Using Tentaculitid Fossils for Environmental and Diagenetic Interpretations (Horn River Formation, Northeastern British Columbia, Canada): Many Questions and a Few Preliminary Answers*

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Abstract

Tentaculitids are common fossils in carbonate-rich beds within basinal Devonian rocks. Whereas other fossils are problematic in their use for geological study – size, abundance, preservation, etc. – tentaculitids are large enough to be studied with a hand lens, are well preserved, and are often sufficiently abundant to be of use. Here, we present preliminary results of our exploration of tentaculitids as indicators of paleoenvironmental and diagenetic parameters in cores from the Middle to Upper Devonian Horn River shale sequence, British Columbia. Although the life habit of tentaculitids is uncertain (i.e. benthic or pelagic), they remain useful in environmental interpretation. Cross-bedded and/or imbricated deposits of tentaculitid fossils indicate concentration by water currents during reworking, transport, and/or deposition, whereas individual, sporadic fossils are likely those that were either in-situ (if benthic) or settled from the water column (if pelagic). Non-imbricated concentrations of tentaculitids, in the absence of fabrics indicative of transport, may have resulted from "blooms" of these tiny organisms or a decrease in sedimentation rate. Processes that effected the preservation of tentaculitid shells are also clues to environmental and diagenetic interpretations. The degree of abrasion and fragmentation is a potential indicator for the intensity of currents and/or relative distance of transport.

Dissolved shells were a potential source for carbonate cement, and provide information about the variability of primary allochem dissolution through a stratigraphic section. A bed of uncompacted specimens may indicate early cementation within that bed; ovate to flattened specimens suggest relative degrees of compaction, on small scales, with a stratigraphic interval. However, care must be taken when considering taphonomy in environmental and diagenetic interpretations; recrystallized and highly compacted specimens can easily be misinterpreted for dissolution and fragmentation. Other phenomena such as the density of fossils, size ranges, taxonomic composition, and shell plasticity are also under investigation, but without preliminary conclusions at the time of writing. Furthermore, biostratigraphy of Western Canadian tentaculitids is in its infancy; future work will build a biostratigraphic framework for these important basinal fossils.

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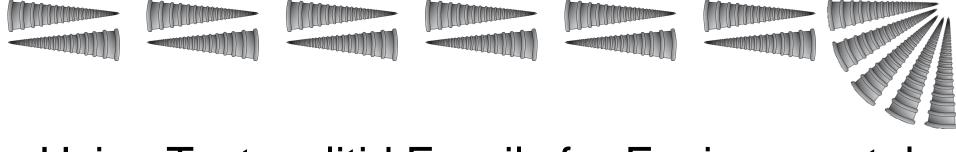
Selected References

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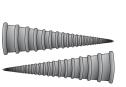
Using Tentaculitid Fossils for Environmental and Diagenetic Interpretations (Horn River Formation, NE B.C., Canada): Many Questions and a Few Preliminary Answers



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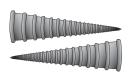














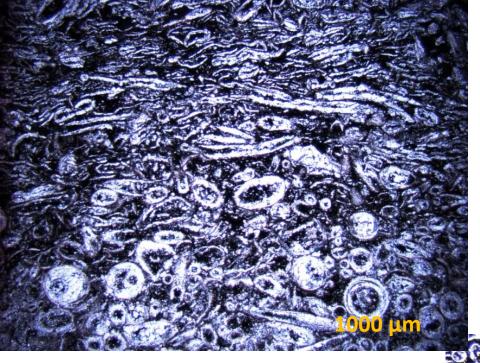


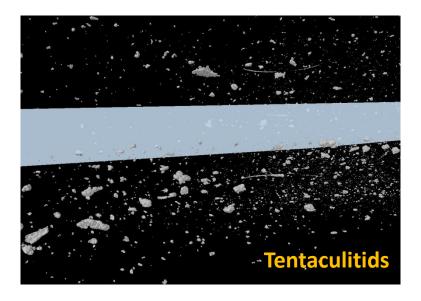


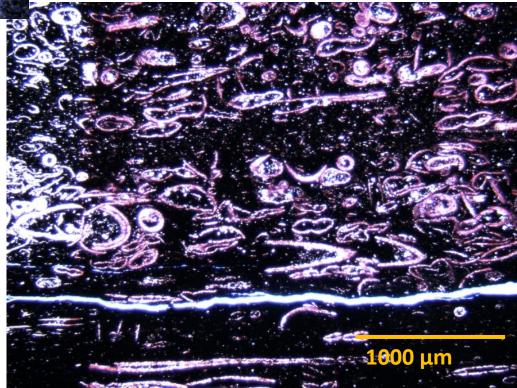
Presenter's notes: Tentaculitids are small, enigmatic fossils commonly found in deep-water paleoenvironments, mainly in the Silurian through Devonian.

