Investigating Slope-Parallel Processes in Mud-Dominated Depositional Systems through Seismic Stratigraphic Mapping of Contourite Drifts: Newfoundland Ridge, Offshore Canada*

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Abstract

Down-slope processes have long been considered the primary control on deep-sea sedimentation. More recently the contribution of slope-parallel processes in deep-sea sedimentation have been highlighted. Slope-parallel processes, such as bathymetric contour parallel currents driven by thermohaline forcings, are capable of reworking and depositing significant volumes of oceanic sediment in mud-dominated accumulations known as contourite drifts. Forcings controlling deposition vary in intensity and focus through time with a record of these dynamics being recorded in the morphologic character of the drifts.

The J-Anomaly and Newfoundland Ridges, offshore eastern Canada, intersect the Deep Western Boundary Current (a slope-parallel current), providing the necessary conditions for significant and long-lived deposition of contourite drifts. A grid of 56 2-D seismic-reflection profiles combined with nine drill sites from IODP Expedition 342 facilitates the ability to link seismic-scale stratal geometries to a robust chronology and information about sediment character. This integrated dataset affords the ability to map the volumetric sediment distribution of these drifts and hence the dynamics of the Deep Western Boundary Current through time, providing insight towards the dynamics involved in slope-parallel depositional systems. Seismic stratigraphic mapping indicates distinct changes in contourite morphologies and depocenters, which are interpreted to reflect changes in current energy and path through time. Seismic facies characteristic of contourite drifts vary from low amplitude transparent reflectors to moderate amplitude concordant wavy reflectors, and are interpreted to reflect changes in current energy. Generating isochron maps identifies lateral shifts in depocenters, with unit thickness on the hundred to thousand of meter scale, which are interpreted to reflect changes in bottom current focus and path. Linking sediment cores to seismic stratigraphic interpretations also enables calculation of volumetric sediment accumulation rates, which more accurately describe contourite depositional history than do linear rates obtained from core alone. Increased understanding of the dynamics involved in mud-dominated depositional systems influenced by the activity of bathymetric contour parallel currents will prove beneficial when developing more accurate depositional models for unconventional hydrocarbon plays.

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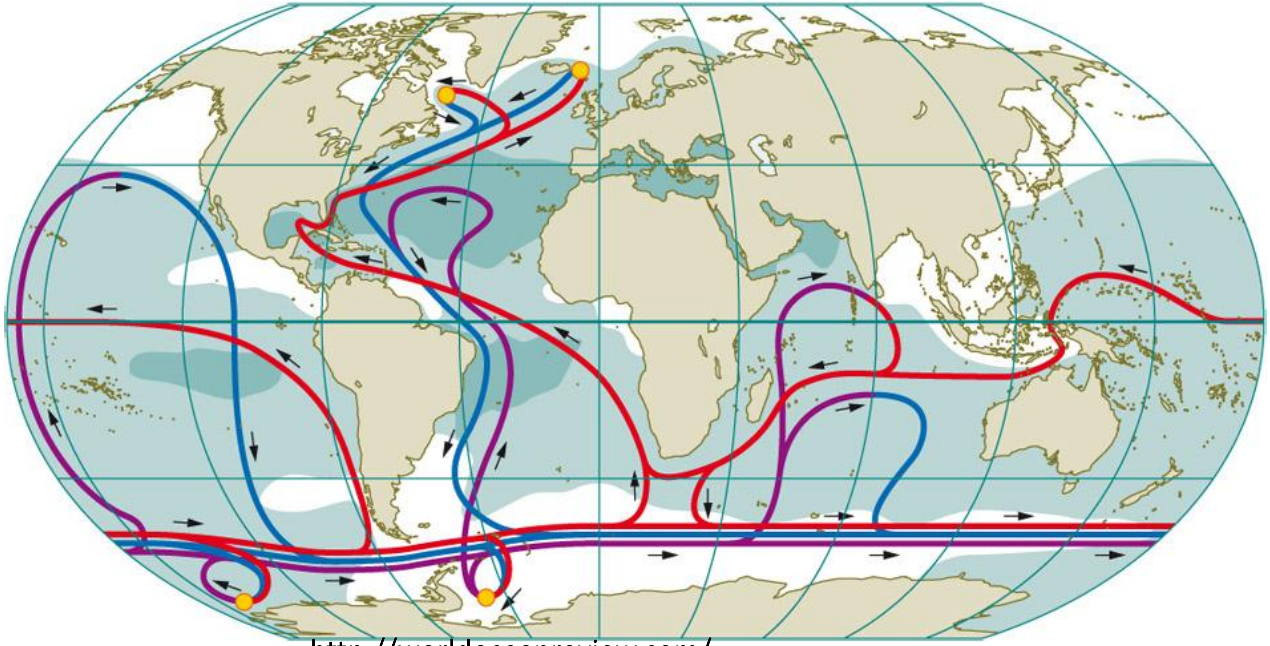
IODP INTEGRATED OCEAN DRILLING PROGRAM

The global climate system and oceanic circulation are intimately connected

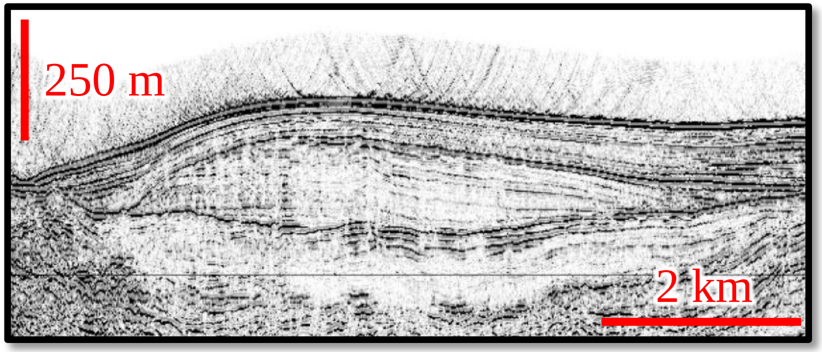


http://worldoceanreview.com/

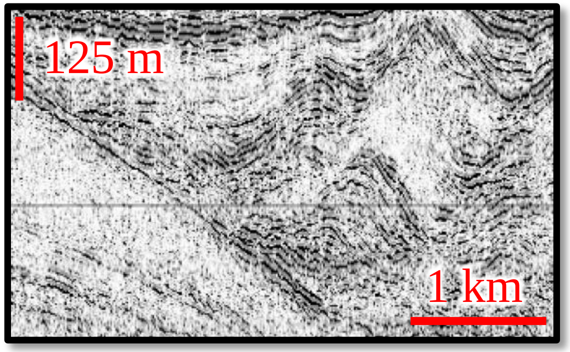
Thermohaline Circulation: the portion of global oceanic circulation driven by density gradients caused by fluctuations in ocean water temperature and salinity

Bottom Current: deep-water semi-permanent current formed by thermohaline or major wind driven circulation (Deep Western Boundary Current)

Sedimentary drifts deposited by oceanic currents display morphology and character related to their evolution

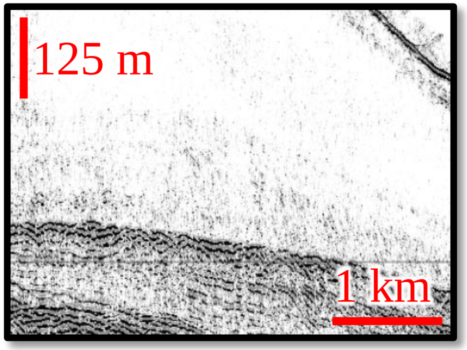


<u>Contourite drift</u>: slope parallel sedimentary body deposited by or significantly affected under the influence of bottom currents.

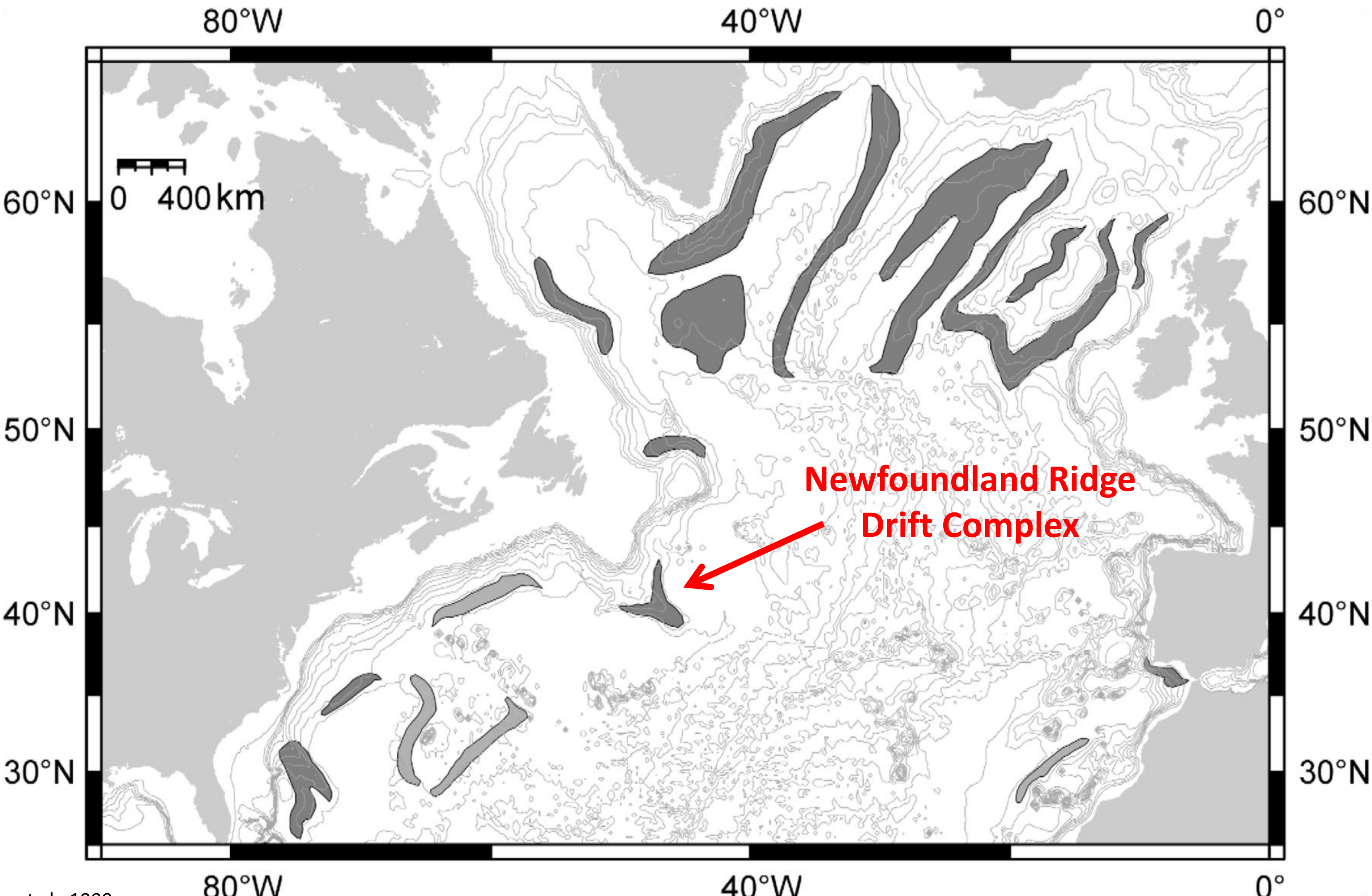


<u>Identification Criteria</u>:

1. Mounded morphology
2. Up-slope migration
3. Basal unconformity
4. Seismic facies (ex. transparent)
5. Slope parallel/ down current elongation

