MINERALOGY OF THE MOSELEY BED, MIDDLE EOCENE, TEXAS

An Undergraduate Research Scholars Thesis

by

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ABSTRACT

Mineralogy of the Moseley Bed, Middle Eocene, Texas

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This study examines the mineralogical and chemical composition of the Middle Eocene Moseley unit, a bed within the upper portion of the Stone City Member of the Crockett Formation. The Stone City Member is exposed along the Brazos River near College Station, Texas. The Stone City Member is composed of several major lithologies, of which the Moseley is distinctive in being well cemented. Methods include using a scanning electron microscope (SEM) to make observations on chemical composition and a stereo microscope to make observations on the grain type, sorting, fabric of the sediment, etc. X-ray diffraction is used to determine mineral composition. An understanding of the Moseley bed's composition allows for a better understanding of the environment during the Middle Eocene, particularly during the Mid-Eocene Climatic Optimum.

SECTION I

INTRODUCTION

The Stone City Member of the Crockett Formation along the Brazos River in Burleson County offers a snapshot of East Texas during the middle Eocene (Wendlandt and Knebel, 1929), an interval of geologic time lasting from 48 to 41 million years ago. The Eocene began with a thermal maximum and ended with the beginning of icehouse conditions, with a sustained decline in global temperatures starting at the beginning of the middle Eocene (Fig. 1). The Stone City Member was deposited during a short period of warming that interrupted the long term cooling trend. The member's upper layer, the Moseley bed, was deposited as the brief warming trend started. It is composed of sediment with a carbonate mineralogy that contrasts with most sediment deposited during that time. A study of the Moseley bed's mineralogy can give a better understanding of the fluctuating climate conditions and environment of East Texas during the transition to the late Eocene.

A simple visual examination of the Stone City Bluff formation reveals that the upper layer, the Moseley bed, is much more lithified than lower, older beds. Upon closer examination, the sediments of the beds below the Moseley bed can be crumbled up in one's hand, but the sediments of the Moseley are formed into a hard rock layer. This suggests a difference in mineralogical composition reflecting a change in the depositional environment.

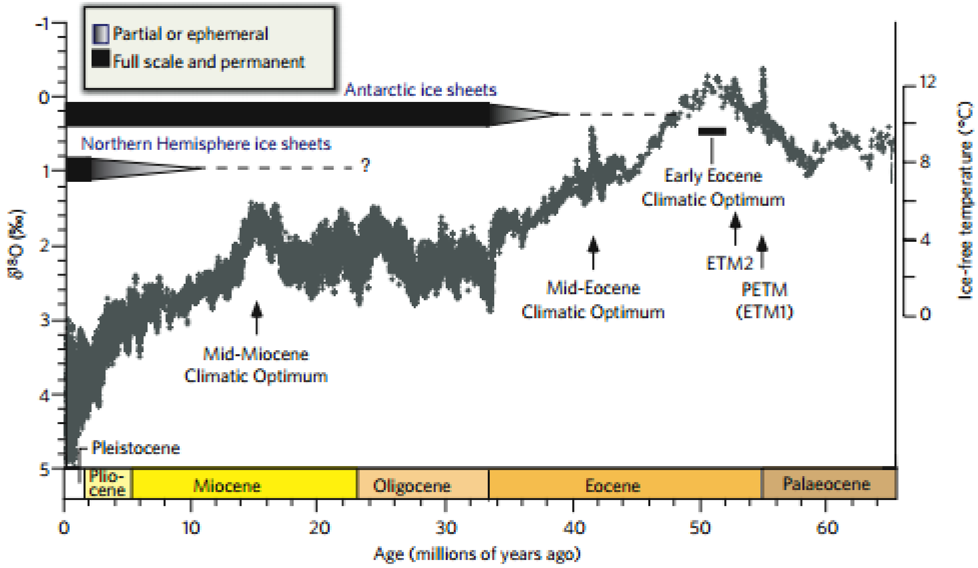

Figure 1: (Zachos et al., 2008) This graph shows the climate, based on oxygen isotope data, during the Cenozoic. The Mid-Eocene Climactic Optimum, which coincided with the deposition of the Stone City Member, is labeled.

