Ecosystem Engineering During the Early Cambrian

Smithsonian National Museum of Natural History

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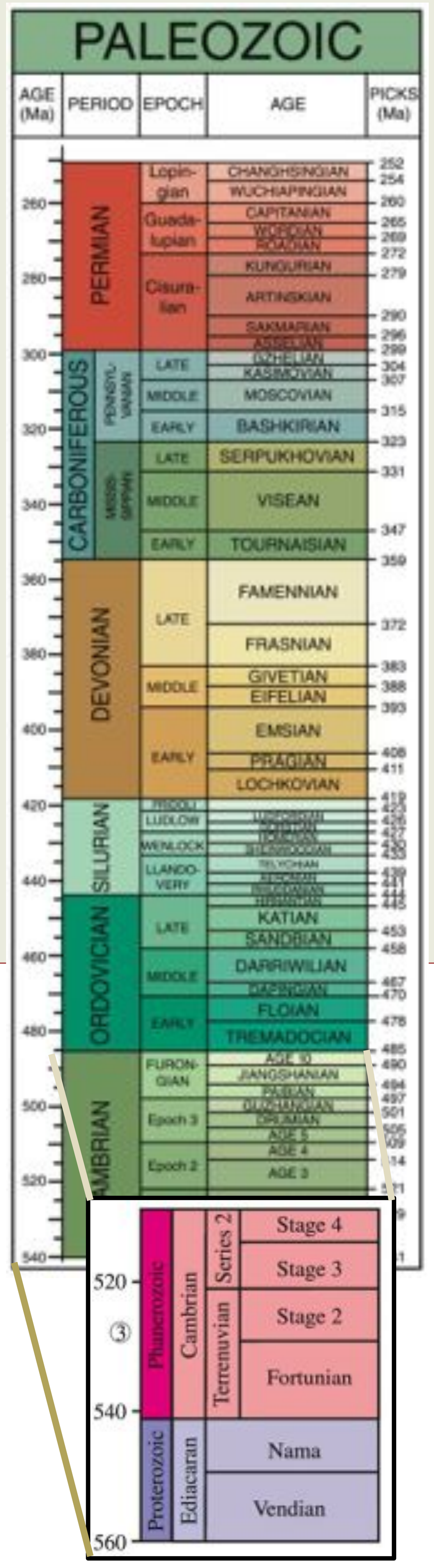

Abstract

Ecosystem engineers are organisms that create, significantly modify or maintain habitats. Trace fossils providing paleontological evidence of ecosystem engineering become abundant in Ediacaran and Cambrian rocks, however not much is known about the organisms that made them. By looking at these ichnofossils and their geometry, specifically length and diameter, we can determine the allometric relationships between the size of the trace and their engineering efforts. I collected fossil burrow length and diameter measurements from published papers, and I applied an allometric analysis to the data. Similar analyses have been collected and applied to contemporary organisms, which allows us to compare our findings in order to better understand and interpret Ediacaran and Early Cambrian trace fossil relationships to their environment.

Introduction and Questions

Ecosystem Engineering and Allometry

Ecosystem engineering is the physical modification of the environment by organisms. Allometric theory can be applied to ecosystem engineering because it explains how much of an effect the organism has on its environment in relation to its body size. Allometry also makes it possible for us to know how these effects may change or to predict a characteristic of that organism. The collected burrow measurements of the Ediacaran and Cambrian trace fossils will be log transformed and analyzed using a linear regression.

