Compressional Reactivation, Atlantic Margin of Brazil: Structural Styles and Consequences for Hydrocarbon Exploration*

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Abstract

The Atlantic margin of Brazil formed by Neocomian rifting. Although in principle the margin is passive, in practice it is seismically active. Immediately next to it is a wide belt of mountains, several kilometres high. We review evidence that these mountains have resulted from several phases of post-rift uplift and exhumation. Evidence for rapid erosion, in the Late Cretaceous, Eocene and Neogene, comes from patterns of offshore clastic sedimentation. These reflect the changing positions of major rivers, in response to topographic barriers and river capture. Evidence for compressive stress comes from the onshore Taubaté Basin and the edge of the continental shelf. In the Taubaté Basin, normal faults were active in the Palaeogene, and strike-slip faults were active in the Neogene. In the Santos Basin, Mesozoic strata end at a hinge, which was active in the Campanian and middle Eocene. Near Cabo Frio, regional growth folds were active in the Late Cretaceous. In the Campos Basin, reverse and strike-slip faults form the edge of a triangular block of basement. Tectonic uplift of this block in the Neogene led to reworking of Eocene turbidites into shelf-fed aprons, which now form reservoirs for the Albacora and Marlim oil fields. In the Espirito Santo Basin, the shelf edge is a major reverse fault, which formed by reactivation of a Neocomian master fault, bounding a half-graben. The same configuration holds for the shelf edges of the Camamu and Sergipe basins. There the shelves have undergone several kilometres of exhumation since the Late Cretaceous. In the Camamu Basin, uplift of the margin and continental interior triggered giant slides. Sharp unconformities constrain the main period of sliding (Campanian to middle Eocene). Horizontal compression also modified the shapes of some offshore basins. Thus the Santos Basin resembles a foreland basin. There is a Late Cretaceous to Eocene depocentre, next to the Serra do Mar, and a distant bulge, which has trapped giant sub-salt accumulations of hydrocarbons. In SE and NE Brazil, apatite fission track analysis (AFTA) points to three post-rift episodes, in the Late Cretaceous, Eocene and Miocene. These have important consequences for burial, maturation and preservation of hydrocarbons. Because the post-rift episodes are synchronous with phases of orogenesis in the Andes, a likely cause is plate-wide horizontal compression.

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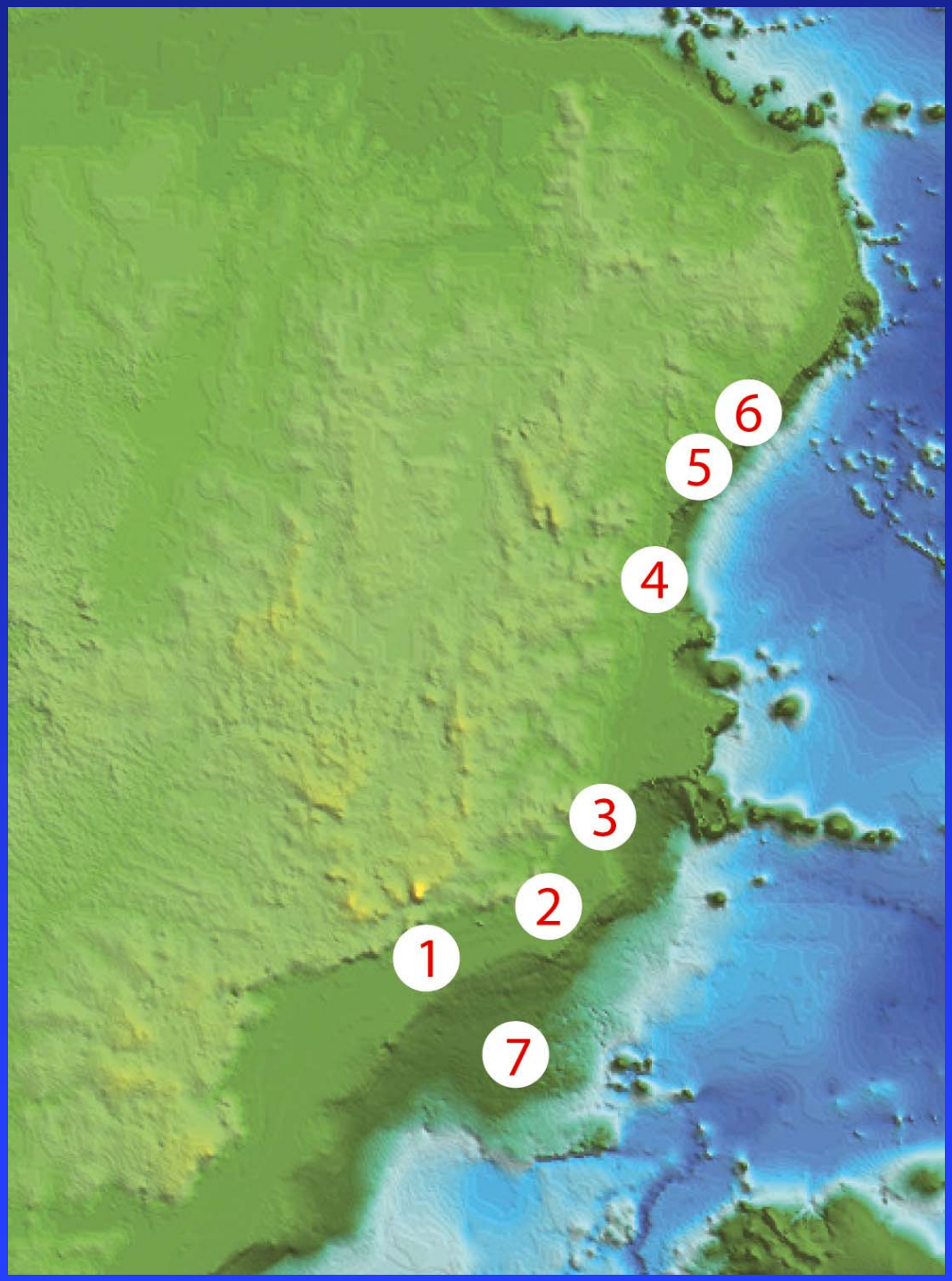
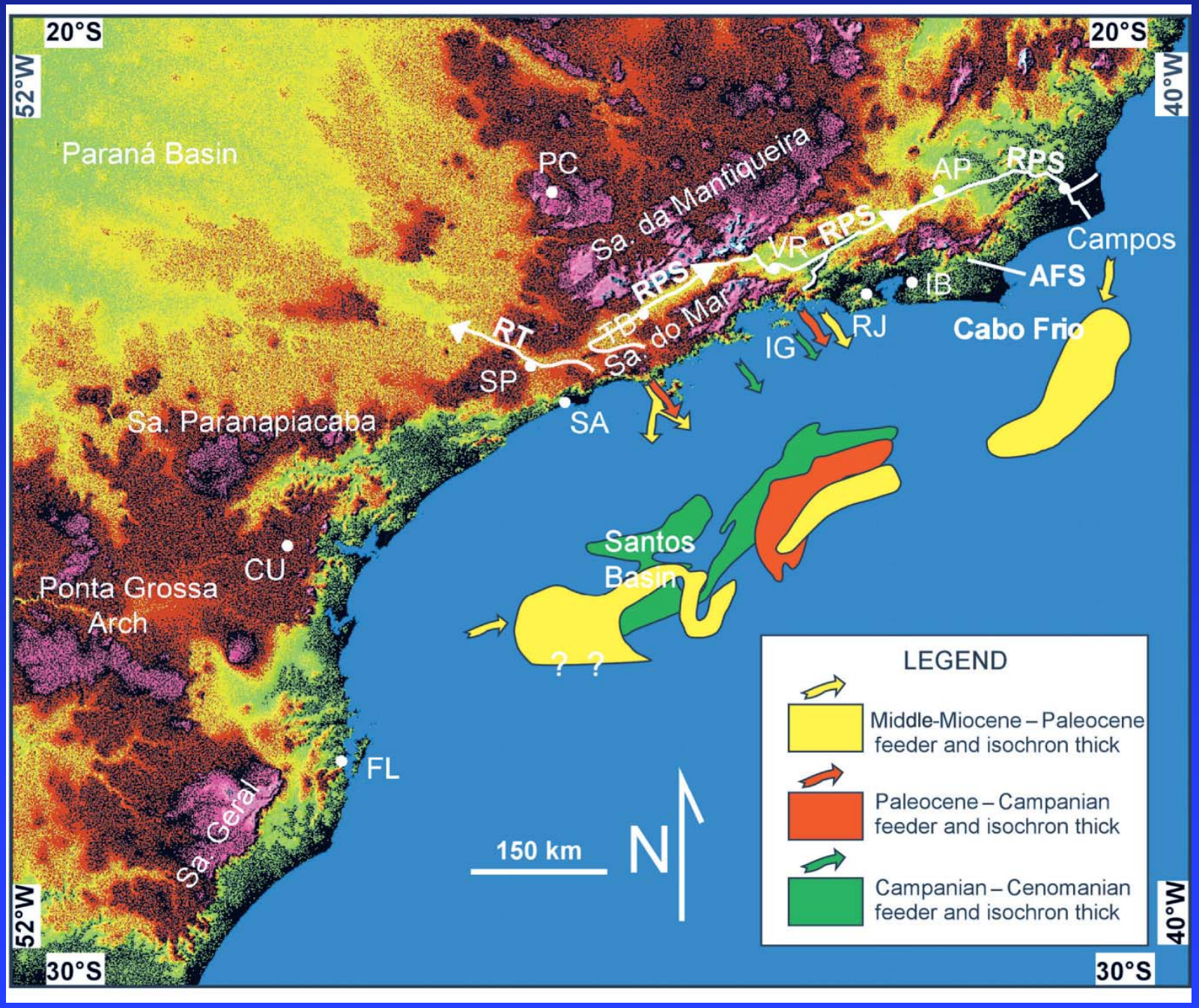
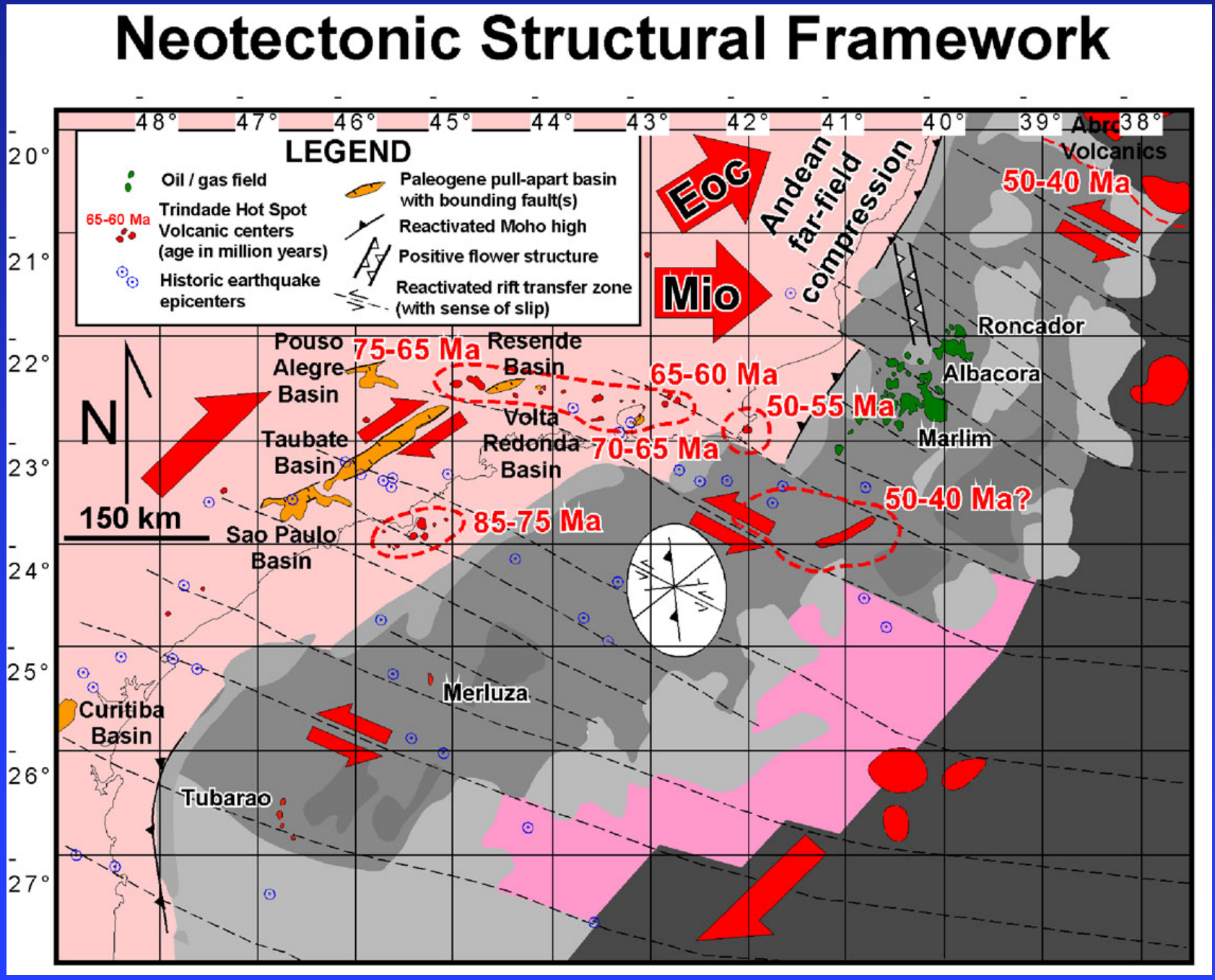


Localities, Atlantic margin

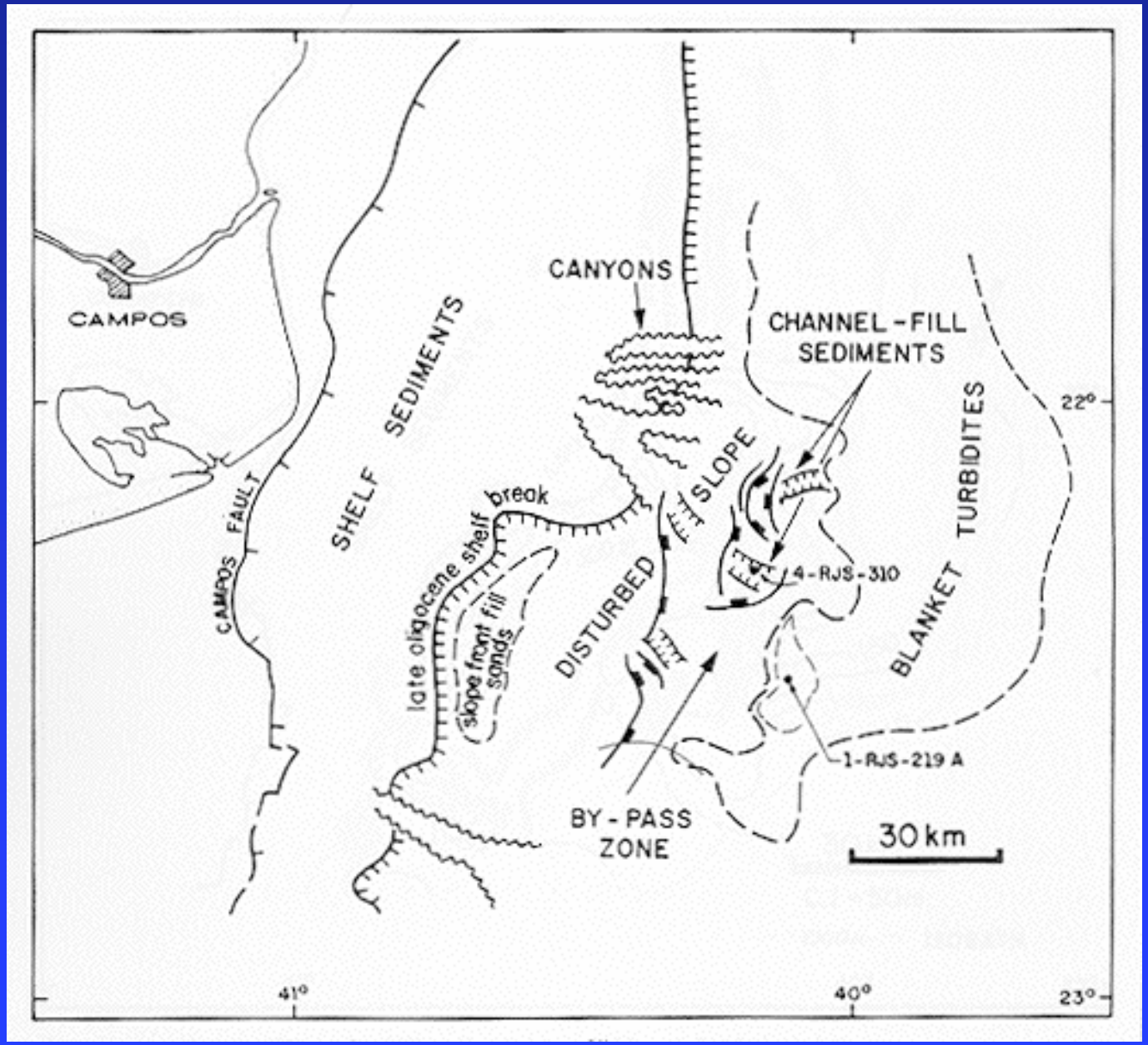
1, 2. Santos and Campos basins (Cobbold, Meisling & Mount, 2001)

