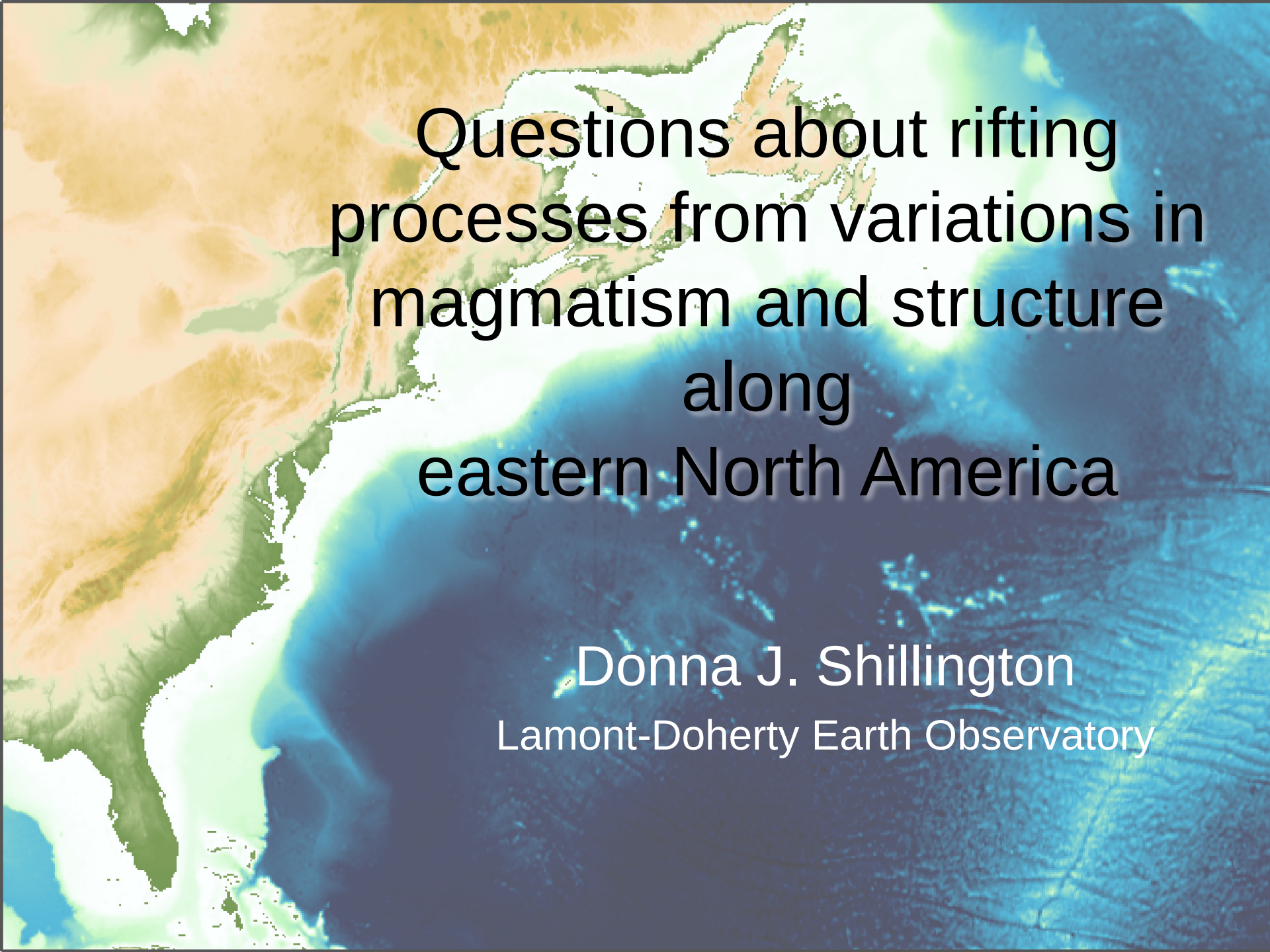
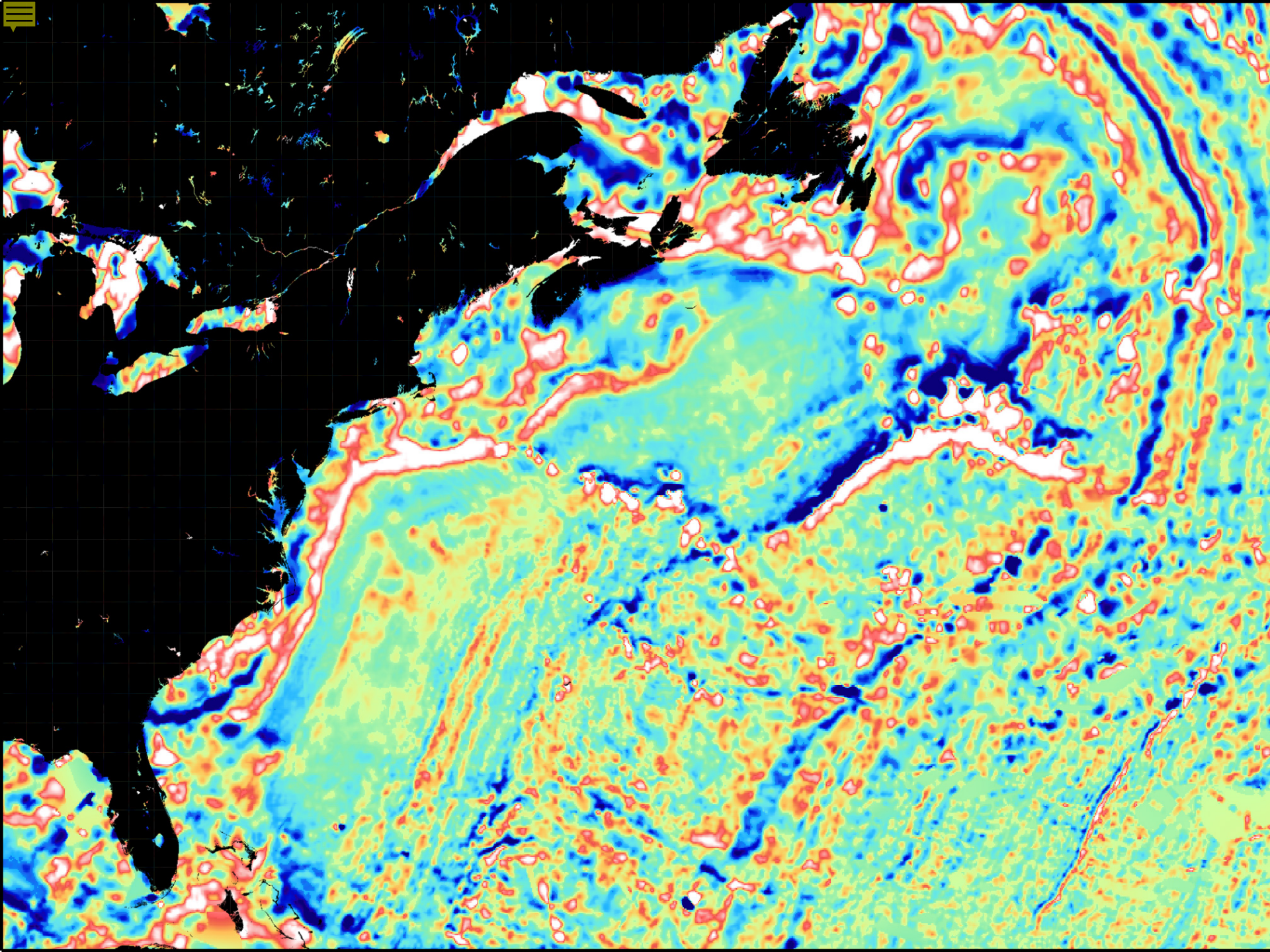


Questions about rifting processes from variations in magmatism and structure along eastern North America

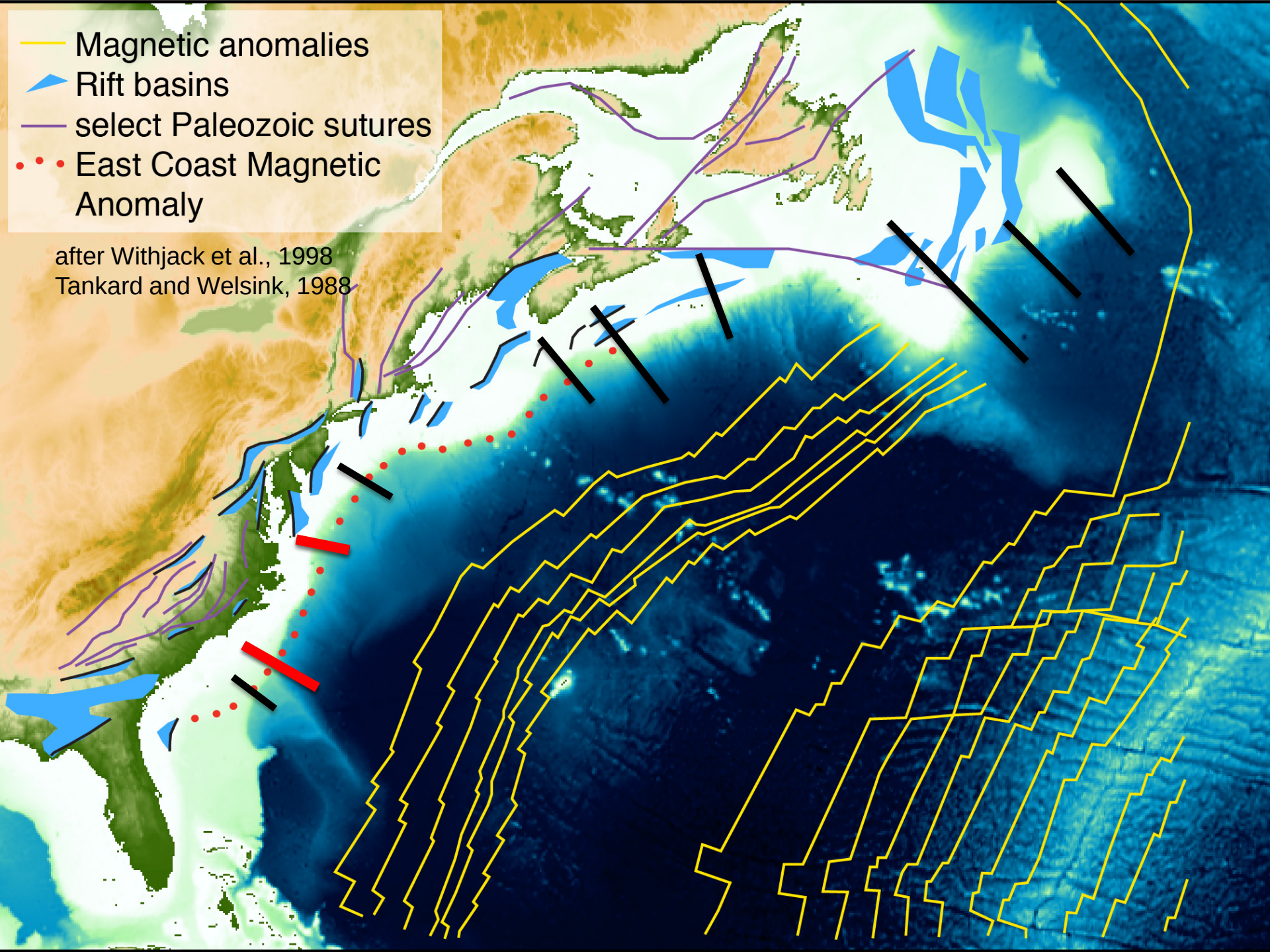
Donna J. Shillington

Lamont-Doherty Earth Observatory



Some key questions about continental extension and rupture

- What is the relationship between the style of rifting and the volume and timing of magmatism?
- What is the nature of the transition between magma-rich and magma-poor rifting?
- How do magmatism and deformation vary within and between segments?
- When does mature seafloor spreading


Magnetic anomalies
Rift basins
select Paleozoic sutures
East Coast Magnetic Anomaly
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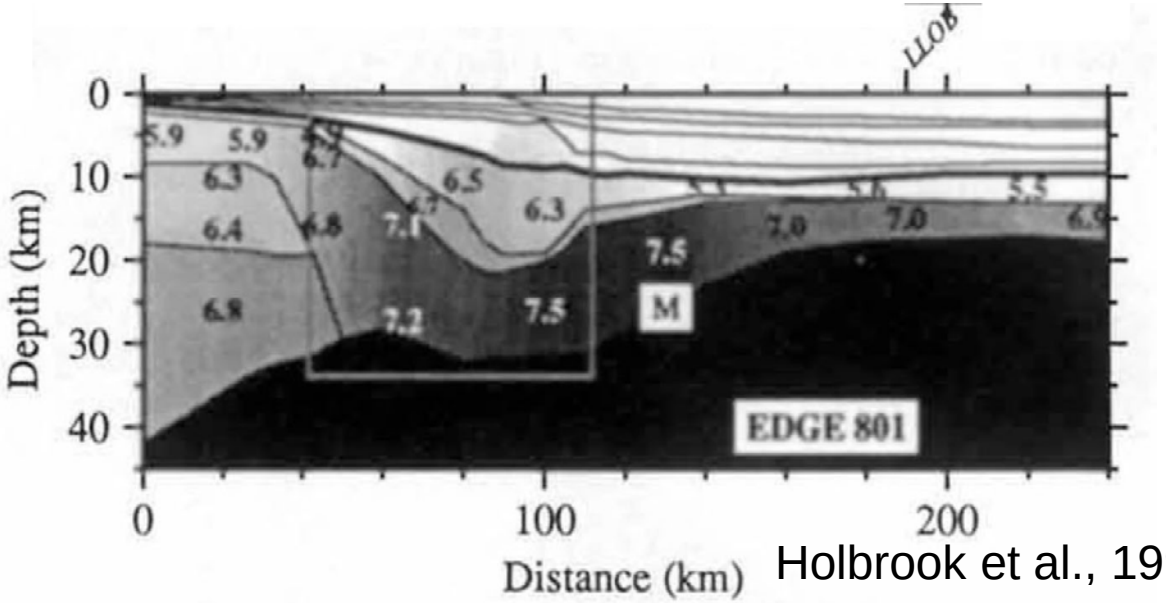
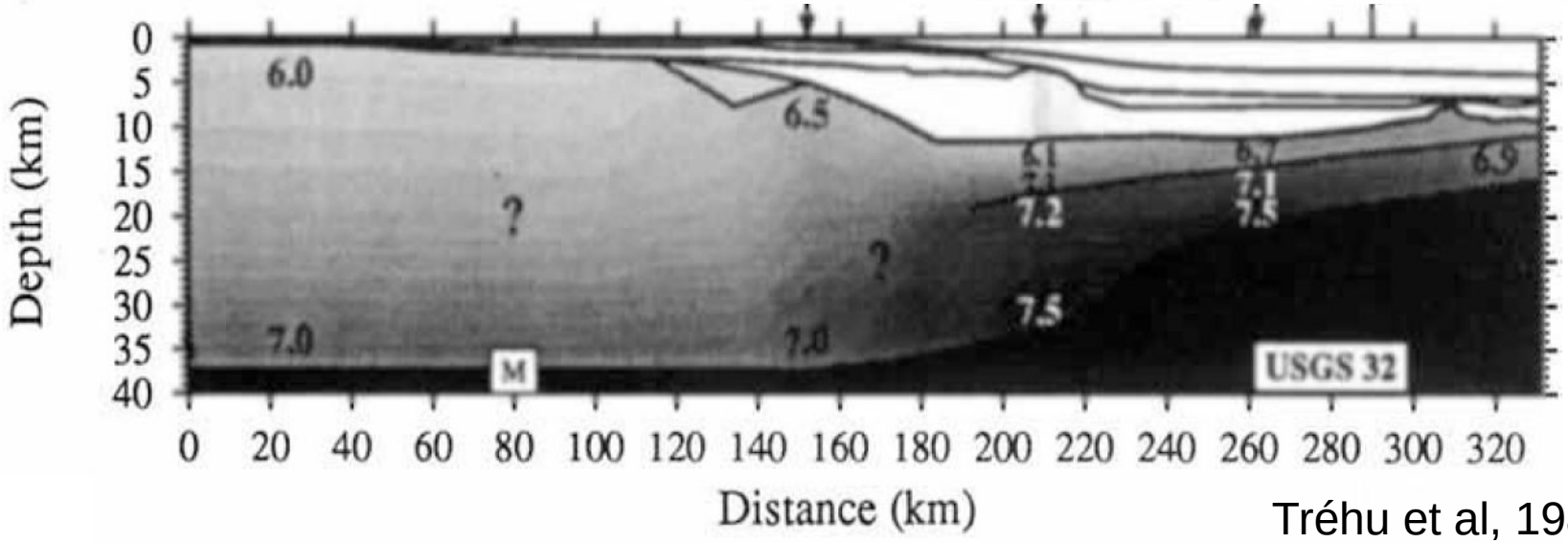
Off the eastern US: magma is abundant...