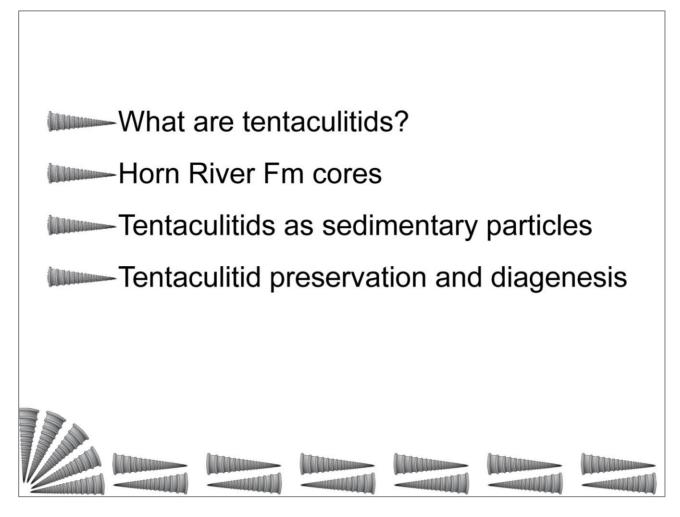
The work that has been done so far on tentaculitids is either biostratigraphy outside of North America, or the ecology and evolution of these organisms.

Our work here is part review and part investigation into what we can learn from tentaculitids about the paleoenvironment and diagenesis of the Horn River Fm in NE BC.





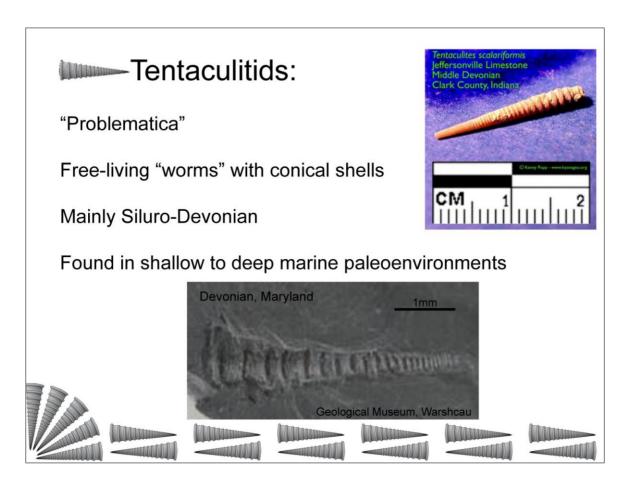




Presenter's notes: Review of Tentaculitid biology and ecology: what are they and how did they live. Introduce the study cores briefly.

Our observations on tentaculitid beds and tentacultids as sedimentary particles.

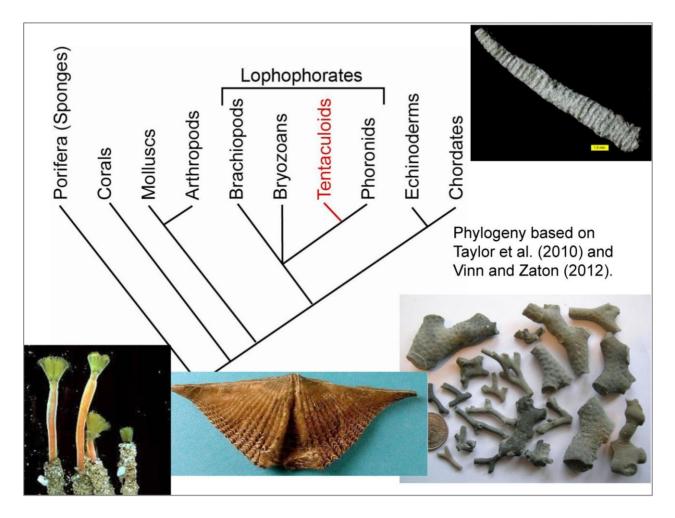
Introduce "taphofacies" of tentaculitids and what taphofacies analysis might indicate for paleoenvironments and diagenesis.



