# South Atlantic Rifting and Some General Principles for Rift Exploration on Continental Margins*

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## Abstract

The main rifting in the South Atlantic occurred in a 5–10 million year period with subsidence creating deep lakes where high quality source rocks developed. Axial drainage with fine clastic deposition predominated in these early rifts, but once the uplifted footwall blocks began to erode, large alluvial fans poured into the grabens. These alluvial fans can contain large basement boulders (2–3 m) and reach up to 2 km in thickness. They scatter seismic energy and the top of the fan is often mis-picked as the top of the intact crystalline basement. Even when the fans are drilled they can be mistaken for intact basement, as the basement clasts are large and there is little matrix. These 'hidden reservoirs' host significant oil reserves on both sides of the Atlantic (e.g. Rio do Bu Field Recôncavo, M'Boundi Congo). Exploration for these reservoirs is inherently very high risk, but can bring large rewards in onshore mature basins, where costs are low. If the removal of large amounts of footwall crests does not redeposit sediment in the adjacent hanging wall half-graben, but instead flows down the dip slope away from the basin towards an adjacent half-graben, then the whole of the basin can be uplifted by 1 km or more. This is due to the unloading of the crust which acts as a flexed beam. This may in turn give rise to an unconformity, even in the middle of the half-graben. The unloading of footwalls and the rebound effect produces an unconformity, which is at the top of the syn-rift sequence. Many authors refer to this as the 'break-up' unconformity since the introduction of this concept by Falvey (1972). However there is no known physical explanation why the onset of ocean spreading should lead to a basinwide uplift. We suggest that the top rift unconformity simply marks the erosion of uplifted footwall block down to approximately the same level. Where basement weaknesses (shear zones) intersect the graben at high angles and are sub-parallel to the rift opening direction then important hard-linked basement involved transfer faults can develop. The transfer faults can separate rift segments of opposing polarity

with complex transtensional and transpressional flower structures. Large oil fields can preferentially develop along these zones where the high angle transfer faults provide oil migration and sediment pathways across the rift (e.g. Mata-Catu Fault Recôncavo Basin). Similar transfer faults occur in the Kwanza Basin, but these zones are still to be explored.

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**Presentation to American Association of Petroleum Geologists**
**International Conference and Exhibition 2014 , Istanbul, Turkey**
**14th-17th September 2014**

**Ian Davison & Eoin O Beirne, Earthmoves Ltd.**
**Camberley, Surrey UK**

**With thanks to ION GEO Ventures and Surestream Petroleum for permission to show seismic data**

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# South Atlantic Salt Basins

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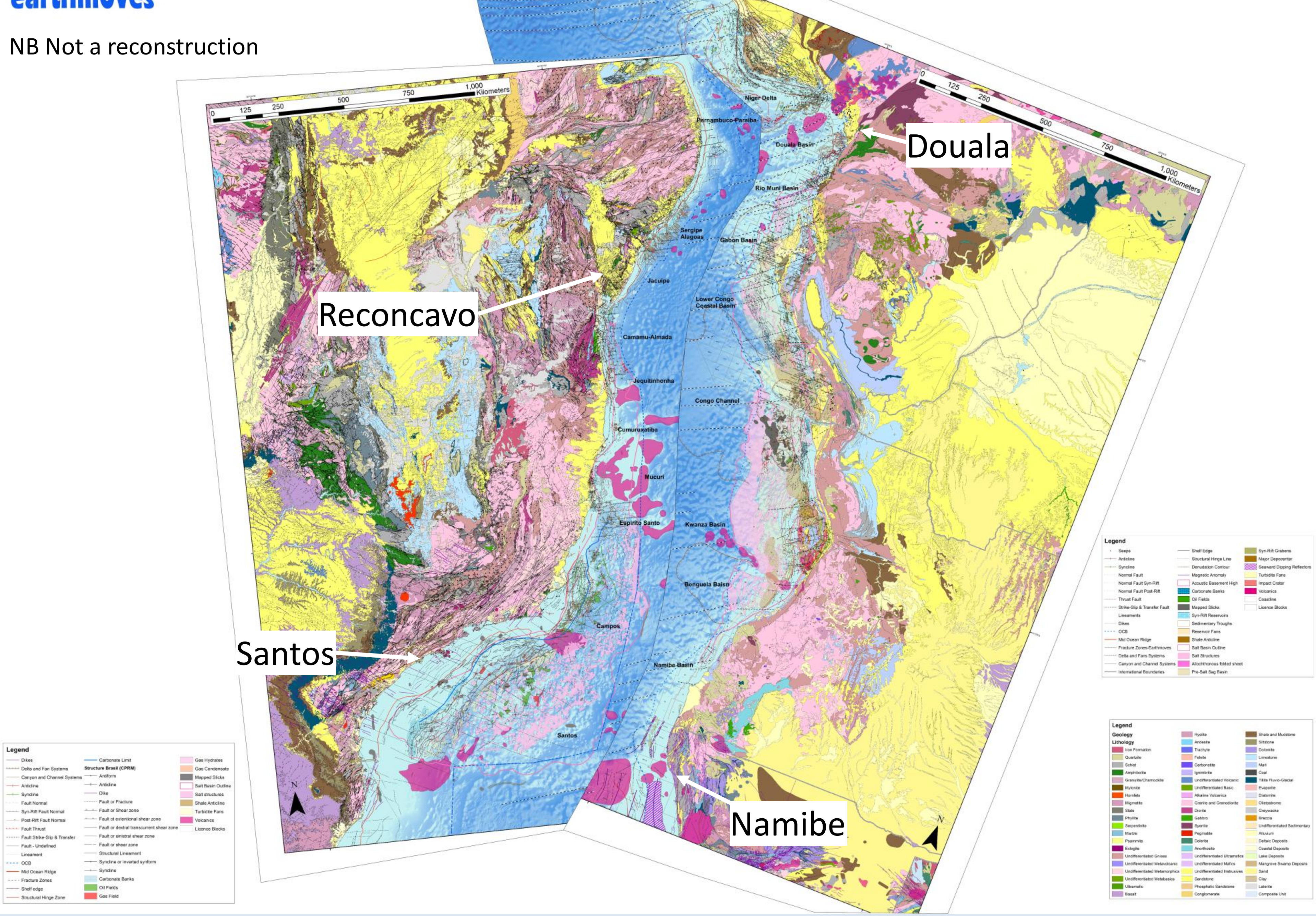
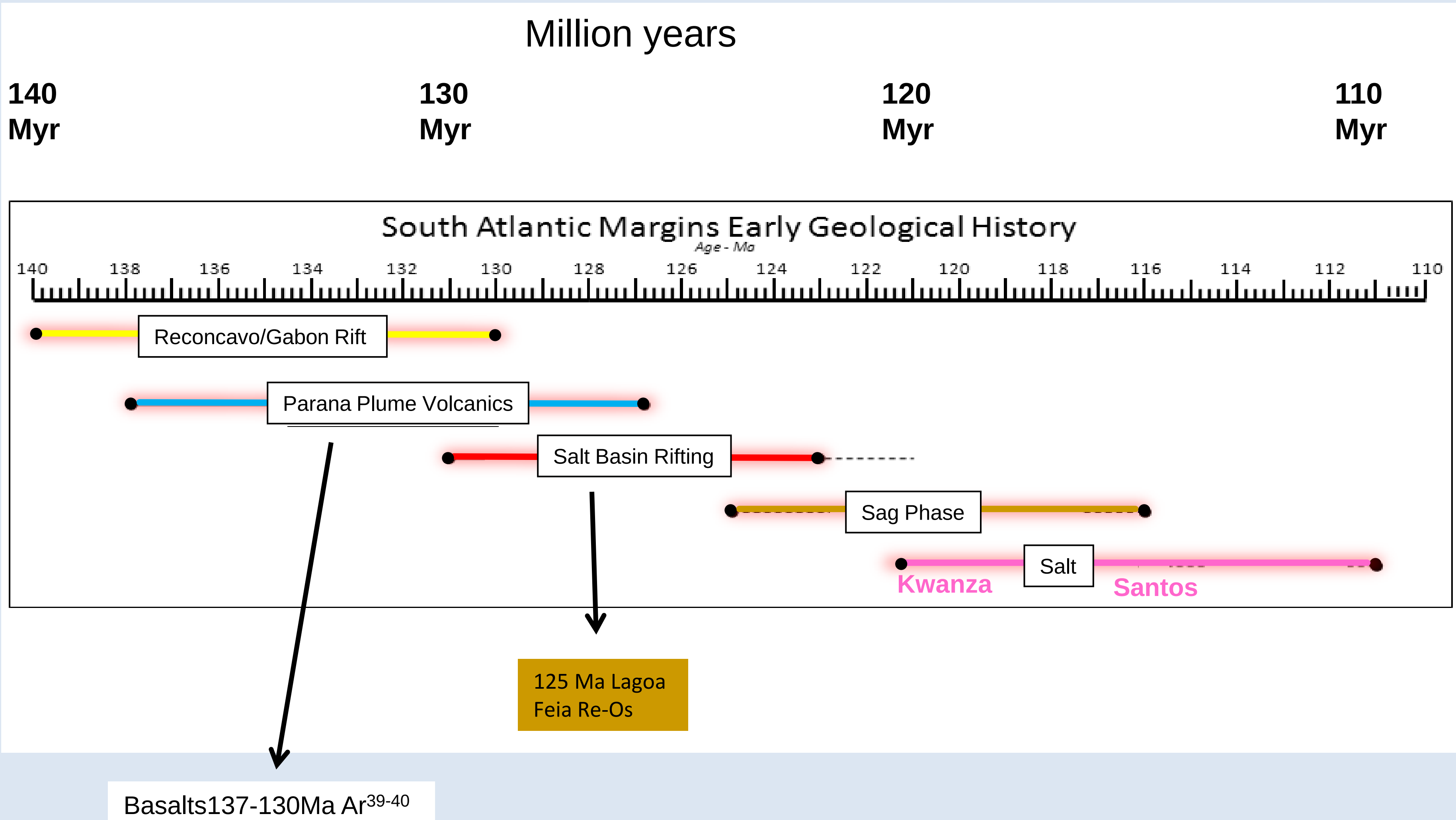
NB Not a reconstruction

