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Reservoir Characterization and Resource Assessment of the Brown Dense Mudstone (Lower Smackover Formation), Gulf Coastal Plain, South Arkansas

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Introduction

The Arkansas Geological Survey has undertaken a 3-year research project to explore the reservoir characteristics and resource potential of the Brown Dense Mudstone in southern Arkansas under the USGS grant (Grant No. G12AC20245). The cores of the Brown Dense section from a recently drilled well, Sessions #1 (API: 03-139-13401-00-00), in Union County, Arkansas were acquired from the Betsy Production Company, for conducting permeability and porosity measurements by Delta Core Analysts, Shreveport, Louisiana and a series of analyses by Weatherford Laboratories, Houston, Texas, including helical CT scanning, thin sections, core descriptions, geochemical analyses (TOC and Rock-Eval Pyrolysis), Field Emission Scanning Electron Microscopy (FE-SEM), X-ray diffraction, rock mechanics tests, and Shale Rock Properties analysis. In addition, a crude oil sample from the Brown Dense Mudstone in the Sessions #1 well was used for GC-MS and stable isotopic analyses performed at the Petroleum Geochemistry and Environmental Forensics Laboratory at the University of Oklahoma.

Lithology:
- Dolostone
- Limestone
- Silty Limestone
- Silty, Calcareous Mudstone
- Mudstone
- Core Missing

Physical Structures:
- Laminations
- Stylolite
- Pinched out Lamination
- Fenestral Pore
- Vug or Allochem Mold
- Desiccation Crack
- Fractures
- Microfault
- Stromatactis Fabric

Constituents:
- Bryozoan / Algal Fragment
- Limestone Lithoclast
- Peloid
- Foraminifera
- Bioclastic Debris
- Brachiopod
- Echinoderm
- Ooid
- Bitumen
- Gastropod
- Geopetal Structure
- Calcareous Nodule

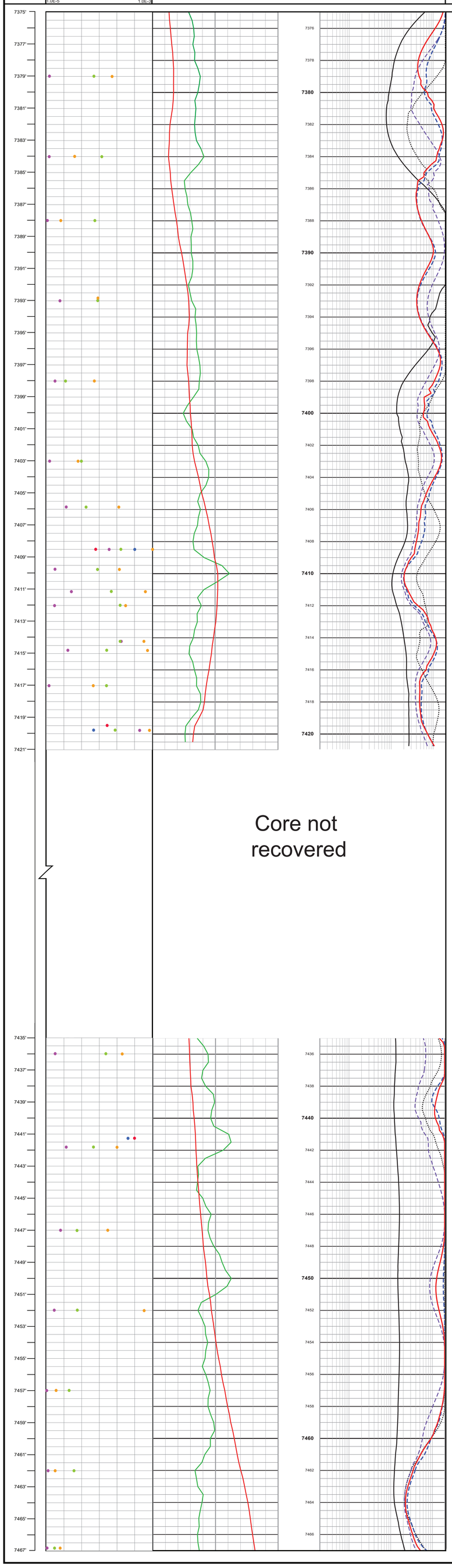
Burrows:
- Undifferentiated
- Arenicolites
- Bioturbation