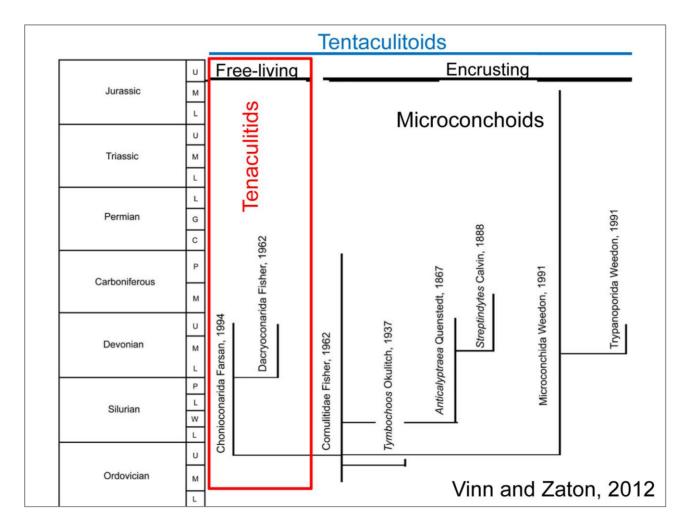
Presenter's notes: Problematic fossils of uncertain affinities and life mode, but have been considered "worms" with a history of being placed in many different groups (molluscs, arthropods, bryozoans, phoronids, etc.). Shells are hollow, conical, and have a variety of concentric ornament of protruding rings.

Originate in Ordovician; heyday in Siluro-Devonian; extinct in the Late Devonian.

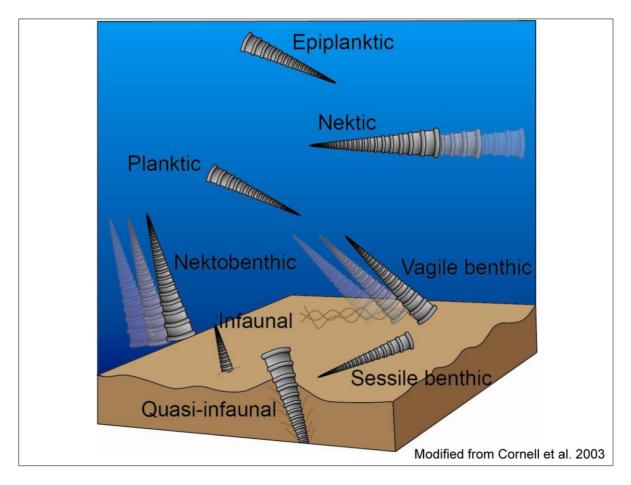
Found in nearly any marine environment. Smaller forms tend to be found in deep-water environments; larger forms, up to several cm in length are common in some shallow water environments, notably in the Middle and Upper Devonian; example: Jeffersonville Limestone, Indiana (blue photo, upper right)



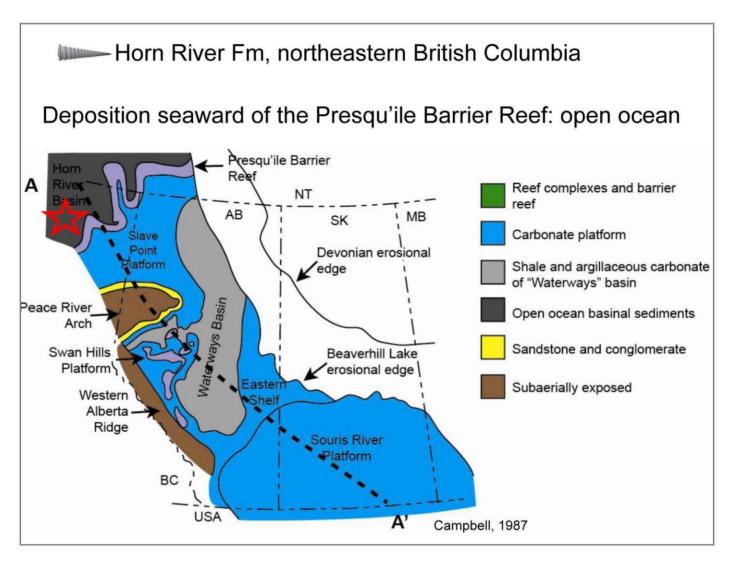
Presenter's notes: Phylogeny or "family tree" reconstructed from two recent studies on relationships of tentaculitoids and other phyla. Currently, tentaculitoids (tentaculitids + their relatives) are placed within the Lophophorates, a superphylum that includes bryozoans, brachiopods, and phoronid (feather-duster) worms (Click for animation at this point – pictures of bry, brachs, and phoronids). Their affinity with phoronids and lophophorates is based on interior shell features and the microstructural layering of calcite in the shell itself.