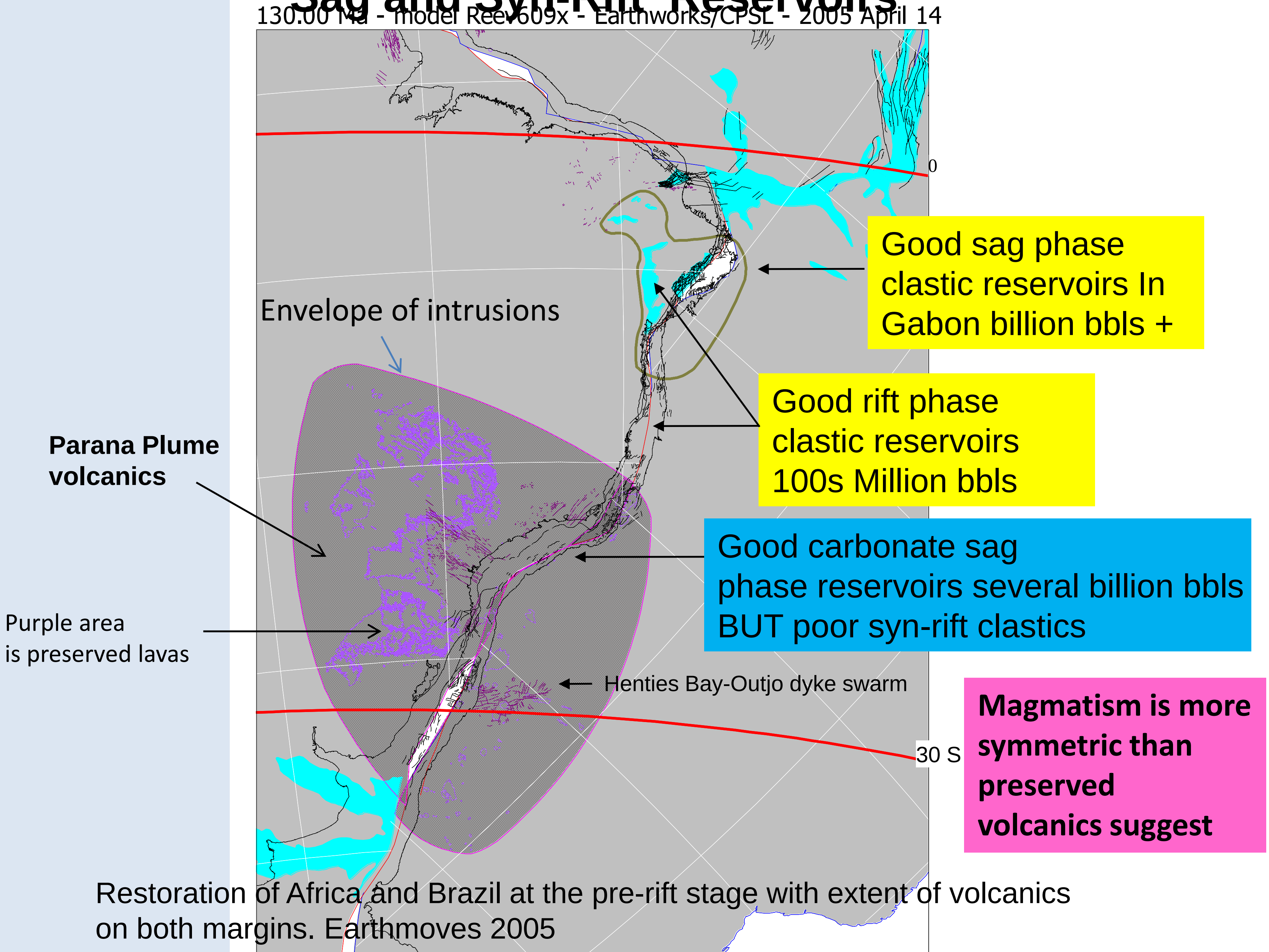


# Early Rifting History of the South Atlantic



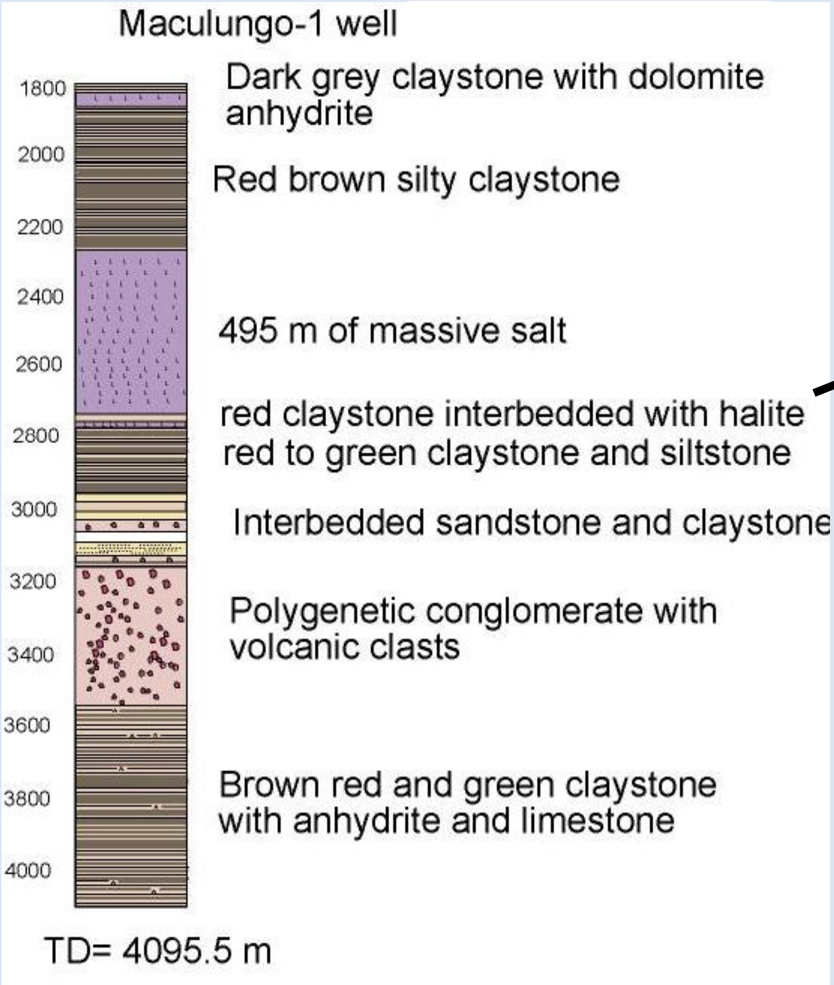

Adapted from Davison *et al*. 2012 Geol. Soc. London

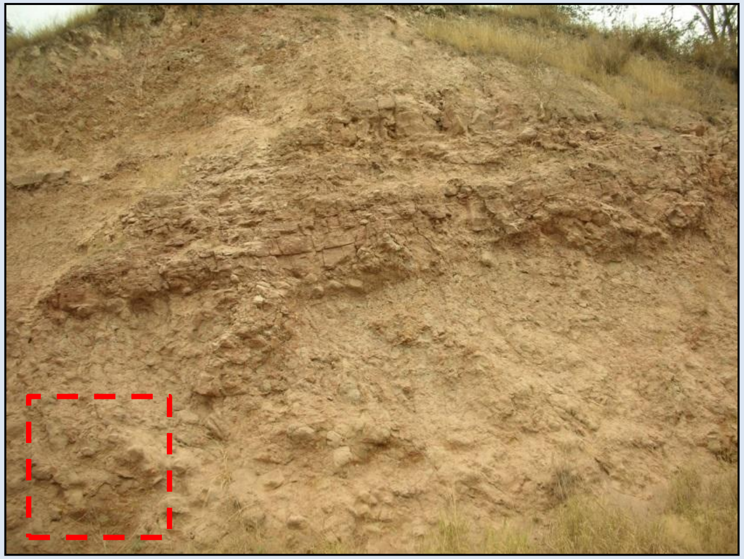
# Sag and Syn-Rift Reservoirs



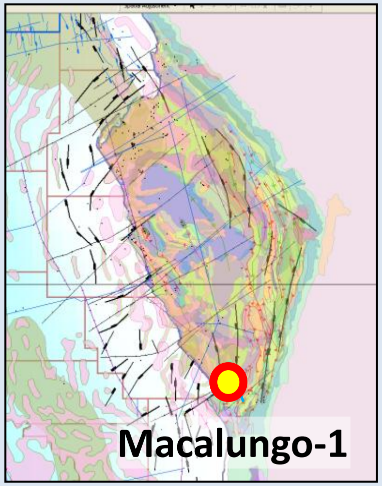

Restoration of Africa and Brazil at the pre-rift stage with extent of volcanics on both margins. Earthmoves 2005

# Syn-Rift Kwanza stratigraphy



Detail of Red Cuvo/Denda Fm. basal conglomeratic breccia with angular clasts consisting mainly of green to dark grey volcanic rocks in a red silt/marl matrix. Early basin fill strata