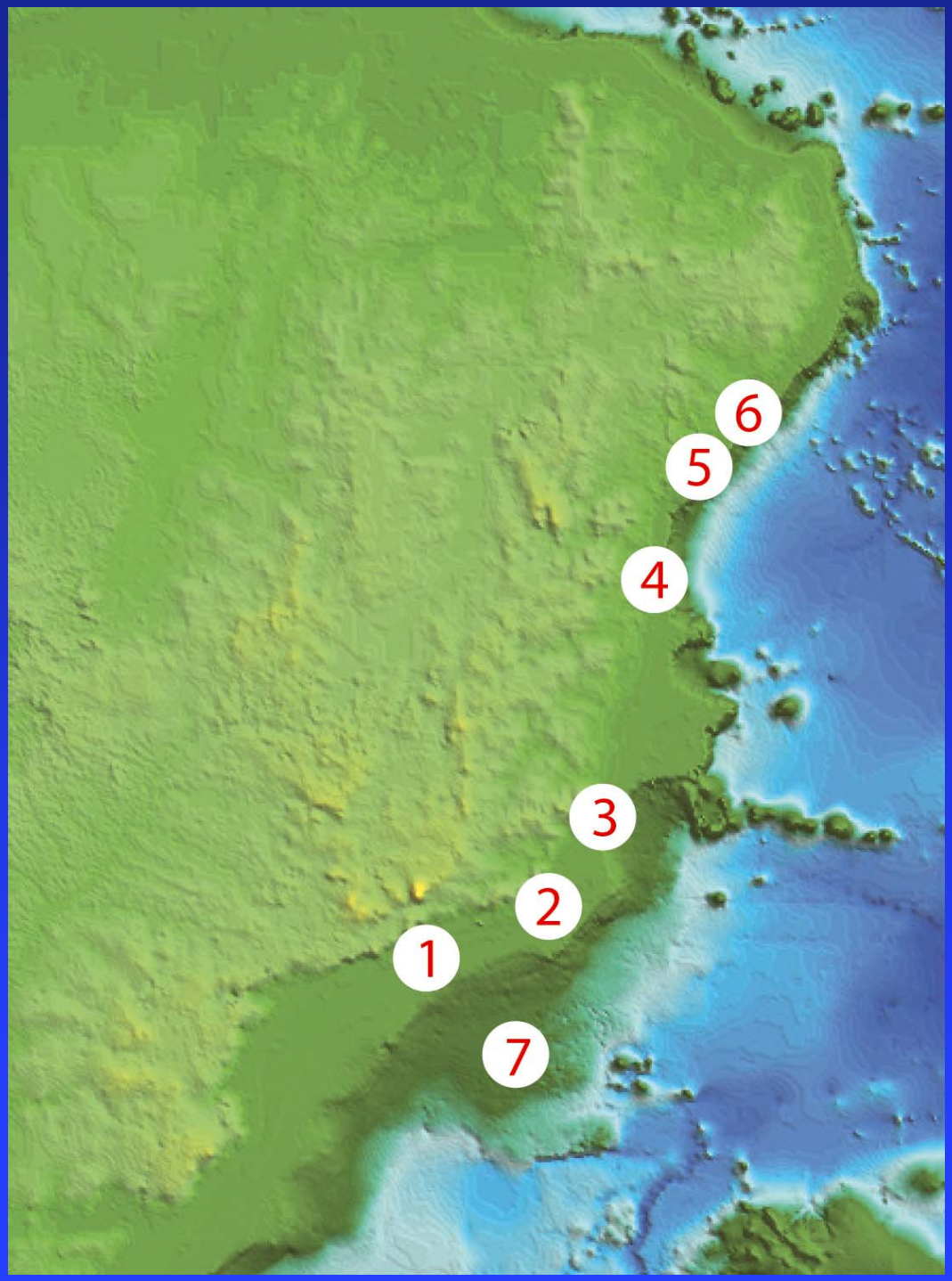


Santos and Campos neotectonics (Cobbold, Meisling & Mount, 2001)



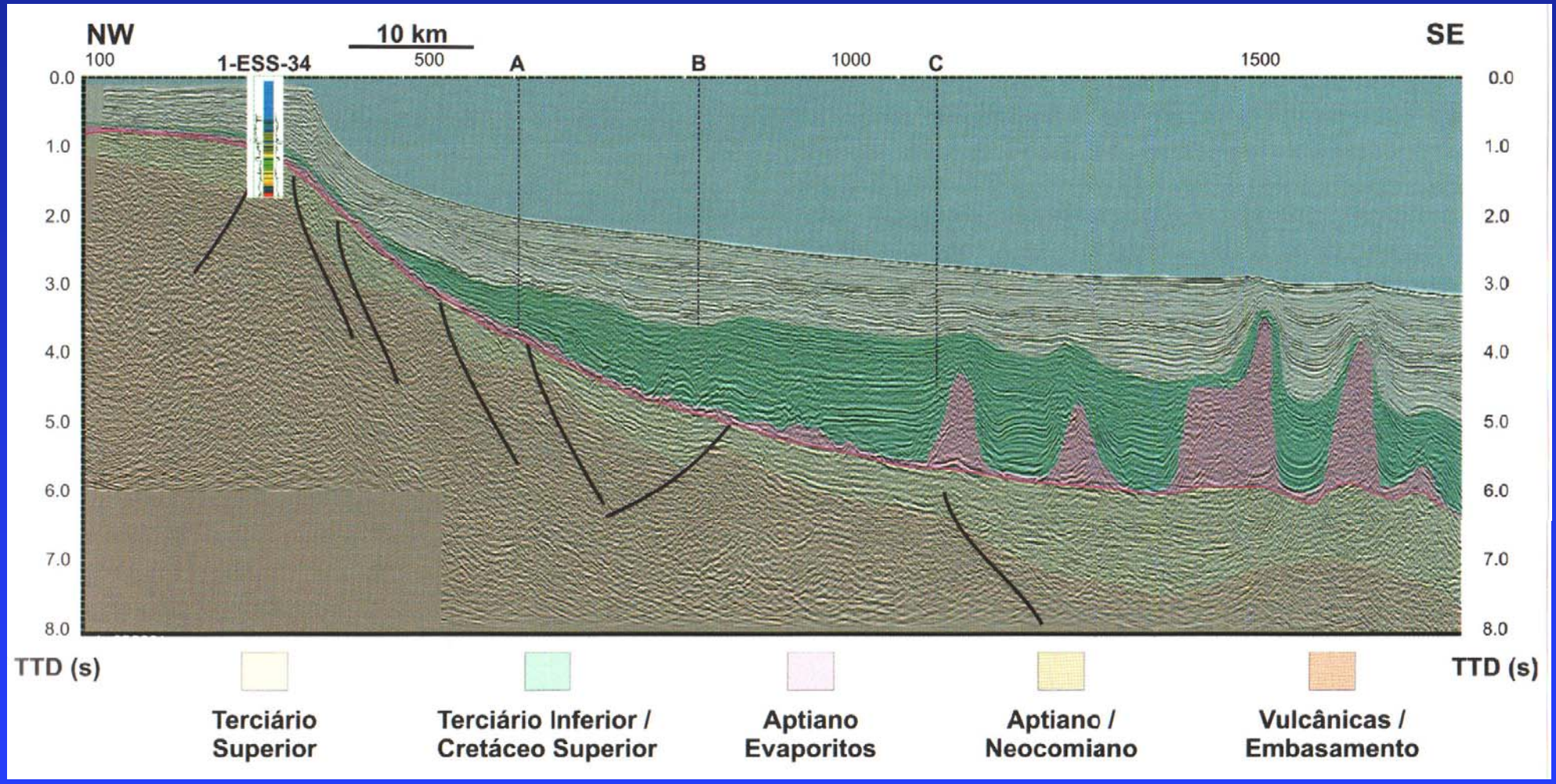
Redeposited turbidites, Campos Basin (Peres, 1993)



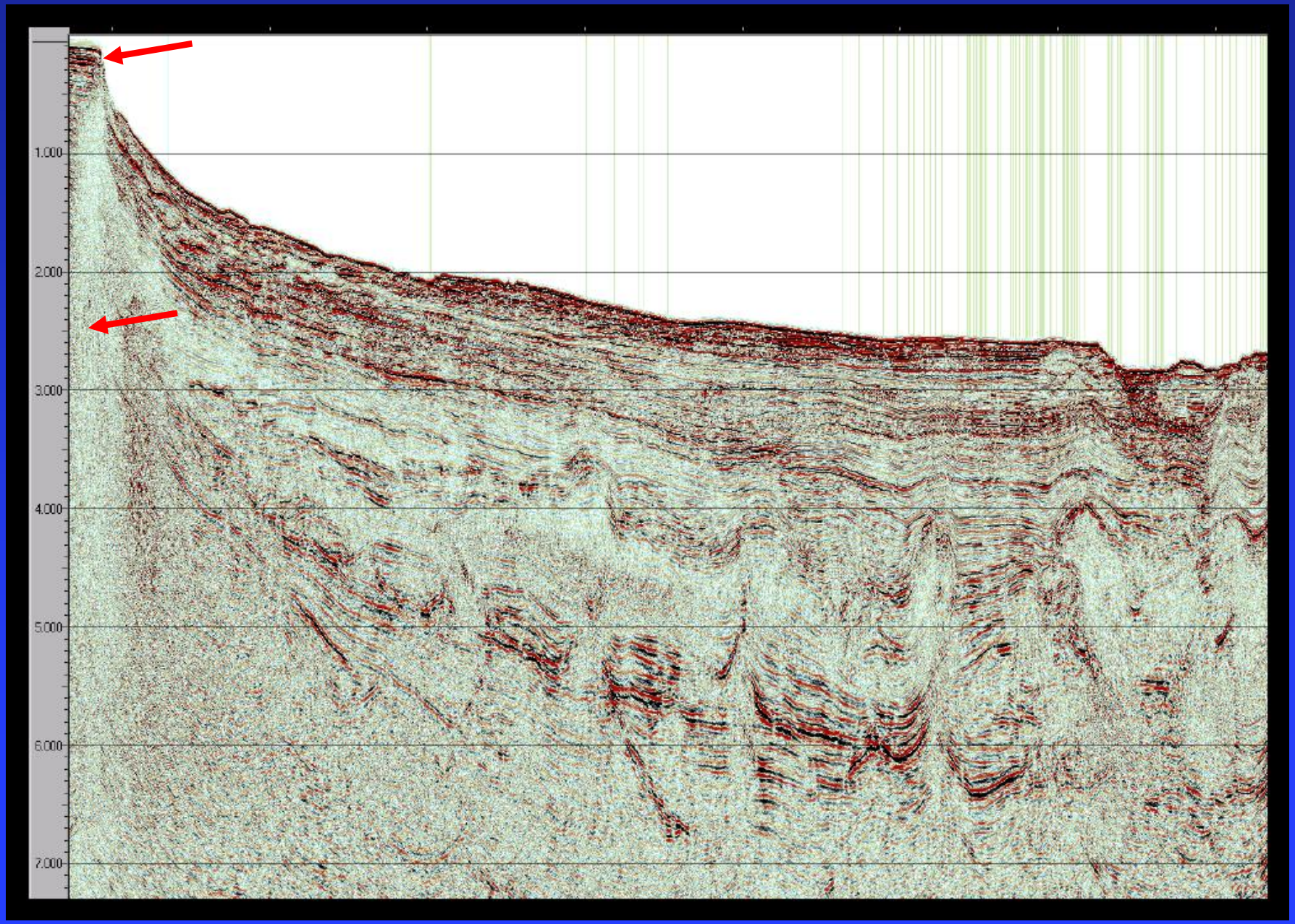


Localities, Atlantic margin

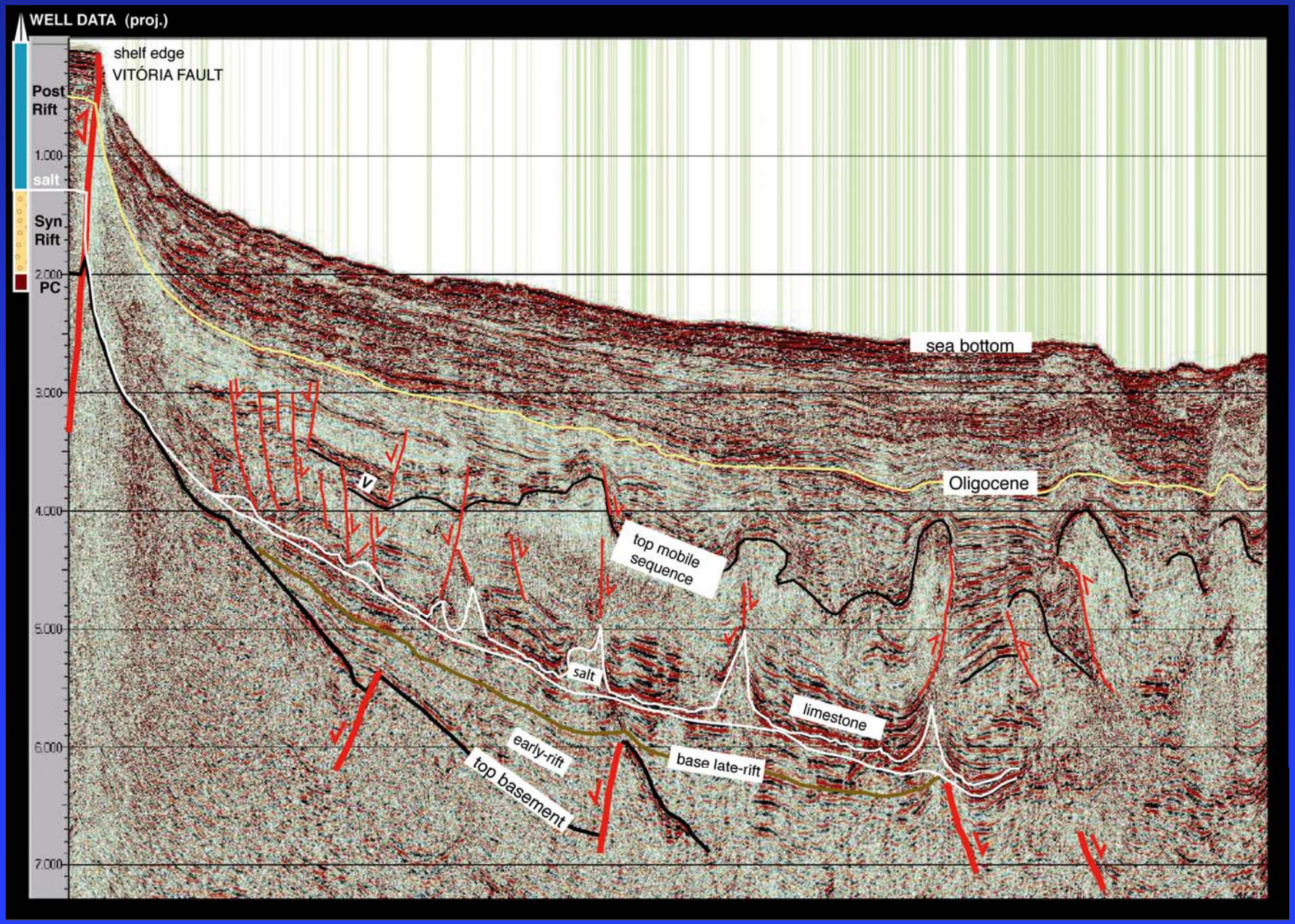
3. Espirito Santo Basin
(Mohriak, 2008)



