and ended at 32 to 30 Ma;

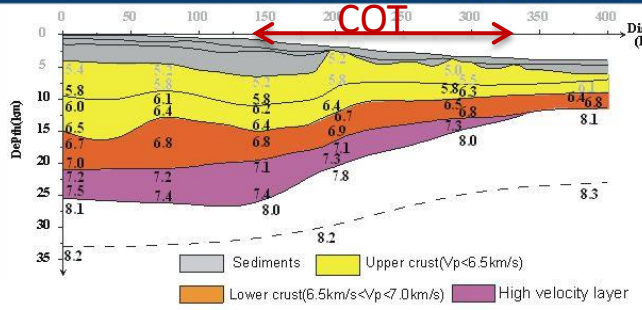
Seafloor spreading: ended at 16.5 to 15.5Ma (Li et al., 2014).



The extent of the COT of Wang et al.(2006)

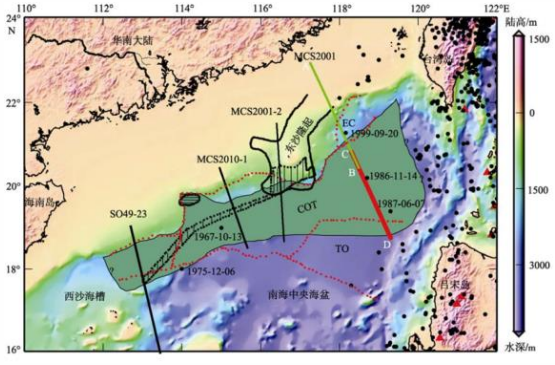


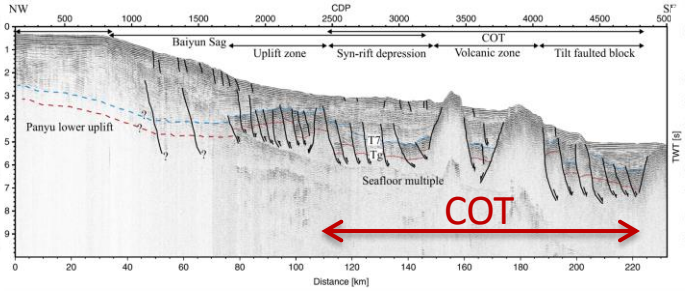


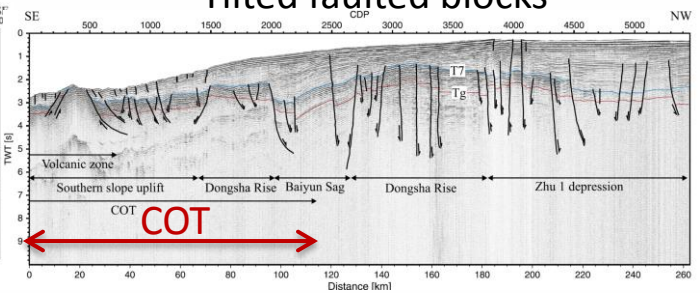


Crustal thinning
High Velocity Layer
Moho depth

Syn-rift depressions
Volcanic zone
Tilted faulted blocks



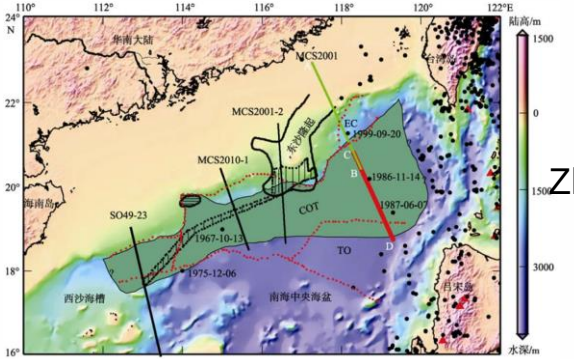




The extent of the COT of Zhu et al.(2012)

Questions

- 1. Which division of the COT at the northern SCS margin is much better?
- 2. Where does the HVL disappear?
- 3. What pattern is the northern margin of the SCS?



Zhu et al.,2012

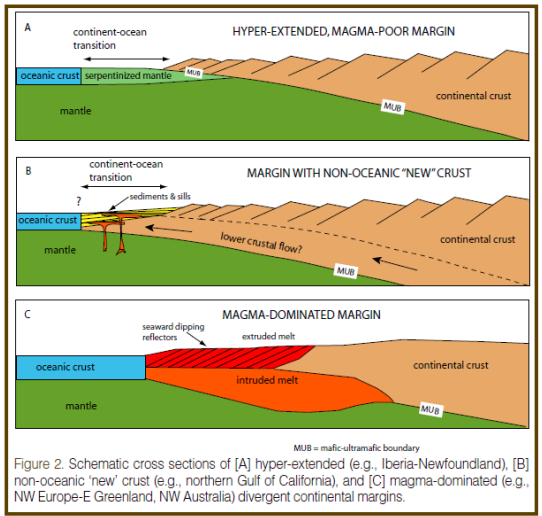
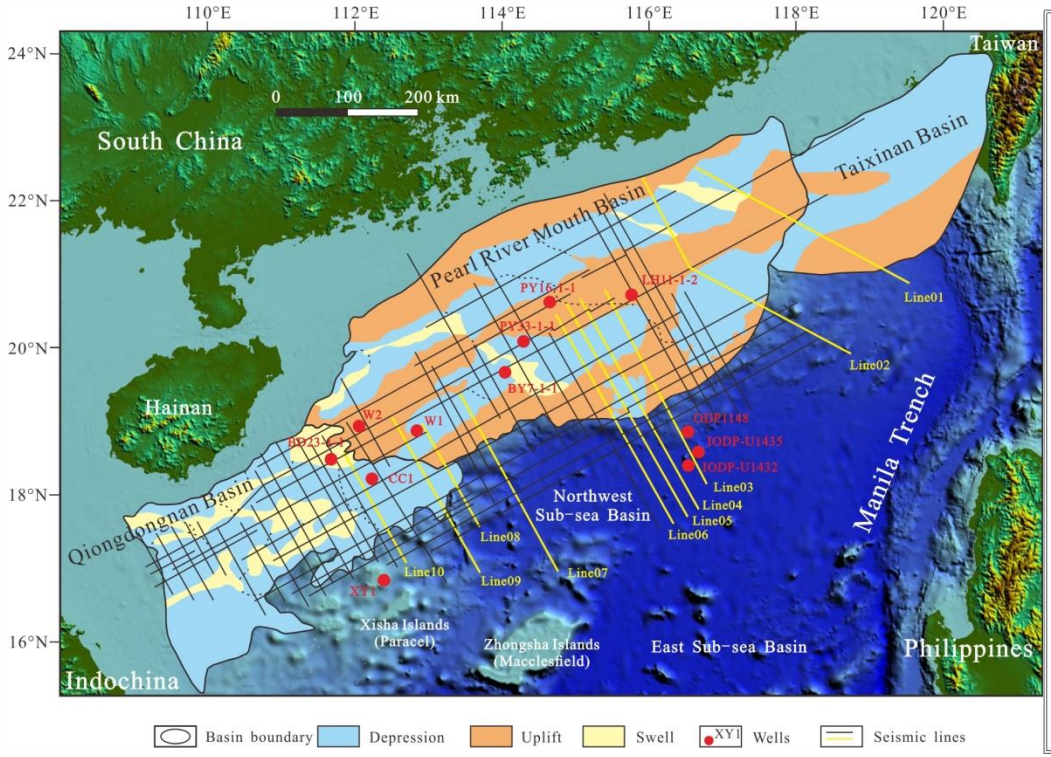
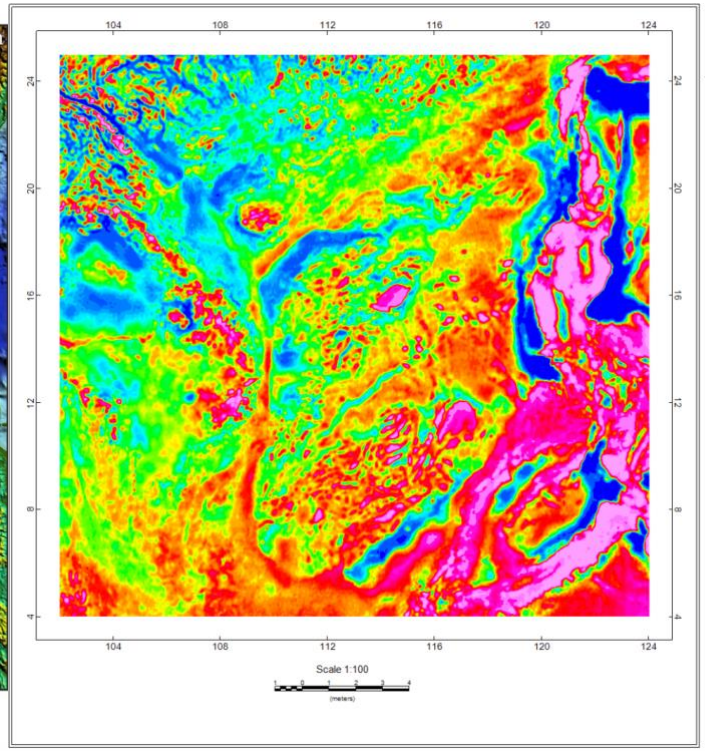