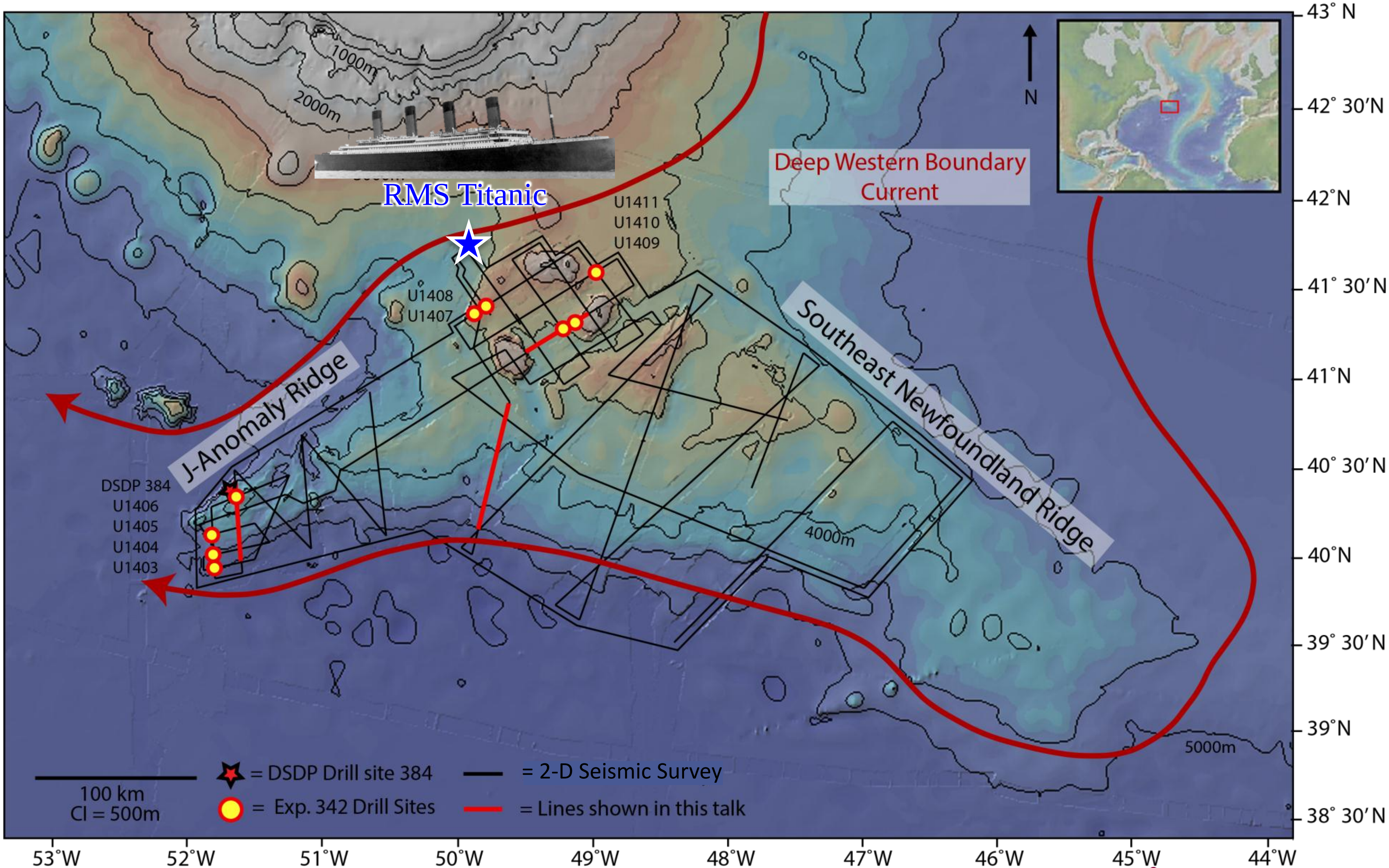


Contourite drifts play a significant role in deep-sea sedimentation and the shaping of continental margins



Faugeres et al., 1999

Conditions over the Southeast Newfoundland and J-Anomaly Ridge are ideal for long-lived deposition of contourite drifts



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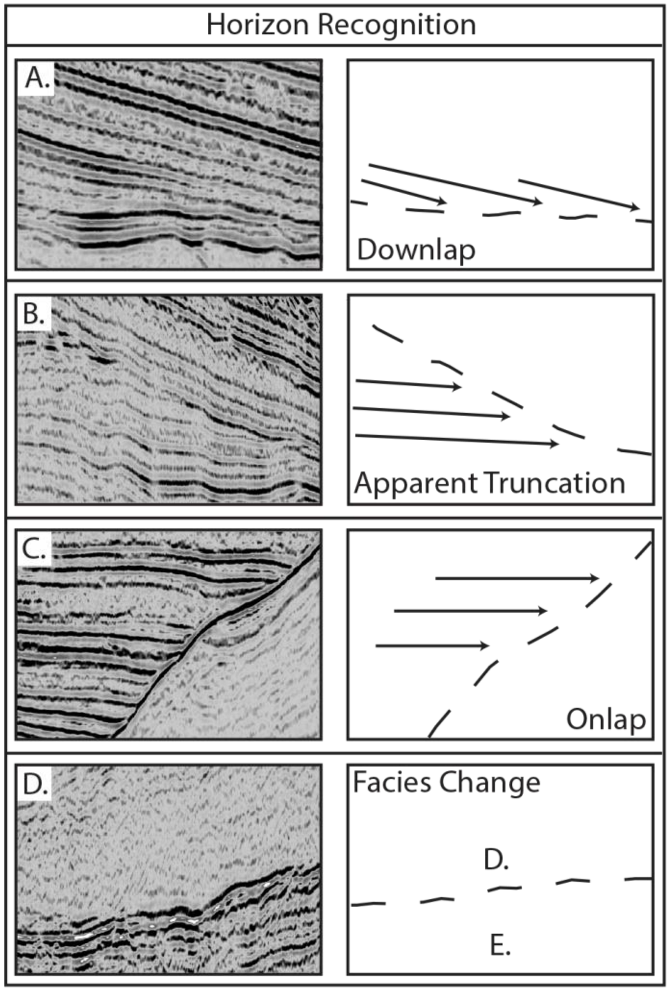
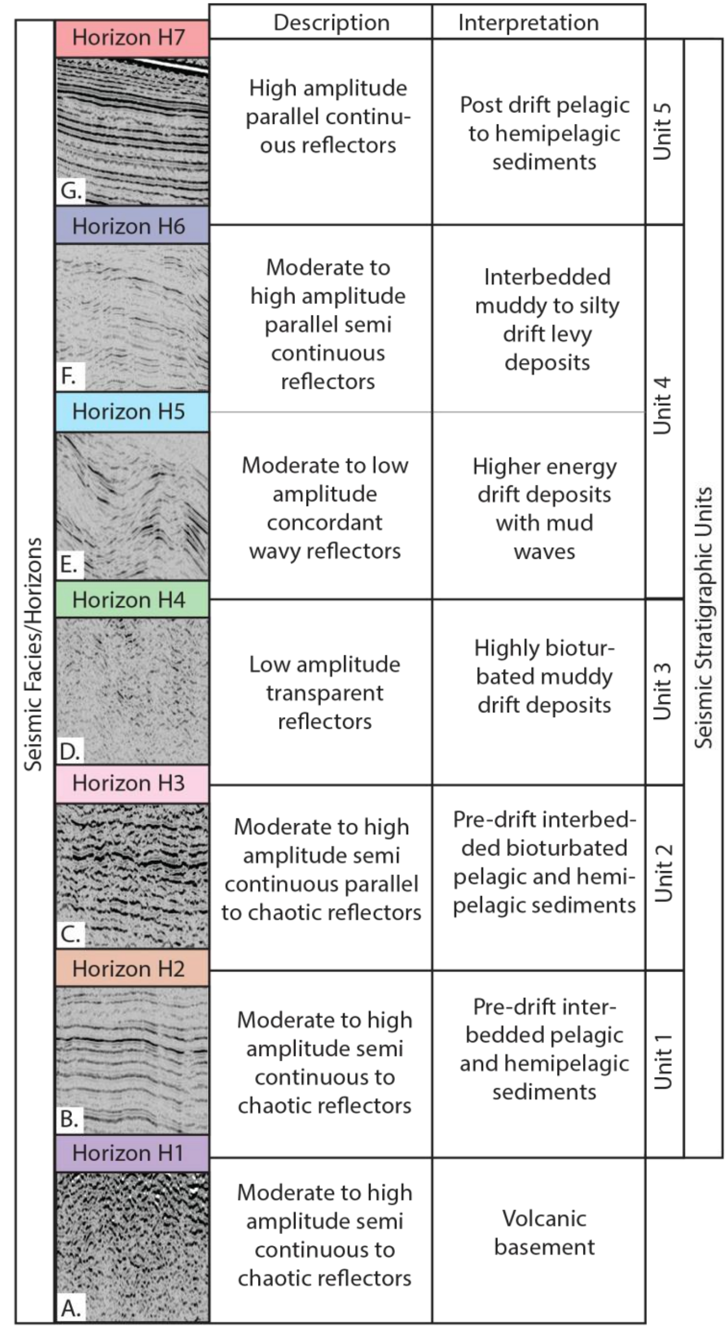
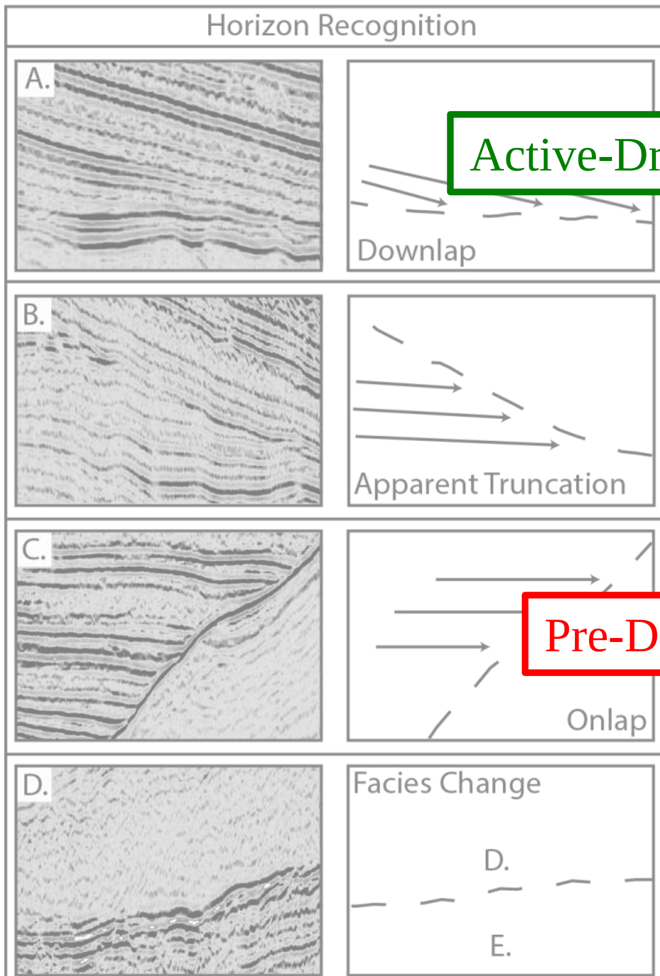
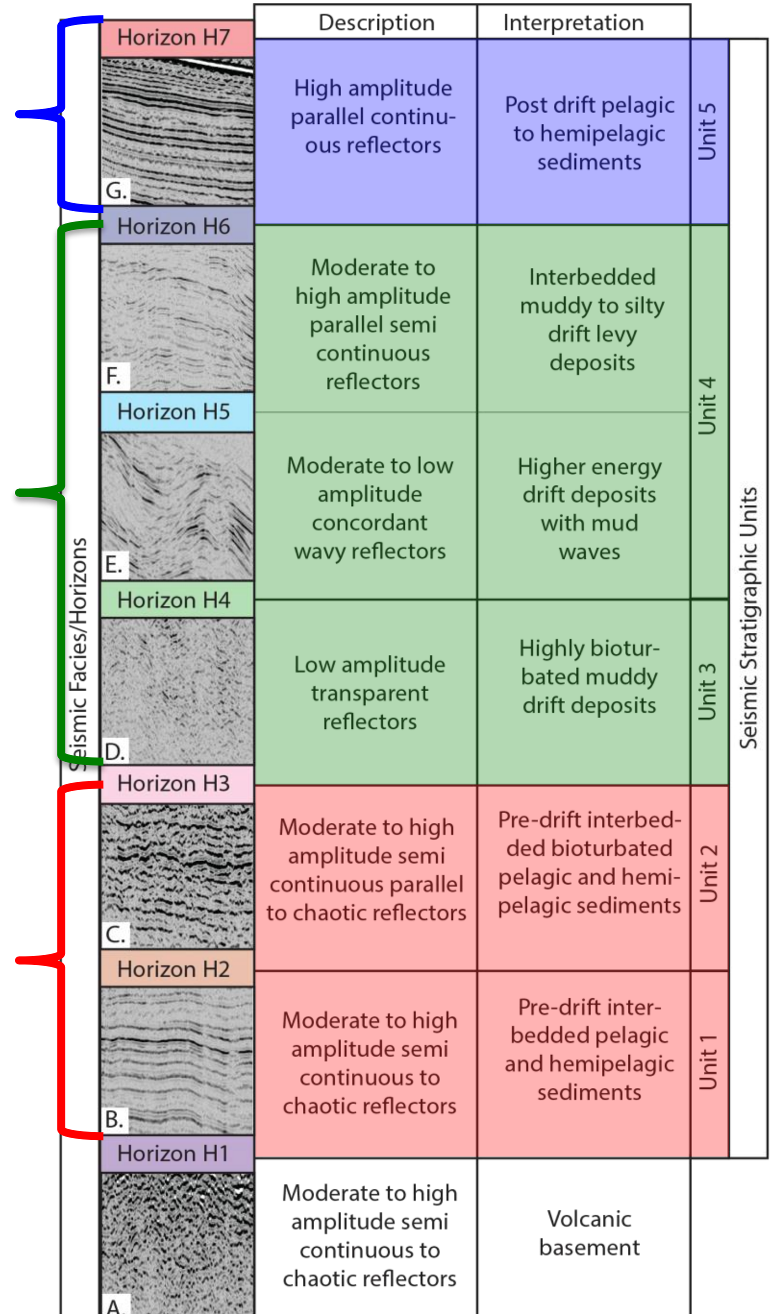
Seismic stratigraphic mapping identifies distinct changes in contourite drift morphology





