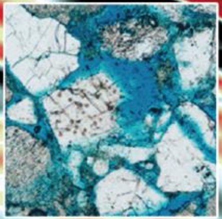
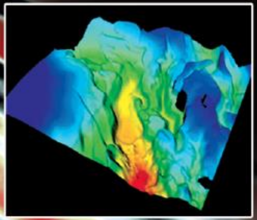
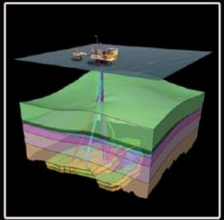

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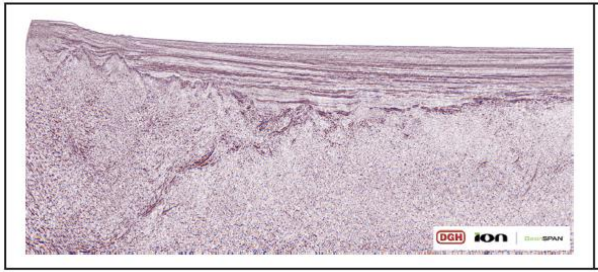
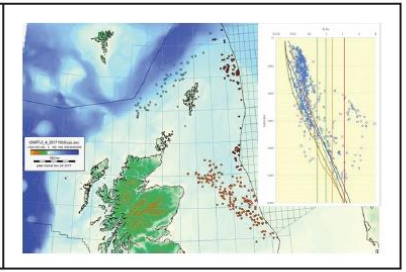
Interplay of heatflow, subsidence and continental break-up: a case study workshop

8-9 October 2018

The Geological Society, Burlington House, Piccadilly, London





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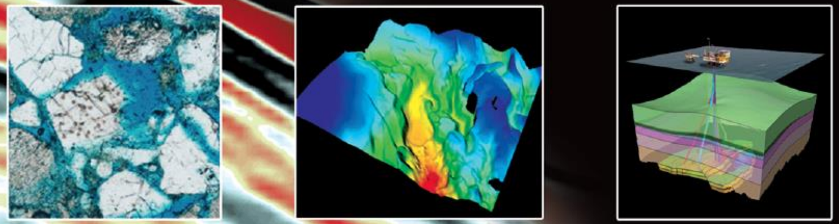

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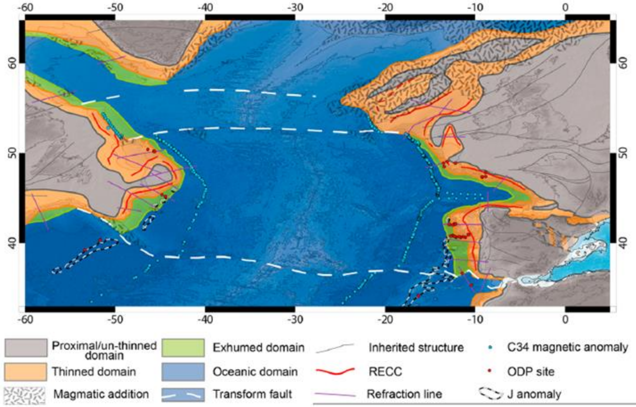
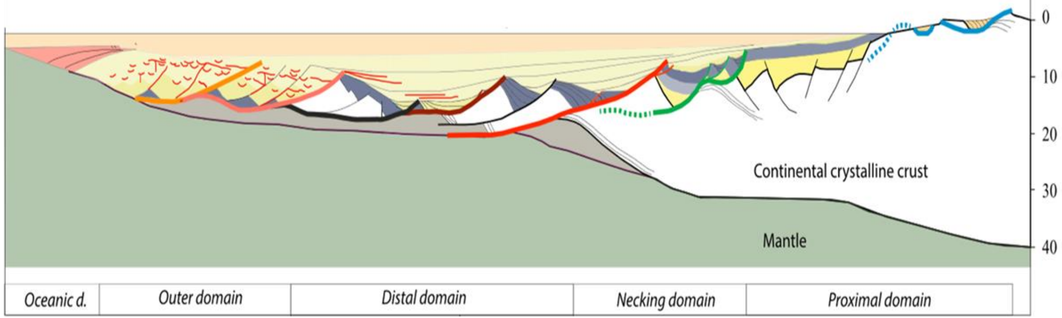


C. Haase, J. Ebbing and T. Funck, 2016.

Key observation: The importance of mapping structural domains.

