Gastropoda, Hyalitha, Brachipoda and Related Microbes of Cambrian Reefs in South-facing Exposures of Pilgrim Formation in Central Montana

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ABSTRACT

Throughout evolution some organisms have left traces of their existence by the process of fossilization. By studying an organism's fossils, its structure and identity can be linked with a particular age or era. Each fossil provides insight into our evolutionary history. I conducted research in five sites in Grizzly Gulch, south of Helena , Montana. All sites contained reefs in the Pilgrim Formation of Late Cambrian age, which is approximately 520 million years old. I analyzed the reefs, extracted a total of 51 specimens and prepared them in the lab for identification. I identified 10 skeletal structures, including organisms of the phyla Hyalitha, Brachiopoda and Mollusca. I also identified other structures on the reefs that helped me to understand specific environmental conditions of this area. These structures included trace fossils which helped identify organisms that existed but were soft bodied. Evidence of their presence was preserved through burrows. In addition, graintypes such as oolites and intraclasts indicated that this area was one shallow water; stromatolites and channels suggested the presence of strong tides. My study concluded from these five reef sites that several different invertebrates dominated the floors of a shallow sea 520 million years ago in the area now called Grizzly Gulch, in central Montana.

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INTRODUCTION

The birth of fossilization occurred millions of years ago, and has been a crucial link to the understanding of environmental conditions and organisms of the past. Fossils include the remains and traces of organisms that have been preserved in the earth. Organisms from the Cambrian Period (Fig. 1) have been preserved in sedimentary rocks. I conducted the study using Cambrian reefs, which are large sedimentary rock mounds that used to exist on the floor of the sea.

But exactly how did the reefs form? As streams flowed into the sea that covered North America, they carried bits of rock and soil (sediment), which started to settle to the bottom, forming layers of mud and sand. Then large rock bodies were formed in which the sediment was bound together by organisms that secreted calcium carbonate (Blatt, 1972). Therefore, these organisms (Fig. 2) would be included and preserved in the reefs as fossils.

For hundreds of years, scientists have discovered fossils and have been able to reconstruct the environmental conditions of many areas of the world. Within the past few years many areas in and around Montana have been analyzed for evidence of the past. By studying fossils, we are able to study evolution and reconstruct habitats.

This is what my research set out to prove. I analyzed a total of five sites in south-facing exposures of the Pilgrim Formation that contained these ancient reefs of the Cambrian age. My purpose was to extract specimens from the reef sites, analyze them for traces of organisms and slowly piece together the environment and habitat that existed

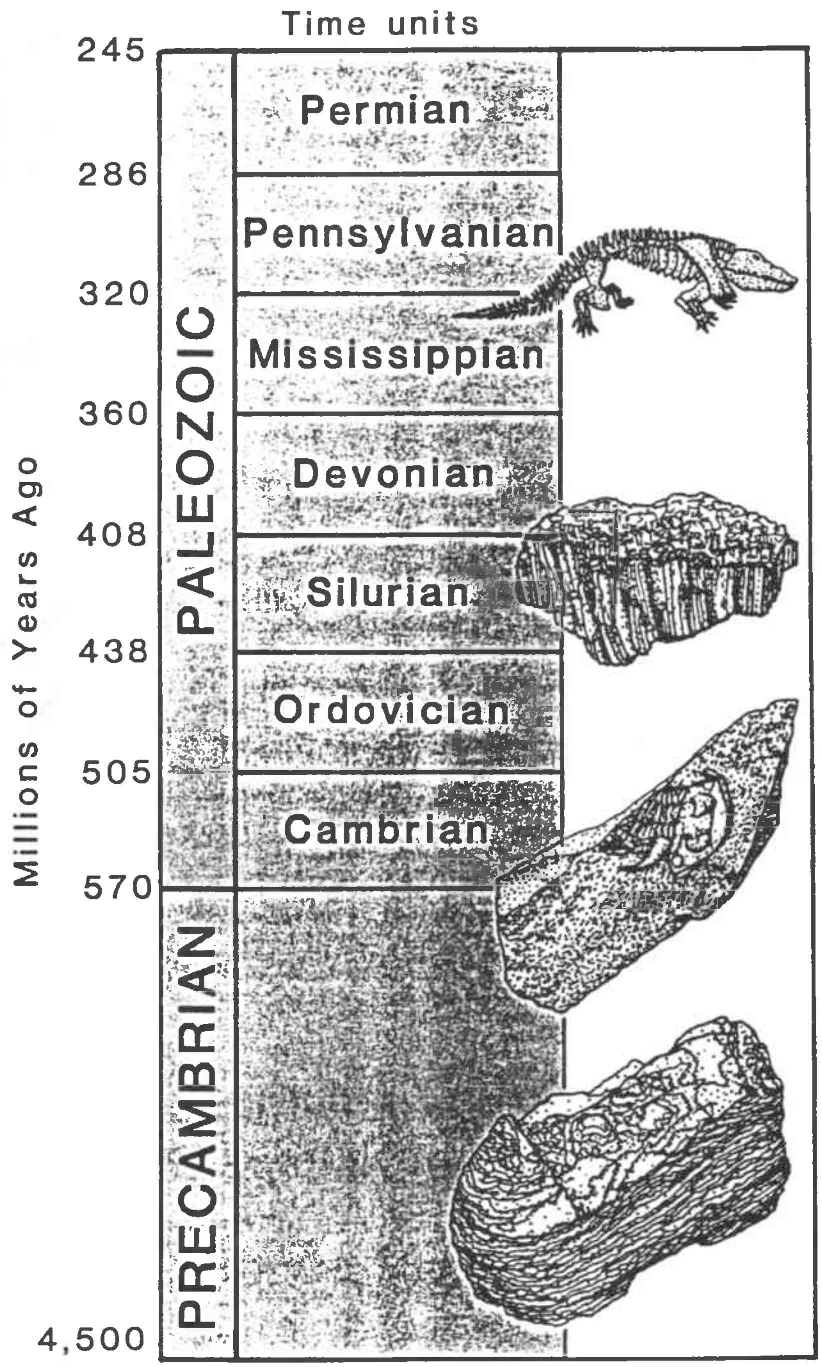

Fig.1 . Timeline indicating each different geologic period (Moore, 1952).

