Geos 223 **Introductory Paleontology** **Spring 2006**

Lab 8: Graptolites and Trace Fossils

Name: ____________________

Section: ____________________

AIMS:

This lab will introduce you to graptolites (Part A), and to a branch of paleontology known as ichnology (the study of trace fossils; Part B). By the end of Part A this lab you should be familiar with the basic anatomy of graptolites, and have an appreciation for how graptolites are used in the biostratigraphic zonation of the Lower Paleozoic. By the end of Part B of this lab you should be familiar with the basic ethological groups of trace fossils, and have an appreciation for how trace fossils can provide important paleoecological and paleoenvironmental information.

PART A: GRAPTOLITES.

Graptolites (Class Graptolithina) are an extinct group of colonial hemichordate deuterostomes, similar in morphology and life habit to the modern colonial pterobranch hemichordate *Rhabdopleura*. The graptolite colony consisted of many clonal zooids, each occupying a theca in the communal skeleton (the rhabdosome). The thecae formed in rows along branches of the rhabdosome called stipes. The rhabdosome was made of a non-mineralized, organic, non-chitinous protein called periderm. Graptolite colonies were either erect fan-like structures growing from the seafloor (most dendroid graptolites, ranging from the Middle Cambrian to the Late Carboniferous) or free-floating in the plankton (the commoner graptoloid graptolites, probably descended from dendroid ancestors and ranging from the Early Ordovician to the Early Devonian). Graptoloid graptolites are very important biostratigraphic zone fossils in Lower Paleozoic strata.

DENDROID GRAPTOLITES:

A1: *Dictyonema*.

Dendroid graptolite colonies formed fan-like structures with thecae-bearing stipes held apart by horizontal struts (dissepiments). They can appear very similar to fenestrate bryozoan colonies. Indeed, by analogy to *Rhabdopleura*, graptolite zooids are believed to have possessed a lophophore structure for filter feeding. Dendroid graptolite zooids were also polymorphic, with autozooids, bizooids, and stolozooids performing different functions within the colony. Most dendroids grew up from the seafloor (anchored by a holdfast structure) in a fashion also reminiscent of fenestrate bryozoans. However, a few dendroids are believed to have been secondarily planktonic.

DRAW a dendroid graptolite. Label the structures you can see.

How do dendroid graptolites differ from fenestrate bryozoans?

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The rate of evolution of dendroid graptolites was not sufficiently high to make them useful for biostratigraphy.

What is the stratigraphic range of the genus *Dictyonema*?

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GRAPTOLOID GRAPTOLITES:

Graptoloid graptolites were planktonic, most likely having evolved from a planktonic dendroid ancestor. Except for the earliest graptoloids (anisograptids), all graptoloid colonies consisted of monomorphic zooids, with no apparent division of labor. Graptoloids are also characterized by development of a prominent thread-like nema extending from the sicula (the theca of the founder zooid of the colony).

Their planktonic mode of life meant that most graptoloid species were widely distributed around the globe during the Early Paleozoic. They also showed a high rate of evolution, and so are used in the biostratigraphic zonation of the Ordovician and Silurian. Four successive coarse-scale "graptoloid faunas" are recognized, each named for the dominant graptoloid families of the time. From oldest to youngest these are: the anisograptid fauna (Tremadoc), the dichograptid fauna, the diplograptid fauna, and the monograptid fauna (Silurian). The first occurrence of particular graptoloid species is used to define extremely high-resolution species-level biostratigraphic zones averaging less than one million years in duration (sometimes less than 500,000 years) within these coarse faunal zones.

Anisograptid fauna.

This fauna characterizes rocks of Tremadoc age (the earliest epoch of the Ordovician), although some anisograptids range through to the Llanvirn-Llandeilo (Middle Ordovician). Anisograptids are a paraphyletic group, evolving from a (planktonic) dendroid graptolite and ancestral to the other graptoloid clades. They possessed a nema, but most retained polymorphic zooids (autothecae plus bithecae). Examples include *Rhabdinopora* (formerly considered a dendroid graptolite; see PaleoBase 1.0), *Clonograptus* (A2 and PaleoBase 1.0), *Anisograptus*, *Bryograptus*, *Kiaerograptus*, and *Staurograptus* (see PaleoBase 1.0).