Issue: No agreement on the subdivision or terminology of these domains

Cross section modified from : Osmundsen, P. T., & Péron-Pinvidic, G. (2018)



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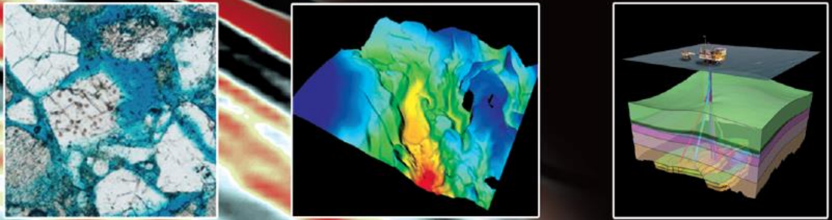

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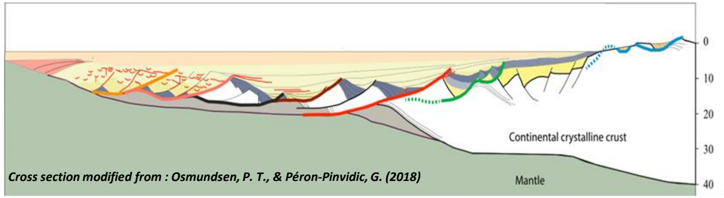

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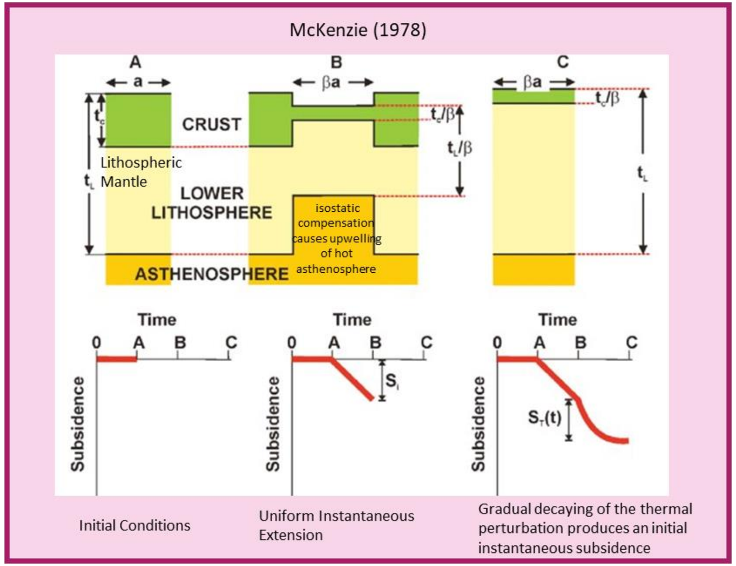

- In areas of low beta the principals of McKenzie 1978 are a good first pass and act as a sense check.
- Rifting is diachronous. In the distal domain extension is still occurring up to 20mya after its ceased in the proximal domain. This makes the use of rift related terminology and propagation of plays difficult across a basin.
- Rift fill and extent of stretching also varies along a margin
- Subsidence does not always directly correlate to the amount of stretching.
- Magma infiltration or emplacement occurs during or after extension. Volume and timing of magma relative to rifting should be considered. End member ‘magma poor’ and ‘magma rich’ models are just that.
- Long after lithosphere breakup magmatic activity and vertical movements continue. (**Not passive**)

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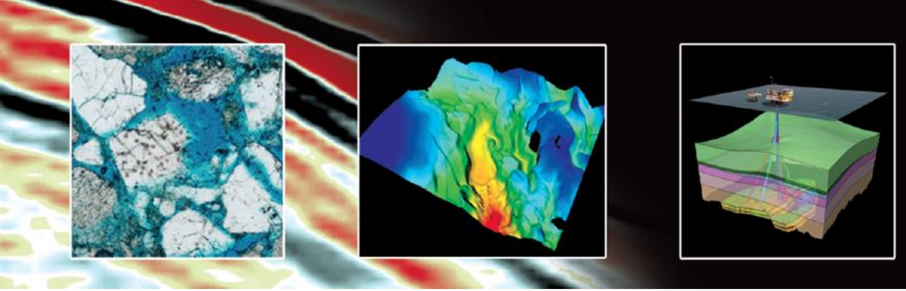

