Marine seismic reflection and refraction data reveal the deep structure of Blake Plateau, offshore the southeastern USA

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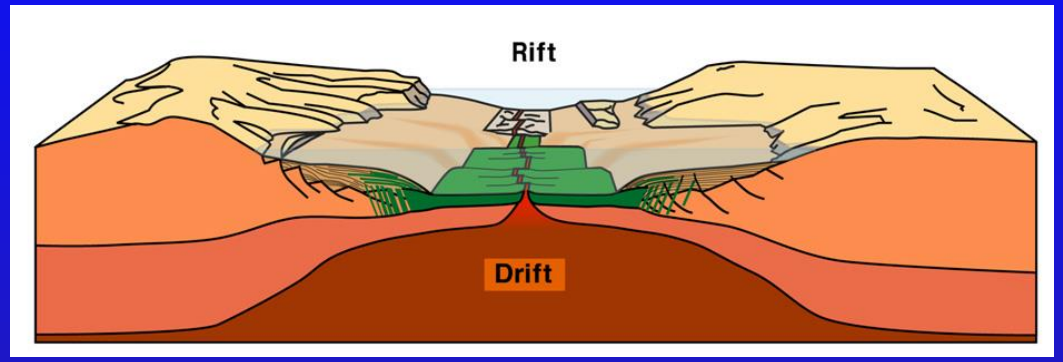
FLAME (Florida Atlantic Margin Evolution)

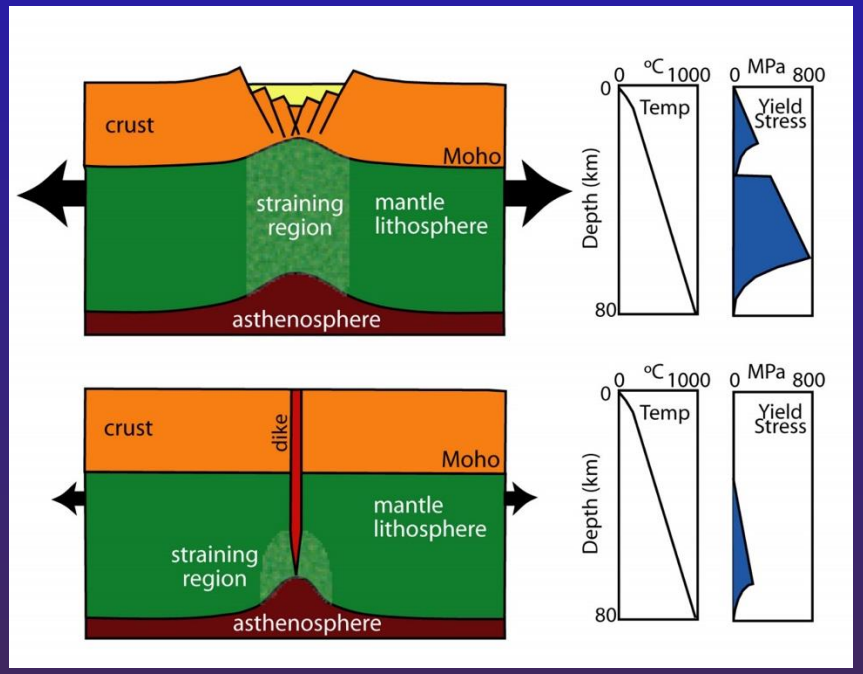
MRSOC Meeting, Sunday December 8, Alexandria VA

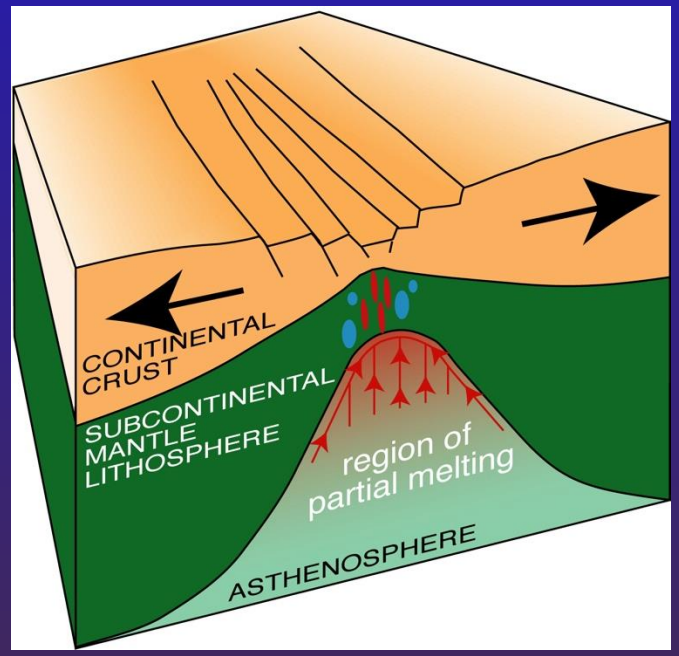
Funded by NSF/MGG

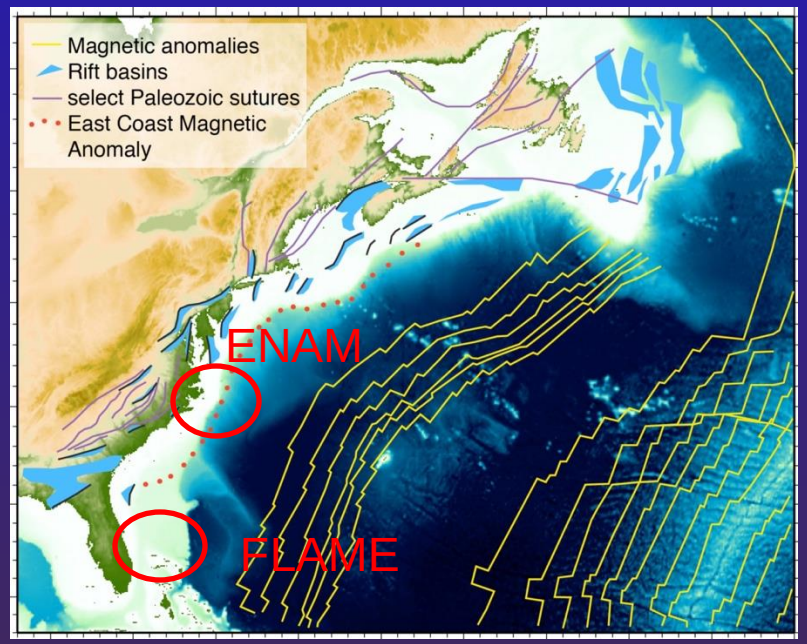
Rifted margin studies



- Investigate the interaction between deformation and magmatism
- Style of deformation, rheology
- State of the deeper mantle
- Role of pre-existing structure continental lithosphere