Dichograptid fauna.

The dichograptid fauna is dominant in rocks of Arenig age, although dichograptids range from the Tremadoc to the Caradoc. Dichograptids possessed a nema, lacked bithecae (i.e., had monomorphic zooids), and lacked a virgella on the sicula. Common examples include *Didymograptus* (A3 and PaleoBase 1.0) and *Tetragraptus* (see PaleoBase 1.0). *Phyllograptus* (A4 and PaleoBase 1.0) is not a dichograptid (it possessed a virgella) but is a common element of the dichograptid fauna.

Diplograptid fauna.

The diplograptid fauna dominates rocks of mid-Ordovician to Early Silurian (Llanvirn-Llandeilo to Llandovery) age. Many groups of graptoloids were present during this interval, but two (the diplograptids and the dicranograptids) are particularly common. Diplograptids and dicranograptids were monomorphic and possessed a virgella on the sicula. Common examples include the diplograptids *Diplograptus* (A5 and PaleoBase 1.0), *Climacograptus* (A6 and PaleoBase 1.0), and *Orthograptus* (A7 and PaleoBase 1.0), and the dicranograptids *Dicranograptus* (A8 and PaleoBase 1.0) and *Dicellograptus* (PaleoBase 1.0).

Monograptid fauna.

The monograptid fauna dominates rocks of Early Silurian (Llandovery) through early Middle Devonian age. The dominant graptoloids during this interval were the monograptids (indeed, they are the only post-Wenlock graptoloids). Monograptids were monomorphic and possessed a virgella. The evolutionary history of monograptids has been well studied at very fine resolution. Common genera include *Monograptus* (A9 and PaleoBase 1.0), *Cyrtograptus* (see PaleoBase 1.0), and *Rastrites* (see PaleoBase 1.0).

How can you differentiate a monograptid from a single stipe of an incompletely preserved dichograptid?

What are “cladia” of the *Cyrtograptus* rhabdosome?

What was the function of cladia?

The importance of graptoloid graptolites in biostratigraphy means that all young budding paleontologists should be able to identify the common members of the group and have some familiarity with what features to look at in a graptoloid in order to identify it. Features used to identify graptoloids include:

- The number of stipes in the rhabdosome.
- The orientation of the stipes relative to the sicula (pendent, declined, horizontal, reclined, or scandent).
- The morphology of the stipes (straight, deflexed, reflexed, or curved).
- The number of thecal rows along each stipe (1, 2, or 4).
- The morphology of the thecae (often difficult to see).

Carefully document each of the features listed above for the graptoloid graptolites listed in the table below (see specimens A2 to A9 and PaleoBase 1.0). You will need to use a hand lens to see these features on the specimens!

Name	**Number of Stipes**	**Orientation of Stipes**	**Morphology of Stipes**	**Number of Thecal Rows**	**Genus Range (Epoch)**
Clonograptus					
Staurograptus					
Didymograptus					
Tetragraptus					
Phyllograptus					
Diplograptus					
Climacograptus					
Orthograptus					
Dicranograptus					
Dicellograptus					
Monograptus					
Cyrtograptus					
Rastrites					

A10: Graptolites and paleoenvionmental data.

In addition to their biostratigraphic utility, graptoloids can provide useful paleoenvironmental information. This large slab contains many elongate graptoloid colonies.

What kinds of graptolites do you recognize on the slab? Be as specific as possible.

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What age is this rock? Be as specific as possible.