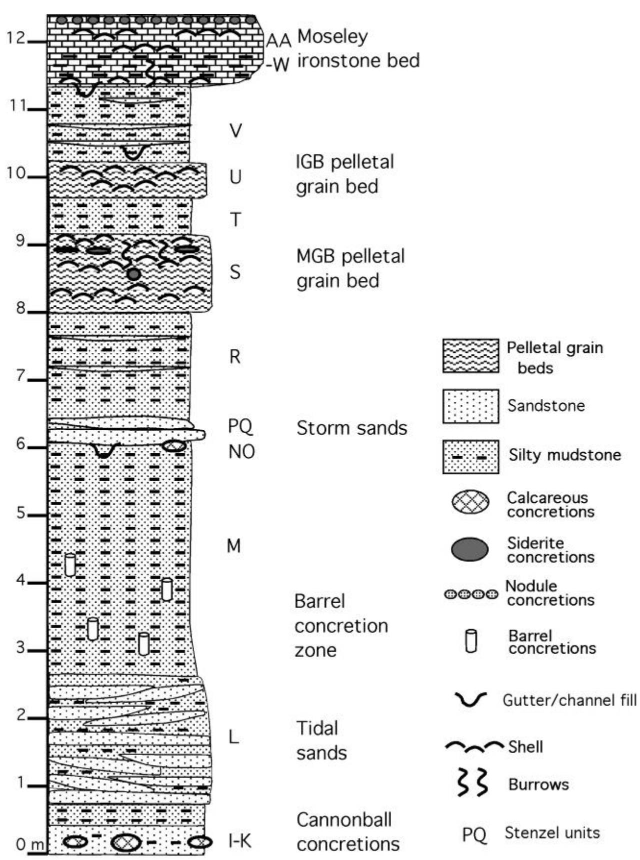

Figure 2: Stratigraphic column of the Stone City Member. Used by permission of Dr. Thomas Yancey.

Mineralogy of the Stone City Member

The Stone City Member (SCM) (Fig. 1) is 50 feet thick (Flis and Flis, 2014). The Main Glauconite bed (MGB) comprises about 23 feet of the formation, is the most studied bed in the SCM, and lies 6 feet below the Moseley bed. At the bottom of the MGB are barrel shaped concretions which contain calcite and pyrite (Hendricks et al., 2012). Pyrite is also present in the sediments surrounding the concretions (Hendricks et al., 2012). Hendricks et al. (2012) concluded that methane expulsion had created the concretions and that this had taken place in a shallow shelf environment.

The MGB contains verdine facies (Harding et al., 2014). Despite being given the descriptor of glauconite for many decades (Stenzel, 1938), the MGB contains mostly odinite (a verdine facies mineral) with only a few traces of glauconite (Harding et al., 2014). The top of the MGB contains apatite and some siderite (Harding et al., 2014).

The MGB contains three facies that vary in bioclast and silt/sand content (Zuschin and Stanton, 2002). In one of the facies, some bioclasts are broken while others are very well preserved, which suggests bioturbation (Flis and Flis, 2014). Another of the facies contains winnowed bioclasts which suggests storms (Zuschin and Stanton, 2002).

Stratigraphy of the Stone City Member

The SCM contains alternating layers of sandstone and mudstone (Stanton and Nelson, 1980; Yancey, Davidoff and Donaho, 1993). These alternating strata were caused by transgressive and regressive cycles (Yancey, 1997). Going towards the top of the transgressive sections, quartzose sand decreases, and pellets and siderite concretions increase (Yancey, 1995). The environment during these cycles was almost consistently marine, but significant variance in depth is evident (Yancey, 1997). The Moseley bed was formed during a transgressive period, and the top of the Moseley bed is a maximum flooding surface (Yancey, 1995).