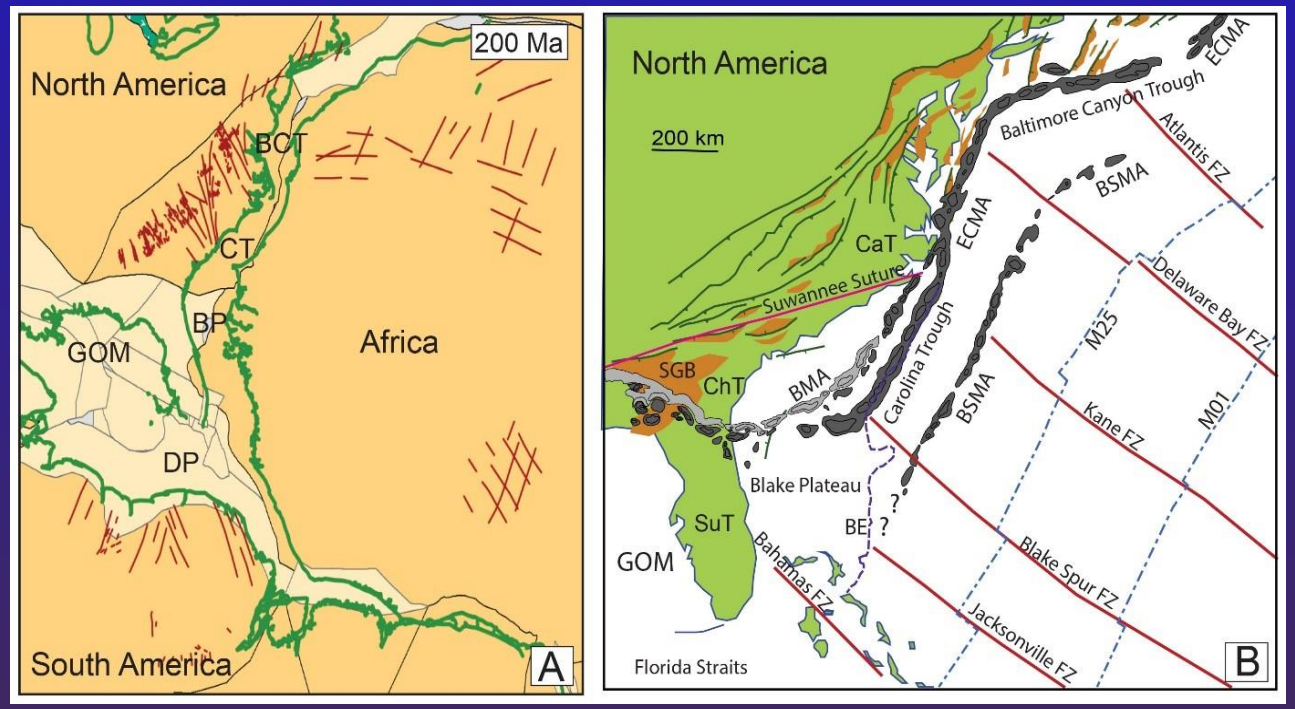


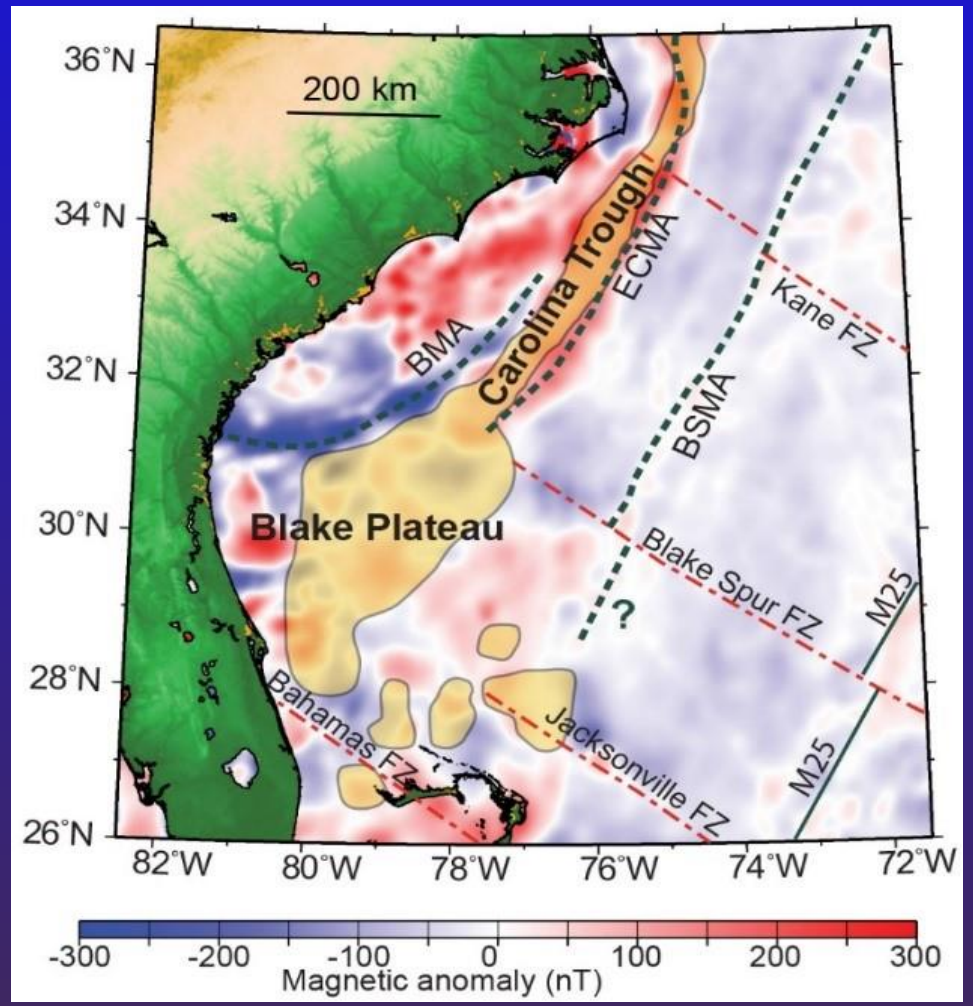




Eastern North America

- Triassic-Jurassic rifting (230-180 Ma), breakup of Pangea
- Reactivated faults, sutures of accreted terranes
- Two sets of magnetic anomalies
- Segmented margin, wider in the south.