Presenter's notes: The tentaculitoids are made up of free-living forms and encrusting forms – those which attach to brachipod shells and whatnot. The tentaculitids refer to the free-living forms – those tiny critters we commonly find in deep water paleoenvironments and their larger kin in shallow water platforms. The term "tentaculitids" is sensu Vinn and Zaton 2012, which they reserve for the free-living tentaculitoids.



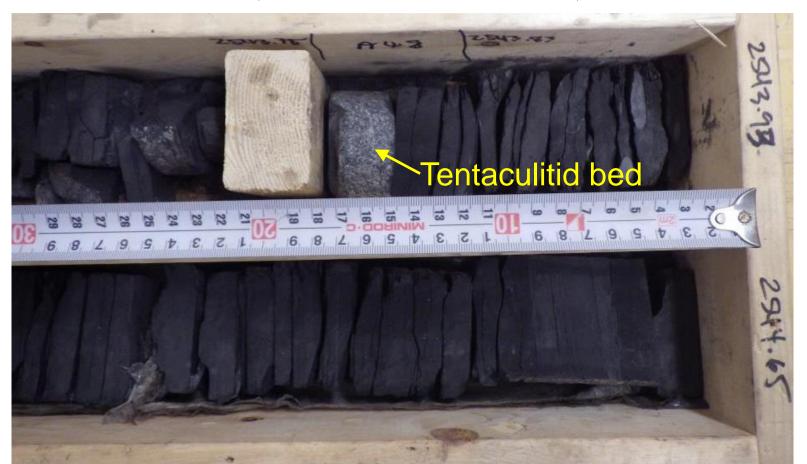
Presenter's notes: Diverse interpretations of tentaculitid life-modes: actively swimming (nektic - in the water column) and nektobenthic (cruising along the sea floor)), floating (planktic - general water column) and epiplanktic (within the photic zone) in the water column, or on/in the sediment: vagile benthic (mobile, on or partially in the sediment), within the sediment (infaunal (buried) or quasi-infaunal (partially buried) and immobile (sessile benthic; sessile = doesn't actively move). There is no good way to know how these animals lived, although those smaller forms in deepwater paleoenvironments are thought to have lived in the water column in planktic or nektic life modes.



Presenter's notes: Cores from NE Alberta. Sediments deposited in the open ocean, seaward of the Presqu'ile Barrier Reef that divided the Elk Point Basin from the Panthalassic ocean.

Horn River Fm:

- Core: Nexen GOTE A-27-I/94-0-8
- Laminated to unlaminated black shale
 - Intervals of calcite and quartz cement
 - Radiolarians, tentaculitids common; some trace fossils



Tentaculitids as sedimentary particles

1. Random distribution, mud-supported: "rain" of particles



→ Little to no sediment disturbance, current energy

Presenter's notes: Tentaculitid "rain" as occasional particles within background silicleastic sedimentation. If there is no disturbance from currents or gravity-flow events, or from tentaculitid die-off events, tentaculitid fossils are distributed randomly along laminae.

Tentaculitids as sedimentary particles

- 1. Random distribution, mud-supported: "rain" of particles
- 2. Packstone-grainstone textures

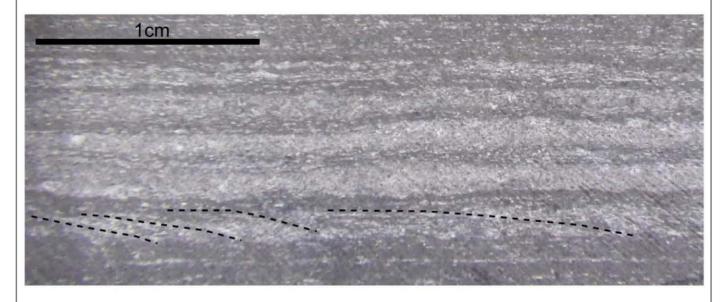


→ No internal structures: sedimentary events or die-offs

Presenter's notes: Where there are water current, gravity flow, or die-off event beds, tentaculitids are dense. Die-off events would have no internal sedimentary structures, perhaps like the photo here.