Figure 2. Schematic cross sections of [A] hyper-extended (e.g., Iberia-Newfoundland), [B] non-oceanic 'new' crust (e.g., northern Gulf of California), and [C] magma-dominated (e.g., NW Europe-E Greenland, NW Australia) divergent continental margins.

Sawyer et al.,2007

Seismic profiles interpretation and gravity modeling

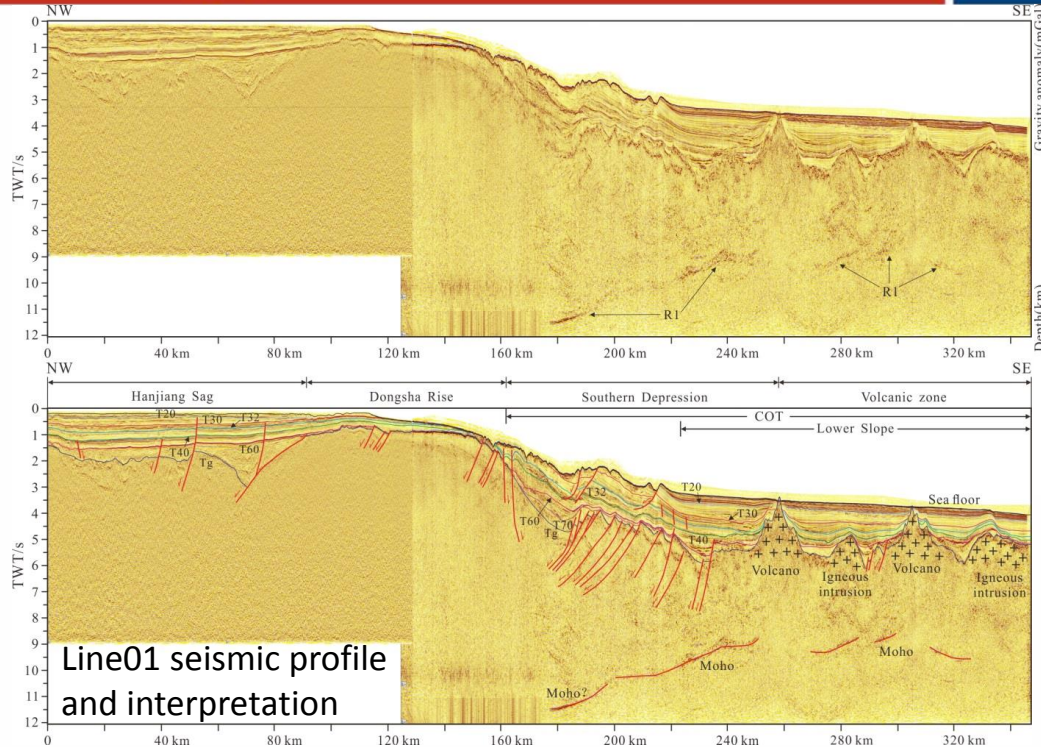




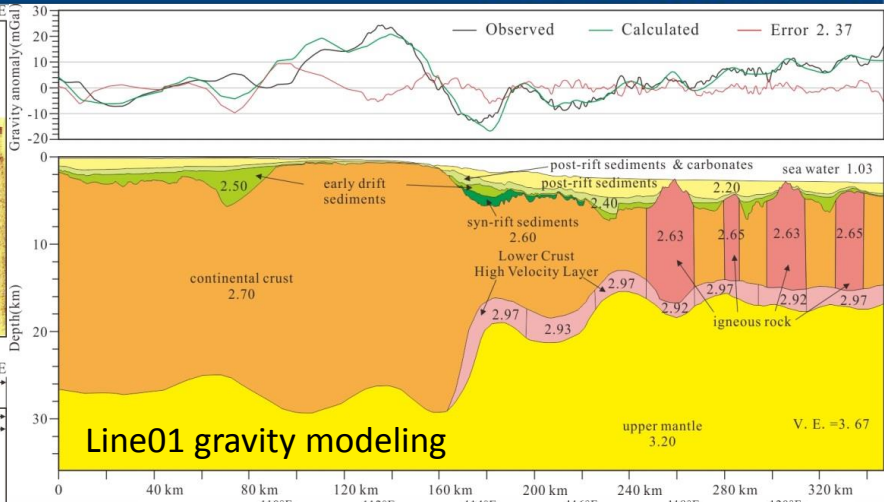
Multi-channel seismic reflection and satellite-derived gravity data.

Characteristics of the COT at the northern margin of the South China Sea

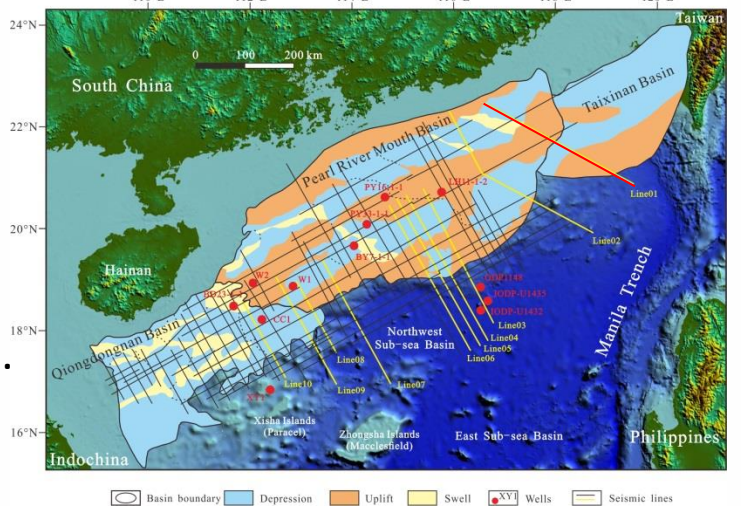
- 1) Crustal thinning and the Moho depth change .
- 2) Volcanoes and igneous intrusive rocks may be present in the lower slope.
- 3) An HVL is likely to be present below the lower crust.
- 4) Syn-rift depressions and tilted fault blocks.
- 5) Gravity anomaly associated with presumed oceanic, transitional, and continental crust.
- 6) The break-up unconformity.