The crust thins relatively abruptly, and the outer part of the margin primarily comprises new magmatic material.



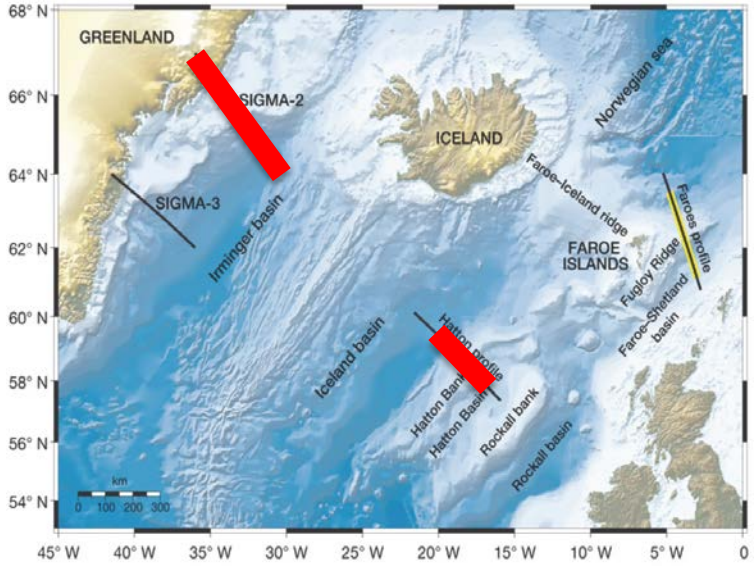
Holbrook et al., 1994



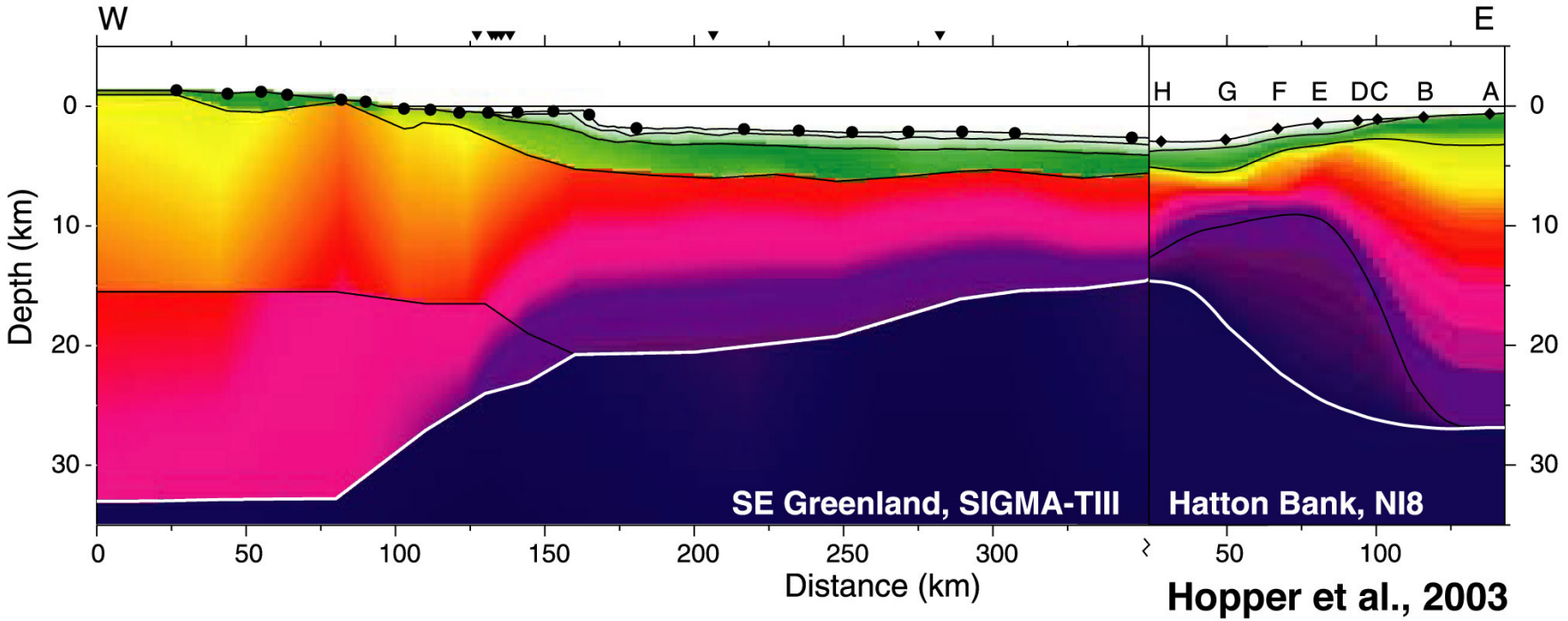
Tréhu et al, 1989

High-velocity bodies at magmatic margins interpreted as mafic synrift underplates…

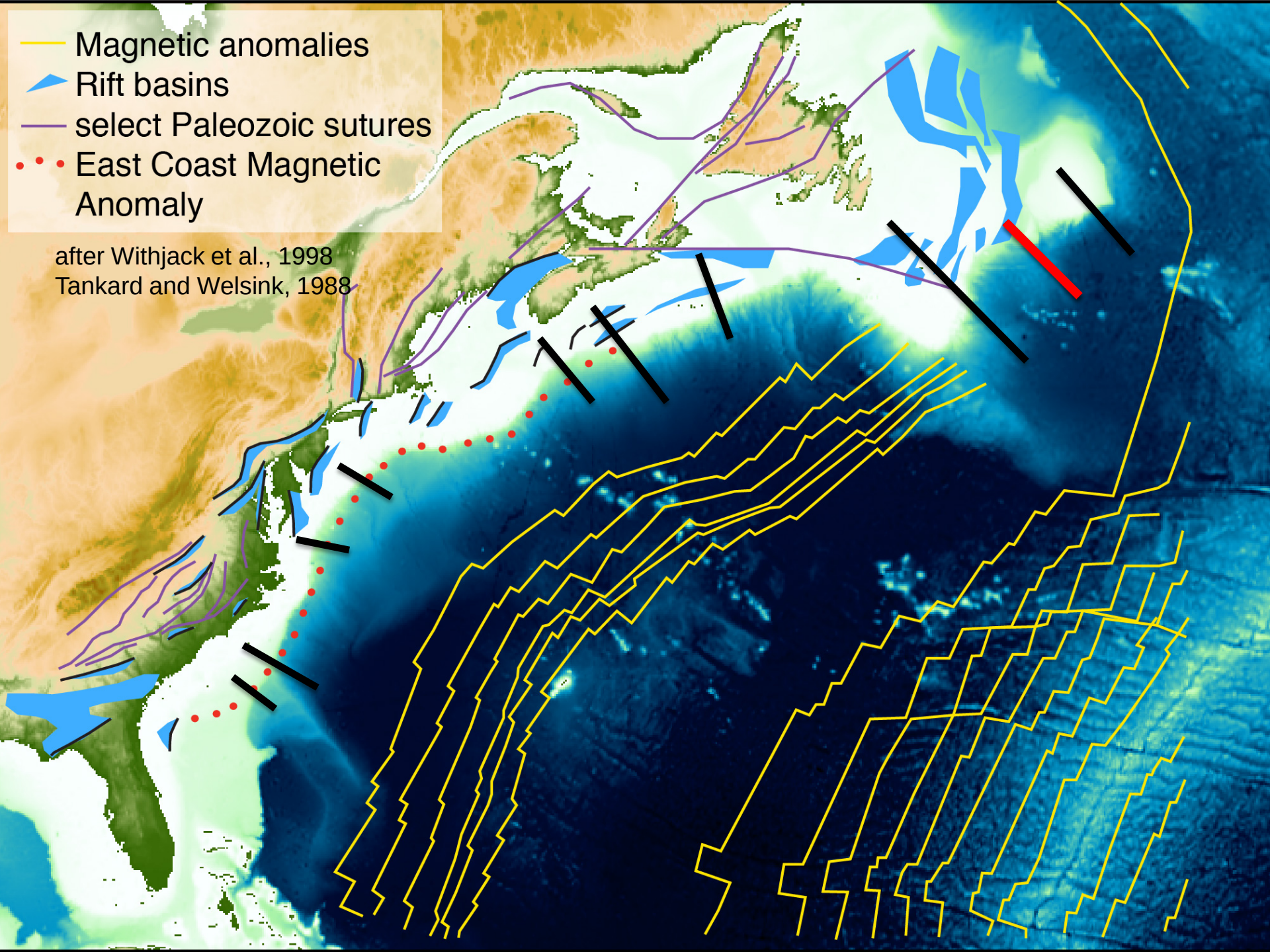
…although debate continues about volumes of new magma versus pre-existing crust



White et al., 2008



Hopper et al., 2003


Magnetic anomalies
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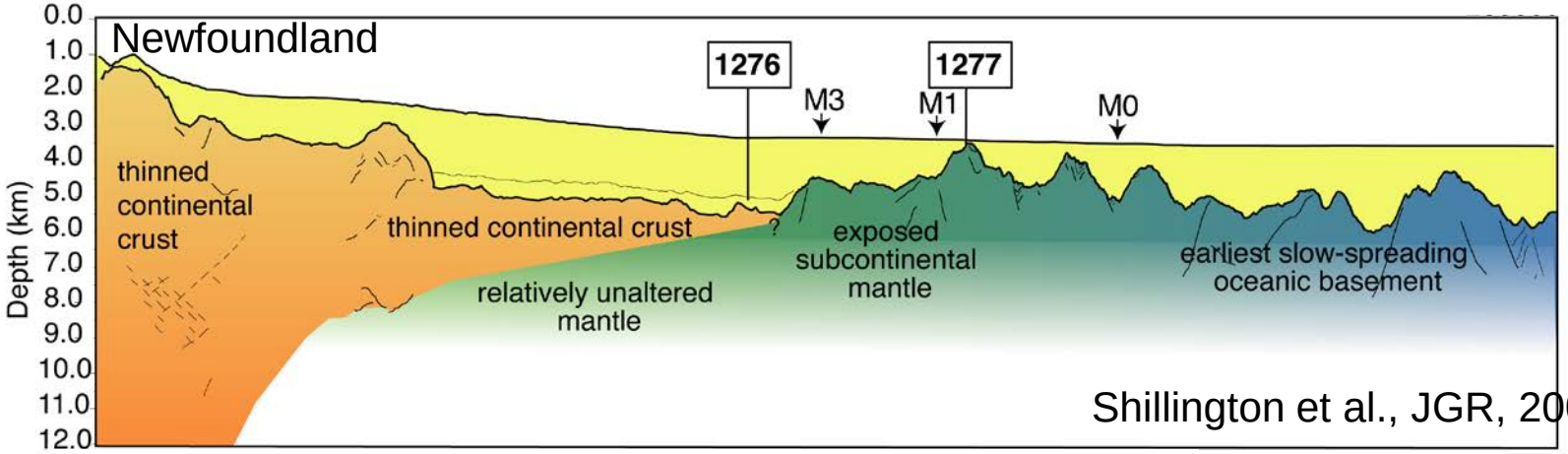
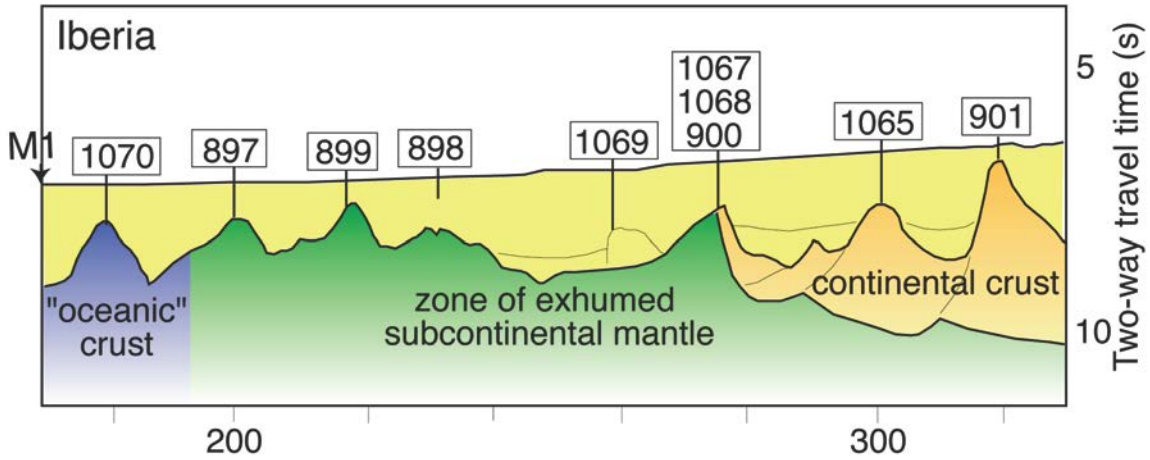
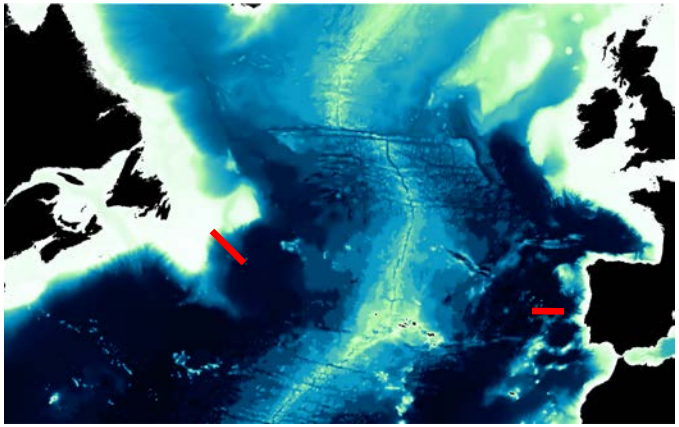
Off Newfoundland: magma is scarce…