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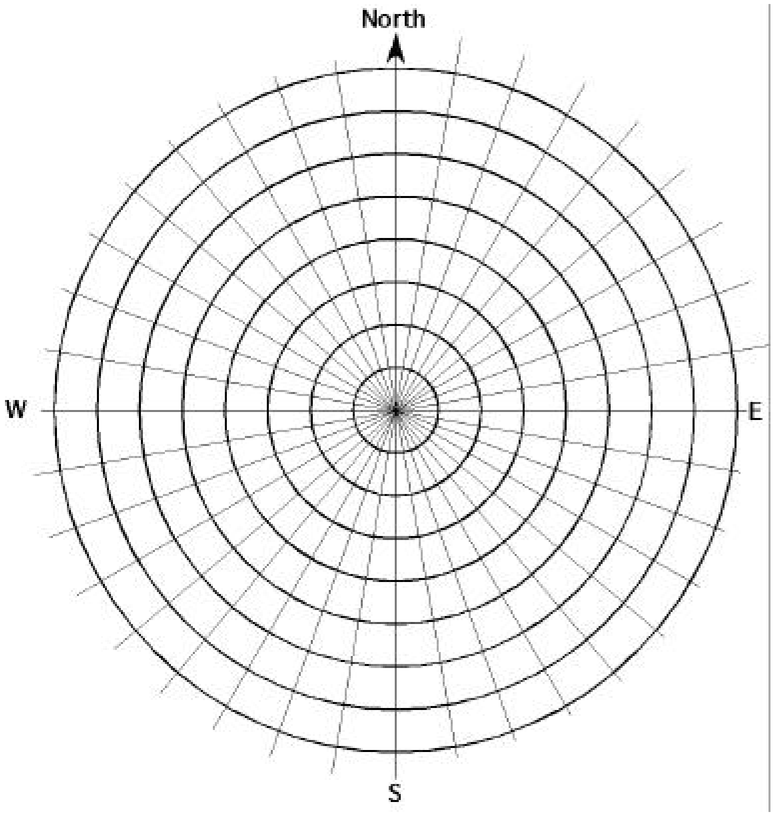
Upon death of the colony, graptoloid rhabdosomes sank to the sea floor where many became buried and fossilized. It might be expected that the orientation of the rhabdosomes on the sea floor would be random, but a glance at the long specimens on this slab suggests that some preferred orientation might exist. From a paleoenvironmental perspective this requires further investigation!

1. Measure and record the orientation of the long axis of a rhabdosome relative to the arrow on the slab (which can be taken to represent north).
2. Repeat this procedure for at least 19 more rhabdosomes representing a range of sizes.
3. Draw a rose plot of these orientations. Remember to include a scale.



What does this plot suggest in terms of paleoenvironmental conditions?

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PART B: TRACE FOSSILS.

A trace fossil is a biogenic sedimentary structure; a record of the behavior of an organism preserved in the rock record. Trace fossils therefore consist of tracks, trails, burrows, and borings of organisms. Trace fossils are sometimes called ICHNOFOSSILS, and the branch of paleontology involving the study of trace fossils is ICHNOLOGY. The nature and utility of trace fossils is discussed in Clarkson (1998, pp. 426-431).

Unlike body fossils, trace fossils cannot be secondarily moved or washed around after deposition of the entombing sediment, as sediment removal leads to destruction of the trace. Traces are also often enhanced by diagenesis (e.g., increased contrast between the infill of a burrow and the surrounding sediment). Trace fossils are given binomial names (a tradition stemming from nineteenth century workers who misidentified traces as fossil algae). Trace fossils can be broadly classified according the type of behavior they represent (Seilacher, 1964). This provides important paleoethological (behavioral) information. Here you will be introduced to a few common trace fossils, broadly arranged by behavior. Make sure you understand why each is classified under a particular behavior.

Suggest two difficulties which would arise if trace fossils were classified according to the identity of the trace maker rather than behavior.

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Surface Locomotory Traces (Repichnia):

These are tracks or trails on bedding planes (originally made on the sediment surface) with evidence of directional movement. The organism was not grazing while it was moving.

B1: *Cruziana*.

