Comparison of Intrabasinal and Extrabasinal Turbidites in Glacial Lake Systems

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Abstract

Turbidites are distinctive fining upward sedimentary sequences caused by density flows in water-based environments (Shanmugam, 1997). While most geologists learn of intrabasinal turbidites, which are caused by seismic and mass wasting events (Shanmugam, 1997), many do not know that similar features can be created from flooding events and are referred to as extrabasinal turbidites (Zavala, 2016). I analyzed two pervious study sites that were impacted by the Cordilleran Ice Sheet, Flathead Lake, MT (Hofmann et al. 2010), and Garden Gulch, MT (Smith 2016), to see if the determined turbidite conclusions matched the criteria established in Zavala et al. (2016). From Zavala et al. (2016), intrabasinal turbidites contain asymmetric ripples, coarse grains, and are geographically isolated, while extrabasinal turbidites have climbing ripples, fine grains, lamination, and are geographically un-isolated. Flathead lake was shown to have asymmetric ripples, fine grain lamination, and geographically un-isolated, while Garden Gulch had climbing ripples, a mixture of grain sizes, and fine grained lamination. Thus, I conclude that both Flathead lake and Garden gulch have extrabasinal turbidites, which agrees with Hofmann et al. (2010), but disagrees with Smith (2017).

Introduction- Turbidites

- **Turbidites** are sedimentary sequences created by turbidity flows (Zavala et al., 2016)
  - Associated with mass wasting and seismic
  - Transports sediment as suspended load (Shanmugam, 1997)
  - Sedimentary sequences = Bouma sequences, fining upward pattern with five distinctive phases (Shanmugam, 1997) (Figure 1)
  - Referred to as **Intrabasinal turbidites**

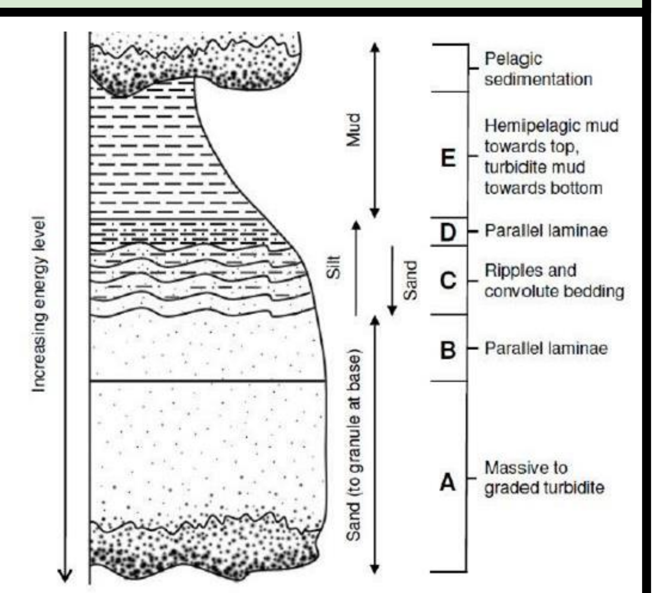


Figure 1: A traditional Bouma turbidite from Bouma's 1962 paper. It is divided into 5 sections, differentiated by the sedimentary characteristics.

- **Hyperpycnites** form from hyperpycnal flows, density differentiations between plume and water (Mulder et al., 1998)
  - Result of outburst or river floods from terrestrial to marine (Zavala et al., 2016) (Figure 2)
  - Referred to as **extrabasinal turbidites**

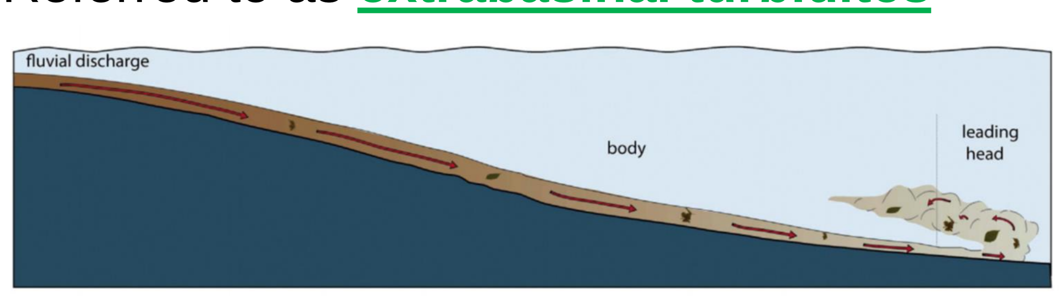


Figure 2: The resulting sediment flow from an outburst flood. Unlike intrabasinal turbidites, the body of the flow is not created from a slump, thus leading to a more even distribution of sediment. (Zavala et al., 2016)

- Hyperpycnites are often incorrectly referred to as turbidites due to their sedimentary similarities
  - Similar, but produced by different processes

Question

What are the distinguishing sedimentary characteristics between intrabasinal and extrabasinal turbidites in glacial lake systems?