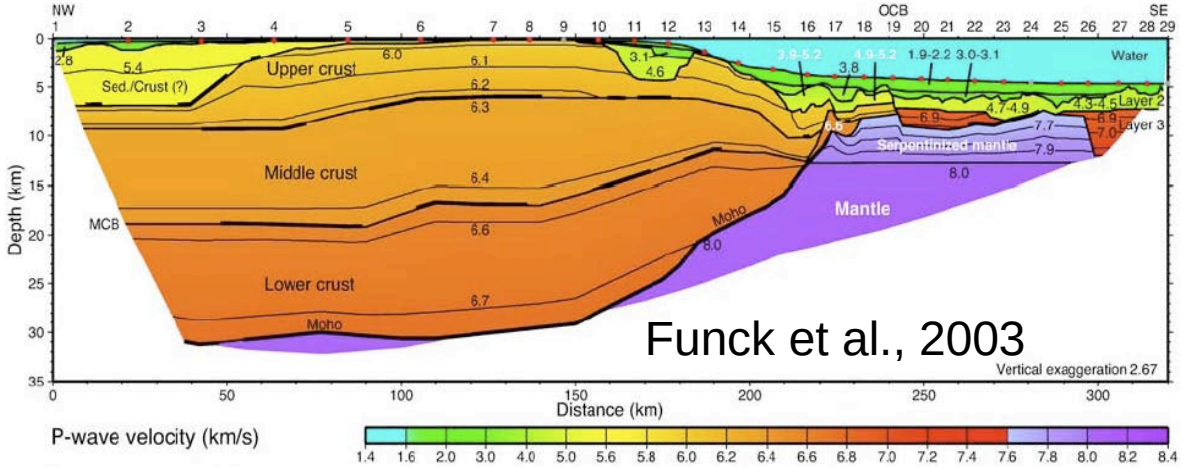
Shillington et al., JGR, 2006



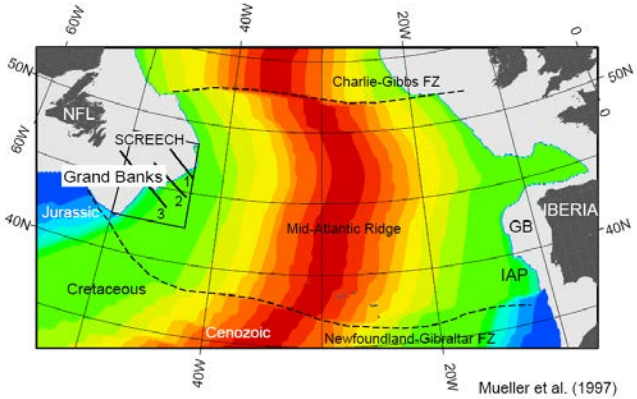


Krawcyzk et al., Proc. ODP Sci. Results,1996

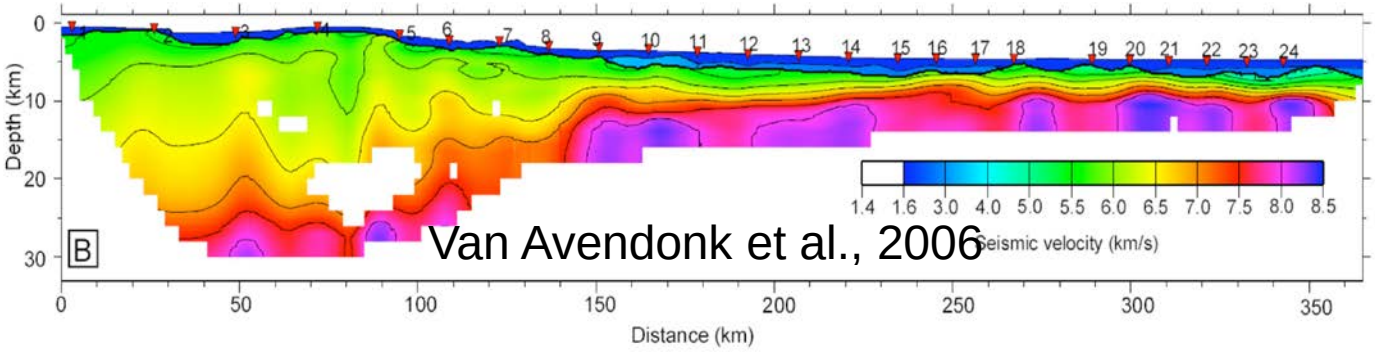
The outer parts of the margin comprise wide regions of highly thinned crust and exposed, serpentinized subcontinental mantle.



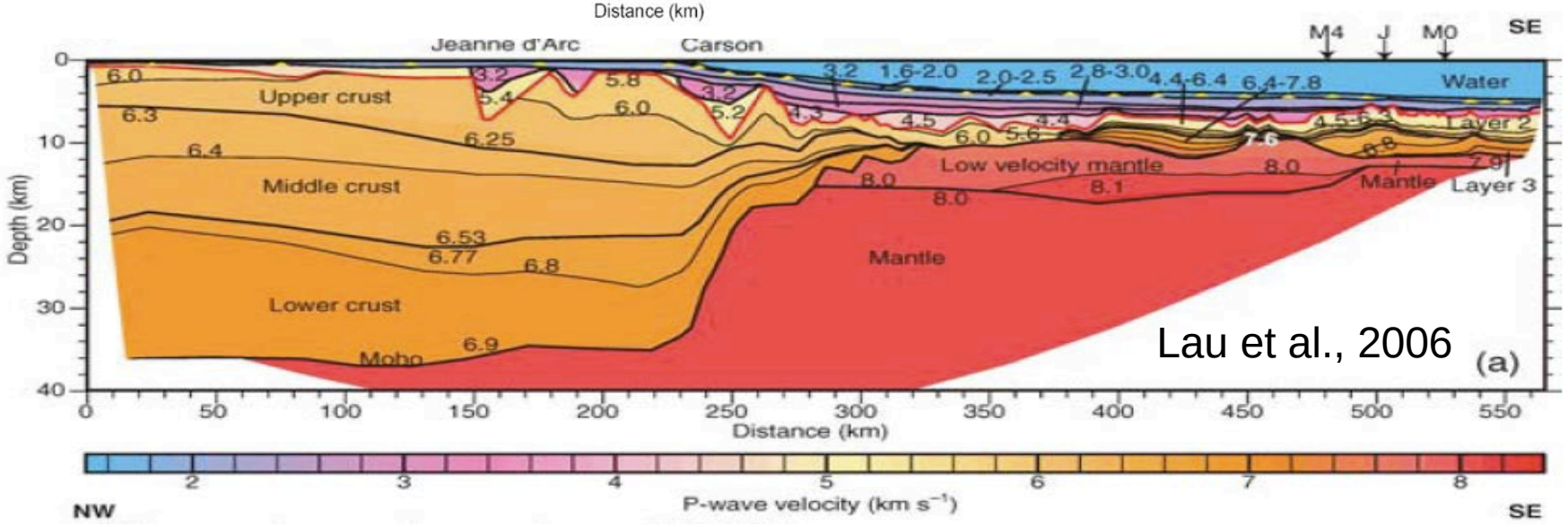
Funck et al., 2003



Mueller et al. (1997)

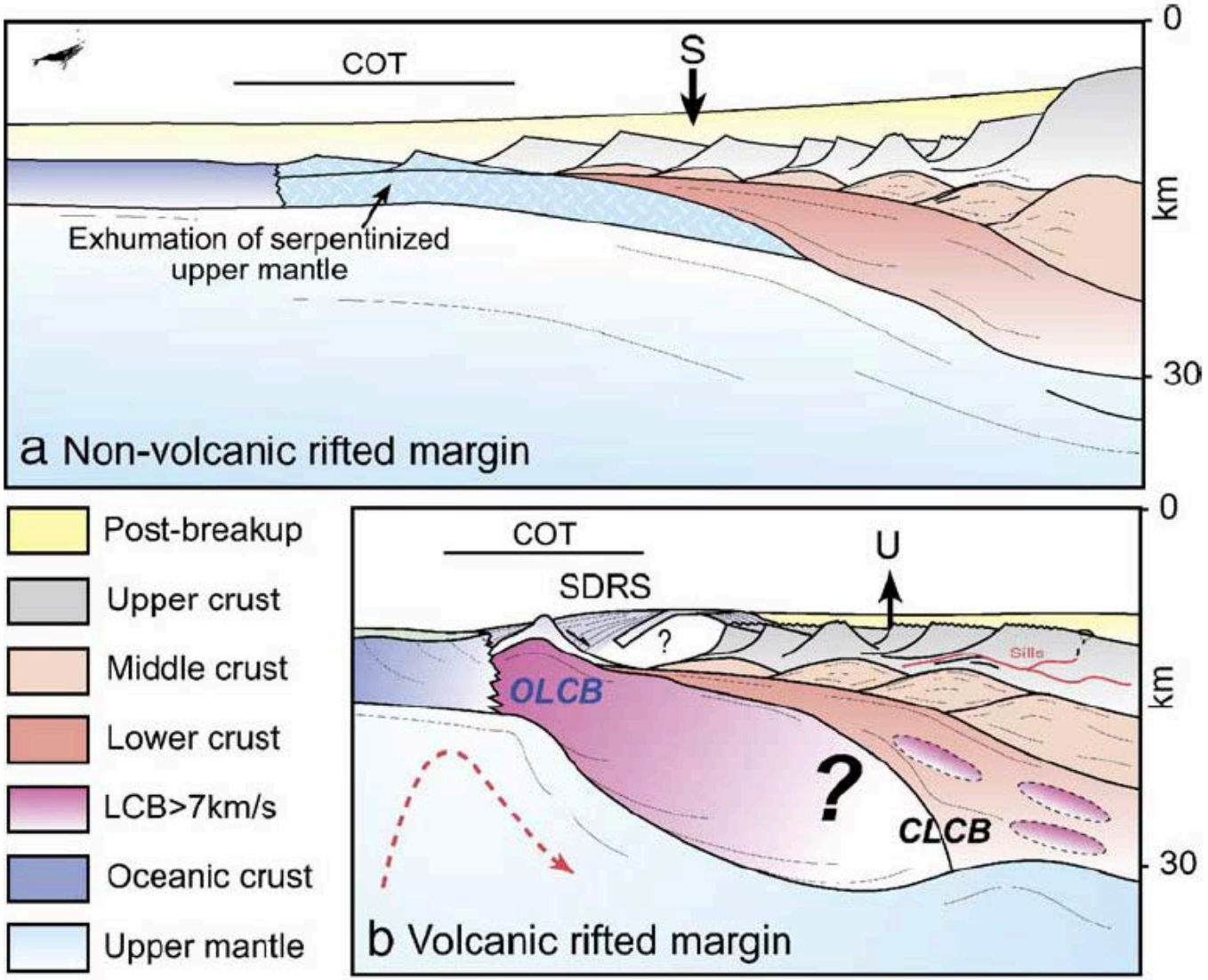


Van Avendonk et al., 2006



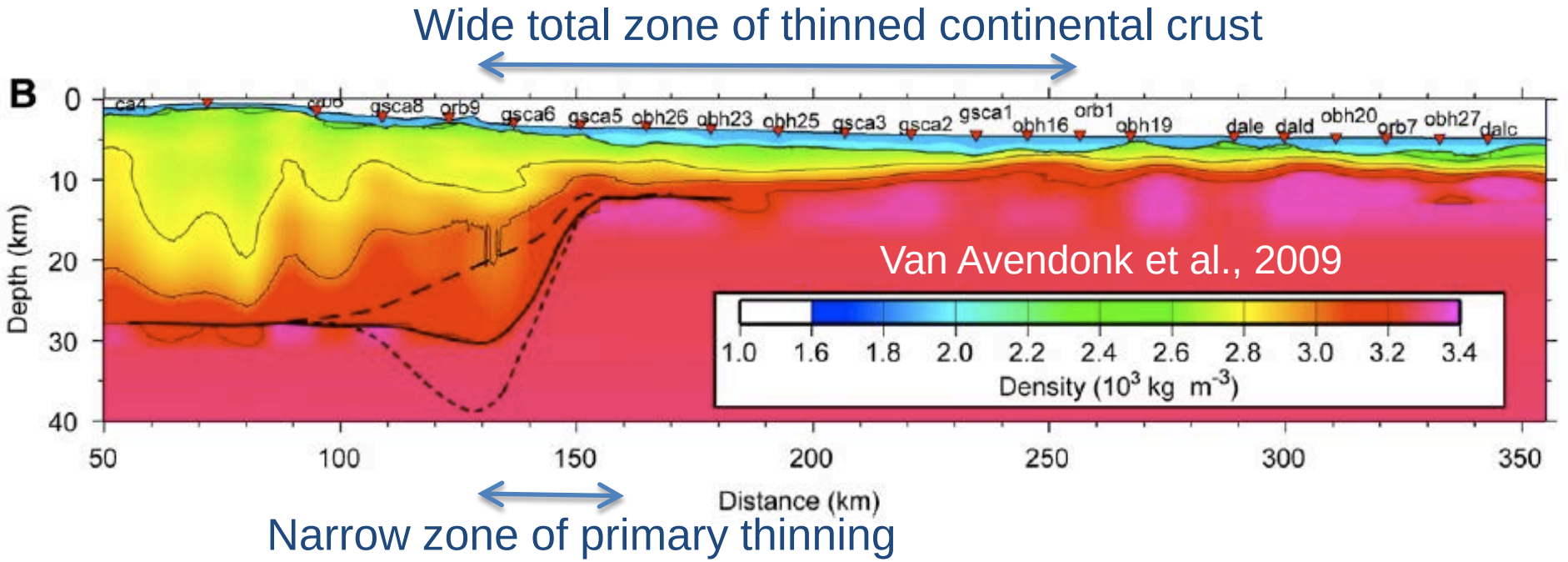
Lau et al., 2006 (a)

“Wide” versus “narrow” rifting?