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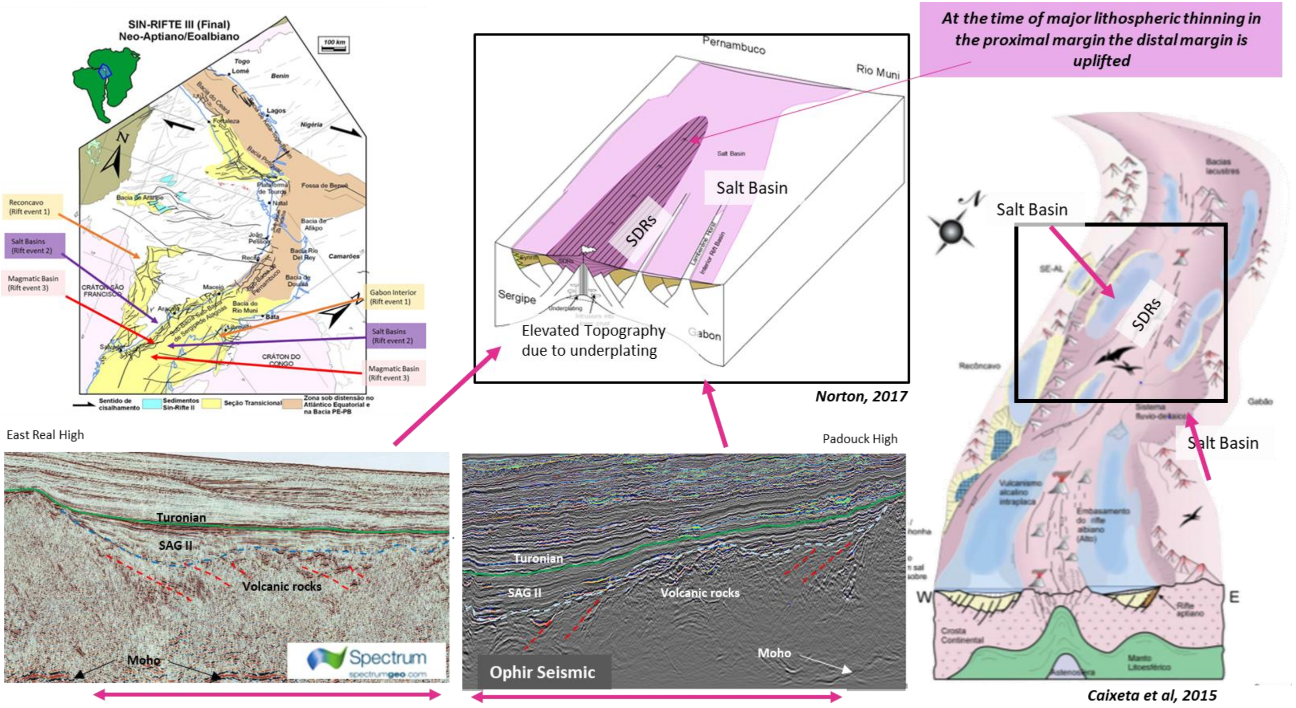

Albian Rifting in the Distal Margin (outboard of the salt basin) associated with magmatic rocks (104Ma 40Ar/39Ar)

Magma emplacement post extension in the 'Outer Domain', an example from Sergipe Alagoas and North Gabon

(Doran, Norton and Pettinotti 2018)

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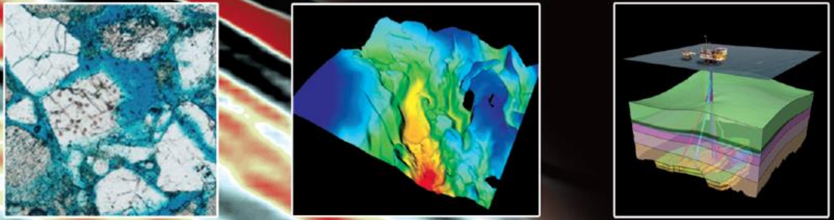