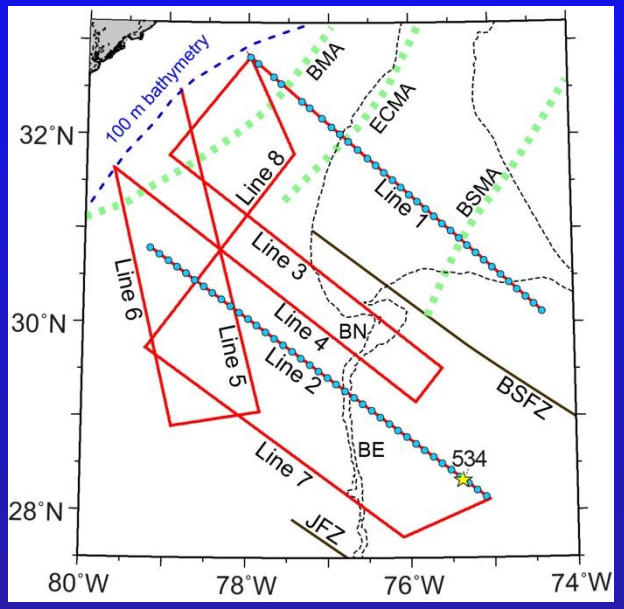




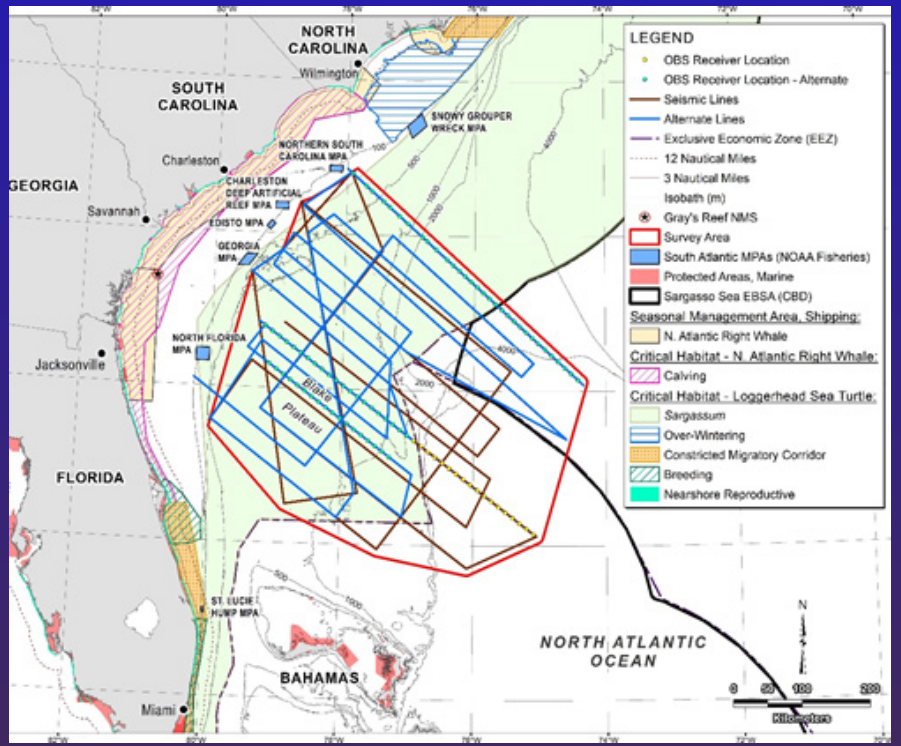
Permitting process MGL2309 and MGL2310

- Protected Species
- Territorial waters, Extended Economic Zone

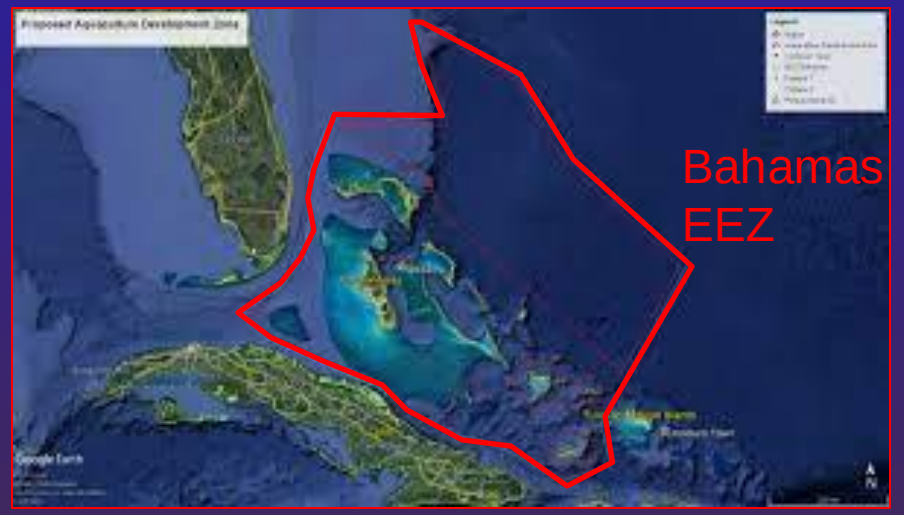
Original cruise plan



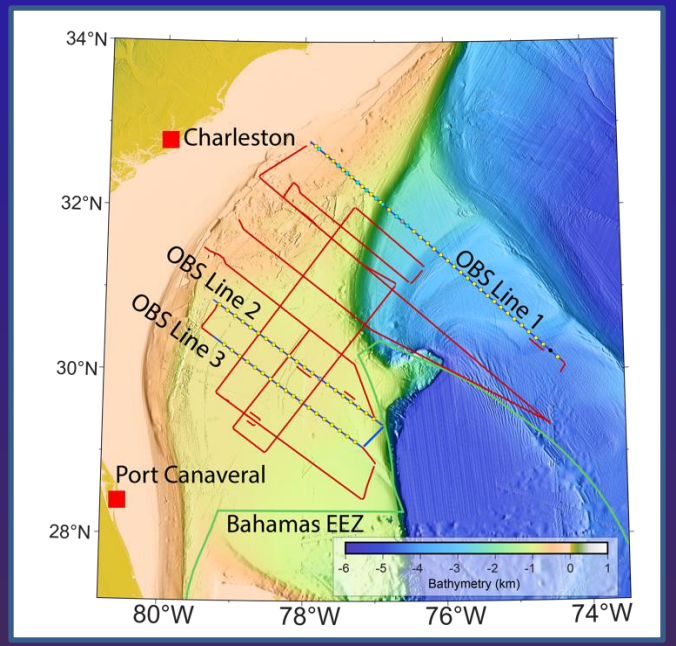
Environmental permitting



We did not receive permission to gather data in Blake-Bahamas basin

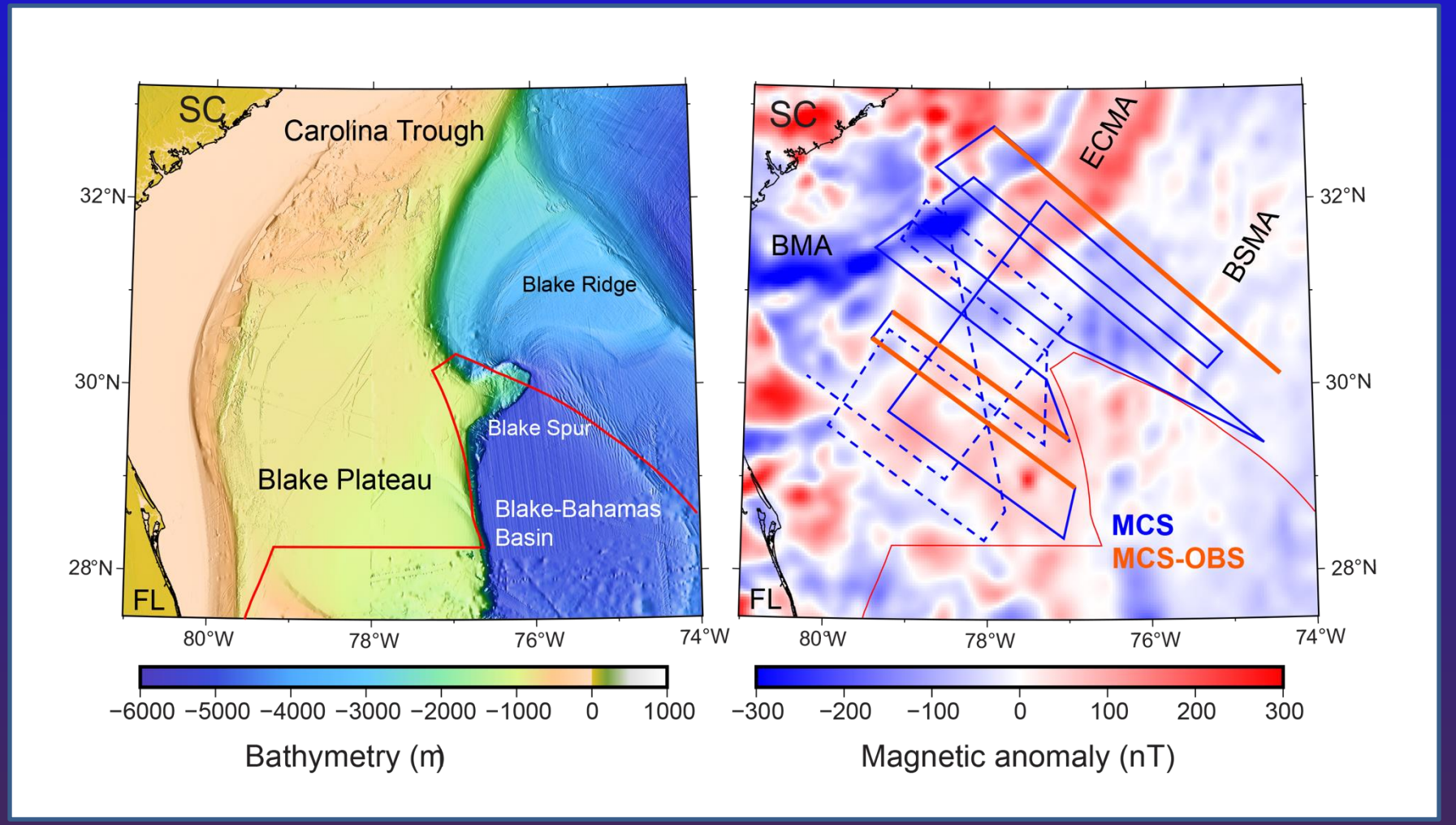


Final plan for MGL cruises



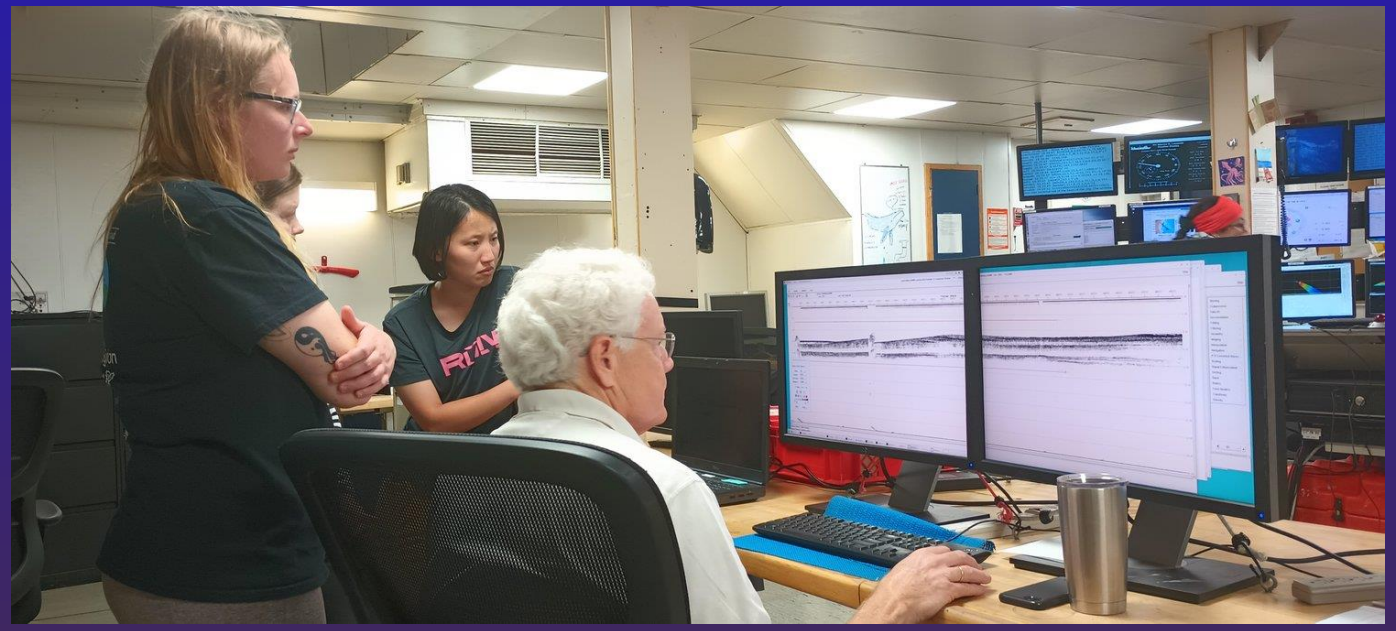
MGL2309 and MGL2310 cruises

- MCS cruise, followed by an OBS cruise, all on R/V Marcus Langseth
- Two OBS lines on Blake Plateau, one OBS line on southern Carolina Trough
- Additional MCS lines

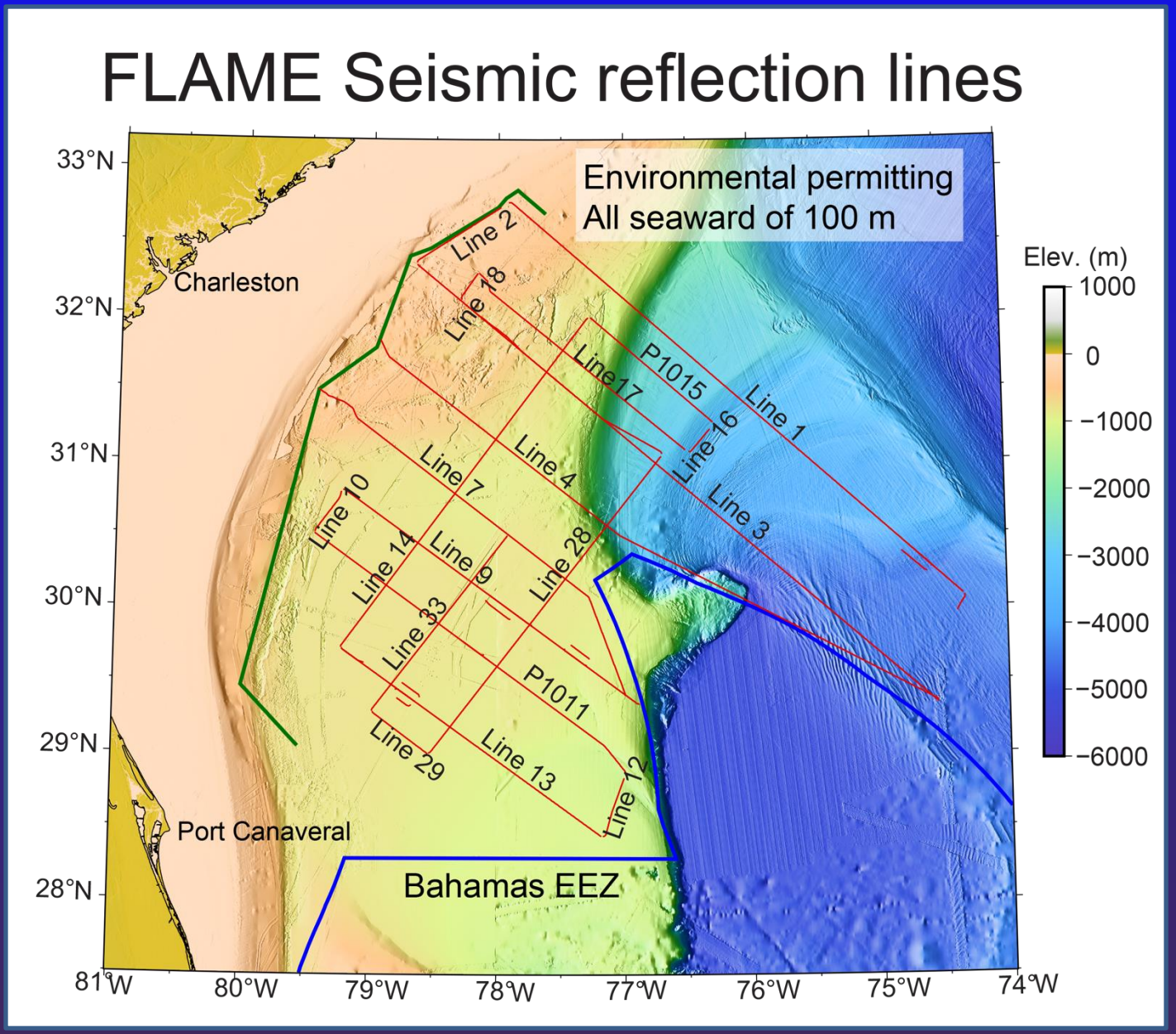


Student participants

- Call-to-sail recruitment by advertisement
- Logistical support from UTIG
- 7 on MGL2309 (MCS) and 5 on MGL2310 (OBS) cruise
- Science discussions, MCS processing



MGL2309: MCS cruise



July 16 - August 19, 2023 (34 days)

Port Canaveral, FL - Charleston, SC

4275 kilometers (on 20 lines)

MCS Streamer:

Length: 12,000 meters, 960 channels
Depth: 12.0 meters
Channel spacing: 12.5 meters
Record length 20.0 seconds
Sampling rate: 500 Hz

Acoustic source :

Array 36 air guns, four strings
Maximum source volume: 6600 in3.
Depth: 10.0 meters
Average pressure: 1941±11 p.s.i.