Background- Study sites

- The Cordilleran Ice Sheet (CIS) covered Washington to Northwestern Montana during the Quaternary glacial period (Figure 3) (Booth et al., 2003)
  - Several lobes would periodically retreat = glacial outburst floods (Hofmann et al., 2010)

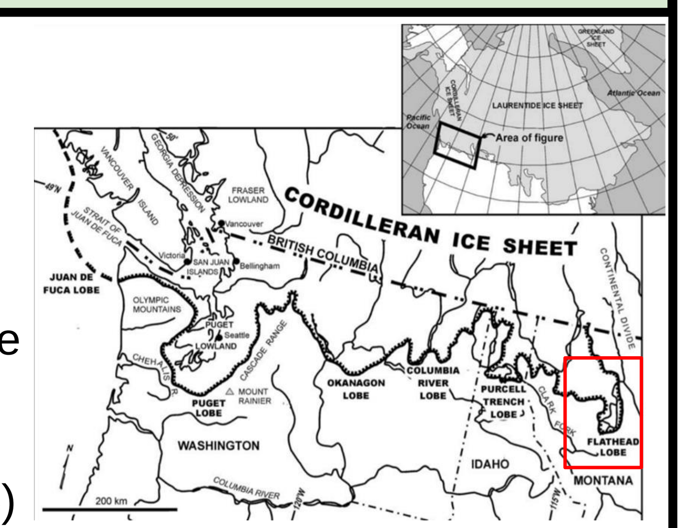


Figure 3: The Cordilleran Ice Sheet and its various lobes imposed over the modern day Western USA. The Flathead Lobe is boxed (Hofmann et al., 2010)

- Flathead Lake, MT was created by the CIS Flathead Lobe (Hofmann et al., 2010)
  - **Hofmann et al. (2010)** determined sedimentary structures = extrabasinal turbidites
- Garden Gulch, MT was impacted by outbursts from Glacial Lake Missoula of the CIS
  - **Smith (2017)** determined sedimentary structures = intrabasinal turbidites

Methods

Literature Analysis:

- Utilize Zavala et al. (2016) for distinctive sedimentary characteristics of intrabasinal and extrabasinal turbidites (Figure 4)

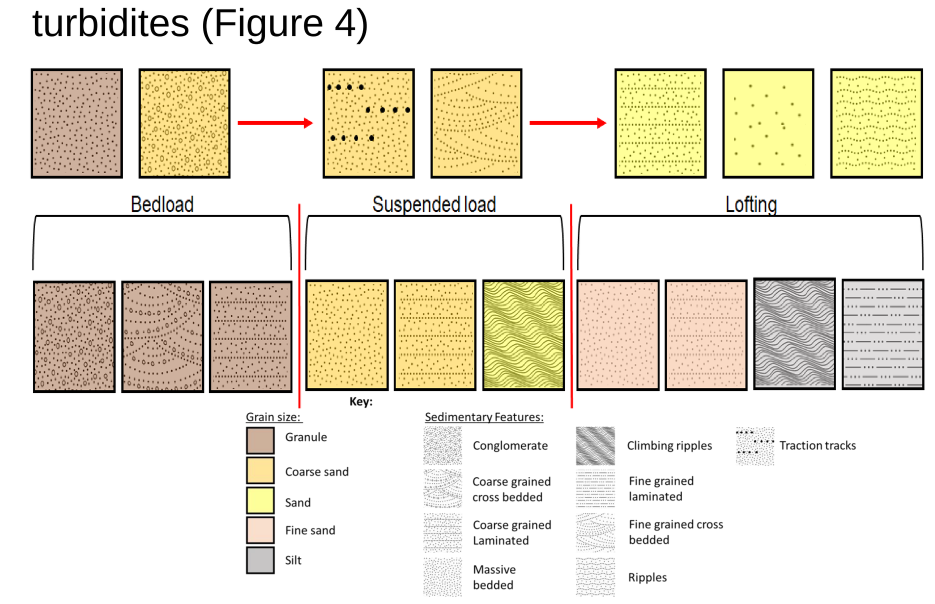


Figure 4: The resulting sedimentary structures of intrabasinal (top) and extrabasinal (bottom) turbidites. Grain sizes and sedimentary structures are defined in the included key. Figure adapted from Zavala et al. (2016).