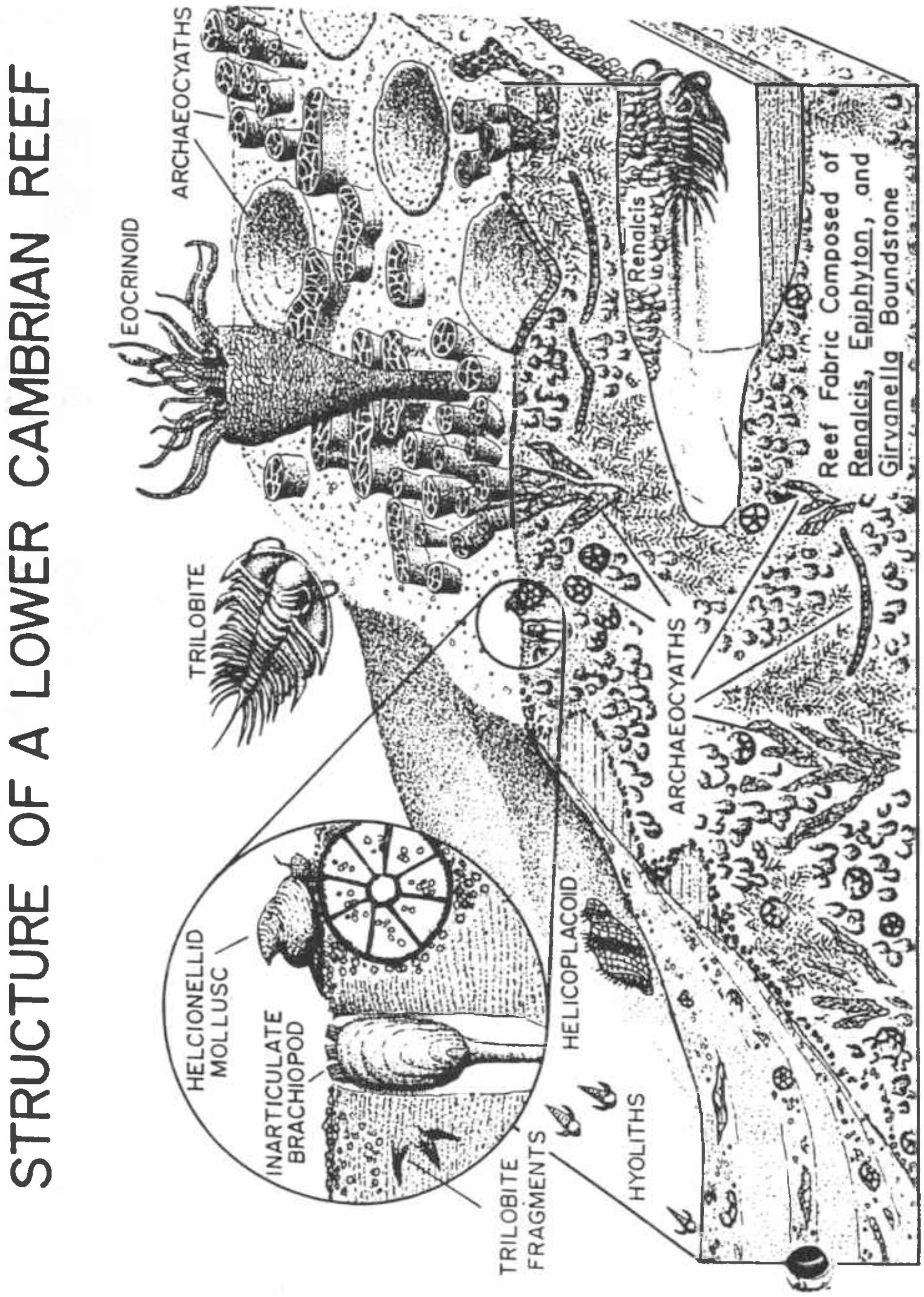

Fig.2. Structure of A Lower Cambrian Reef. Indicates the different types of organisms that existed during the Cambrian Period (Moore, 1952).

in this area 520 million years ago. I identified 10 skeletal fossils and also observed trace fossils (burrows) and other structures that helped construct an evolutionary picture.

Trace fossils

Trace fossils are "the work of an animal" (Bromley, 1990). They are the results of an animal's presence which differ from actual fossils, which are the skeletal structural remains of animals. Trace fossils are important because they show the presence of particular animals when the body fossils were not preserved.

There are several key characteristics of trace fossils. First, trace fossils are one of three types (Bromley 1990):

1. footprints, burrows and tracks
2. borings, and etchings
3. Coprolites and pseudofaeces

Secondly, trace fossils can further be categorized on behavior of the organism. Bromley (1990) recognizes six different classes:

1. dwelling
2. protection
3. locomotion
4. feeding
5. reproduction
6. social behavior

Brachiopods

The phylum Brachiopoda is quite significant in this study because brachiopods are well preserved and quite abundant in Cambrian reefs. In addition, they are easily distinguished based on their shape, size and symmetry (Moore, 1952). Brachiopods are marine invertebrates with a soft body within two shells or valves (bivalve). Brachiopods are inhabitants of the sea floor, and are thus bottom dwellers.

Gastropods

Contained within the phylum Mollusca, the snails are in the class Gastropoda. There are some main traits that distinguish mollusks from other phyla (Moore, 1952):

1. Complete absence of segmentation
2. Bilateral symmetrical organization of the body
3. Enclosure by the body wall
4. Concentration of sensory structures in head
5. Special characters of the nervous and digestive system
6. Distinctive aspects of larval stages.

The gastropods in the Grizzly Gulch reefs have a planispiral shell. Originally they were exclusively marine organisms but during the Cenozoic Period they adapted to fresh waters (Moore, 1952). However, before this, especially in the Cambrian Period, they only lived in the sea. They lived on the sea bottom and were thus bottom dwellers just like the brachiopods (Moore, 1952).

Hyaliths

Hyaliths are a separate phylum from Mollusca but have a common ancestry with the mollusks. Hyaiths are marine, bilaterally symmetrical invertebrates with a conical shell. They range from 4 to 30 mm in length (Moore, 1960). They are abundant and diverse in Cambrian limestone.

Stromatolites

Stromatolites are thinly-layered fossils which look like cabbage that has been sliced in half. They formed when sticky mats of threadlike blue-green cyanobacteria and algae trapped limy mud layers. Clusters of stromatolites developed in shallow regions. These organic mats are found on tidal flats and also in the subtidal zone and contain several different species of bacteria and algae. There are three different classes of stromatolites based on geometric structure (Boardman, 1987):

1. Laterally linked hemispheroids
2. Discrete, vertically stacked mats
3. Discrete sphereoids

Cyanobacteria

Renalcis and *Epiphyton* are two genera of calcareous microfossils that were originally identified as algae, but most recently have been referred to as cyanobacteria . They are prevalant in reefal limestone of Cambrian age (Boardman, 1987). They form an association with other mound and reef organisms. *Epiphyton* has tree-like extensions composed of fine grained dense calcium carbonate. *Renalcis* is irregularly branched with chambers.

Graintypes

The graintypes on the reefs were identified to help construct an accurate environment of this area during the Cambrian. Two graintypes were discovered, oolites and intraclasts. An oolite or ooid is a sand sized carbonate particle. Oolites have concentric rings of calcium carbonate built up much like the layers of an onion, but on a much smaller scale. These rings commonly surround a core or nucleus of another particle (Blatt, 1972). Intraclasts are particles or fragments of carbonate sediment that was eroded from the sea bottom. The intraclasts range in size and shape (Blatt, 1972).

Channels

Channels are common in Cambrian reefs. They are formed in shallow subtidal or intertidal marine environments. The presence of channels indicates tidal currents or perhaps strong wave action (Blatt, 1972).

MATERIAL AND METHODS

Location of Reefs

The study was conducted in five reef sites west of Grizzly Gulch, south of Helena, Montana (Fig. 3). These sites were selected because of good preservation of fossils and fossil structures. Grizzly Gulch is a wild narrow, mostly under developed canyon located in and just south of Mount Helena City Park.

In May 1997, I studied sites 1 and 2. In June-August I studied sites 3, 4 and 5 (Fig. 4,5). Towards the end of the summer I focused mainly on sites 2 and 5, because they provided many well preserved specimens in and near the reefs.

Study of Reefs

Two types of specimens were collected:

1. Float pieces (not attached to any reefs) were examined and collected
2. Specimens on specific mounds were extracted and recorded using a grid system.

