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STROMATOLITES OF THE MORRISON FORMATION (UPPER JURASSIC), UNION COUNTY, NEW MEXICO: A PRELIMINARY REPORT

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Abstract—Stromatolitic bioherms are present in lacustrine facies of the medial portion of the Morrison Formation at two localities in the Dry Cimarron Valley, Union County, New Mexico. The stromatolite-bearing lacustrine facies of the Morrison probably represents an extensive, closed lake basin that covered much of the southern High Plains during part of the Late Jurassic. The Morrison stromatolites are similar to *Rivularia* bioherms, and display laterally-linked, undulatory to pseudocolumnar laminations. Carbon- and oxygen-isotope measurements indicate multiple episodes of carbonate deposition. The isotope data also indicate the stromatolitic carbonate was deposited in a lake fed by continental rainfall.

INTRODUCTION

During an April 1986, Fort Hays State University field excursion to the Dry Cimarron River Valley of Union County, New Mexico, several pieces of stromatolitic boundstone float were collected along the base of the mesa approximately 200 m west of NM Highway 370 (Fig. 1). Seven lithostratigraphic units, ranging from Triassic through Cretaceous in age, crop out along the mesa: Travesser Formation (Triassic), Entrada Sandstone (Middle Jurassic), Bell Ranch Formation (Upper Jurassic), Morrison Formation (Upper Jurassic), Lytle Sandstone (Lower Cretaceous), Glencairn Formation (Lower Cretaceous) and Mesa Rica Sandstone (Lower Cretaceous). The source of the stromatolitic float was traced to two isolated zones within the Morrison Formation, approximately 15 m above the Morrison-Bell Ranch contact (Figs. 2A, 3). At these two localities, several discrete stromatolite bioherms were found in situ (Fig. 4). The localities are University of New Mexico (UNM) locality 1501 in the NW¼ NW¼ SW¼, sec. 18, T31N, R33E and UNM locality 1502 in the SE¼ SE¼ NE¼, sec. 13, T31N, R32E, Union County, New Mexico.

To our knowledge, the Morrison Formation was not previously known to contain stromatolitic bioherms in Union County, New Mexico, although previous workers (West, 1978; Lockley et al., 1986) have described "stromatolitic algae" and "cryptalgal structures" in the Morrison of southeastern Colorado and northwestern Oklahoma. During a biostratigraphic-paleoecologic study of the lower Morrison Formation in Cimarron County, Oklahoma, West (1978) described lacustrine laminated cryptalgal-stromatolitic structures in association with "pelletoidal limestones." Lockley et al. (1986) described lacustrine shoreline carbonate facies and associated "algal biscuits" in the Morrison Formation in the Purgatoire Valley of southeastern Colorado. The purpose of this account is to report the occurrence of stromatolitic bioherms in the Morrison Formation of the Dry Cimarron Valley of northeastern New Mexico and present some preliminary analyses of these stromatolites.

GEOLOGICAL CONTEXT

Stratigraphy

A measured stratigraphic section through UNM locality 1501 reveals that the in situ stromatolites are approximately 15 m above the base of the Morrison Formation (Fig. 3, section A). Because the Morrison Formation is much covered at the stromatolite localities (Fig. 2A), a second stratigraphic section (Fig. 3, section B) was measured 2 km north of UNM locality 1501 (Fig. 2B). At this section, the Morrison Formation is well exposed, but contains no stromatolitic bioherms. Lithologic correlation of the two measured sections supports the following conclusions:

1. There is an unconformity at the base of the Morrison where it rests on the Bell Ranch Formation. This unconformity is recognized