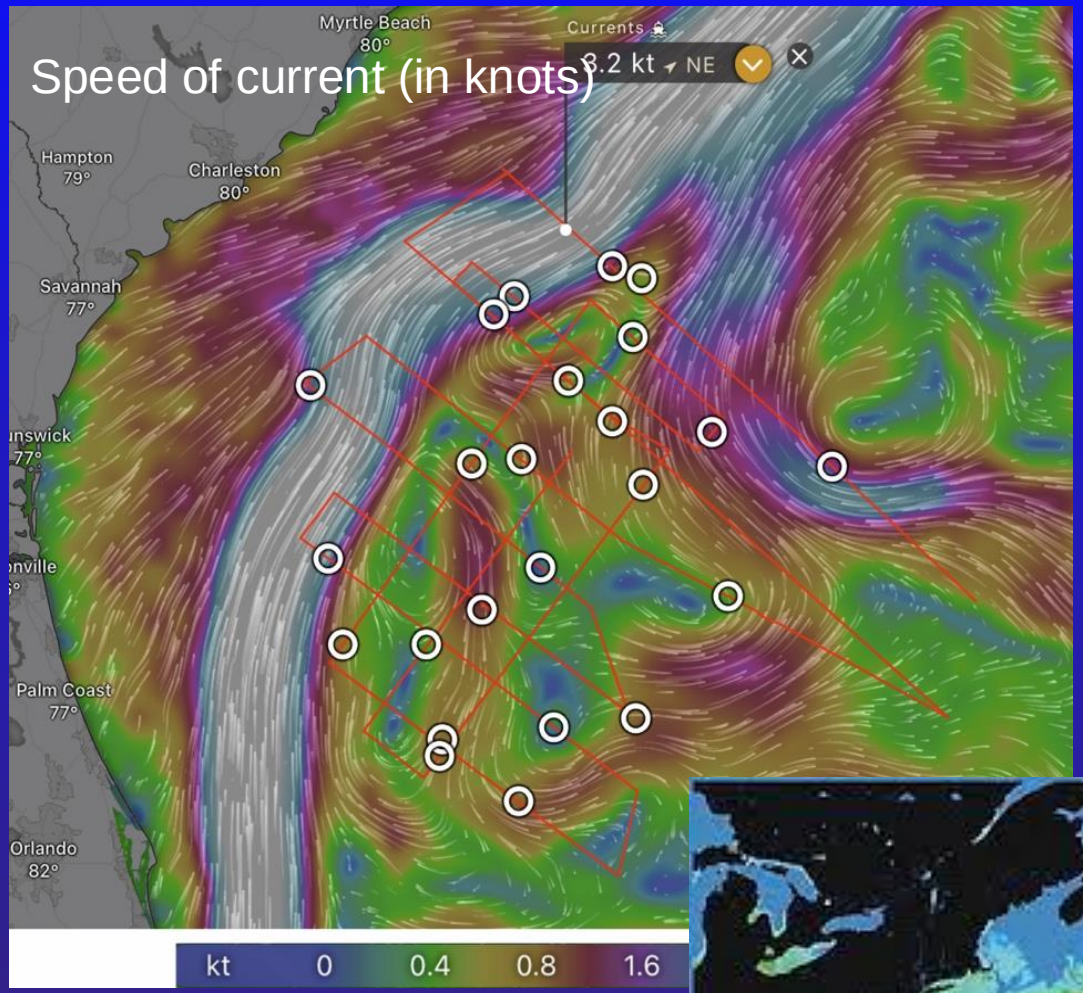
MGL2309 Shot spacing used: 50 meters

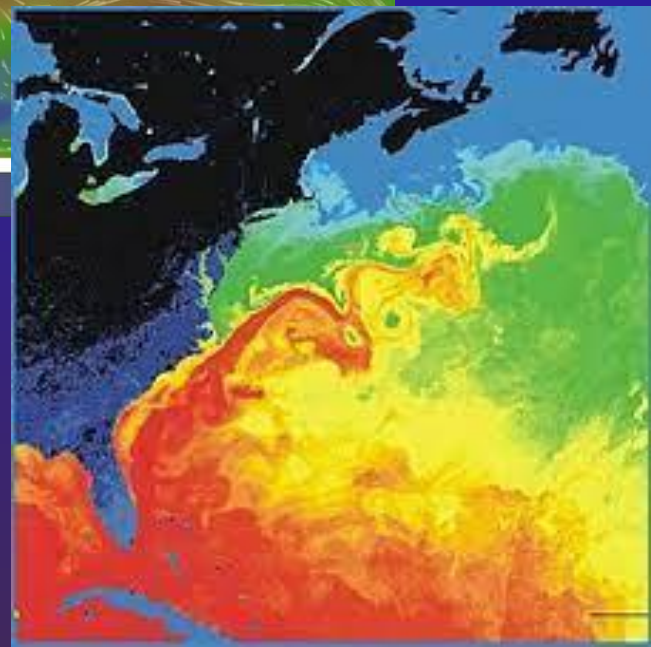
MGL2309 Cruise impressions

- Streamer and air gun array require maintenance, some down-time.
- High data quality.
- Good coordination from science officer.
- Primary lines, most secondary MCS lines were shot.

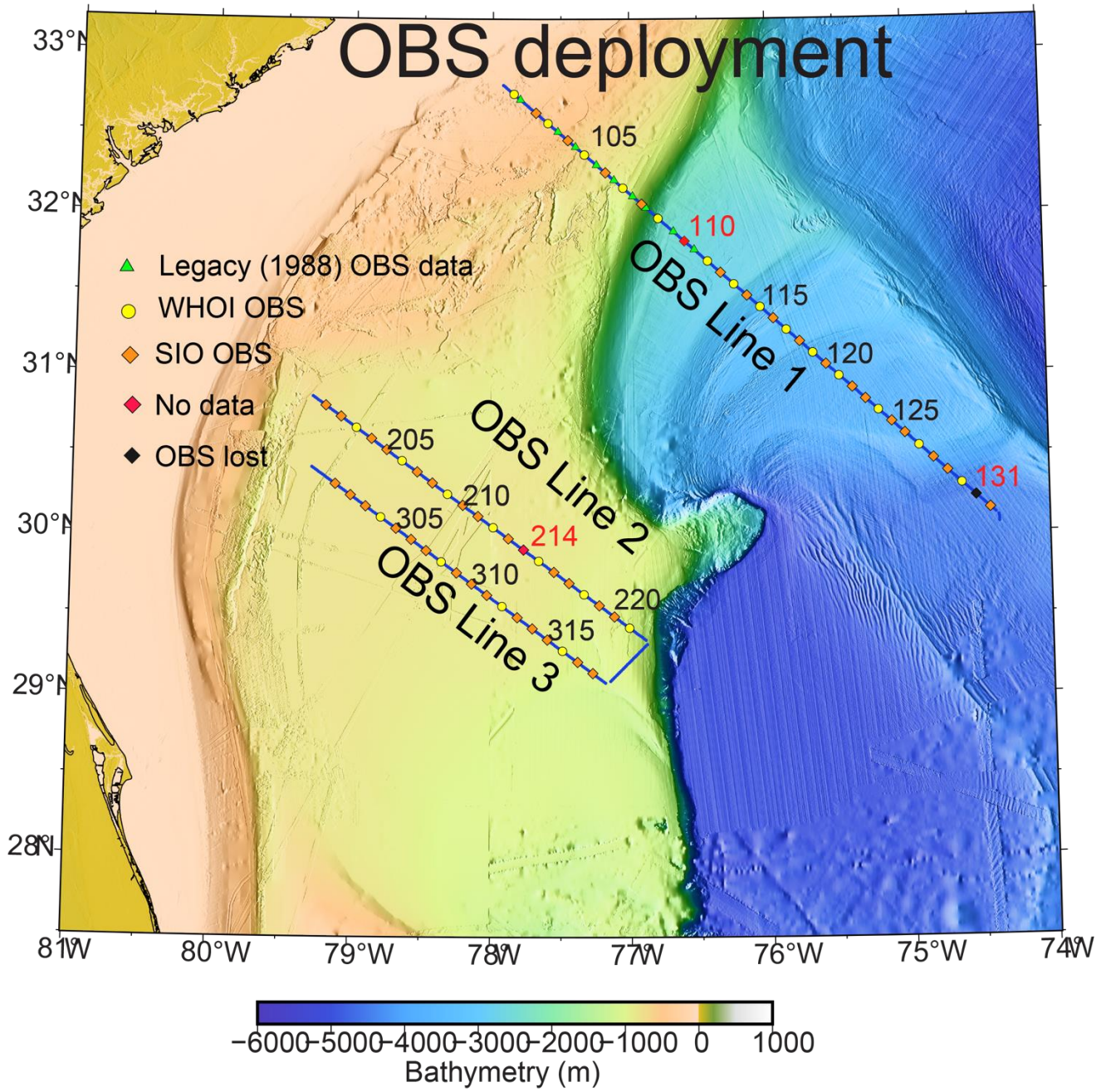
The Gulf Stream

- 3 knot currents seaward of continental shelf.
- Variations over the course of days.
- Slow progress
- Streamer feathering
- Seismic data quality ultimately fine.





Ocean temperature



MGL2310: OBS cruise

August 23 - September 18, 2023 (25 days)

Charleston, SC - Charleston, SC

Three profiles
Line 1 reoccupied an existing OBS refraction line (Holbrook et al., JGR 1994)
1016 kilometers (3 profiles)

OBSIC

39 instruments from WHOI and SIO

71 OBS drops, two deployments

Acoustic source:

Array 36 air guns, 10 meters depth

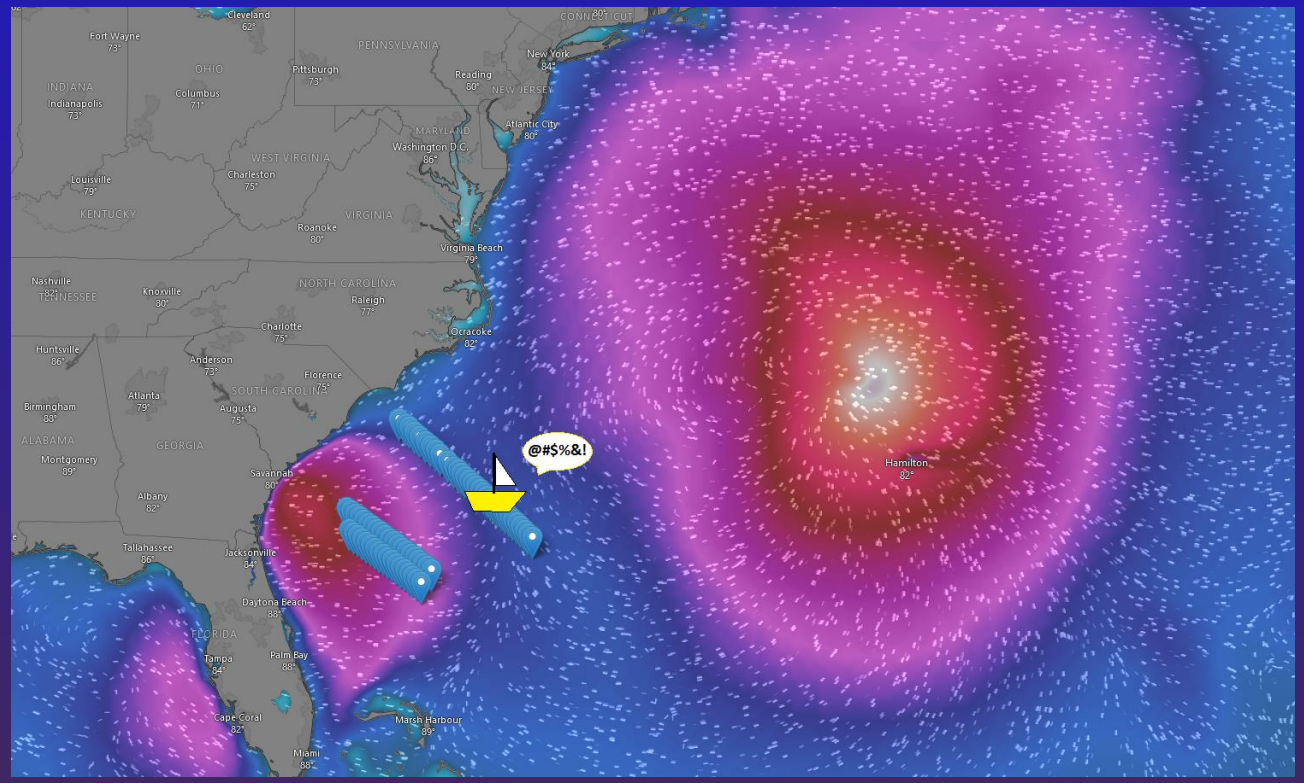
MGL2309 Shot spacing used: 50 meters

OBS Operations

- Air-gun maintenance required at several times.
- Efficient coordination with Langseth science officer, OBSIC
- High data quality
- Navy data redaction
- Weather
- Primary science goals (three profiles) precisely met.