A grid system was constructed for each mound, so that each specimen could be traced back to the specific location on the reef (Fig. 6). The grid system was constructed by marking and labeling each meter or 10 cm on the mound. Site 2 was a location where a mound was diagrammed using the grid system, then sampled (Fig. 7 and 8). The specimens were taken to the lab, permanently labeled and examined further for mineralized skeletal remnants and other significant structures. The specimens were cut with a diamond blade rock saw into thin slabs approximately 1.5 cm in thickness. The slabs were then etched in dilute hydrochloric acid and analyzed under a dissecting

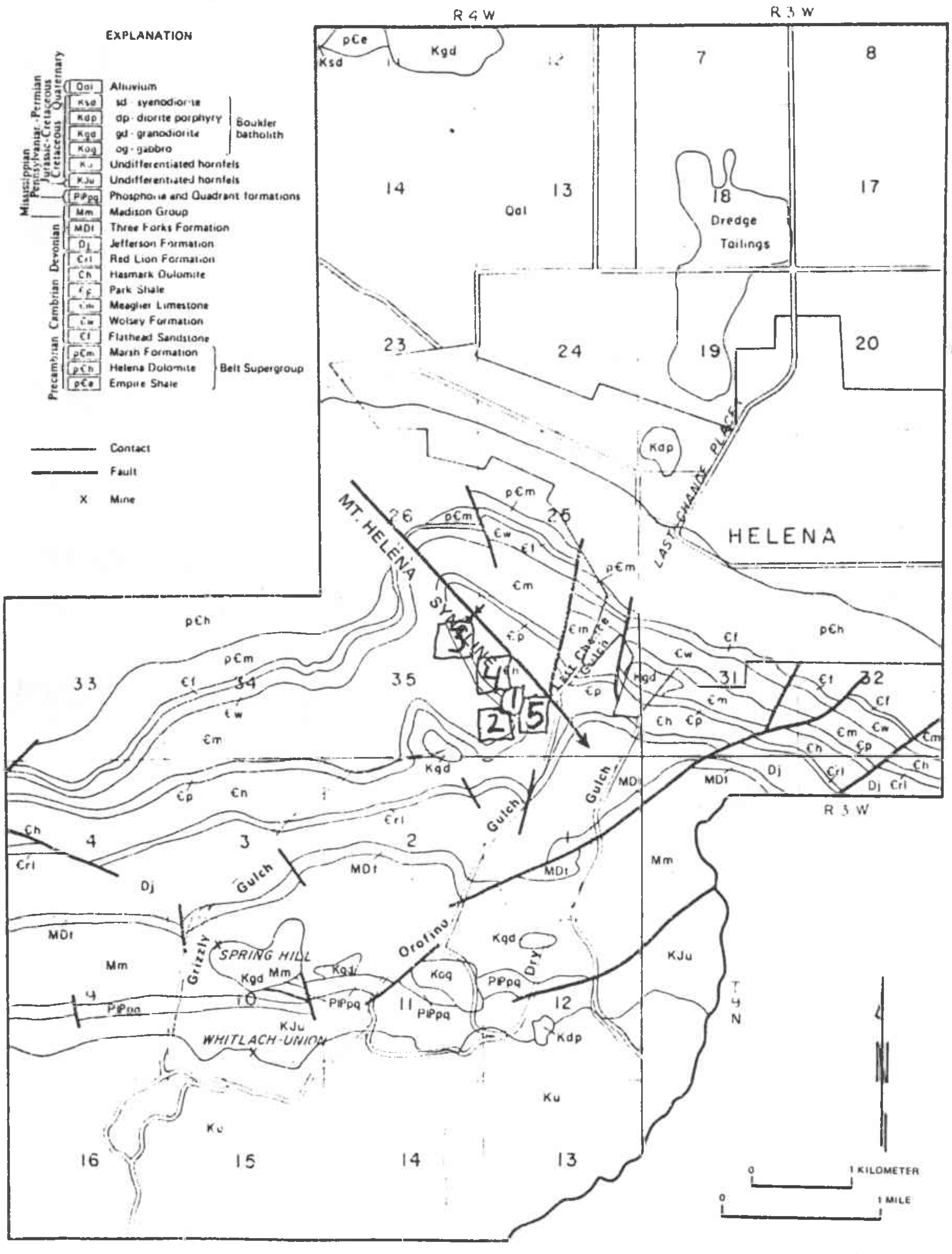

Fig.3. Map of Grizzly Gulch, south of Helena, Montana. Indicating the five sites that were analyzed (Knopf, 1963).

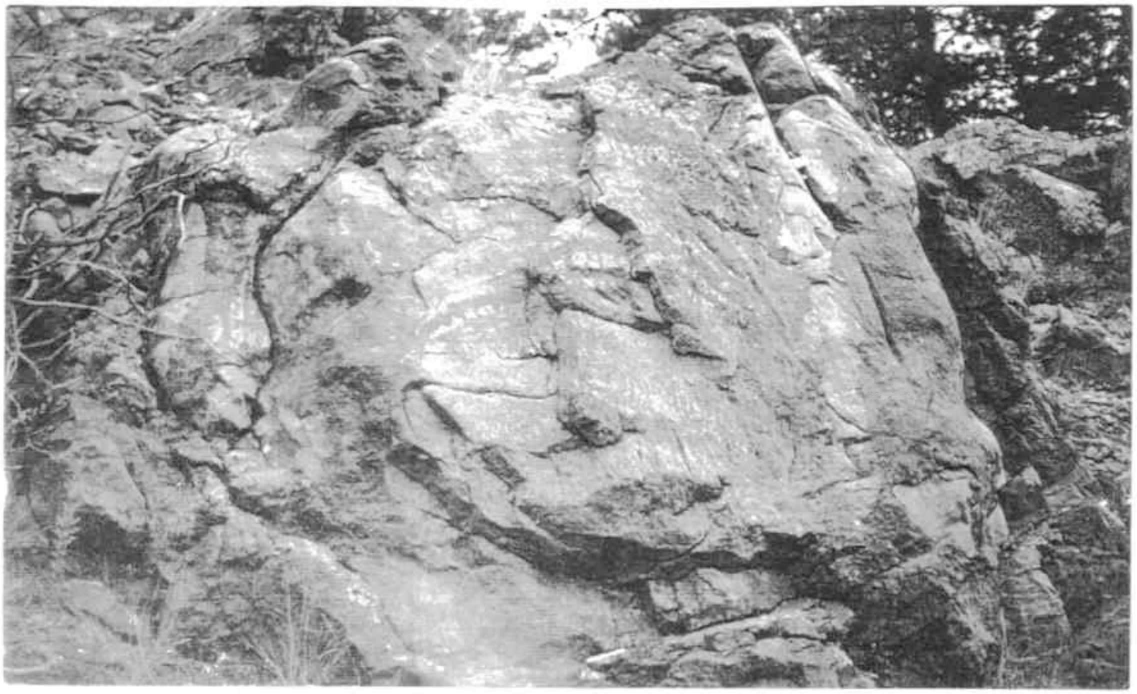

Fig.4. Photo of a Cambrian reef outcrop at Site 5. Pen in lower middle of photo is 13.5 mm in length.

Fig.5. Photo of various outcrops of Site 5.