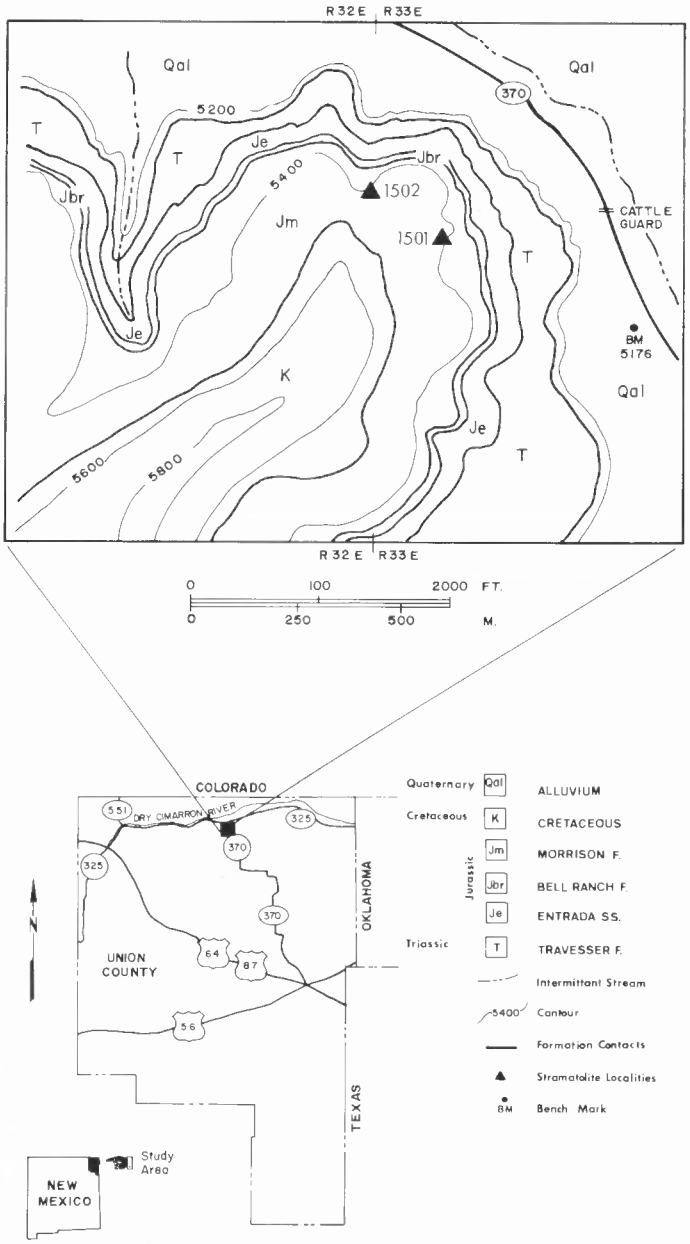


FIGURE 1. Geologic map of the area around the stromatolite localities, Union County, New Mexico.