Photos – P.V.A. Baptista 2006

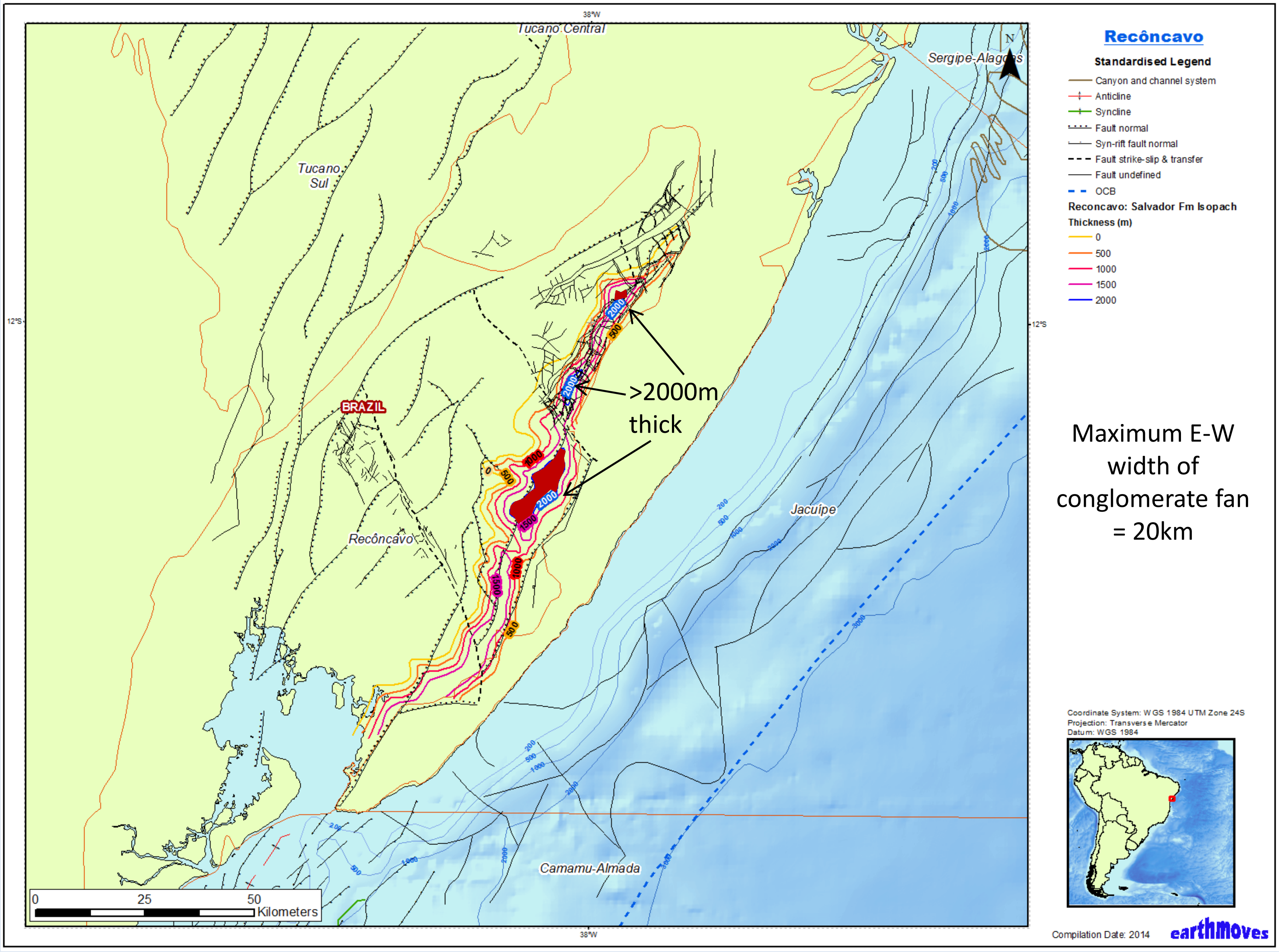
# Reconcavo Rift, NE Brazil

# Salvador Formation Conglomerates

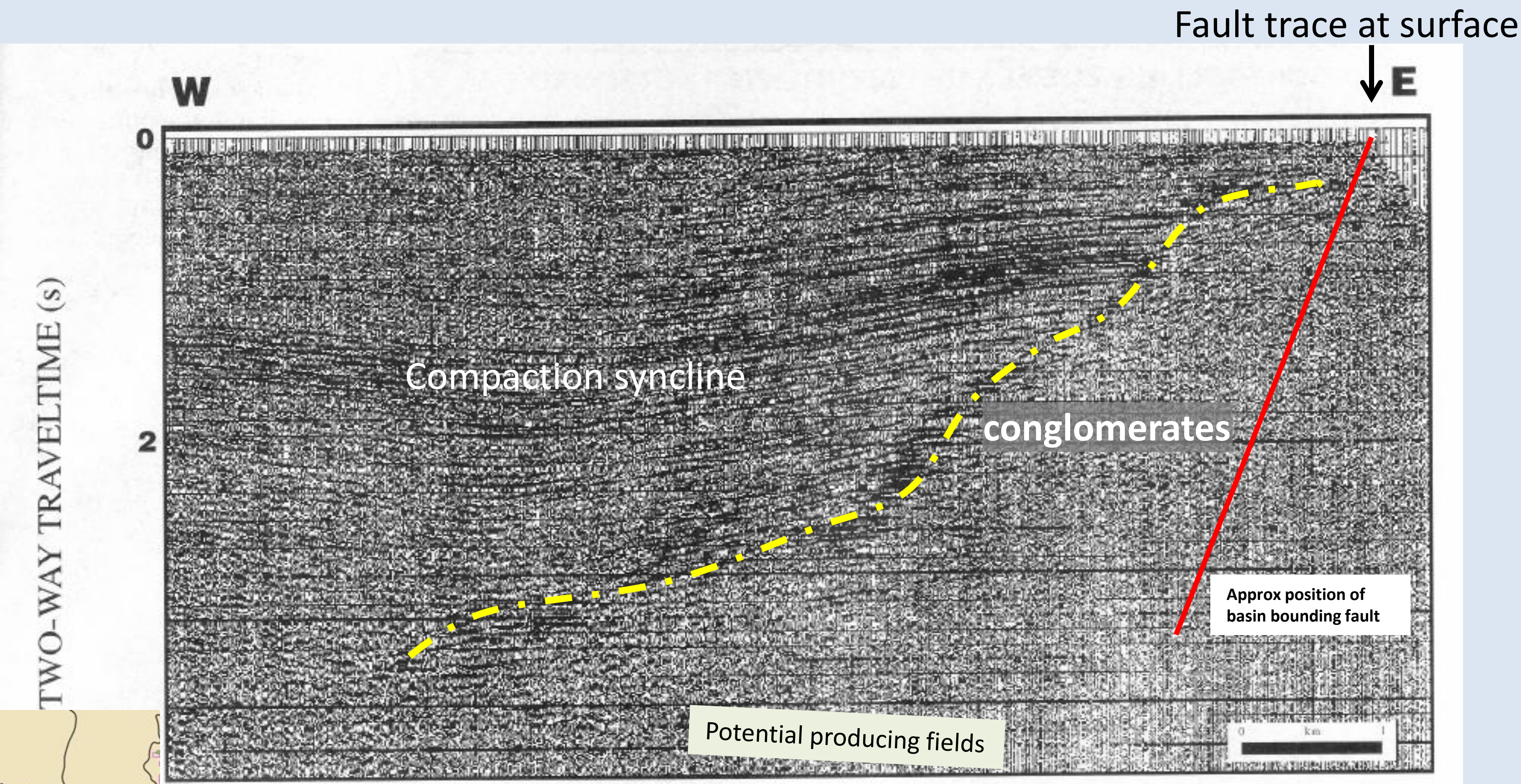


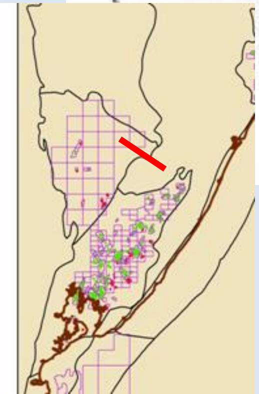