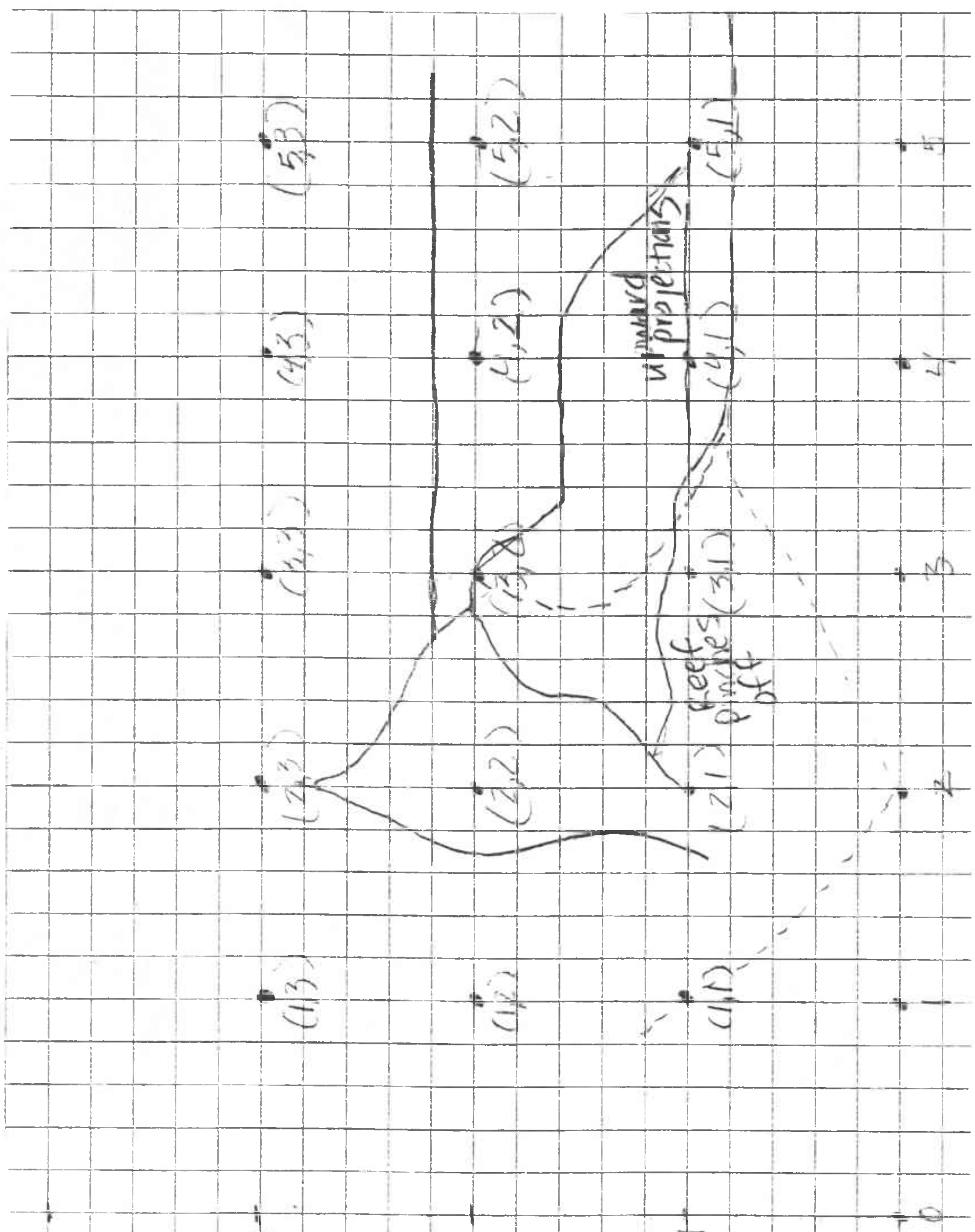

Fig.6. Drawing and grid system devised for a reef in site 2.

Fig.7. Picture of loose boulder early grid system. From a reef that was measured in site 2. Pen in photo is 14 mm in length.

Fig.8. Picture of loose boulder, late grid system. Shows how a grid system was drawn on a loose boulder from a reef at site 2. Grid spacing is 10cm.

microscope using glycerin. Glycerin was used because the limestone would absorb it and enhance observation of fossils and fossil structures. A total of eight slabs was selected which showed promising structures and fossils. The eight were trimmed to specified dimensions and then sent to Spectrum Petrographics Laboratory where eight thin sections were made of the slabs (Table 3). The thin sections were further analyzed for key remains of organisms, pictures were taken under the microscope of the important grain types and trace fossils.

Identification of Fossils and Fossil Structures

To identify the fossils, similar but different methods were used for each different fossil and fossil structure. For the trace fossils, each one was measured on the specimens and then the Treatise on Invertebrate Paleontology was used to match the trace fossils with a genus based on these measurements and shape (Moore, 1962). For the hyaliths, brachiopods and gastropods, similar methods were used. They were all measured and then the Treatise on Invertebrate Paleontology was used to match these fossils with a genus (Moore, 1960; Moore 1965). The oolites, intraclasts, calcareous algae, stromatolites, and channels were obvious visually. They were composed with others previously described (Boardman, 1987 and Moore, 1952). A total of 51 specimens was collected and analyzed. Table 1 shows the number of specimens extracted from each site.

RESULTS

Trace Fossils

Six specimens displayed significant trace fossils (Table 4). Specimen 2-8D displayed curvy, thin white lines on the surface and also round white circles that contained cavities that ranged from 2 mm in diameter to 6 mm in diameter. The thin curvy lines were 17 and 18 mm long.

Specimen 2-4D also displayed white circular structures with cavities and the diameters were measured as 4 mm, 6 mm. Thin white curvy lines were observed as well, and were 10 mm in length. Specimen 2-1A had a circular end but extended downward in a 4-mm line. Specimen 2-7C displayed one of the largest white curvy structures, 34 mm long, that also bore small cavities. Another oval structure contained a 7-mm cavity. Specimen 3-4E contained a diverse array of burrows. One was half-moon-shaped with a diameter of 6 mm. A long, somewhat straight, white line was 22 mm long. Small white circles with cavities ranged in diameter from 3 to 6 mm. The last specimen contained a curvy white structure. Two long curvy lines had lengths of 9 and 19 mm and two somewhat elongated circular structures were 9 and 15 mm long, with cavity diameters of 4 and 6 mm. These trace fossils were identified as remnants from one of two genera, the *Helminthospis* or the *Chondrites*.

Table 1. Specimens, with good preservation, extracted from Sites 2-5 in Grizzly Gulch, south of Helena, Montana.

Site 2	Site 3	Site 4	Site 5	Site 5 floats		
2-7	3-1	4-1	1.2,6	5F2	5F41	5F9
2-9	3-4	4-2	5-7	5F34	5F44	5F37
2-1	3-3	4-3	5-7.5	5F1	5F35	5F47
2-8	3-2		5-6.3	5F45	5F17	5F8
2-3			5-6.5	5F6	5F12	5F3
2-10			.5,7.5	5F46	5F36	5F42
2-4			5-6	5F7	5F40	5F19
2-6				5F22	5F38	
				5F43	5F31	
				5F19	5F14	
				10	5F15	

Table 2. Specimens containing specific fossils identified.

Trace Fossils	Snails	Brachio-pods	Hyaliths	Intraclasts	Oolites	Calcareous Cyanobacteria	Stromatolites and Channels
2-8 A	5F45	GME 8	5F43	GME 5	GME 7	2-7 A	Site 2
2- 4 D	5F2	2-4D	5F19			2-7 B	Site 5
2-1 A						2-9 B	
2-7 C						2-6 B	
2-4 E							
2-3 C							

Table 3. Specimens labeled, identification and slide numbers.

Specimen Collected	Identification	Slide Number
2-3 B	Fingerlike structures	GME 6
2-6 B	Calcareous algae	GME 1
2-9 B	Cyanobacteria	GME 4
2-7 B	*Renalcis*	GME 3
3-1 D	Intraclasts	GME 5
2-2 A	Grain patterns	GME 7
2-4 C	Brachipods	GME 8
2-7 A	*Renalcis*	GME 2

Table 4. Identification and measurements of trace fossils.

Trace Fossil	Diameter of Burrows (mm)	Length of Tracks (mm)	Identification
2-8 A	2, 6	17, 18	*Chondrites* or *Helminthospis*
2-4 D	4, 6	10	
2-1 A	4	9	
2-7 C	4,5 and 7	34	
2-4 E	3, 6	22	
2-3 C	4, 6	9, 19	

Table 5. Identification and measurements of Brachiopods.

Brachiopod	Dimensions (mm)	Identification
GME 8 A	2 x 5	*Lingulella*
GME 8 B	5 x 7	*Lingulepis*
2-4 D 1	2 x 4	*Lingulepis*
2-4 D 2	3 x 6	*Lingulepis*
2-4 D 3	3 x 5	*Lingulepis*
2-4 D 4	4 x 7	*Fordinia*

Table 6. Identification and measurements of gastropods.

Gastropods	Dimensions (mm)	Identification
5 F 45	4 x 7	Helcinoellacea
5 F 2	4 x 9	

Table 7. Identification and measurements of hyaliths.