Seismic stratigraphic … identifies distinct changes in contourite drift morphology

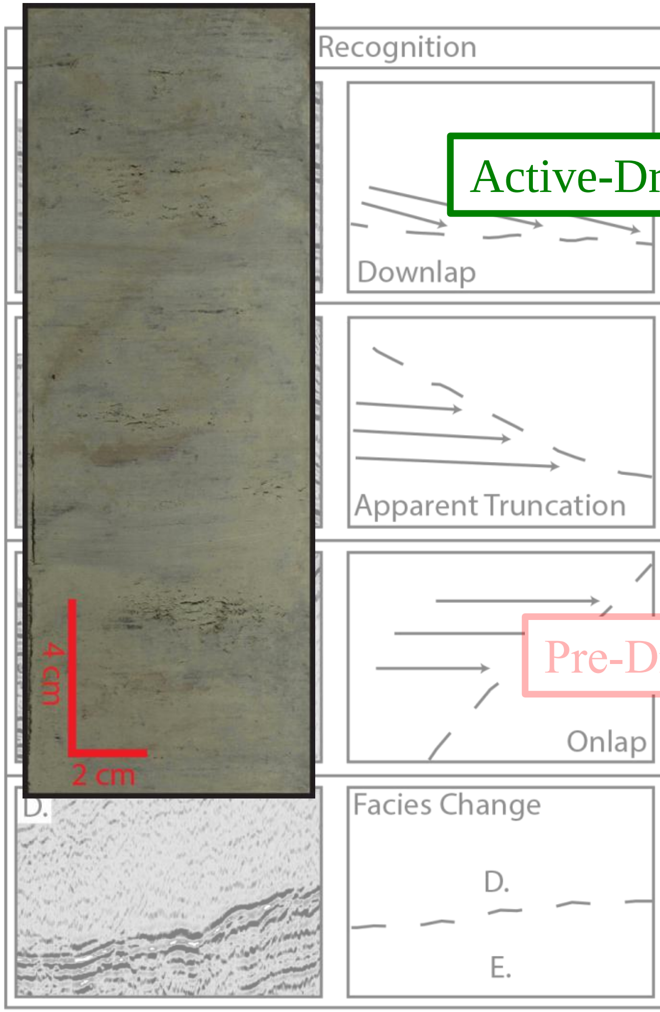




Seismic stratigraphic r… identifies distinct changes in co… ft morphology

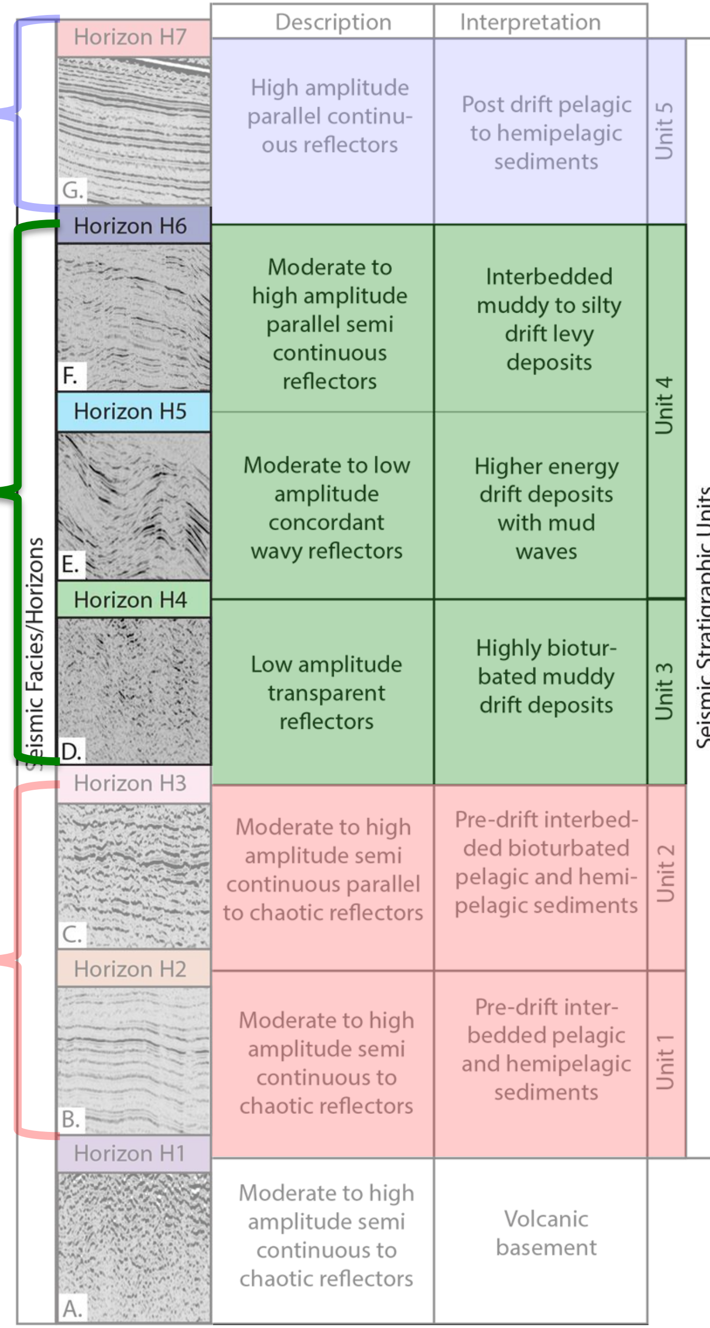
Post-Drift Phase

Site U1404A
(Exp. 342)



Active-Drift Phase

Pre-Drift Phase



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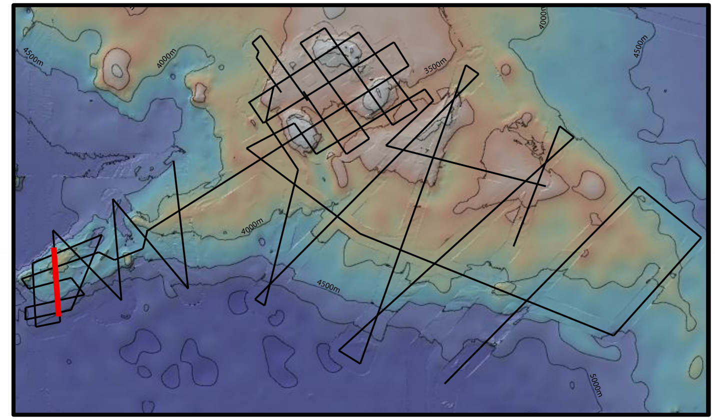
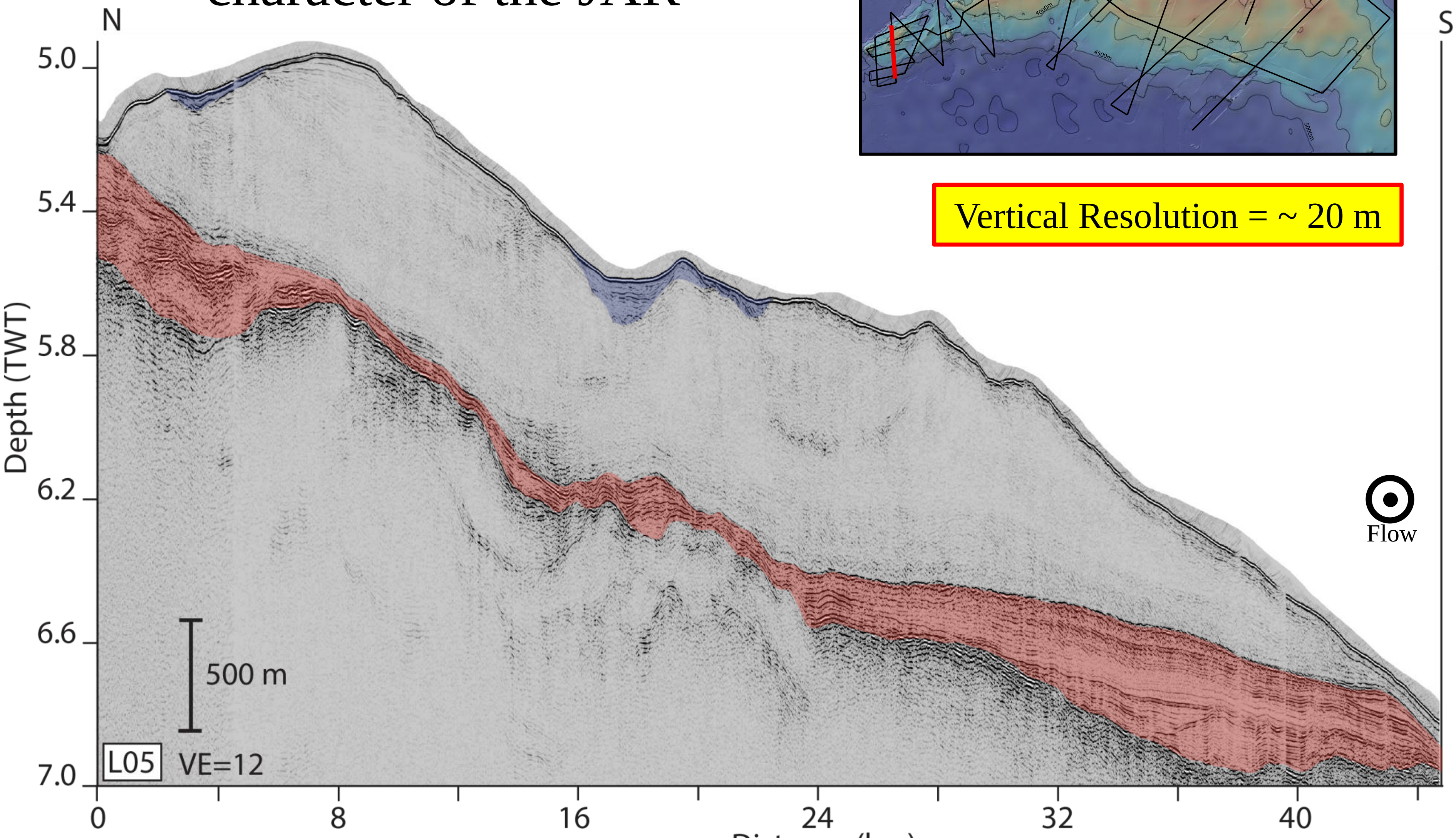
Seismic reflection profile L05 displays representative seismic character of the JAR