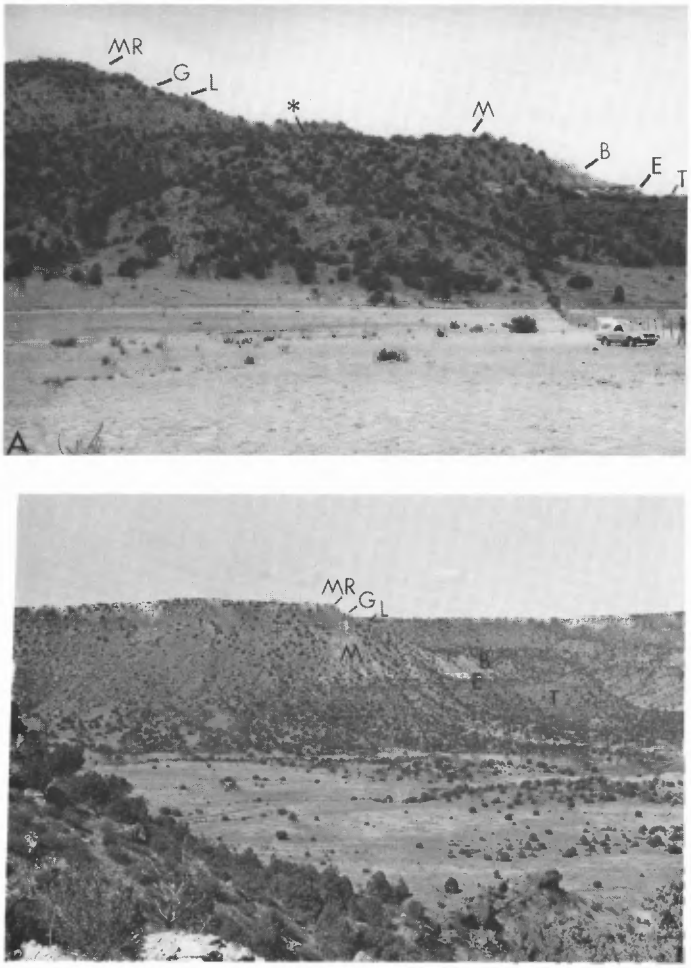


FIGURE 2. Jurassic strata at and near the stromatolite localities. A, View of UNM locality 1501 (asterisk) and the location of measured section A (Fig. 3). B, View of the escarpment north of UNM localities 1501 and 1502 where section B (Fig. 3) was measured. Abbreviations are: B = Bell Ranch Formation, E = Entrada Sandstone, G = Glencairn Formation, L = Lytle Sandstone, M = Morrison Formation, MR = Mesa Rica Sandstone and T = Travesser Formation.

by the correlation of two laminar/ripple-laminar sandstones considered to be the topmost bed of the Bell Ranch Formation, and the correlation of the "agate bed" in both sections (Fig. 3). Close lithological resemblances and the short intervening distance (2 km) suggest that these are reasonable correlations. These correlations indicate that there is almost 10 m of stratigraphic relief between the top of the Bell Ranch Formation and the Morrison "agate bed" over a distance of 2 km. This unconformity was more extensively documented throughout the Dry Cimarron Valley by Cooley (1955). It corresponds to the "J-5" unconformity of Pipiringos and O'Sullivan (1978) which, on the Colorado Plateau, separates the Morrison Formation from the underlying Summerville and Wanakah formations, probable correlatives of the Bell Ranch Formation of northeastern New Mexico (Lucas et al., 1985).

2. Above the "agate bed" in section B (Fig. 3), approximately 38 m of siltstone, claystone and limestone are present. These strata arguably are of lacustrine origin, particularly because they lack any fluvial bedforms, are fine-grained and laterally extensive. They are overlain by the uppermost 23 m of the Morrison which consist of sandstones, claystones and siltstones of fluvial origin: the sandstones are trough- and epsilon-crossbedded, lenticular bodies. The conclusion that much of the Morrison (lower two-thirds) is dominantly lacustrine in the Dry Cimarron Valley was further documented by West (1978) and Abbott (1979).

3. In section A (Fig. 3), the stromatolite bioherms are 14.5 m above the "agate bed." In section B (Fig. 3), 14.5 m above the agate bed are