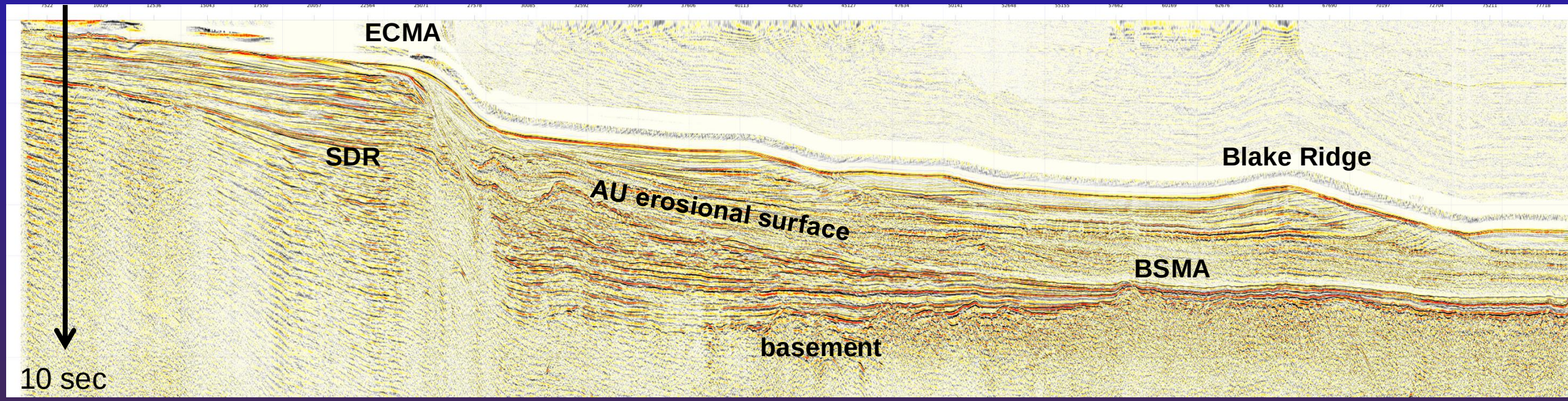
Tropical storms

- Two hurricanes impacted OBS refraction operation (Idalia and Lee)
- Very complicated instrument deployments, shooting strategy
- Suddenly everyone on board is a weather expert
- 4-5 days of ship time lost, just within contingency estimate.



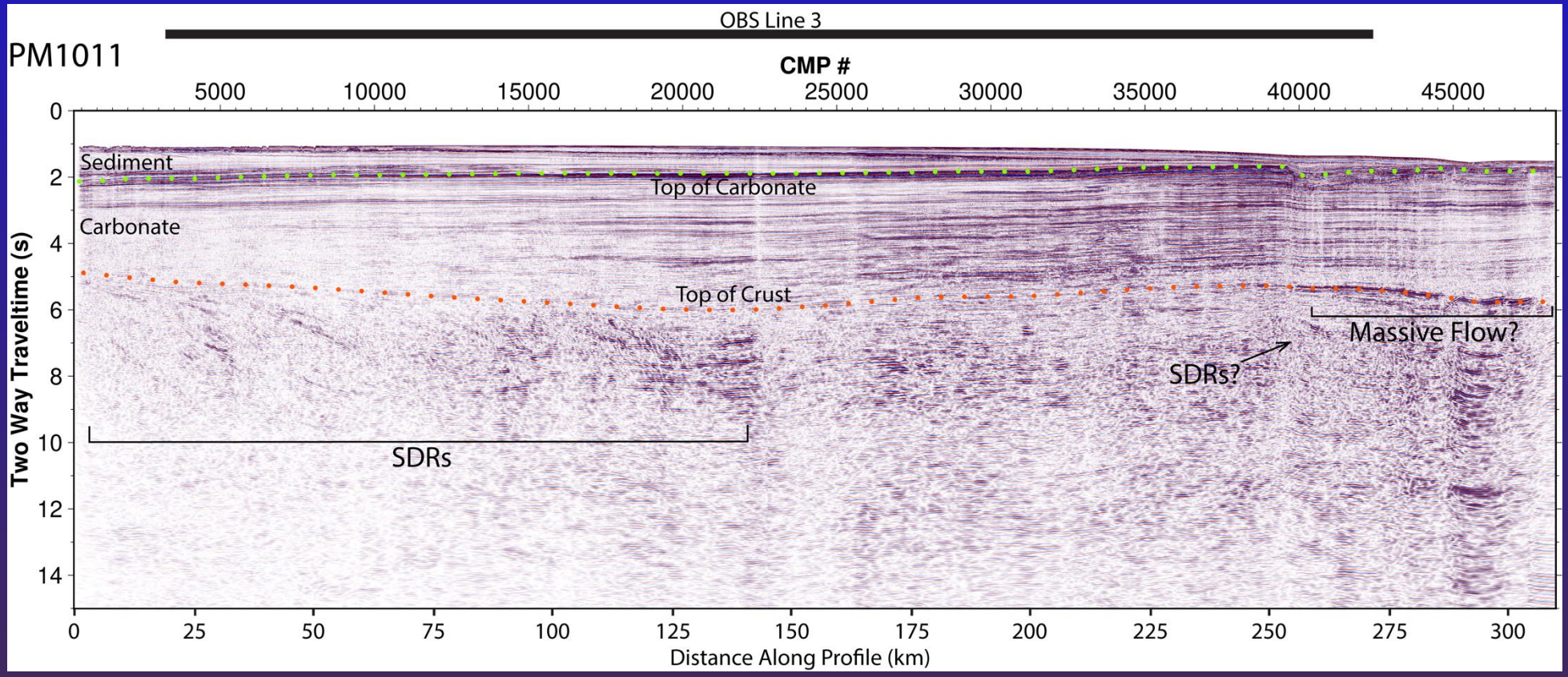
MCS image, Line 1 (southern Carolina Trough)

- Stratigraphy record of deposition and major erosional events, deep currents.
- Basement is deep and rough at continental slope.
- Smoother and high-standing basement east of Blake Spur Magnetic Anomaly (BSMA)
- Seaward-dipping reflections near East Coast Magnetic Anomaly



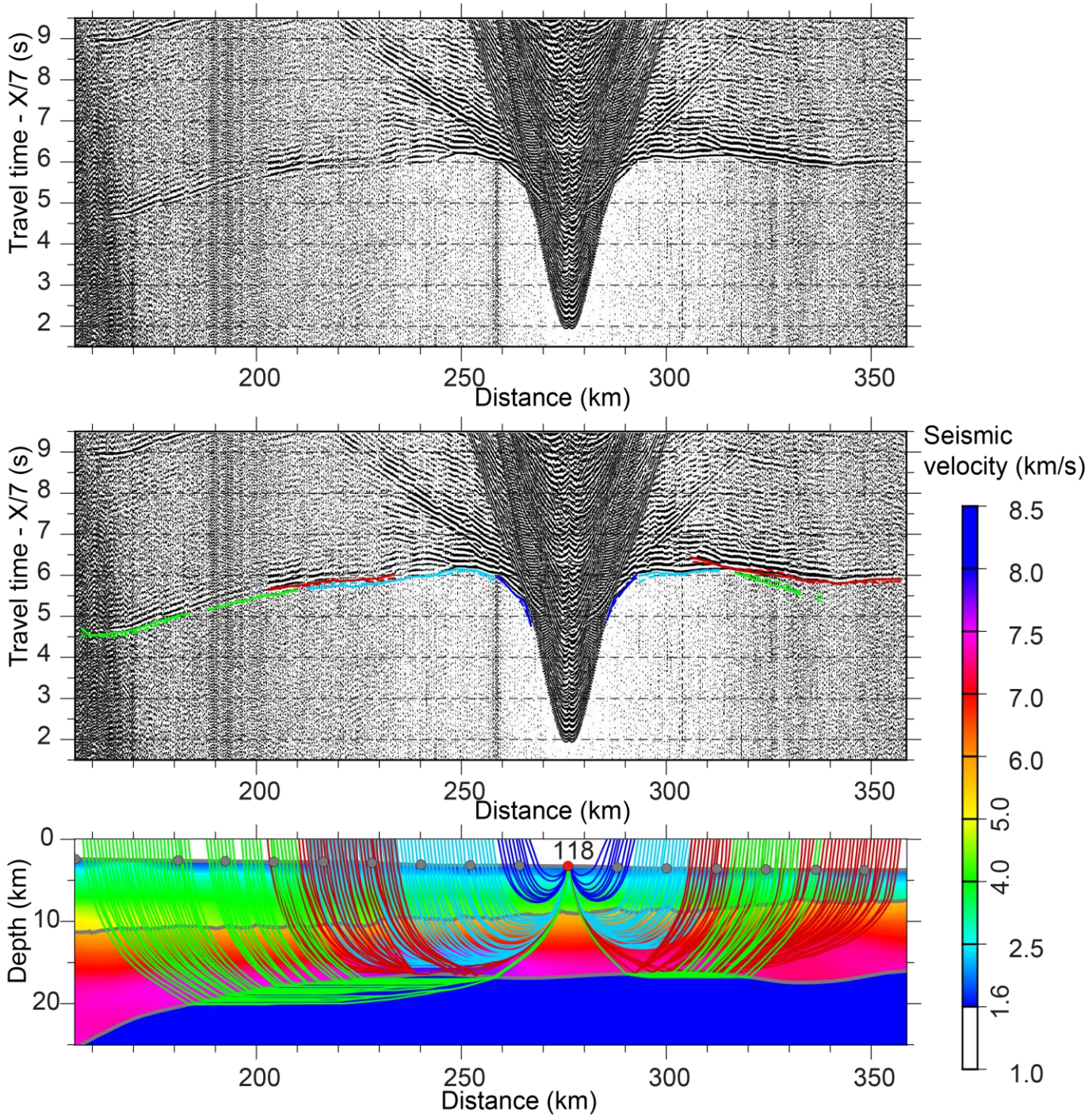
MCS Line 11 (Blake Plateau)

- Shallow sediment layer and carbonates thin to the east
- Package of SDRs present from CMP ~250 – 20000 (0 - ~125 km), topped by east dipping reflection
- High amplitude, dome shaped reflection from CMP 35000-48000 may be massive basalt flow
- No clear Moho reflection in MCS at this stage