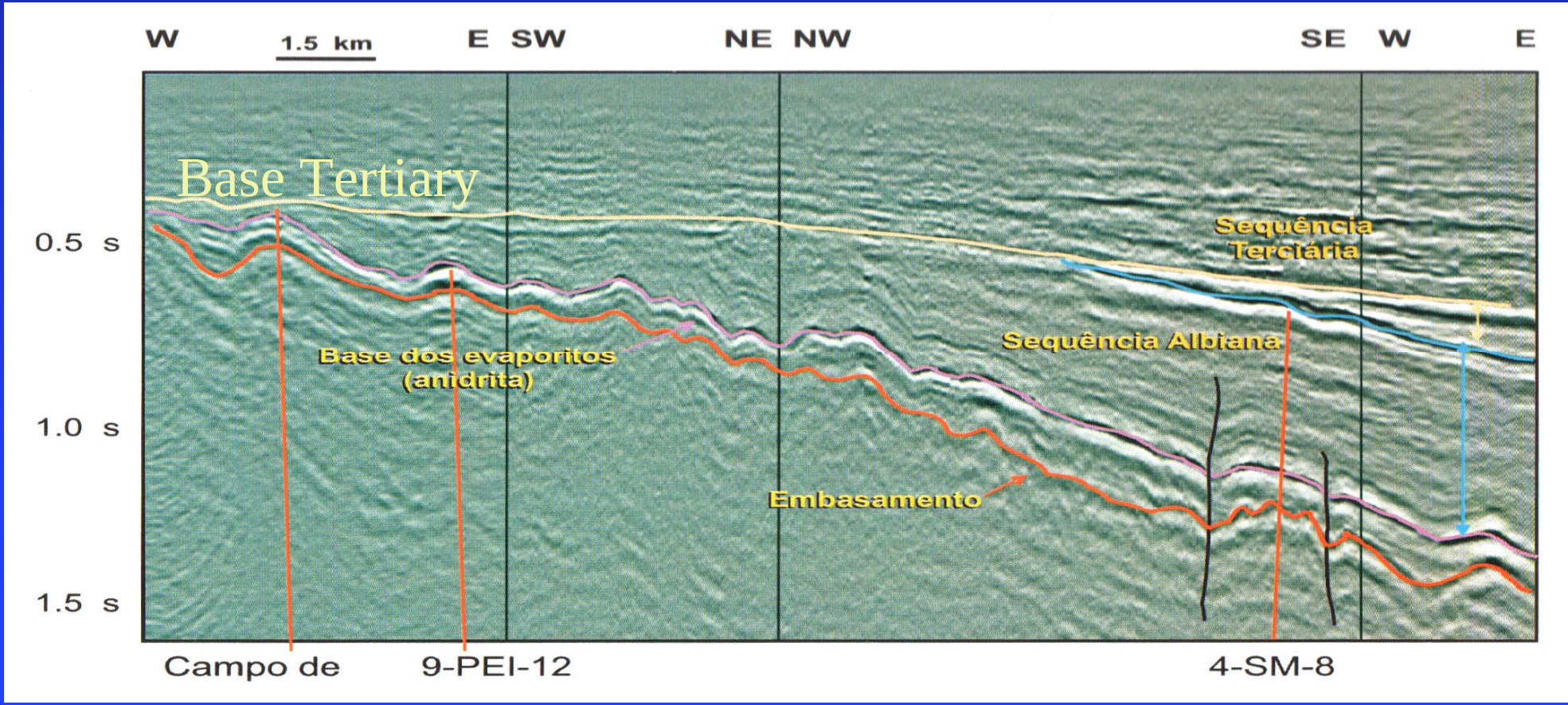
Espirito Santo Basin - 20°S
(courtesy TGS Nopec)

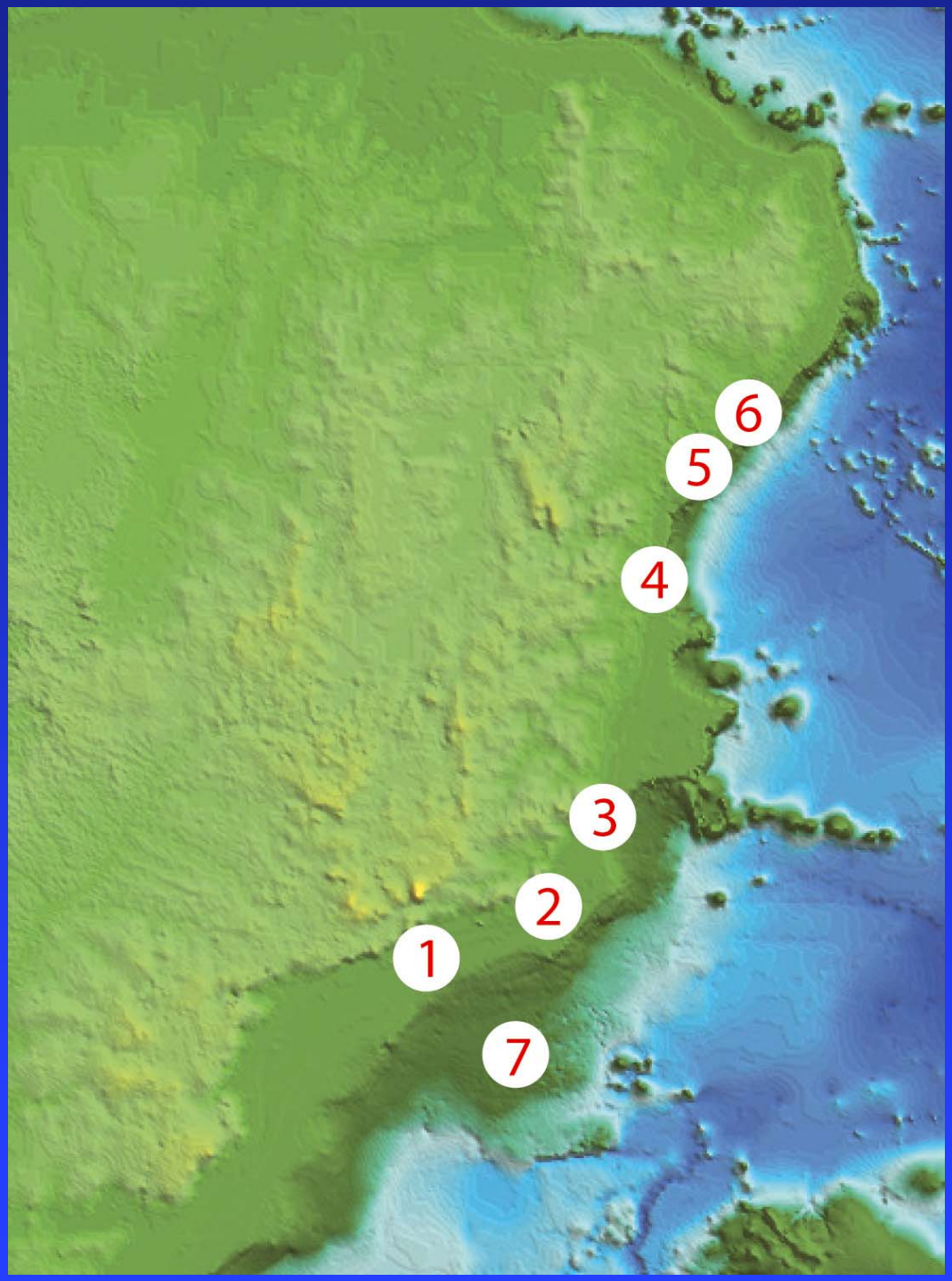


Espirito Santo Basin - 20°S
(courtesy TGS Nopec)



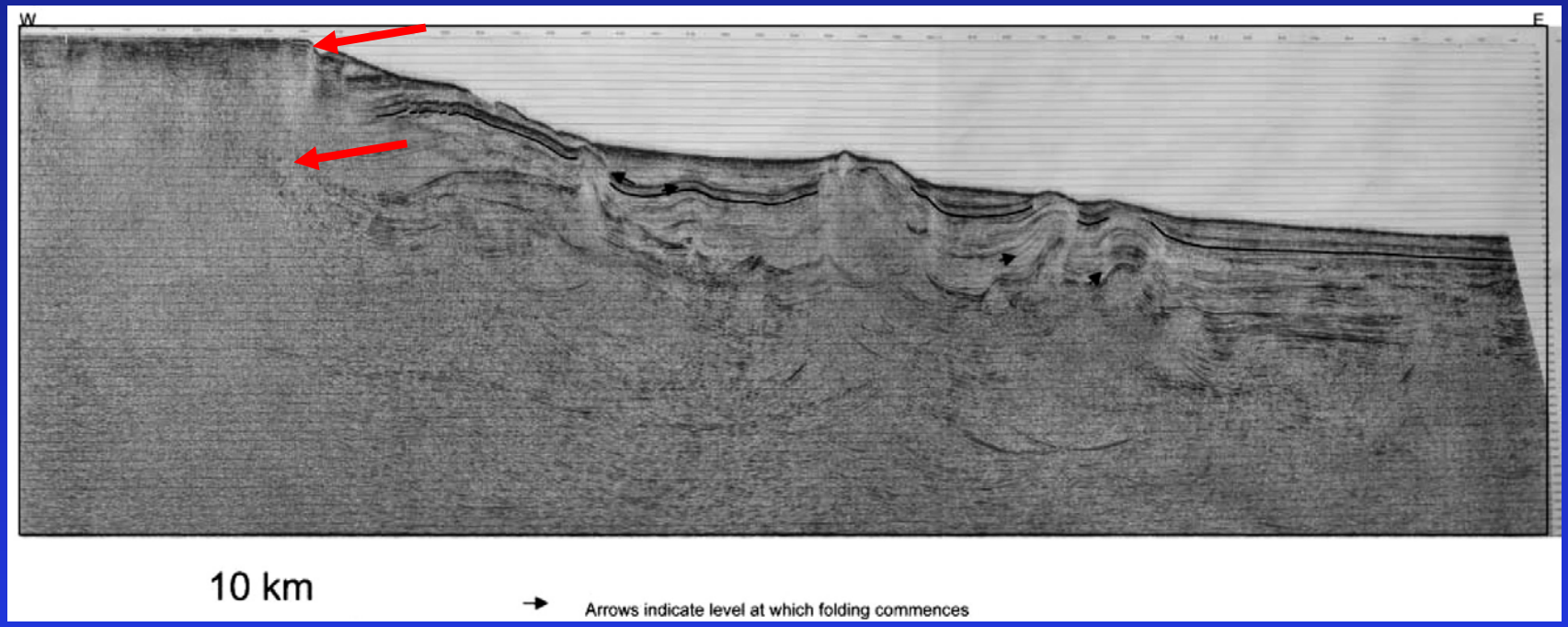
Espirito Santo Basin onland
(França & Mohriak, 2008)