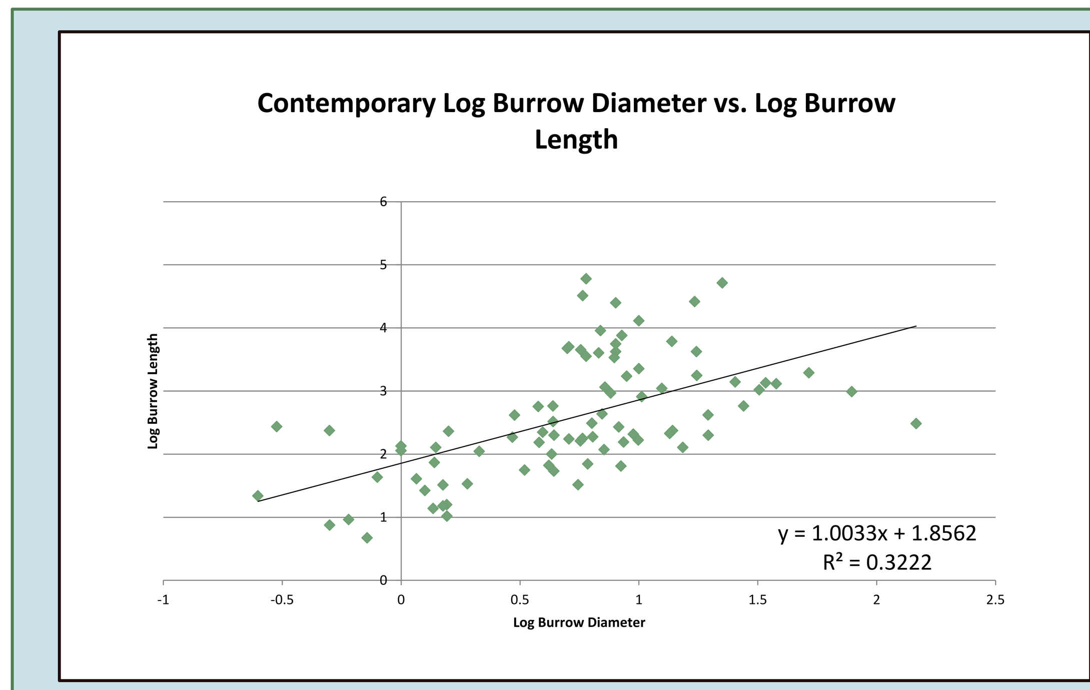

Figure 1: The contemporary data analysis shows a highly significant correlation between burrow length and diameter. This graph will be used for comparison to trace fossil analysis (Salle & Jones, 2014).

Contemporary vs. Fossil

The fossil record can only provide information on physical characteristics of the trace fossils. Measurements of various burrow diameters and lengths are place on a graph and analyzed. We can compare our trace fossil data to contemporary burrowing in order to understand trace fossil allometric patterns over time. Thibaud's graph on contemporary data shows a strong length to width ratio (Fig. 1). This comparison will help us understand Ediacaran and Cambrian engineering efforts.

Questions:

1. How will length and diameter relationships in the trace fossil data relate to contemporary relationships?
2. Is there a difference between these relationships when looking at vertical and horizontal burrows?
3. Will the relationships significantly differ between the Ediacaran and Middle Cambrian?