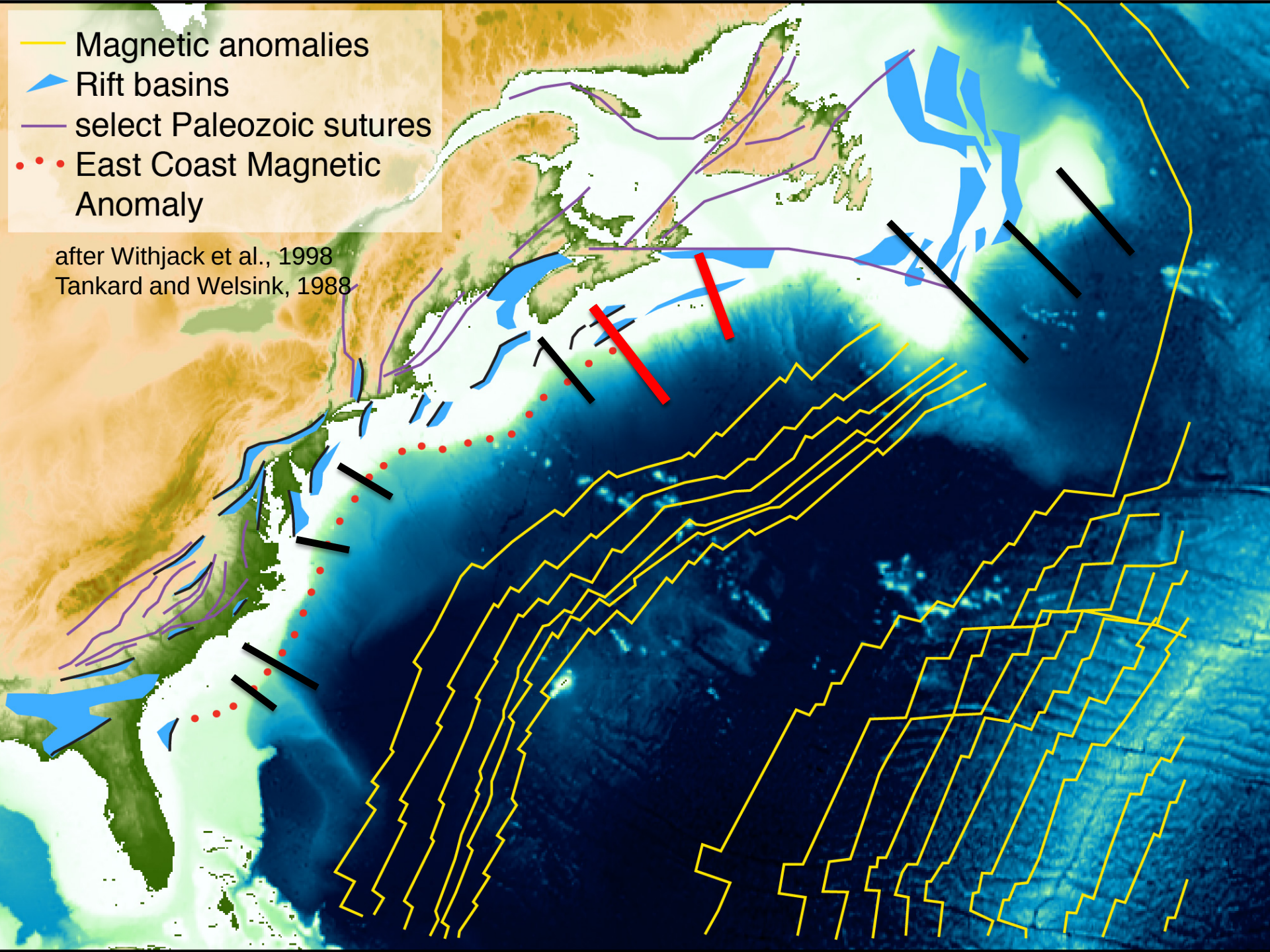


Gernigon et al, 2006

“Wide” versus “narrow” rifting?



- Common observation: magma-poor rifts are wider than magma-rich rifts
- Many magma-poor and magma-rich margins defy simple characterization as ‘wide’ or ‘narrow’
- Areas of the ENAM with comparable volumes of magmatism have variable thinning profiles and modes of deformation


Magnetic anomalies
Rift basins
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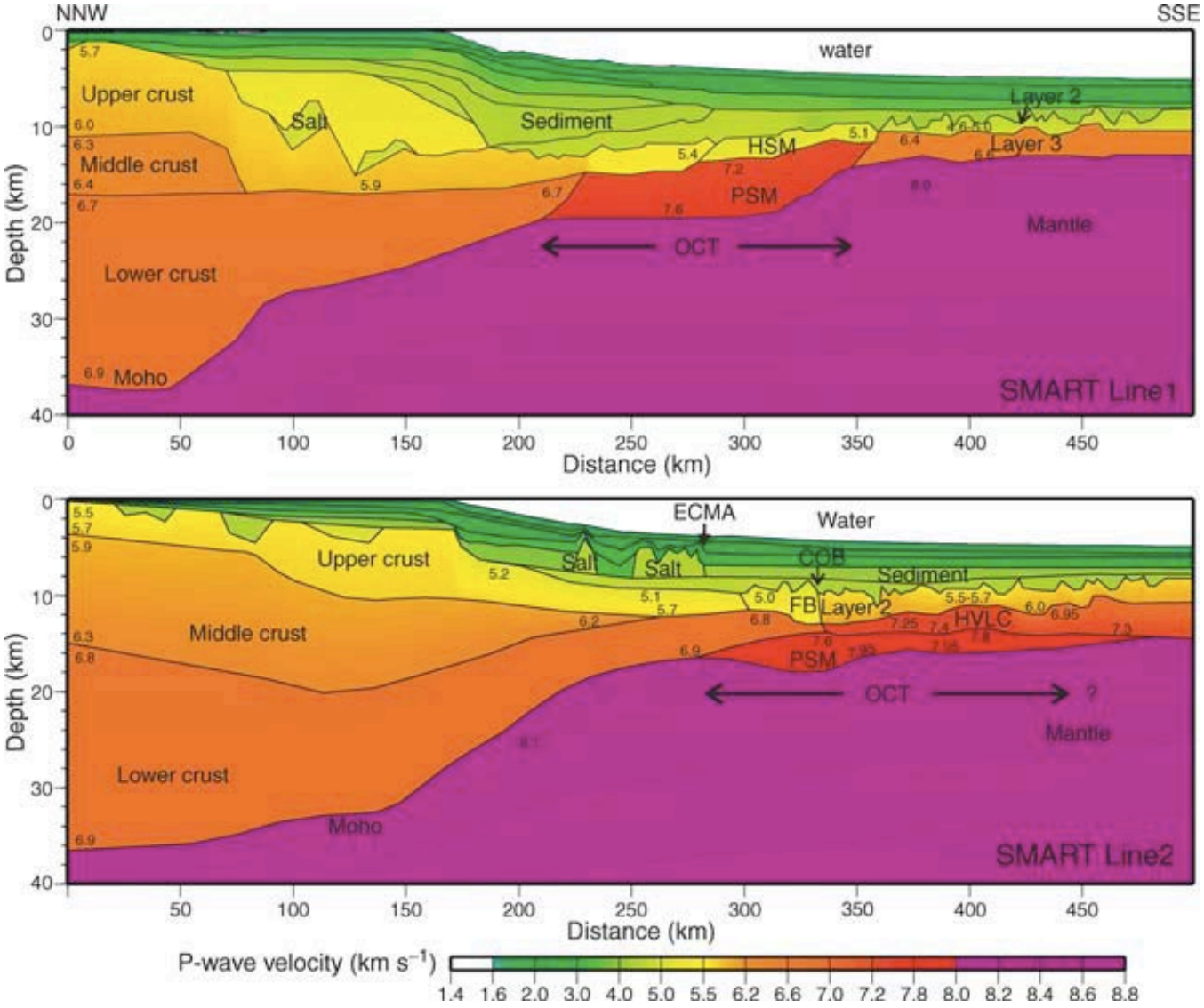
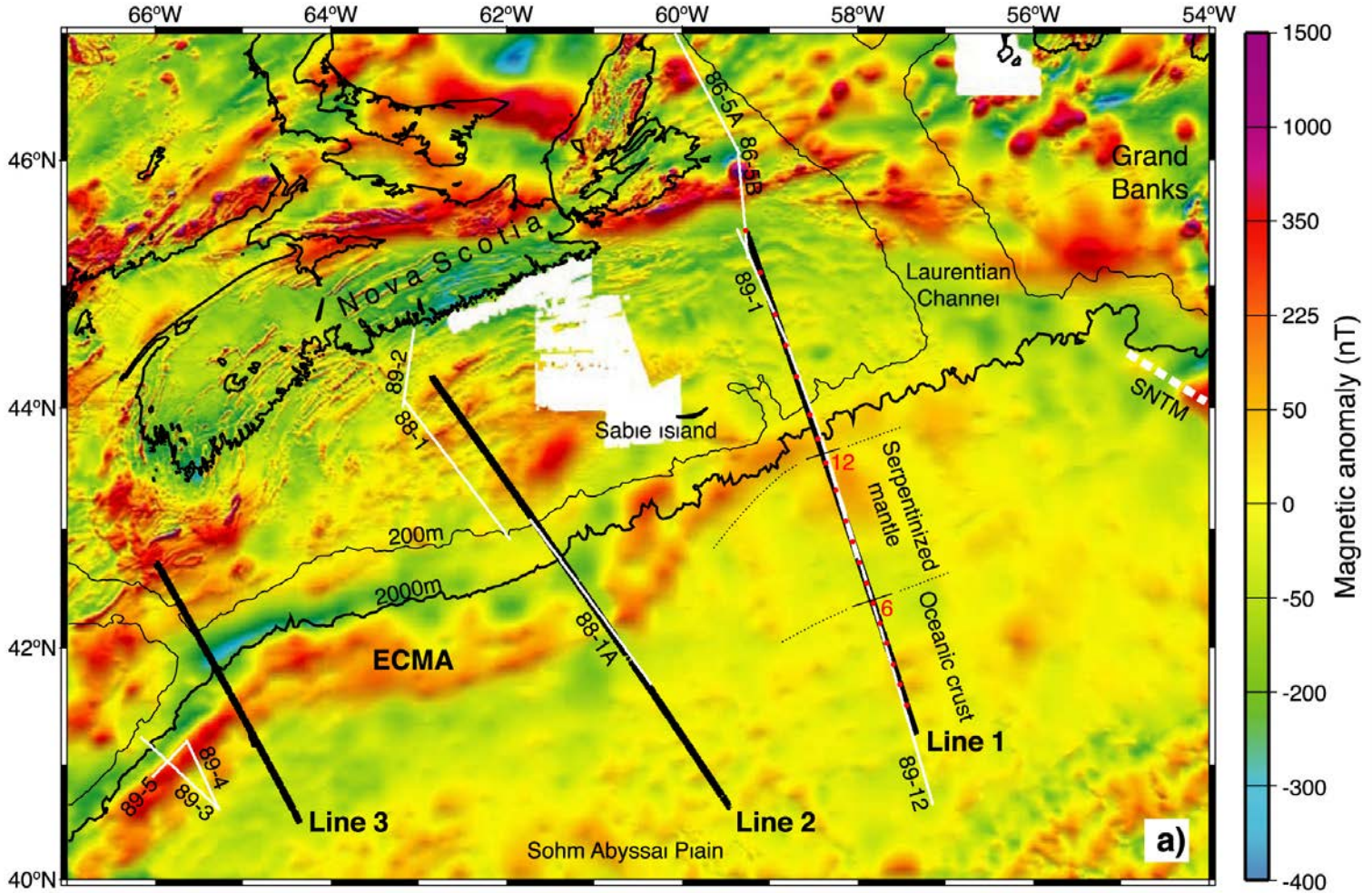
Off Nova Scotia: a transition in magmati