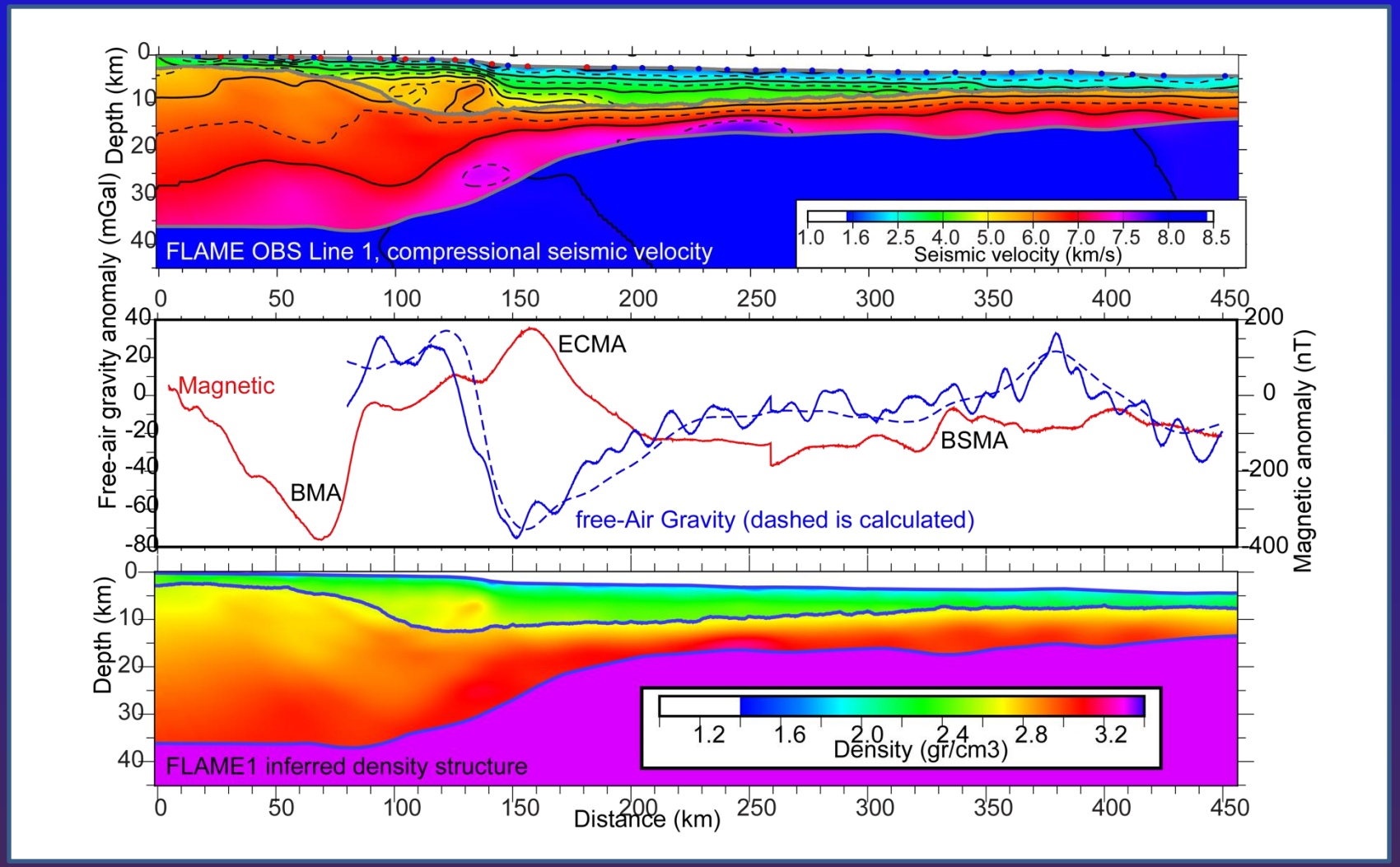
OBS refraction data

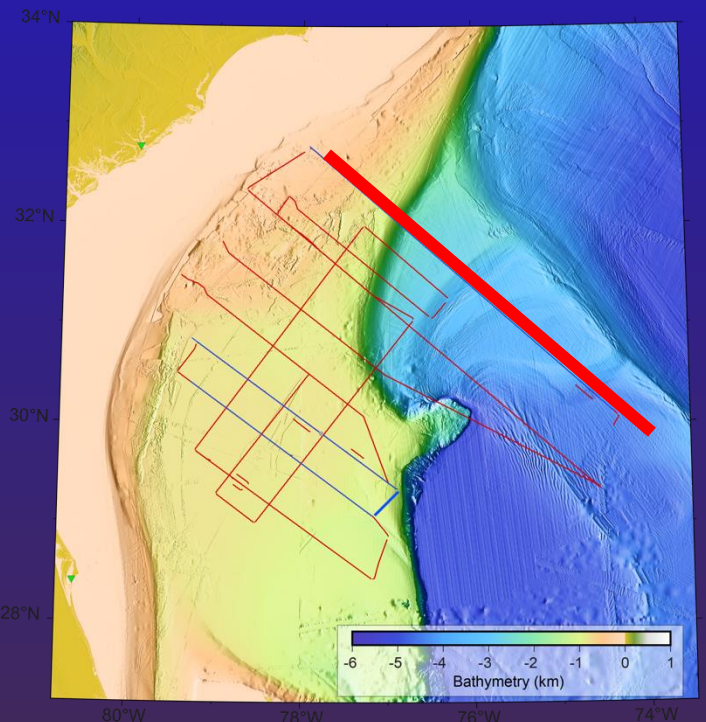
- Four-component, ~10 Hz refractions
- Psed, Pg, PmP, Pn
- Great offsets (> 100 km)
- Reflection/refraction tomography
- Three layers (sediments, crust, mantle)
- Data fits ~ 70 msec.



OBS Line 1 (Carolina Trough)

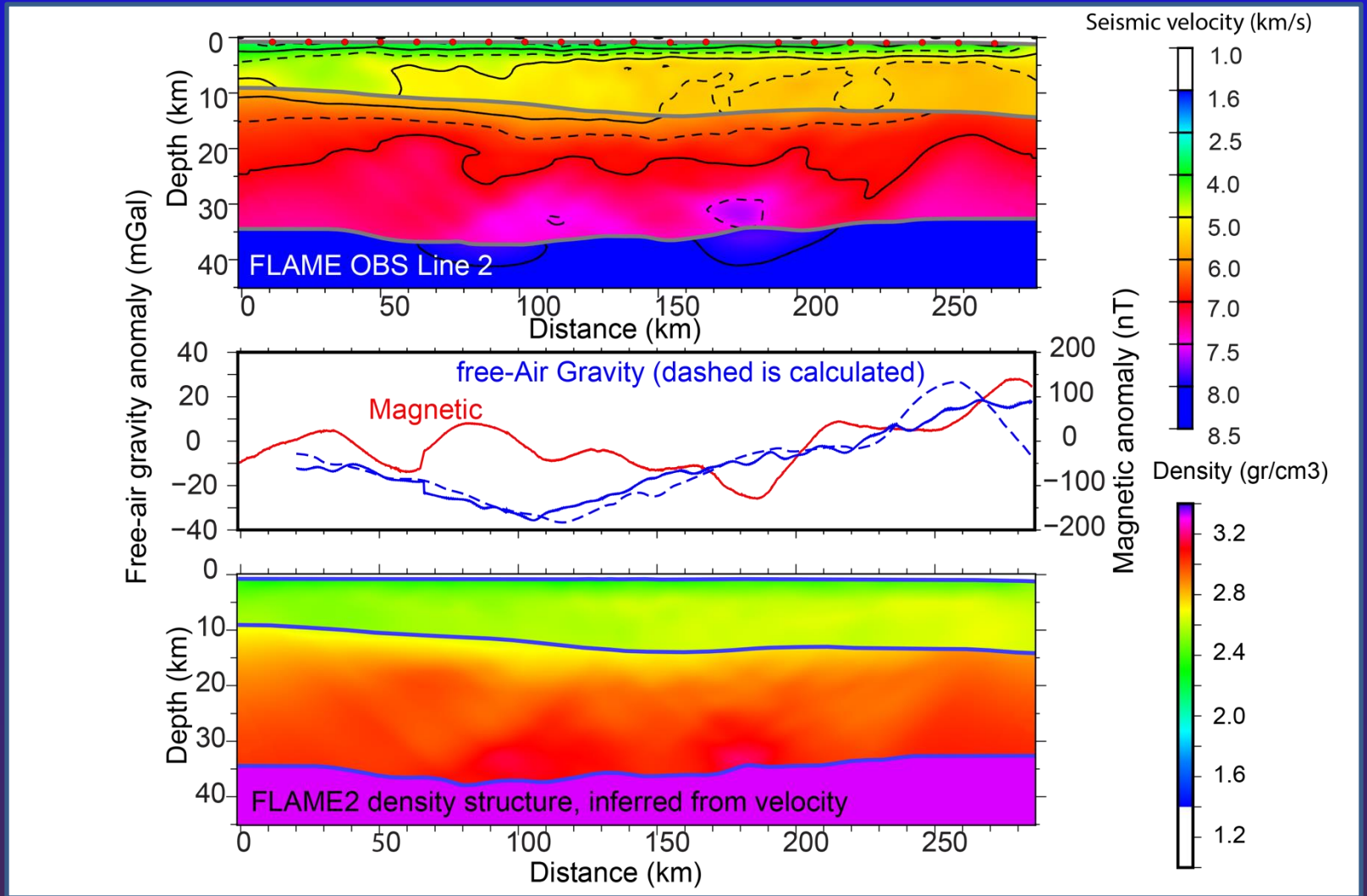
- Magmatic intrusions in lower crust, proximal margin.
- Many similarities with seismic studies mid-Atlantic margin.

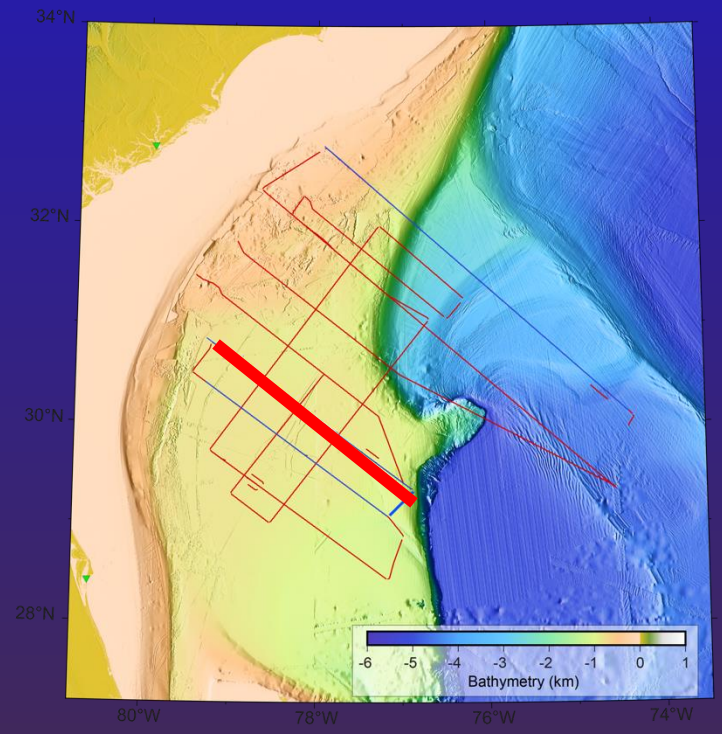




OBS Line 2 (Blake Plateau)

- Thick igneous crust (27 km), tapering towards Blake Escarpment (east).
- High-velocity lower crust indicate very high mantle potential temperatures during rifting..