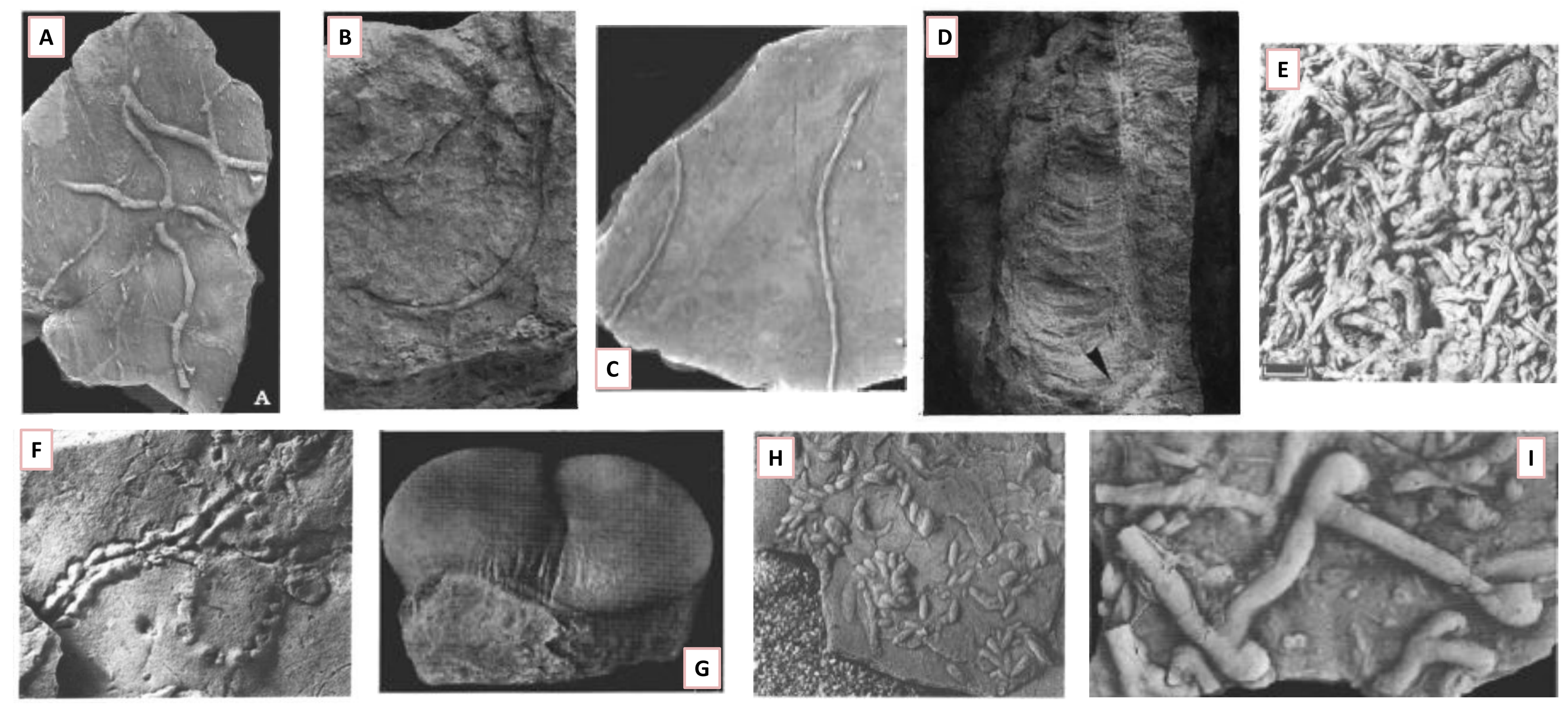

Figure 2: A, *Palaeophycus tubularis*. Image enlarged for detail (Orlowski & Zylinska, 1996). B, *Arenicolites isp.* Image enlarged for detail (Orlowski, 1989). C, *Planolites montanus*. Image enlarged for detail (Orlowski & Zylinska, 1996). D, *Diplocraterion parallelum* Image enlarged for detail (Orlowski, 1989). E, *Palaeophycus canalis*. Scale bar 2 cm (Walter et al. 1989). F, *Nereites isp.* Scale bar 1 cm (Walter et al. 1989). G, *Bergaueria elliptica*. Image enlarged for detail (Orlowski & Zylinska, 1996). H, *Phycodes pedum* . Scale bar 1 cm (Walter et al. 1989). I, T*reptichnus rectangularis.* Image enlarged for detail (Orlowski & Zylinska, 1996).