Wu et al., 2006

Off Nova Scotia: a transition in magmati

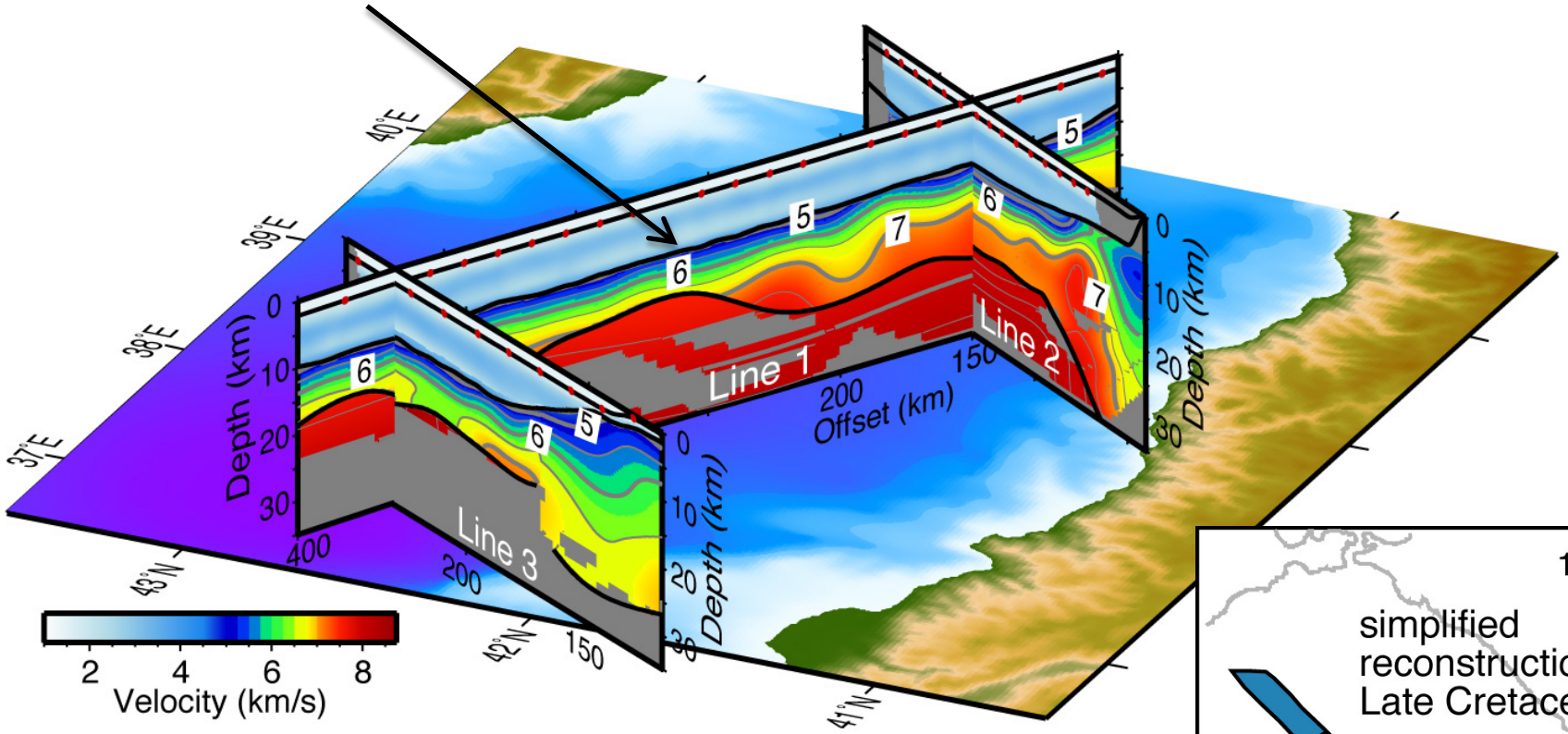


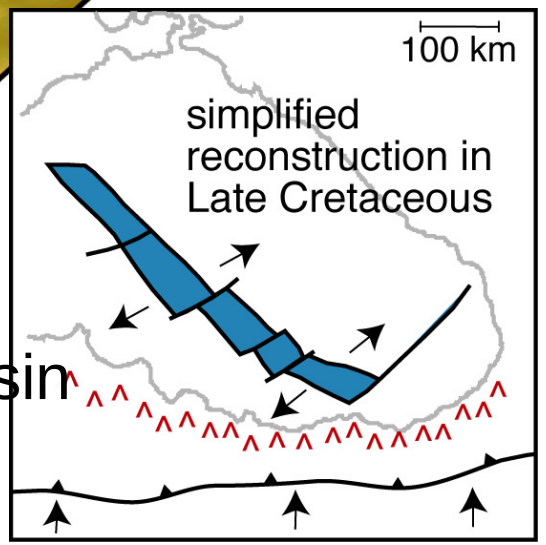
Funck et al., JGR, 2004
Keen & Potter, Tectonophys. 1988

…but the nature of this transition is not well-constrained by existing geophysical data.

Along-rift changes in magmatism can be abrupt

Sharp along-strike change in magmatism over ~20 km



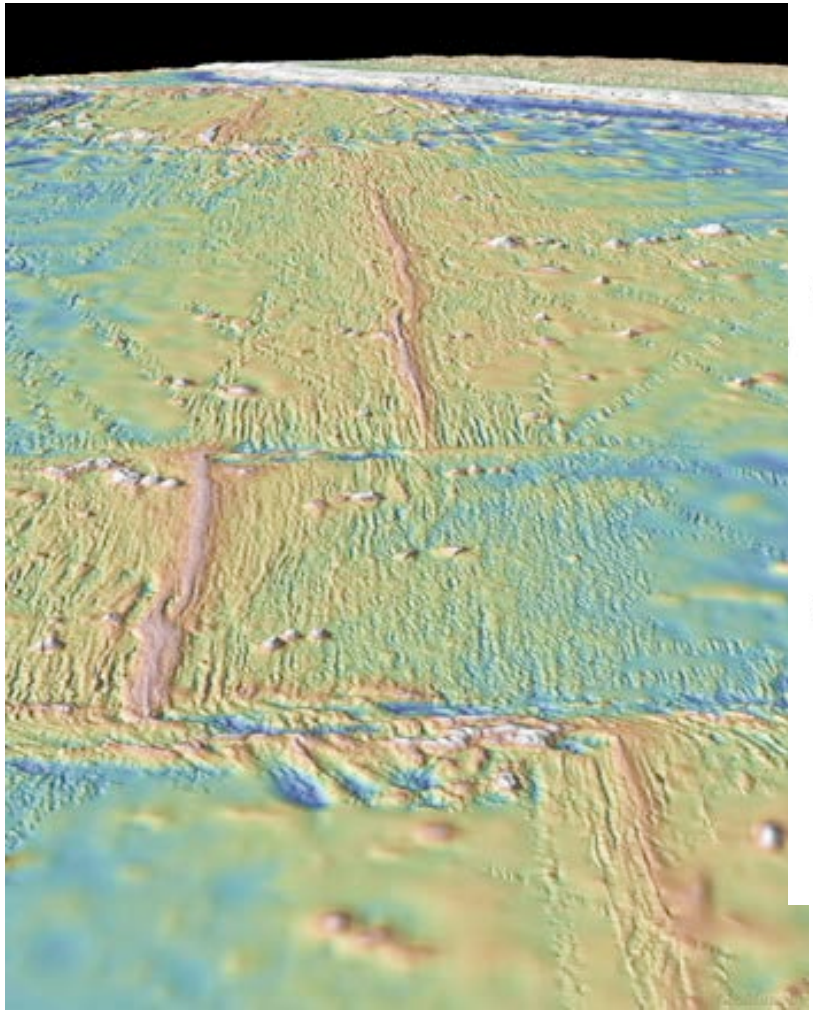


Eastern Black Sea, Cretaceous back-arc basin

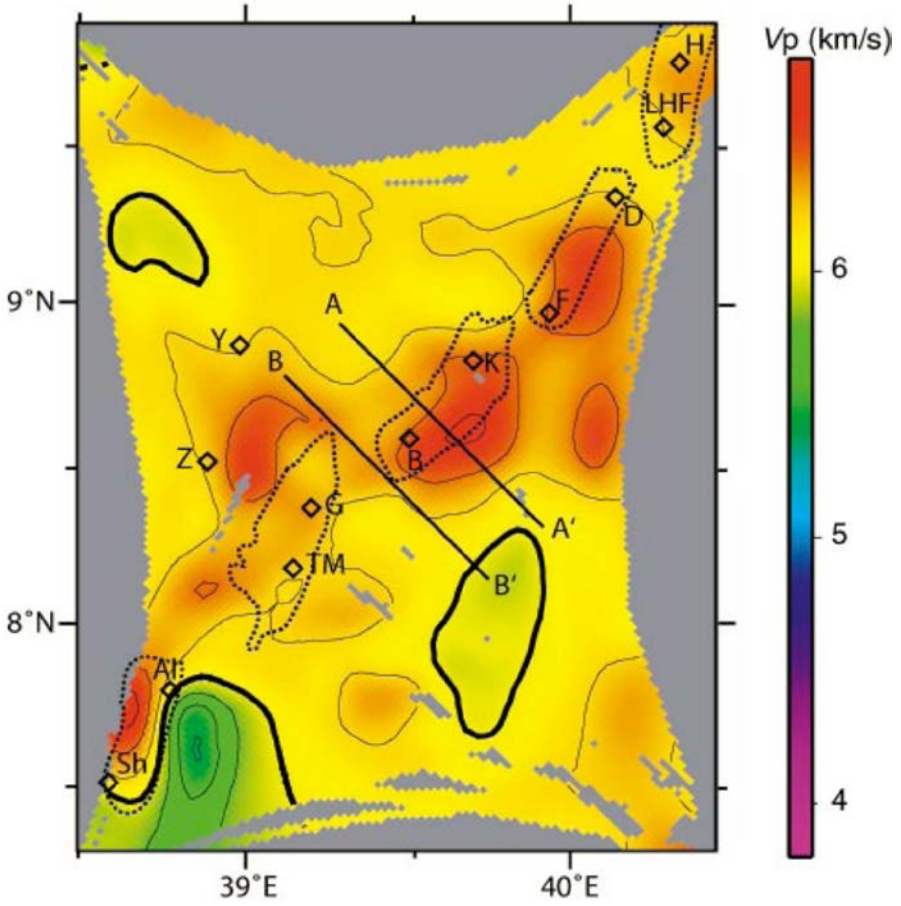
Shillington et al., *Geology,* 2009

Emergence and evolution of tectonic and magmatic segmentation

Mid-ocean ridges

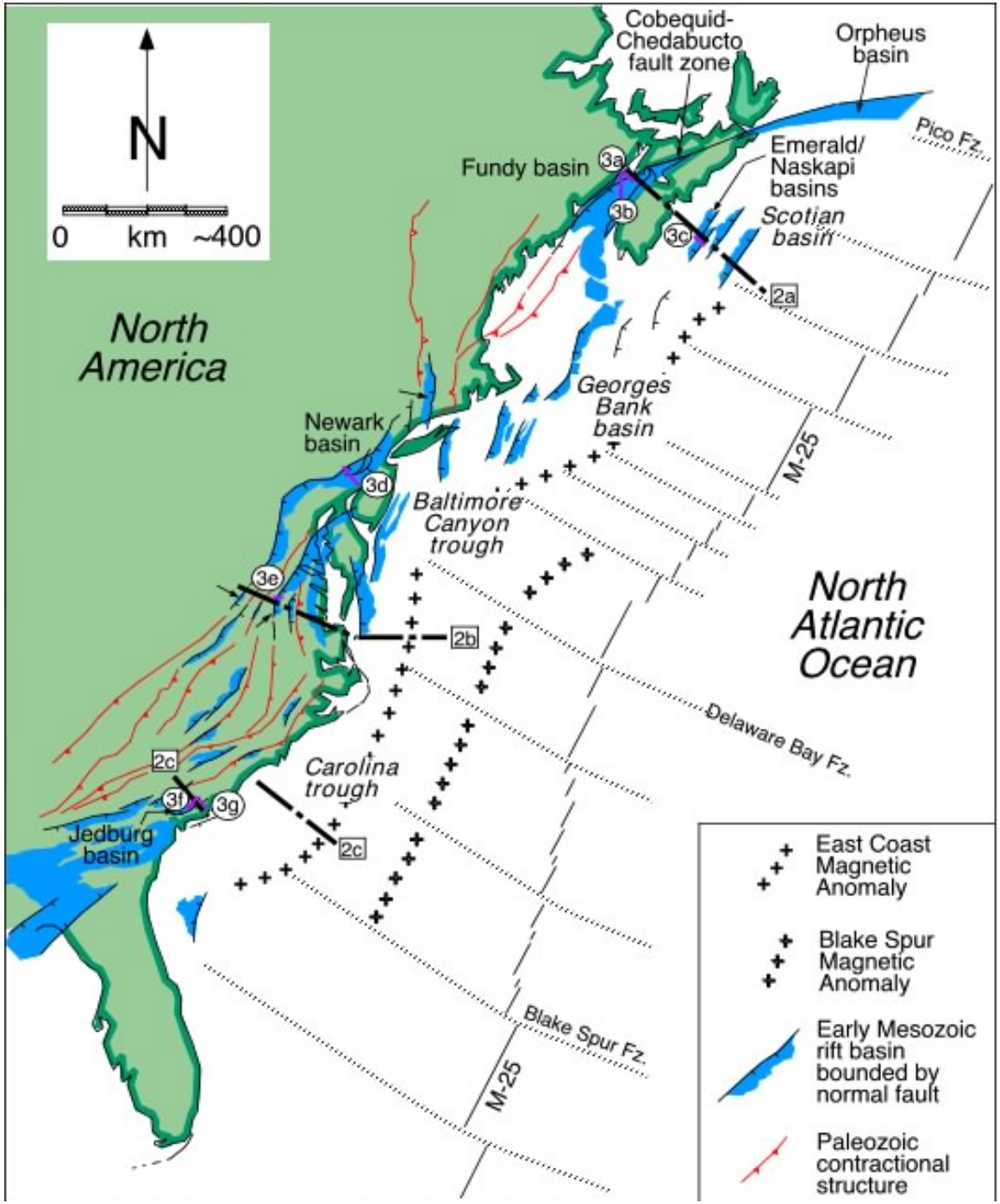


Rifts



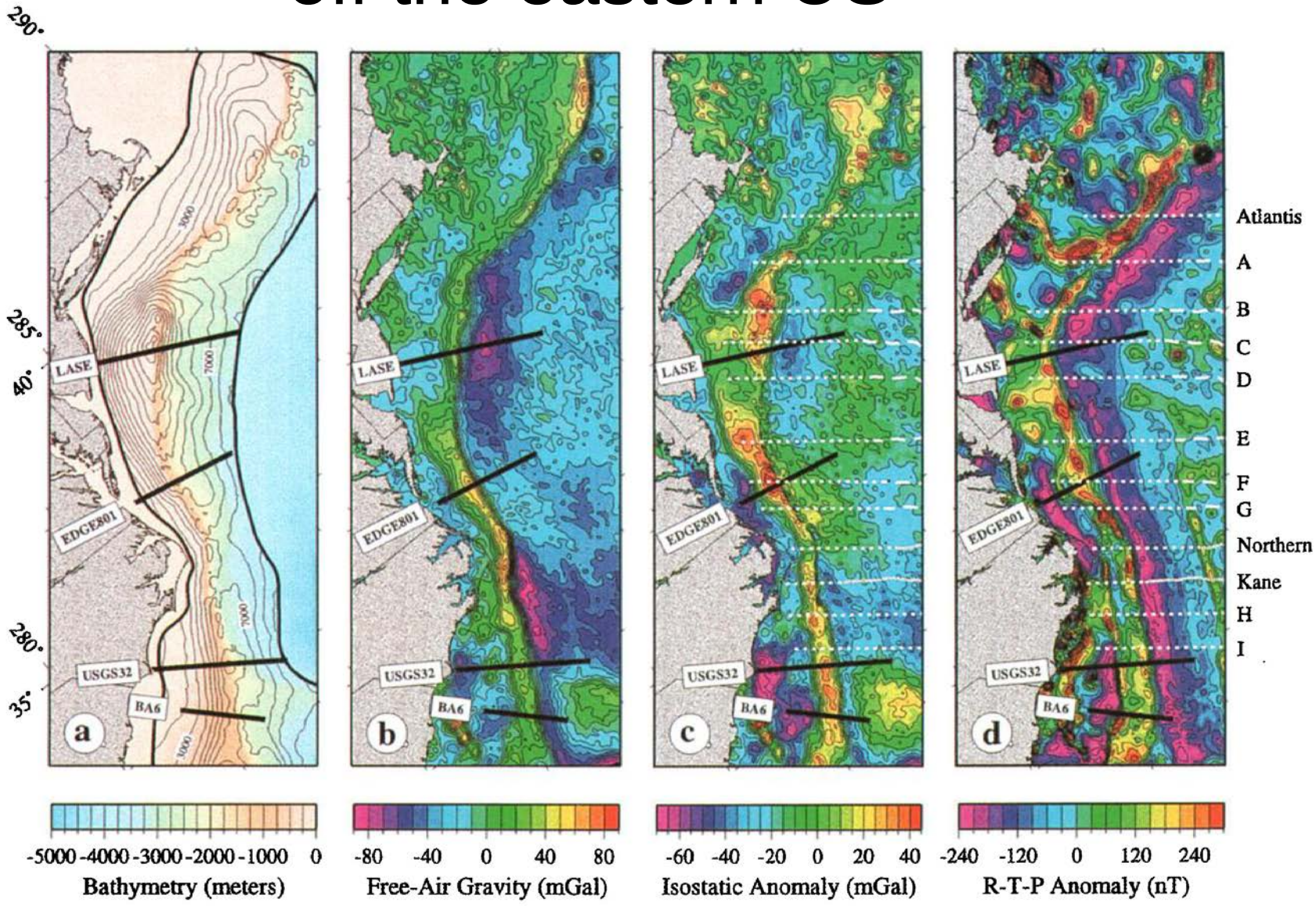
Keranen et al., 2004

How does segmentation evolve from the initiation of rifting to the formation of a mature mid-ocean ridge?