Environment of the Stone City Bluff Formation

The SCM is renowned for the abundance of marine invertebrate fossils at the site including gastropods and mollusks (Flis and Flis, 2014), indicating it was a vibrant ecosystem during the Eocene. These fossils are more than fodder for amateur paleontologists, however. The presence of certain fossils indicate the type of environment at the time of deposition. For example, octocoral fossils have been found in the SCM (Giammona and Stanton, 1980), and since corals live in such particular environments, their presence indicates that the environment was warm and shallow marine. Octocoral fossils are rare in the SCM (Giammona and Stanton, 1980), but their mere presence is significant. The environment suggested by the corals is consistent will the shallow continental shelf environment theorized by Yancey (1997) and Hendricks et al. (2012). Like today in the Gulf Coast, the area that is now the Brazos River Valley experienced cyclical storms during the Eocene (Yancey, 1995). As stated earlier, winnowed bioclasts are evidence of these storms (Zuschin and Stanton, 2002). The storms decreased in strength over the course of a cycle (Yancey, 1995).

The Moseley bed’s depositional environment was not extremely different from the rest of the SCM’s depositional environment. The member was part of a continental shelf that experienced regressive/transgressive cycles, storms, and eustatic sea change (Davidoff and Yancey, 1993).

Despite the similarities to the rest of the member, the Moseley bed represents a transition climatically. The Mid-Eocene Climactic Optimum (MECO) stands out from the cooling trend of the rest of the Eocene. A possible cause of the MECO is a sudden increase in CO2 brought on by arc volcanism associated with plate reorganization (Bohaty and Zachos, 2003). After the MECO (and the formation of the Moseley bed), global temperatures began to decline again, and glaciers became more common.

SECTION II

METHODS

Examination of mineral content

A scanning electron microscope (SEM) was used to determine relative abundance of elements in samples from the Moseley bed. Three samples were taken from the Moseley bed and mounted. They were then taken to the SEM located in the Interdisciplinary Life Sciences Building on the Texas A&M campus. After the scan, the computer generated a chart with peaks which corresponded to specific elements in the sample. The weight percentage of each element in the sample was given.

In order to double check the findings of the SEM, more samples were taken from the Moseley bed and ground into powder using a mortar and pestle for x-ray diffraction (XRD). The objective was to only examine the matrix, so bioclasts were avoided or picked out in order to avoid contamination. The samples were then sent by Dr. Yancey, the faculty advisor on the project, to a third party, who compared the peaks from the XRD data to known peaks from siderite, quartz, and calcite.

Examination of matrix and grains

Thin sections from the Moseley Bed were examined under a fixed objective stereo microscope. Twelve thin sections from the Moseley bed belonging to Dr. Yancey were used as samples. The samples were taken from the upper, middle, and lower portions of the Moseley bed. Notes were taken on the fabric of the thin sections. Attention was given to grain size, sorting, composition, maturity of the sediment and unique depositional features. Notes were made for each individual slide and labeled accordingly in a notebook.

SECTION III

RESULTS

Stereo Microscope Observations

The composition of Moseley sediments was determined by observations made using a stereo microscope on samples cut into thin section slices and on broken and cut surfaces of the rock. The sediment consists primarily of grains of fecal pellets and bioclasts in a carbonate mud matrix. In all samples, the pellets have the same size range, but the proportion of pellets to other grains differs. Samples from near the bottom of the Moseley bed have relatively less grains and bioclasts than samples from the top portion. In all the samples, bioclasts consist of bivalve and gastropod shells and bryozoa and corals.

The sediment of the Moseley bed is divided into two areas: pellet-dominated sediment and mud-dominated sediment. The boundary between the two areas is irregular, so the two areas do not form horizontal layers. The mud-dominated area contains some pellets but much less than the pellet-dominated area. Some gastropod shells are filled with quartz-grains. Quartz-grains are not present in the surrounding fine-grained sediment. The sorting of grains varies from well sorted in the pellet-dominated sediment to a few poorly sorted areas in the mud-dominated area. A notable feature from the top portion of the bed is carbonate-crystal filled fractures that pinch-out at their ends. The fractures are predominately located in the pellet-dominated area. One fracture, which is connected to the system of fractures, is located in the mud-dominated area. The sediment immediately surrounding this fracture is stained. The crystals within this fracture grew from the margins to the center as elongate crystals in radiating clusters. Samples from the lower portion of the bed do not contain similar fractures.