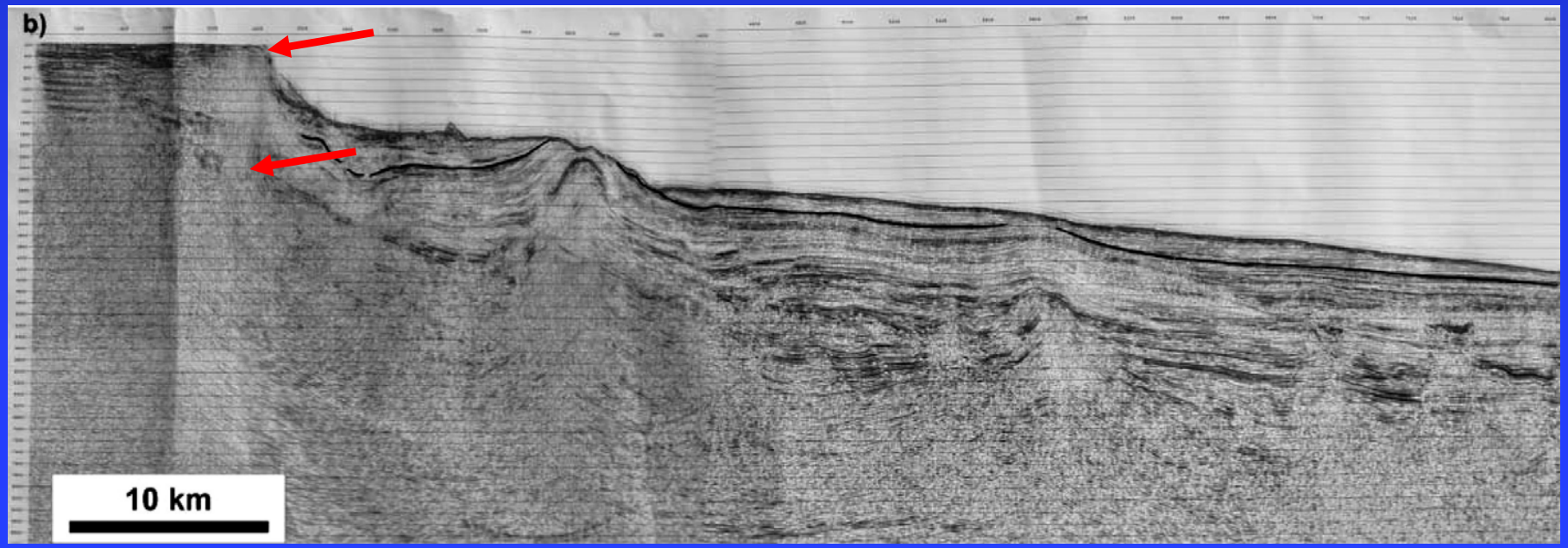




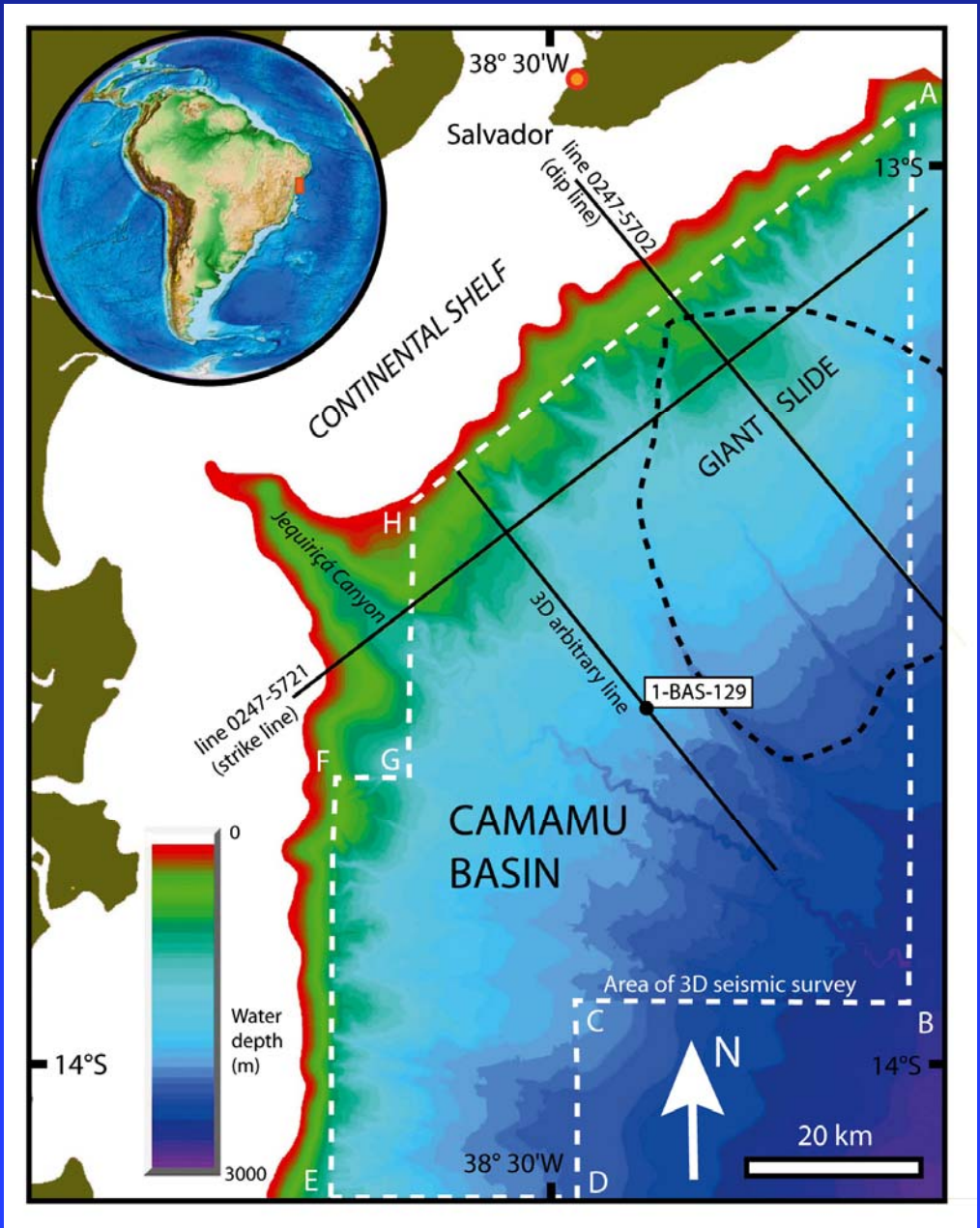
Localities, Atlantic margin

4. Jequitinhonha Basin (Davison, 2007)

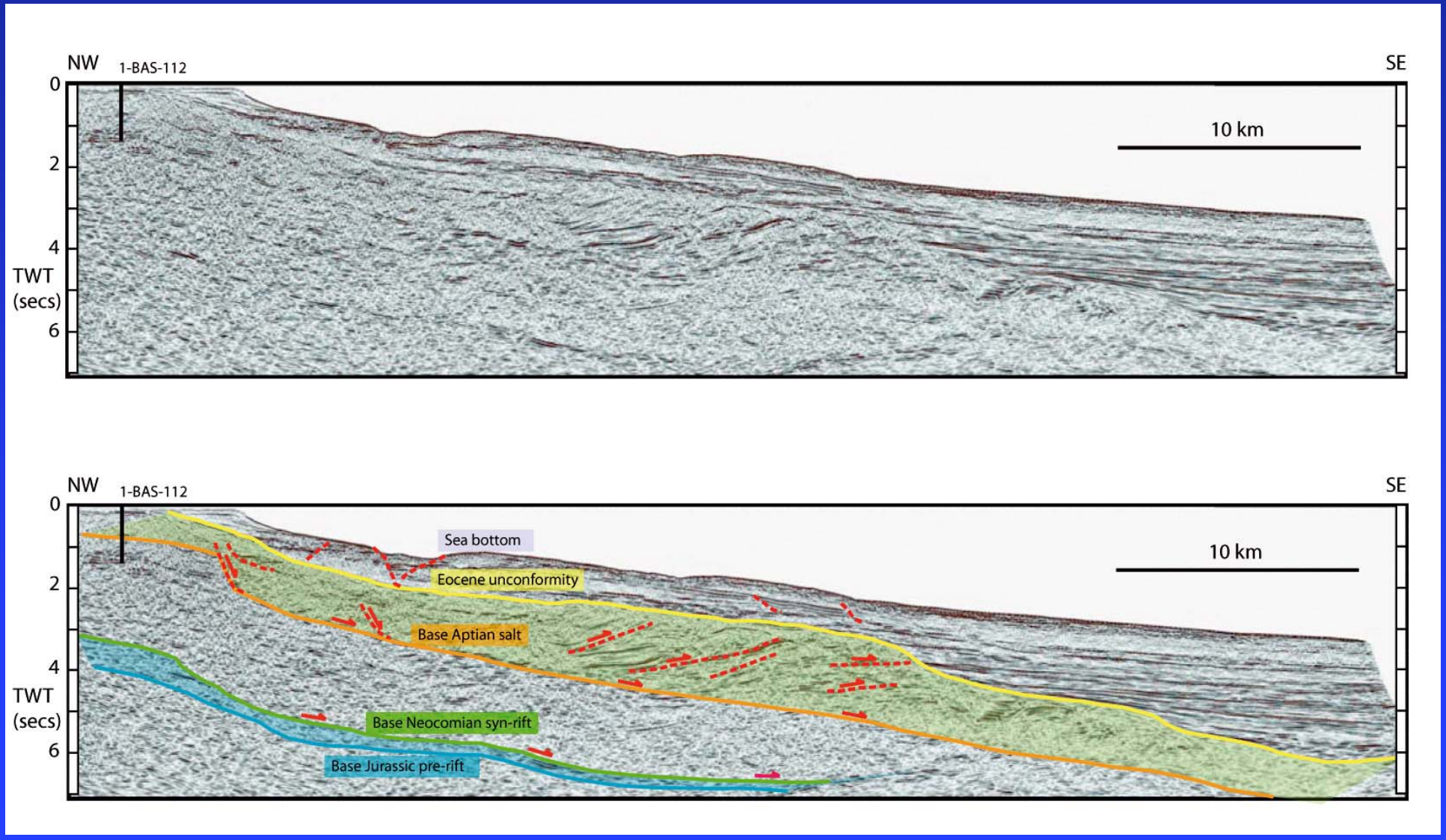




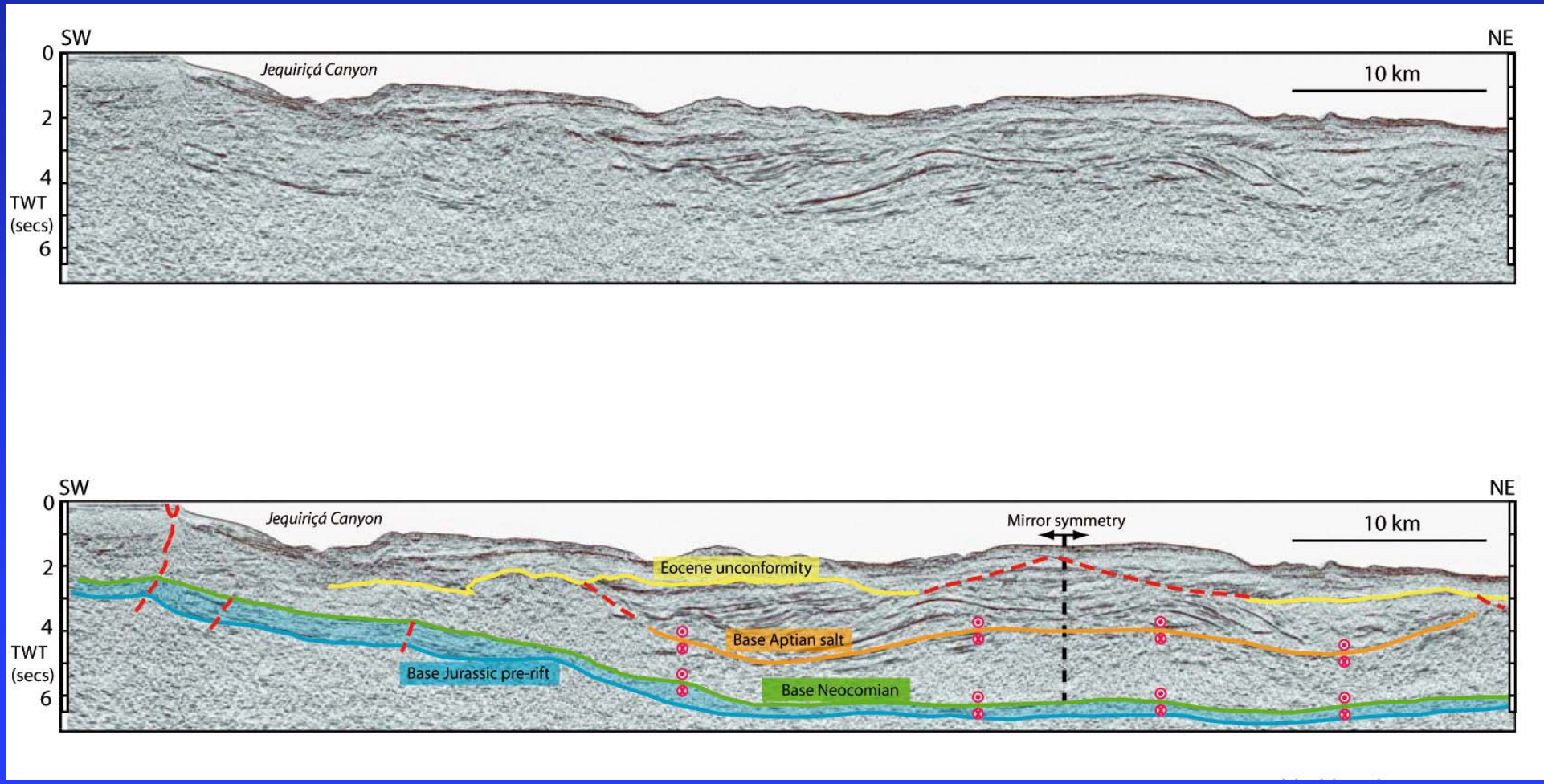
5. Camamu Basin
(Cobbold et al., in press)

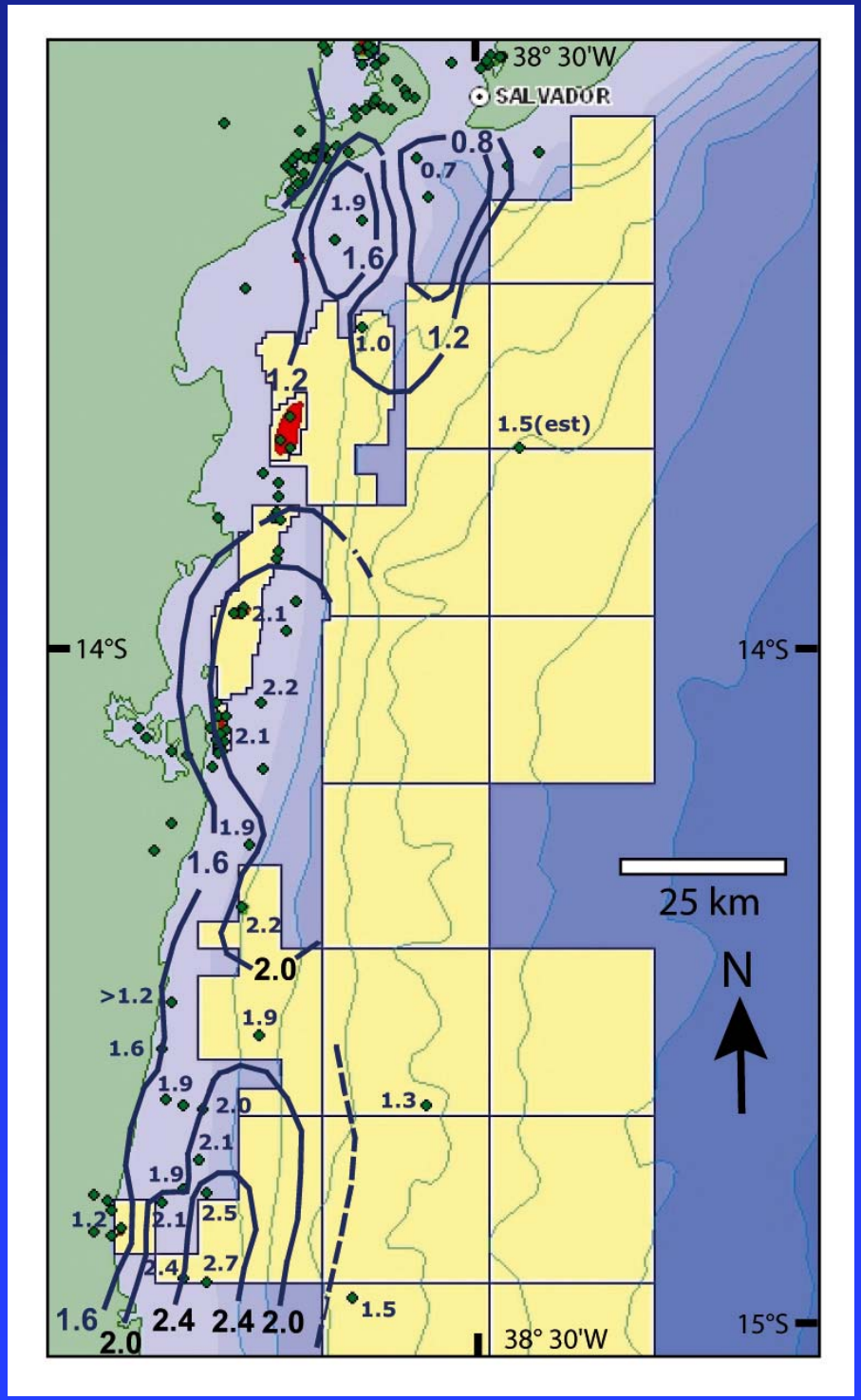


Camamu dip line
(Cobbold et al., in press)



Camamu strike line
(Cobbold et al., in press)