- Analyze sedimentary results from 19 Flathead Lake piston cores from **Hofmann et al. (2010)**, and outcrop analysis of Garden Gulch from **Smith (2017)**
- **Criteria from Zavala et al. (2016):**

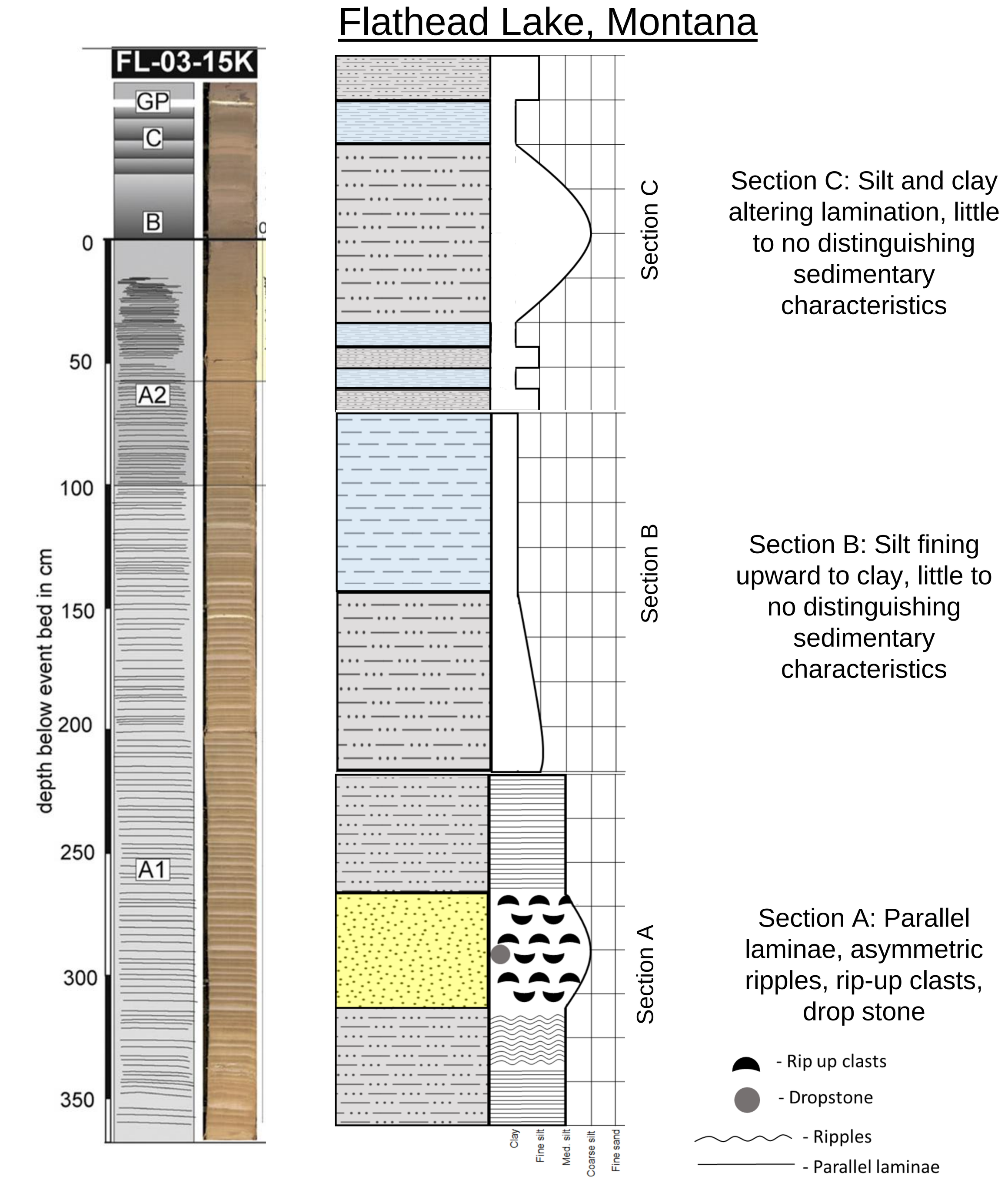
Intrabasinal = asymmetrical ripples, coarser grains (sand), geographically isolated

Extrabasinal = climbing ripples, finer grains (silt and clay), geographically un-isolated (feature appears over long distance), frequent fine-grained lamination

- **Goal: Reconstruct Flathead Lake and Garden Gulch sedimentary sequences to conclude if features are intrabasinal or extrabasinal turbidites**