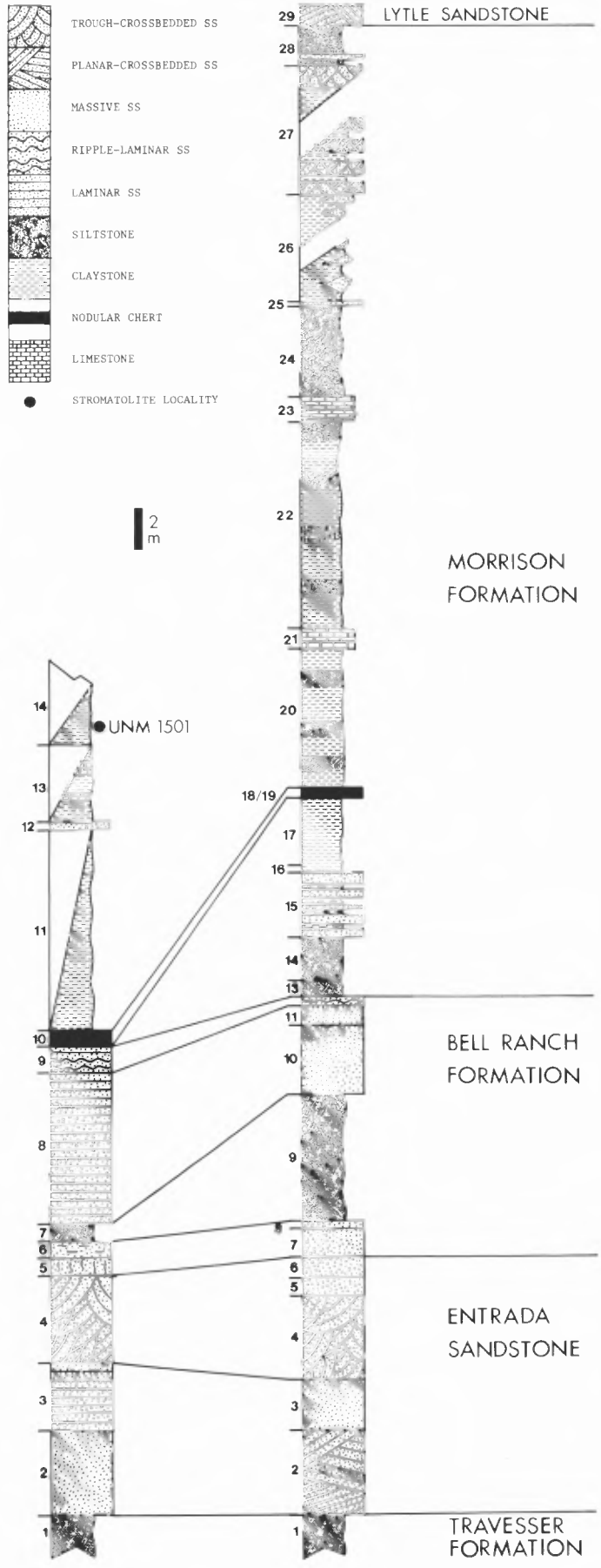


FIGURE 3. Measured stratigraphic sections at UNM locality 1501 (section A) and north of localities 1501 and 1502 (section B). For locations of stratigraphic sections and descriptions of lithologic units see Appendix 1.

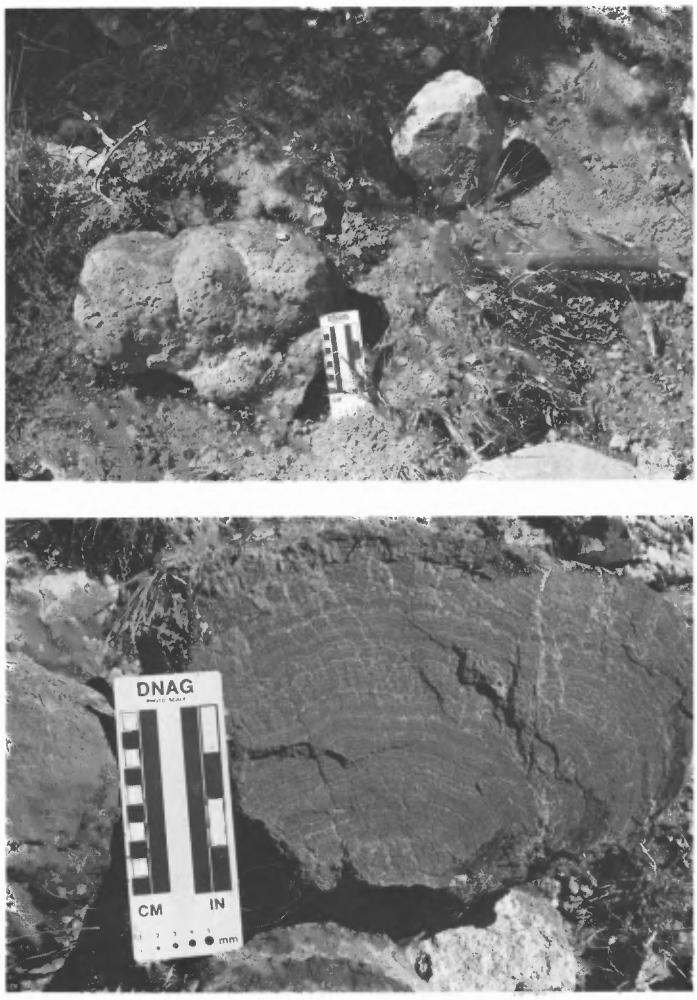


FIGURE 4. Stromatolitic bioherms at UNM locality 1501. A, View of bioherms in situ. B, Close-up of naturally formed cross section of a bioherm.

interbedded siltstones and claystones (unit 22 of section B) bracketed by limestones with wavy, algal laminae. This well supports placement of the stromatolite horizon in the lacustrine interval of the lower part of the Morrison.