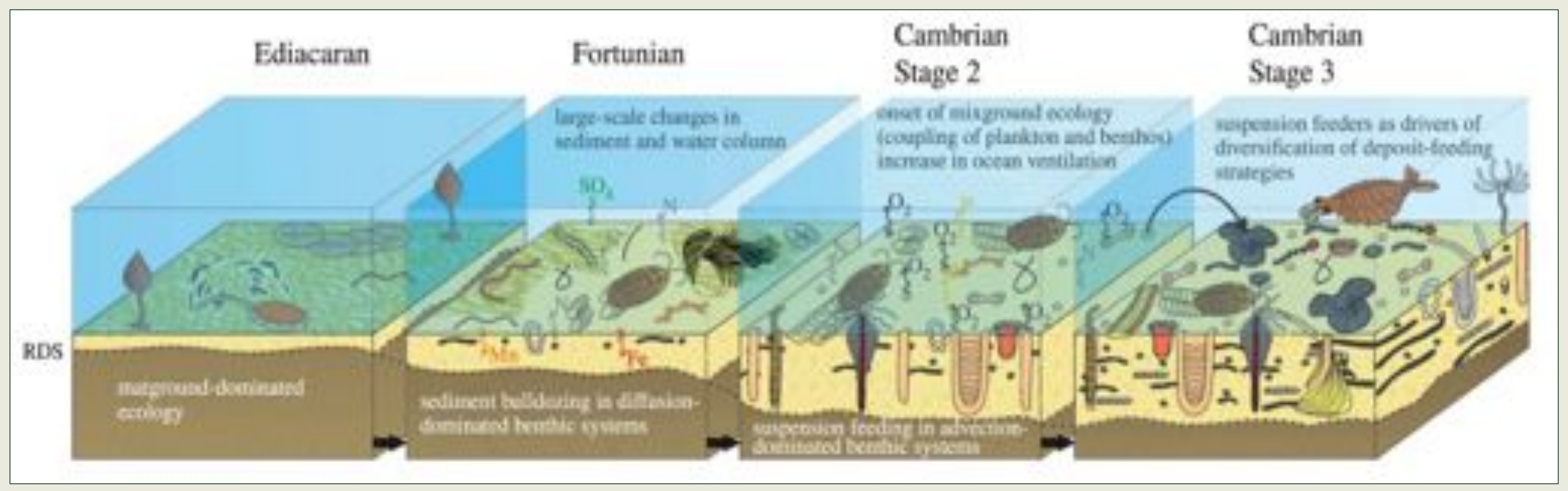

Figure 3: Changes in benthic faunas and ecosystem engineering through the Ediacaran–Cambrian transition. Burrows and traces become much larger and more advanced with time (Mangano & Buatois, 2014).

Materials and Methods

Based upon published literature I collected on trace fossils during the Ediacaran and Early Cambrian periods, I gathered data on their characteristics such as length, diameter, depth, type of trace, behavior and first appearance. Some length and diameter measurements were described in the literature and others were measured directly from their pictures with tools such as rulers and calipers (Fig. 4, 5).

Once I compiled all my information, I created a database with each of the trace fossil characteristics that allows for easy sorting and quick analysis (Fig. 6). 255 ichnospecies are observed, with 146 of them being burrows. 87 of those burrows are horizontal and 59 are vertical. I log transformed my length and diameter measurements, graphed my points on a scatter plot and continued to do an allometric analysis of my data.

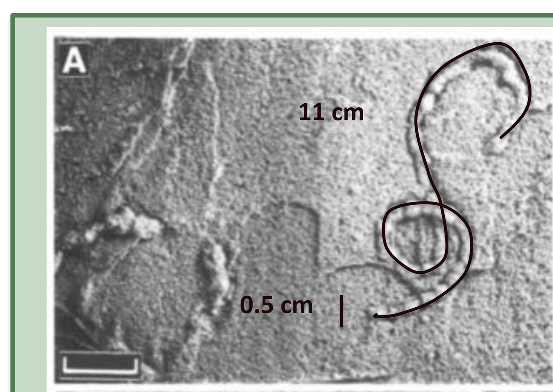

Figure 4: Length and diameter measurements of *Torrowangea rosei* are shown (Walter et al. 1989). Length = 11 cm Diameter = 0.5 cm. Scale bar is 1 cm.

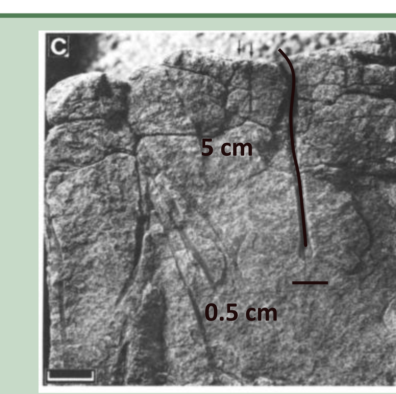

Figure 5: Length and diameter measurements of *Skolithos ramosus* are shown (Walter et al. 1989). Length = 5 cm Diameter = 0.5 cm. Scale bar 1 cm.

