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Distribution of Dasycladacean Algae in the Permian Capitan Formation and Carlsbad Group, Guadalupe Mountains, Texas and New Mexico, U.S.A.

Verteilung der Dasycladaceen (Chlorophyta) im Perm der Capitan Formation und Carlsbad Gruppe, Guadalupe Mountains, Texas und New Mexico, U.S.A.

by

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Abstract

Dasycladacean algae are present in the Permian (Guadalupian/Kazanian) Capitan reef complex in fore reef, reef, and also in shelf facies. Dasyclads, when linked with sedimentologic evidence, may be helpful in the interpretation of paleoenvironment. Samples were collected in the Guadalupe Mountains of Texas and New Mexico.

In the Breccia Member (fore-reef facies) of the middle Capitan Formation, dasyclads are known only from one elongate bed of fusulinid biosparite. The long axes of the grains are parallel and the bed is graded. Grain types, orientation of grains, grading, and steep variable dips within this unit suggest that the bed accumulated as a grain-flow deposit. Particles within this deposit, including the dasyclads, were probably transported from the outer shelf or shelf margin into the forereef.

In the Massive Member (reef facies) of the middle and upper Capitan Formation, dasycladacean segments are a component of the internal sediment in reef framework and in neptunian dikes. Just shelfward of the Capitan reef, in contemporaneous shelf sediments, dasycladacean algae are a component of the diverse biosparites that make up the back reef apron. Interbedded with the diverse biosparites are beds of biosparite dominated by dasycladacean algae. Abrasion on the margins of grains and sorting by size suggest that these dasyclad-dominated biosparites represent winnowed current deposits.

Farther shelfward, in the outershelf lagoon, many biopelmicrites contain dasycladacean algae. Still farther shelfward, sparse biomicrites contain a low diversity fossil assemblage that includes abundant dasycladacean algae. These algae are interpreted to have thrived in quiet, intermittently hypersaline waters.

In the pisoid/tepee zone dasyclads grew in pools between tepee structures. In the inner shelf, an abundance of calcispheres suggests that some type of dasyclad may have been present.

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Zusammenfassung

Dasycladaceen kommen im Perm (Guadalupium/Kazanium) des Capitan Riff Komplexes sowohl im Vorriff und Riff als auch in der Schelffazies vor. Zusammen mit sedimentologischen Daten können sie zur Interpretation des Palaeoenvironments herangezogen werden.

Im „Breccia Member" (Vorriff Fazies) der mittleren Capitan Formation sind Dasycladaceen nur aus einer Lage aus fusulinidem Biosparit bekannt. Sie ist gradiert und die Längsachsen der Komponenten sind parallel orientiert. Komponententypen, Kornorienterung und Gradierung, sowie steile und variable interne Neigungswinkel weisen diese Lage als „grain flow" aus. Die Komponenten, einschließlich der Dasycladaceen, sind höchstwahrscheinlich vom äußeren Schelf oder Schelfrand her transportiert worden.

Im „Massive Member" (Riff Fazies) der mittleren und oberen Capitan Formation kommen Dasycladaceensegmente im Internsediment des Riffgerüstes vor, sowie in „Neptunian Dikes" In gleichaltrigen Schelfsedimenten unmittelbar hinter dem Capitan Riff sind Dasycladaceen häufig in variablen Biospariten, die den Sedimenten des Rückriffes entsprechen. In diese variablen Biosparite sind Biosparitlagen eingelagert, die von Dasycladaceen dominiert werden. Die Abrasion der Komponenten und ihre Korngrößensortierung deutet darauf hin, daß diese Dasycladaceen-dominierten Biosparite durch Strömungen ausgewaschen wurden.