Looks like drilling through basement

# Salvador Fm. Conglomerates isopach



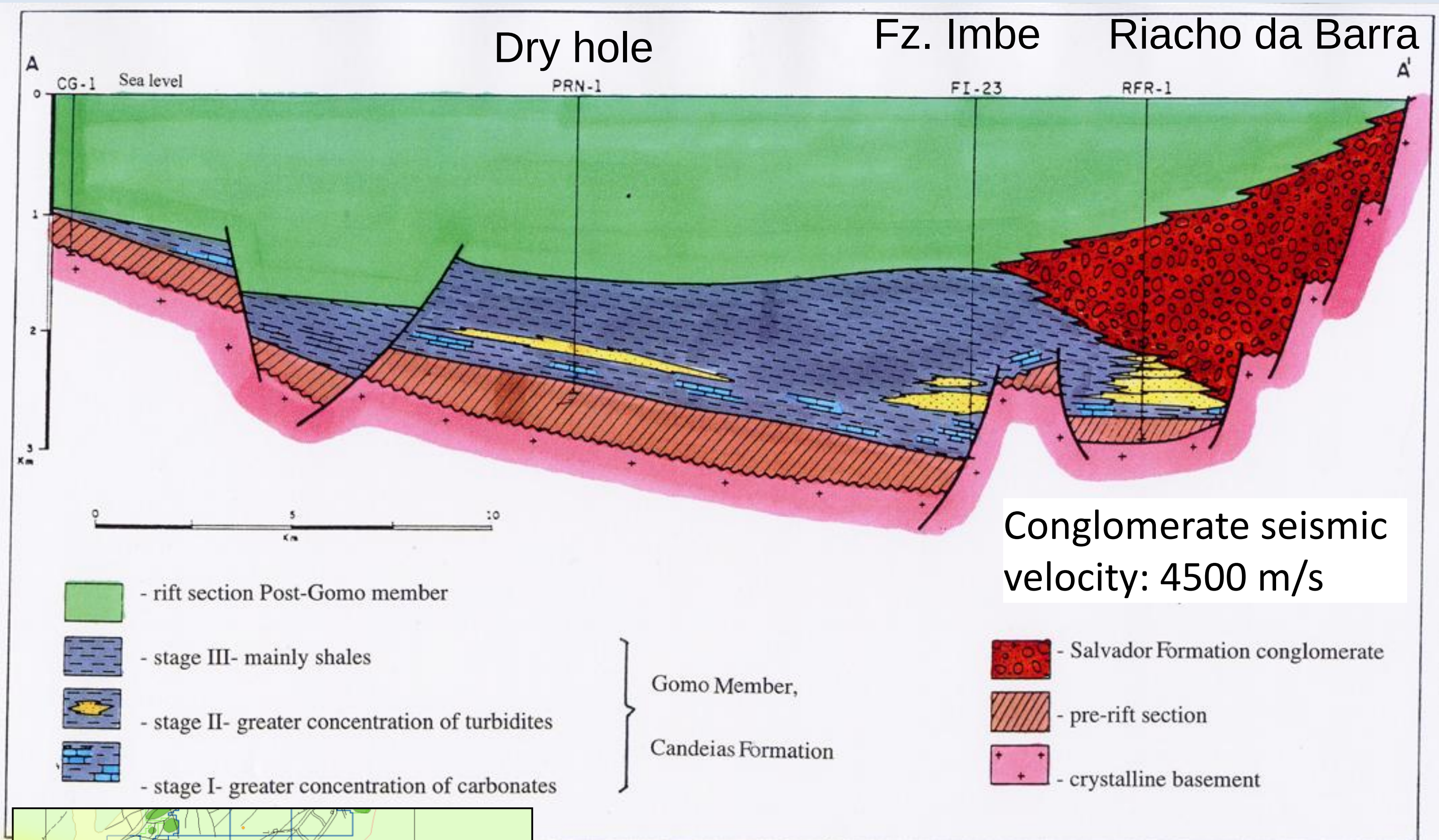
# South Tucano Basin- analogue to west African seismic examples