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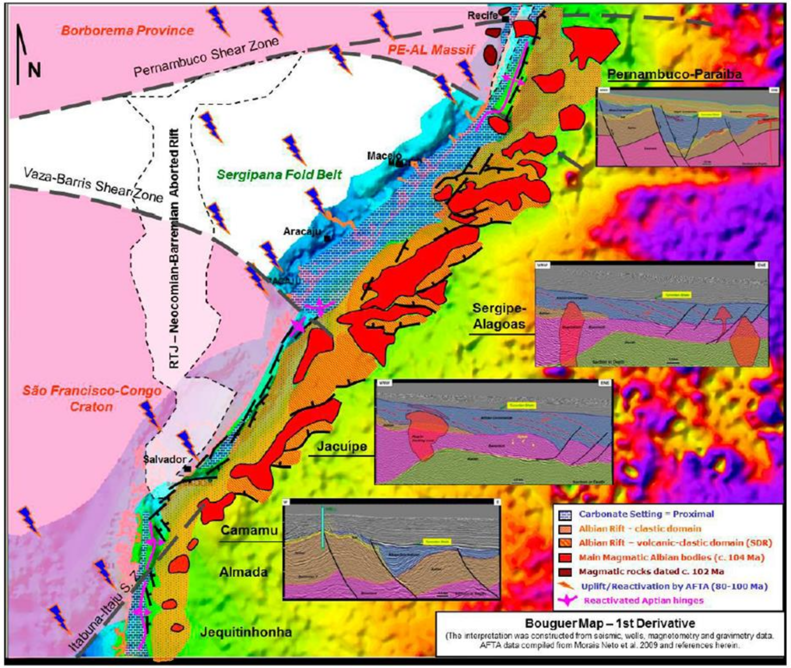
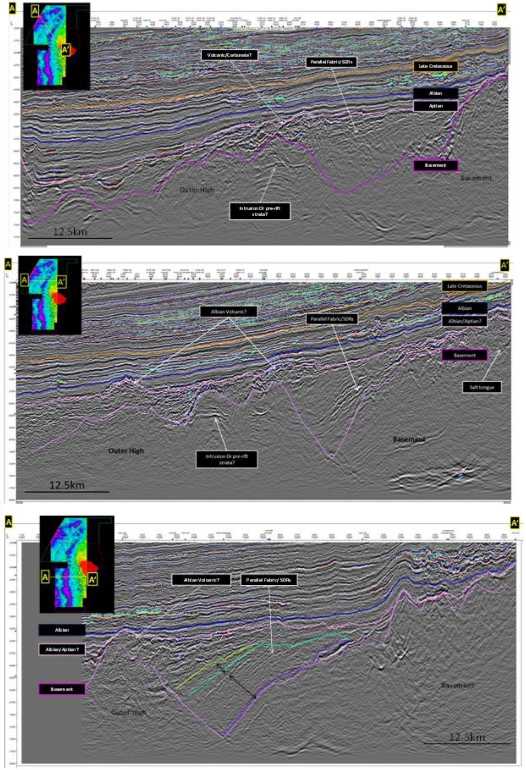


Caixeta et al, 2011



Changes in rift variation along strike in the outer portions of margins. An example from North Gabon and Sergipe Alagoas. Note the variation in volume of magmatic material.

(Doran, Norton and Pettinotti 2018)

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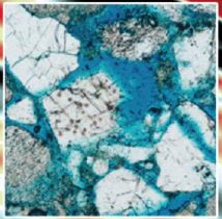