See also PaleoBase 1.0. *Cruziana* is typically ascribed to arthropod locomotion (e.g., trilobites in the Paleozoic).

What suggests that an arthropod made this trace?

Is this trace fossil preserved in epirelief or hyporelief?

What is the stratigraphic range of *Cruziana*?

Resting Traces (Cubichnia):

Cubichnia are resting imprints made by a mobile organism while temporarily hiding in the sediment. They often resemble the underside of the trace maker, and may lie at the end of a locomotory trace.

B2: *Asteriacites*.

See also the paper by Bell (2004), Clarkson (1998, fig. 12.12e), and PaleoBase 1.0.

What animal produced this trace?

When is the oldest occurrence of *Asteriacites*?

Does this fit with your expectations given the hypothesized trace maker? Why?

B3: *Rusophycus.*

See also Clarkson (1998, fig. 11.15b) and PaleoBase 1.0. *Rusophycus* is often described as a trilobite resting trace.

What is the stratigraphic range of *Rusophycus*?

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What other organisms could have made *Rusophycus*?

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Rusophycus traces were also produced by trilobites digging for prey (see papers by Jensen [1990] and Brandt *et al*. [1995]).

Surface Grazing or Feeding Traces (Pascichnia):

These are meandering or patterned trails produced by organisms while grazing food from the sediment surface. The trail typically does not cross itself (or other such trails), and may have a fecal string associated with it.

B4: *Nereites.*

See also PaleoBase 1.0. This is a common pascichnian trace fossil with chevron-shaped lobes and a median fecal string.

DRAW a portion of a Nereites trace.

B5: Loosely meandering trail.

B6: Tightly meandering trail.

Excavatory Feeding Traces (Fodichnia):

These are burrows made by animals feeding within the sediment (below the surface). They often show evidence of repeated "probing" into the sediment, and may be backfilled (since there was no need for the organism to maintain an open burrow system). The burrows typically do not cross earlier burrows for feeding efficiency.

B7: *Chondrites.*

See also PaleoBase 1.0. This trace fossil is common in many depositional environments, and often represents the deepest tier below the sediment surface. Note the branching pattern of burrows, produced as the trace-maker repeatedly probed different areas of sediment for food particles.

B8: *Zoophycos.*

See also PaleoBase 1.0. The spirally arranged spreiten marks and central axis of *Zoophycos* are easily recognized. The environmental distribution of this trace fossil was examined by Bottjer *et al*. (1988).

How did the environmental distribution of *Zoophycos* change through the Phanerozoic?

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Farming Traces (Agrichnia):

These are regularly patterned horizontal open burrow systems, typically below the sediment surface. The open burrow system had vertical shafts rising to the sediment surface above, and the network was therefore supplied with fresh seawater. The deep-sea graphoglyptid traces *Palaeodictyon* (B9; see also PaleoBase 1.0) and *Cosmoraphe* (B10; see also PaleoBase 1.0) are examples of farming traces.

What was the function of the open burrow network of agrichnian traces?

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Dwelling Traces (Domichnia):

These are burrows which served as permanent residences for organisms. The animals would typically have fed outside the confines of the burrows by filter-feeding, scavenging, or capturing prey. In order to keep the burrow at a suitable depth below the sediment surface, the organism had to dig deeper (if overlying sediment was removed) or infill the burrow base (if more sediment was draped over the surface). These modifications are sometimes preserved as backfilled “spreiten” around the burrow. Traces preserving escape or equilibrium structures are sometimes classified as “fugichnia” or “equilibrichnia”, respectively. The burrow walls are sometimes strengthened against collapse by a lining of mud/sand pellets or fecal pellets (e.g., *Ophiomorpha*; see PaleoBase 1.0, and the paper by Bottjer *et al*. [1988]).

B11: *Skolithos*. (See also PaleoBase 1.0)

Skolithos refers to a simple vertical shaft in the sediment. This trace is characteristic of shoreface environments. Rocks dominated by *Skolithos* burrows are often called “piperock”, and are common in Cambrian age shoreline sandstones.