Mineral Content Data

Siderite has been found in other layers of the formation, so siderite was hypothesized to also be present in the Moseley unit. A scanning electron microscope (SEM) and x-ray diffraction (XRD) were used because they respectively can determine the elemental and mineralogical composition of a substance. SEM is a semi-quantitative method of determining the relative abundance of selected elements within a substance. Figure 3 depicts the data collected from the SEM. The table on the right side of Figure 3 lists the elements that were searched for. The SEM excites atoms with an electron beam, and the resulting graph indicates the chemical composition of the matrix by giving x-ray counts vs. energy. Taller peaks indicate greater x-ray counts and thus a greater abundance of that element. The SEM found iron, which is necessary for siderite, and calcium, which is necessary for calcite. Figure 4 depicts the data collected from XRD. XRD records the refraction of an x-ray beam and the orientation and spacing of arrays of atoms in a mineral structure. XRD is used to determine mineralogical composition, so it is a more accurate method for confirming the presence of siderite than SEM. The XRD data indicated that siderite was a major component of the sediment.

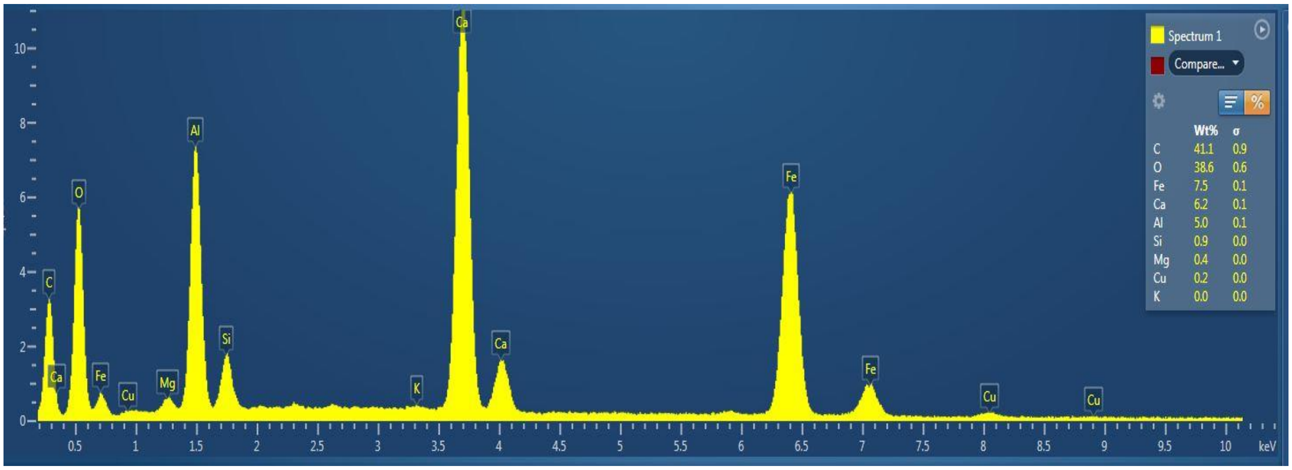

Figure 3: This graph depicts the data collected from the SEM. Fe is known to be a component of siderite. Ca, the tallest peak, is a component of calcite. Al is a component of clays. Mg, Cu, and K were used as controls.