Weiter schelfwärts, in der äußeren Lagune, sind Dasycladaceen häufig in Biospariten. Noch weiter landwärts enthalten seltene Biomikrite mit gering diversen Fossil-Vergesellschaftungen häufig Dasycladaceen. Es wird

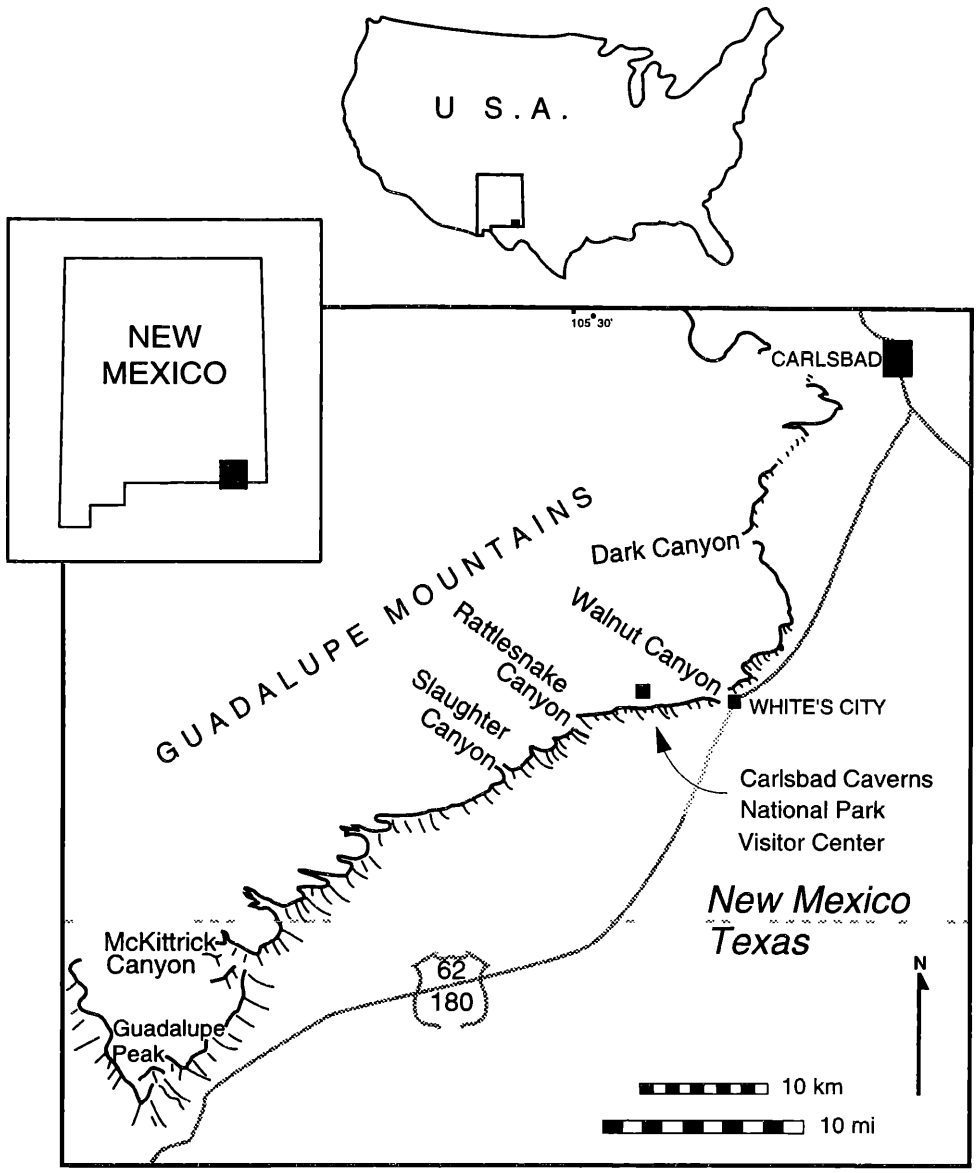

Figure 1: Location of the study area.

angenommen, daß diese Algen in ruhigem, zeitweise hypersalinem Wasser gewachsen sind.
In der Pisoid/Tepee Zone gediehen Dasycladaceen in Pfützen zwischen den Tepee Strukturen. Im Innenschelf deuten häufige Calcisphären auf die Existenz von Dasycladaceen hin.