Hyaliths	Dimensions (mm)	Identification
5 F 43	9 x 6	Orthothecida
5 F 19	11 x 4	

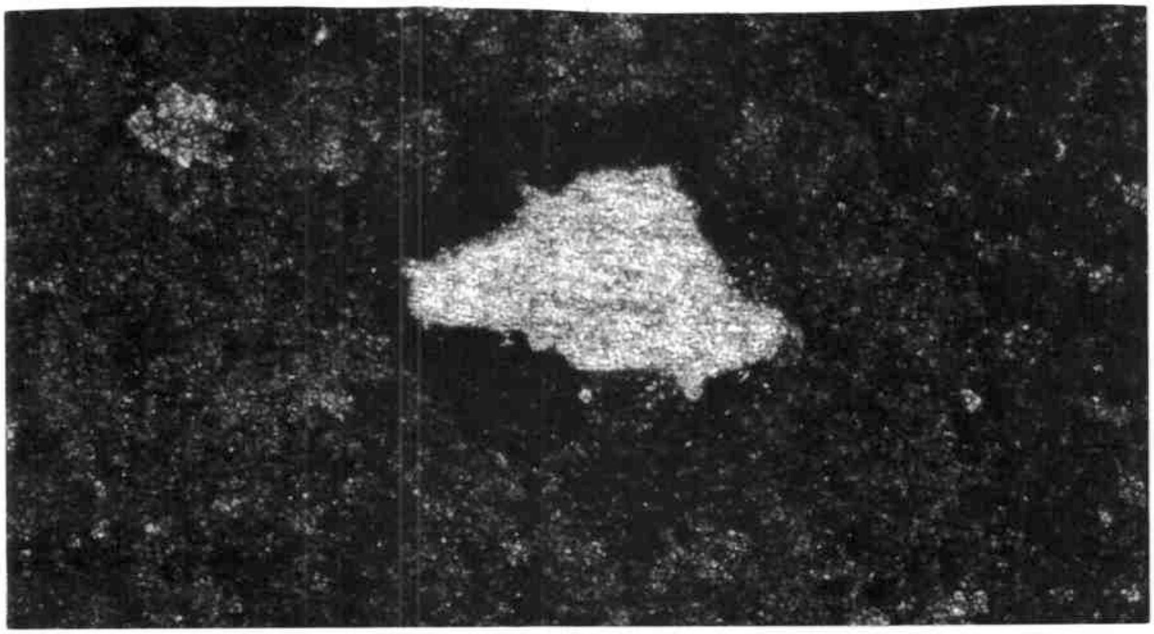

Fig.9. Shows a magnified burrow of thin section GME 4. Burrow is filled with clear, sparry calcite cement. Burrow is 3 mm x 2 mm.

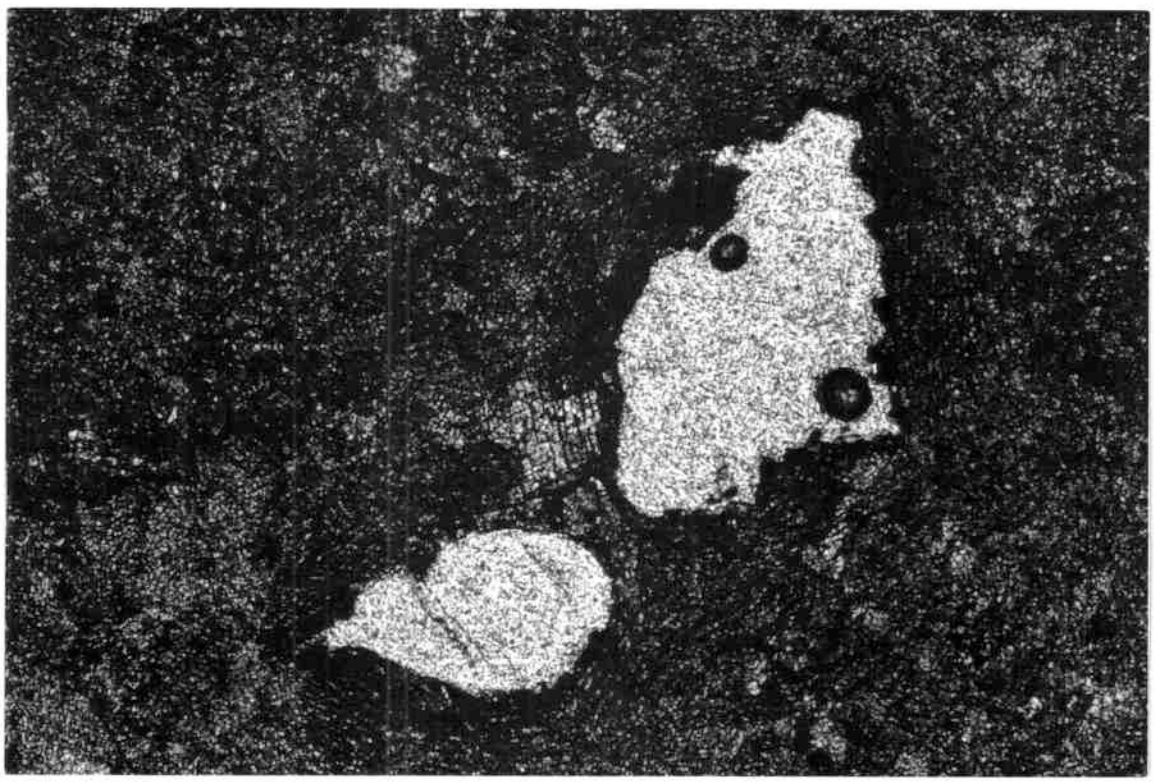

Fig.10. Shows two burrows magnified from thin section GME 7. Burrows are filled with clear sparry calcite cement. Large burrow is 4 mm x 2 mm.

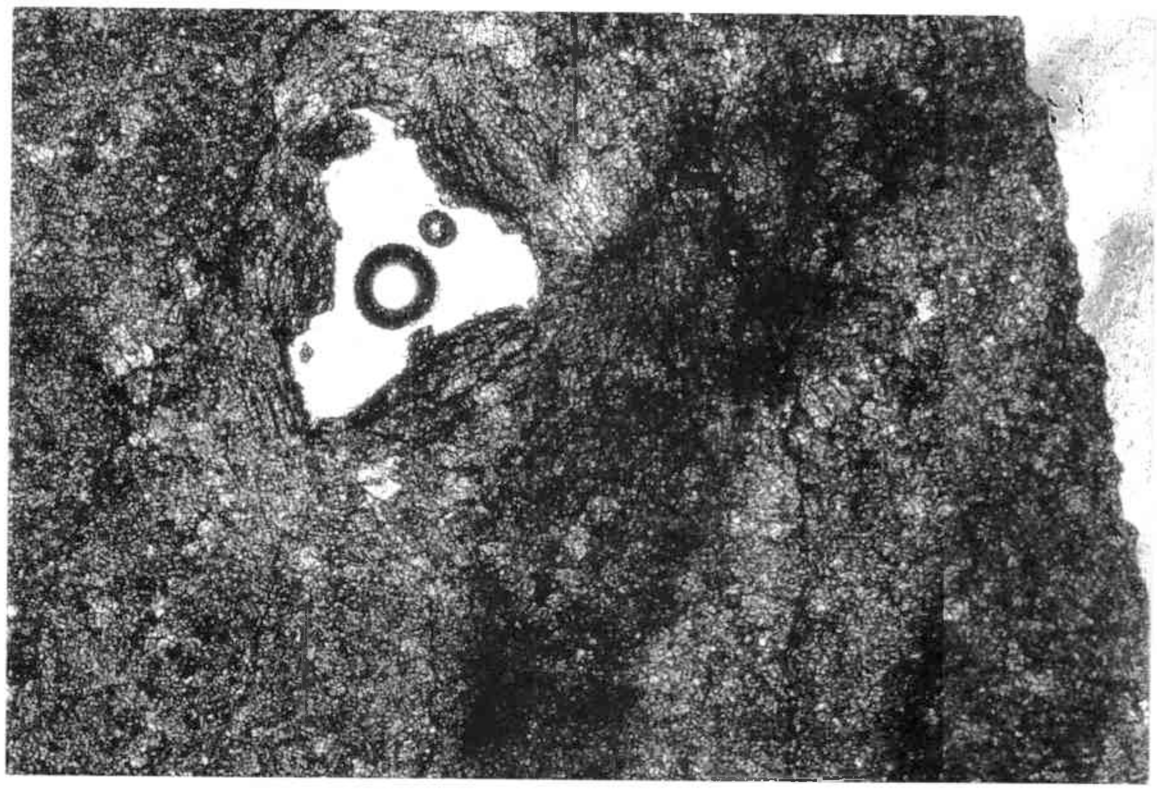

Fig.11. Shows a magnified cavity of specimen GME 5. The two round structures in the cavity are artifacts, bubbles in the glycerin. The concentric grain orientation around the burrow is caused by displacement of weakly bound sediment by the organism. Burrow Is approximately 2 mm x 2 mm.