Facies associations

The stromatolitic bioherms at UNM localities 1501 and 1502 are associated with oosparites and calcareous mudstones. These oosparites, calcareous mudstones and the bioherms probably formed at the margin of a shallow lake situated within an alluvial plain during deposition of the Morrison. Extensive carbonate precipitation is known to take place at lake margins (e.g., Eugster, 1980; Wilkinson et al., 1980), and algal stromatolites are also known to contribute to carbonate precipitation near lake shorelines (e.g., Smoot, 1978). Periodic drying and subsequent cracking of the mudflats could have produced the abundant intraclasts found in the oolitic limestones (Fig. 5A–C). The fine-grained, angular to subangular quartzose silt and sand found nucleating ooids, within sparitic and micritic cement, and within algal laminae, could have been blown onto the mudflats and into the shallow waters during these same dry periods. Precipitation of micrite on rounded to subrounded mud intraclasts and various clastic fragments generated various ooid shapes (Fig. 5A–B). Most ooid coatings exhibit radial texture and seem to have two distinct layers.

The rounded to subrounded intraclasts range in size from 0.05 mm to 0.22 mm and average 0.11 mm. Approximately 8 to 10% of the intraclasts are large (2–6 mm) and angular to tabular. Some of these large intraclasts consist of micrite and small ooids in a micritic and sparitic matrix. The latter type indicates a micritic mud encasing and cementing ooids and other intraclasts and subsequently being ripped up by wave activity or recracking by desiccation. The cyclic growth patterns observed in the algal stromatolites could also be explained by periodic wet and dry periods. Cyclic patterns in the stromatolites are indicated by laminae which can be correlated from one bioherm to another (see below).

Extent of Late Jurassic lake

The non-marine, predominantly fluvial origin of the Morrison Formation has long been well accepted (Mook, 1916). Many localized, lacustrine facies of the Morrison have also been documented (e.g., Dodson et al., 1980). Recently, Bell (1981) identified a closed, playa-lake basin in the Brushy Basin Member of the Morrison that occupied most of the present San Juan Basin of northwestern New Mexico and adjacent areas (also see Turner-Peterson, 1985; Bell, 1986; and Turner-Peterson and Fishman, 1986). We believe a lake basin of similar size may have existed during part of Morrison deposition on the southern High Plains.

In east-central New Mexico (parts of San Miguel, Harding, Guadalupe and Quay Counties), the medial portion of the Morrison Formation is dominated by laterally discontinuous, fine-grained sandstone with minor, pale-green mudstone and local chert- and clay-pebble conglomerate, particularly at the bases of sandstones (e.g., Wanek, 1962; Trauger and Bushman, 1964; Hunt, 1986). However, northward in Union County, New Mexico and Cimarron County, Oklahoma, the interbedded siltstones, claystones and limestones here identified as of lacustrine origin occupy the medial portion of the Morrison (Stovall, 1943; Cooley, 1955; Baldwin and Muehlberger, 1959; West, 1978; Abbott, 1979). This lacustrine facies has been well documented as far north as the Purgatoire Valley in southeastern Colorado (Lockley et al., 1986).

The simple facies pattern on the southern High Plains—a medial Morrison sand complex giving way northward to a lacustrine facies—is remarkably similar to the facies pattern in the San Juan Basin. There, fluvial sandstones of the uppermost Westwater Canyon Member and Brushy Basin Member give way northward to mudflat and playa-basin facies (e.g., Turner-Peterson, 1985, fig. 9). The existence of a large, shallow-lake basin in the Morrison Formation of the southern High Plains thus seems a reasonable inference from available data. Nevertheless, further analysis of the Morrison Formation in this area is needed to determine precisely the former extent and nature of this Late Jurassic lake basin.