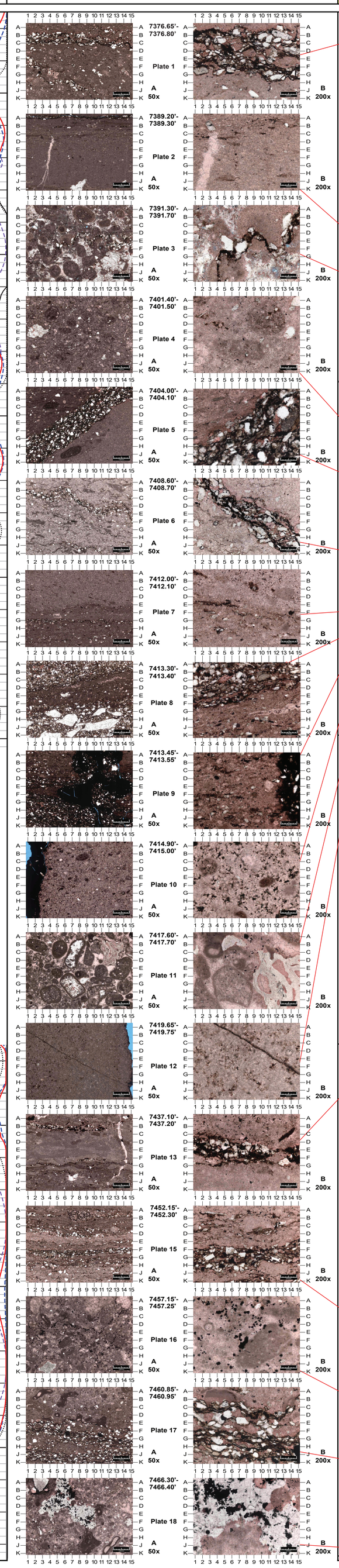
Analysis:
- T General Thin Section Description
- X X-Ray Diffraction
- G Geochem
- R Rock Mechanics
- F Field Emission Scanning Electron Microscopy
- S Shale Rock Properties

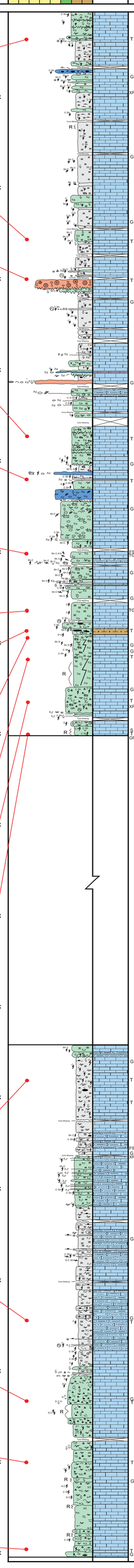
Accessory Minerals:
- Py Pyrite
- A Anhydrite
- C Calcite
- D Dolomite
- Sh Solid Hydrocarbons

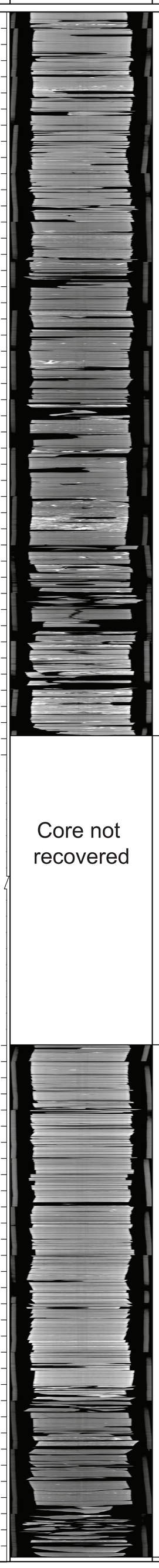
Contacts:
- Stylolitic
- Sharp
- Irregular
- R Rubble

Core Depth (Ft) | Tmax (°C) | TOC (wt.%) | HI (mg HC/g TOC) | Porosity (%) | Permeability (mD) | Gamma Ray (GR) gAPI | Spontaneous Potential (SP) mV | Array Induction Resistivity Environmentally Compensated Log Processing ohm.m (AE10, AE20, AE30, AE60, AE90) | Thin Section Photographs | Boundstone | Grainstone | Packstone | Wackestone | Mudstone | Analysis | Degree of Bioturbation | Solid Hydrocarbon | Oil Stain | Depth (1"=2') | CT Scans | Unit Descriptions | Depositional Environment | Core Depth (Ft)









***Note:** Lithology column is drawn based on visual estimates and binocular microscope examination of slabbed core, and combined with applications of 10% HCL. Color designations are based on the *Geological Rock-Color Chart* published by Munsell (2009) and are assessed on unwet core.

