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Lithology and depositional environments of a portion of the Clays Ferry Formation (Middle and Upper Ordovician) exposed at Silver Creek, Madison County, Kentucky

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ABSTRACT

We measure, describe, and interpret a carbonate stratigraphic section within the Clays Ferry Formation (Middle and Upper Ordovician) cropping out in Madison County, Kentucky (USGS Kirksville 7.5" quadrangle). The total thickness of the measured section is 4.76 m. We sampled the stratigraphic section at approximately half-meter intervals, also taking samples at lithology changes. We collected a total 20 samples, all of which were slabbed, and then selected 12 samples for thin section analysis.

Observed lithologies represent discrete depositional environments. The rocks are dominantly limestones with some carbonate shales deposited in shallow-water depositional environments that are generally open-marine, subtidal with perhaps some intertidal units. Burrowed mudstones and wackestones are more common lower in the stratigraphic section and perhaps represent the shallowest depositional environments. Upsection, laminated pelloidal packstones/grainstones occur and contain varying amounts of fragmented fossils. The next prominent unit is a 1.5-meter-thick interval, where shaly carbonate is interbedded with ~10-cm thick limestone beds containing a diverse fossil assemblage, indicating subtidal, open-marine conditions. Several 15-to-25-cm thick grainstone beds mostly comprised of nested, strophomenid brachiopods are prominent ledge-formers being deposited under turbulent conditions. Fossiliferous packstones and grainstones with brachiopods, bryozoans, and crinoids then dominate indicating open-marine, subtidal environments; one such horizon displays 10- to 15 cm-high dune bedforms. Upsection for the next ~1.5 meters these lithologies reoccur and are interbedded with one another, representing migration of depositional environments over a shallow-marine platform.

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INTRODUCTION

During the Middle to Upper Ordovician, portions of east-central Kentucky were part of a shallow carbonate platform that Ettensohn et al. (2004) call the Lexington Platform (Figure 1). During this time, the rising Appalachian Mountains formed the Taconic foreland basin to the west of the mountain chain and to the east of the platform. Another deeper-water basin, the Sebree Trough, was situated to the north of the Lexington Platform. As the Appalachian system continued to develop, younger Paleozoic sediments were deposited atop the Ordovician section, forming the present stratigraphy.

East- Central Kentucky now lies west of the Valley and Ridge thrust belt within the Appalachian Plateau, which is characterized by horizontal to gently-dipping Paleozoic sedimentary rocks. The depositional environments present in the area range from peritidal to open marine, shallow-water conditions.

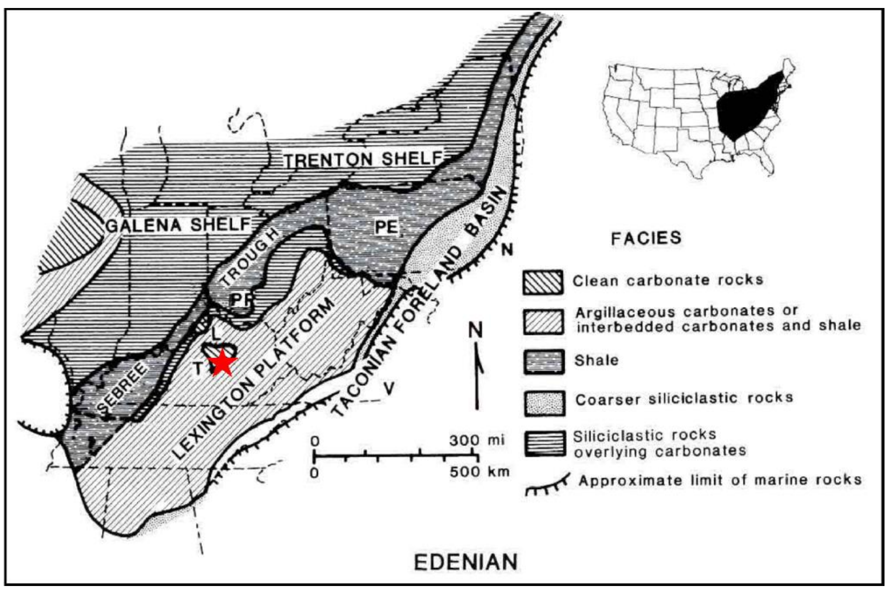

Figure 1. Depositional and tectonic setting of the Middle to Upper Ordovician of east-central Kentucky. The study area is shown with the red star situated upon the Lexington Platform. Modified after Ettensohn et al. (2004).

Stratigraphy

The Clays Ferry Formation is the subject of this investigation, and is Middle to Upper Ordovician in age. These rocks were deposited on the Lexington Platform as the Cincinnatian Series and Edenian Stage (Fig. 2). The underlying Lexington Limestone contains thick limestone sequences with little to no mud. The younger, overlying Garrard Formation is dominated by silts, shales, and mudstones. The Clays Ferry Formation at the study location is comprised dominantly of limestones with some carbonate shales.

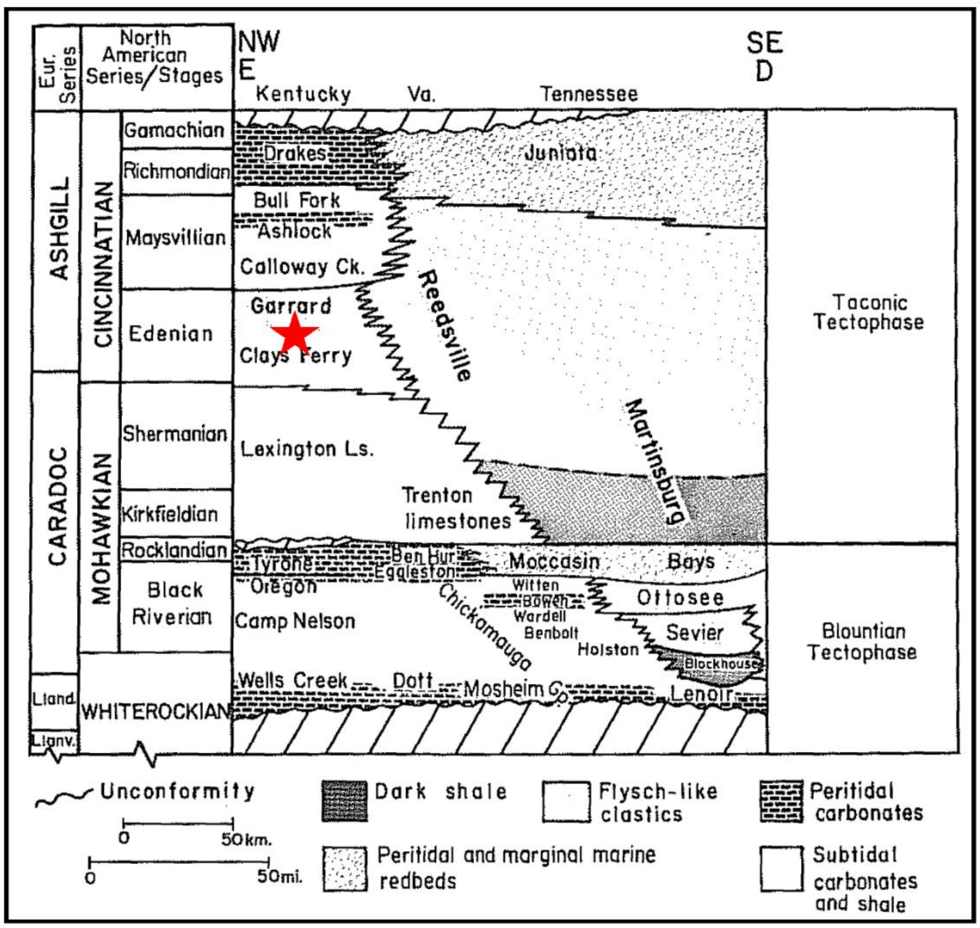

Figure 2. Stratigraphy and distribution of Ordovician rocks of the central Appalachian Basin. Note the stratigraphic location of the Clays Ferry Formation and its depositional location in east-central Kentucky upon the Lexington Platform (red star). Modified after Ettensohn (1991).