1. Introduction

The Guadalupe Mountains of West Texas and southeastern New Mexico (Fig. 1) provide outstanding outcrops of middle Permian (Kazanian/Gudalupian) shelf, reef, and slope sediments. The shelf margin buildup, mapped as the Capitan Formation, is divided into the Massive Member (massive reef-framework, cement, and internal sediment) and the Breccia Member (vaguely bedded, steeply dipping fore-reef debris). The Capitan is also divided into lower, middle, and upper sections, which correlate to the three units of the Carlsbad Group; the Seven Rivers, Yates, and Tansill formations, respectively (see Fig. 2). The Carlsbad Group was deposited as bedded shelf sediments in association with and contemporaneously with the Capitan reef. The depositional environments that surround the basin and form the shelf are traditionally described as basin, slope, shelf margin, outer shelf, pisoid/tepee zone, inner shelf, and evaporitic lagoon (Fig. 2).
The purpose of this paper is to describe facies around the margin of the basin and to discuss the role of dasycladacean algae in each environment (Fig. 3). Taxonomic study of the dasycladacean algae (JOHNSON, 1942) is linked with studies of facies and depositional environment (NEESE, 1979; SARG, 1981; SCHWARTZ, 1981; ESTEBAN & PRAY, 1983; KIRKLAND GEORGE, 1992). In this study area, an understanding of the dasycladacean algae present seems to be important for detailed interpretation of depositional environment.

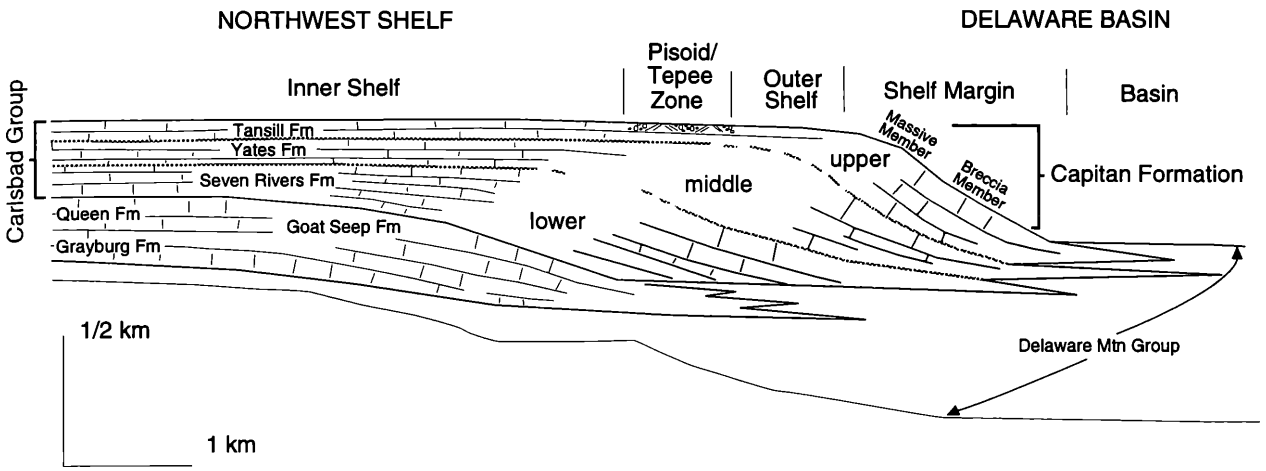

Figure 2: Stratigraphy and terminology used in reference to the Capitan Formation (modified from KING, 1948; BABCOCK & YUREWICZ, 1989).

2. Materials and Methods

The samples used for this study were collected in the Guadalupe Mountains between 1987 and 1993. Samples collected within the boundaries of Carlsbad Caverns National Park and Guadalupe Mountains National Park were taken with permission and with care to avoid disfiguring outcrops. Because this is one of a series of studies, more than 300 samples and more than 270 thin sections were available. The majority of the thin sections were taken from the reef and outer shelf. Dasyclads were only abundant in about 20% of the thin sections. Much of the area is rugged and difficult to access. Because of this the majority of the sampling, and therefore the most detailed analyses, were carried out on the upper and middle Capitan, the Tansill, and the Yates formations. However, much of the section was visited and sampled, and similar facies and relationships were seen deeper in the section.

3. Distribution of Dasycladacean Algae

Dasycladacean algae are found in the following paleoenvironments: fore-reef, reef, outer shelf lagoon, pools between teepee structures, and inner shelf lagoon. Description of dasycladacean algae in these environments starts with the fore reef and proceeds shelfward.