Top of Requested Description Interval (7375.00 ft)

7475.00 – 7380.00 ft: Interval consists of brownish gray to dark gray (5YR 4/1 – N3) limestone ranging from mudstone to wackestone layers. A packstone layer occurs from 7378.60 – 7378.80 ft. Allochems include echinoderms, lithoclasts, foraminifera, and undifferentiated bioclastic debris. Fractures are generally thinner than 1 millimeter and are healed mostly by calcite as well as bitumen, dolomite, and anhydrite. Laminations are sparse. Stylolites are also present and occur with thin layers of silty mudstone. Possible fenestral pores are sparse. Sharp lower contact.

7380.00 – 7391.45 ft: Interval consists of brownish gray to dark gray (5YR 4/1 – N3) limestone ranging from mostly lime mudstone with less common wackestone. Laminations are fairly common. The laminated portions contain common laminations of silty mudstone. Undifferentiated bioclastic material is the primary allochem with less common foraminifera and lithoclasts. A stromatactis texture is present at 7386.30 ft. A fracture-induced microfault occurs at 7389.60 ft. Fractures are generally thinner than 1 millimeter and are healed mostly by calcite as well as bitumen, dolomite, and anhydrite. Vugs or grain-moldic pores have been occluded mostly by calcite. Missing lower contact.

7391.45 – 7391.60 ft: Spacer inserted

7391.60 – 7392.35 ft: Interval consists of an oolitic limestone (7391.60 – 7392.15 ft) and a bioclastic limestone (7392.15 – 7392.35 ft). The oolitic limestone has a grainstone texture and is dark yellowish brown (10YR 2/2). The bioclastic limestone has a wackestone to packstone texture and is medium dark gray (N4). The allochems in these two layers have been commonly recrystallized and have been identified as peloids. Ooids are abundant in the grainstone. The grainstone portion has oil staining that is strongest at the top becoming sparse within the wackestone to packstone layer. A stylolitic contact separates the two layers. Vugs in the grainstone have been occluded by gypsum/anhydrite as well as calcite and dolomite. Calcite and bitumen-filled fractures are present in the wackestone to packstone unit. Sharp lower contact.

7392.35 – 7403.50 ft: Interval consists of brownish gray to medium gray (5YR 4/1 – N5) limestone. A silty limestone layer occurs from 7398.30 – 7398.80 ft. The texture of these limestones generally range from mudstone to wackestone. Several packstone (7398.60 ft) and grainstone (7397.80 – 7398.00 ft) layers are also present. A dolopackstone unit occurs at 7397.30 ft. Laminations are fairly common. The laminated portions contain common laminations of silty mudstone. Stromatactis texture occurs at 7392.70 ft and is abundant from 7400.70 – 7402.00 ft. Bioturbation occurs at 7393.40 ft, 7396.25 ft, 7396.60 ft, 7396.80 ft, and 7397.00 ft, and generally occurs as undifferentiated horizontal or vertical, elliptical burrows. Allochems include undifferentiated bioclastic material, algal or bryozoan fragments, peloids, and lithoclasts. Vugs or allochem-molds are sparse and have been mostly occluded by calcite with less common anhydrite/gypsum and dolomite. Possible mudcracks occur at 7394.25 ft. Oil stain is moderately common from 7403.20 – 7403.40 ft. Fractures occur throughout and are typically filled by calcite as well as bitumen, anhydrite, and dolomite. Stylolites are also present throughout and occur as contacts between many layers. Sharp lower contact.

7403.50 – 7407.65 ft: Interval consists of brownish gray to medium dark gray (5YR 4/1 – N4) limestone. The oil stained portion of this interval 7405.10 ft is olive black (5Y 2/1). A silty mudstone layer occurs at 7403.95 – 7404.00 ft. The limestone texture ranges from mostly wackestone to packstone. Allochems include peloids, undifferentiated bioclastic material, possible bivalves, gastropod fragments. Stromatactis texture is moderately common throughout. An *Arenicolites*-like burrow occurs at 7404.65 – 7404.75 ft. An anhydrite vug occurs at 7404.80 ft with a dolomite vug occurring at 7405.75 ft. The darker portions of this interval contain more bitumen and clay while the lighter portions are cleaner limestones. Fractures are present throughout and are healed by calcite, bitumen, dolomite, and gypsum/anhydrite. Sharp lower contact.