Line01 seismic profile and interpretation



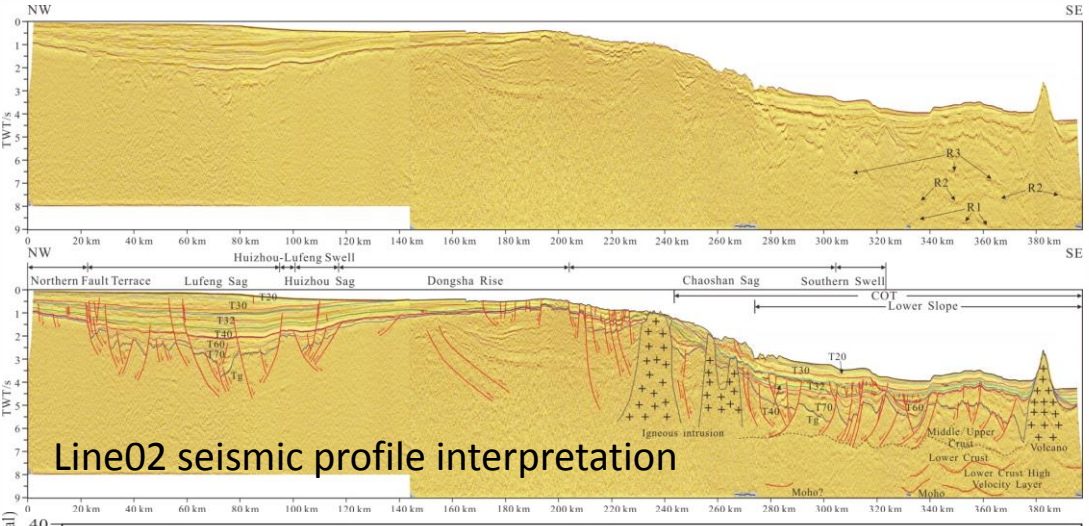
Line01 gravity modeling



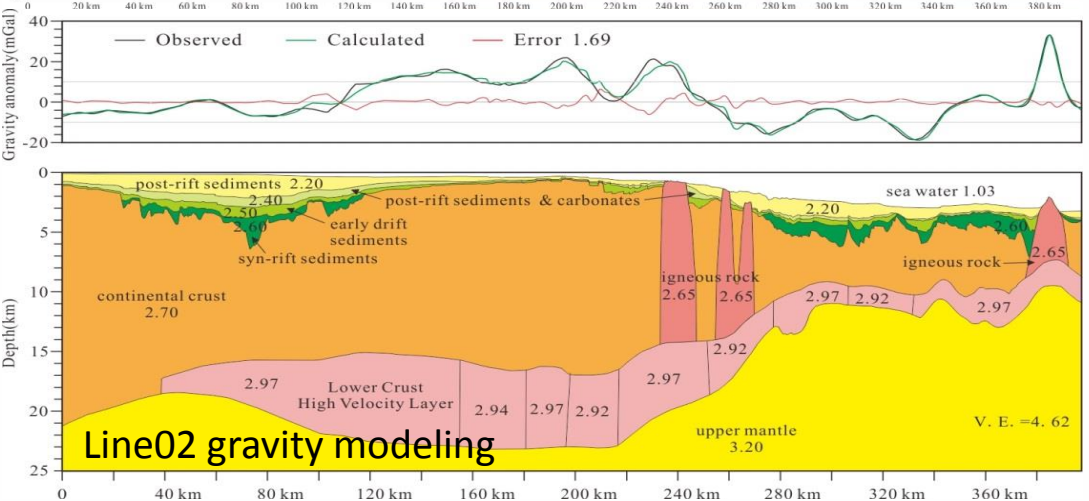
Syn-rift depression and volcanic zone.

Moho depth changes from 11s to 9s (Two-way-travel time).

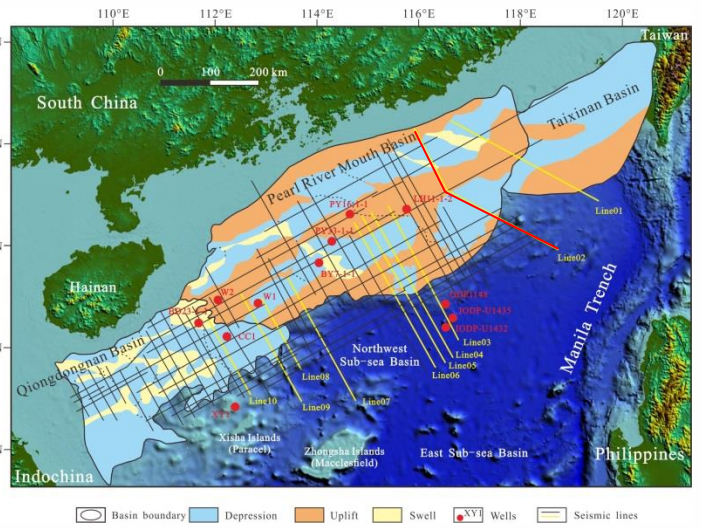
High Velocity Layer with a thickness of 2-3 km.



Line02 seismic profile interpretation



Line02 gravity modeling

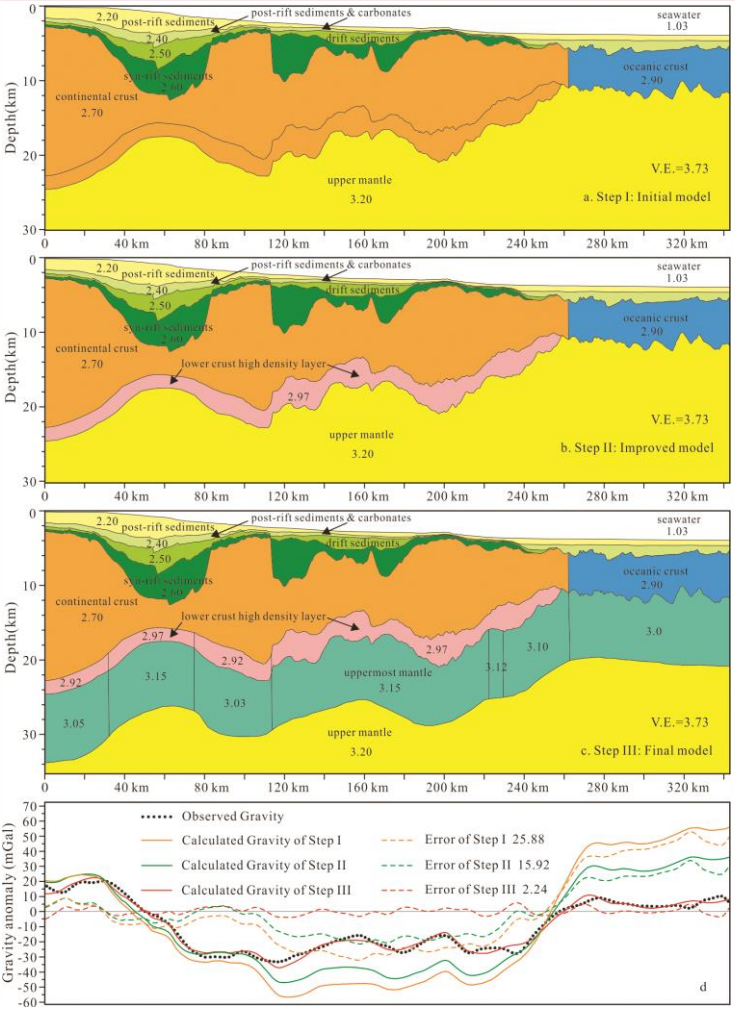


Syn-rift depression affected by igneous intrusion and sills.