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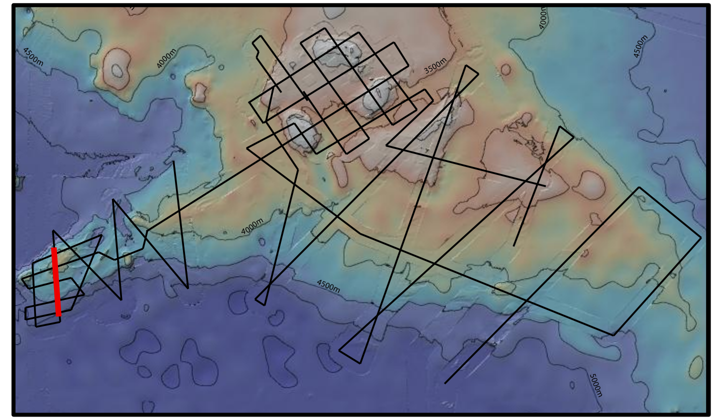

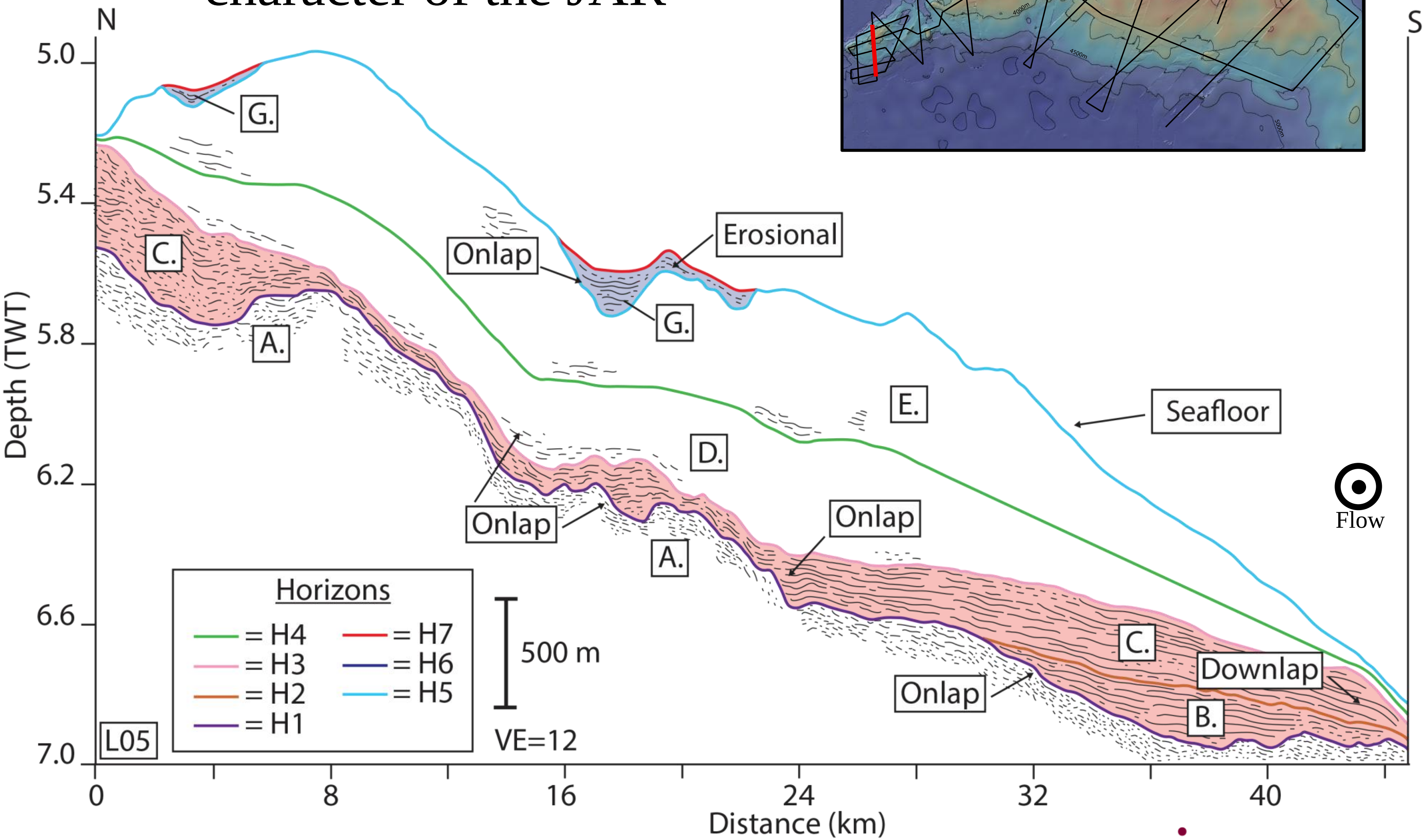

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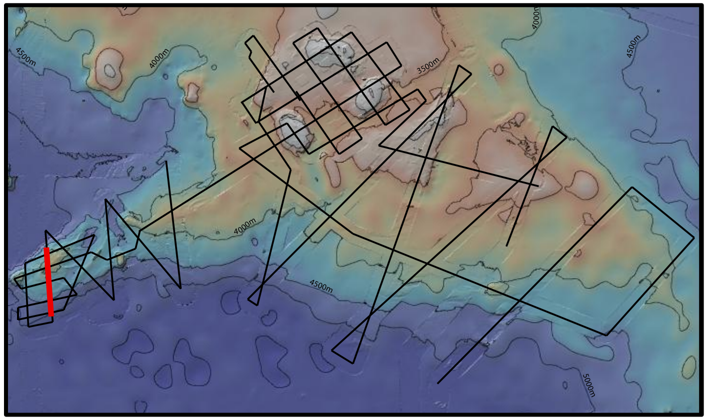