Tentaculitids as sedimentary particles

- 1. Random distribution, mud-supported: "rain" of particles
- 2. Packstone-grainstone textures: cross-beds



→ Sedimentary structures: currents, gravity flow events

Presenter's notes: Sedimentary structures would be found in sedimentation, rather than die-off/biotic, events, like current winnowing of sediments, gravity flows, etc.

Tentacula as sedimentary particles

- 1. Random distribution, mud-supported: "rain" of particles
- 2. Packstone-grainstone textures
- 3. Imbrication



→ Imbrication is rare, even in event beds

Presenter's notes: I have rarely found imbricated tentaculitids, EVEN within very obvious current-driven beds, like cross-bedded deposits or little turbidite-like deposits. Why? I don't know. That's for the future flume work.

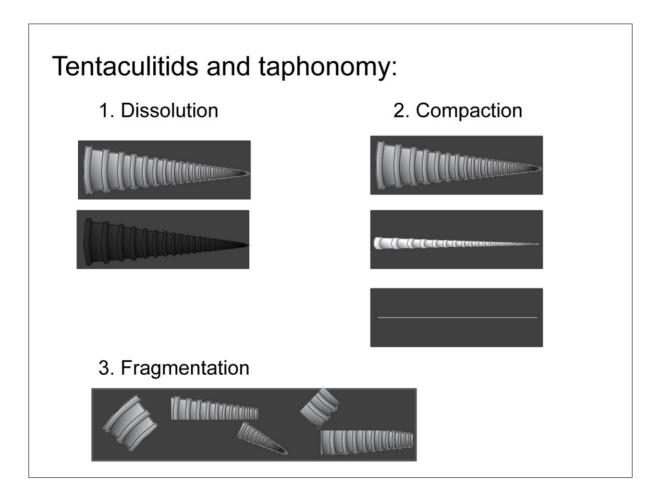
Taphofacies and Diagenesis

Taphofacies: facies defined by preservational state of fossils Speyer and Brett, 1986

Taphonomy: everything that happens to a fossil between death of the organism and discovery

e.g., degree of fragmentation, disarticulation, dissolution, abrasion, compaction, etc., or any combination of these

Presenter's notes: Taphonomy is the state of preservation; everything that happens to a fossil between death and final discovery, and includes processes that happen on the sediment surface (breakage, abrasion, destruction, dissolution, etc. by organisms or by physical processes), those that occur after burial (dissolution, compaction, breakage), and those that occur during diagenesis (mineral replacement and alteration, dissolution, shearing). Taphofacies was introduced by Speyer and Brett in 1986; it didn't catch on fast, but has had an increase in use and application in the last 15 years. This could be quite applicable to tentaculitids, since the situation in this core and in others is that tentacultids are the dominant fossil that can be seen by the eye, and because they show varying degrees of alteration and destruction.

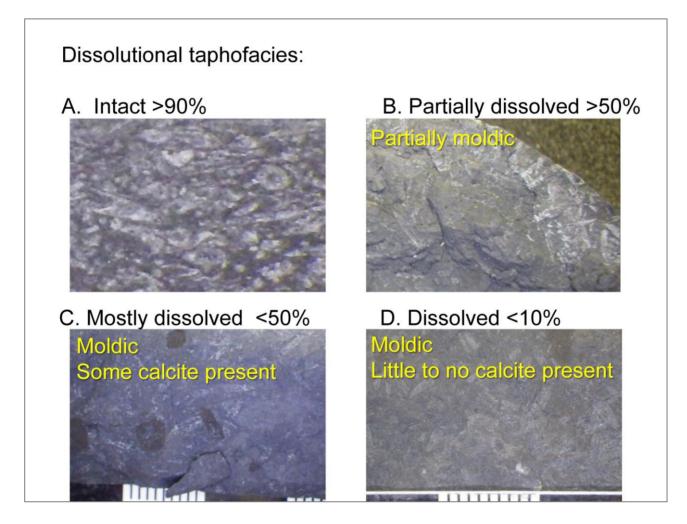


Presenter's notes: There are three major taphonomic influences on the preservation of tentaculitids.

Dissolution happens after burial, and leaves a mold of the fossil. If it happened before burial, we would have no evidence. Compaction happens after burial and before cementation.

Fragmentation usually happens before burial, but can happen after burial. The difference is whether the fragments are mixed (before burial) or are still in place (after burial; the fragments haven't moved anywhere).

Taphofacies would be defined based on a combination of all of these taphonomic categories.