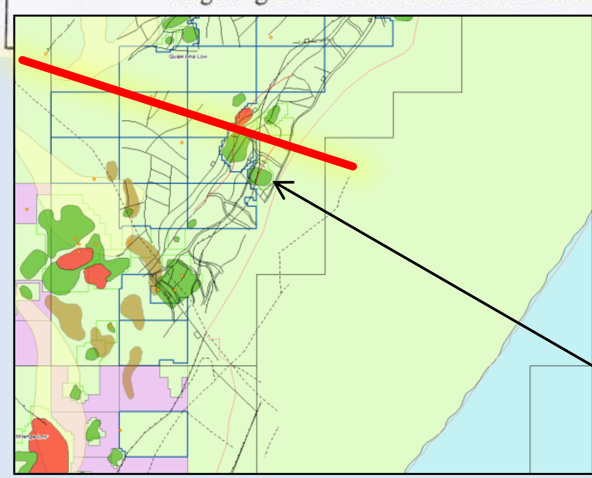


Reflectors in syn-rift fill strongest at inter-fingering zone between conglomerates and finer material, but no reflector at actual top of fan. Approximate fan edge shown in dashed yellow

From Milani and Davison 1988



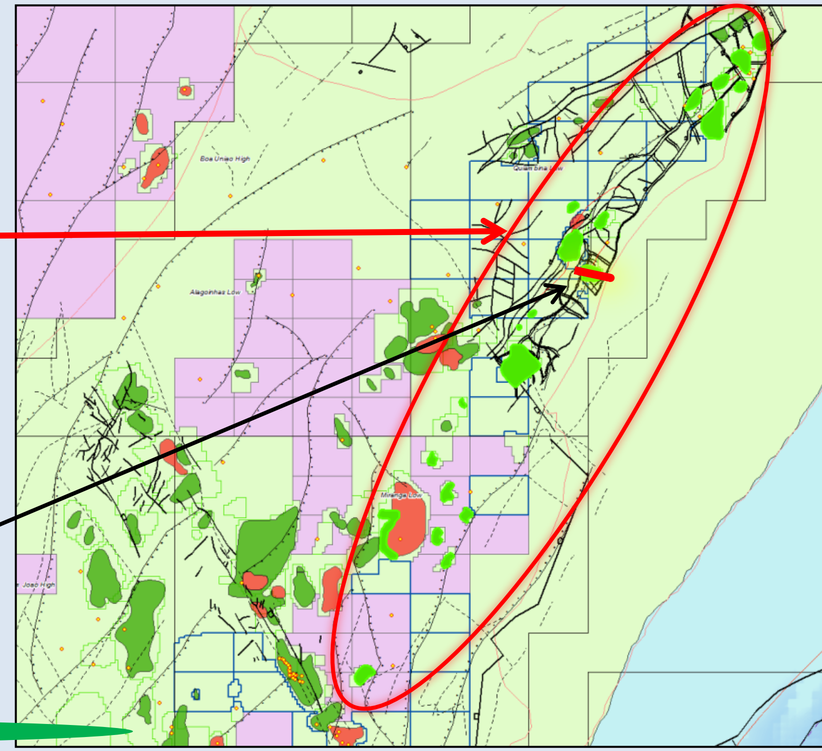

Good quality turbidite ssts. under the fan, Riacho da Barra, Faz. Imbe, Rio do Bu