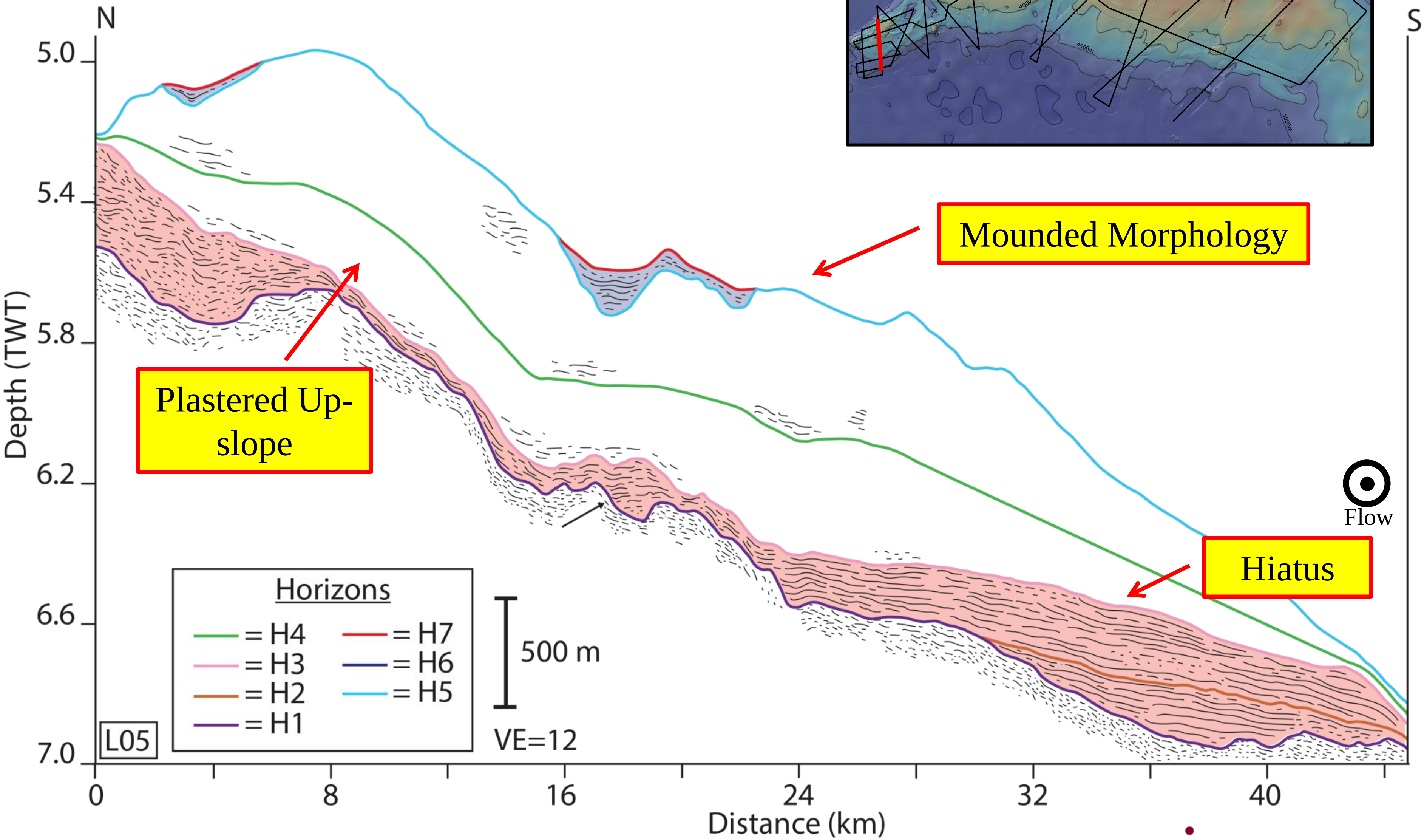

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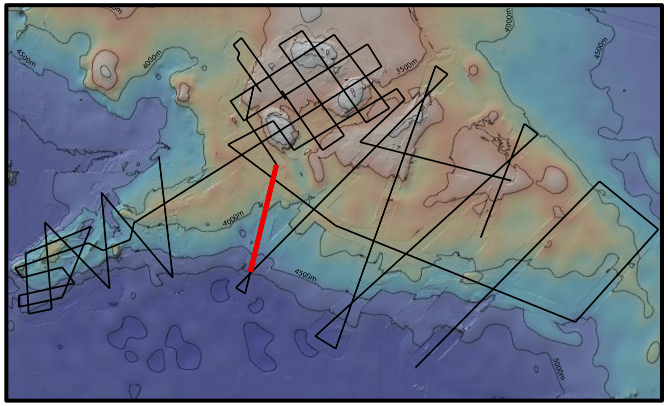
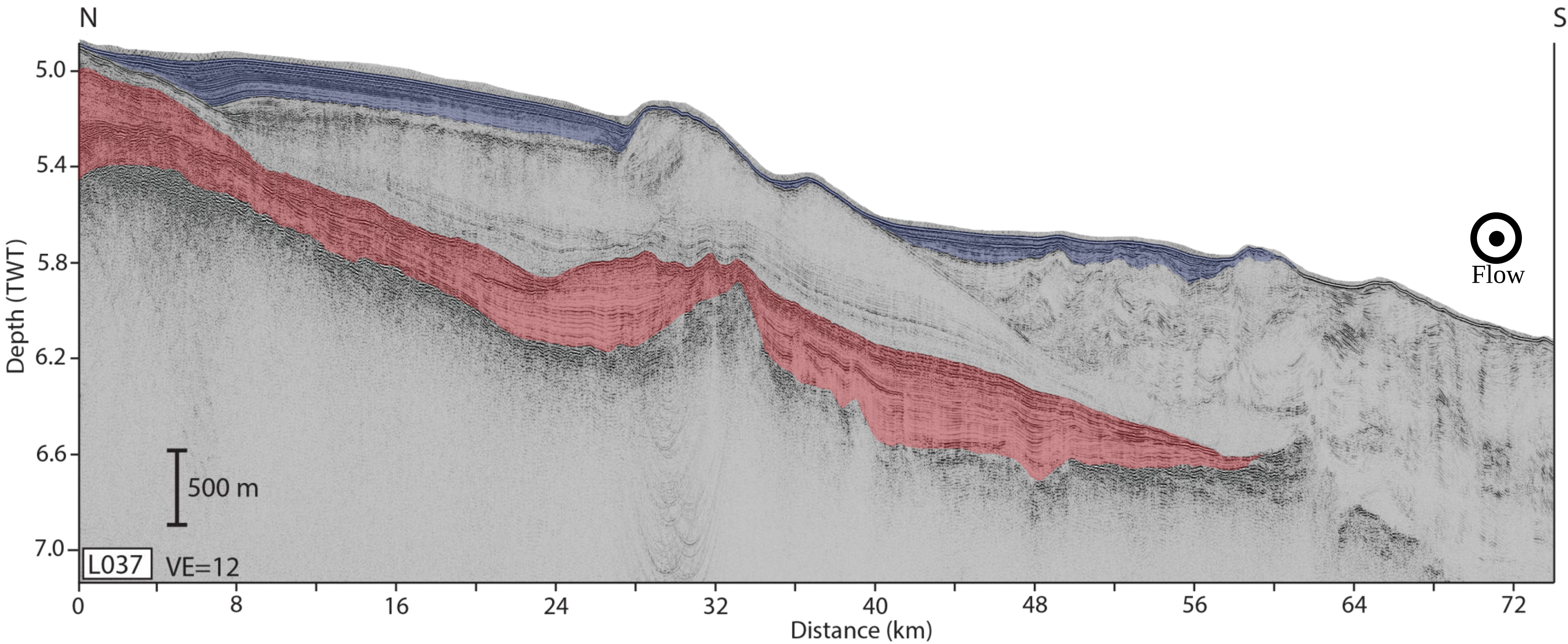
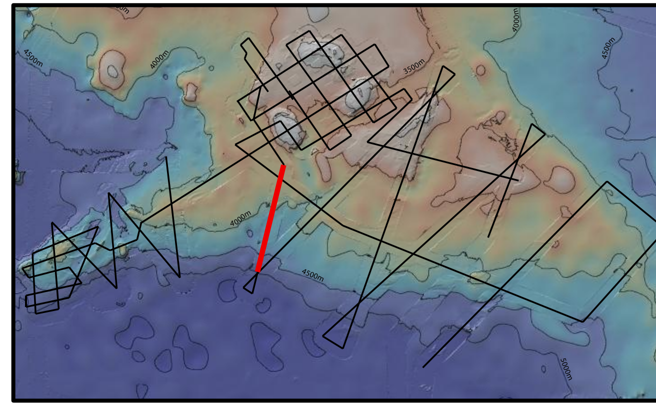
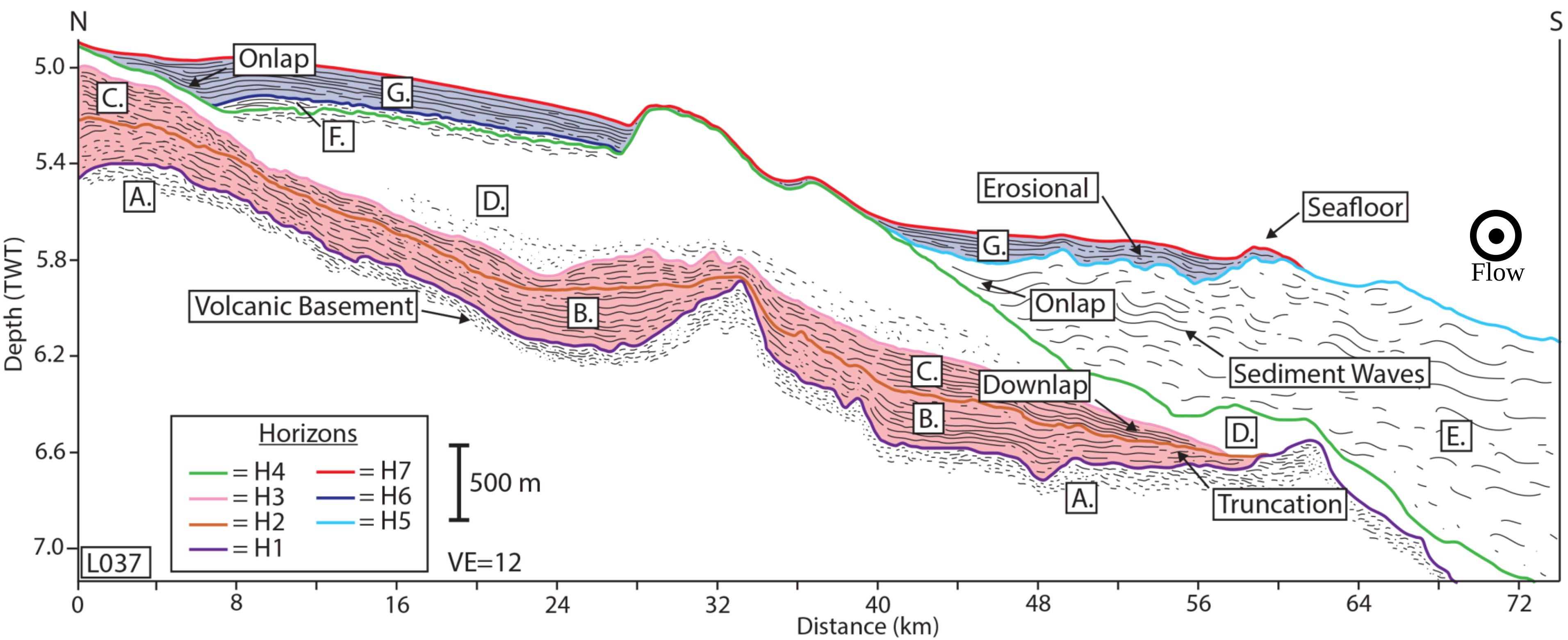
Seismic reflection profile L037 displays representative seismic character of the SENR





Seismic reflection profile L037 displays representative seismic character of the SENR





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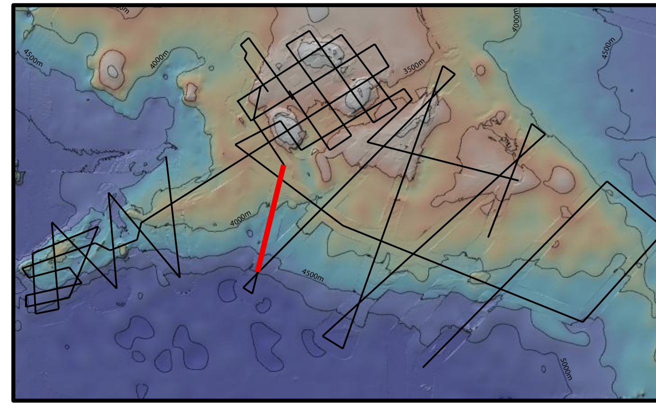