Entry #	Ichnogenus	Ichnospecies	Ichnosub-species	Full Name	Trace Type	Burrow Direction	Burrow Diameter (cm)	Burrow Length (cm)	Log Diameter	Log Length	First Appearance
5	Treptichnus	rectangularis		Treptichnus rectangularis	Burrow	Horizontal	0.3	6	-0.52287875	0.77815125	Lower Cambrian
6	Treptichnus	rectangularis		Treptichnus rectangularis	Burrow	Horizontal	0.4	4	-0.39794001	0.60205999	Middle Cambrian
7	Treptichnus	pedum		Treptichnus pedum	Burrow	Horizontal	0.19	5.5	-0.7212464	0.74036269	Ediacaran
8	Treptichnus	tripleurum		Treptichnus tripleurum	Burrow	Horizontal	0.55	7	-0.25963731	0.84509804	Ediacaran
17	Diplocraterion	parallelum		Diplocraterion parallelum	Burrow	Vertical	0.3	11	-0.52287875	1.04139269	Lower Cambrian
18	Diplocraterion	parallelum		Diplocraterion parallelum	Burrow	Vertical	0.2		-0.69897		Upper Cambrian
19	Diplocraterion	parallelum		Diplocraterion parallelum	Burrow	Vertical	3.5	4	0.54406804	0.60205999	Upper Cambrian
20	Diplocraterion	parallelum		Diplocraterion parallelum	Burrow	Vertical	0.3	23	-0.52287875	1.36172784	Lower Cambrian
21	Diplocraterion	parallelum		Diplocraterion parallelum	Burrow	Vertical	2.5	15	0.39794001	1.17609126	Lower Cambrian
22	Diplocraterion	isp.	1	Diplocraterion isp. 1	Burrow	Vertical	0.2		-0.69897		Lower Cambrian
23	Diplocraterion	isp.	2	Diplocraterion isp. 2	Burrow	Vertical	0.2	6.5	-0.69897	0.81291336	Lower Cambrian
24	Diplocraterion	isp.	3	Diplocraterion isp. 3	Burrow	Vertical	0.3		-0.52287875		Middle Cambrian
25	Rhizocorallium	jenese		Rhizocorallium jenese	Burrow	Vertical	0.6	2.3	-0.22184875	0.36172784	Lower Cambrian
26	Astropolichnus	hispanicus		Astropolichnus hispanicus	Burrow	Vertical	5	3.4	0.69897	0.53147892	Lower Cambrian
28	Palaeophycus	isp.		Palaeophycus isp.	Burrow	Horizontal	7	7.5	0.84509804	0.87506126	Lower Cambrian

Figure 6: A section of the database created showing the data collected multiple variables such as length, diameter, and time category.

Results

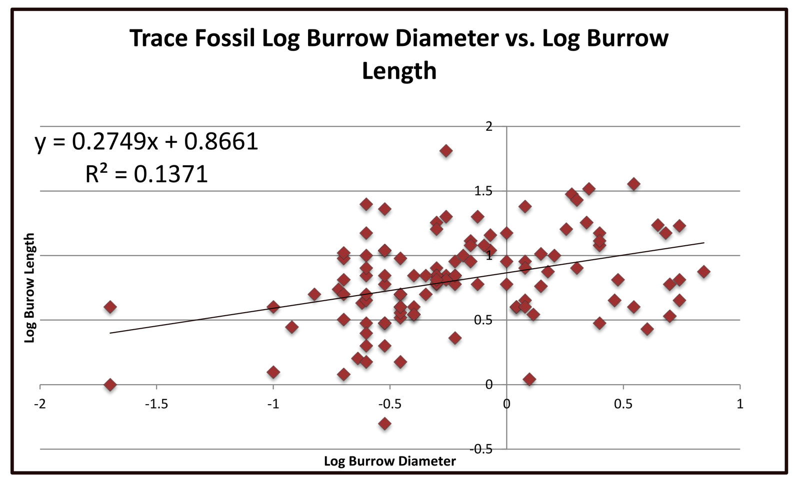

Figure 7: Left: Trace fossil burrow length plotted against diameter as a linear regression with a strong positive correlation.