Study Locality

The study area is located approximately 9 miles west of Richmond, Kentucky along KY 876 (Barnes Mill Road) where the road crosses a bridge over Silver Creek (Fig. 3). The area displays limestone outcrops of the Clays Ferry Formation in the stream bed, but was mapped as alluvium by Greene (1965). The outcrops are flat-lying and form a 4.76 m-thick stratigraphic sequence of limestones that stair-step upstream and upsection over several sets of falls within an overland distance of ~400 m.

The base of the well-exposed stratigraphic section begins downstream of the bridge and continues about 100 m upstream where the main set falls occur, perfectly exposing about 1.5 m of stratigraphic section (Fig. 3). Outcrops continue in the stream bed creating large lateral exposures of single beds that stretch upsection for about 200 m. Then two smaller sets of falls occur, separated by about 100-m-long flat, stream-bed exposure.

Study Objectives

The objectives of this study are to measure a stratigraphic section of the well-exposed rocks at the study area and then describe, analyze, and interpret the rock units to identify their environments of deposition.

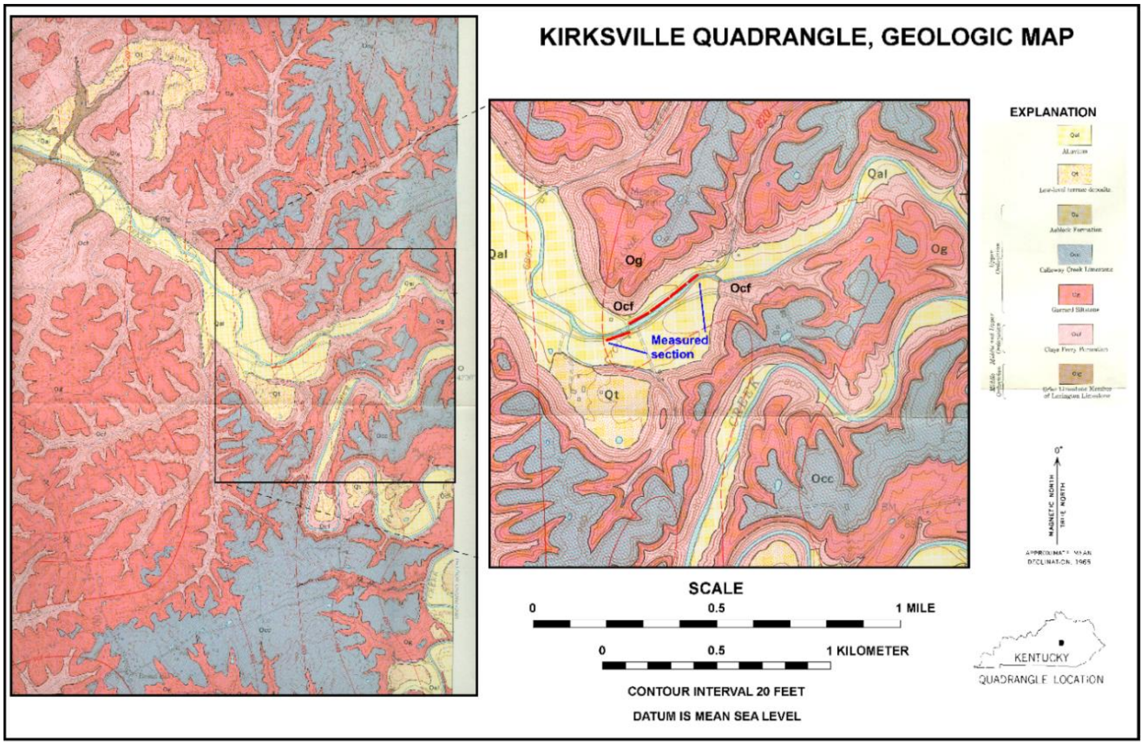

Figure 3. Geologic map of the study locality modified from Greene (1965). The location of the measured stratigraphic section is shown by the red lines within the stream bed of Silver Creek.

METHODS

We measured a stratigraphic section that is 4.76 m thick (Fig 4). Samples were taken 0.5 m intervals or at significant and/or interesting lithology changes. All 20 samples were cut, slabbed, and polished to expose and examine the rock interiors. Twelve samples were chosen for thin sections, which were prepared by Texas Petrographic.

MEASURED SECTION AND LITHOLOGY

The carbonate stratigraphic section exposed in the study area is comprised of five main lithologies: mudstone, packstone, fine-grained, fossiliferous grainstone, carbonate shale, and coarse-grained grainstones comprised of large, nested fossils. These lithologies are shown in the stratigraphic section in Figure 4 and are summarized in Table 1 below.

Mudstone lithology (Lithology 1)

Mudstones are most common in the lower portion of the stratigraphic section, but occur throughout the measured section (mudstone units include VIII, VII, VI, V, III, I, 1, 3, 8, 10, 12, 15, 16, 17, 18, 19, 21, 23, and 25). Their weathered surfaces are gray-blue in color and are highly bioturbated, containing various fossils. Prominent vertical and horizontal burrows are visible in slabs and thin section (Fig. 5A). Allochems are mainly fossils with sporadic occurrences of peloids. Marine fossils such as crinoid columnals and strophomenid brachiopods are found on bedding planes, although some fossils are found in bed interiors. These fossil fragments are generally too small to be identified, but larger fragments included trilobites, echinoderm plates, and ostracods (Fig. 5B).

Table 1. Characteristics of the 5 lithologies recognized by this study.

Lithology	Name	Description
1	Mudstone	Mud matrix, highly bioturbated with small unidentifiable fossil fragments.
2	Packstone	Very-fine grained, well sorted, bioturbated with small peloid and fossil fragments.
3	Grainstone	Well-sorted, very-fine grained fraction with large fossil fragments.
4	Carbonate Shale	Highly weathered, interbedded grainstone beds and lenses.
5	Nested Grainstone	Poorly-sorted, coarse-grained, contains large tightly-packed fossils.