Bruhn, 1985

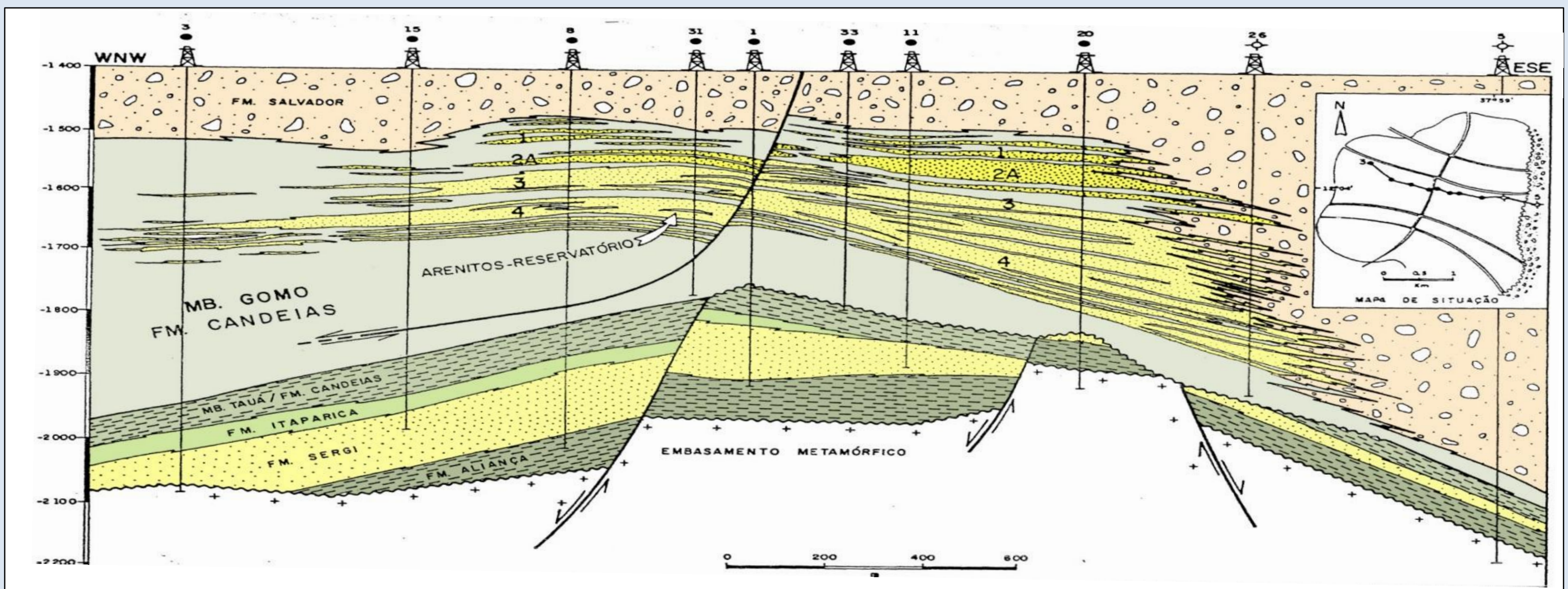
# Oil Fields

- Riacho da Barra

Fields under the fan



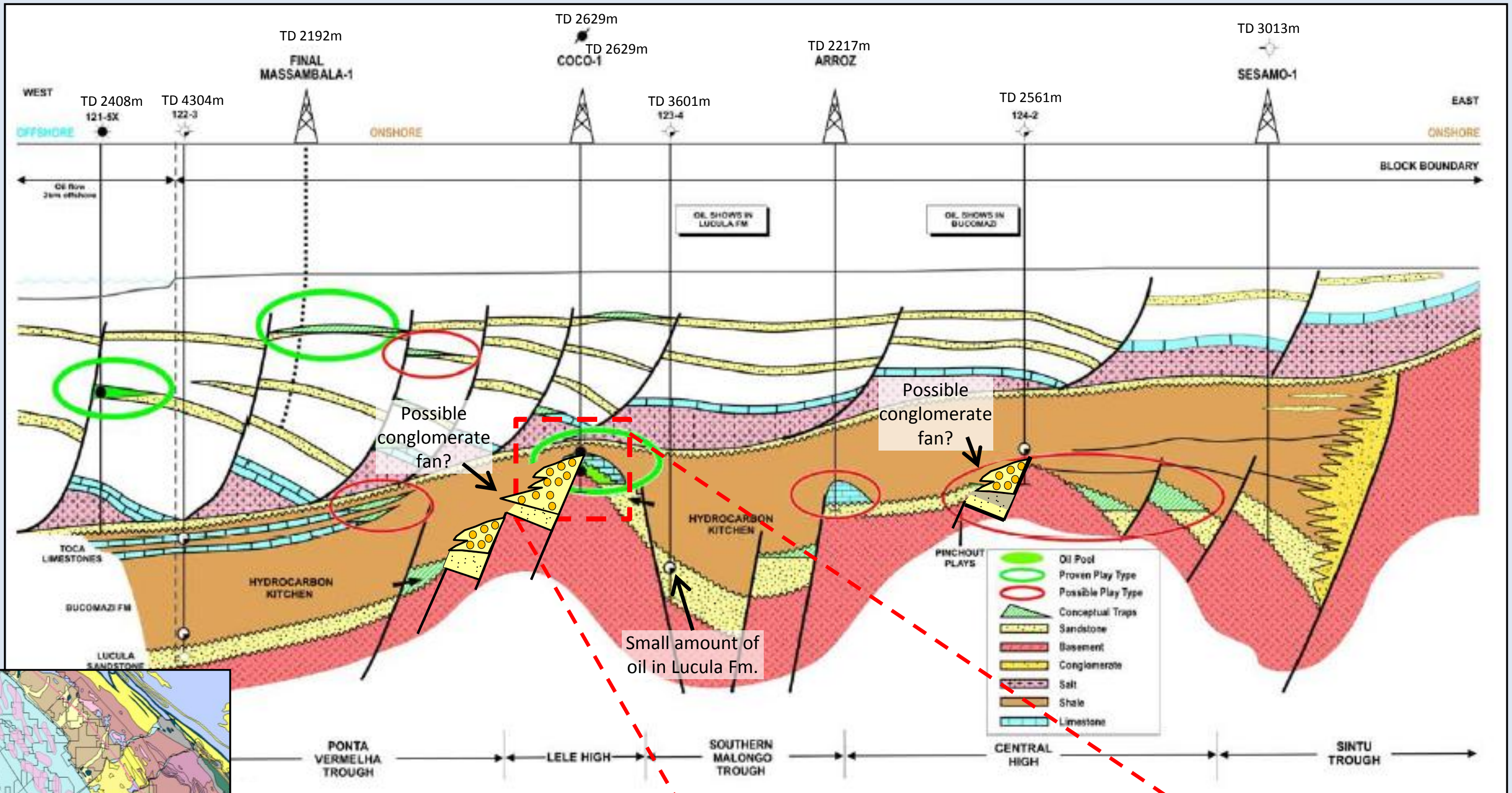
Riacho da Barra

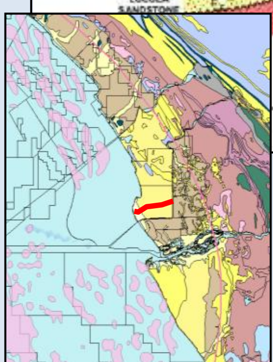


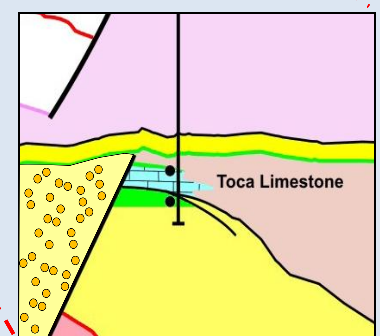

Bruhn, 1985

# Plays

## - Cabinda South






Roc Oil Presentation, 2008

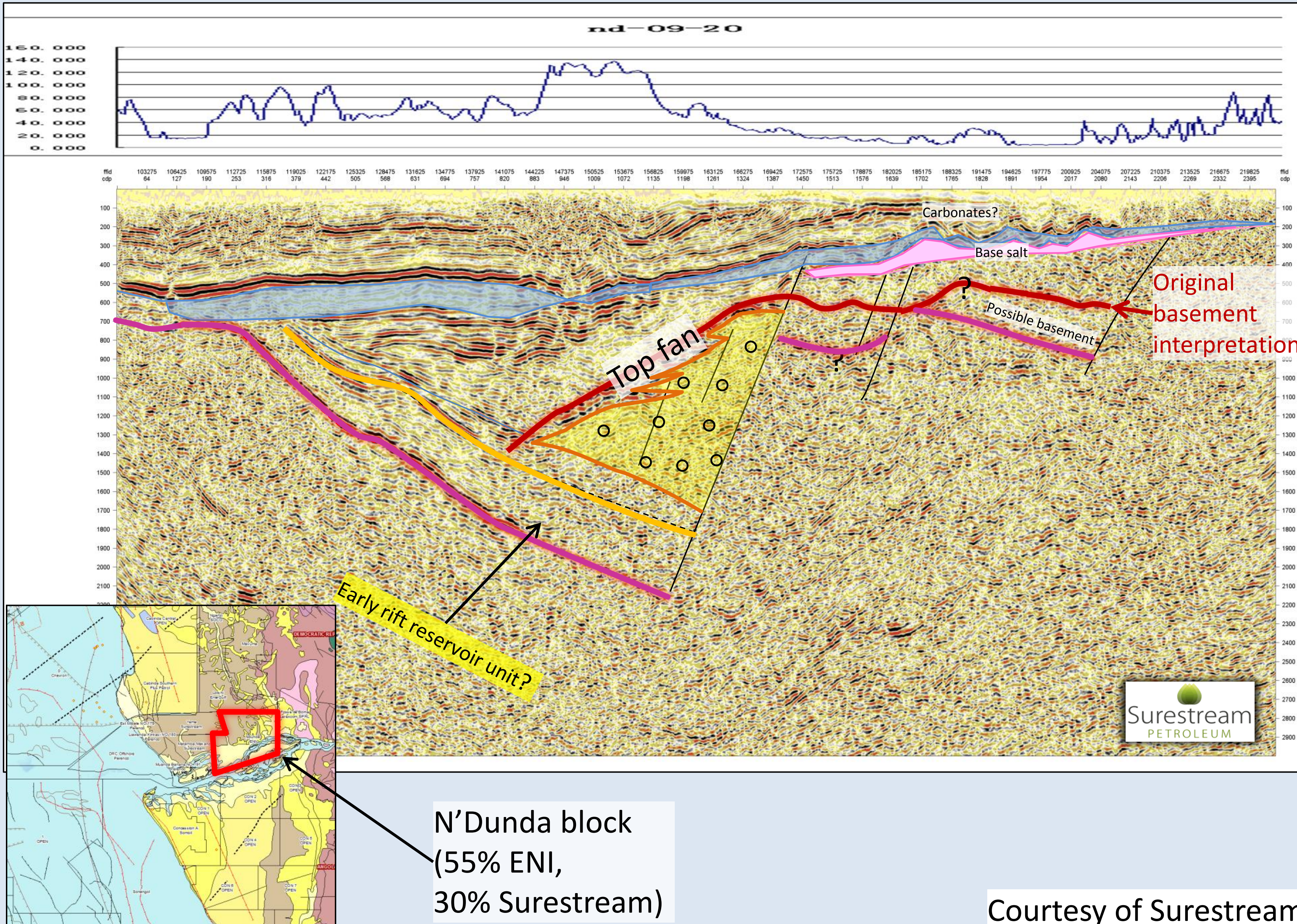
Coco-1 well and 122-3, Toca reservoir onshore, sub-commercial oil (Coco-1 flowed 26° API)