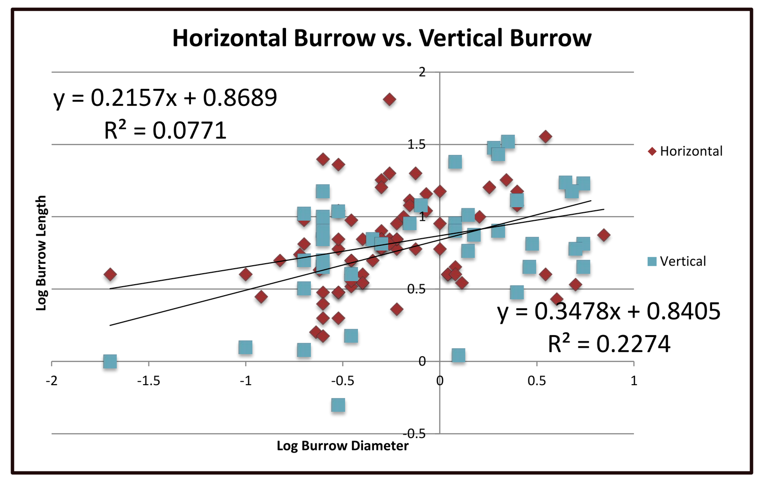

Figure 8: Graph showing comparison between vertical and horizontal burrows with no significant difference.

Length and Diameter Relationships

Fossil and contemporary burrow lengths show strong positive allometric scaling with burrow diameter (Fig. 7). Contemporary exponent is far higher than the fossil exponent (i.e., C length increases as diameter increases at a far greater rate than fossil burrows. This might reflect O2limitation of burrowing.

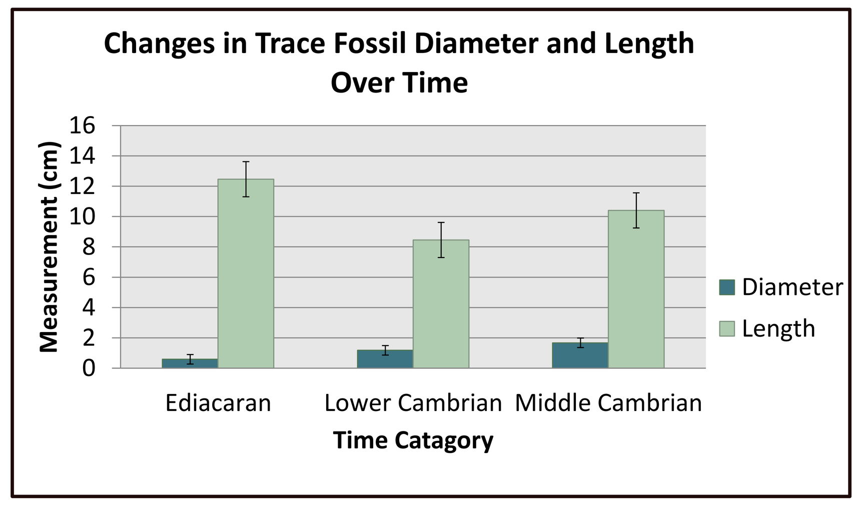

Figure 9: Double bar graph comparing the average burrow diameter and average burrow length throughout the Ediacaran, Lower Cambrian and Middle Cambrian. Diameter is increasing with time, while length is not.

Vertical vs. Horizontal

Vertical and horizontal allometries do not differ (Fig. 8). This was unexpected; we thought that being V would allow access to the water column and more O2. This implies that vertical ands horizontal burrowing are equally constrained.

Changes Over Time

Over time burrow diameter increases, whereas length does not (i.e., the average length/diameter ratio declines over time) (Fig.9). This indicates that the length constraint persists.

Discussion

- Throughout time, the length of burrows is not changing, but there is an increase in diameter. Constraints during the Early Cambrian such as low oxygen concentrations in the water column and sediments, and lack of circulatory systems in the organisms could have strictly limited the depth and lengths of burrowing activity during that time.
- In order to get a better understanding of ecosystem engineering during the Early Cambrian, we need to continue to analyze geometric volumes as well as other kinds of trace fossils, such as trails and impressions. Information on the environment, like oxygen levels, temperature and sediment types will be essential as well.

Figure 10: Contemporary worm burrow.

Acknowledgements

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