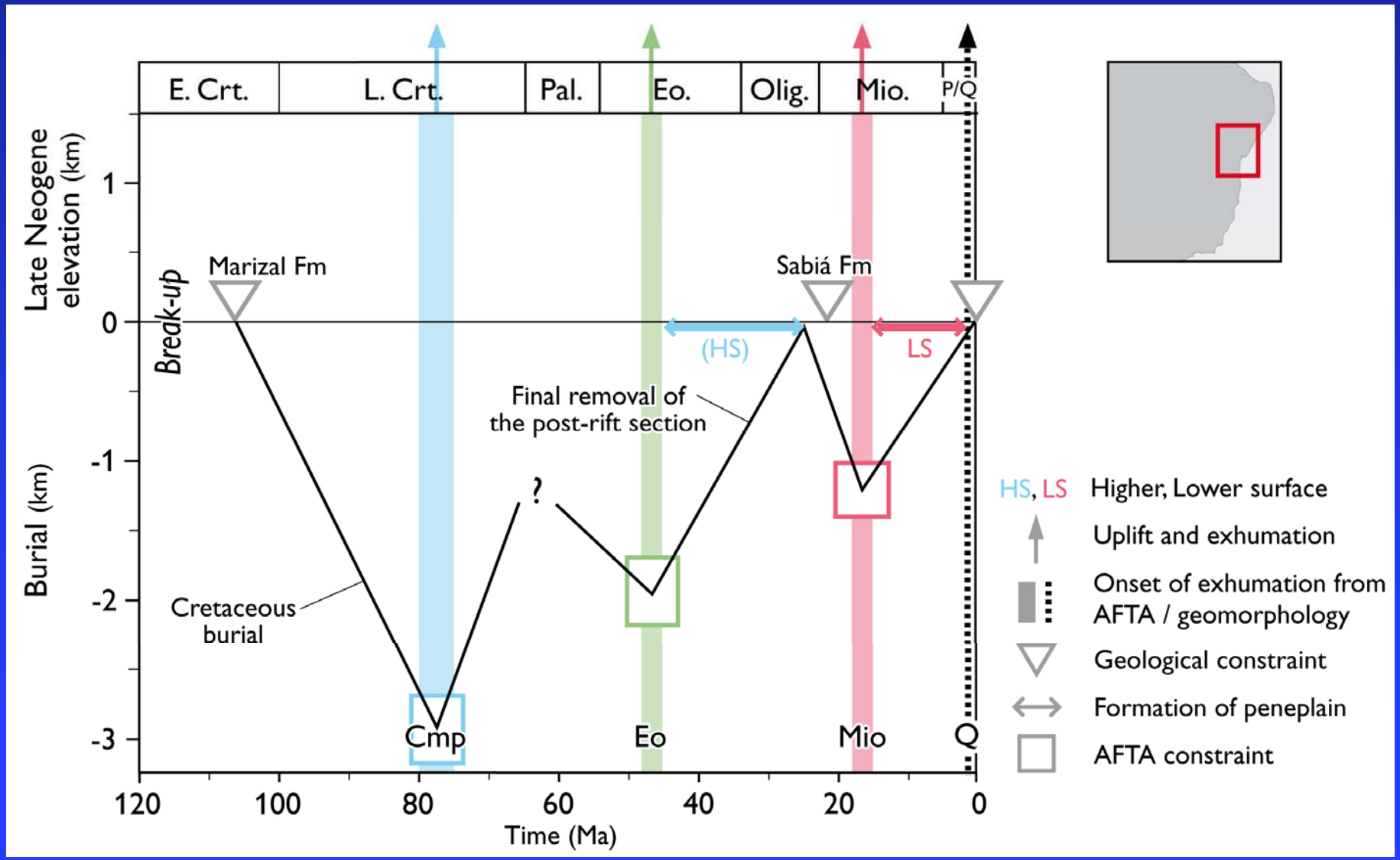


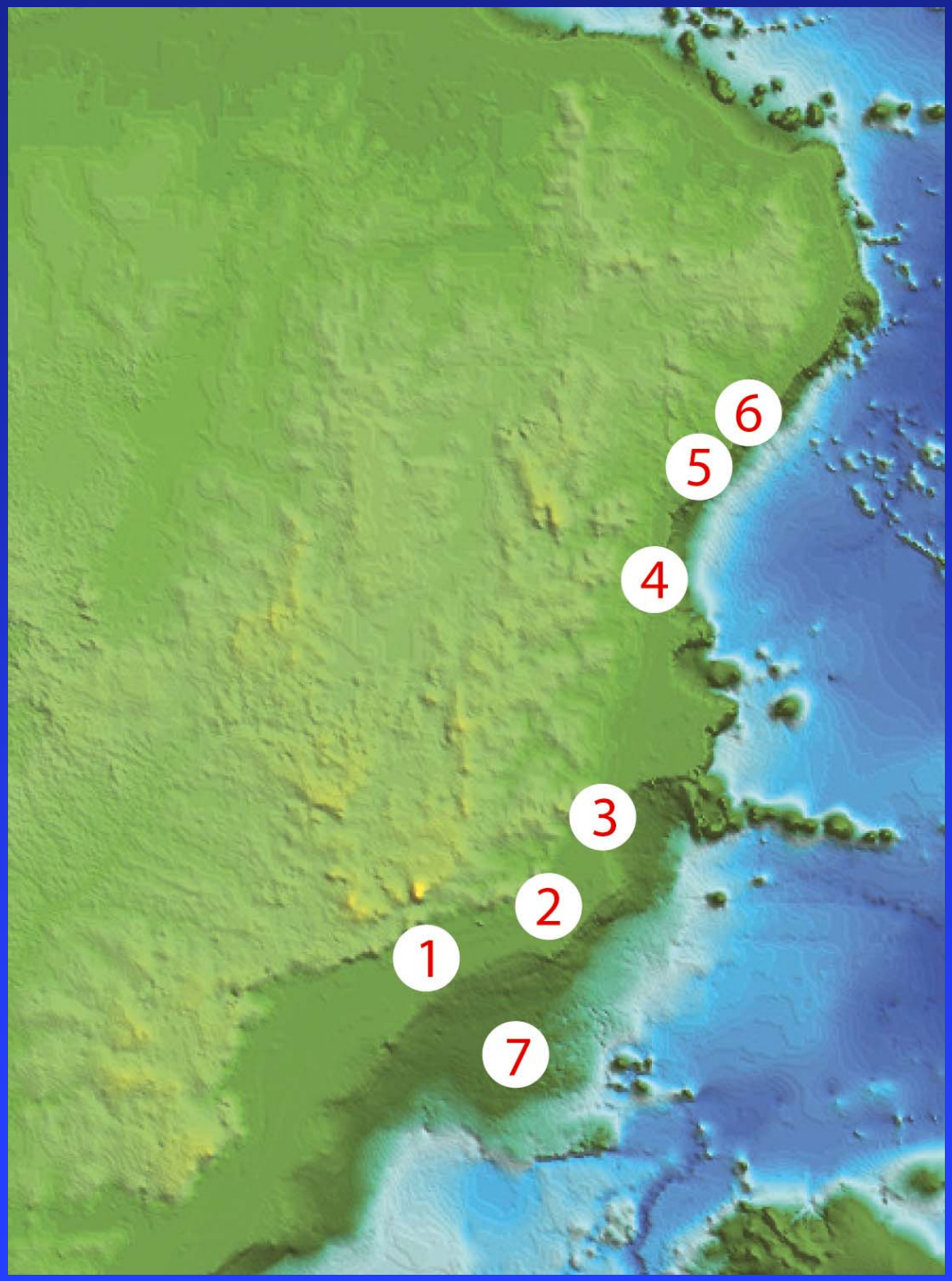


Camamu

depth to top of oil window in km below sea level (Cobbold et al., in press)

Burial curve for post-rift sediments in Bahia State (Japsen et al., 2009)





Localities, Atlantic margin

6. Sergipe Basin (Mohriak, 2003)

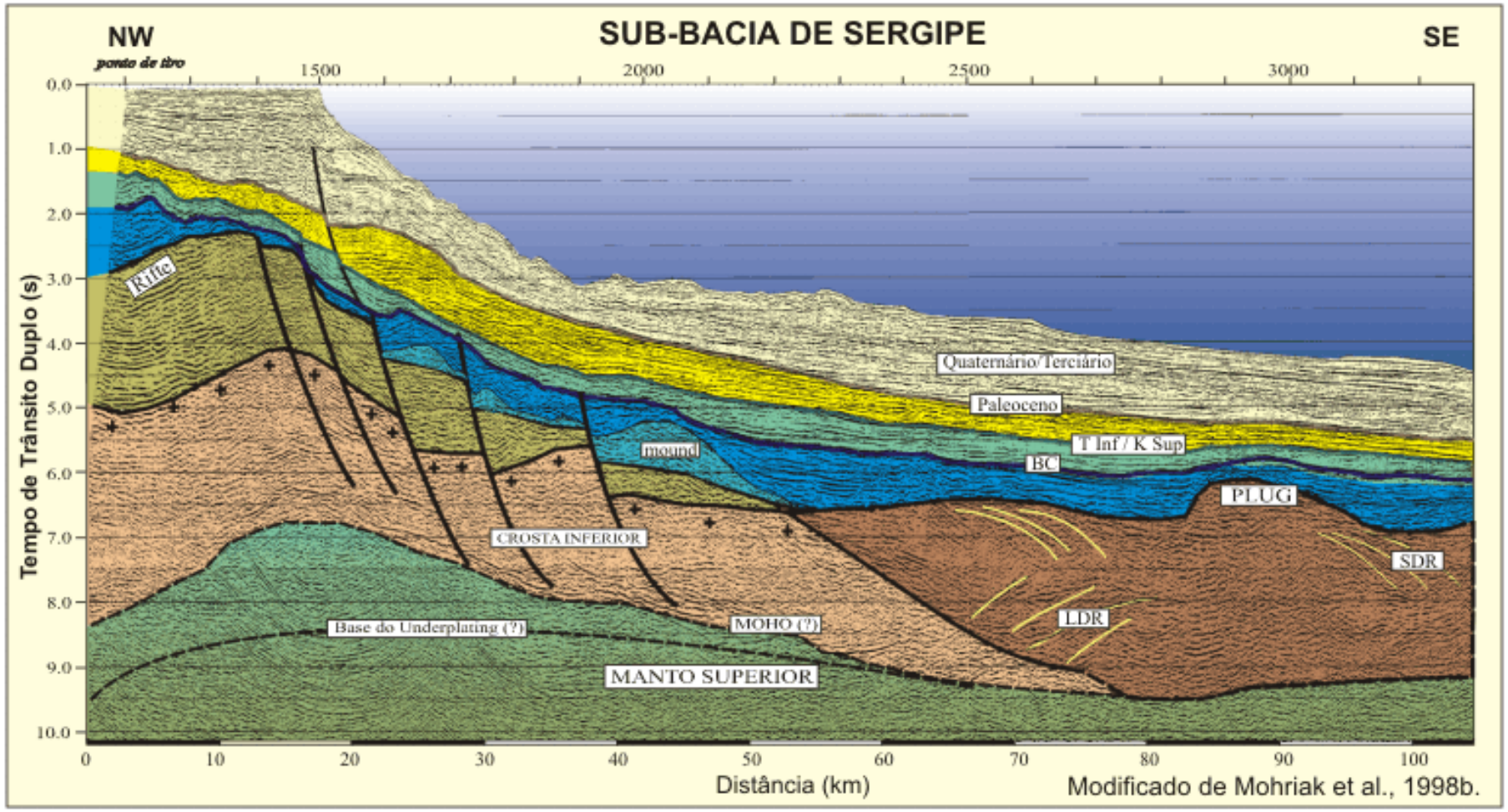
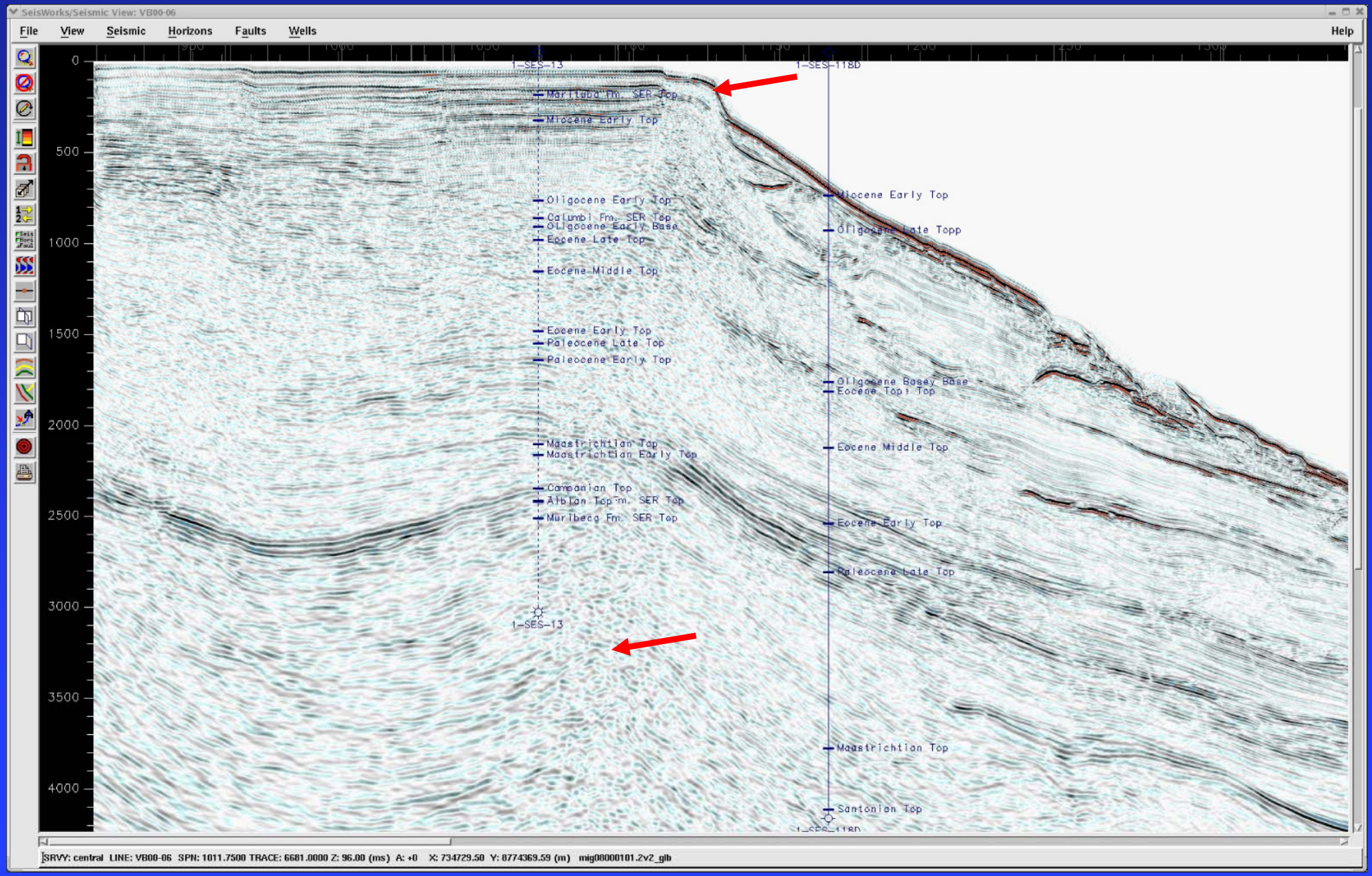


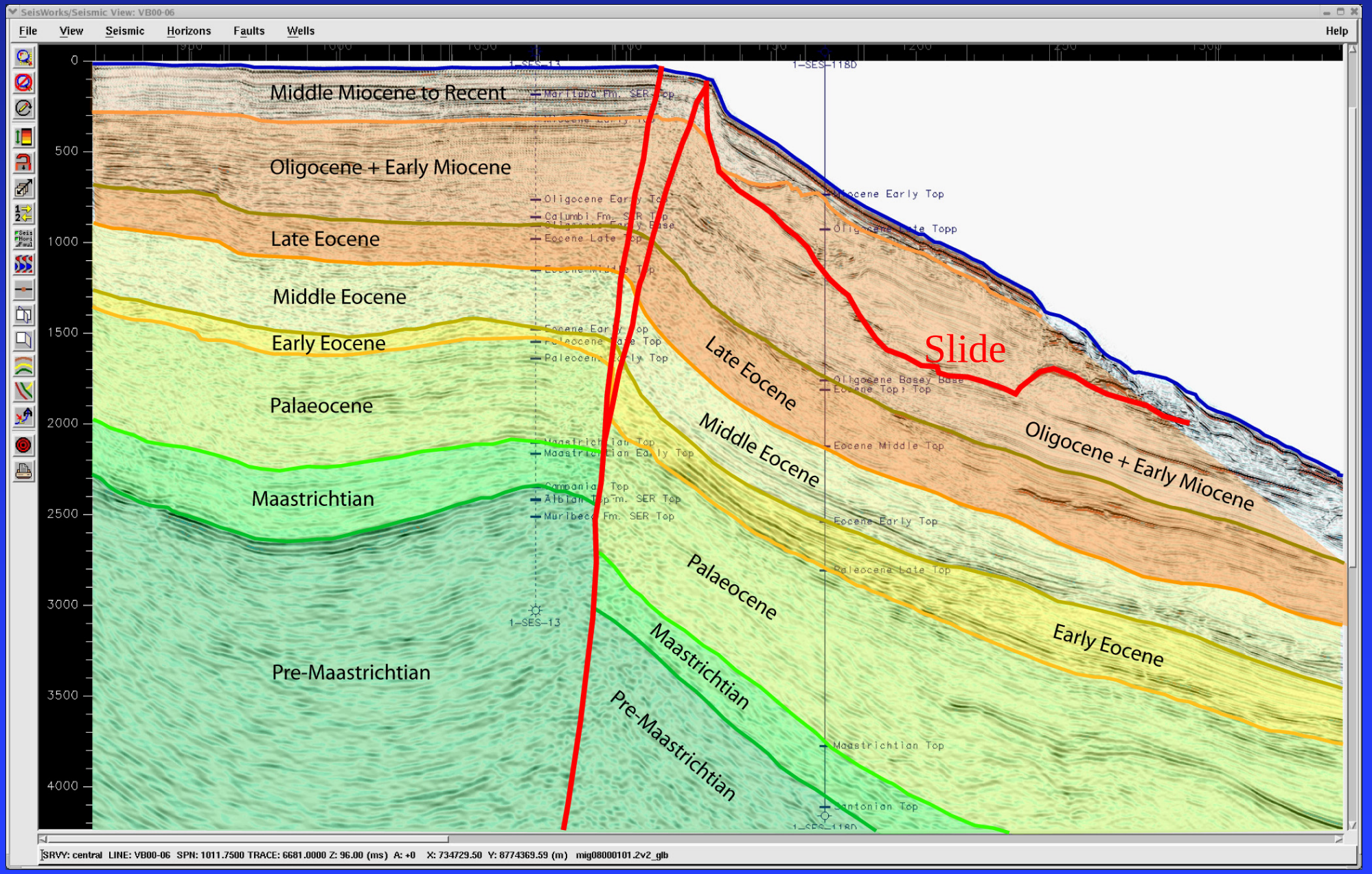
Figura III.52 – Interpretação da seção sísmica na sub-Bacia de Sergipe, mostrando afinamento das seqüências estratigráficas da fase rifte na direção da bacia profunda e possível ocorrência de cunhas de refletores mergulhantes para o mar e intrusões vulcânicas próximo do limite entre crosta continental e crosta oceânica