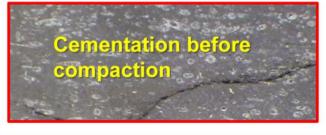


Presenter's notes: We recognized 4 dissolutional taphonomic states. Where tentaculitids are abundant and are partially to totally dissolved, the rock often is calcite-cemented: localized origin of calcite cement from abundant tentaculitids. Where any calcite is dissolved, the fossil is a mold – simply the outline of the fossil in the rock. In partial dissolutional states, at least part of the fossil is a mold. An intact fossil is not moldic.

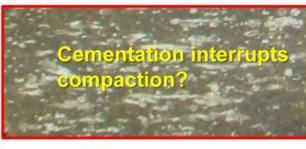
Compaction:

A. Uncompacted
Good "V" structure
Apertures are circles

→ Any texture



B. Partially compacted
Swashed "V"
Apertures ovoid
→ Any texture



C. Fully compacted
Lines, dots

→ Often in WS texture



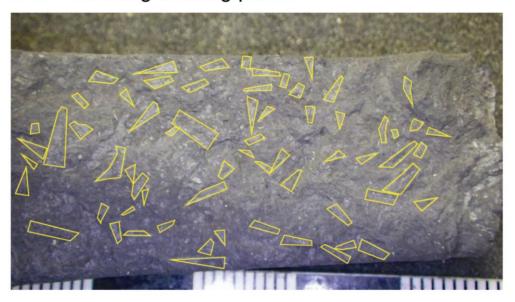
Presenter's notes: Compaction is affected by several factors:

The fill in the fossil – mud or crystalline calcite can keep the fossil from compacting. However, if no other evidence, assume it is soft mud or nothing.

The compaction of sediment versus timing of cementation of sediment – the captions say it all (animated over the pictures).

Fragmentation

Best seen along bedding planes



→ Energy involved, time on sea floor, to fragment

Presenter's notes: Fragmentation: Fragments are hard to determine in core unless you look at bedding planes. On the vertical surface, all tentaculitids are represented by a cross-section through some portion of the organism. Can never tell for sure whether the tentaculitid is a fragment or a whole specimen. Fragmentation is best observed along a bedding plane, because there at least we have a plan view of the whole specimen. The yellow lines are animated over the photo.

Taphofacies: all taphonomic aspects combined

Example: partially dissolved and partially compacted



Presenter's notes: Taphofacies is defined as a combination of taphonomic states – in this example, partially dissolved and partially compacted taphofacies. This would tell us something about cementation-compaction timing and the potential for locally-produced cement, which combined suggests something about the timing of release/dissolution of calcite from the tentaculitid fossils during sediment compaction.

Conclusions

If planktonic-nektonic, little information on benthic conditions

No further information vet

Scattered, or form dense beds.

Tentaculitid "rain," water currents, gravity flows, die-offs Rarely imbricated: flume and ooze-tank experiments

Taphofacies can be defined based on a combination of:

Fragmentation → sedimentation dynamics

Compaction → sediment compaction, diagenesis

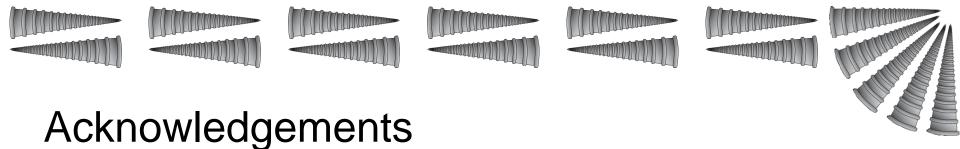
Dissolution → diagenesis



Presenter's notes: No way to really know how these guys lived. Jury is out. Likely will remain out. No modern analogues. Someone may ask about tusk shells or scaphopods (those are infaunal, and are definitely molluscs, not lophophorates, so a completely different life mode: shell shape and different phyla make comparisons between scaphopods and tentaculitids tentative at best) or about squids or other cephalopods (ditto on above; these guys were chambered in early life, which would suggest that they were in the water column; that's about it). Someone may ask if they can swim with their lophophore; who knows?

Future: flume and ooze-tank experiments to look at how dead tentaculitids settle to the benthos, how they act as sedimentary particles when under flow (and why no imbrication), and how water flows around the tentaculitid on the micron scale (scaled up to a giant tentaculitid model in an ooze tank with an ooze of sufficient Reynold's number to model actual conditions that the tentaculitid would face).

Taphofacies can be very useful to interpreting the history of the core, and tentaculitids are perfect because they are abundant and they clearly display their preservational state.



Levi Knapp Lindsey Leighton