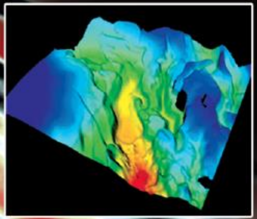

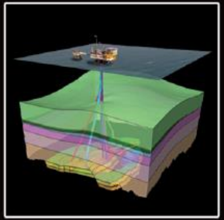

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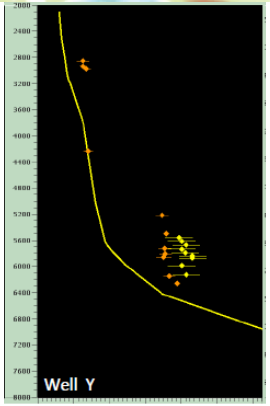
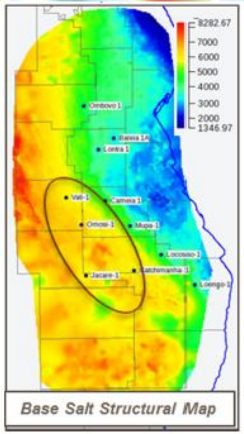
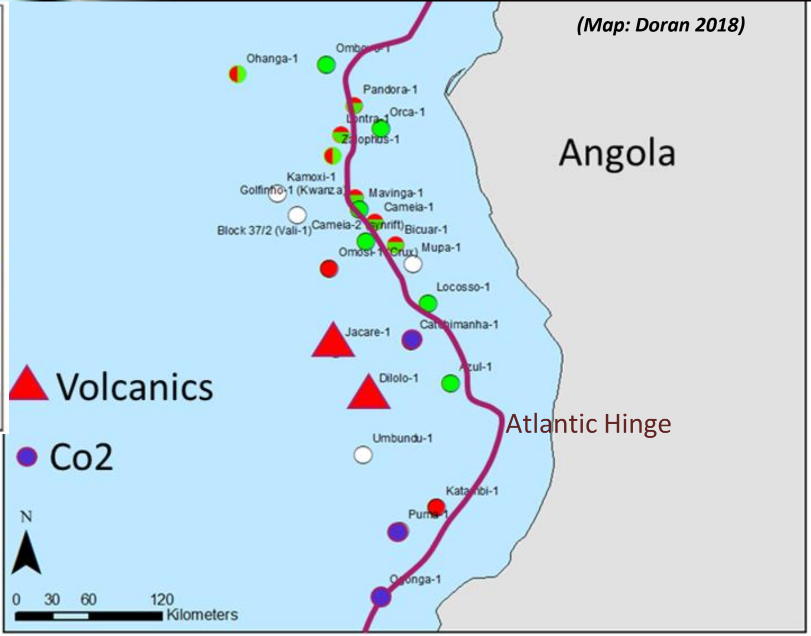
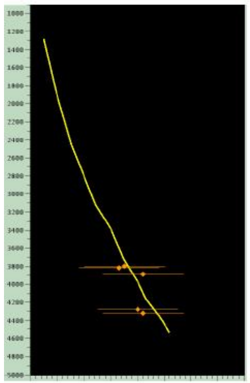
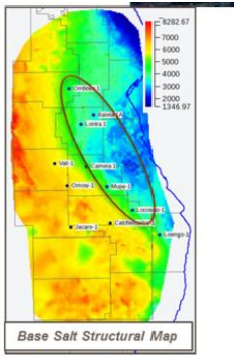






Data from Rodger Baudino et al., 2018, AAPG Lisbon. Also presented as a case study in the workshop.





Excellent Calibration in Proximal-Necking domains, Very Good

Data from Rodger Baudino et al., 2018, AAPG Lisbon. Also presented as a case study in the workshop.

- We are observing differences in the maturity of our sediments across different structural domains: There is still debate on why;
- rift related process or post rift processes (hydrothermal fluids/exhumed mantle).
- Angola and Gabon are two examples of basins where we observe an increase in gas, cements and CO_2 outboard of the necking zone.

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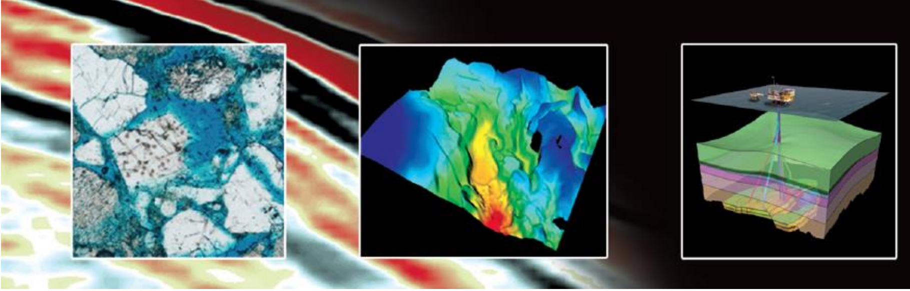