AGU24 presentations

Wednesday, 8:30-12:20.

T31E poster session:

Tectonic, Magmatic, and Geodynamic Studies of Rifts, Rifted Margins, and Ridges

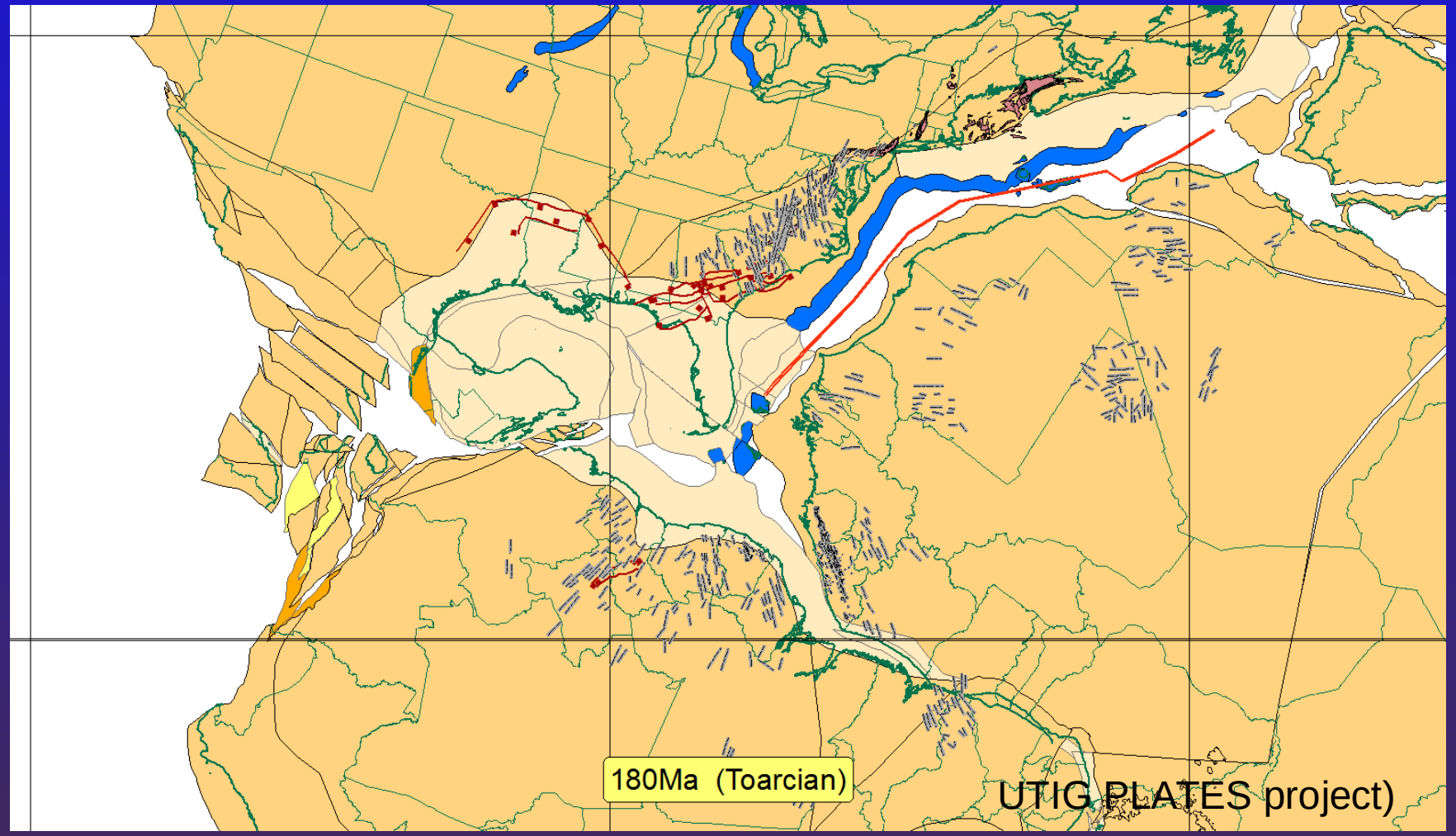
- T31E-3175: Illuminating the Blake Plateau's Crustal Structure with New Active Source Seismic Data. Collin Brandl
- T31E-3173: New marine seismic data show the extent of syn-rift volcanism during continental breakup offshore the southeastern United States. Harm Van Avendonk

Thank You !

The End

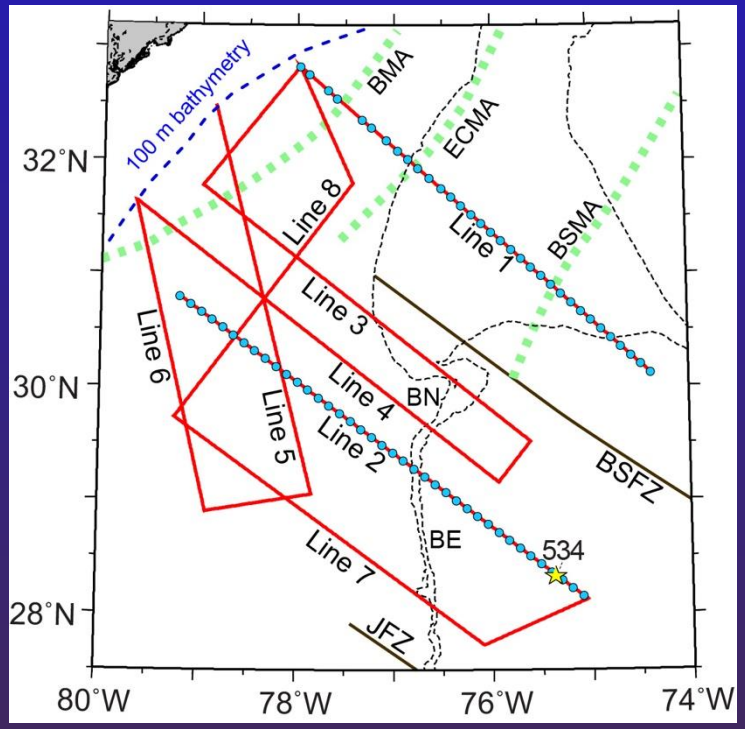
Opening of Central Atlantic Ocean

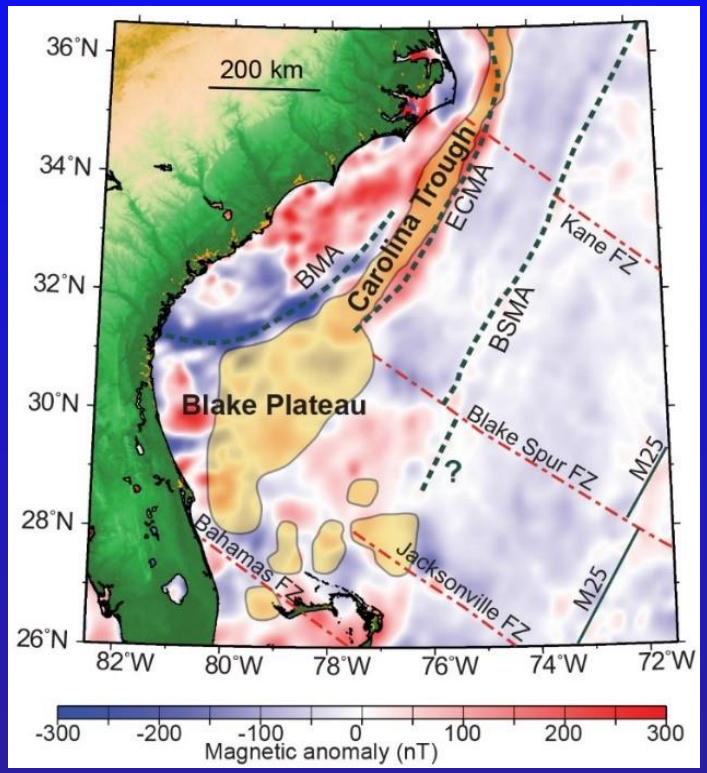
- Early Jurassic (180 Ma):
- Southeastern United States, West Africa are conjugate margins



Florida Atlantic Margin Evolution (FLAME)

- Compare deep structure Blake Plateau, Carolina Trough
- Collaboration between UTIG and LDEO
- Funded by NSF/MGG
- R/V Marcus Langseth, OBSIC, seismic reflection/refraction study