STROMATOLITES

Description

Using the terminology of Preiss (1972, p. 69), a brief description of the stromatolites from the Dry Cimarron can be presented. The Jurassic stromatolites occur as subspherical and domed bioherms that range in diameter from 7 cm to 43 cm. The stromatolites are non-columnar and have laterally linked laminations. These laminations are undulatory and, in places, slightly pseudocolumnar. The larger stromatolites commonly exhibit roll-over growth at their margins. Most stromatolites appear to have a small, subcircular basal-attachment shape. In a few specimens, the roll-over growth extends laterally as an individual sphere, as if it grew rapidly sideways, or joined with another algal sphere as if the stromatolites grew in "clumps." Cyclic growth patterns are apparent in every algal specimen collected (e.g., Fig. 4B). Four to five major cycles are visible in whole specimens. Two scales of lamination, thick laminae (10–30 mm thick) superimposed on thin laminae (0.2–1.0 mm thick), result in a composite repetitive mode of laminar organization (Monty, 1976, fig. 1C).

The stromatolites also exhibit curved, vertical cracks that cut across their laminae. They thus record at least two episodes of carbonate precipitation. The first episode was the growth in a Jurassic lake of the photosynthetic microbial community and the simultaneous deposition of the micritic calcite laminae that compose 95–99% of the stromatolitic bioherm. These laminae alternate in color from green-black to green-gray, reflecting variations in the proportions of organic matter and inorganic materials. A separate episode of calcite deposition is repre-