Figure III.52 – Interpretation of the seismic section in the Sergipe sub-basin, showing pinch-out of syn-rift stratigraphic sequences in the deep water region, and possible occurrence of seaward-dipping wedges and volcanic intrusions near the continental-oceanic crust boundary

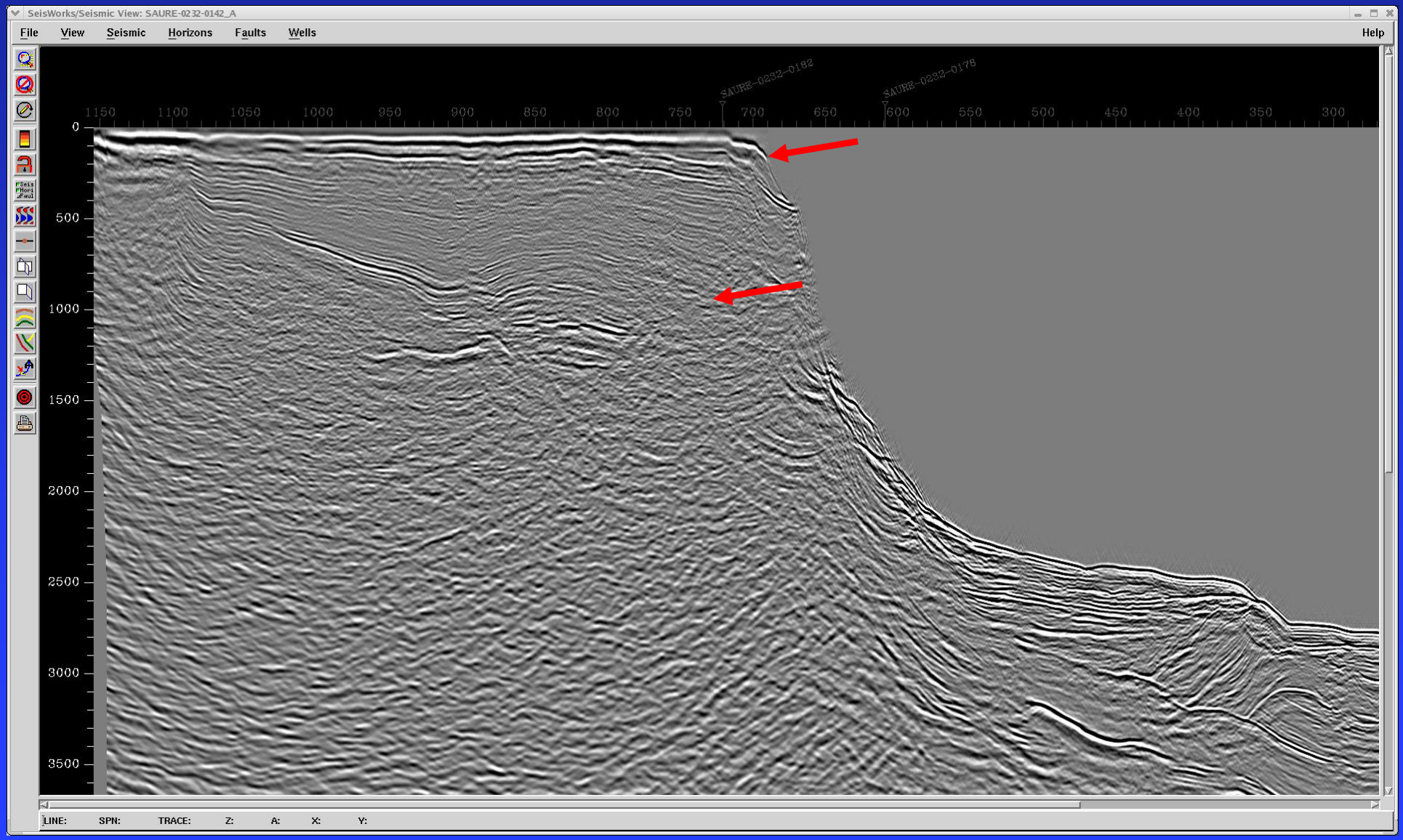
Sergipe Basin
(Seismic profile VB00-06, courtesy CGG Veritas; Wells, Banco de Dados de Exploração e Produção)



Sergipe Basin
(Seismic profile VB00-06, courtesy CGG Veritas; Wells, Banco de Dados de Exploração e Produção)

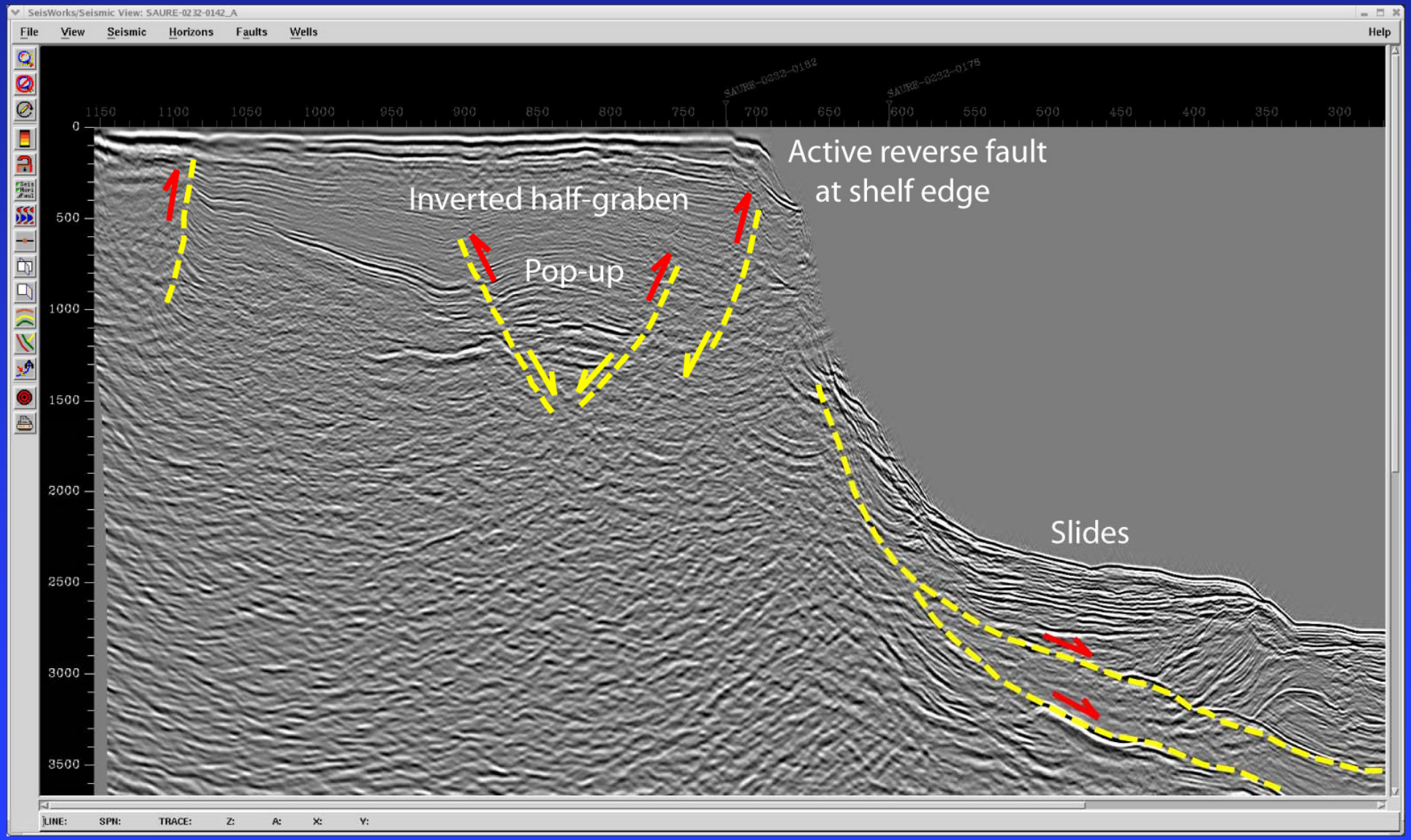


Sergipe shelf
(SAURE-232-0142A, courtesy FUGRO)

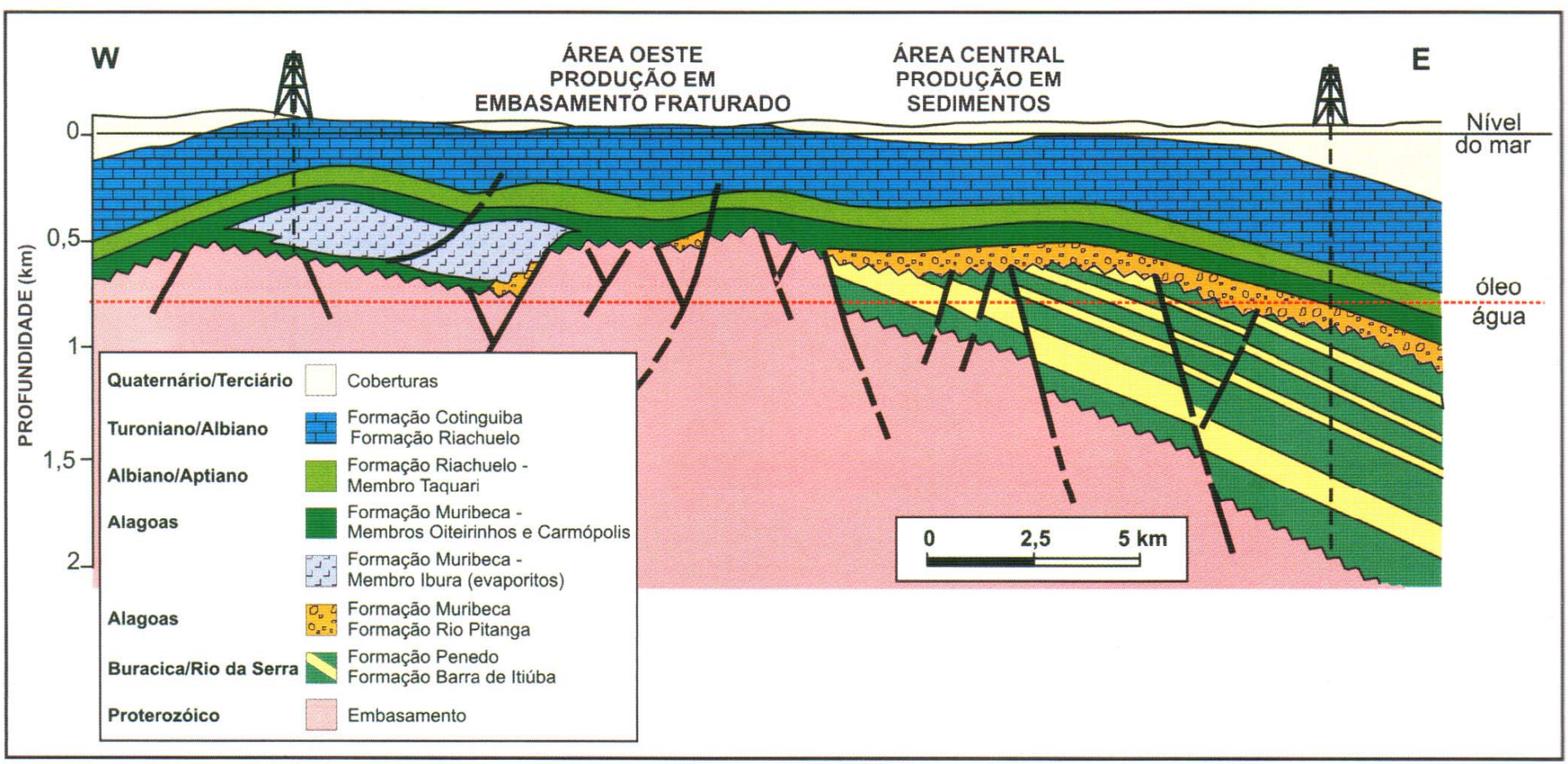


Sergipe shelf

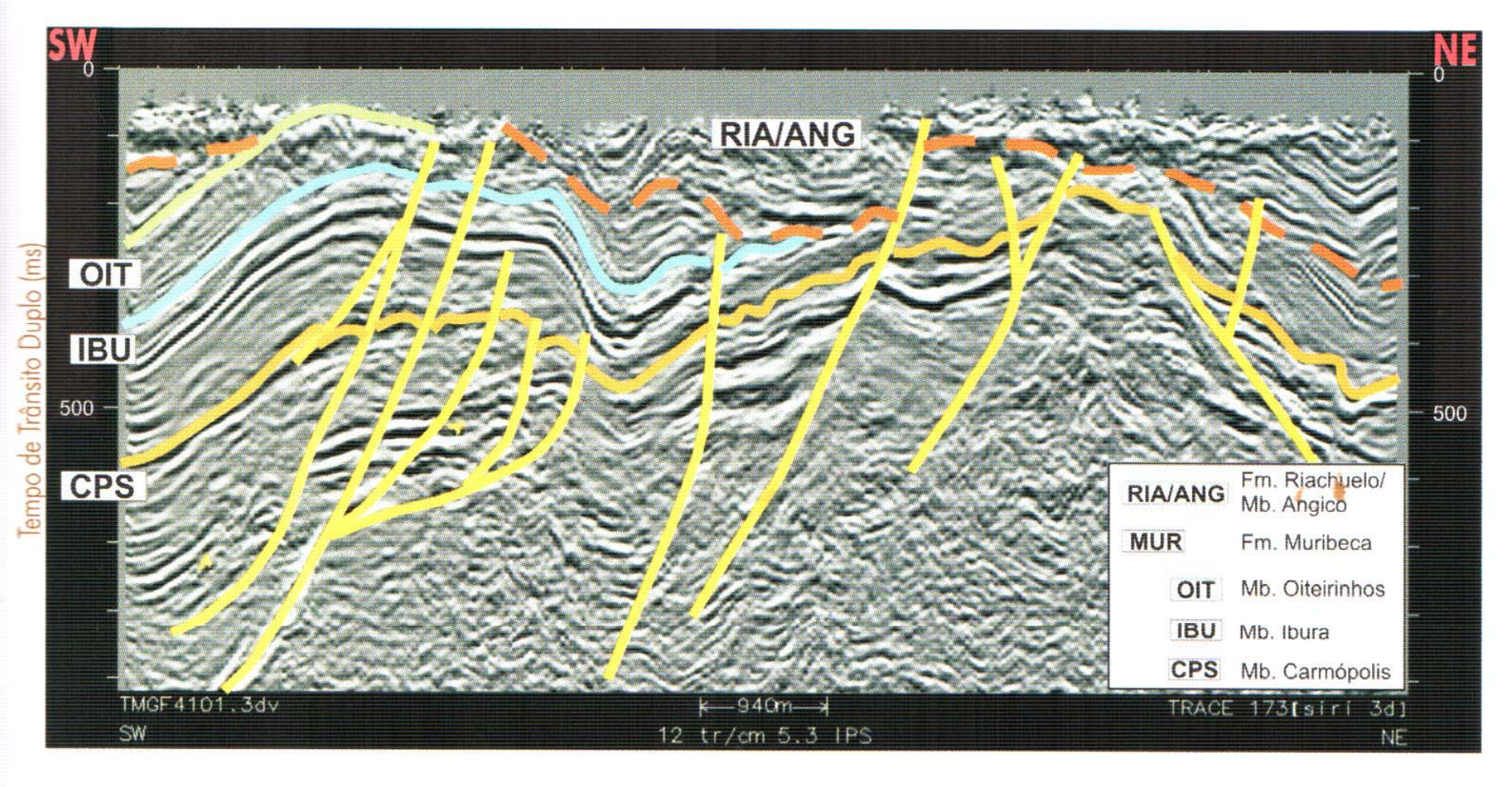
(SAURE-232-0142A, courtesy FUGRO)