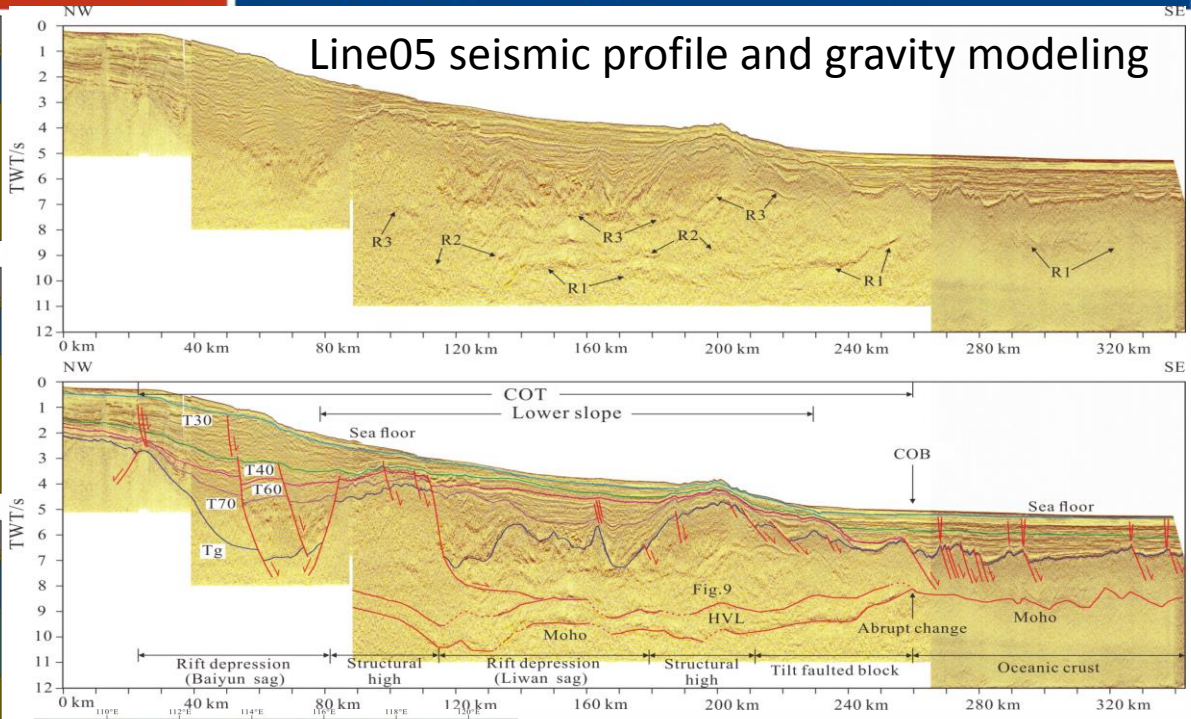
Volcanic zone.

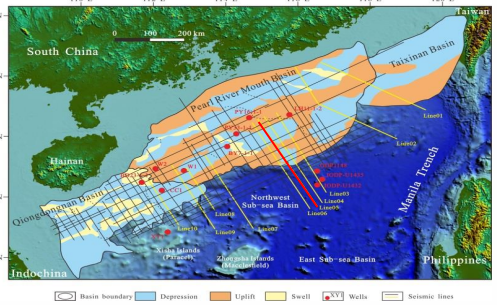
A detachment fault (between 6s and 7s).

A much thicker HVL (~10 km thick at the shelf) below the lower crust.