B12: U-Shaped Burrows.

Arenicolites (B12a) and *Diplocraterion* (B12b; see also PaleoBase 1.0) are U-shaped dwelling traces. Spreiten are often seen in cross-section. In plan view (i.e., looking down on the bedding surface) the two burrow entrances and the remnants of the spreiten give these traces a distinctive “dumb-bell” outline.

Rhizocorallium (B12c; see also PaleoBase 1.0) is very similar to *Diplocraterion*, but bends at a right angle to run more or less horizontally through the sediment rather than being entirely vertical.

Borings:

Some animals can erode cavities in hard substrates (rock, wood, etc.) to make a dwelling (e.g,. pholid bivalves; see Lab 5, specimen B4). The boreholes can be preserved (with or without the original occupant inside) and, since they represent the boring behavior of the organism, they are considered trace fossils (Domichnia). Similarly, clionid sponges bore into shells to set up home. Their tiny borings are therefore trace fossils on a body fossil (see specimen B13a).

Some borings into shells record predation by gastropods such as naticids or muricids (see specimen B13b). Such drill holes provide an important source of data for studies of predation intensity through time, even when the predators themselves are not preserved.

TRACE FOSSILS AND BIOTURBATION:

Burrowing organisms naturally disrupt the original bedding of the sediment: this churning effect is called bioturbation. The degree to which the original bedding has been disrupted reflects the degree to which subsurface niches were exploited by the animals. The biological overprint of sedimentary structures is called the "ichnofabric", and can be quantified using the "ichnofabric index" scale (see the paper by Droser and Bottjer, 1986).

What ichnofabric index do the following samples show?

B14a: ___________________

B14b: ___________________

B14c: ___________________

What factors might determine the extent and depth of bioturbation within the sediment?

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TRACE FOSSILS AND TIERING:

Trace fossils can also yield valuable paleoecological information, such as tiering within the infaunal habitat (e.g., see the papers by Ausich and Bottjer [1982], Bottjer and Ausich [1986], Bromley and Ekdale [1986], Pemberton and Frey [1984], Seilacher [1974], and Taylor and Goldring [1993]).

What is tiering?

How has the extent of infaunal tiering changed through the Phanerozoic?

TRACE FOSSILS AS PALEOENVIRONMENTAL INDICATORS:

Some types of animal behavior are rather restricted in terms of the range of environments they are expressed within. This means that trace fossils can provide paleoenvironmental information (e.g., see the papers by Bottjer *et al.* [1988], Farrow [1966], Fürsich [1975], McCann [1993], Olivero [1996], and Seilacher [1967, 1978]). Delimitation of ichnofacies is one such use of trace fossils.

What are ichnofacies?

Using the literature, lecture notes, and Clarkson (1998) to help, complete the table below:

Ichnofacies	Environment	Typical Ichnogenera
Skolithos		
Cruziana		
Zoophycos		
Nereites		

TRACE FOSSILS AND THE CAMBRIAN RADIATION:

Trace fossils make an important contribution to our understanding of the Cambrian radiation of metazoans (e.g., see the papers by Buatios and Mángano [2003], Crimes [1974, 1987, 1992], Crimes and Anderson [1985], Droser and Bottjer [1988], Droser *et al.* [1999, 2002], and Jensen et al. [2000]).

List the typical Late Neoproterozoic ichnogenera and the types of behavior they represent:

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List the typical Early Cambrian ichnogenera and the types of behavior they represent:

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What is the ethological significance of the transition in trace fossil types during this interval?

TRACE FOSSILS AND BIOSTRATIGRAPHY:

Trace fossils have been used as a biostratigraphic tool in the Cambrian (e.g., see the papers by Seilacher [1970] and Crimes [1987, 1992]).

Under what circumstances might trace fossils have advantages over body fossils for biostratigraphy?

The trace fossil *Treptichnus pedum* (formerly called *Phycodes pedum*) is particularly important as a biostratigraphic marker. Why?