Underwater inspection of air guns

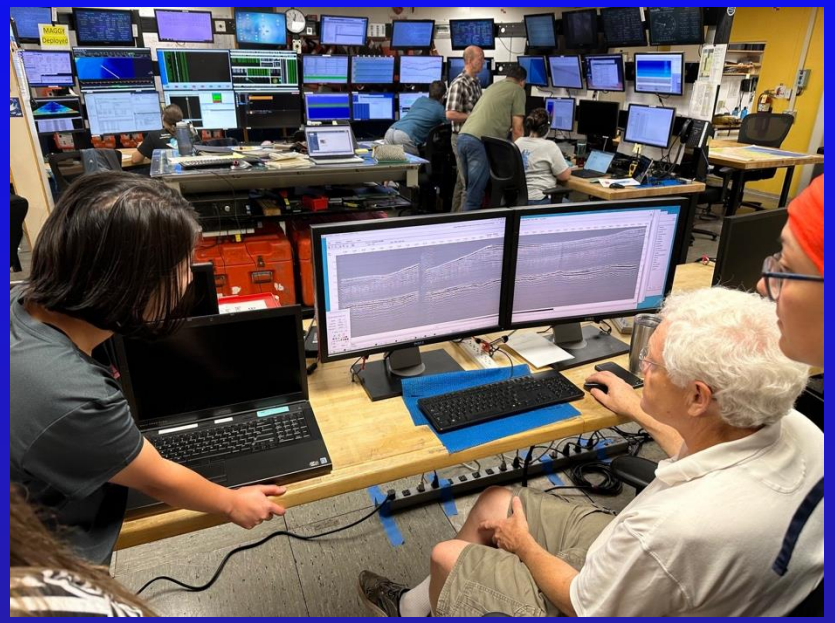
- Photographs from work boat

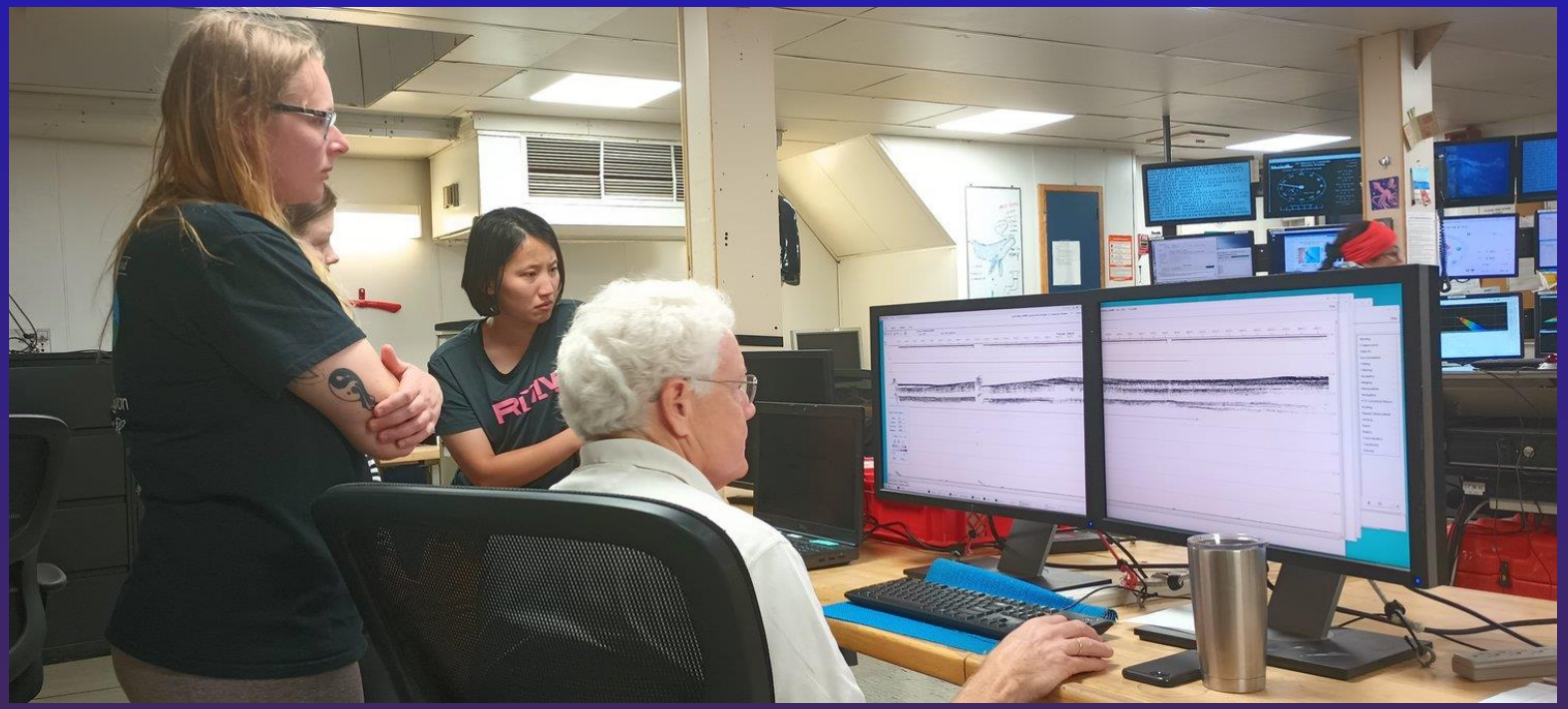
Protected Species

- Five observers
- Very few marine mammals, turtles
- Seasonal pattern

On-board seismic processing

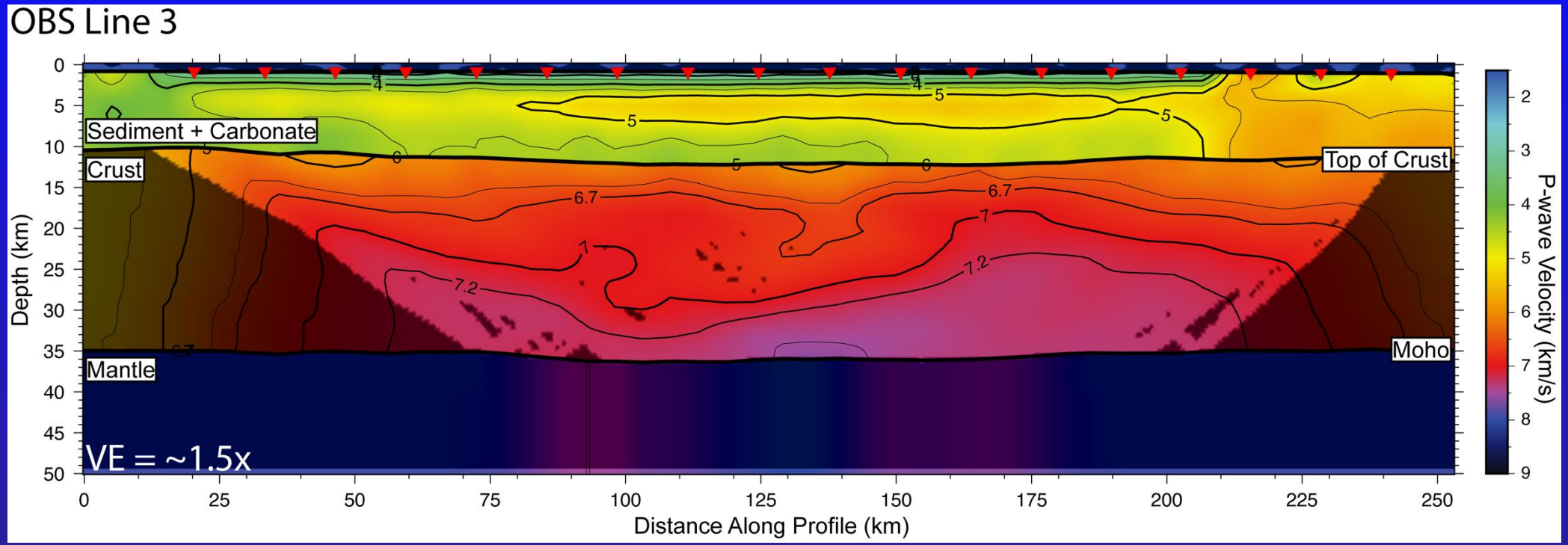
- Reflection data, line by line
- Led by Nathan Bangs and Anne Bécel
- Semblance-based velocity picks, muting, stacking.
- Preliminary results.





Redaction of short-period OBS data by the US Navy

- Monitoring of ocean-bottom seismic/acoustic data in US waters.
- OBSIC had clearance to secure the raw OBS data
- No preliminary on-board processing
- US Navy screening/redaction September 2023 until February 2024.
- Algorithms, personnel involved in screening changes over the years.
- **Ultimately, less than 1% of MGL2310 data was redacted**

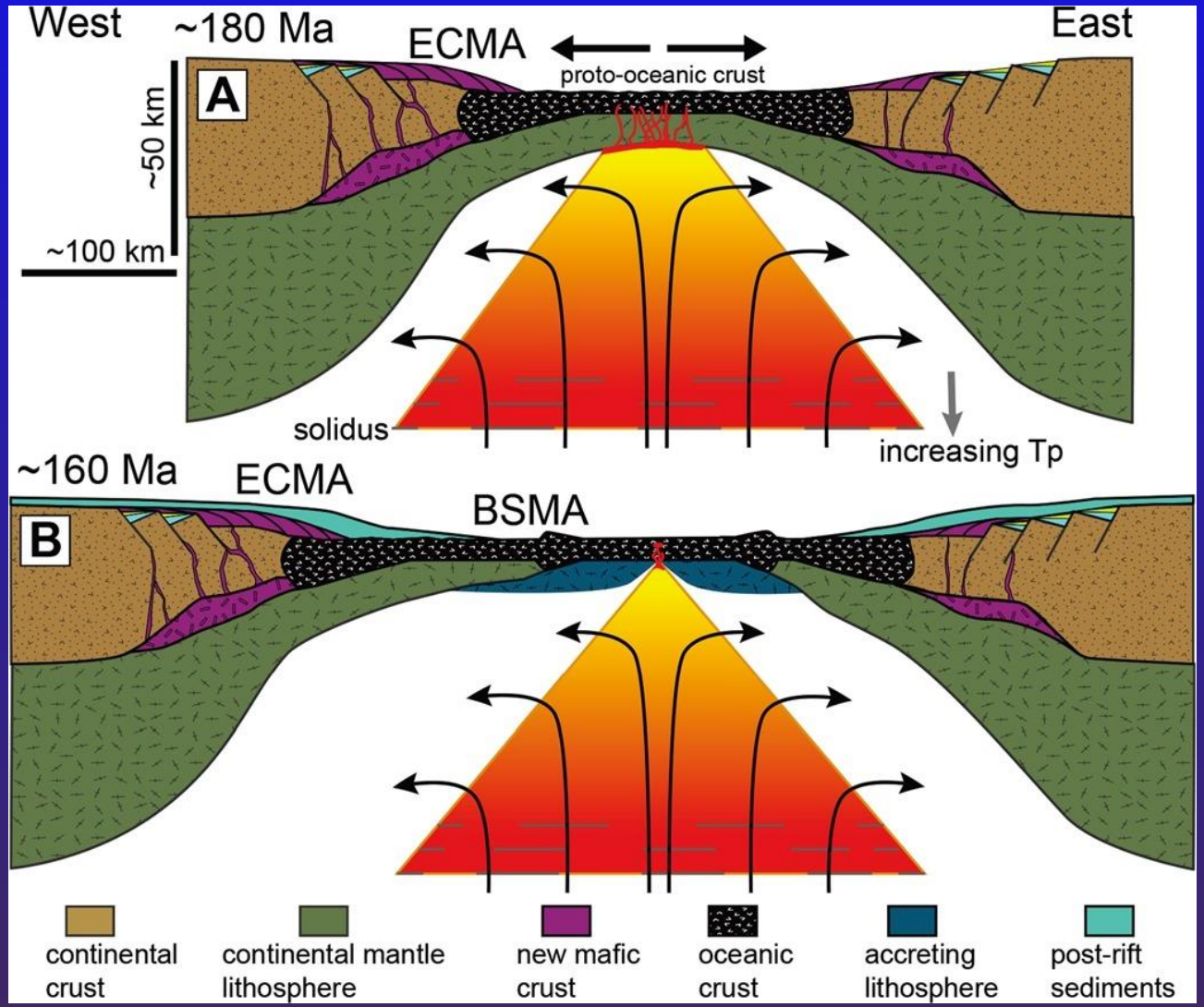


Overall Chi2 = 1.27, rms = 111 ms
P1 Chi2 = 2.45, rms = 156 ms
P2 Chi2 = 1.29, rms = 56.9 ms
P-2 Chi2 = .267, rms = 25.8 ms
P-3 Chi2 = .66, rms = 81.4 ms
P1,-2 Chi2 = 2.26, rms 149 ms
P2,-3 Chi2 = 1.07, rms 103 ms

OBS Line 3:

1) Three layers : Sediment + Carbonate (9.5-11.5 km thick), Crust (23-25 km thick), Mantle
2) Sed+Carb layer has velocities from ~2.5 -5.5 km/s, higher velocities near seafloor from ~210 – 250 km
3) Crust has velocities from ~5.5 – 7.5 km/s, HVLC has varying thickness from ~2 – 12 km
4) Reflection from top of crust taken from MCS stack, ~10-12 km depth
5) Moho inverted with wide angle reflections, ~35-37 km depth

Thin crust in the distal margin, Carolina Trough



Shuck et al. (2019)