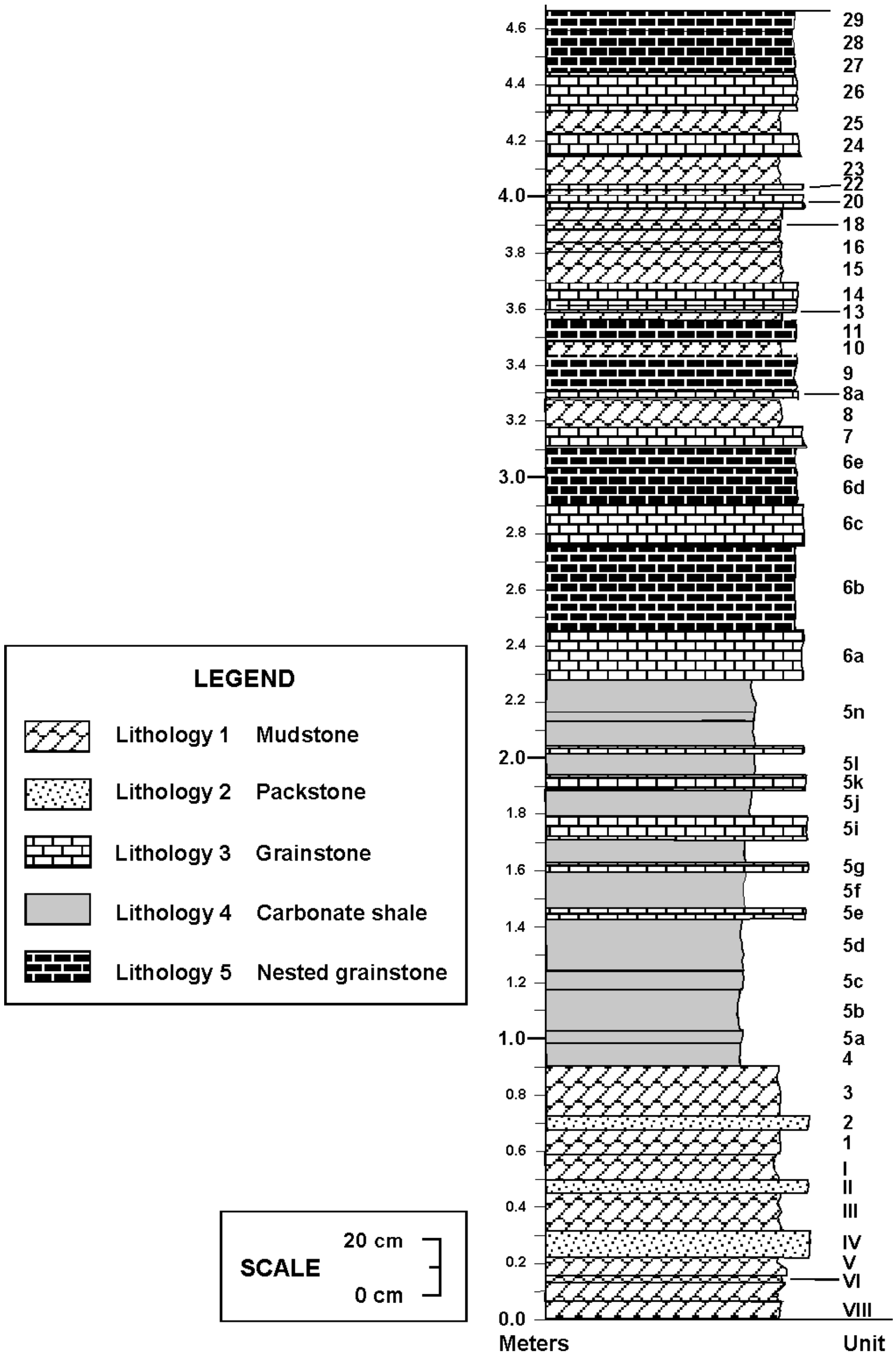

Figure 4. Measured stratigraphic section showing location and thickness of recognized lithologies.

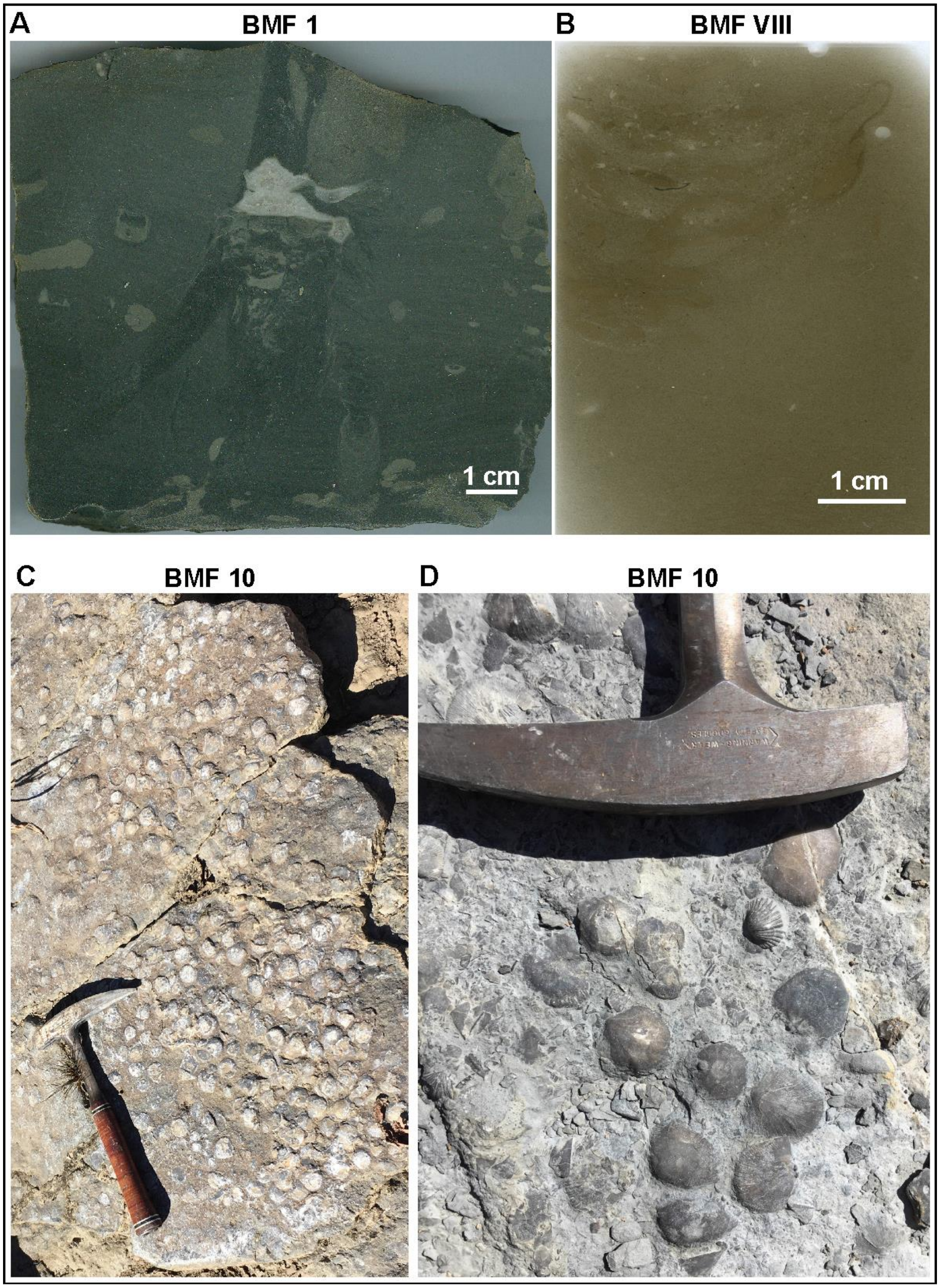

Figure 5. Illustrations of the mudstone lithology. **A.** Polished slab (sample BMF-1) showing mud matrix and partially-bioturbated mudstone. **B.** Thin section scan (sample BMF VIII) showing mudstone lithology. **C** and **D.** Strophomenid brachiopods on bedding planes.

<u>Packstone lithology</u> (Lithology 2)

Packstone lithologies are first found immediately upsection of the basal mudstones (units IV, II, and 2). They are heavily bioturbated with vertical and horizontal burrows; some layering is preserved as seen in hand sample. Allochems are very fine grained and well sorted (Fig. 6). Some packstone beds grade laterally into mudstone. Bedding surfaces often display trace fossils in the form of trails. The bulk of this lithology is formed by silt- to very-fine-sand sized fossil fragments with or without peloid grains. Larger fossil fragments also occur within some samples.