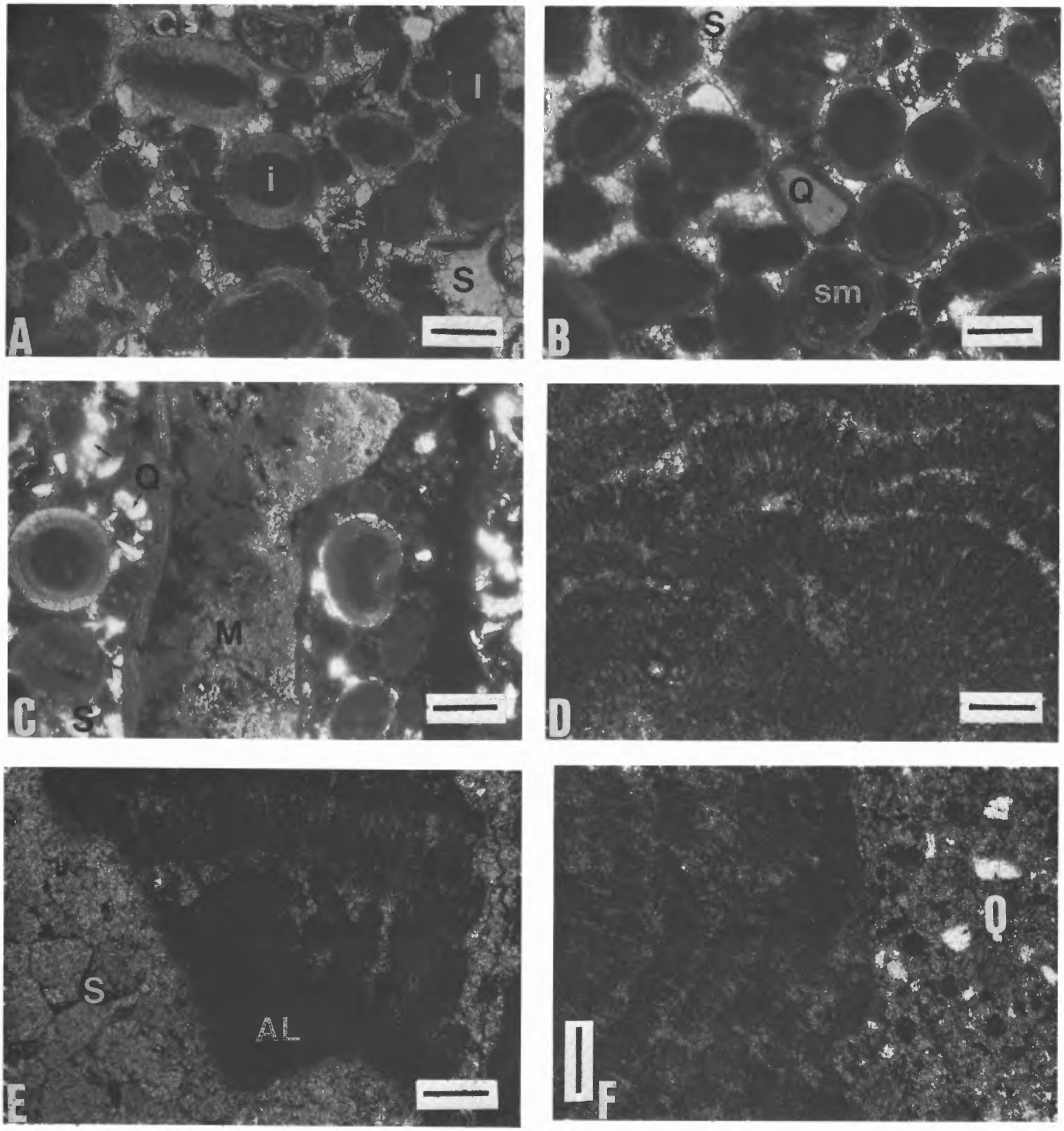


FIGURE 5. Photomicrographs of oosparitic limestone and algal laminae in crossed polarized light. Bar scales = 100 μ. A, Oosparitic limestone showing subrounded micritic intraclast without ooid coating (I), ooid with rounded micritic intraclast (i), quartzose silt-size clast (Q) and sparry calcite (S). B, Oosparitic limestone showing subangular quartzose sand-size clast (Q), sparry calcite (S) and sparitic/micritic intraclast (SM). C, Oosparitic limestone showing subrounded/angular quartzose silt-size (S; note partial destruction of adjacent ooid) and one-fourth of a large, tabular micritic intraclast with ooid coating and limonite (opaques) alteration (Q); dark area above bar scale includes part of previously cemented ooids. D, Algal laminae showing micritic and sparitic growth and vertically striped fabric. E, Algal laminae (AL) and sparry calcite infilling (s). F, Silt-sized quartz and micritic intraclasts in a micritic and sparitic matrix; opaques are limonite alteration.

sented by white sparry calcite infillings which occupy equidimensionally-situated cracks, typically spaced several mm to 1 cm apart. The various crack-fillings possibly represent more than one episode of deposition. Quartzose silt found in some of these cracks suggests they may have been caused by desiccation.

In order to analyze their major and minor mineral components, representative samples of the algal stromatolites were crushed by hand and in a Pitchford Scientific Instruments Division (PSI) rock crusher. The material was washed in 10% HCl acid until all calcium carbonate was dissolved. The residue was bathed with xylene to remove all traces of oil and suctioned through a paper filter. The residue and paper filter were baked in a Boekel 200 oven at 105°C for one hour, or until the sample was fully dried. The samples were mixed and mounted on a glass slide with an acetone medium and run in a Rigaku "GiegerFlex" x-ray diffractometer CN 2013 from 5 to 70 with CuK-alpha radiation. The residue had a composition of silica (quartz) and showed no traces of any other minerals. The composition of the algal stromatolites is: micritic calcite as laminae and sparry calcite as crack fill (99%); quartzose silt in crack fill (0.8%); and, a trace of dead oil.

Identification

No detailed attempt has yet been made to identify the stromatolites or stromatolite-building organisms. In thin section, the Morrison stromatolites have the typically striped fabric of *Rivularia* (cf. Monty, 1976, fig. 6A–B; Dragastan, 1985, p. 104, fig. 1), which is well known from the Mesozoic aand still lives in calcareous lakes. Such an identification can be considered tentative, pending further study.