Offshore, Toca carbonates porosity ranges from 6-18% with permeabilities from ~1-50mD. (No published onshore reservoir data available).

Lucula sandstone reservoir see to be present throughout basin - even on structural highs.

Modified from Roc Oil website 2008

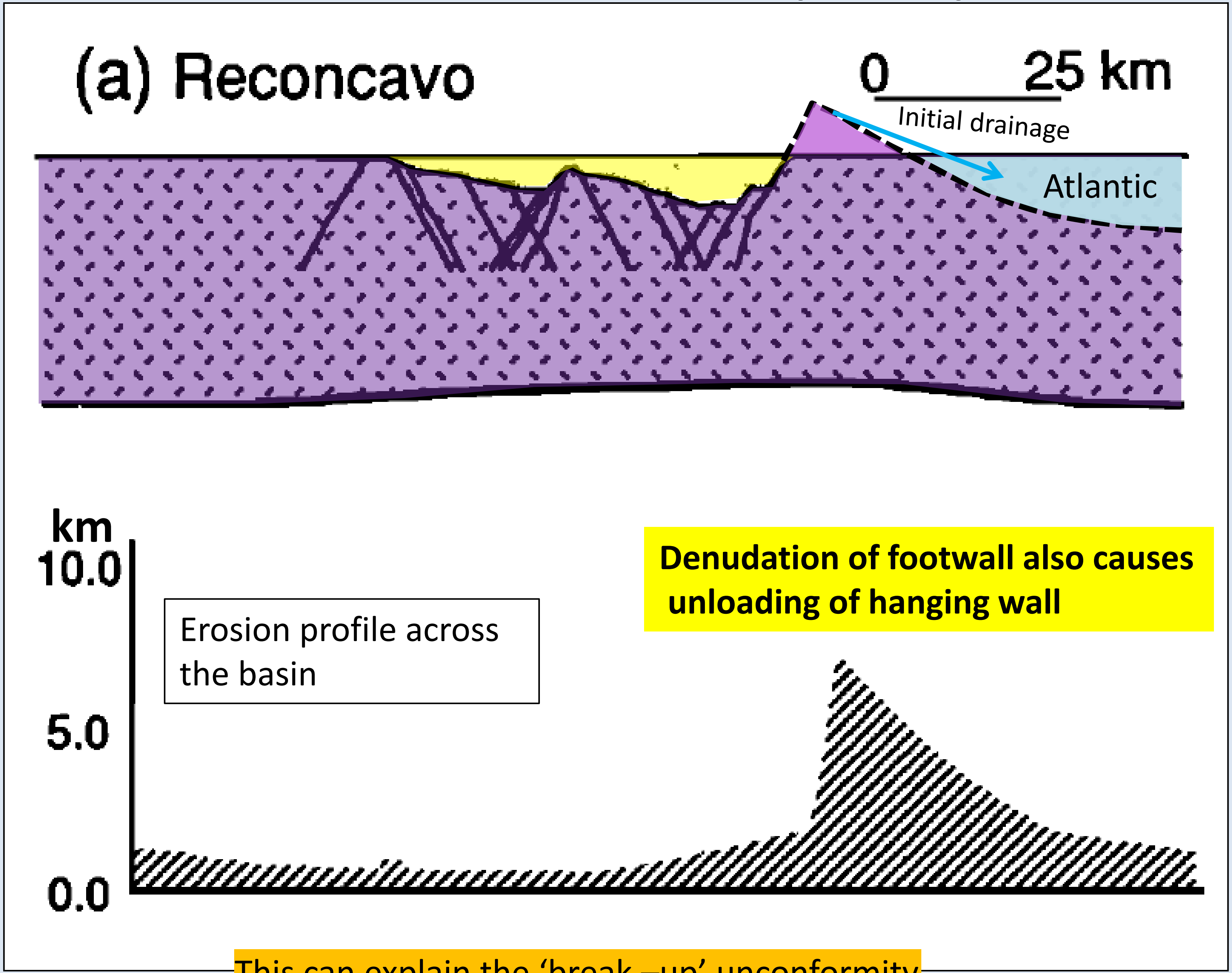
# N'Dunda Block, DRC




N'Dunda block
(55% ENI,
30% Surestream)