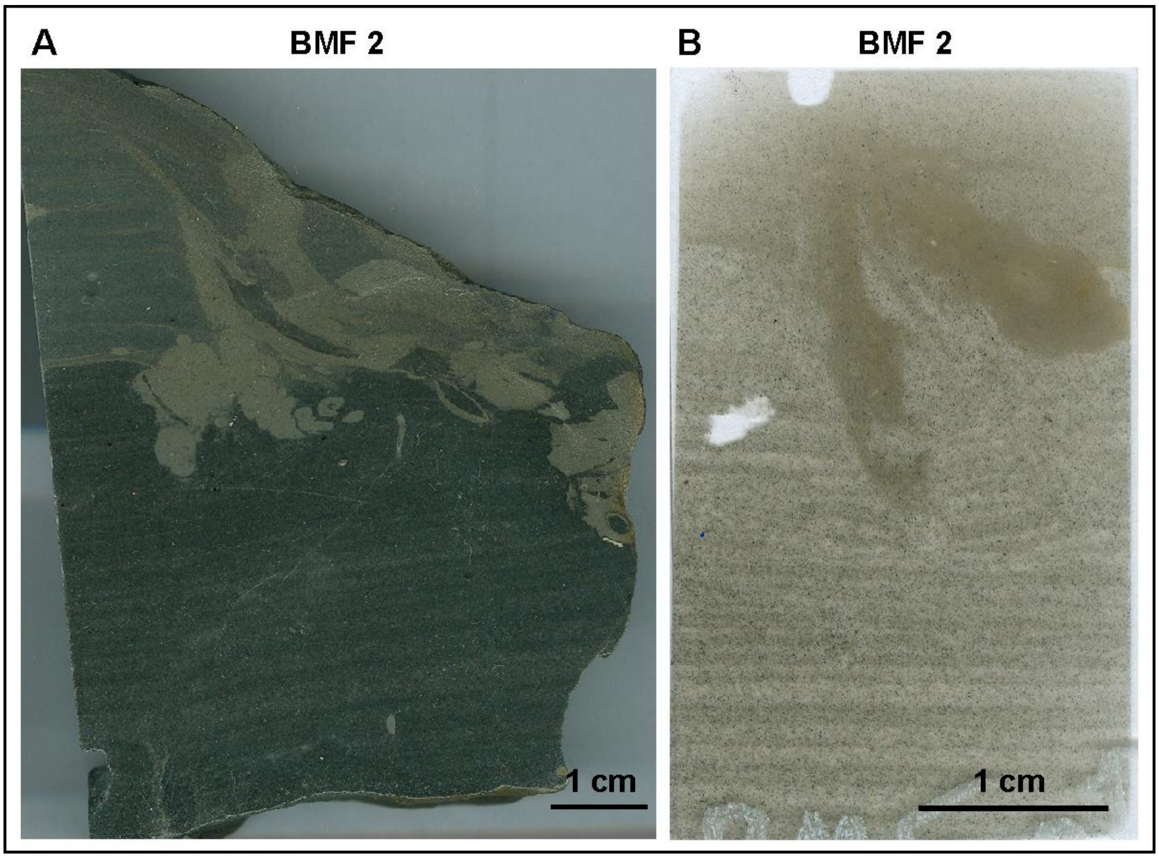

Figure 6. Illustrations of the packstone lithology. **A.** Polished slab showing laminations composed of very-fine-grained fossil fragments with some peloids that are disturbed by bioturbation at the top. **B.** Thin-section scan (sample BMF 2) showing the same features.

<u>Grainstone</u> (Lithology 3)

Grainstones are abundant throughout the measured section and are poorly sorted and coarse grained, often containing many large fossil fragments (units 5e, 5g, 5i, 5k, 5m, 6a, 6c, 7, 8a, 13, 14, 20, 22, 24, and 26). These grainstones generally form ledges, are heavily bioturbated, and contain large fossils found on the surface and interior of bedding planes (Figs. 7, 8). Allochems appear in two different size fractions: silt- to very-fine-grained-sand- sized fossil fragments, and fossils that are centimeters in size. Fossils show a diverse, open-marine assemblage comprised of brachiopods, mollusks, and bryozoans. In thin section, the fine-grained fraction contains abundant trilobites and echinoderm fragments. Some samples contain dolomite rhombs that are located between large fossil fragments. Unit 5 is the first appearance of the grainstone lithology found in the measured section, and they are interbedded with carbonate shales found at the base of first, and largest, waterfalls. Some of these grainstone beds thicken and thin laterally; some beds are laterally discontinuous and pinch-out into the host carbonate shales.

<u>Carbonate Shale</u> (Lithology 4)

The carbonate shales contain fine-grained clastic material, weather to clay, and sometimes contain large fossils such as bryozoans and brachiopods on top of bedding planes (units 4, 5a, 5b, 5c, 5d, 5f, 5h, 5j, 5l, 5n,). This lithology is most prominent as the major portion of unit 5, a 1.5-meter-thick sequence interbedded with the consolidated grainstones described (Fig. 9).

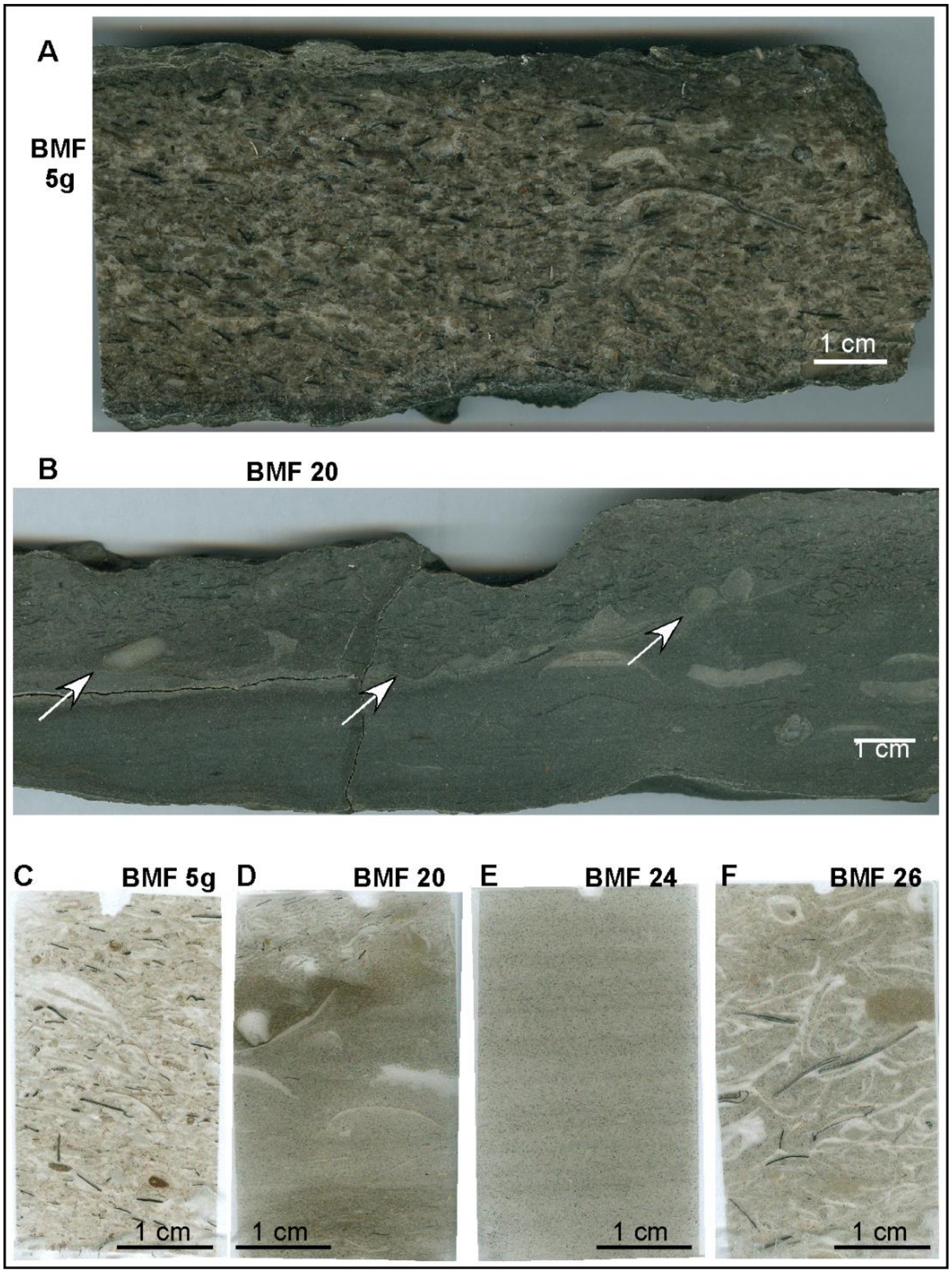

Figure 7. Illustrations of the finer-grained grainstone lithology. **A.** Polished slab (sample BMF 5g) showing large fossil fragments. **B.** Polished slab (sample BMF 20) showing lower layer of fine-grained fossil fragments, erosional surface (arrows), and coarser-grained upper layer. Note larger fossils in each layer. **C.** Thin section scan (sample BMF 5g) showing the two allochem size fractions: fine-grained sand-sized and large fossil fragments (mainly brachiopods). **D.** Thin section scan (sample BMF 20) with brachiopods and bryozoans. **E.** Thin section scan (sample BMF 24) showing fine-grained size fraction composed of fossil fragments. **G.** Thin section scan (sample BMF 26) with large mollusk (clams?) and trilobite pieces.