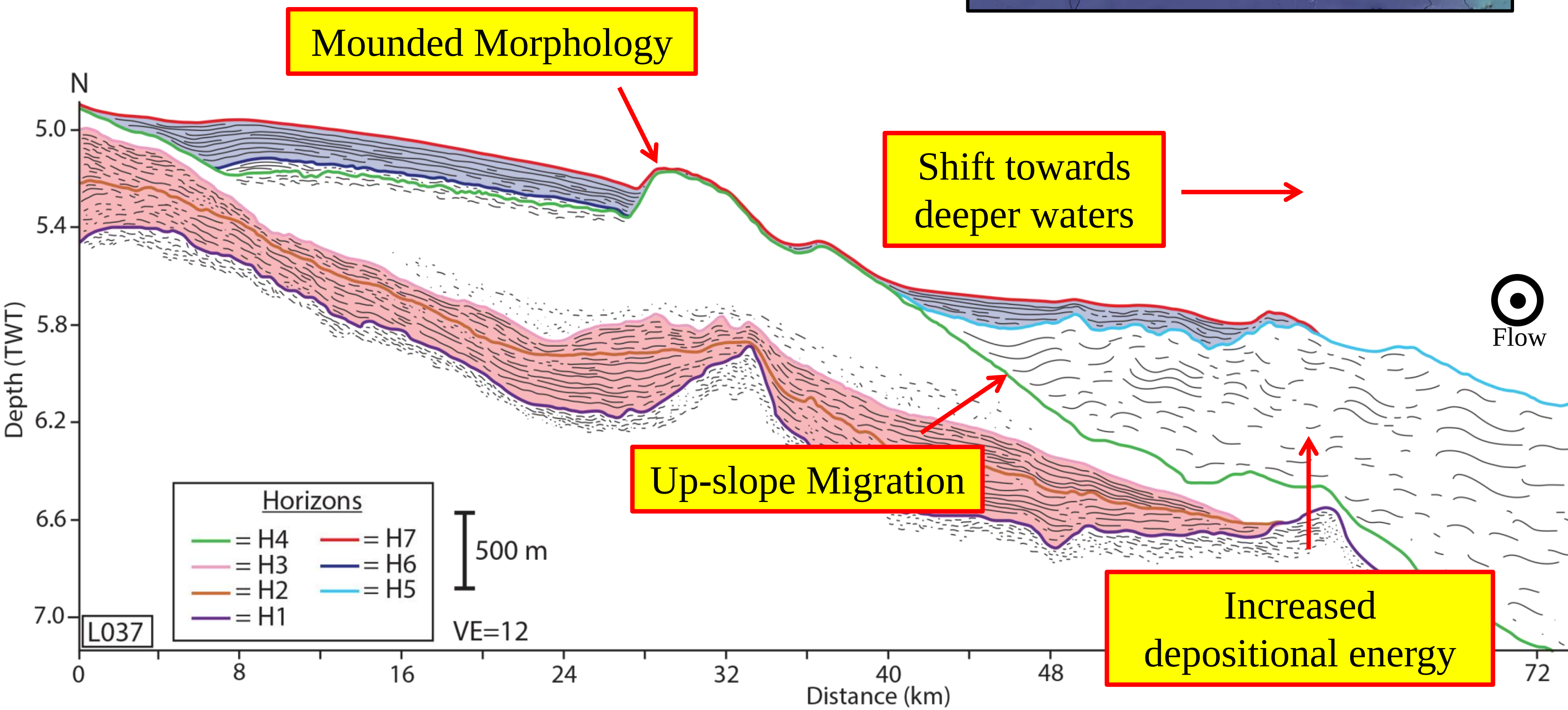

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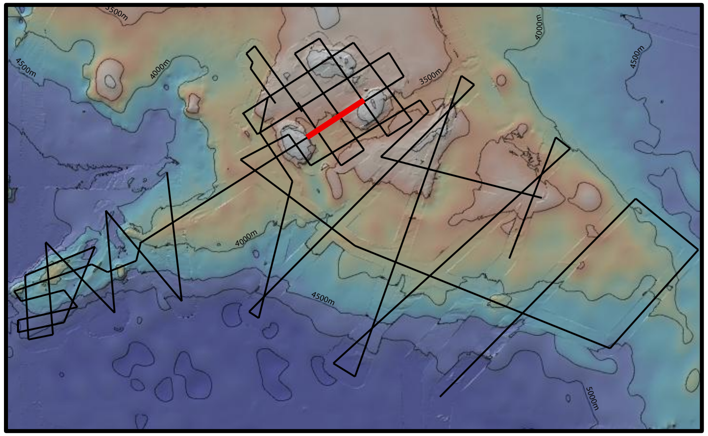
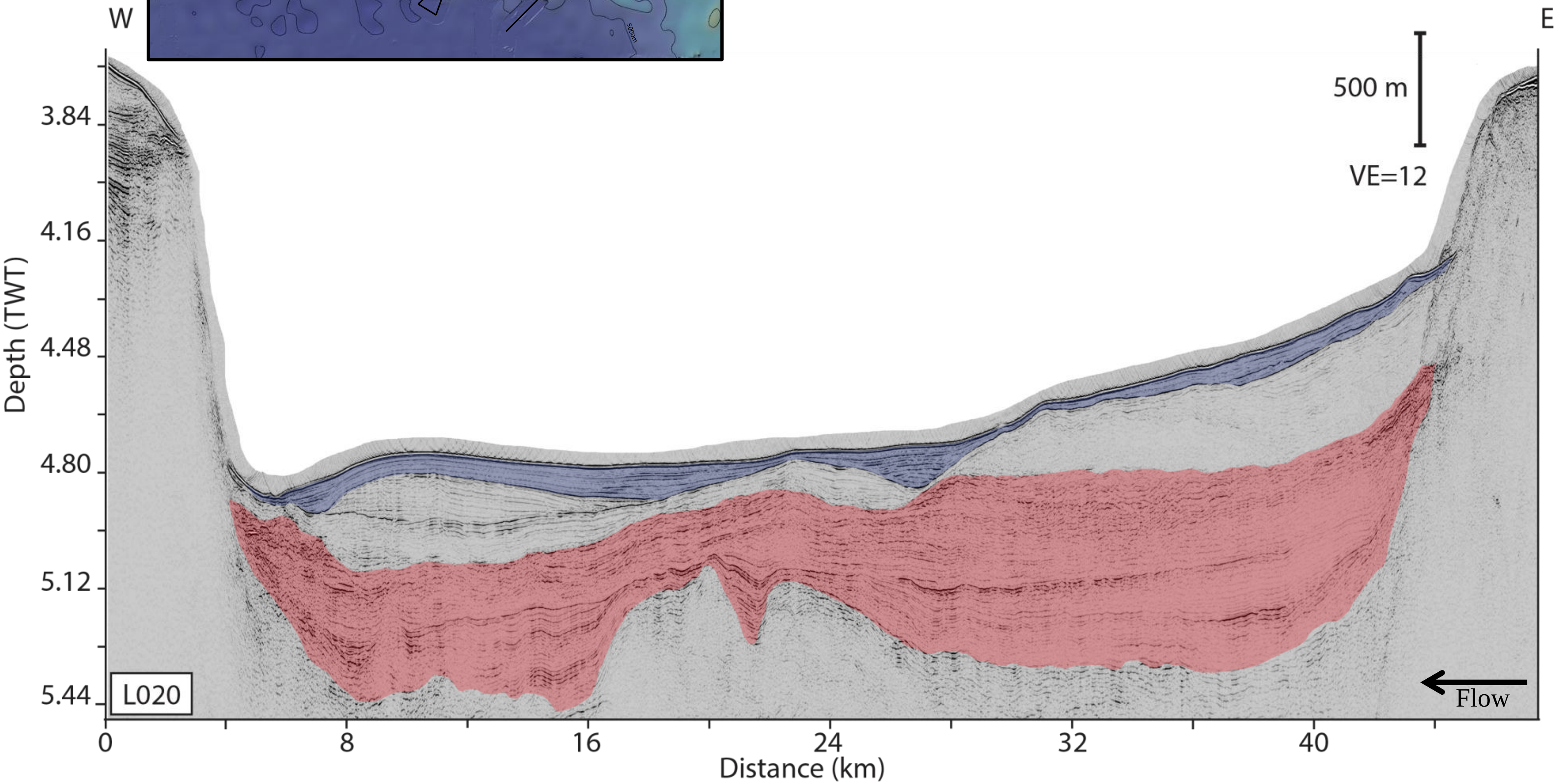
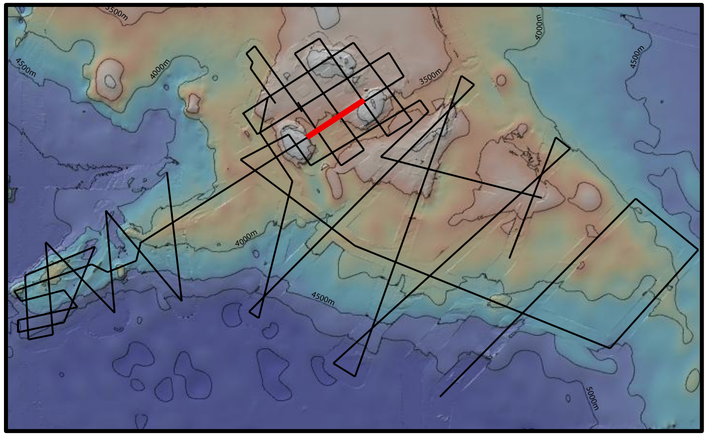
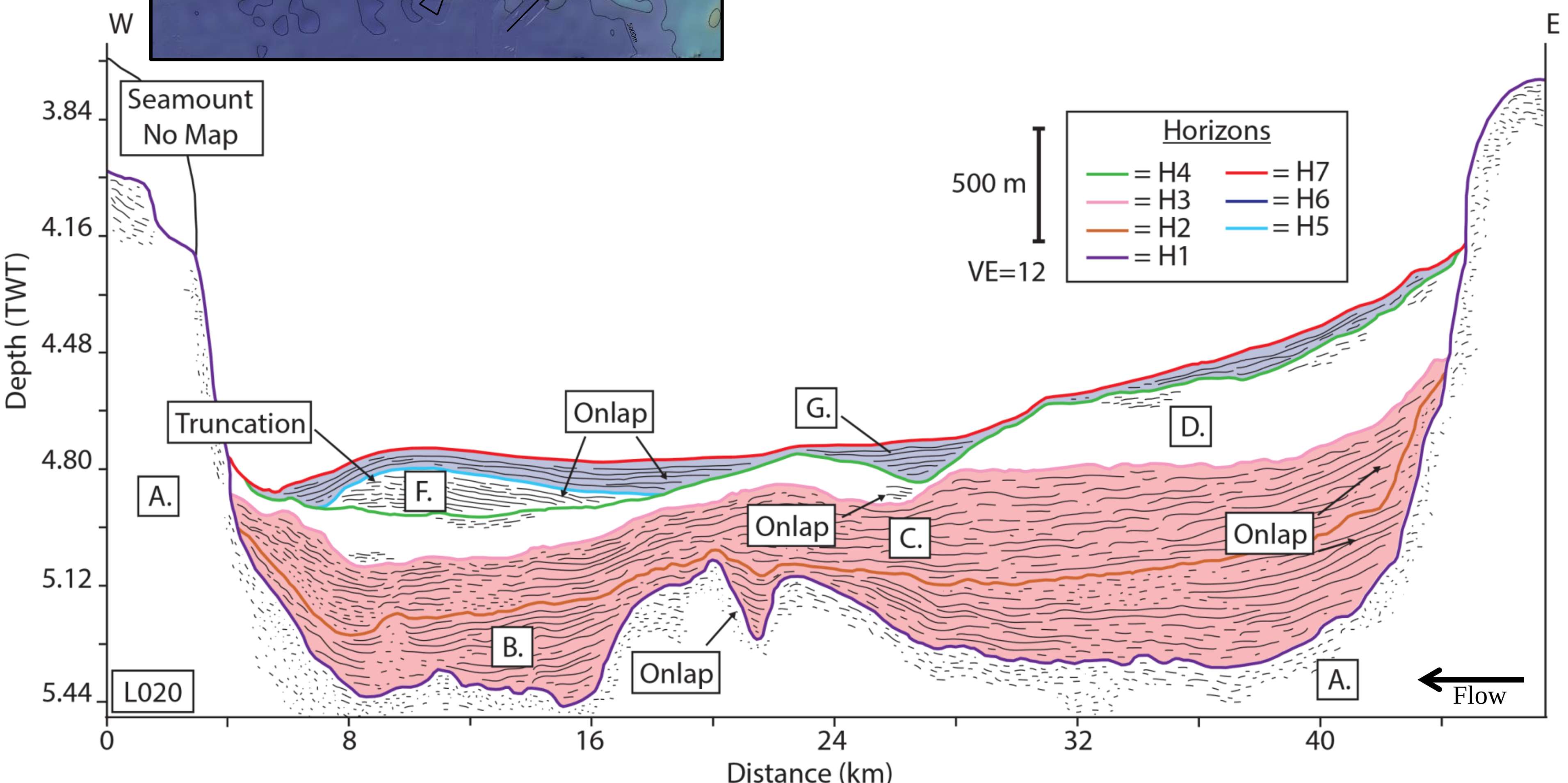
Seismic reflection profile L020 displays representative seismic character in close proximity to the SENR seamounts





Seismic reflection profile L020 displays representative seismic character in close proximity to the SENR seamounts