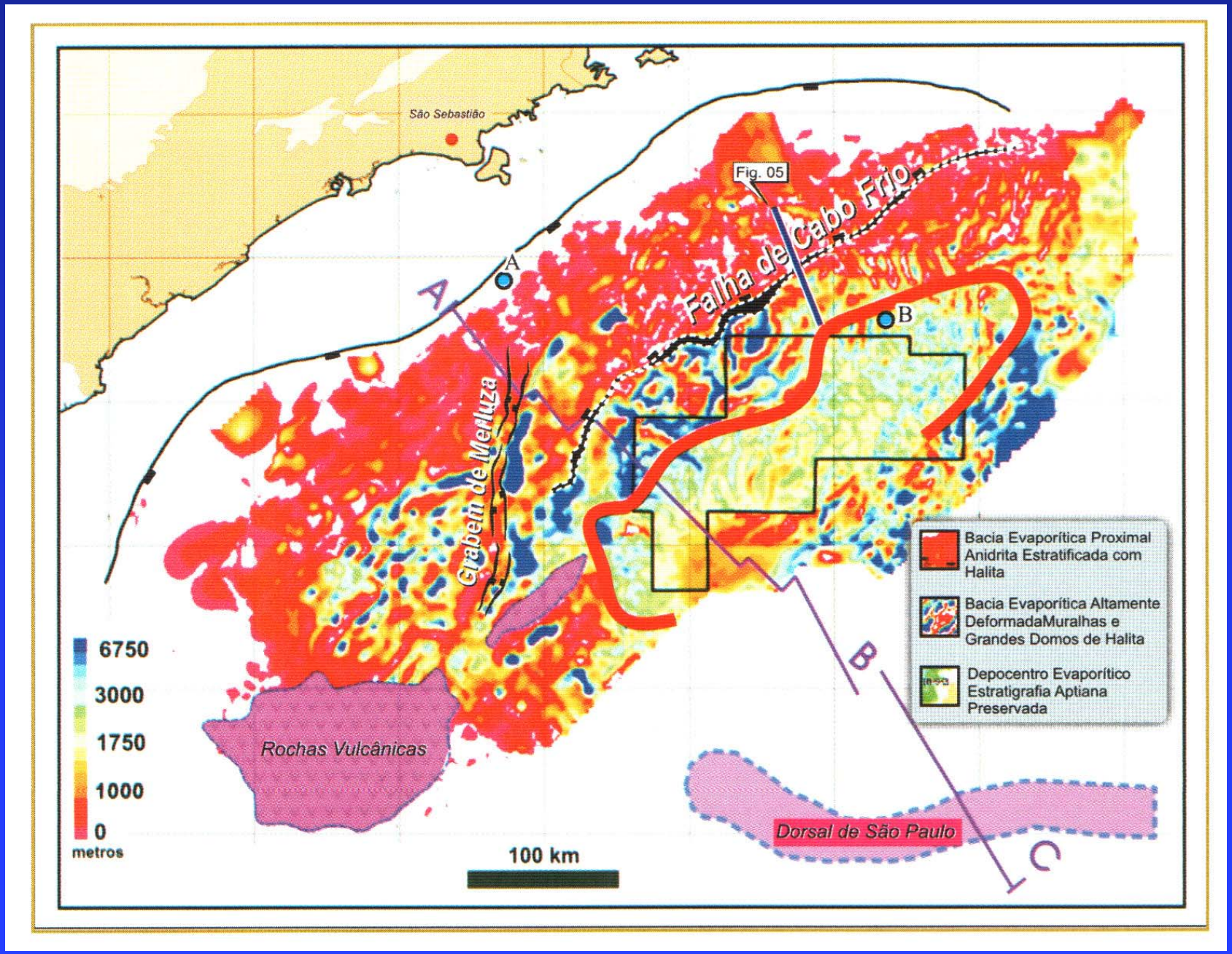
Carmopolis Field, Sergipe Basin
(Souza Lima, 2008)



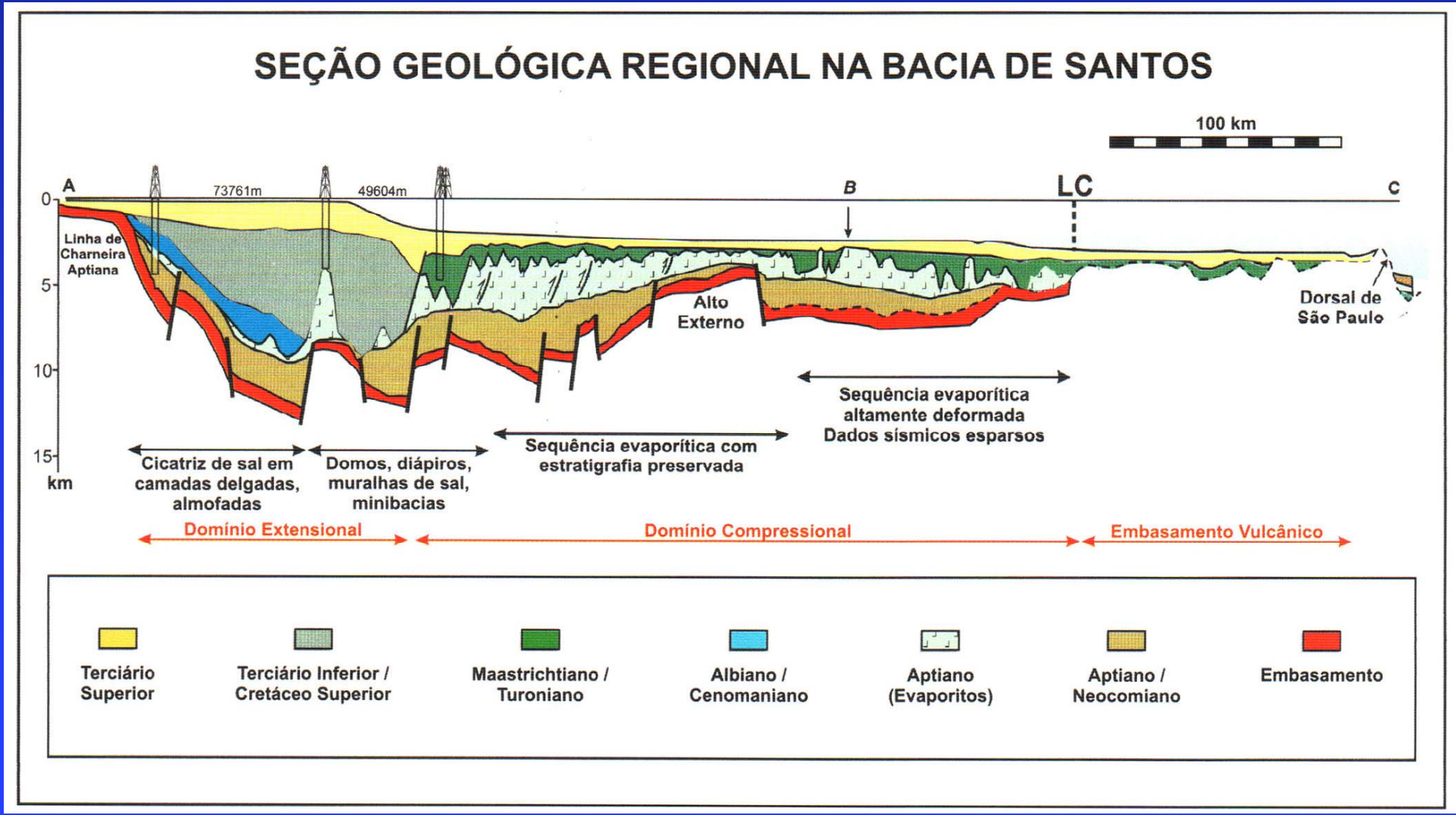
Sergipe Basin
(Souza Lima, 2008)



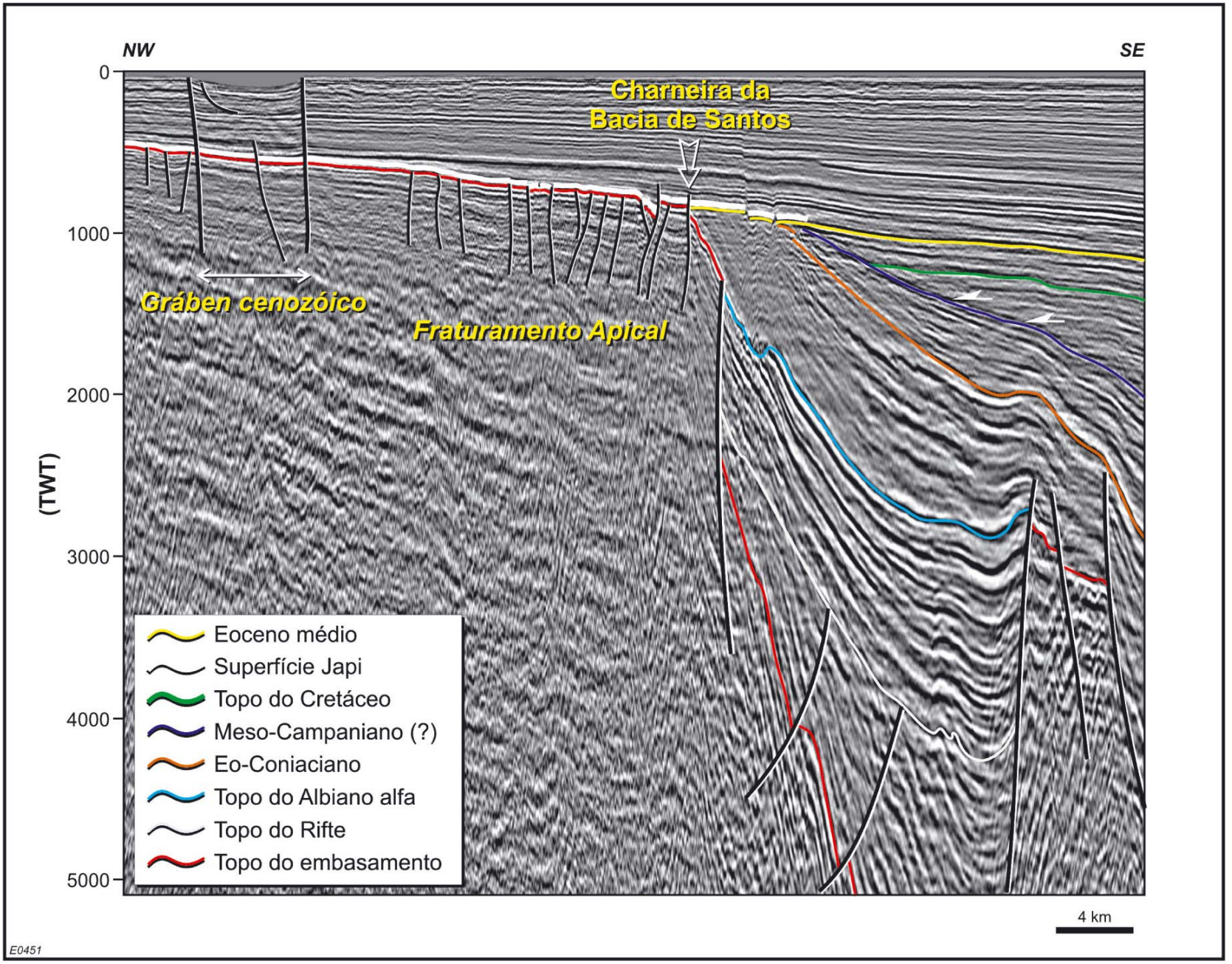
7. Santos Basin, salt isopachs
(Gamboa et al., 2008)



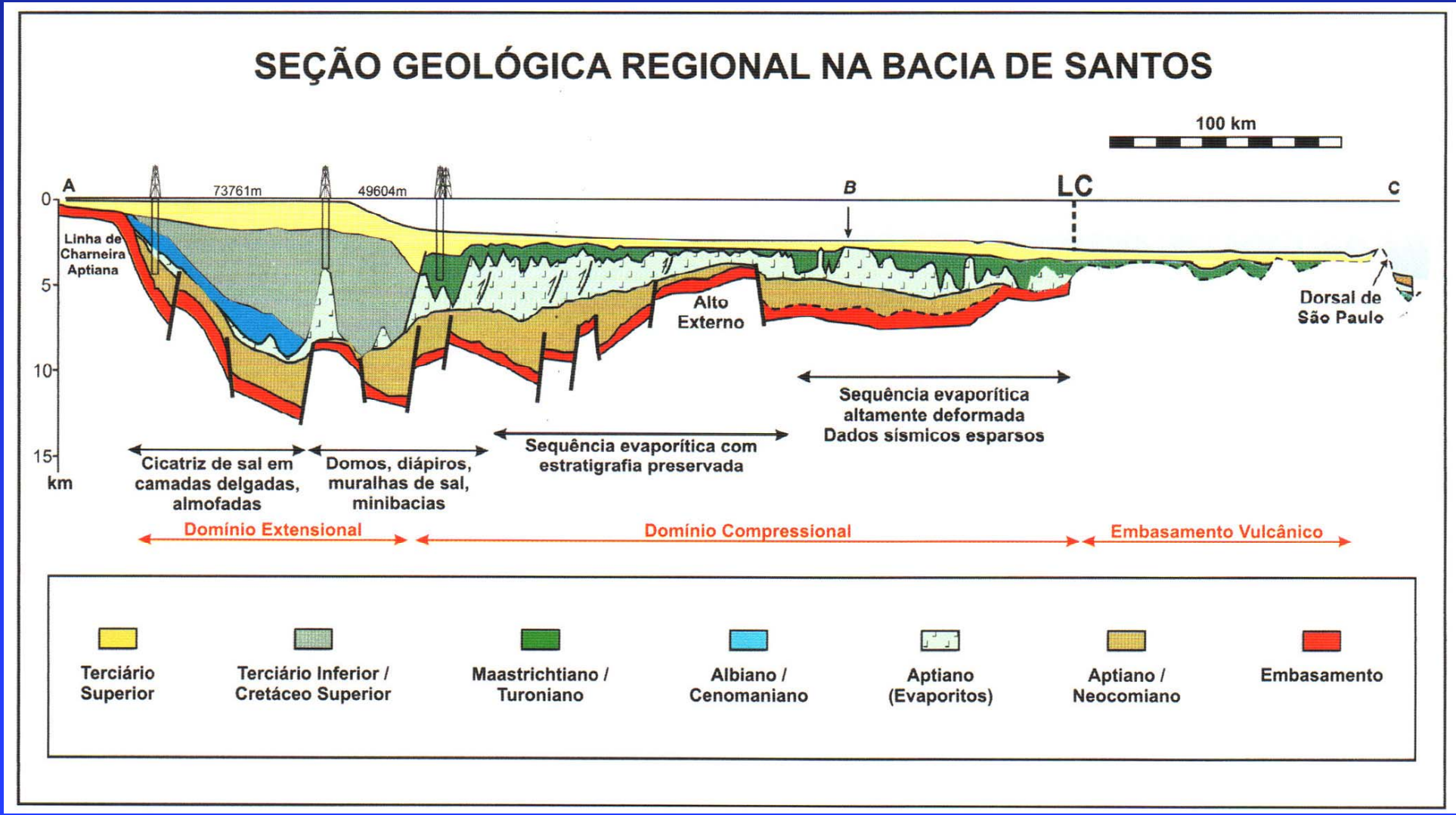
Regional section, Santos Basin
(Gamboa et al., 2008)
Above salt, looks like a foreland basin!