Hyalitha

Two hyaliths were observed in the specimens, specifically on 5F43 and 5F19 but they differed in size and shape. The hyalith on 5F19 was elongated with a sharp pointed tip and the whole fossil measured 11mm in length and 4 mm in width. The hyalith on 5F43 was more triangular with a rounded tip and measurements of 9mm long and 6mm wide. These hyaliths were identified as belonging to the Order Orthothecid (Table 7).

Brachiopoda

Six brachiopod fossils were analyzed, and identified. Two fossils on specimen GME-8 were observed and their measurements are 2 mm wide and 5 mm long and 5mm wide and 7 mm long, respectively. Specimen 2-4 D was analyzed and four brachiopods fossils were observed and measured at 2x4,3x6,3x5, and 4x7mm. The specimen measuring 2x5 mm on GME-8 appeared to be the most elongated of all specimens . The other brachiopod on GME-8 appeared more round for the majority of the shell and appeared to curve and pinch off forming a small cone. The four specimens on 2-4D also appeared similar to the 5x7mm fossil on GME-8, round and then cone shaped at the tip of the brachiopod but they differed in the size of the fossil. Specimen GME 8 A was identified as *Lingulella*, Specimens GME 8 B, 2-4 D1, 2-4 D2, 2-4 D3 were identified as *Lingulepis* and Specimen 2-4 D 4 was identified as *Fordinia* (Table 5).

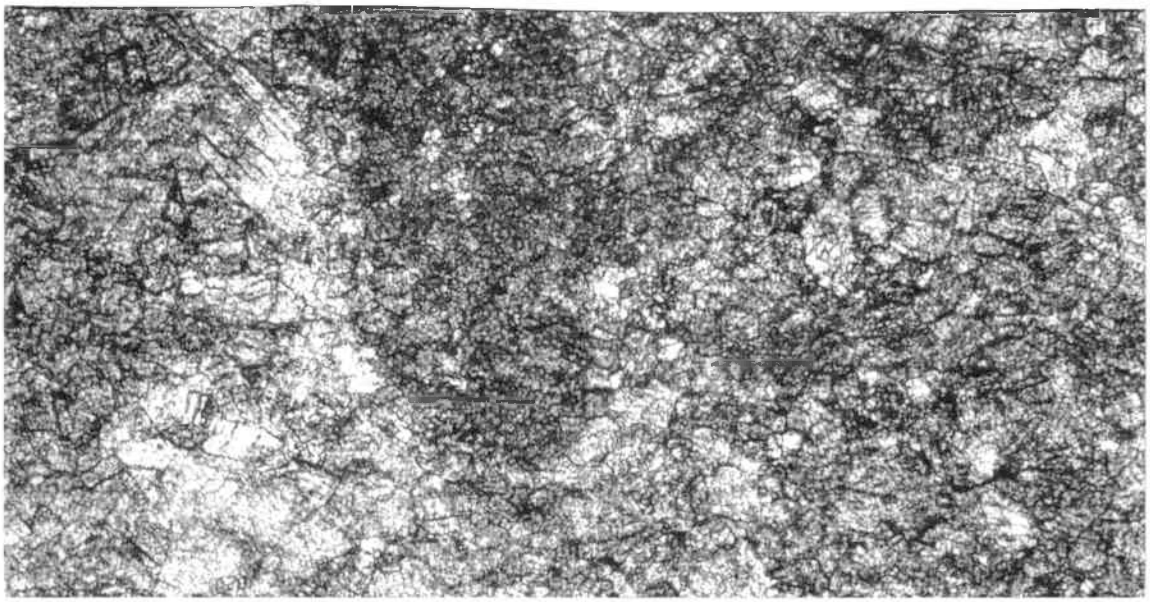

Fig. 12. Contrasting light and dark grains of thin section. The primary textures of the microfossils have been nearly destroyed by secondary dolomitization. The white areas are the "fingers". Large dark boundstone area is approximately 5 mm in length.

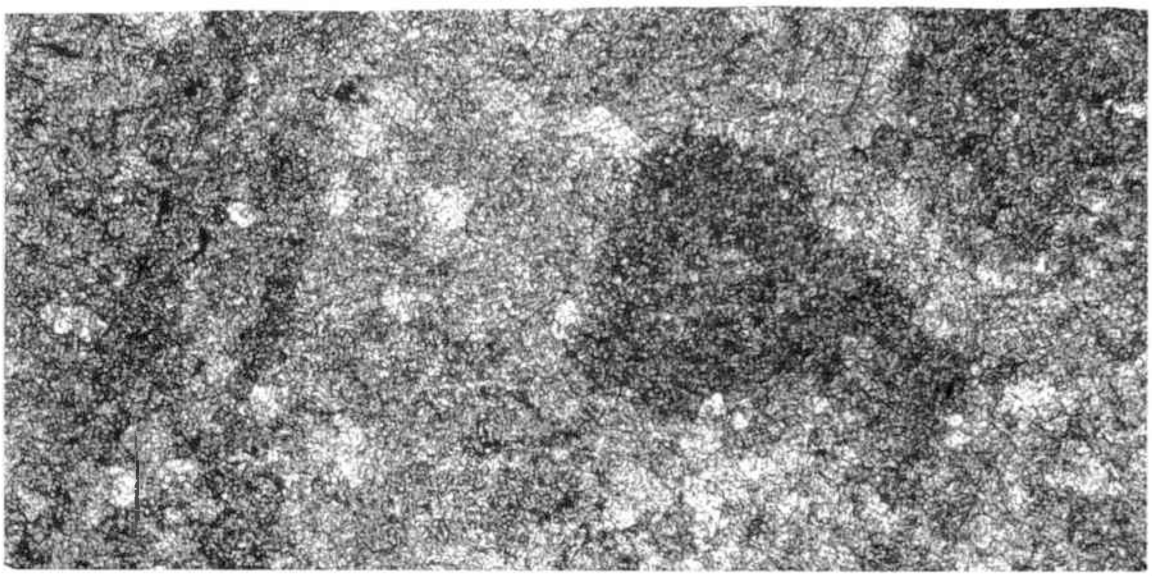

Fig. 13. Contrasting light and dark of the reef's microbial boundstone, in thin section GME 8. Fine tubes in the dark "Renalcis-like" boundstone are identified as Girvanella, a calcareous algae. Dark boundstone area is approximately 3 mm.

Stromatolites

Vertical stromatolites were observed on reefs in sites 2 and 5. They fit into the category of vertical because they appear to be caused by tides formed in water flow that also result in channels.

Gastropods

Two gastropods were observed, on specimens 5F45 and 5F2. The fossil on 5F45 appeared to be wider and more rounded. The gastropod on 5F2 was more pointed with a diameter of 4 mm and a length of 9 mm. The two gastropods were identified from the superfamily Helcinoellacea (Table 6).

Calcareous Cyanobacteria

The ones I observed had irregular chambers and cracking of the sediment of the algal mats which are features of intertidal deposits. I observed two genera, *Epiphyton* and *Renalcis* in specimens 2-6B, 2-9 B, 2-7, B and 2-7 A.

Grain types

Oolites were observed mainly on specimen GME7 and appeared to be dark circles with a light background. Intraclasts were observed on GME 5 as web like circular structures outlined in a light grain with a dark grain in the actual circular structure.