3.1. Fore-reef

The Breccia Member or fore-reef consists of sand-sized particles to large (several meters) blocks of debris shed basinward from the reef. The dasycladacean algae in this unit are known to be abundant only within one elongate bed of fusulinid-dominated biosparite. Disarticulated segments of *Mizzia minuta* are most common, although one possible example of *Macroporella apachena* JOHNSON 1951 was found as well. This bed is in the middle Capitan, or Yates equivalent, portion of the Breccia Member. The bed, approximately 2 m wide, extends down the upper one-third of the forereef (MRUK, personal communication, 1993) for a distance of more than 100 m. Dips in this bed are steep and highly variable (27° to 66°) suggesting deposition between allochthonous reef-blocks. Grains within the bed are aligned with their long axes parallel, and the bed is inversely graded (BEBOUT & MRUK, 1993). Separation by size and grain type is clear. The coarser portion of the flow is dominated by the fusulinid *Polydiexodina*. The finer portion of the flow contains a mixture of grain types including bryozoans, fusulinids, crinoid fragments, peloids, sponge fragments, trilobite fragments, encrusted grains, and dasyclads (MRUK, personal communication, 1993). Some of the grains, particularly the bryozoan fragments, show distinct abraded margins. The algae within this bed are almost always found as disarticulated segments (Pl. 1, Figs. 1, 2). Fusulinid-dominated deposits containing some dasycladacean algae are also found in the Yates Formation on the outer shelf.

Because of particle sorting, grain-orientation, associated reef debris, and deposit morphology, this bed is interpreted to have accumulated as a grain-flow deposit (BEBOUT & MRUK, 1993). All of the particles, including the dasycladacean algae, probably originated on the outer shelf or shelf margin (BEBOUT & MRUK, 1993).

3.2. Reef

In the Capitan Massive, or reef facies, dasycladacean algae are uncommon and have not been found *in situ*. However, they sporadically occur as a component of the internal sediment in-filling framework voids. In McKittrick Canyon, disarticulated segments of *Mizzia* are reported as a common component of the internal sediment in one neptunian dike (PRAY & STANTON, 1992; KIRKLAND et al., 1993).

In internal sediment within the reef, dasyclad fragments usually occur as disarticulated segments. They have been

found at several localities along the reef escarpment including Dark, Walnut, and McKittrick Canyons (Fig. 1). The upper Capitan (Tansill equivalent) outcrops at Dark and Walnut Canyons probably represent relatively shallow zones of the reef (BABCOCK, 1977; BABCOCK & YUREWICZ, 1989; TOOMEY & BABCOCK, 1983). In McKittrick Canyon (middle Capitan or Yates equivalent outcrops), dasycladacean algae are found in the upper 75 m of reef outcrop. These observations suggest that dasycladacean algae lived in the upper portions of the reef.

3.3. Outer Shelf

3.3.1. Back Reef Apron

In Walnut Canyon the Massive Member of the Capitan Formation is abruptly transitional to bedded, time-equivalent, sediments of the Tansill Formation. Just shelfward of the reef the first facies of the Tansill Formation is a narrow, elongate belt of biosparite interpreted as back reef apron. In these biosparites dasyclads are an abundant component of a diverse biota. Other grain types present include: abundant angular to sub-angular replaced grains with micritic rims (probably sponge fragments), grains coated by encrusting organisms such as *Tubiphytes*, a variety of benthic foraminifera, articulated brachiopods, trilobite fragments, and a few oolitically coated grains.
Interbedded with these diverse biosparites are dasycladacean-dominated biosparites. These rocks are striking in that they are composed almost exclusively of dasycladacean algae. The dasycladacean-dominated beds are thin (4-10 cm) and are probably not laterally extensive (10's of cm), though vegetative cover and outcrop quality prevent precise measurement (the maximum dimension measured between cover was 80 cm). Typically specimens of the genus *Macroporella* PIA 1912 are aligned with their long axes approximately parallel. Specimens of the genus *Mizzia* are usually disarticulated. Species found in this facies include *Mizzia velebitana* JOHNSON & DORR, *Mizzia minuta,* and *Mizzia yabei* KARPINSKY. *Diplopora* sp.? SCHAFHÄUTL 1863 has also been reported (JOHNSON, 1942). Few individual dasyclad segments are broken, but many show evidence of abrasion on outer margins, suggesting transport or agitation. Some segments appear to be sorted by size (Pl. 1, Figs. 3–5).
Because of evidence for transport and sorting by size, these dasyclad-rich beds are interpreted as winnowed current deposits. Another hypothesis is possible – blooms of dasycladacean algae may have occurred in the back reef. However, this second possibility is considered less likely because angularity of the grains suggests rapid sedimentation and the paucity of mud suggests relatively high-energy conditions (KIRKLAND GEORGE, 1992).