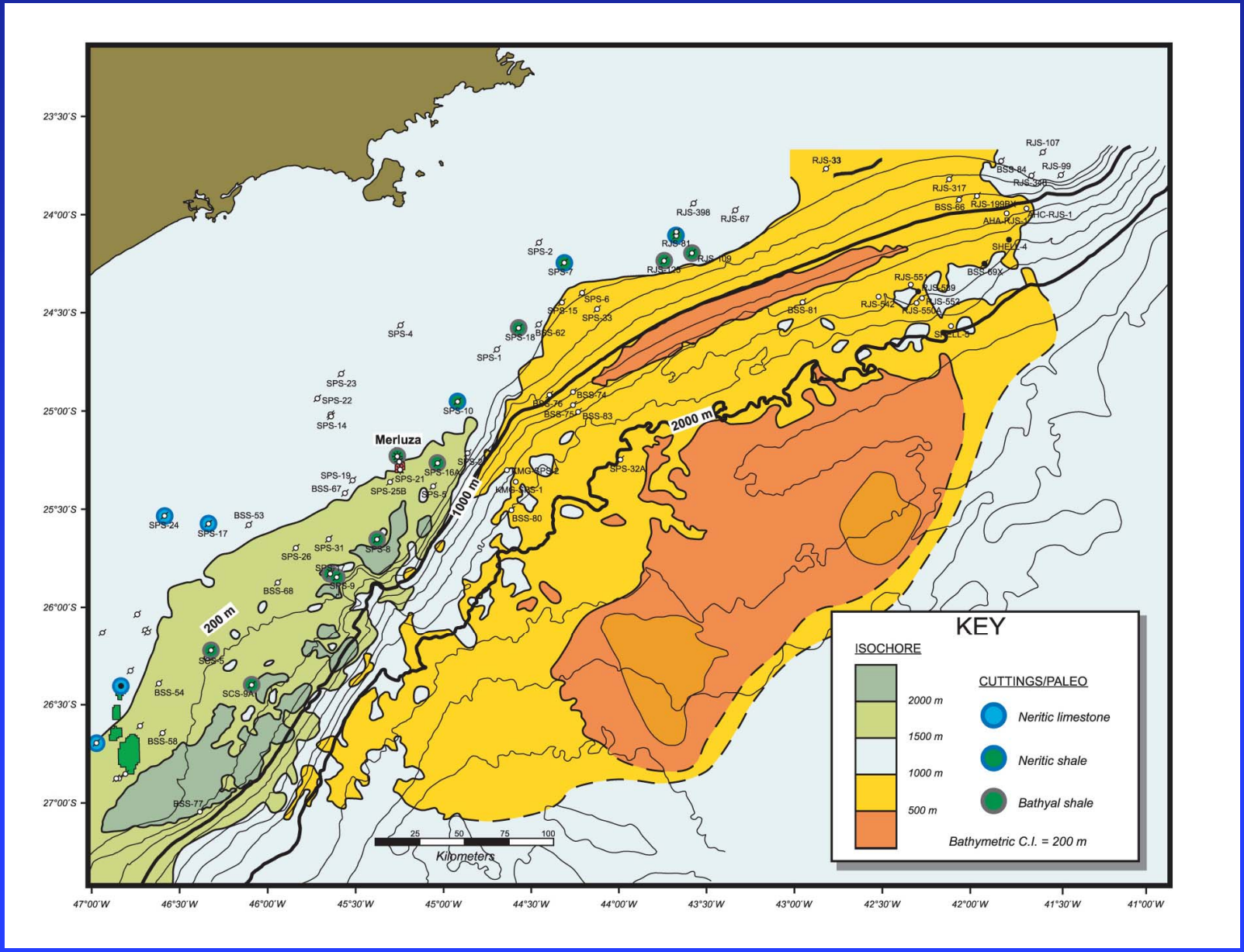
Santos Basin, Late Cretaceous hinge
(Zalán & Oliveira, 2005)



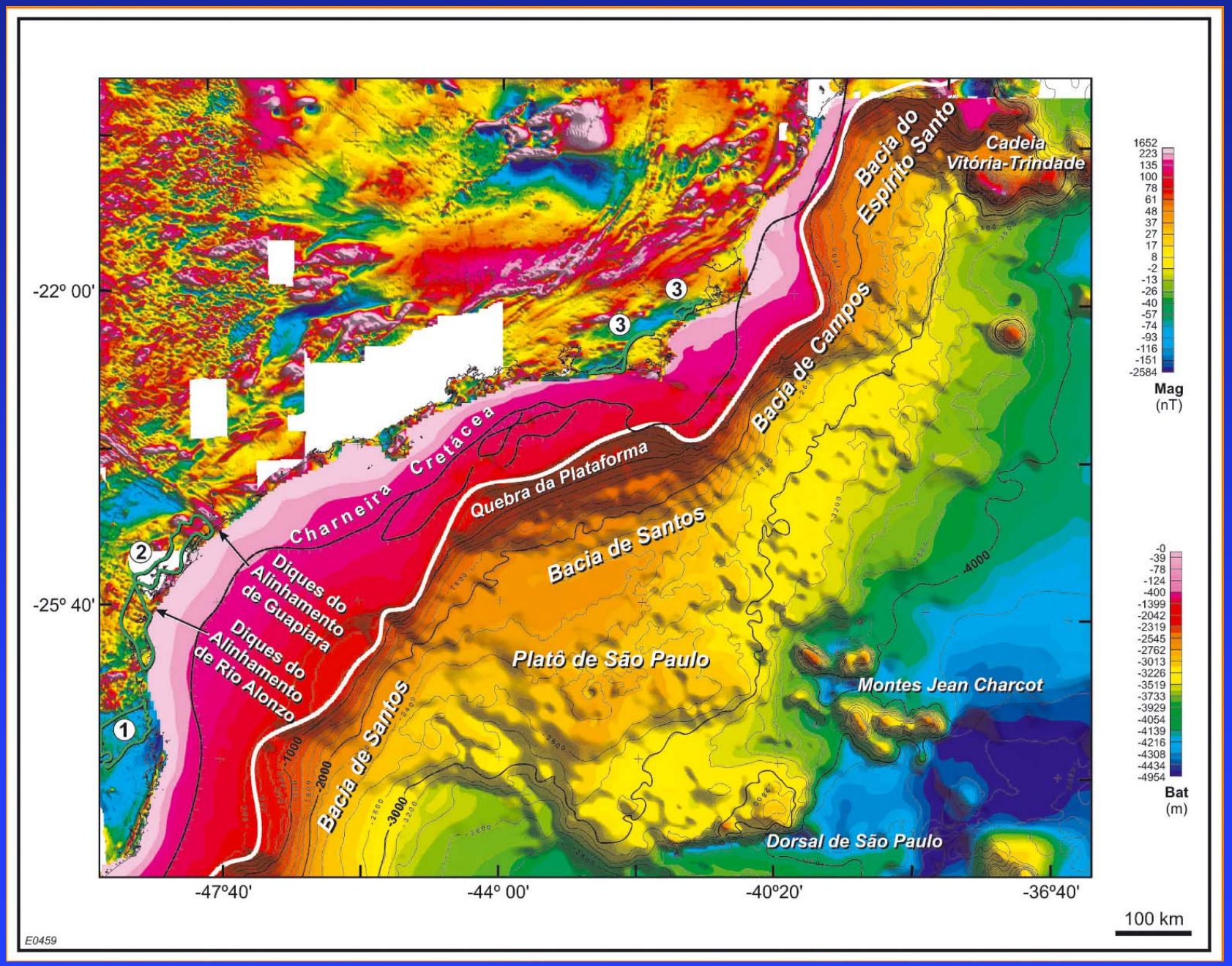
Regional section, Santos Basin
(Gamboa et al., 2008)
Looks like a foreland basin!



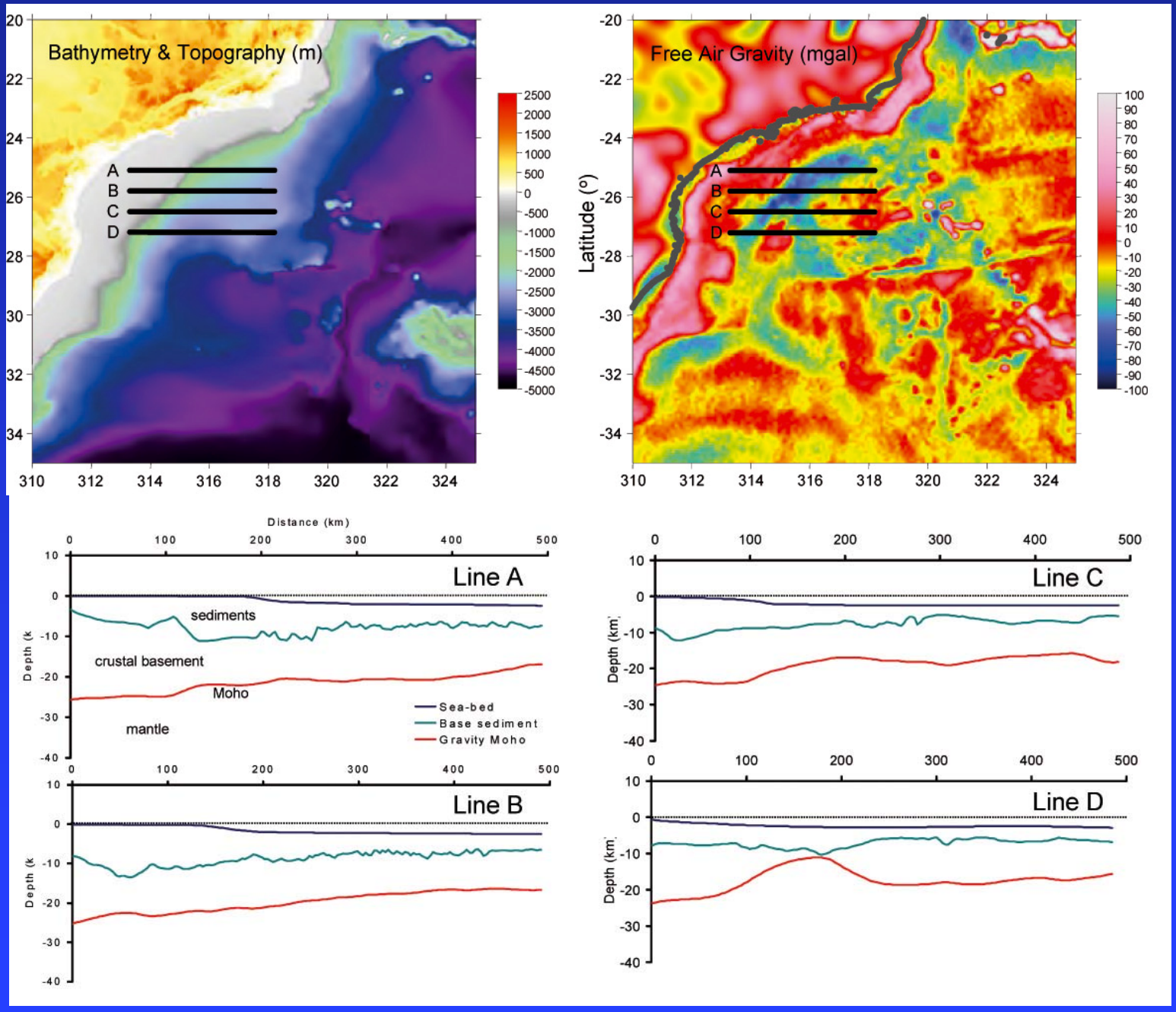
Neogene thickness, Santos Basin
(Modica & Brush, 2004)



Relief at sea bottom, Santos Basin
(Zalán & Oliveira, 2005)



Crustal structure (Scotchman et al., 2006)

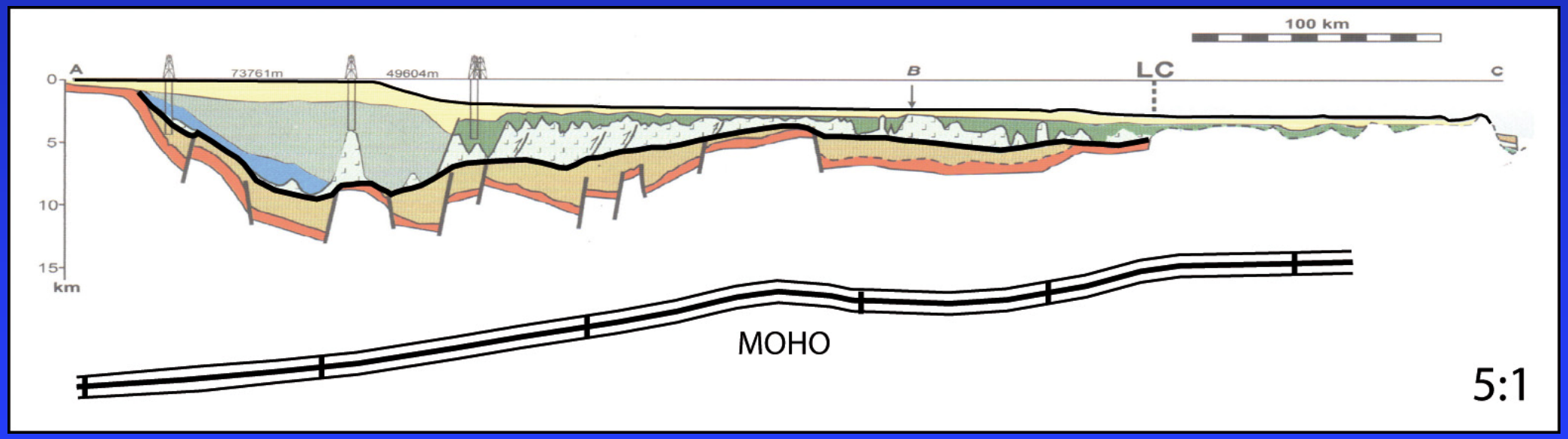


Regional section, Santos Basin

(Gamboa et al., 2008)

Moho

(from Scotchman et al., 2006)



“Foredeep” “Forebulge”

Conclusions

- The Atlantic margin of Brazil went through phases of compressional inversion in the Late Cretaceous, Eocene and Miocene.
- Between the Sergipe and Espirito Santo basins, reverse faults formed at the coastline or shelf break, by reactivation of Mesozoic normal faults or Precambrian thrusts.
- In the Campos Basin, reactivation led to local uplift of a basement high, which became a source of shelf-fed turbidites.
- In the inner Santos Basin, a Late Cretaceous hinge line formed by reactivation of basement, probably in strike-slip mode.
- The Outer High of the Santos Basin developed as a post-rift flexural bulge, by vertical loading and perhaps by horizontal compression.
- These post-rift events significantly influenced the petroleum systems.

Food for thought

- The World's biggest accumulations of petroleum (for example, Middle East, Alaska) are mostly in foreland basins.