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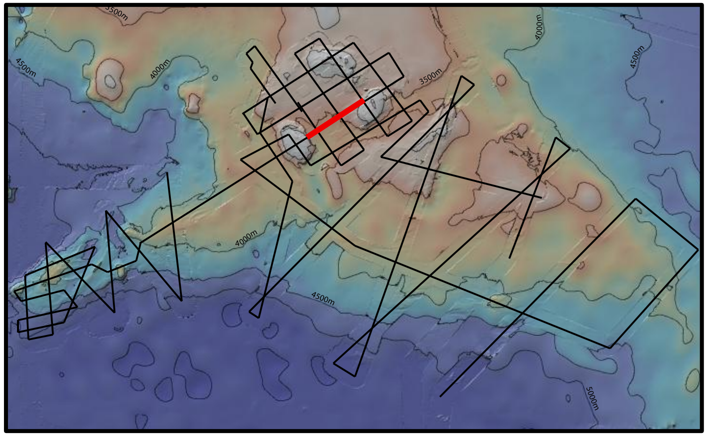
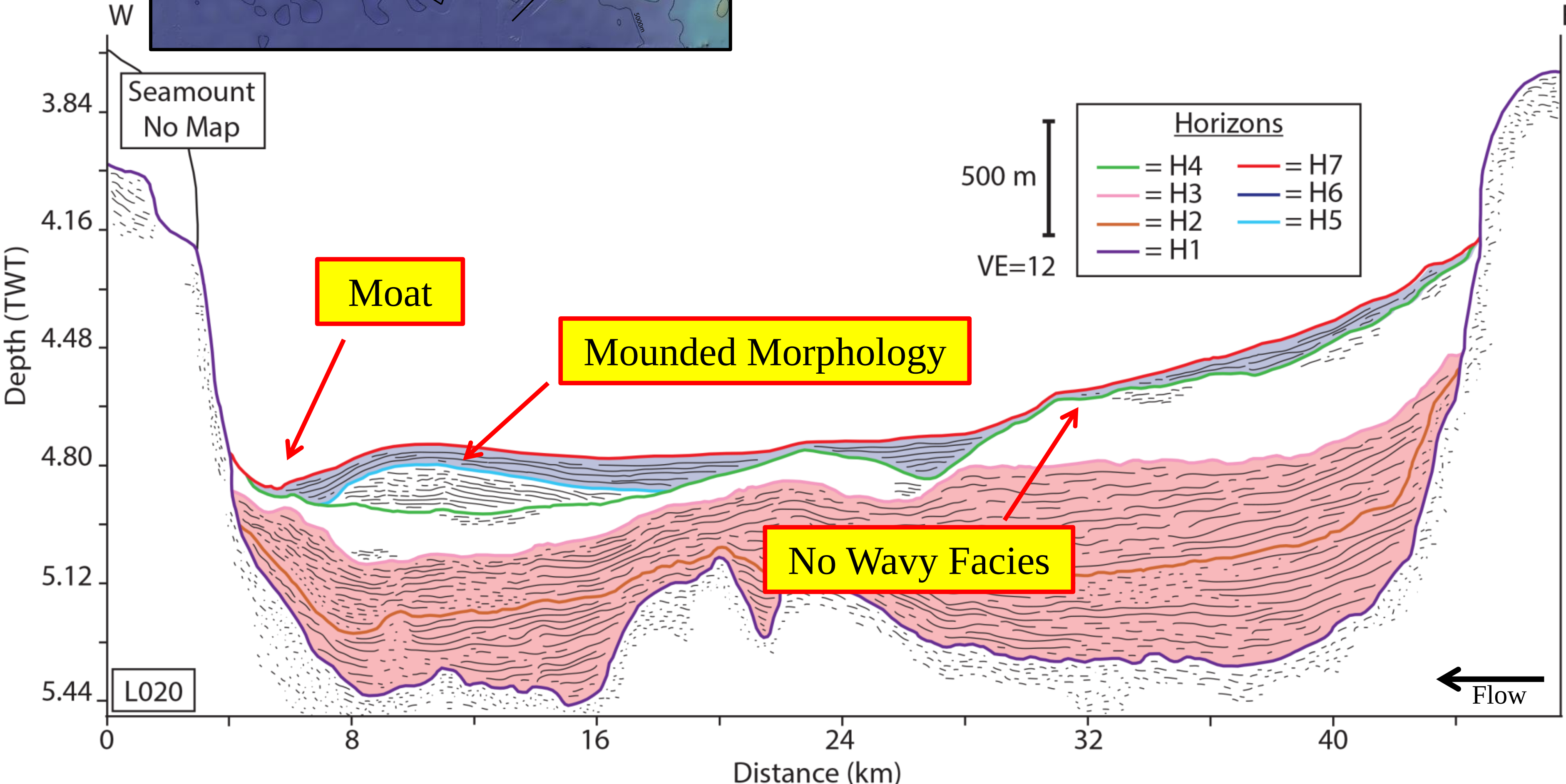
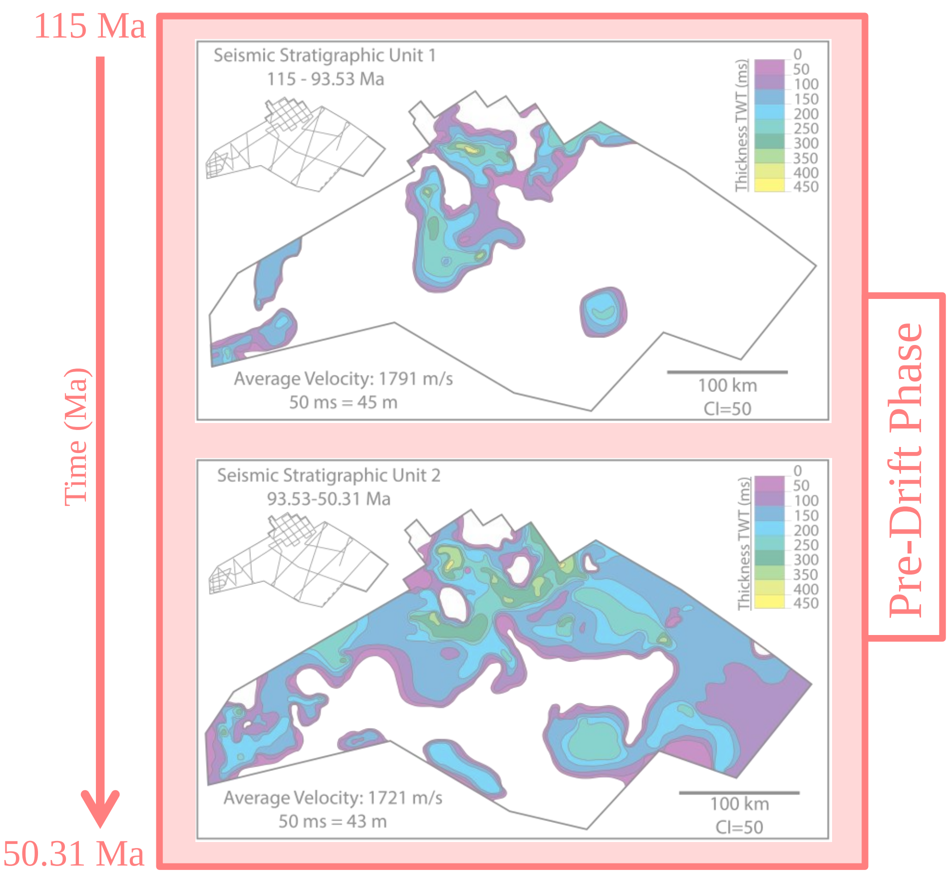
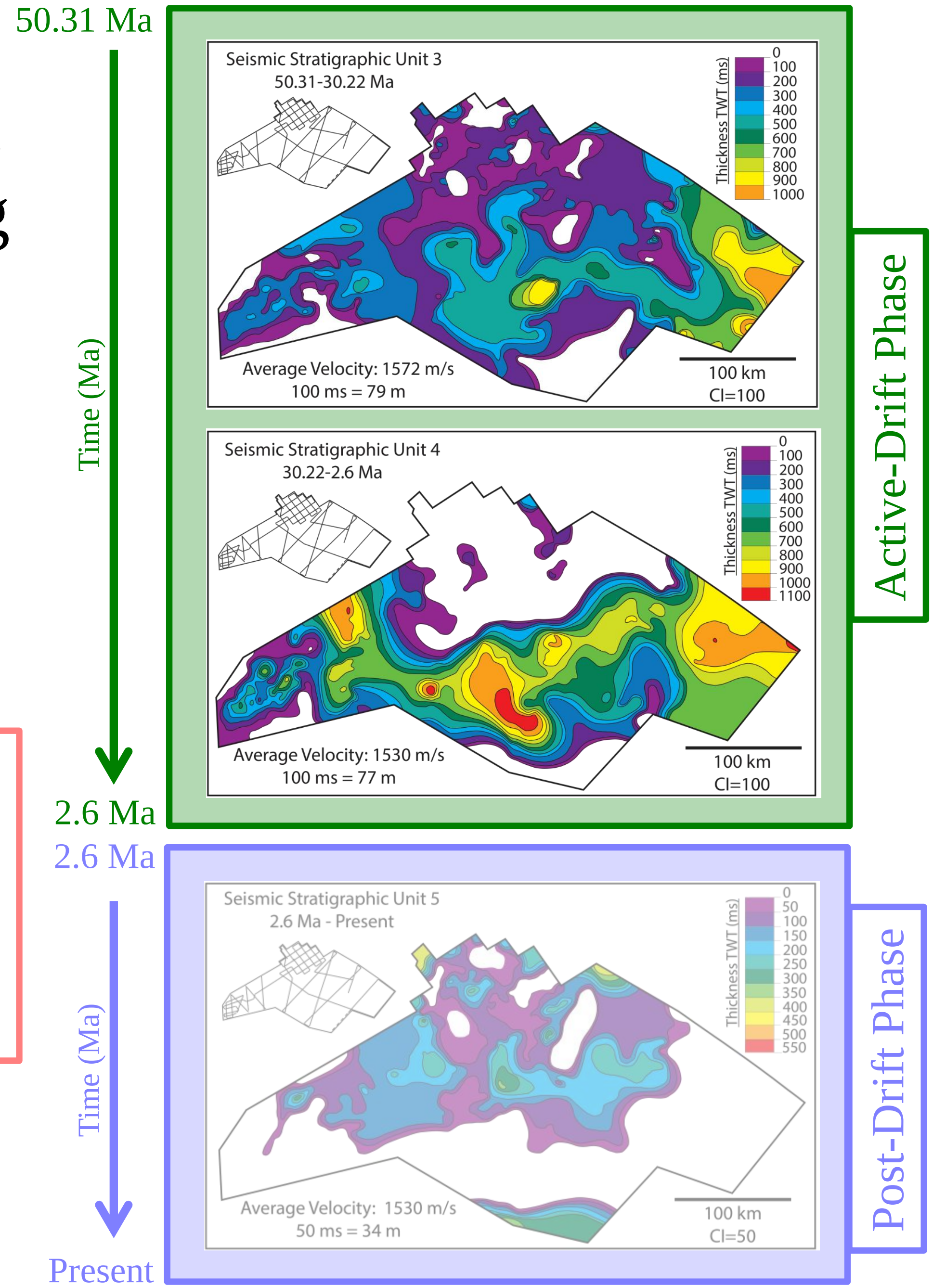




Isochron mapping provides a more complete understanding of contourite drift evolution





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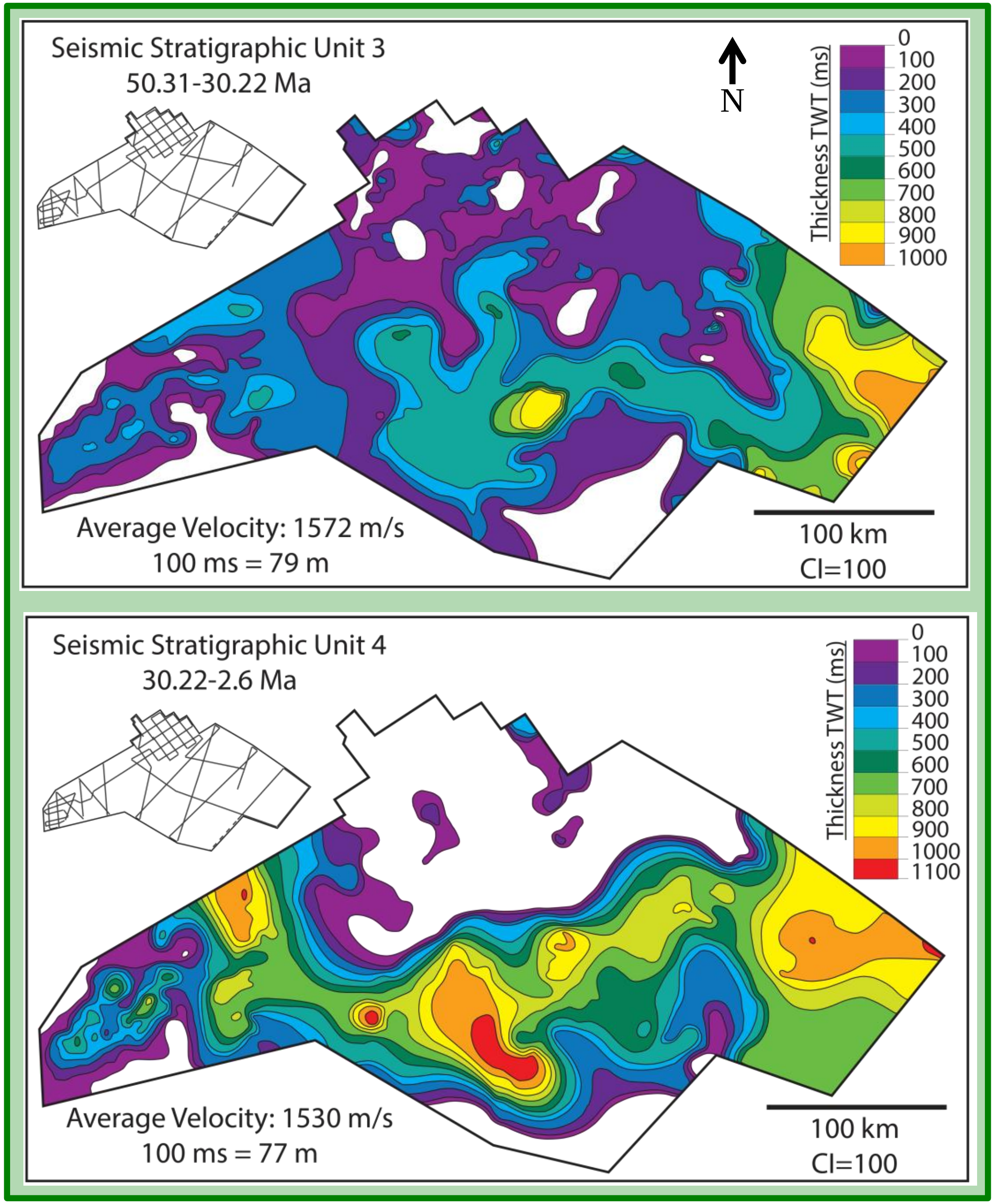
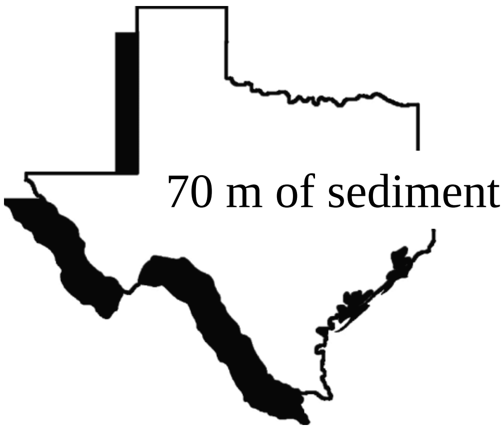