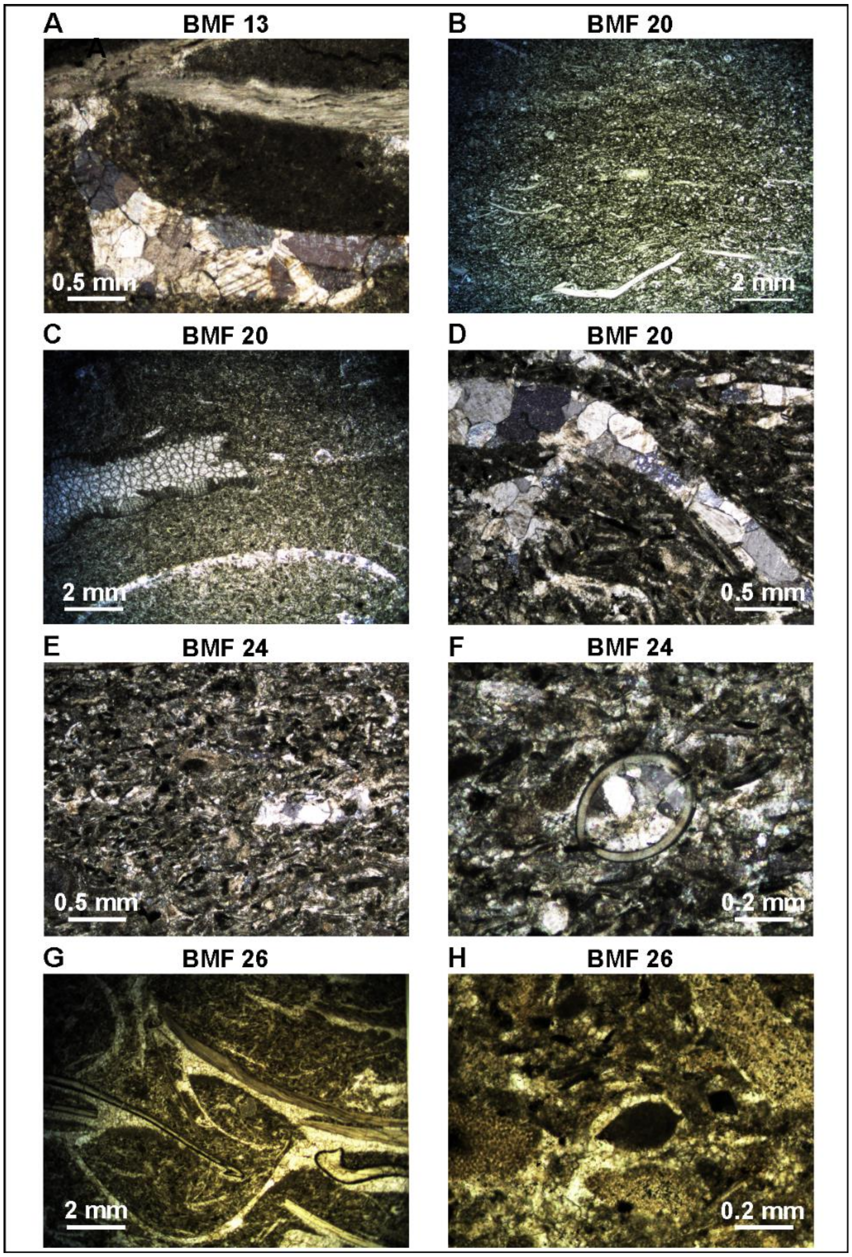

Figure 8. Photomicrographs of the grainstone lithology. **A.** (sample BMF-13) Note brachiopod (top) and mollusk (bottom). **B.** (sample BMF-20) Note fine-grained, sand-sized allochems with larger fossils (trilobite fragment near bottom). **C.** (sample BMF-20) Close-up showing large bryozoan (top, left) and clam valve (bottom). **D.** (sample BMF-20) Close-up showing large mollusk fragment with finer-grained allochems consisting of fossil fragments and peloids. **E.** (sample BMF-24) Fine-grained allochems with larger echinoderm fragments, concave-down ostracod valves, peloids, and unidentifiable fossils. **F.** (sample BMF-24) Note articulated ostracod. **G.** (sample BMF-26) Large brachiopod and trilobite pieces together with fine-grained-sand-sized allochems. **B.** (sample BMF-26) Articulated clam with mud filling (center), larger echinoderm plates, and finer-grained allochems including fossil hash and peloids.

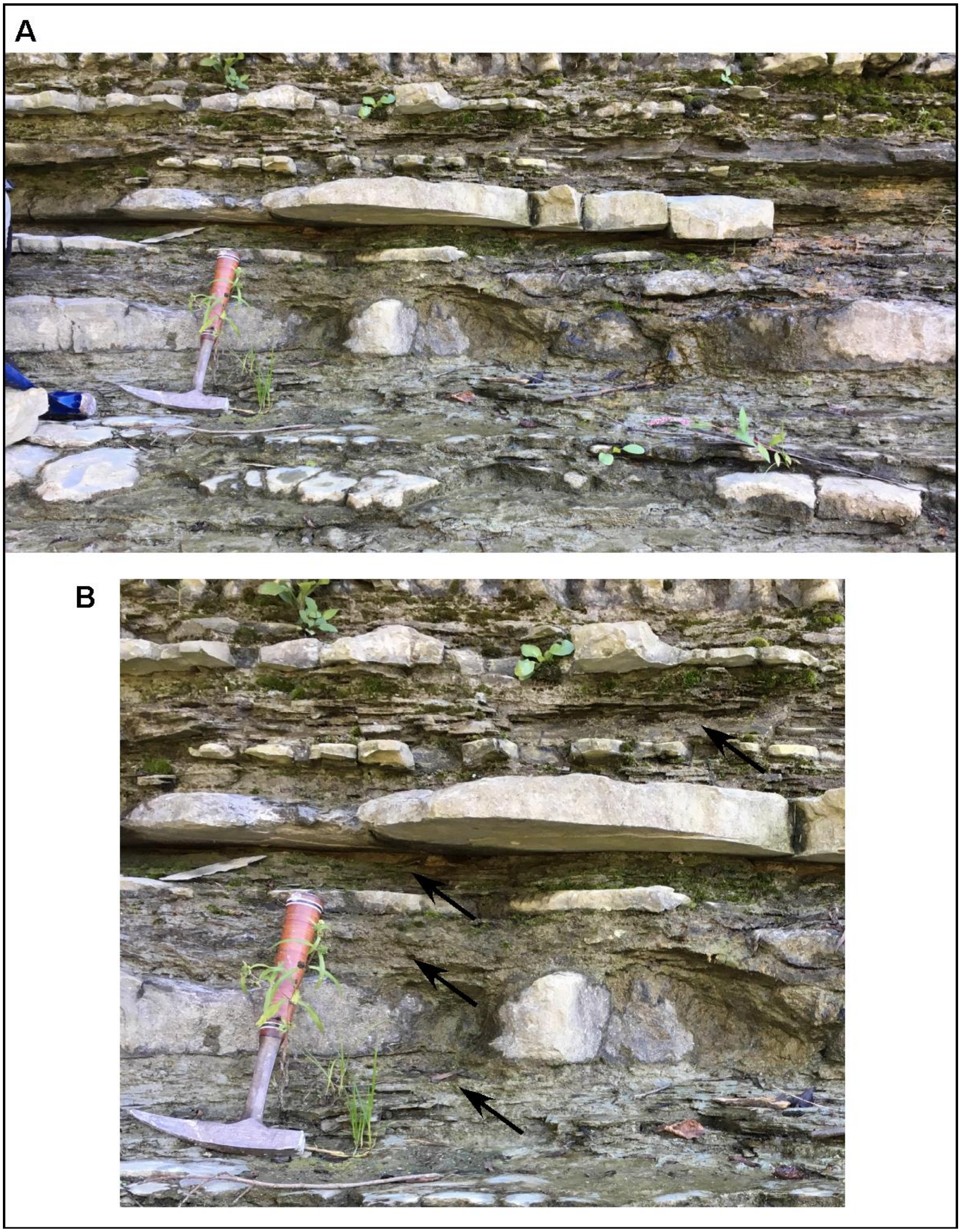

Figure 9. Illustrations of the carbonate shale lithology. **A.** Field photograph of unit 5 showing interbedded carbonate shale and limestone beds and lenses. **B.** Close-up of same photograph noting carbonate shale (arrows).