DISCUSSION AND CONCLUSIONS

From the results, the environment in Grizzly Gulch, south of Helena, Montana, during the Cambrian age appeared to be marine, composed of a shallow sea flourishing with bottom dwellers, which include gastropods, brachiopods, hyaliths and cyanobacteria.

Trace Fossils

From the observations, all specimens appeared to exhibit two basic trace fossils, of different measurements. First, the round structures with the central hollow cavity turned out to be burrows (Fig. 9, 10,11). The structure described as the cavity is the lumen of the burrow, and all of the burrows I observed contained a lumen with a boundary that was combined with sediment and differed on degree of calcification. The burrows identified were all similiar to the burrow in Fig. 15 and differed in diameter of the lumen. Second, the wavy lines according to Bromley (1990) is a key characteristic of worm burrows. I was able to match my worm burrows with those of two ichnogenera, Chondrites or Helminthospis. The tracks observed are similar to these two genera that are pictured in Fig. 6. These two genera exhibit various lengths of burrows but resemble the wavy, white line. These two genera flourished in a marine habitat and mainly on the sea floors which coordinate with other fossil habitats I identified. Bromley (1990) indicates that these genera were able to survive in shallow sea bottoms and some were able to pump oxygenated water through open burrow into anaerobic sediment which could also explain the burrow function. This is significant because it coordinates with the other fossils on similar specimens that were bottom dwellers such as the brachiopods and gastropods, thus the trace fossils observed in the specimens appear to be ichnogenera

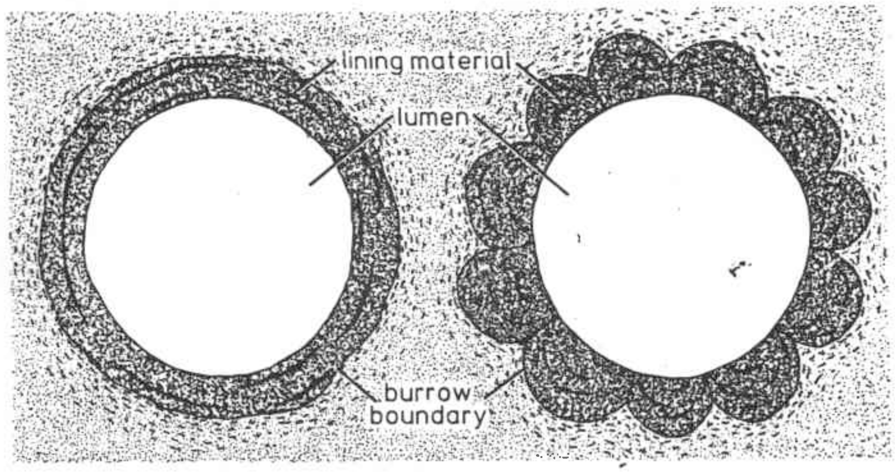

Fig. 15. Diagram of a typical burrow and its different parts (Bromley 1990).

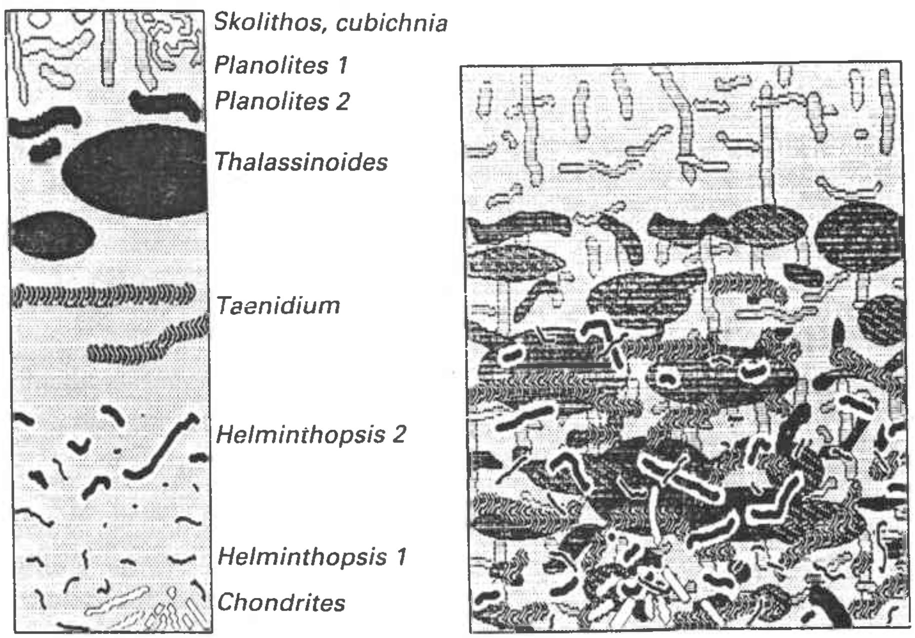

Fig. 16. Different ichnogenera including Helminthopsis and Chondrites (Bromley, 1990).

Fig. 17. Picture of a channel between two reef mounds in site 5. Pen in photo is 13.5 mm in length.

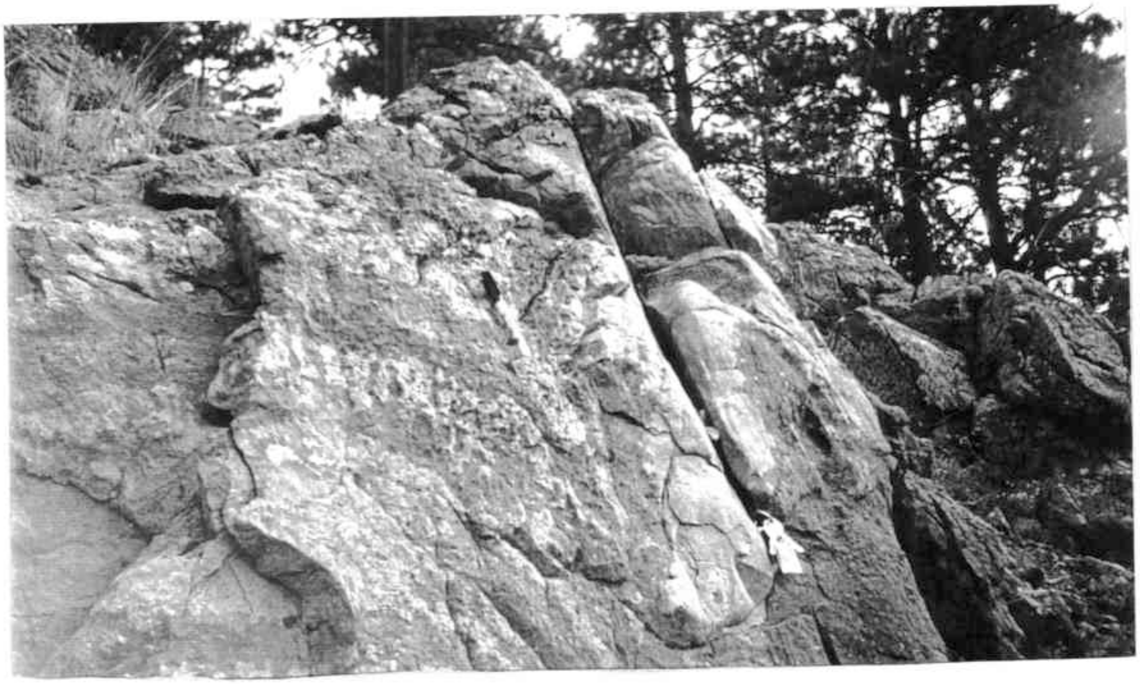

Fig. 18. Picture of a channel of the reef in site 5; shows a different angle of view. Pen is 13.5 mm in length.