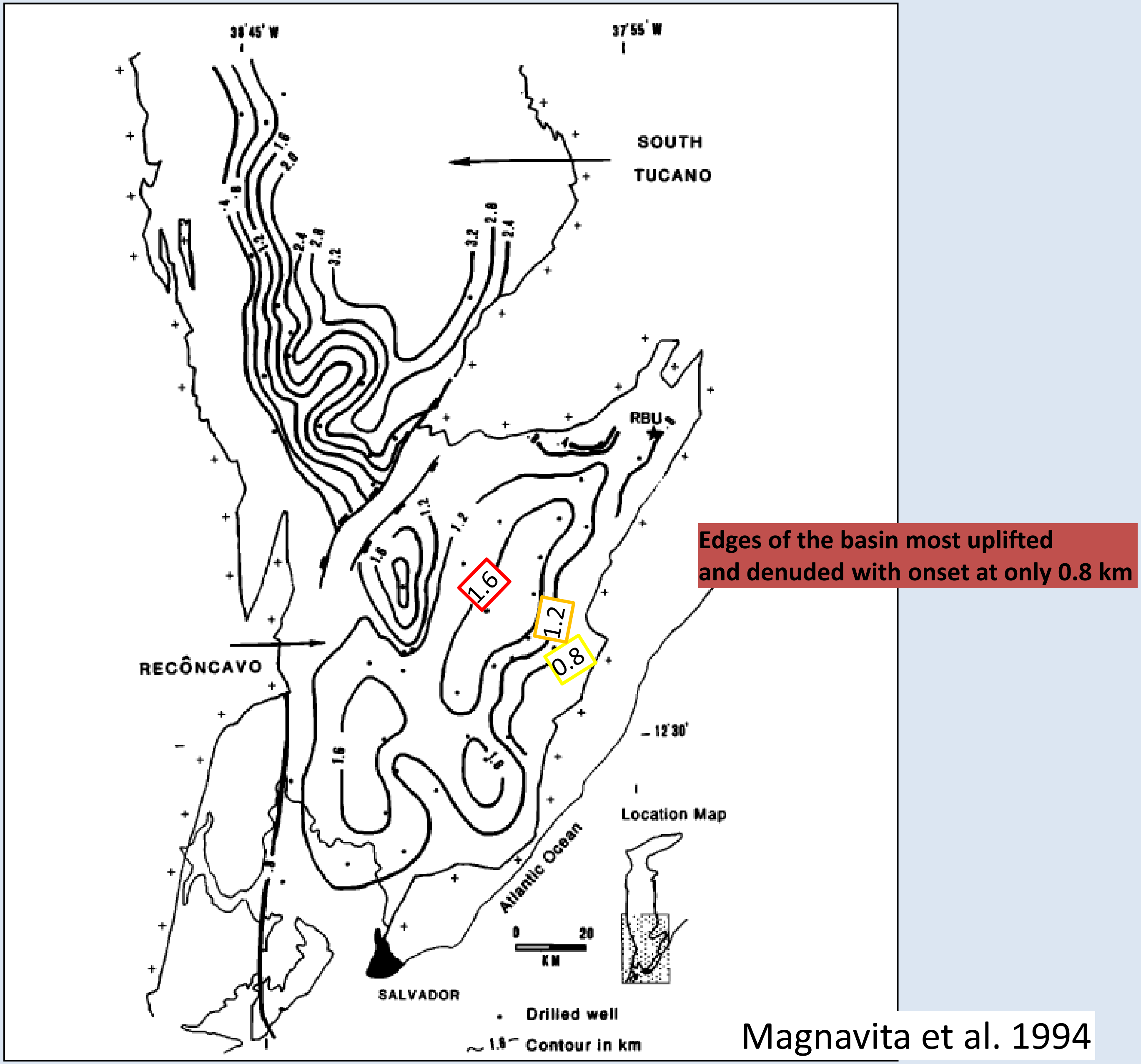
Courtesy of Surestream

# Flexural cantilever model (Kusznir)




This can explain the ‘break –up’ unconformity
It is not due to ocean spreading

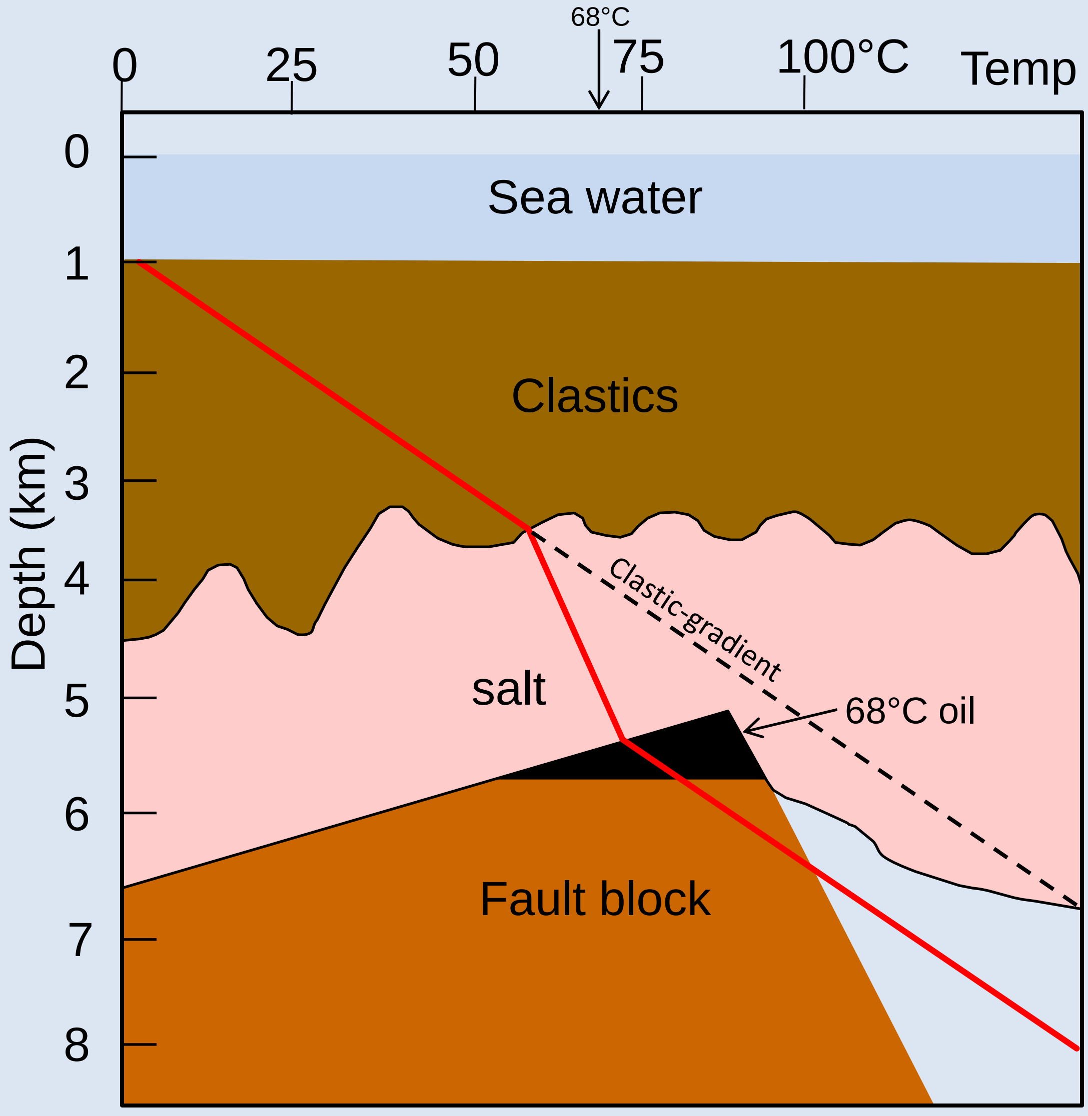
Magnavita et al. 1992




Magnavita et al. 1994

Depth of onset of maturity of organic matter using vitrinite reflectance

# Pre-salt cooling effect




Assumed 25°C/km
thin crust

Salt geotherm **6-8** °C /km

Source in
oil window down here

Modelled temperature gradient through the Tupi Well RJS-628

Davison and Underhill 2012

# Conclusions

Alluvial fans are common along the rift margins, which hide potential reservoirs beneath.

Such Fans are often mistaken for top basement on seismic data and in wells **where no core is taken**.

Flexural uplift and denudation cause uplift of the rift basins.

‘Break up’ unconformity can be explained by footwall uplift rather than ocean spreading initiation –
so should we drop this term?

Post-rift salt layer cools down the rift by 20° C/km of salt.