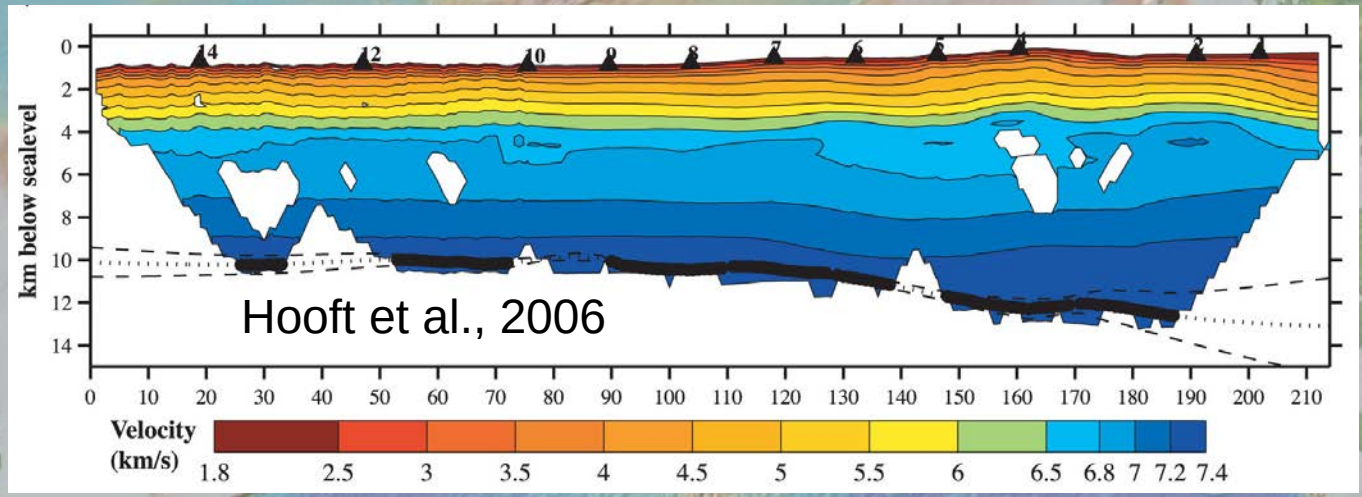
Withjack et al, 1988

Segmentation of the magmatic margin off the eastern US



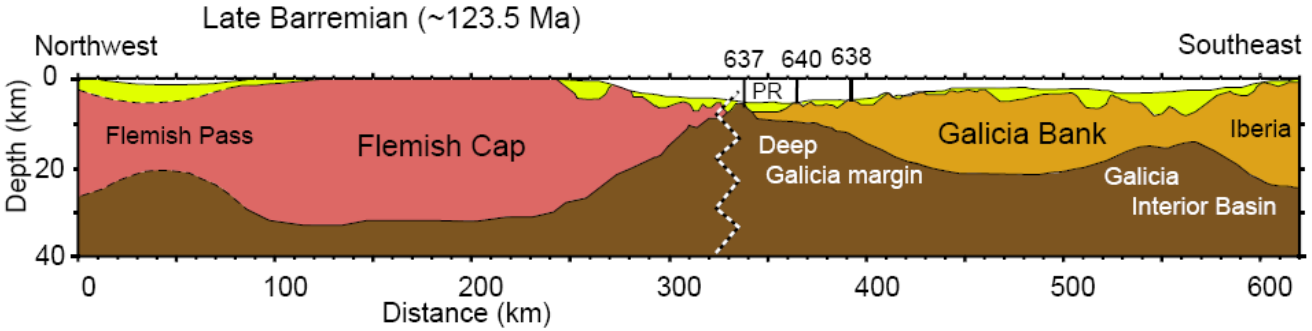
Behn and Lin, *JGR,* 2000

In other highly magmatic settings, magmatism may overwhelm melt focusing mechanisms

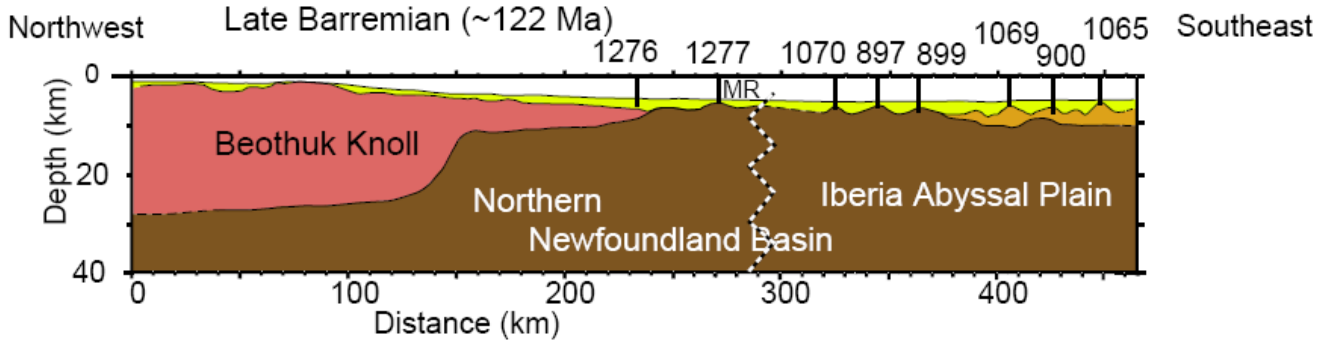


Hooft et al., 2006

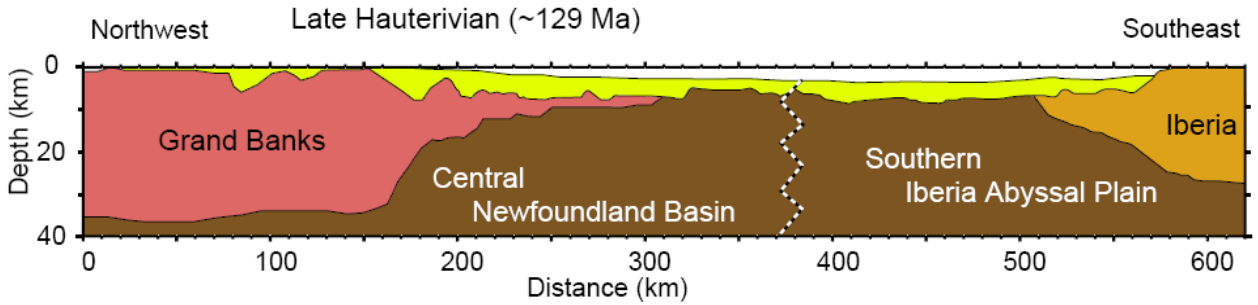
Segmentation of the magma-poor margin off Newfoundland



Keen and Barrett (1981); Funck et al. (2003); Whitmarsh et al. (1996)

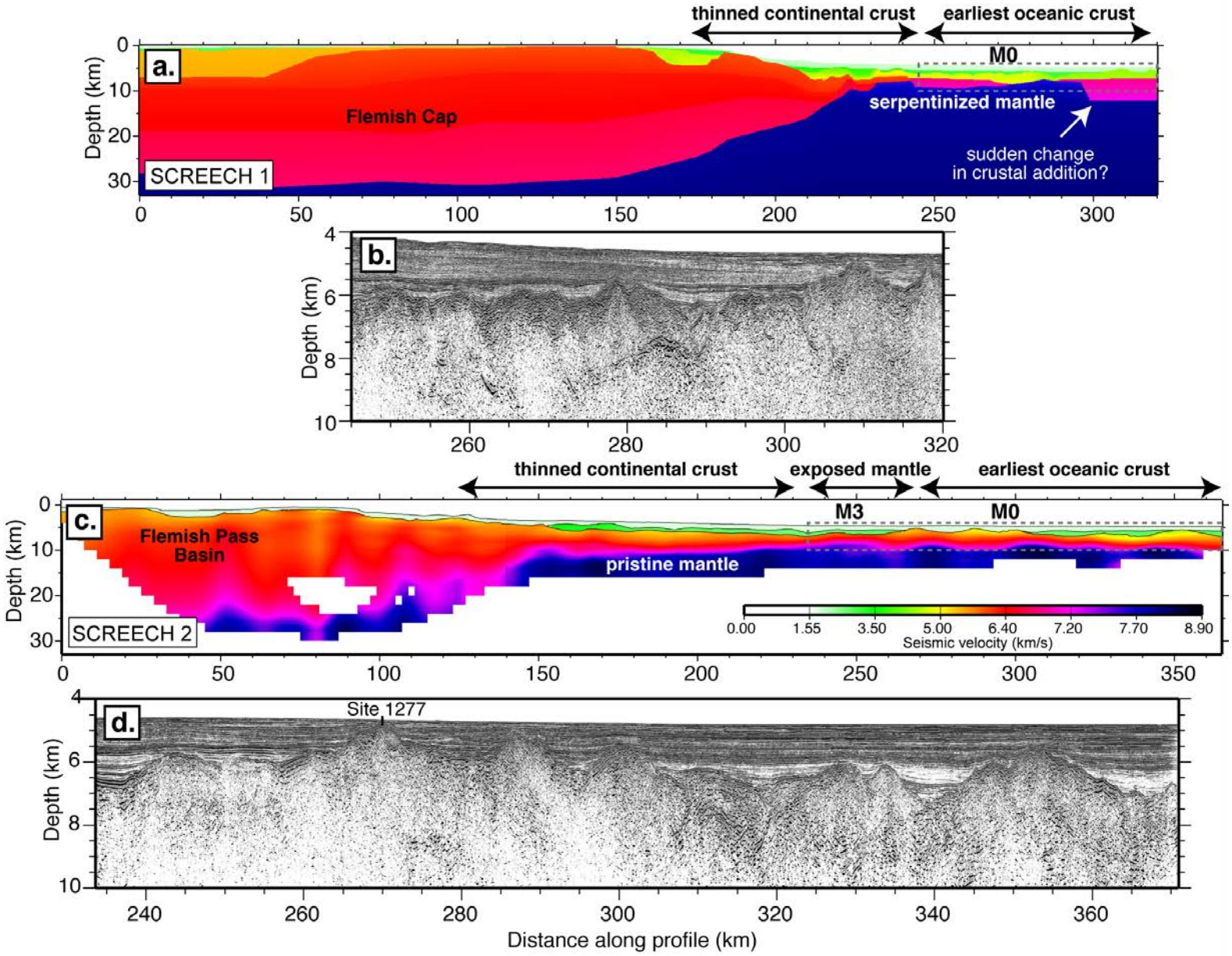


Van Avendonk et al. (2006); Chian et al. (1999)



Lau et al. (2006); Dean et al. (2000)

Van Avendonk et al., *JGR,* 2006

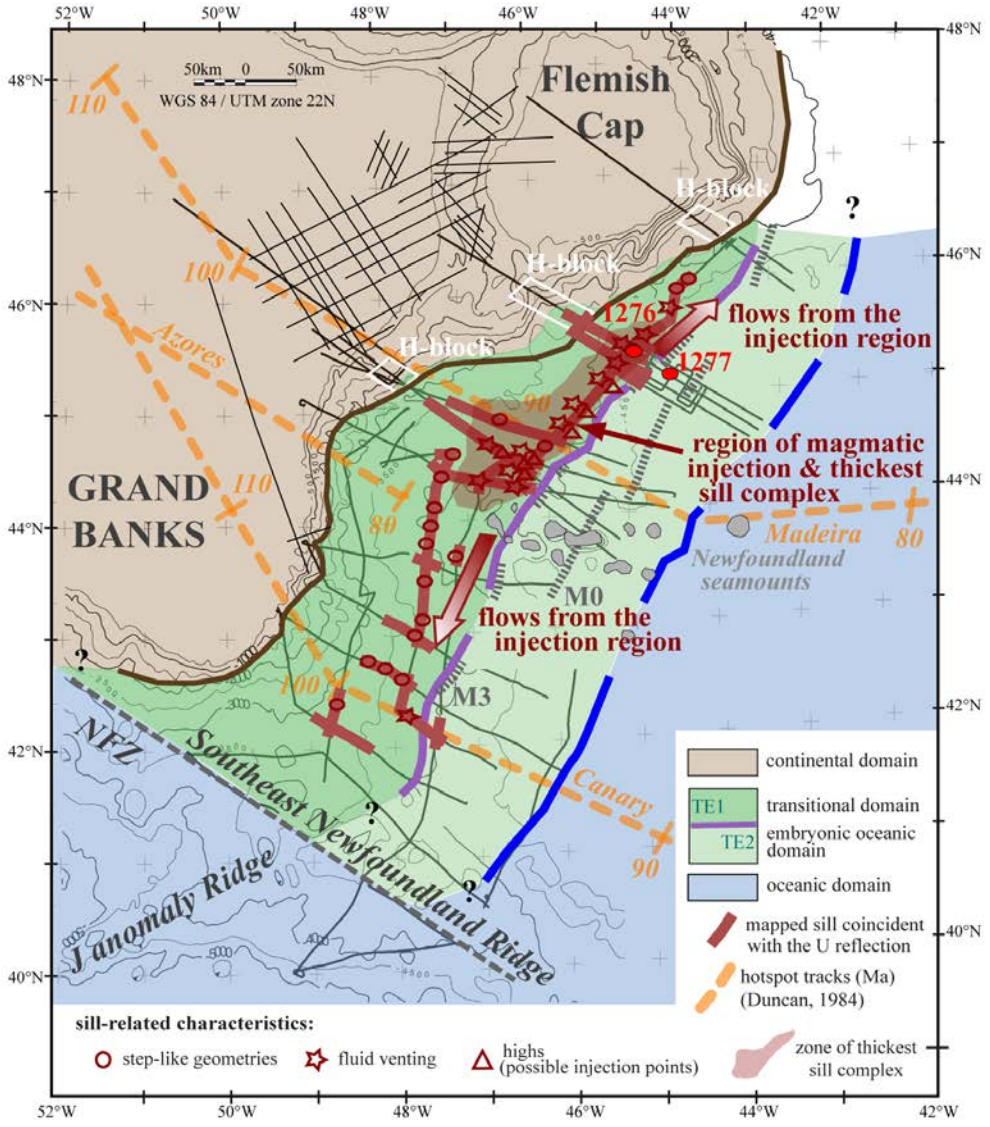

thinned continental crust
earliest oceanic crust
a.
M0
Flemish Cap
serpentinized mantle
sudden change
in crustal addition?
SCREECH 1
Depth (km)
0
10
20
30
0
50
100
150
200
250
300
b.
Depth (km)
4
6
8
10
260
280
300
320
thinned continental crust
exposed mantle
earliest oceanic crust
c.
M3
M0
Flemish Pass
Basin
pristine mantle
SCREECH 2
0.00
1.55
3.50
5.00
6.40
7.20
7.70
8.90
Seismic velocity (km/s)
0
50
100
150
200
250
300
350
d.
Site 1277
Depth (km)
4
6
8
10
240
260
280
300
320
340
360
Distance along profile (km)

Are we there yet?
When does mature seafloor spreading begin?