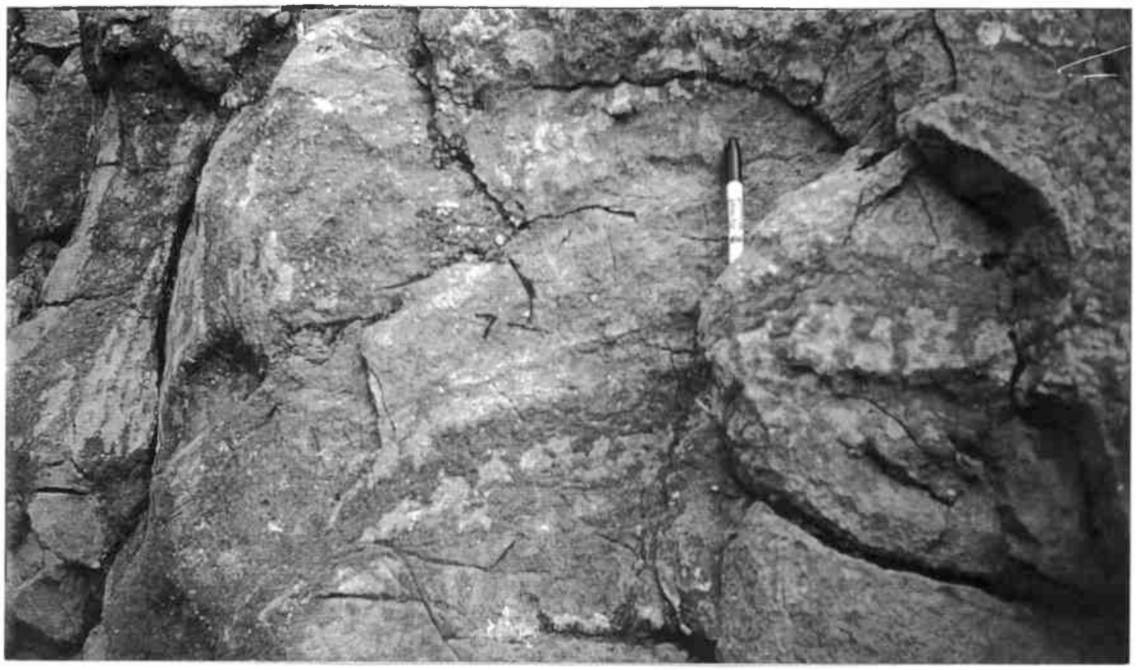

Fig. 19. Close-up of fingerlike structures and the contrasting light and dark beds of a reef mound in site 5. Pen in photo is 13.5 mm in length.

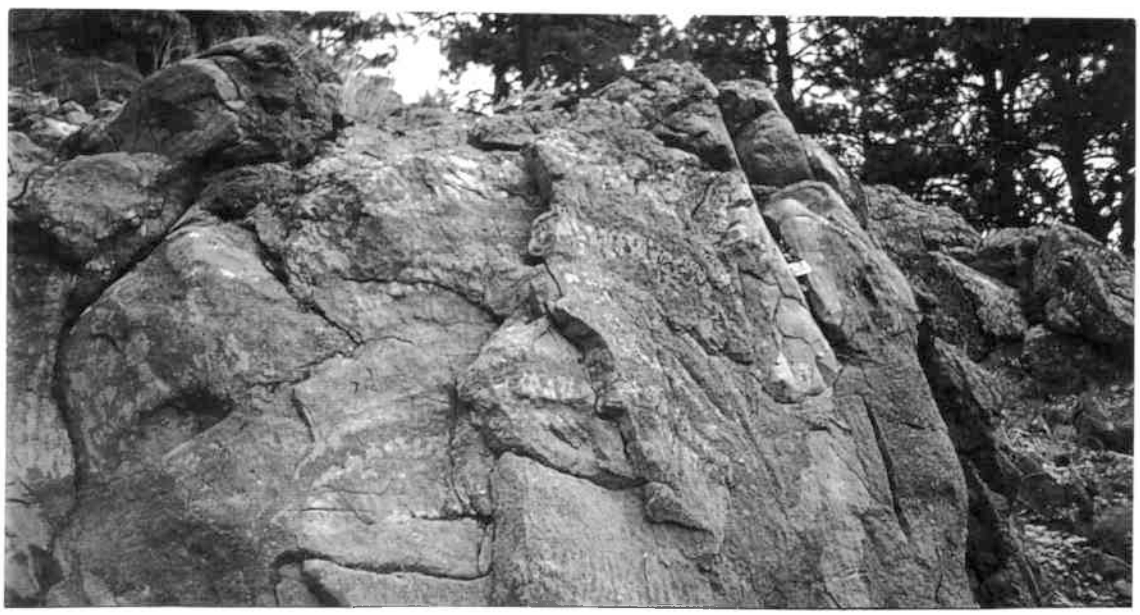

Fig. 20. Channel and convex upward beds of a reef mound in site 5. Keys in photo extend to a length of 13 mm.

Chondrites or *Helminthospis*. However, the particular species which formed the trace cannot be determined without further information.

Hyalitha

The two hyaliths appeared to belong to the Order Orthothecida, because they lacked ligulas which are shelf like extensions at the base of the hyaliths. The members of this order dominated the earth starting in the Cambrian age. However, no further identification could be made because of a lack of detail on the fossils.

Brachipoda

All six brachiopods specimens resembled those of the Class Inarticulata, and the subfamily Lingulelleniae. The key features that made these brachiopods fit was the subfamily's key characteristics, elongate but triangular. This subfamily was prevelant in the Lower Cambrian age. However the six brachipods differed in which members of the subfamily they best resembled. The 2x5 mm specimen appeared closely similar to *Lingulella*, which is more elongated than other members and best fits with this specimen. The 5x7, 3x5,3x6 and 2x4 mm specimens all resembled *Lingulepis* because of the elongation but cone tip. Finally, the 4x7 mm specimens appeared more similar to that of *Fordinia* because it was more pointed at the tip which is the key characteristic of this member (H267).

Gastropoda

A few members of this phylum were similar in appearance to the two hyaliths. These two gastropods were most identical to the Super Family Helcinonellacea, which have a cap-shaped or coiled shell and existed during the Cambrian age. Two families are within this superfamily, Family Helcionellida and Coreospiridae. Both show similarities to the two fossils, so the two gastropods were not identified with a specific family. The first family is elongated with a cap shaped shell which is similar to the first fossil. However the second family has coiling and extensions on the margin which resemble both of the fossils thus,complete identification could not be performed.

Calcareous Cyanobacteria

Renalsis and *Epiphyton* appear as dendritic and chambered structures. These two genera were visible in areas near the burrows where many of the organisms thrived. These two genera exemplify organisms restricted to shallow depths because of their reliance on adequate light. The cyanobacteria play a significant role in producing carbonate mud, grains and structures such as stromatolites.

Grain types

The presence of these grain types indicate that the sea was shallow. They are evidence of large scale cross bedding formation in tidal bars (Fig. 12, 13, 14,15) . Tidal setting is one in which a grain is moved periodically and will develop an oolitic coating and is evidence for current transport where the grain is buried and than uncovered. Intraclasts represent deposition of host sediment and indicate the presence of tidal flats. They are a result of carbonate sediment exposed to air by tides that develop the stromatolites.

Stromatolites and Channels

Their role was to produce a binding and sediment stabilizing effect for mound production by the organism. The tides formed in water flow resulted in channels that I observed near the burrows (Fig. 17, 18, 19,20).

My study provided information on the evolutionary history of this region of Montana. Specifically, I was able to show the existence of hyaliths, brachiopods, and gastropods 520 million years ago and the conditions of this area. The sea was shallow with strong tidal currents and flourished with bottom dwellers. The thin sections suggested that the dark boundstone in the thrombolite mounds contain abundant Renalsis-like microbial fossils and some probable Girvanella. The white fingers, separating and imbedded in the black boundstone are from outcrop observations, clearly another calcareous microbial species. My study reconstructed the environmental conditions and habitat of Grizzly Gulch. This information indicates that fossils are crucial links to our past. The next step is to continue to explore areas around Helena which will help to increase the evolutionary picture of the Cambrian Age in what is now known as Montana.

LITERATURE CITED

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