Timing and magnitude are key

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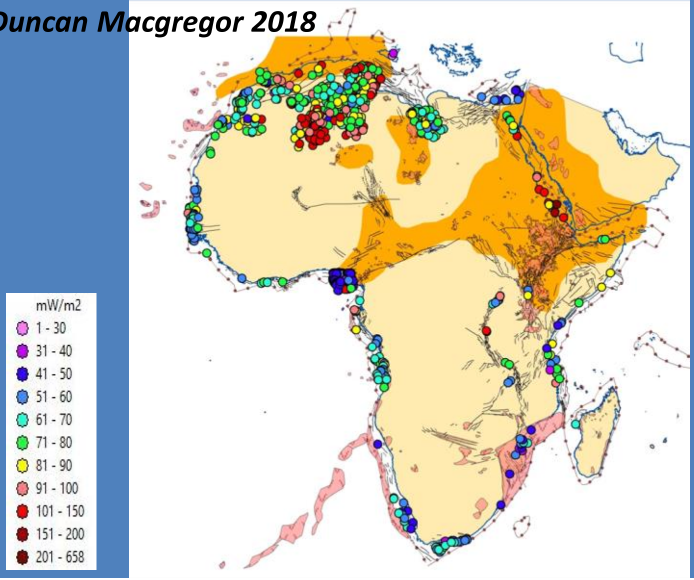
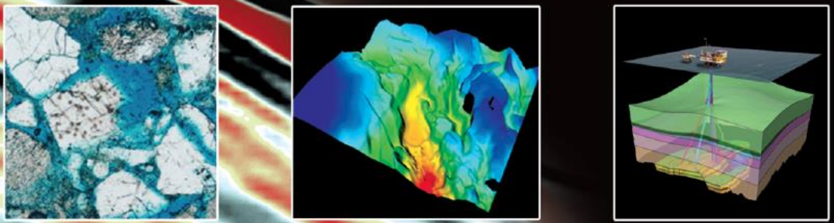
- Key observations on our margins indicate that many of our ‘passive margins’ are not post rift. Each with unique histories.
  - High (GTG >35ºC PD) temperatures have been recorded
  - Often associated with:
    - Dynamic Topography
    - Prolonged magmatism
    - Cratonic edges
  - Many Culprits:
    - mantle serpentinization
    - hydrothermal circulation
    - mantle plumes
    - intraplate magmatism
    - prograde metamorphism of volcano clastics
    - Lithosphere delamination
    - Edge driven convection

Duncan Macgregor 2018



Quicklook Heat Flow map of Africa, constructed using thermal conductivity/age/depth relationships calibrated to Moroccan and Algerian datasets. Volcanics of various ages in pink. Orange polygon represents regions of interpreted lithosphere under 100km thick, interpreted by Fishwick *et al* from analysis of S wave velocities. The small polygon under the Hoggar in Algeria has been interpreted by Ayadi *et al* to extend further west to encompass the region of thermal anomalies below the Ahnet basin. As such it can be noted that nearly all quicklook heat flows on this map above 100 mW/m2 are associated with thinned lithosphere (i.e. raised asthenosphere).



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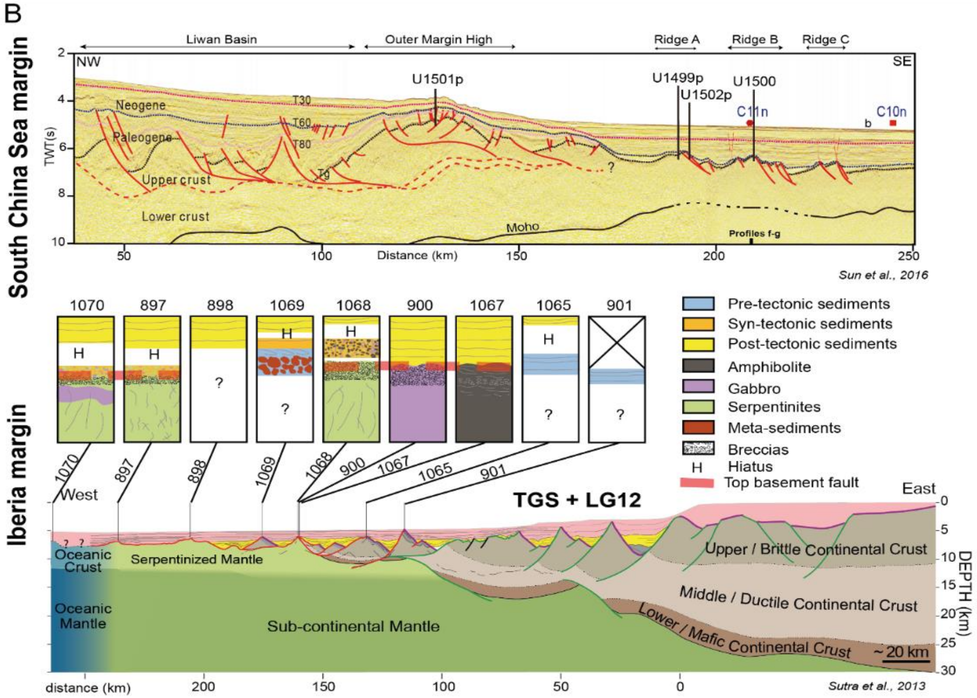

Nirrengarten et al., 2018.

- We were reminded how variable our rocks can be in the distal parts of our margins. Rock properties, thermal blanketing and conductivity could account for some of the variations in temperature measurements and maturity markers !!