- The most seaward mantle and/or magmatic rocks recovered off Newfoundland and Iberia show evidence for inheritance.

- Dating of magmatic rocks shows alternating alkaline and MOR magmatism at least 10 m.y. after first magnetic anomalies (Jagoutz et al., 2007)

- Wide-spread postrift magmatism until ~105-95 Ma



Péron-Pinvidic, Shillington & Tucholke, 2010

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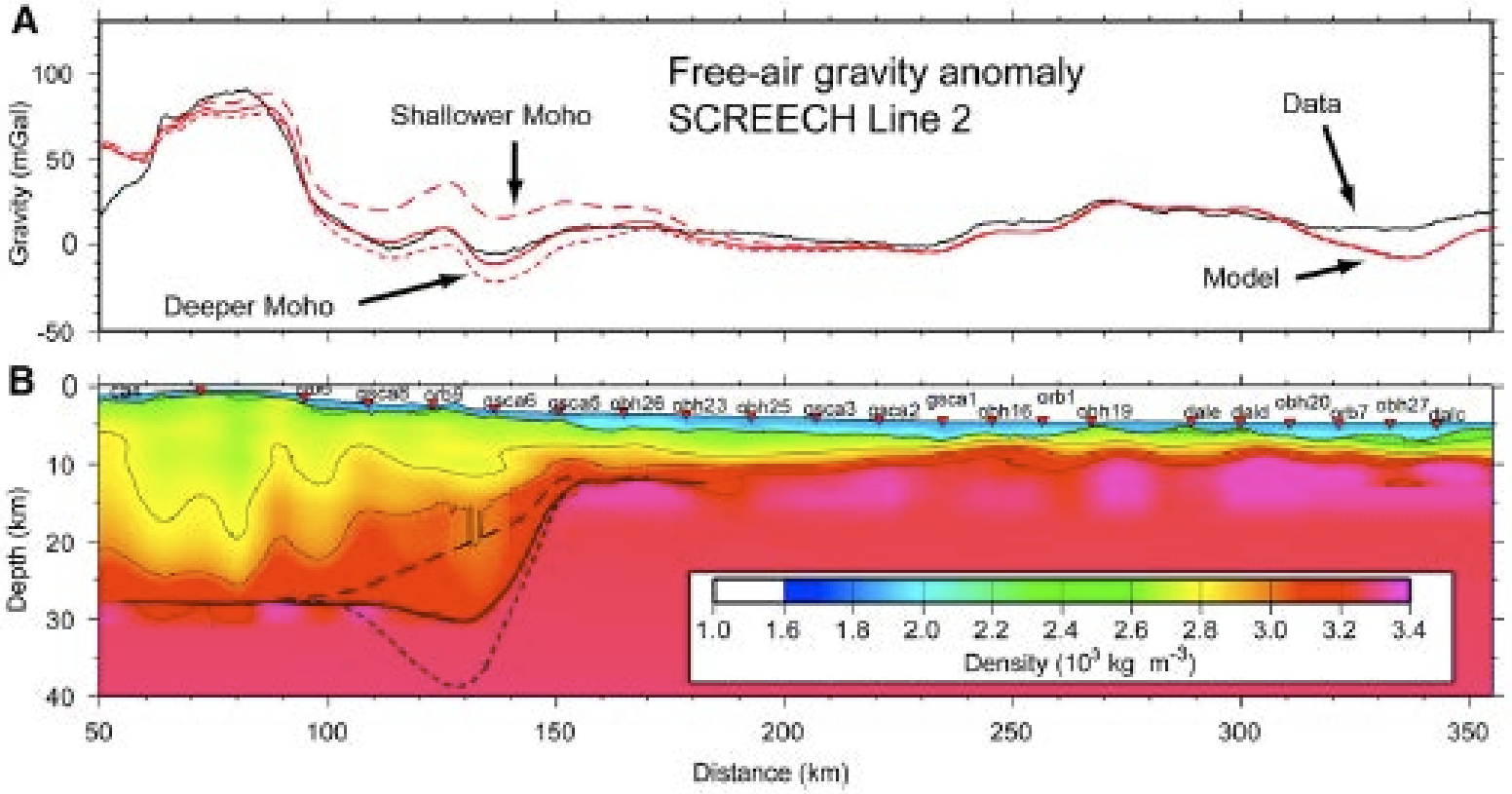
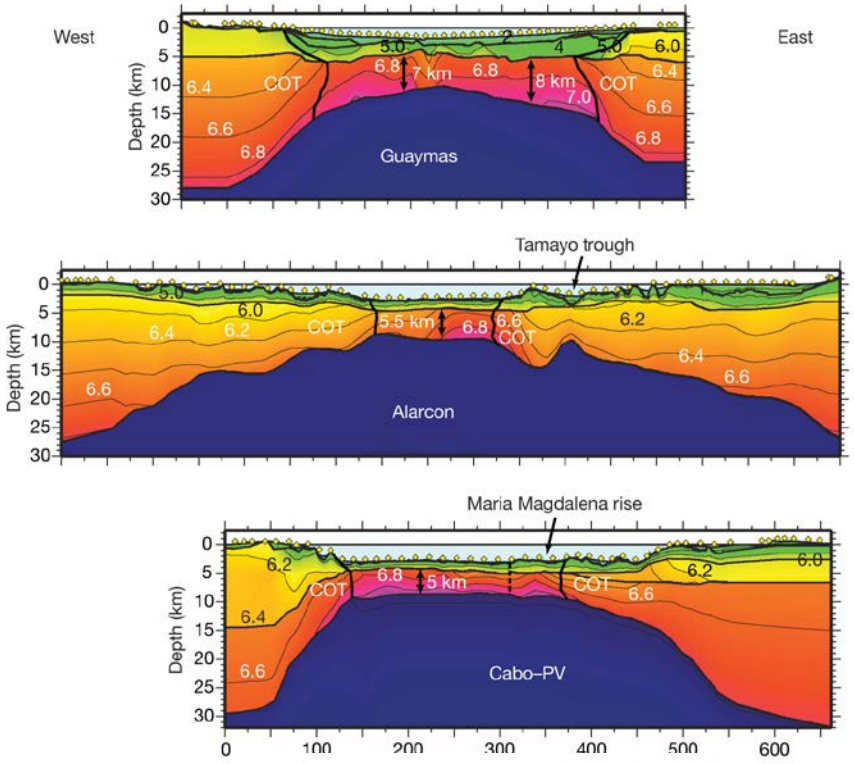
Abrupt thinning of the crust with wide zone of thinned continental crust seaward

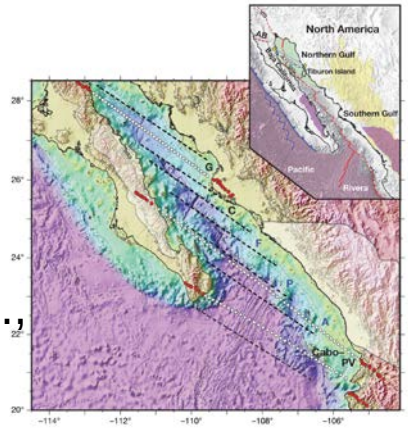


Van Avendonk et al., 2009

Examples of along-strike variability

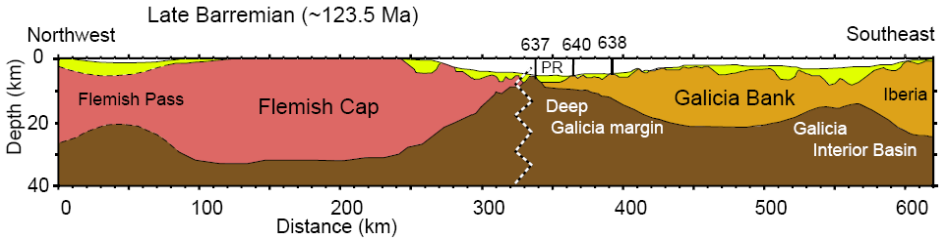
Gulf of California



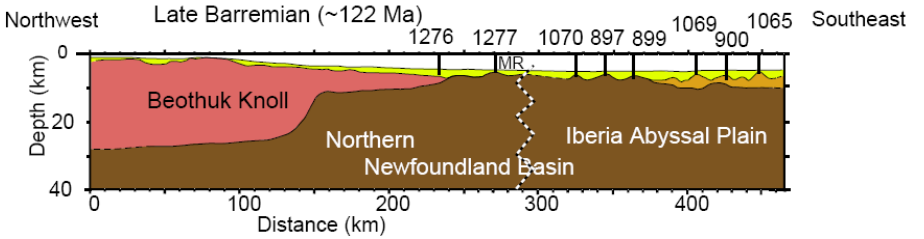


Lizarralde et al., *Nature,* 2007

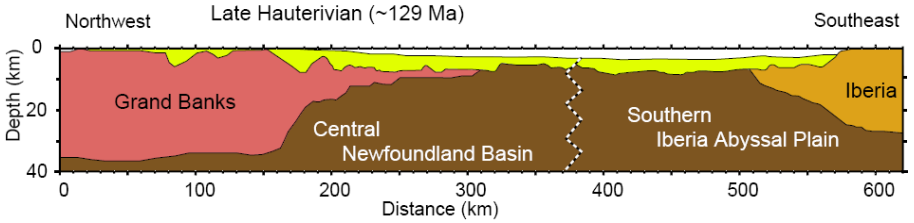
Newfoundland-Iberia



Keen and Barrett (1981); Funck et al. (2003); Whitmarsh et al. (1996)



Van Avendonk et al. (2006); Chian et al. (1999)



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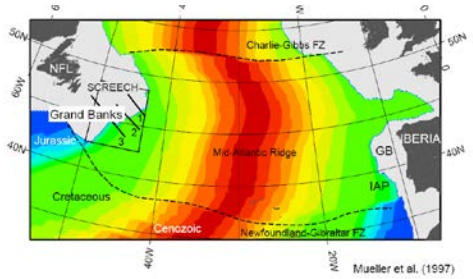


Van Avendonk et al., *JGR,* 2006

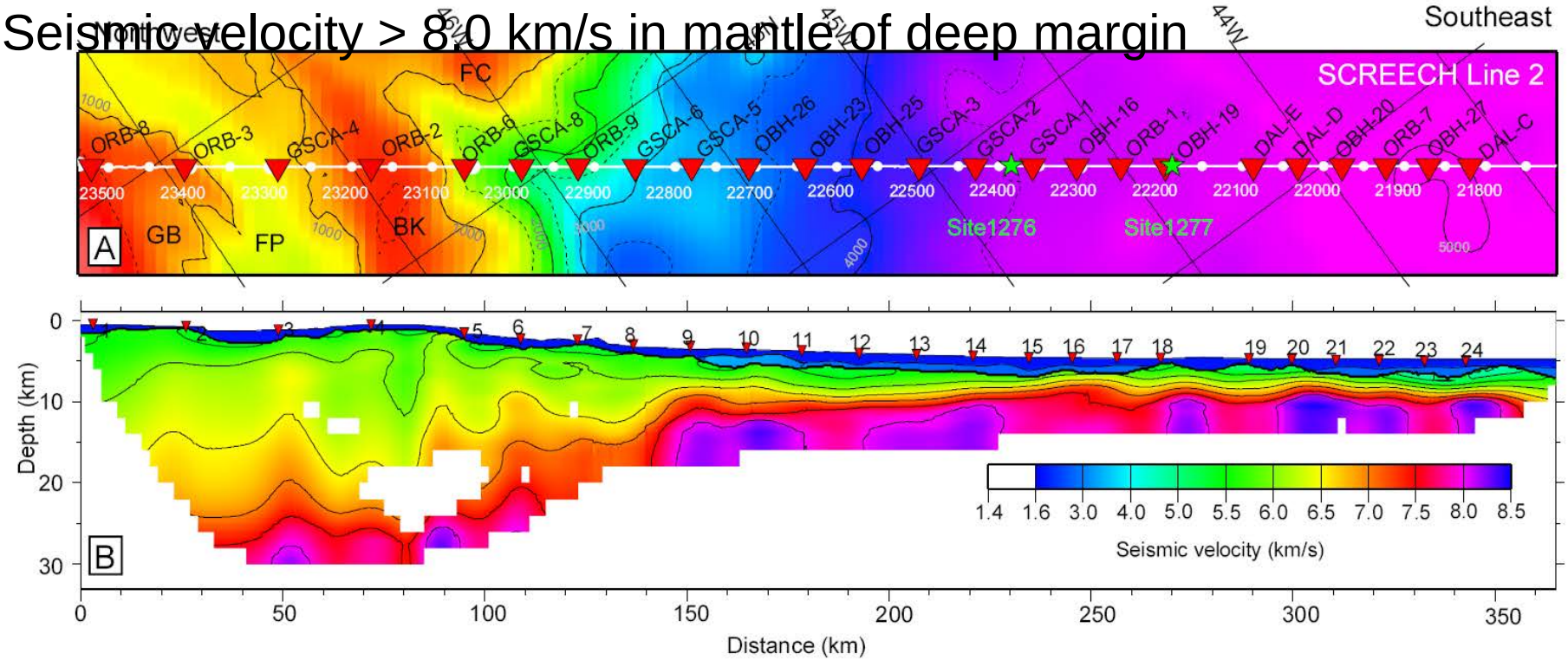
Tomographic inversion of seismic refraction data on SCREECH 2