Grainstones containing large, nested fossils (Lithology 5)

This grainstone lithology is distinct from Lithology 3 above in that it contains large, nested fossils with much less sand-sized allochems (units 6b, 6d, 6e, 9, 11, 27, 28, 29; Figs. 9, 10). The larger fossil fragments, particularly brachiopod valves, are oriented concave-up and are stacked with the shells fitting into one another vertically. These units typically extend laterally with consistent thickness, and forms prominent ledges, including the top of the higher, basal waterfall of Silver Creek. These rocks are poorly-sorted, coarse-grained, with abundant large fossils. The larger fossils are usually dominated by strophomenid brachiopods with lesser amounts of bryozoans. Smaller fossils include echinoderms and trilobites.

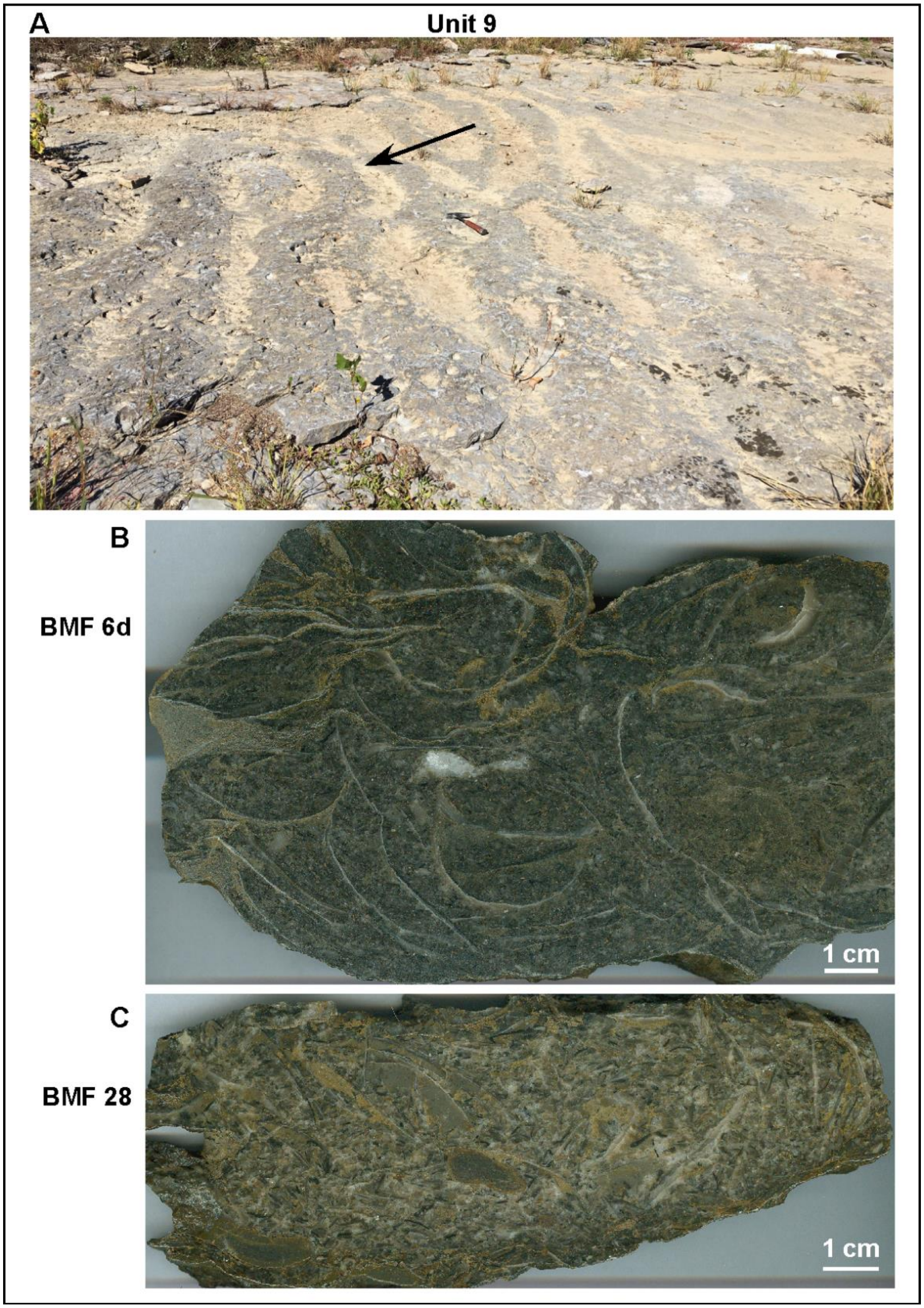

Figure 9. Illustrations of the nested grainstone lithology (Lithology 5). **A**. Bedding plane of unit 9 showing asymmetrical dune bedforms; arrow shows transport direction. **B.** Polished slab (sample BMF 6d) showing large fossils, brachiopods and bryozoans, within a fine-sand-sized fraction. **C.** Polished slab (sample BMF 6d) with large pieces of brachiopods.