3.3.2. Lagoon

Lagoonal facies were studied in detail in the Tansill Formation, and similar facies and trends were seen in two localities of the Yates and Seven Rivers formations (KIRKLAND GEORGE, 1992). Shelfward of the back-reef apron the mud content of samples increases. Peloids are the dominant allochem. Other components of this facies include: micritic grains, foraminifera, ostracods, gastropods, and micrite-rimmed grains filled with sparry calcite. In addition, many beds contain abundant dasycladacean algae. In the Tansill Formation, the genus *Mizzia* is most common (*M. minuta, M. velebitana, M. yabei*), but *Anthracoporella* sp. PIA 1920 and *Macroporella* sp.? have also been reported (JOHNSON, 1942). Both the Yates and Seven Rivers formations contain unidentified dasycladacean algae. In all three formations these sediments are interpreted as lagoonal (KIRKLAND GEORGE, 1992).
Farther shelfward samples contain even greater amounts of mud, dasyclads, gastropods, ostracods, a few types of foraminifera, small stromatolites, fenestral fabrics, and evaporite molds. Individual samples usually contain only one genus of dasycladacean algae, but commonly segments are abundant (Pl. 1, Fig. 6). In samples from the Tansill Formation individual segments of *Mizzia* show less abrasion than segments in samples taken closer to the shelf margin. Taken together these observations suggest quiet waters and, perhaps, intermittently hypersaline conditions in the shelfward margins of the lagoon. The abundance of dasycladacean algae in these samples also suggests that they thrived in this environment.

3.4. Pisoid/Tepee Zone

Farther shelfward fenestral fabrics grade into facies containing abundant micrite-rich pisoids and eventually into facies containing tepee structures and distinctive, evenly laminated pisoids, or walnutoids (ESTEBAN & PRAY, 1983). Dasycladacean algae are reported as commonly forming the nuclei of some pisoids (SCHWARTZ, 1981; ESTEBAN & PRAY, 1983), and also occurring in the depressions between tepee structures (NEESE, 1979). The distribution of dasycladaceans in this environment suggests that they thrived in the shallow pools between tepee structures.
Several features suggest that the waters in these inter-tepee pools may have been highly saline. Thick crusts of cement are associated with the tepee structures. The pisoids have even, concentric laminae, and the percentage of broken pisoids is relatively high. The abundance of pisoids and thick cement crusts suggest that the water was saturated with respect to $CaCO_3$ and the high percentage of broken pisoids is also consistent with rapid precipitation from hypersaline waters (HALLEY, 1977).

3.5. Inner Shelf

Inner shelf carbonates were studied in detail by SARG (1981). He defined three facies described here in their relative position from the pisoid/tepee zone shelfward:

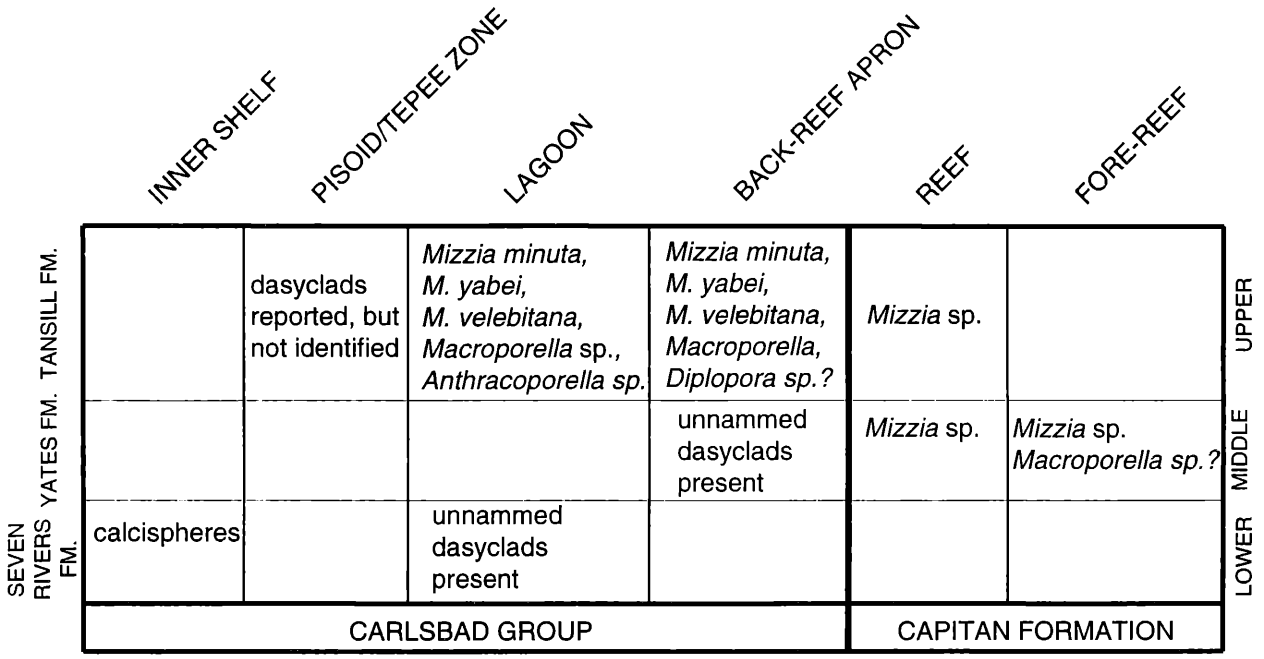

Figure 3: Distribution of dasycladacean algae in the Capitan Formation and equivalent Carlsbad Group. Blank spaces represent portions of the section that were not studied.

1) pellet wackestone/mudstone with associated algal stromatolites, higher levels of mud and fewer skeletal grains than adjacent facies; 2) current-laminated or burrowed skeletal-rich pellet packstones/wackestones with a low diversity assemblage, but abundant calcispheres; and, near the margin of the evaporitic lagoon, 3) current-laminated grapestone grainstones interbedded with fine-grained quartz sandstone.

The skeletal-rich packstone facies is confined to the Seven Rivers Formation. In some samples calcispheres make up >10% of grains (SARG, 1981). The abundance of these calcispheres suggests that a form of dasycladacean algae may have been lived in the outer shelf as well (RUPP, 1966; MARSZALEK, 1975). The depositional environment for these rocks was interpreted as shallow subaqueous with current energy ranging from quiet to active (SARG, 1981).

4. Discussion and Conclusions

Dasycladacean algae are found throughout the Capitan reef and across much of the shelf. In a single fore-reef locality they are found as allochems transported from the shelf. In the upper zone of the reef they are present in internal sediment. In a zone just shelfward of the reef they are an abundant component of the back reef debris. Many back reef beds are dominated by dasycladacean algae, and these beds probably represent winnowed current deposits.

Farther shelfward dasyclads are abundant in the outer shelf lagoon. They seem to have thrived in quiet, probably hypersaline, waters on the margin of this outer shelf lagoon. In the zone of pisoid and tepee formation, dasyclads lived in the pools, which may also have been hypersaline, between tepee structures. Finally, in some facies of the inner shelf lagoon, an abundance of calcispheres suggests that a form of dasycladacean algae was present.

Acknowledgments

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PLATE 1

Fig. 1. Fusulinid-dominated biosparite from fore-reef grain-flow, McKittrick Canyon (40 x).

Fig. 2. Dasycladacean algal fragment (*Mizzia* sp.?) in fore-reef grain-flow, McKittrick Canyon (15 x).

Fig. 3. *Mizzia minuta*-dominated biosparite from the back-reef apron facies, Walnut Canyon (8 x).

Fig. 4. Naturally weathered surface of float showing *Mizzia velebitana*-dominated biosparite from the back-reef apron facies, Walnut Canyon (10 x).

Fig. 5. *Mizzia yabei*-dominated biosparite from back-reef apron facies, Walnut Canyon (9 x).

Fig. 6. *Mizzia velebitana*-dominated biomicrite from lagoonal facies, McKittrick Canyon (7 x).

PLATE 1