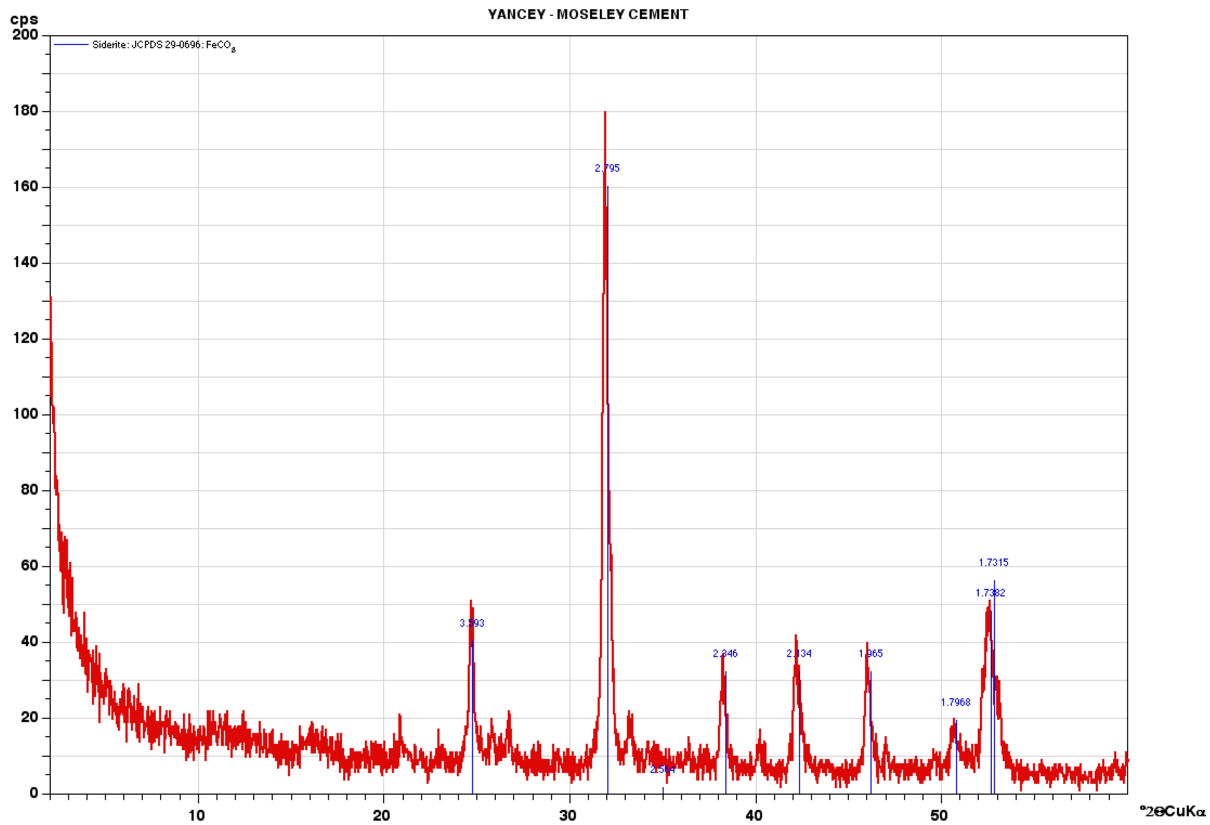

Figure 4: This graph depicts the data collected from x-ray diffraction in red. The blue lines correspond to the known standard for siderite.

SECTION IV

DISCUSSION

Interpretation of Microscope Observations

The pellet dominated sediment and the mud dominated sediment represent different levels of energy within the deposition: a high level of energy for pellet deposition and a low level of energy for mud deposition. This suggests varying energy conditions. The shells containing quartz grains indicate that the energy of the environment could be very high at times. Since quartz grains were only observed inside shells, the shells must have originated in a different area with quartz sand substrate.

The fractures found at the top of the Moseley bed formed after the sediment had been partially lithified. The fractures were then formed, most likely through dewatering. Pellets broken away from the rest of the sediment are evidence that the sediment was only partially lithified at the time of the formation of the fractures. Afterwards, carbonate crystals formed in the open spaces created by the fractures. The minerals were provided by fluids flowing through the sediment. Later, the sediment completely lithified.

Interpretation of Matrix Composition

When Fe ions are available to form Fe-bearing carbonates in an environment, oxygen levels can affect the mineral composition of those carbonates, so the type of carbonate present can suggest the type of environment (Mozley, 1989; Postma, 1981). Siderite forms under reducing and low sulfate conditions typically in either a methanogenic environment or a suboxic or anoxic environment.

Despite being less common in marine environments, the formation of siderite due to methanogenesis is supported in the Moseley unit. A study by Hendricks et al. found that methane seeps were the cause of barrel concretions in a section about seven meters below the Moseley unit. So, methane is known to have been present in the environment. However, the barrel concretions contained pyrite. In order for siderite rather than pyrite to predominately form in the Moseley unit, sulfate reduction must have occurred as well.

SECTION V

CONCLUSION

The Moseley unit was deposited under varying levels of energy of deposition. The environment's energy was sometimes very high and sometimes low. Later, while the sediment was partially lithified, de-watering took place, and carbonate-rich fluids flowed through the unit. Siderite is a major mineral within the unit. The presence of siderite in conjunction with past research indicates that the environment was methanogenic. Sulfate reduction also took place to allow for the formation of siderite.

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