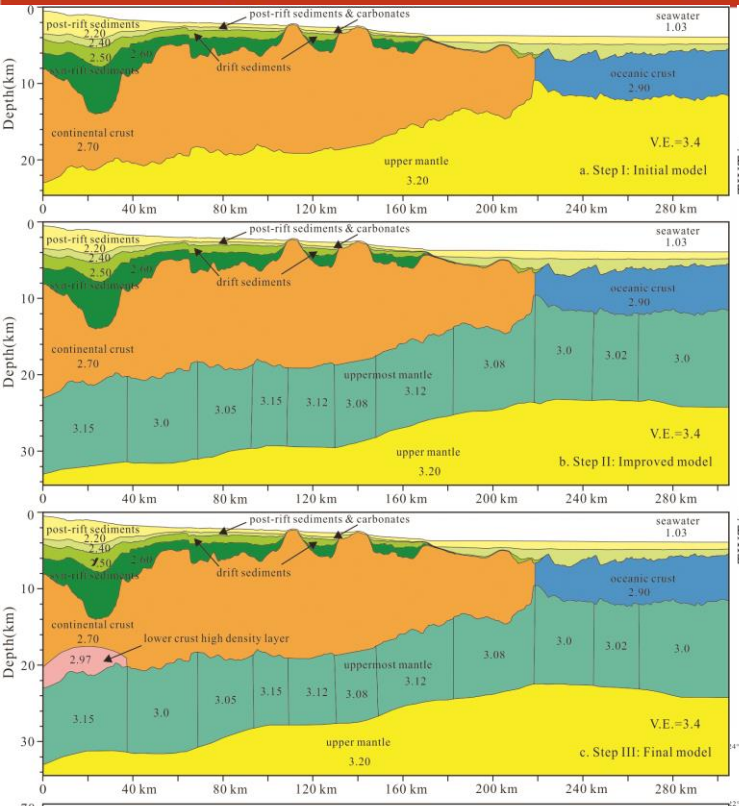


Line05 seismic profile and gravity modeling

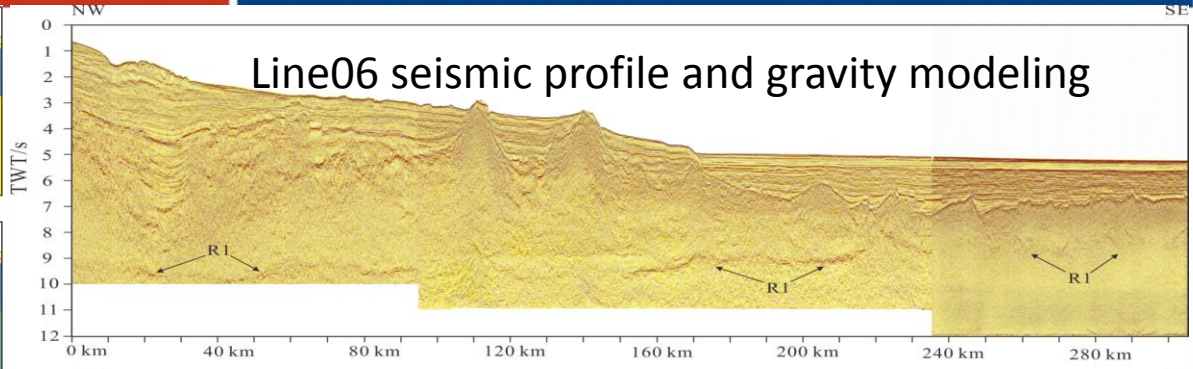


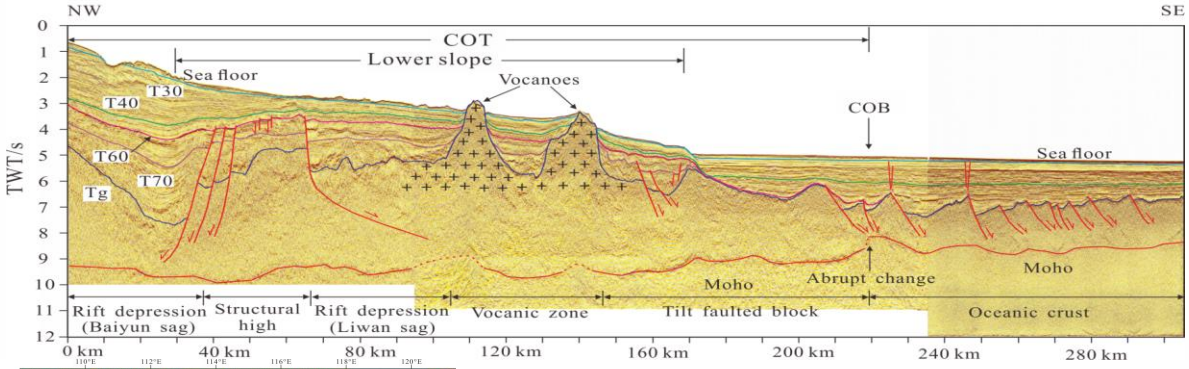


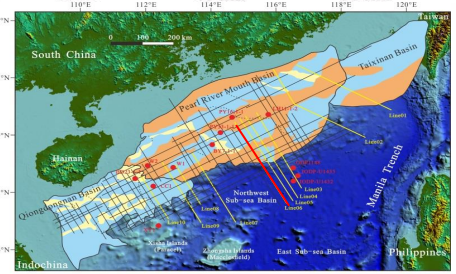
Rift depressions.
Structural highs.
Tilted faults blocks.
Moho depth (10.5s to 8s).
An HVL with 0.8-6km thick.



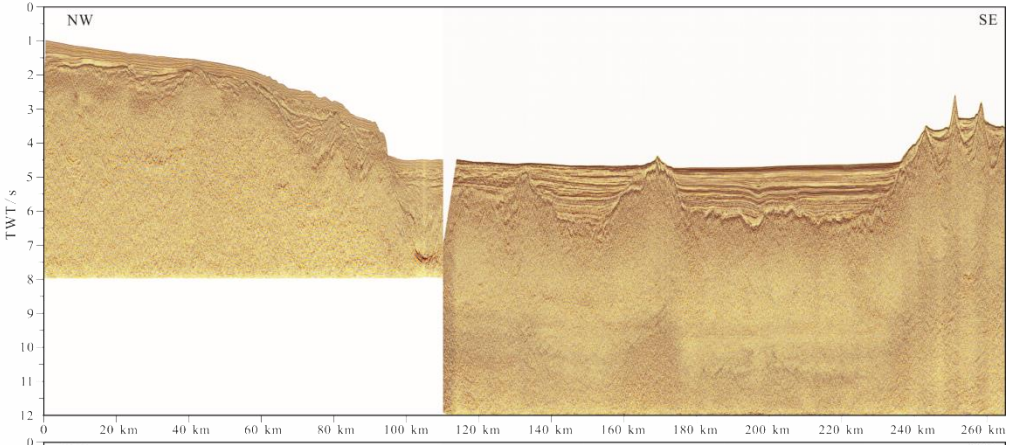
Line06 seismic profile and gravity modeling

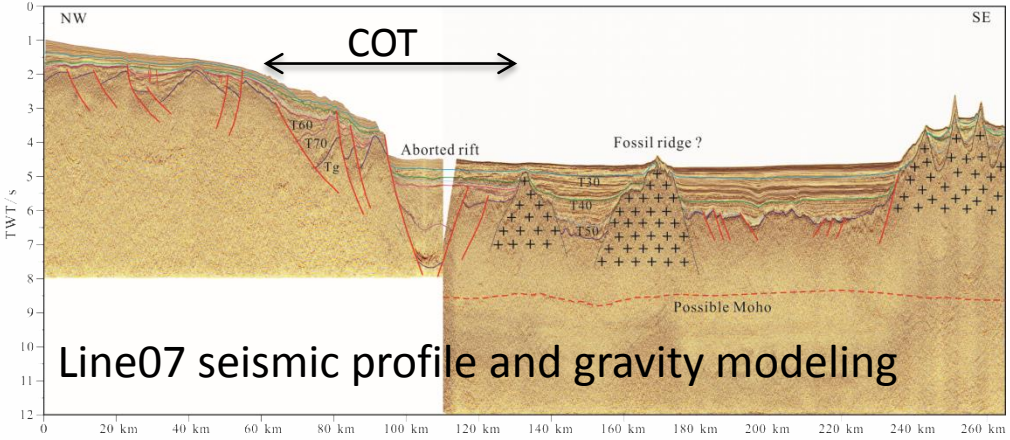






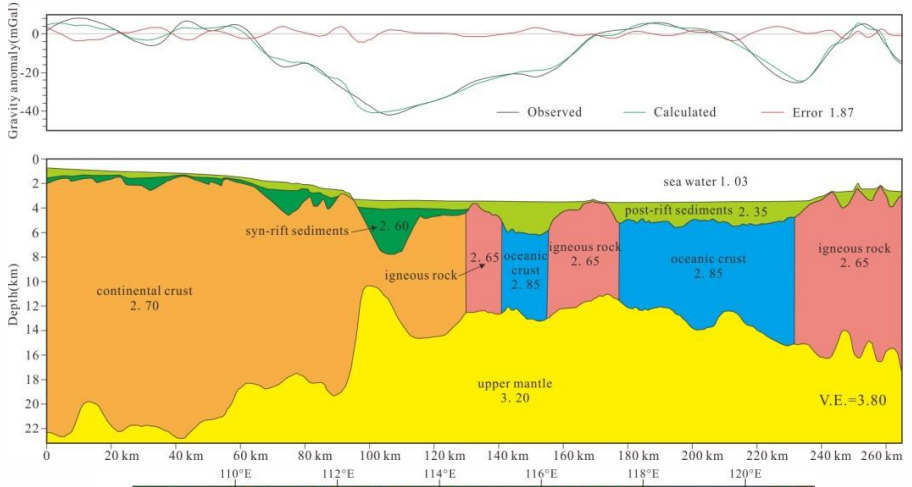
Syn-rift depressions. Volcanic zone.
Tilted faults blocks.
Moho depth (10s to 8s).
A limited HVL with 2-3 km thick.