- In an example from Sergipe Alagoas (From Fausto) there was clear spatial variations in measured present day temperature data in rocks of very similar properties. Distributions appeared to relate to:
    - Fracture zones,
    - Reactivated faults
    - Volcanic centers
    - Crustal domains

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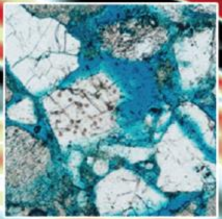
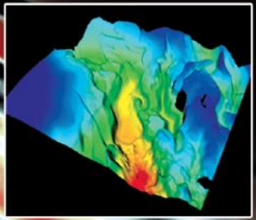
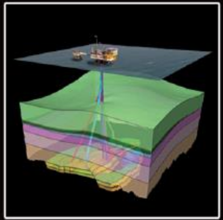
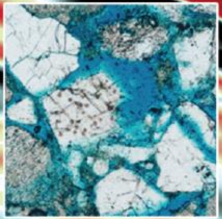
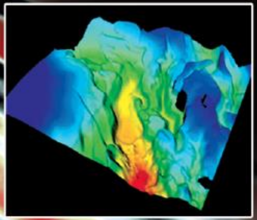
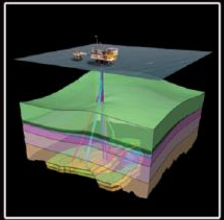




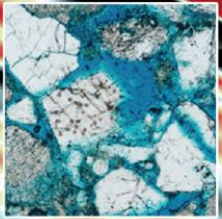
- Issues with data/approaches:
    - We don’t have enough (can we share data: Industry Consortia?)
    - Gradients are very sensitive to measurement and other errors.
    - Each dataset (Tmax/Ro/AFTA) has associated uncertainty and quality issues.
    - Uncertainties below the TD of our current data: limited insights to syn rift processes unless strata has been penetrated.
    - Heavy use of surface heatflow (Qs) but we lack calibration and uncertainty on sediment properties (RHP), conductivity and transient effects.
    - Potential fields, refraction and deep reflection used to constrain crust can be non unique. Be careful. When you start to infiltrate continental crust with magmatic material you can thicken and increase its density making the interpretation of its original composition very difficult.
    - Backstripping a key input but a range uncertainties on paleo bath and compaction remain.

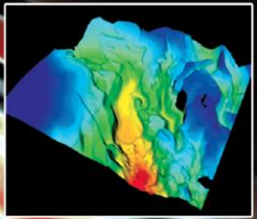


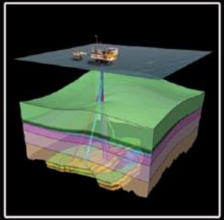




- Best Practice:
- Mega regional approach is important (some mantle process have huge spatial footprints)
- Domain mapping is a must (see first slide)
- Integration of all datasets are key:
    - PD Temperature data and geochem maturity parameters
    - Refraction seismic
    - Potential fields (grav and magnetics)
    - Map your magma: Sills on seismic, volcanoes onshore are these a smoking gun?
    - Maximise the information within cements: Single aqueous FLINC, Sr/O isotopes. CL for carbonate cements
    - Onshore uplift and geology could be key to dynamic mantle movements
    - AFTA with seismic
    - Our boring oceanic stratigraphy holds nuggets of information key to constrain timing of mantle processes. **Suggestion: bombard NW with you seismic surveys on oceanic crust**.







- With so much uncertainty what is the role of a basin model ?:

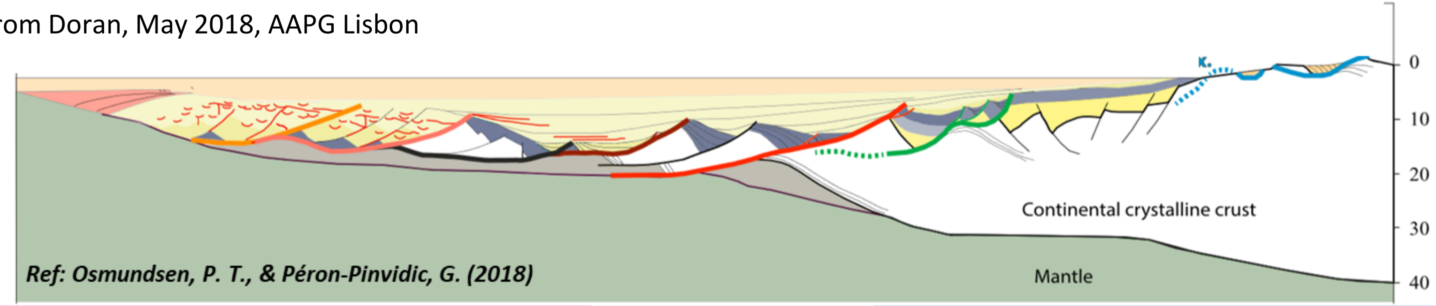
- The strength of a model is to start, focus and facilitate conversations between different disciplines

- Coupling lithosphere and sediment process is a must, either in isolation can be misleading.