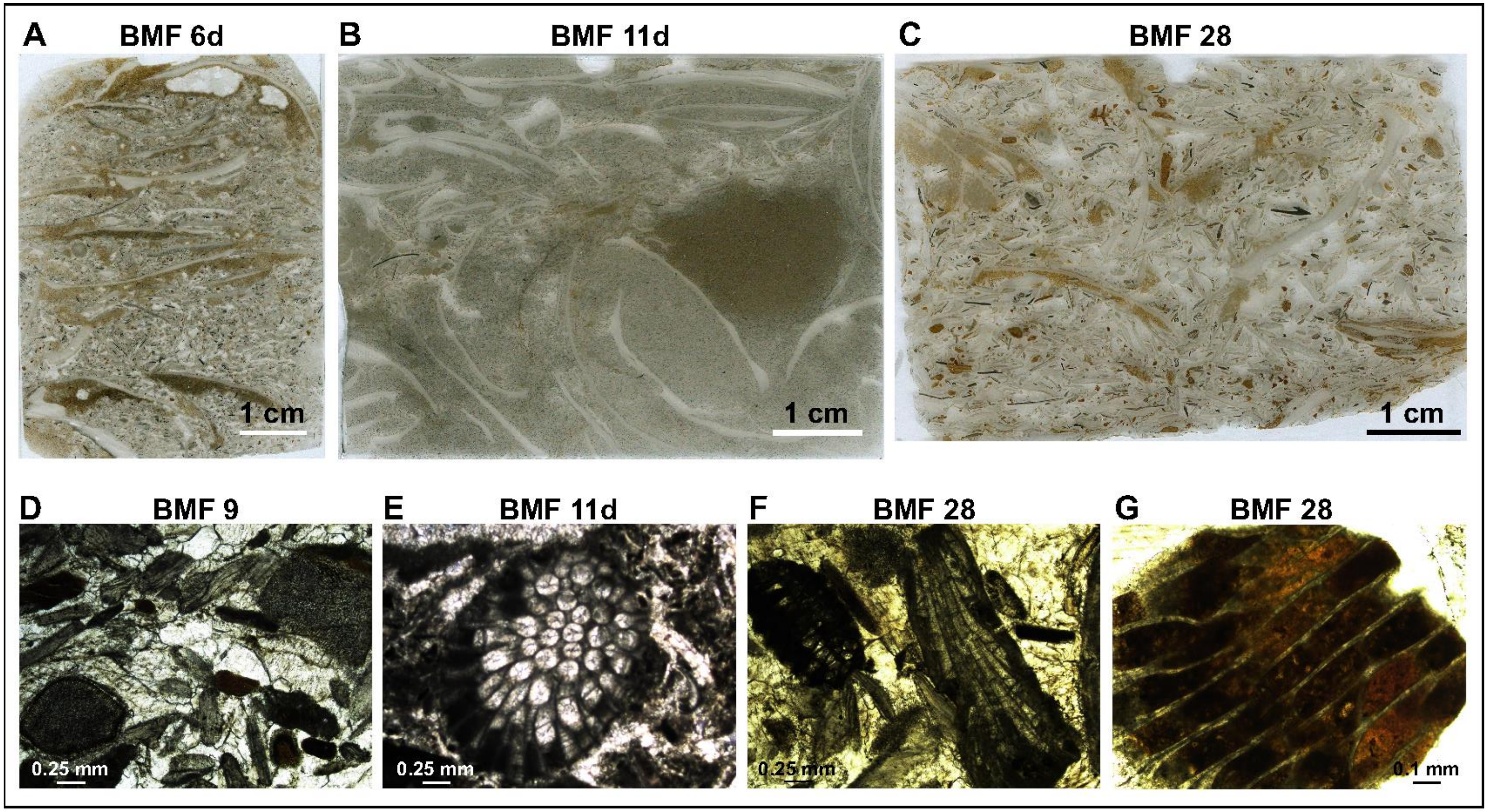

Figure 10. Illustrations of the nested grainstone lithology (Lithology 5). **A.** Thin-section scan (BMF-6d) showing large, nested fossils together with very-fine-sand-sized allochems. **B.** Thin-section scan (BMF-11d) showing large brachiopod valves, bryozoans, and finer-grained allochems. **C.** Thin-section scan (BMF-28) showing packed brachiopods, bryozoans, and trilobite pieces. **D.** Thin-section photomicrograph (BMF-9) showing echinoderm plates, brachiopod fragments, and calcite spar matrix. **E.** Thin-section photomicrograph (BMF-11d) showing large bryozoan with mud filling in outer theca. **F.** Thin-section photomicrograph (BMF-28) showing bryozoan fragments. **E.** Thin-section photomicrograph (BMF-28) showing bryozoan with mud-filled theca.

INFERRED ENVIRONMENTS OF DEPOSITION

The depositional setting for the study area is a carbonate platform named the Lexington Platform by Ettensohn et al. (2004). Carbonate platforms are characterized by dominantly shallow water where calcium-carbonate-secreting organisms produce the carbonate sediment preserved in the rock record as limestones (Wilson 1975).

Limestone lithologies formed on carbonate platforms are controlled by water depth and the organisms that inhabit particular depositional environments. Unlike clastics that characteristically produce facies belts, depositional environments on carbonate platforms produce a mosaic of facies that are sensitive to small variations in water depth that occur laterally over the platform (Wilson 1975). Thus in the short term, we would expect to see lateral migration of facies formed in adjacent depositional environments produce stratigraphic sequences as a consequence of Walthers Law. In the long term, larger changes of relative sea level - controlled by any combination of eustatic sea level change, basin uplift or subsidence, and change in sediment supply – will control lithology, deposition, and building a stratigraphic succession.

The lithologies we see at the Barnes Mill Falls locality are broadly consistent with the depositional setting of a carbonate platform. Limestones dominate the stratigraphic section, accounting for four of five observed lithologies, again consistent with deposition on a shallow-water carbonate platform. Moreover, the fossils observed are brachiopods, bryozoans, trilobites, echinoderms, and mollusks that strongly suggest normal marine salinity and thus open-marine conditions. The high diversity of the fauna also suggests shallow water because organism diversity would be expected to decrease in both tidal and deeper-water depositional environments.

<u>Lithology 1</u> (Mudstone)

Lithology 1 are mudstones composed of fine-grained calcium carbonate deposited in a non-turbulent depositional environment. In a carbonate platform setting, these conditions would occur in slightly deeper water depths that are sheltered from waves and currents. These rocks are also heavily bioturbated, which is consistent with subtidal environments. The few peloids observed possibly originate from micritized fossils and/or modified fecal pellets. The fossils that occur within the bed interiors are so fine-grained that they cannot be identified, so they are perhaps transported from adjacent depositional environments with higher turbulence. Well-preserved fossils found on bedding planes of this lithology strongly suggest that these organisms have not been transported and thus likely lived within this depositional environment. Fossil diversity is low, suggesting that Lithology 1 was deposited in slightly deeper waters.

<u>Lithology 2</u> (Packstone)

Lithology 2 are packstones composed of fine-grained, well-sorted, fossil fragments. This lithology is heavily bioturbated with horizontal and vertical burrows found in most samples; bedding planes exhibit trails. The majority of fossils are silt to very-fine sand that occur with or without peloids. Laminations are preserved in some of these packstones at bed bottoms with other portions of the rock disturbed by bioturbation in the upper part of beds. Laminations were possibly produced by bottom currents, storms, or some other high-energy depositional process. Then processes like bioturbation modified these deposits. The depositional environment was likely below wave base otherwise mud could not be deposited. Fine-grained fossil fragments were likely transported from adjacent, shallower areas of the platform, and well-preserved, *in situ* fossils are consistent with an open-marine fauna.

<u>Lithology 3</u> (Grainstone)

Lithology 3 are poorly-sorted grainstones than contain silt- to very-fine-sand-sized fossil fragments together with many large, centimeter-scale fossils. The fauna are a diverse, open-marine, and consist of abundant brachiopods, bryozoans, trilobites, echinoderms, and mollusks. The lack of carbonate mud indicates turbulent waters, which were energetic enough to fragment organism remains. Therefore, Lithology 3 likely formed in some kind of carbonate shoal environment.

<u>Lithology 4</u> (Carbonate shale)

The carbonate shales weather to a clay-like consistency, and contain significant amounts of clastic mud. The few fossils observed are found on bedding planes between the host shales and Lithology 3. These shales are possibly a result of pulses of clastic sediments swept into the study area, perhaps sourced from the rising Taconic highland to the east (Ettensohn et al. 1991).

<u>Lithology 5</u> (Nested grainstone)

Lithology 5 are grainstones with large, nested fossils stacked on top of one another that is otherwise similar to Lithology 3. The diverse fauna indicate open-marine conditions. The rocks lack mud and the nested character of large fossils, usually brachiopod valves, indicates high turbulence. A carbonate shoal - likely more exposed than that producing Lithology 3 - is a plausible depositional environment.

Stratigraphic Overview

The stratigraphic section begins with mainly mudstones and interbedded packstones that were likely deposited in deeper-waters of the carbonate platform due to their high mud content (Fig. 4). The section continues with input of fine-grained clastic sediment that produces carbonate shales. This phase of deposition was caused by either influx of clastic sediment, decrease in carbonate production superimposed on background clastic deposition, or some combination of these two factors. However, grainstones are interbedded with carbonate shale and document periods of dominant carbonate deposition. The upper stratigraphic section consists of mostly grainstones with some mudstones and packstones that indicate healthy carbonate deposition in turbulent waters, generally not conducive to carbonate deposition.

SUMMARY

The Clays Ferry Formation was deposited atop the Lexington Platform during the Middle to Upper Ordovician (Ettensohn et al. 2004). Carbonate platforms are characterized by a mosaic of facies that are sensitive to slight changes in water depth. The lithologies found are mudstones, packstones, grainstones, nested grainstones, and carbonate shales. The mudstones and packstones are formed in deeper-water environments. Both grainstone units were likely deposited in carbonate shoals with the nested grainstones forming in slightly more-turbulent depositional environments. The stratigraphic section is dominated by limestones but a ~1.5-meter thick sequence of carbonate shale suggests more clastic input onto the platform, likely caused by some combination of change in sediment supply perhaps associated with tectonics.

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APPENDIX

Table A1. Measured section units, thicknesses, and descriptions.