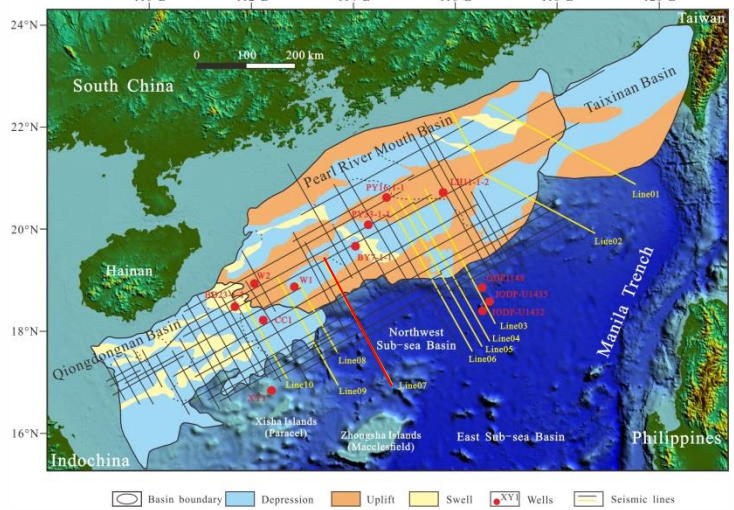


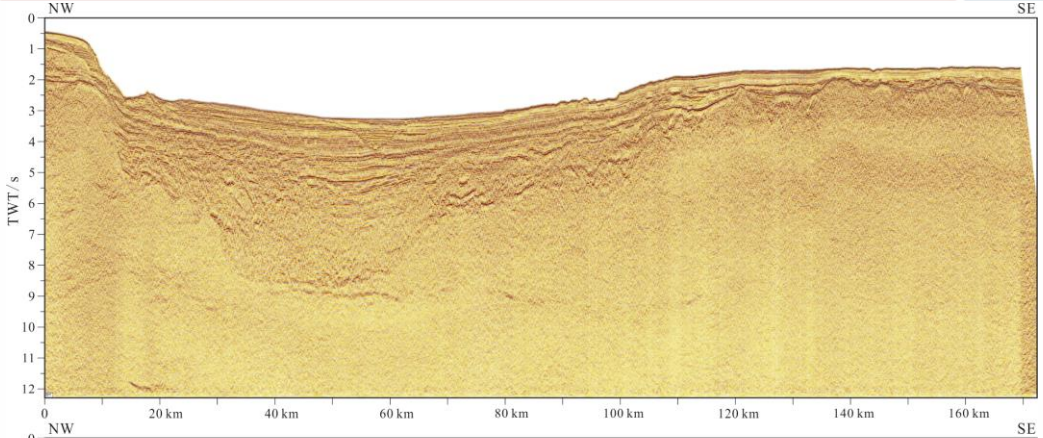


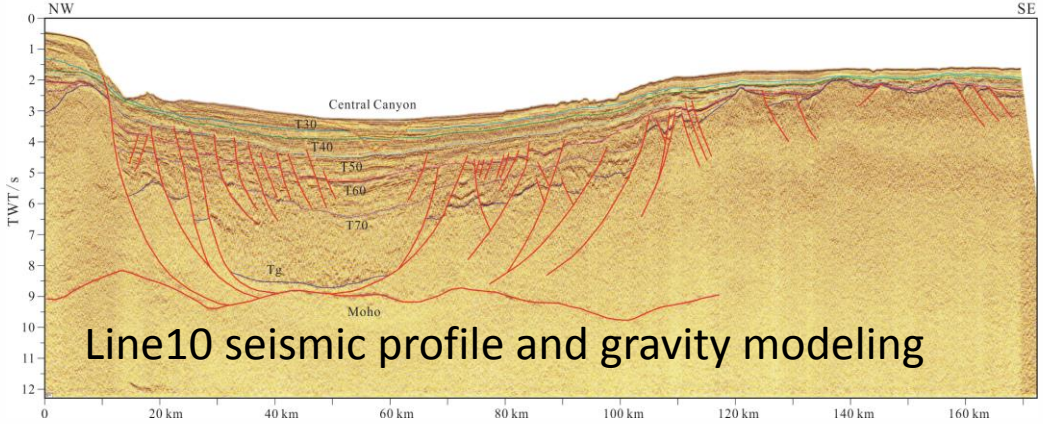
Line07 seismic profile and gravity modeling