7407.65 – 7419.80 ft: Interval consists of brownish gray to dark gray (5YR 4/1 – N3) limestone to silty limestone. This interval consists mostly of wackestone. The interval from 7413.20 – 7413.55 ft consists of interlaminated limestone (mudstone-wackestone), argillaceous, calcareous siltstone, and a silty mudstone. This interval contains common gypsum/anhydrite clasts. The limestone lamination at 7413.25 ft has been broken up possibly by the fractures, which are common from 7413.50 – 7416.65 ft. The previously mentioned fracture interval has been healed by abundant bitumen. The laminated portions contain common laminations of silty mudstone. A possible hardground occurs at 7410.80 ft. Stromatactics texture is common from 7413.80 – 7415.00 ft. Allochems include undifferentiated bioclastic material, peloids, foraminifera, and lithoclasts. Stylolites are moderately common throughout. Vugs or allochem molds are occluded by calcite, dolomite, and gypsum/anhydrite. Missing lower contact.

Interval from 7419.80 to 7435.00 ft not recovered

Top of Core 2 (7435.00 ft)

7435.00 – 7435.75 ft: Interval consists of a brownish gray to dark gray (5YR 4/1 – N3) limestone (7435.00 – 7435.40 ft) to silty limestone (7435.40 – 7435.75 ft). These layers are both wackestones with undifferentiated bioclastic material. Silty mudstone laminations are present. Fractures have been healed by calcite with some bitumen. Irregular lower contact.

7435.75 – 7440.40 ft: Interval consists of medium gray to brownish black (N5 – 5YR 2/1) limestone. This interval consists of planar algal limestone. Algal laminations are abundant throughout and are interlaminated with silty mudstone layers. Stylolites are commonly present throughout the unit and often occur as contacts. Fractures are healed with bitumen and calcite. Possible desiccation cracks occur as well. Vugs are possible associated with fractures. Rare possible fenestral pores are also present. Sharp lower contact.

7440.40 – 7445.00 ft: Interval consists of interlaminated silty limestone and limestone. These layers range between wackestone a packstone textures. Several algal limestones are also present (7440.70 – 7440.90 ft and 7441.35 – 7441.55 ft). Silty mudstone laminations are common. The silty laminations are brownish black (5YR 2/1) while the limestones are brownish gray to medium dark gray (5YR 4/1 – N4). Stylolitic contacts are present within the algal limestones but are rare elsewhere in the interval. A possible algal limestone clast occurs at 7441.20 ft. Undifferentiated bioclastic material is sparse throughout. Fractures are more common within the less argillaceous portions of the interval and are healed by calcite and contain bitumen. Irregular lower contact.

7445.00 – 7453.90 ft: Interval consists of interlaminated limestone and silty limestone. The limestone portion of this interval occurs exclusively as algal limestones. The silty limestone texture is a mudstone to wackestone. Silty mudstone laminations are common. The silty laminations are brownish black (5YR 2/1) while the limestones are brownish gray to medium dark gray (5YR 4/1 – N4). Stylolitic contacts are present within the algal limestones but are rare elsewhere in the interval. Possible fenestral pores are also present within the algal laminations. Pinched out laminations occur sparsely (7450.70 ft, 7451.50 ft, 7452.10 ft, 7453.10 ft). Undifferentiated bioclastic material is rare. Fractures have been healed by calcite, dolomite, and/or gypsum/anhydrite and also may contain bitumen. Sharp lower contact.

7453.90 – 7466.70 ft: Interval consists of brownish gray to dark gray (5YR 4/1 – N3) limestone ranging from mudstone to wackestone layers. Silty mudstone laminations are rare and only occur in association with stylolites. Allochems include brachiopods, benthic foraminifera, undifferentiated bioclastic material, and lithoclasts. Fractures are moderately common and have been healed by calcite, dolomite, and gypsum/anhydrite. Bitumen is also present within many fractures. Grain-moldic pores or vugs are sparse. A geopetal structure is present within a brachiopod fragment at 7466.60 ft. Missing lower contact.

Bottom of Core 2 (7466.70 ft)

Depositional Environment: Middle to Inner Ramp; Middle to Outer Ramp; Ooid Shoal; Middle to Outer Ramp; Inner Ramp; Middle to Inner Ramp; Middle to Outer Ramp; Basin; Basin to Outer Ramp; Basin to Outer Ramp; Middle to Inner Ramp