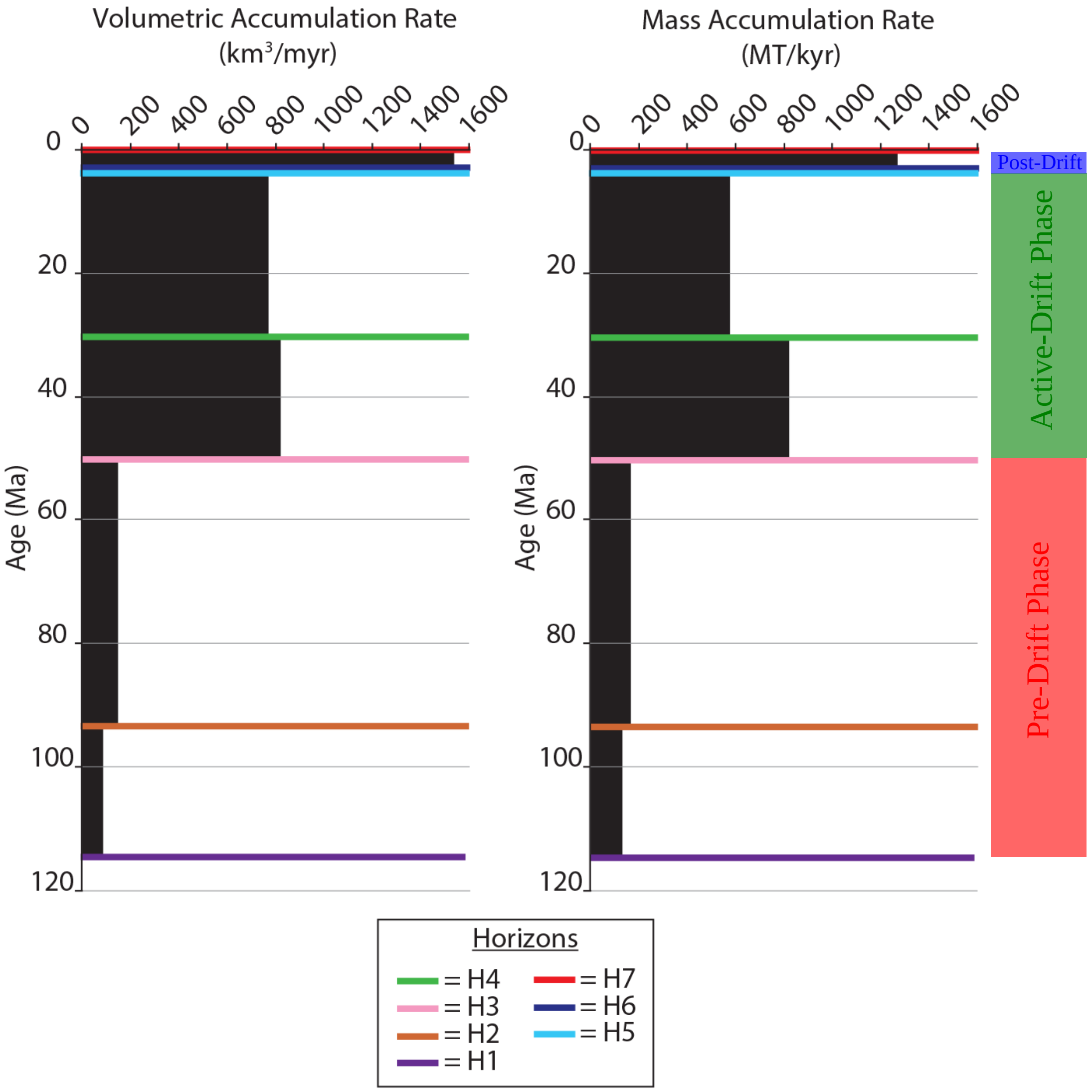
Active-Drift Phase sedimentation

- Points of maximum accumulations are located in the southern half of the study area
- Sedimentary thickness reaches a thickness up to 1100 ms (TWT) (~850 m)
- Display mounded, elongate, slope parallel morphology
- Deposition focuses into a well defined belt from Seismic Stratigraphic Unit 3 to Seismic Stratigraphic Unit 4

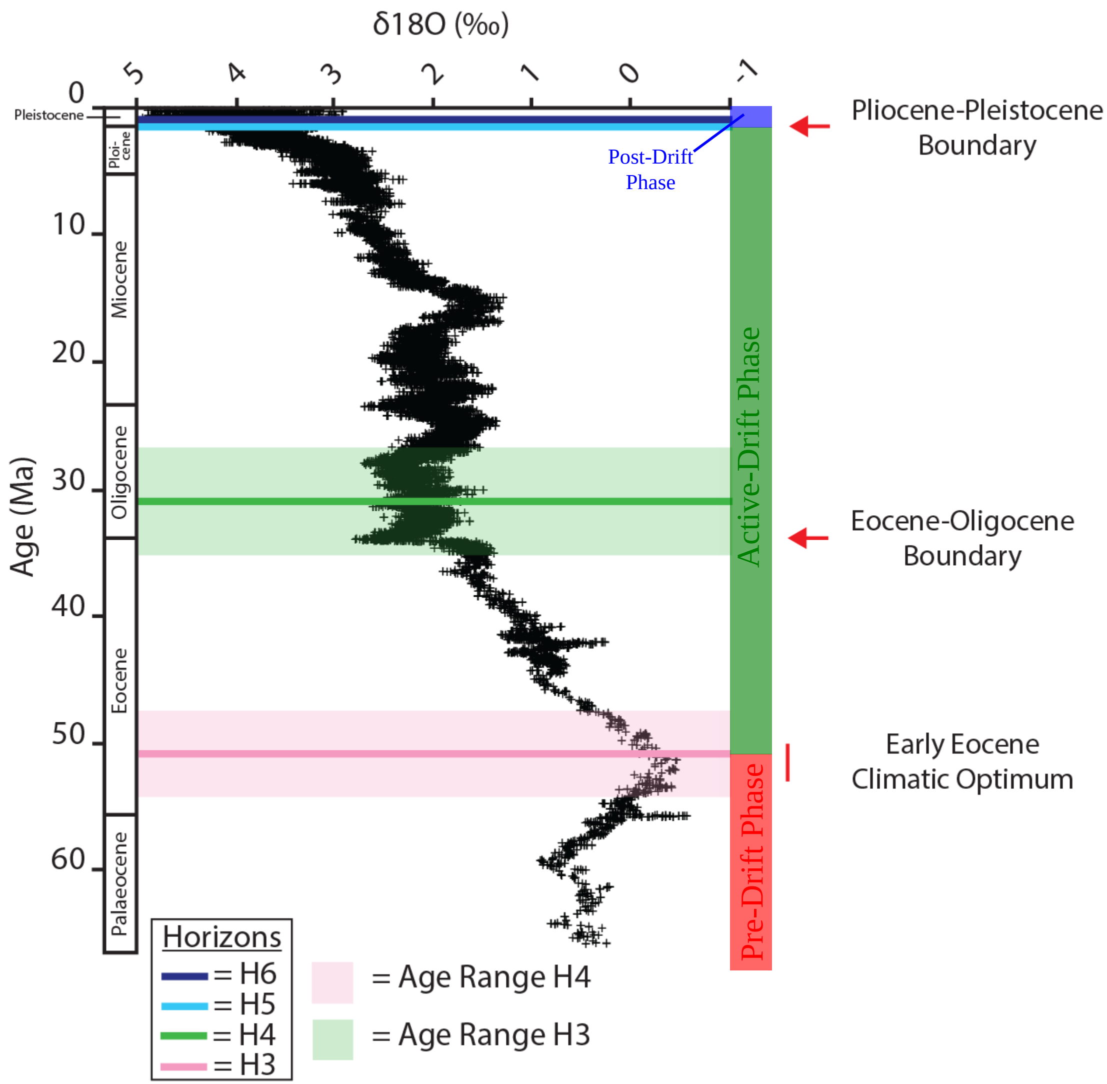
Volumetric and mass accumulation rates respond to the dynamic evolution of bottom-current controlled systems

- Horizon H3 marks the onset of drifts accumulation
- Above Horizon H3 there is ~5 fold increase in volumetric accumulation rate
- Above Horizon H4 there is a ~7 % decrease in volumetric accumulation rate





How do our seismic stratigraphic interpretations correlate to Cenozoic climatic and tectonic events?



Onset of Northern Hemisphere ice sheets and closing of the Isthmus of Panama

Onset of Southern Hemisphere ice sheets and the opening of southern ocean gateways (i.e. Tasmania-Antarctic Passage)

End of the early Eocene Climatic Optimum, and the beginning of a global cooling trend

Zachos et al., 2008

What drives the dynamics of contourite systems?

- **Bathymetry of depositional site**
  - What role do volcanic and sedimentary bathymetric features play?
- **Global temperature**
- **Tectonic forcings**

This study

- Sea level fluctuations
  - How do these systems respond to eustatic fluctuations?
- Supply of sediment
  - How do changes in the quantity, composition, and availability of sediment influence the formation of contourite drifts?
- Ocean chemistry
  - Is the Carbonate Compensation Depth (CCD) affected by thermohaline forcings?
- Interaction between currents
  - How do these systems responded when oceanic currents interact?

Takeaways

1. Sedimentary systems deposited under the influence of oceanic currents are complex. **Contourite drifts are not simple mounds of sediment.**

1. The ability for thermohaline circulation to rework and deposit deep-sea sediment is not restricted to contourite drift systems. **Oceanic currents have the potential to interact with all marine sediment.**

1. Forcings that interact with marine sediment evolve through geologic time, with an archive of this evolution being recorded in the sediments of contourite drifts. **Deciphering the history of contourite drift systems leads to an increased understanding of continental margin dynamics.**

Acknowledgements

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Virginia Tech Geosciences

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