An aborted rift and a fossil ridge

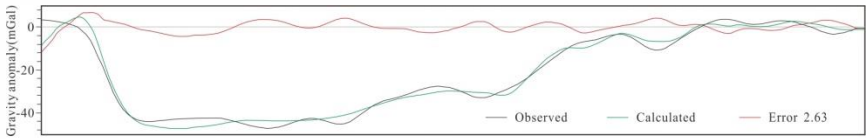


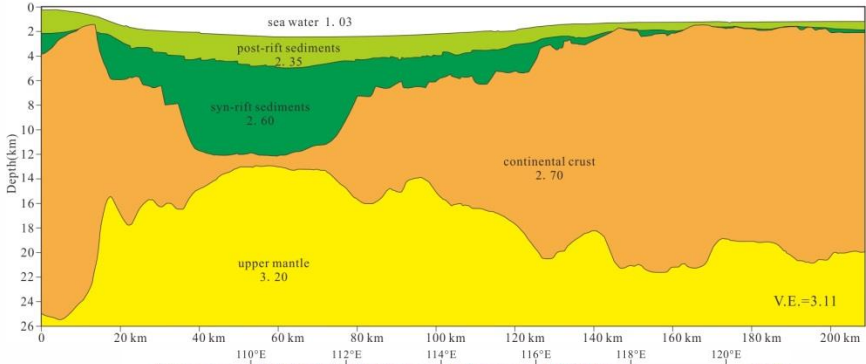


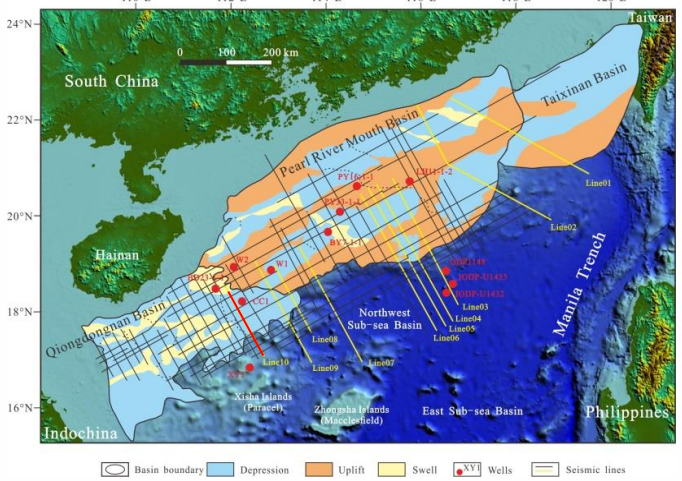




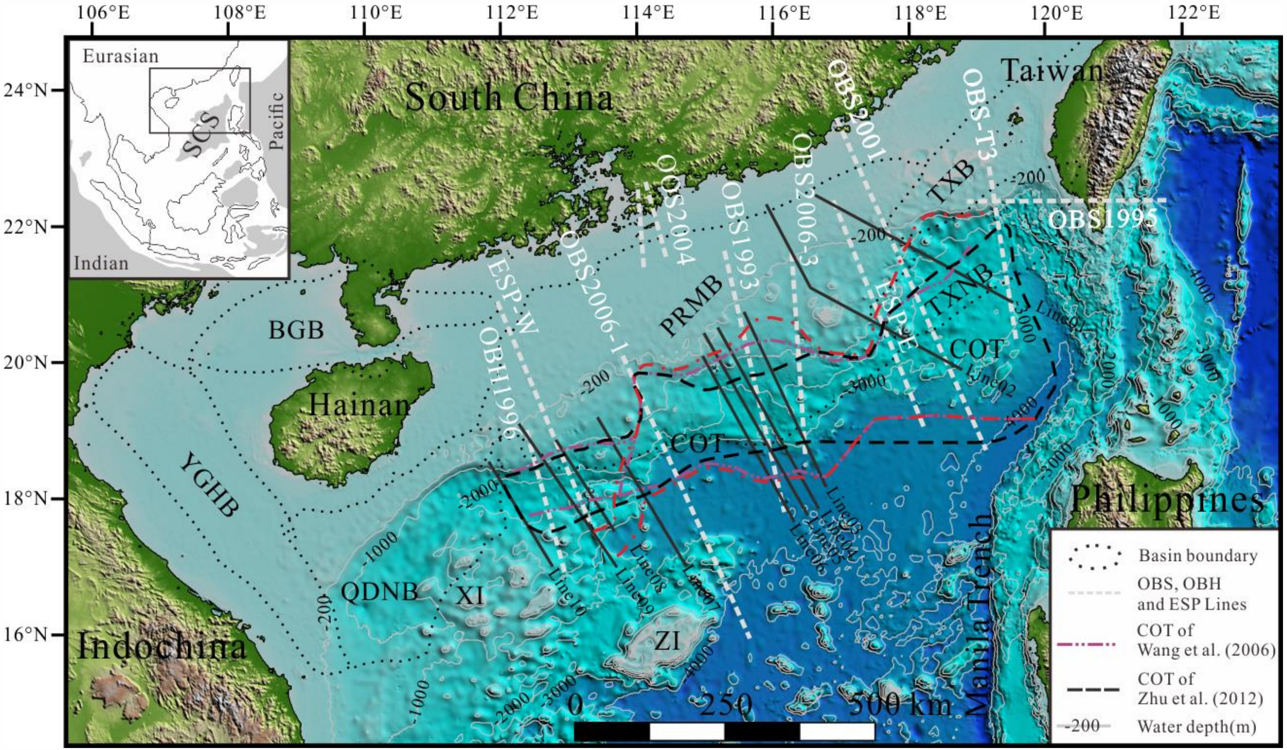
Line10 seismic profile and gravity modeling





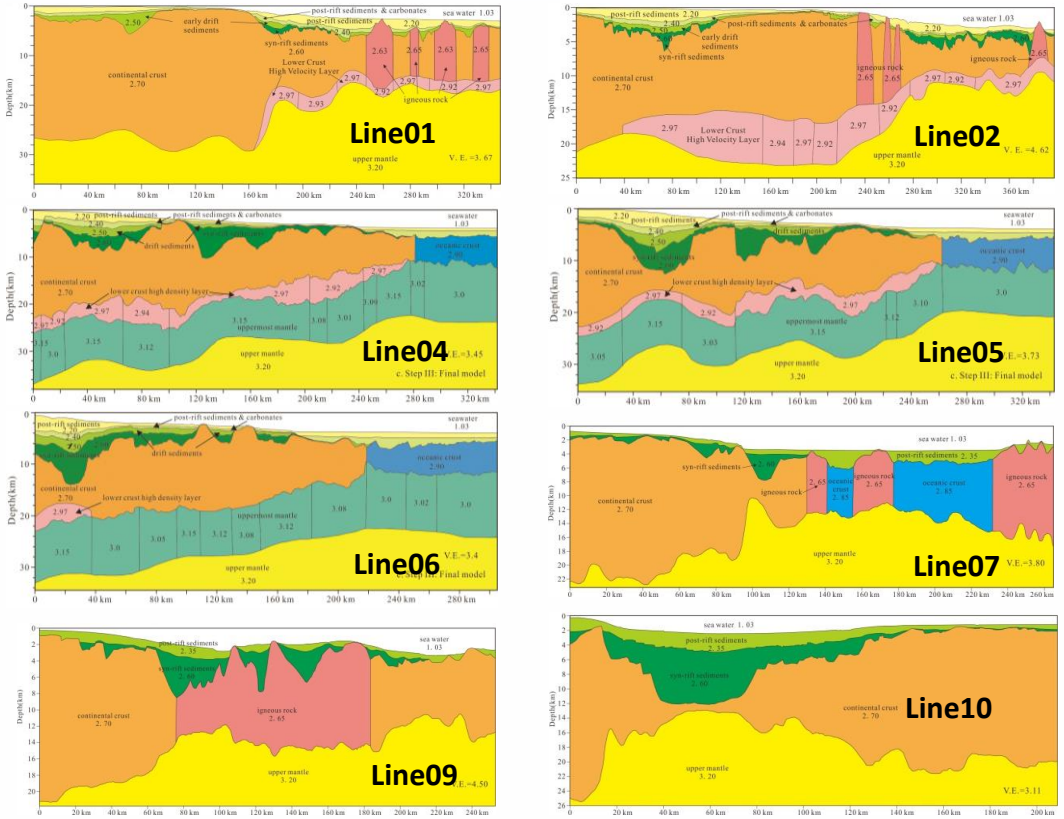


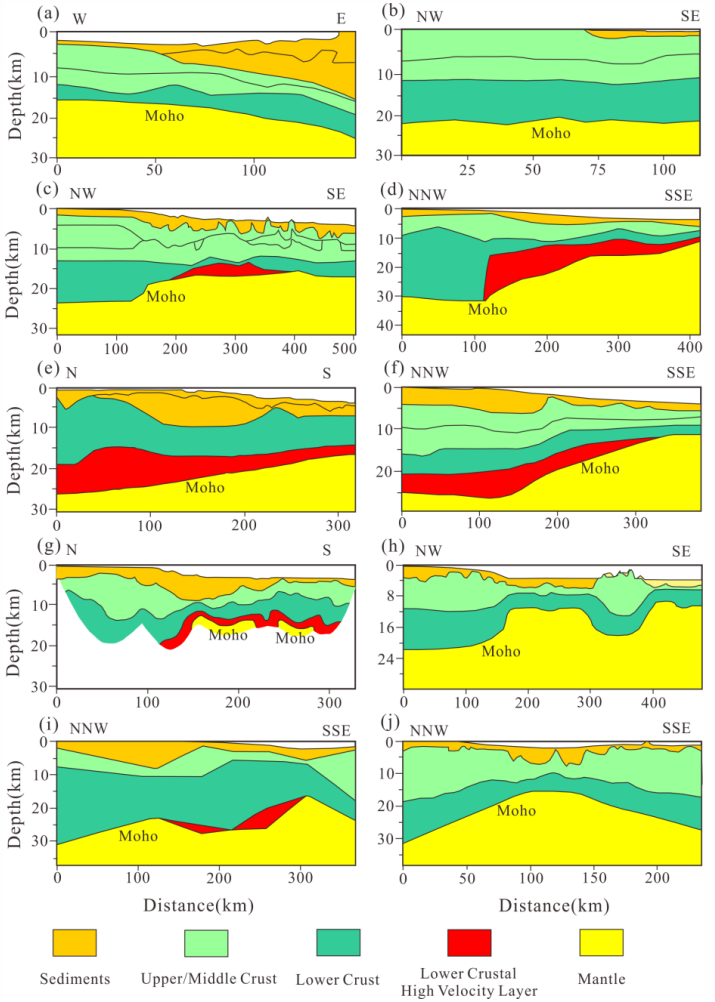
Hyper-extended continental crust (< 0.5s/2 km).