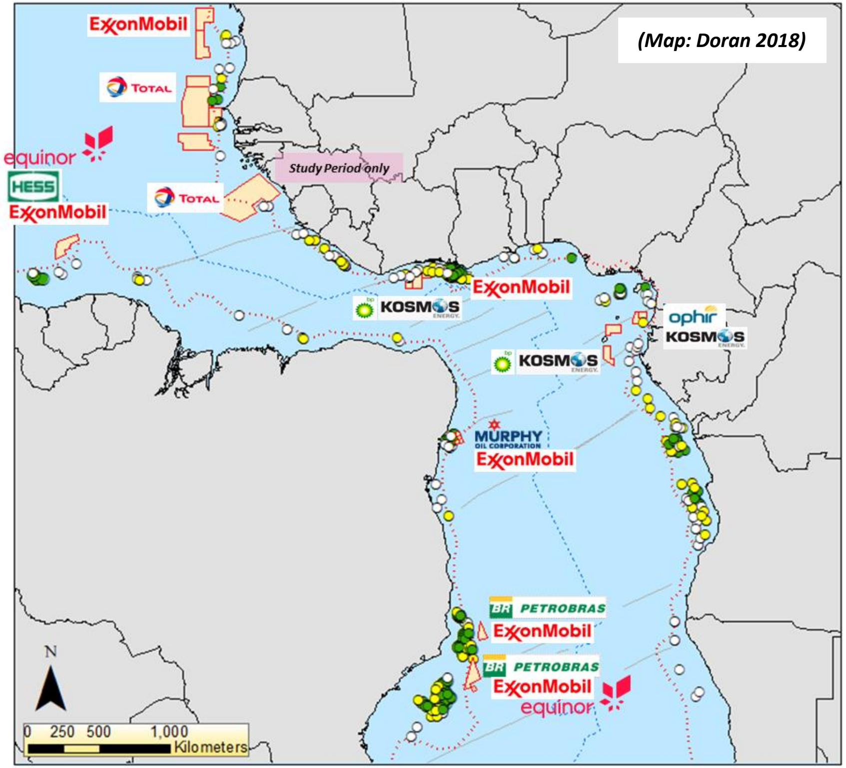
- Explore the uncertainties and their impacts

- Plea to collaborate to supply your ‘magic numbers’

Table from Doran, May 2018, AAPG Lisbon



Distal Domain		Proximal Domain
Increasing but can be very variable across a few kms: SDRs, sills/dykes and volcanoes. Do transform faults control the changes in spatial distribution?	Volume of Magma	Low, but not absent
Younger, up to 20mya younger as in the cases of the South Atlantic	Break up of crust	Older
Observations made relating to shallow water (lava deltas in North Gabon pin bathymetry to as little as ~200m)	Breakup of both crust and mantle	Deepwater, drowning of carbonate platform
After breakup of crust and mantle. Does not appear to be as developed as in the proximal domain.	Age of associated thermal Sag	Most likely to occur before breakup of crust and mantle
Source rocks associated with volcanism, a reoccurring theme. Do Srs exist in the outer parts of our margins that are not present in the proximal domains?	Source Rock Prediction	Classic Approach: Rift, Sag and Drift source facies
Can cause pervasive cementation in clastics, but can create porosity in carbonates. (CO_2 risk)/ Is this the greatest play risk in the outer parts of our margins?	Reservoir and Fluid Quality (Hydrothermal Fluids)	Not a play concern
Dominated by the shallow asthenosphere. Is lithosphere composition important or is the thickness more critical?	Paleo Heatflow	Dominated by radiogenic elements in the continental crust. Highest at time of rift, equilibrates post thermal sag, some impact of distal magmatism
Can remain high in the vicinity of prolonged magmatism, mantle plumes, intraplate volcanism etc. .	Present Day Heatflow	



Despite the many uncertainties optimism exists in the industry.

Map of acreage capture during 2017 & 2018 in the South Atlantic. Created October 2018.