Unit	Thickness (cm)	Cumulative Thickness (cm)	Field Description
VIII	0.06	0.06	Mudstone with horizontal burrows.
VII	0.08	0.14	Mudstone with trails on bedding surface.
VI	0.02	0.16	Mudstone weathered into rounded polygons (not mud cracks).
V	0.08	0.24	Mudstone with strophomenid brachiopods sitting on top of surface of bed
IV	0.09	0.33	Packstone with possible peloid laminations. Vertical burrows about 2 cm long.
III	0.14	0.47	Brittle mudstone with some trails.
II	0.04	0.51	Packstone (?); no visible sedimentary structures.
I	0.10	0.61	Mudstone with lumpy surface; shows some trails.
1	0.08	0.69	Mudstone gray/blue in color. Located at base of falls.
2	0.05	0.74	Packstone with peloidal laminations within the top half. Horizontal burrows at the base. Weathers to clay.
3	0.18	0.92	Mudstone with possible burrows on surface. This unit consists of three small mud beds with lumpy weathering.
4	0.08	1.00	Carbonate shale with burrows and small laminations at bottom. Below first ledge of main falls and pinches out.

Unit	Thickness (cm)	Cumulative Thickness (cm)	Field Description
5a	0.05	1.05	Carbonate shale; fresh pieces are brittle, weathers into clay. Shale layers vary in thickness and brachiopods are found on bedding surfaces. Thin laminae in cross section.
5b	0.15	1.20	Carbonate shale with burrows and weathered bryozoans. Similar to 5a.
5c	0.06	1.26	Carbonate shale; continuous layer with limestone lenses encased laterally in shale. Contains a 2-cm bryozoan.
5d	0.18	1.44	Carbonate shale.
5e	0.05	1.49	Heavily-bioturbated limestone with brachiopods on surface.
5f	0.13	1.62	Highly-weathered carbonate shale with same weathering characteristics as previous shale units. No fossils.
5g	0.04	1.66	Limestone with brachiopods and many unidentifiable fossil fragments found on top surface.
5h	0.07	1.73	Carbonate shale with brachiopods.
5i	0.09	1.82	Medium-grained limestone with preserved layering. Contains burrows/trails on bedding surface.
5j	0.09	1.91	Bioturbated. carbonate shale.
5k	0.06	1.97	Heavily-bioturbated carbonate shale with lumpy weathering. Contains burrows, bryozoans, and gastropod on bed surface.
5l	0.07	2.04	Bioturbated, carbonate shale; lumpy weathering.

Unit	Thickness (cm)	Cumulative Thickness (cm)	Field Description
5m	0.04	2.08	Medium-grained limestone. No fossils are observed.
5n	0.23	2.31	Carbonate shale contained laminated limestone lenses surrounded by shale. Forms last shaly unit before top of the main falls.
6a	0.18	2.49	Grainstone with rough surface; contains numerous, large fossils including brachiopods and crinoids. Heavily bioturbated.
6b	0.30	2.79	Fossiliferous grainstone with nested brachiopods. Brachiopod valves are oriented concave upward.
6c	0.15	2.94	Limestone containing weathered brachiopods.
6d	0.13	3.07	Grainstone with nested brachiopods; possible bioturbated surface.
6e	0.06	3.13	Grainstone with brachiopods. Similar to unit 6d but thinner.
7	0.08	3.21	Limestone bed containing numerous strophomenid brachiopods. Bedding surface shows a 5-x-10 meter area of closely-spaced brachiopods.
8	0.09	3.30	Bioturbated mudstone layer that encases limestone lens, BMF 8a.
8a	0.03	3.33	Fossiliferous grainstone with trilobites and stylolites.
9	0.14	3.47	Fossiliferous grainstone with nested brachiopod valves on surface. Contains 10-cm-high asymmetrical dune bedforms with azimuth 277º transport direction.

Unit	Thickness (cm)	Cumulative Thickness (cm)	Field Description
10	0.04	3.51	Mudstone with strophomenid brachiopods and a 12-cm-long cephalopod on bedding surface.
11	0.08	3.59	Packstone or grainstone, with nested strophomenid brachiopods on top surface.
12	0.07	3.66	Mudstone that weathers into lumpy pieces.
13	0.03	3.69	Grainstone containing strophomenid brachiopods and trails on top surface.
14	0.05	3.74	Grainstone with strophomenid brachiopods; similar to unit 13.
15	0.11	3.85	Bioturbated mudstone forming multiple layers
16	0.04	3.89	Mudstone with trilobites, fossil fragments, and trails.
17	0.05	3.94	Bioturbated mudstone with strophomenid brachiopods on surface.
18	0.03	3.97	Bioturbated mudstone weathering into lumpy surface with crater-like holes. Some brachiopods on surface.
19	0.03	4.00	Mudstone, no trails or fossils observed.
20	0.05	4.05	Laminated fossiliferous packstone or Grainstone with bryozoans and unidentifiable fossils. Contains two layers with erosional contact. The upper layer is fossil hash possibly from brachiopods, bryozoans, and gastropods(?). Bottom layer dominated by mud.
21	0.01	4.06	Mudstone, heavily weathered.
22	0.02	4.08	Medium-grained limestone with trails on top bedding surface.

Unit	Thickness (cm)	Cumulative Thickness (cm)	Field Description
23	0.11	4.19	Mudstone, heavily weathered.
24	0.09	4.28	Laminated pack/grainstone with several large vertical burrows.
25	0.07	4.35	Mudstone containing small limestone lens.
26	0.14	4.49	Fossiliferous grain/packstone with nested brachiopods. This unit forms a natural bridge over third set of falls.
27	0.06	4.55	Grainstone containing nested brachiopods.
28	0.19	4.74	Fossiliferous grainstone varying in thickness (8 cm-18 cm). Weathers into small holes and sometimes shows nested brachiopods. Numerous bryozoans are found throughout unit.
29	0.02	4.76	Fossiliferous grainstone that caps the third set of falls.
TOTAL		**4.76 meters**	

Table A2. Thin section descriptions.

Thin Section	Description
BMF VIII	Bioturbated, very fine-grained packstone composed mainly of unidentifiable fossil fragments with some peloids. Large fossil components include a large 4-mm trilobite piece, ostracods, and echinoderms.
BMF 2	Fine grained, well-sorted fossil and peloid pack/grainstone, laminated in lower portion with burrowing at the top. Fine- grained fossils generally not identifiable.
BMF 5g	Poorly-sorted, coarse-grained, fossiliferous grainstone. Large brachiopods and bryozoans occur with numerous echinoderm and trilobite fragments. Dolomite rhombs are ubiquitous.
BMF 6d	Bioturbated, poorly-sorted fossil grainstone that contains large brachiopods. Abundant echinoderm fragments.
BMF 9	Fossiliferous, coarse-grained grainstone. Trilobites and mollusk fragments are dominant with ancillary bryozoans and echinoderms. Secondary dolomite rhombs are common.
BMF 11	Poorly-sorted, fossiliferous grainstone with large (4+ cm), strophomenid brachiopods. Contains equal amounts of brachiopods, echinoderms, and trilobites with a few bryozoans.
BMF 13	Poorly-sorted, bioturbated fossil packstone/grainstone with large (cm+) brachiopod valves that occur with bryozoan fragments. Large clam (?) fragments and trilobite fragments are also common.
BMF 16	Well-sorted, fossiliferous grainstone with layered trilobite fragments.
BMF 20	Poorly-sorted, fossiliferous grainstone with trilobite, brachiopod, and echinoderm pieces. Sample has two layers: a lower traction layer with silt-sized fossil fragments and an upper layer with larger grains and bioturbation. Large trilobite fragments occur in lower layer parallel to bedding.

Thin Section	**Description**
BMF 24	Very coarse-grained grainstone with fragmented fossils forming traction laminations. Trilobites, echinoderms, and ostracods dominant. One articulated ostracod; separated values often oriented concave-down indicating current deposition.
BMF 26	Fossiliferous grainstone, poorly-sorted with large mollusk fragments (~1 cm) and many trilobites (~2 mm). Brachiopod and bryozoan fragments occur with echinoderms present in lower abundance.
BMF 28	Poorly sorted, fossiliferous grainstone with subequal amounts of brachiopods, bryozoans, echinoderms, and trilobites. Brachiopod valves and bryozoans often centimeters long and nested; other fossils are coarse-sand sized. Some fossils, like bryozoan theca, filled with mud. Some intraclasts occur.