The extent of the COT at the northern margin of the South China Sea

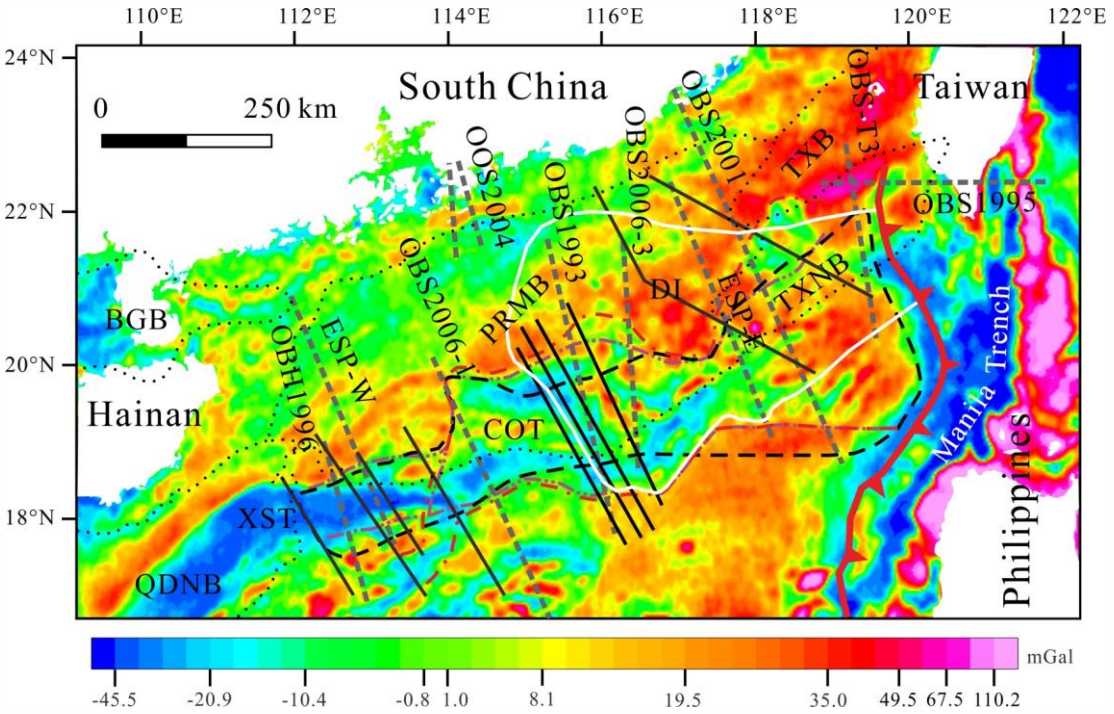
The extent delineated by Wang et al. (2006) is much better.





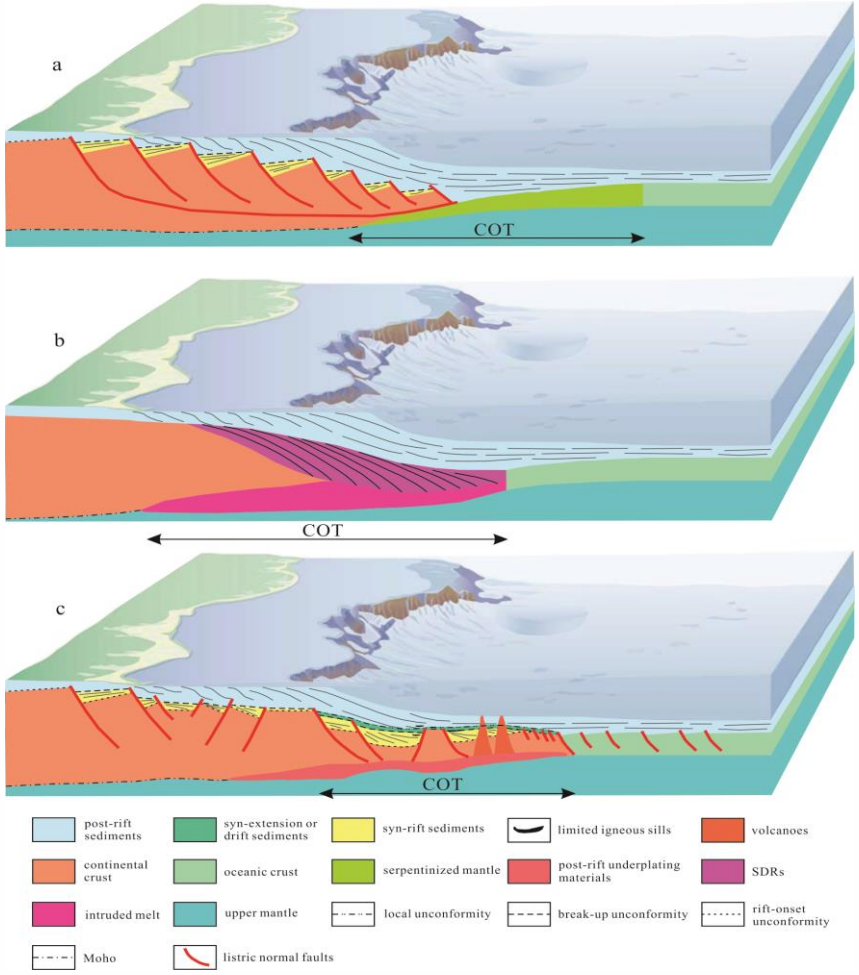
Left：Gravity modeling;

Right：ESP, OBH, and OBS profiles



Distribution of the HVL in the northern SCS. White line shows the extent of the HVL.

Non-coupling of the spatial extent between HVL and COT



- Characteristics the mid-northern margin of the SCS:
- (1) wide regions of COT;
- (2) syn-rift depressions and tilted fault blocks ;
- (3) no clear evidence of exposed mantle lithosphere;
- (4) some limited syn-rift magmatism and significant post-seafloor spreading volcanism;
- (5) a local extent of the HVL below lower crust.

Conclusions

- 1. The shallow structures of the COT is characterized by syn-rift depressions, structural high with igneous sills, volcanic zone, and tilted fault blocks bounded by normal fault seaward.
- 2. The high velocity layer (HVL) is mainly located in the northeast South China Sea margin.
- 3. The non-coupling of the spatial extent between HVL and COT shows that the HVL may not be a necessary sign of the COT at the northern SCS margin.
- 4. An intermediate rifting mode was proposed to explain the mid-northern margin of the SCS which is closer to the magma-poor margins than volcanic margins.

The End

Thank you for your time!

Acknowledge support from Institute for Geophysics, University of Texas at Austin.

Thanks to China National Offshore Oil Corporation Ltd. and Guangzhou Marine Geological Survey Bureau for providing seismic data.