Results

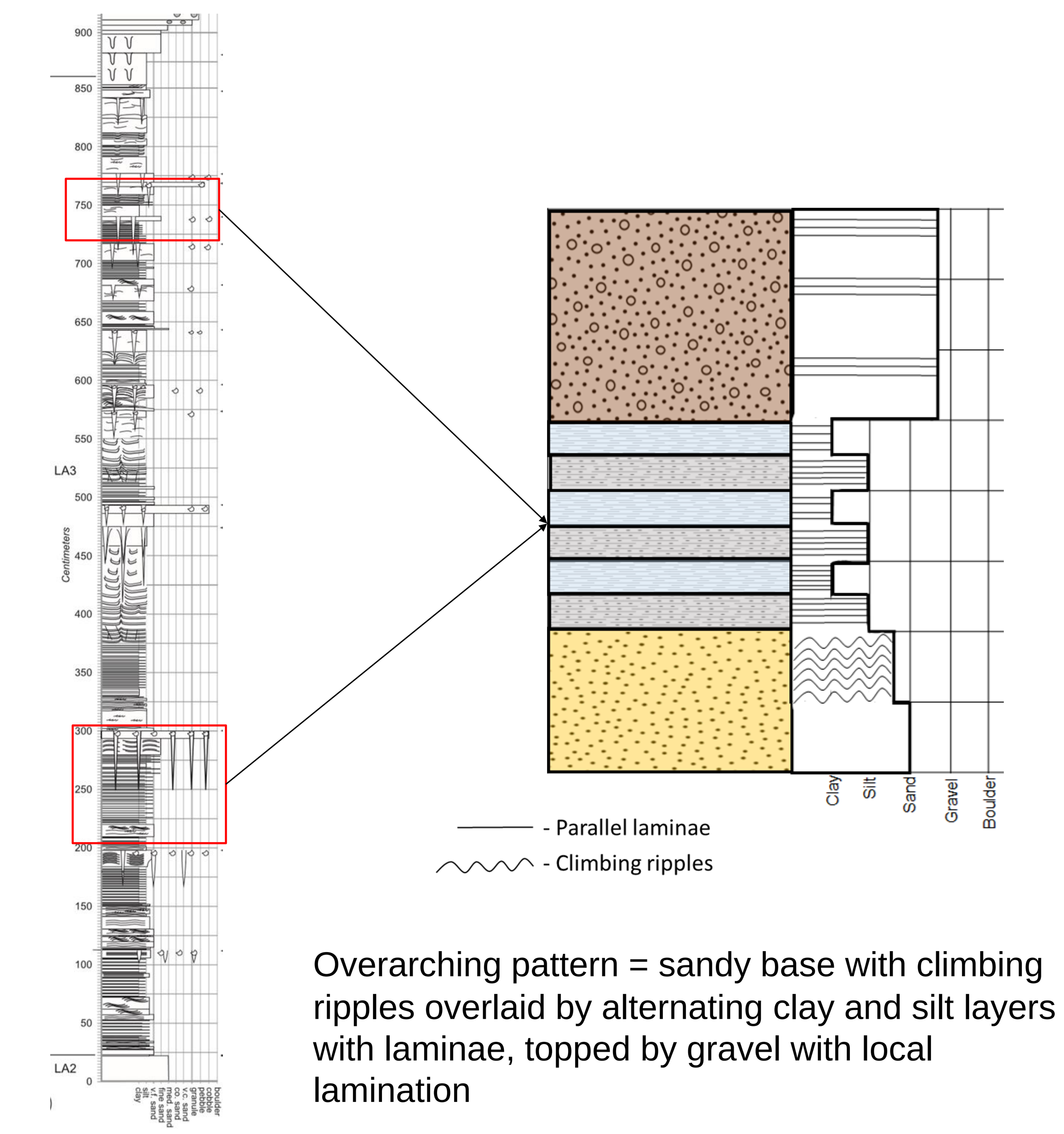
Flathead Lake, Montana



Criteria:

Asymmetric ripples	Fine grained (fine sand to clay)	Geographically un-isolated	Well preserved fine grained lamination

Garden Gulch, Montana



Overarching pattern = sandy base with climbing ripples overlaid by alternating clay and silt layers with laminae, topped by gravel with local lamination

Criteria:

Climbing ripples	Mixture fine to coarse grains (clay to gravel)	Geographically isolated	Well preserved fine grained lamination

Discussion

Flathead Lake

- Fining upward small grains (Sections B and C) → indicative of extrabasinal suspended load or lofting stage at the plume tail
- Asymmetric ripples (A)→ suggests intrabasinal flow according to Zavala et. al (2016)
- Geographical location → suggests extrabasinal flow from ice sheet to lake (Hofmann et al. 2010)
- Fine grain lamination = long periods of traction time → indicating long, hyperpycnal flow event

Garden Gulch

- Climbing ripples → suggests extrabasinal suspended load; disagrees with Smith (2017) conclusion
- Climbing ripples and fine grained sediments combined → longer residence time to develop structures → suggests long formation event = extrabasinal flow

Conclusion

- The criteria set in Zavala et al. (2016) is extremely helpful, but extrabasinal glacial turbidites have some major differences like ripple type and drop stones
- Flathead lake most likely experiences **extrabasinal flows**, like Hofmann et al. (2010) suggests
- Garden Gulch probably show **extrabasinal turbidites**, which disagrees with Smith (2017)
- Future research → focus more on distinguishing between the types in order to properly understand the geological history of an area

References/ Acknowledgements

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