Continental crust thinned to 25-27 km beneath Beothuk Knoll / Flemish Pass

Seismic velocity 7.0-7.5 km/s in lower crust beneath continental slope

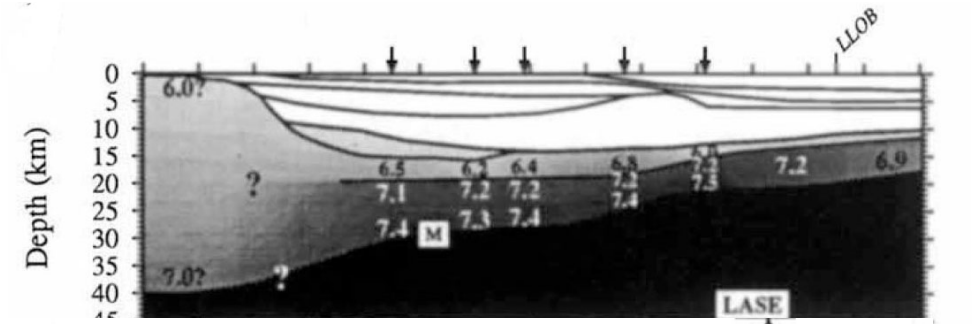
Seismic velocity 5.5-6.5 km/s in crust of deep margin

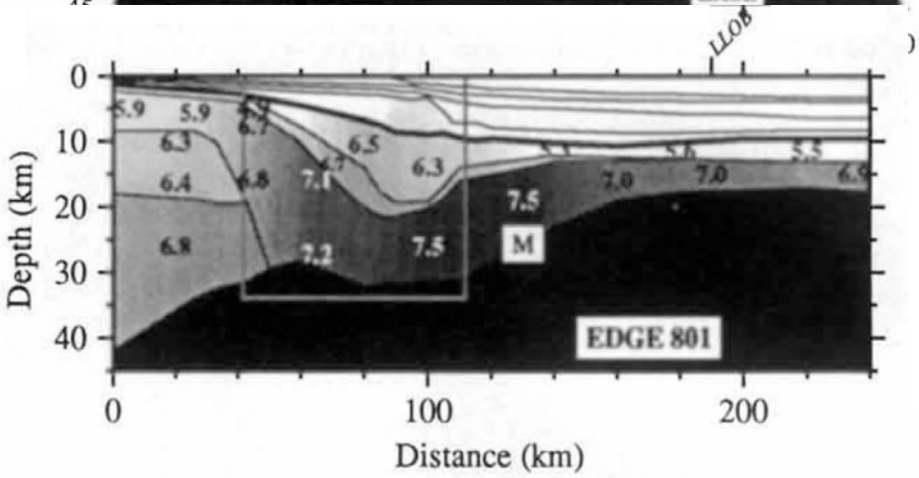
Seismic velocity > 8.0 km/s in mantle of deep margin

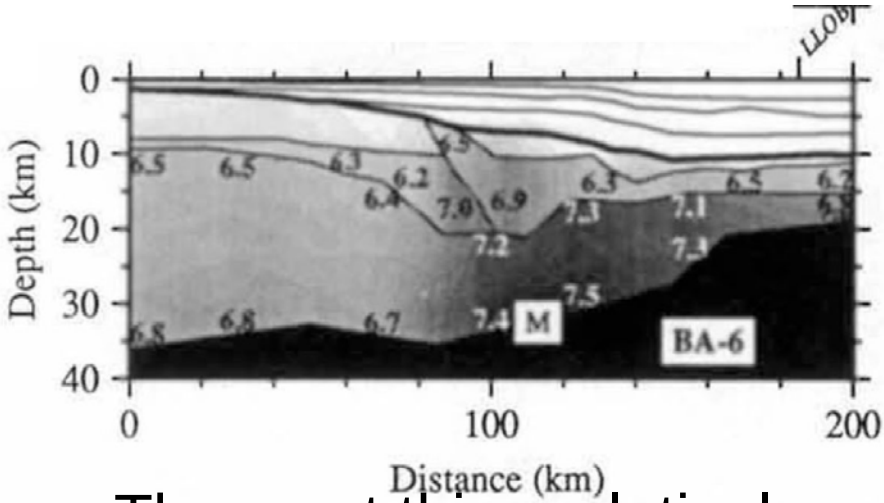


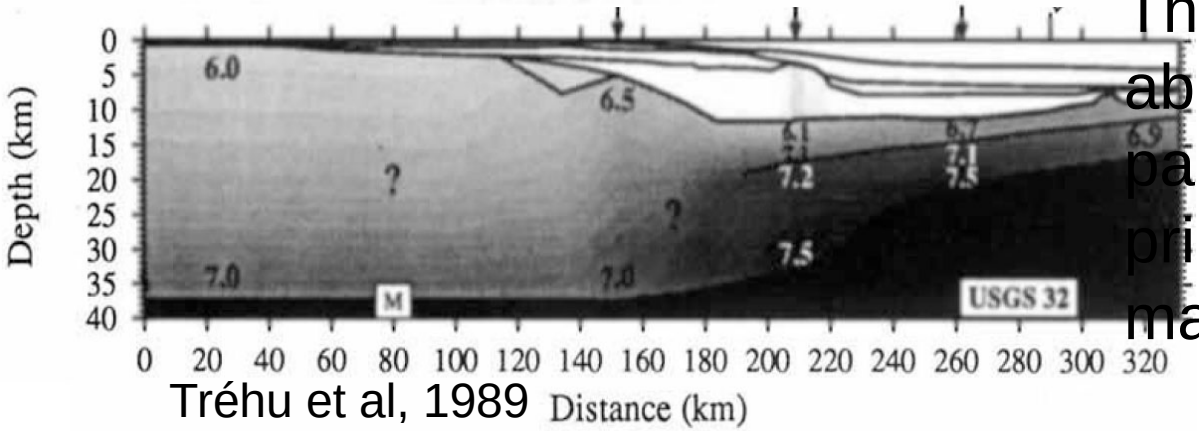
Van Avendonk et al. (2006)

Off the eastern US: magma is abundant...



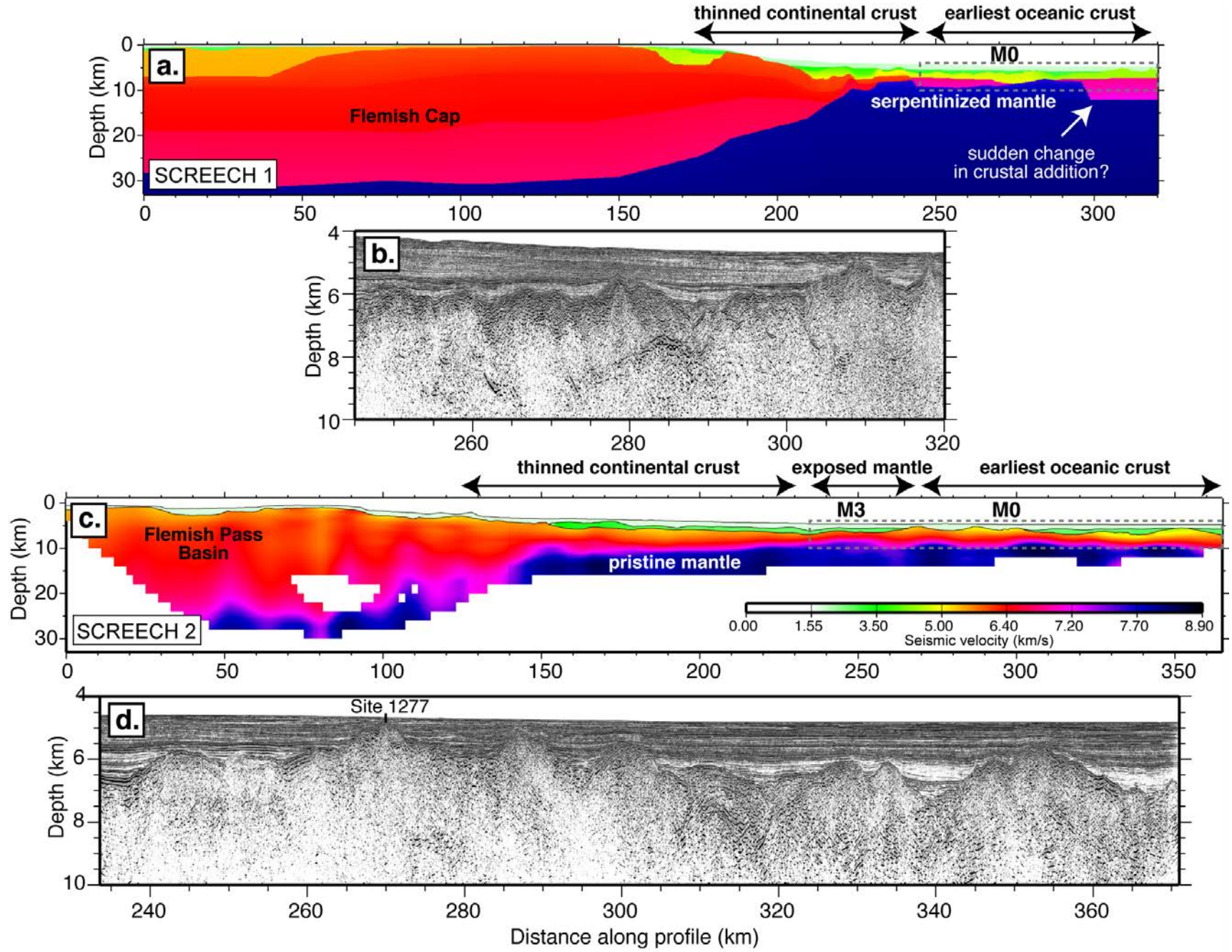






Tréhu et al, 1989

The crust thins relatively abruptly, and the outer part of the margin primarily comprises new magmatic material.


thinned continental crust
earliest oceanic crust
a.
M0
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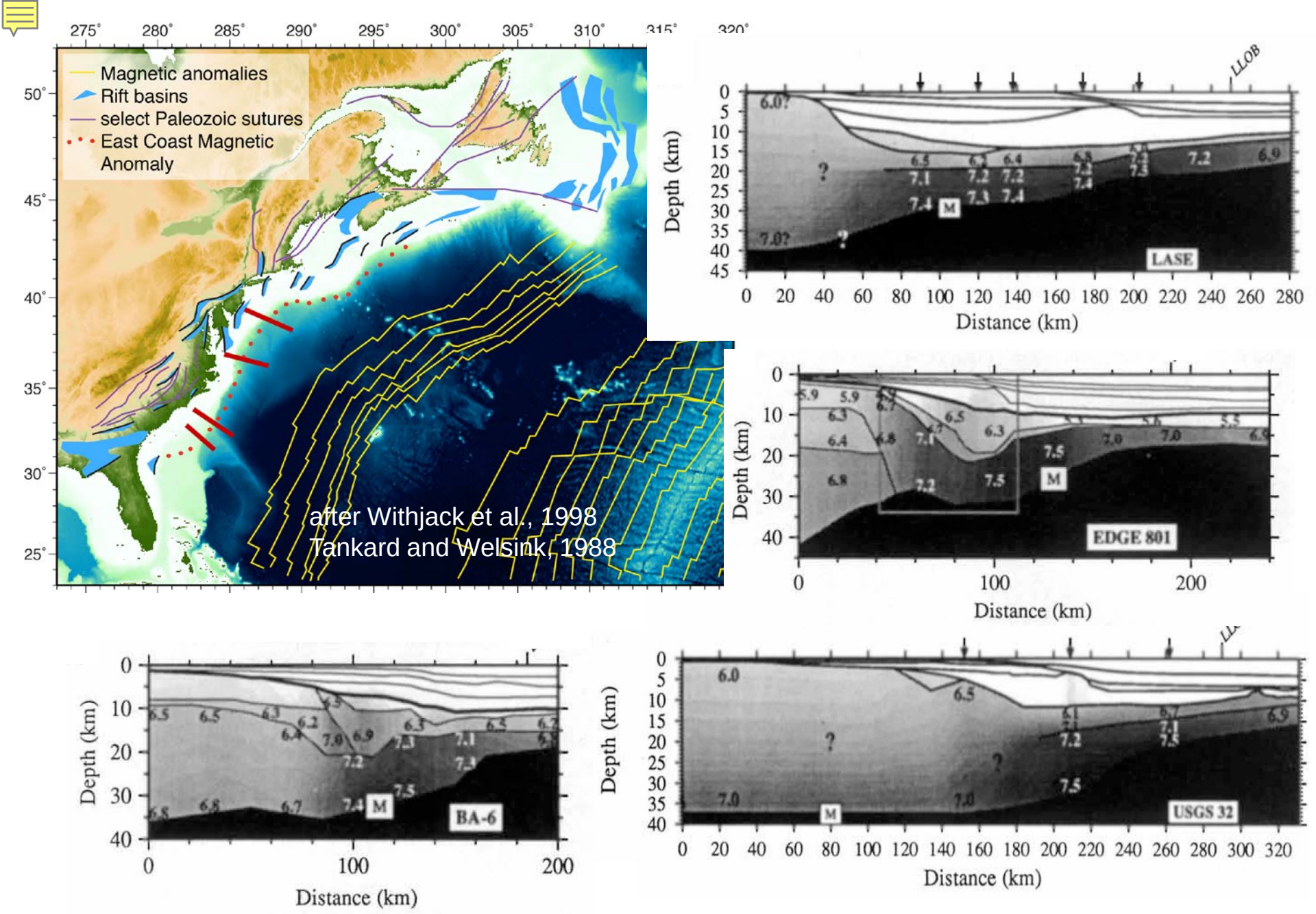
sudden change
in crustal addition?
SCREECH 1
Depth (km)
b.
thinned continental crust
exposed mantle
earliest oceanic crust
c.
M3
M0
Flemish Pass
Basin
pristine mantle
SCREECH 2
0.00 1.55 3.50 5.00 6.40 7.20 7.70 8.90
Seismic velocity (km/s)
d.
Site 1277
Distance along profile (km)



LASE working group, 1986; Trehu et al., 1989, Holbrook & Kelemen, 1993, Holbrook et a