Stable isotopes

Carbon and oxygen isotopic measurements indicate that multiple episodes of carbonate deposition have occurred in the Morrison stromatolites (Fig. 6). Whole-rock $\delta^{13}C$ and $\delta^{18}O$ values are –2.1 and –7.29, respectively. Individual primary micritic stromatolitic laminae give $\delta^{13}C_{PDB}$ and $\delta^{18}O_{PDB}$ values ranging from –1.7 to –2.8 and –6.55 to –8.79, respectively. The darker laminae (data points A_1 and A_2 in Fig. 6) appear to be almost 1 permil enriched in ^{13}C, relative to the lighter laminae (Fig. 6, points B_1 through B_3). This shift would be expected if the photosynthetic organisms, which selectively incorporate ^{12}C into organic matter, had been relatively more abundant and active during the deposition of the darker laminae. The white sparry calcite (Fig. 6, points D_1, D_2 and E) is markedly depleted, both in ^{13}C and ^{18}O, relative to the primary micritic laminae. These depleted isotopic values are typical of bicarbonate-bearing ground waters which derive from continental rainfall (which is ^{18}O-depleted, relative to seawater) and which reflect the activity of soil microbiota (which release isotopically-light carbon as CO_2). An isotopic trend is observed from large white sparry calcite veins (Fig. 6, point E) to smaller void-fillings (Fig. 6, points D_1 and D_2) to even smaller, greenish vein deposits (Fig. 6, points C_1 and C_2). These infillings likely formed when either vertical movement of the sedimentary basin and/or erosion of overlying strata fractured the rocks and introduced ground water.

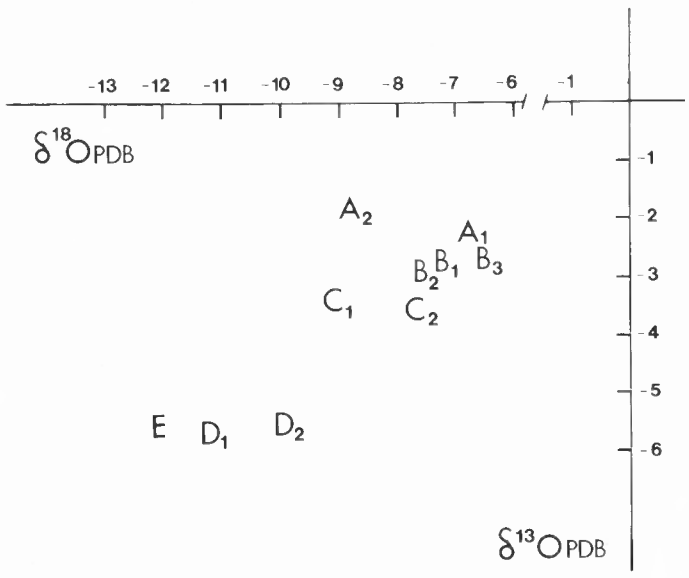


FIGURE 6. Carbon and oxygen isotopic analyses of carbonate mineral phases in the stromatolite. Letters designate stromatolite components as follows: A = dark stromatolitic laminae, B = lighter stromatolitic laminae, C = light greenish carbonate in small veins, D = white sparry calcite void infilling and E = white sparry calcite in large vein.

Both the analyses of the whole-rock and the primary micritic laminae give $\delta^{13}C$ and $\delta^{18}O$ values which are somewhat more negative than those expected for carbonates deposited in equilibrium with the open ocean water. For example, typical $\delta^{13}C_{PDB}$ and $\delta^{18}O_{PDB}$ values for Late Jurassic marine carbonates range between +0.4 to +1.4, and 0 to –1, respectively (Lindh, 1983). Our tentative interpretation of the isotope data is that this stromatolitic carbonate was deposited in a lake fed by continental rainfall. The abundance of stromatolites suggests that the lake was moderately to highly saline.

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APPENDIX 1—MEASURED STRATIGRAPHIC SECTIONS

The measured stratigraphic sections in Figure 3 are described below; colors are those of Goddard et al. (1979).

Section A

Measured in the SE¼ SW¼ NW¼, NE¼ NW¼ SW¼ and NW¼ NW¼ SW¼, sec. 18, T31N, R33E, Union County, New Mexico.

unit	lithology	thickness (m)
	Morrison Formation	
14	Claystone; light greenish gray (5 GY 8/1) to light gray (N 7); slightly silty; slightly calcareous; mostly covered; 0.9 m above base are in-situ stromatolitic bioherms (UNM locality 1501).	3.0+
13	Claystone; grayish red (5 R 4/2); slightly silty; very calcareous; contains come thin (2–3 cm thick) beds of well indurated, algal-laminated, sandy, light gray (N 7) and yellowish gray (5 Y 8/1) limestone; mostly covered.	3.6
12	Sandstone; mottled pale brown (5 YR 5/2) and yellowish gray (5 Y 7/2); quartzose; fine to medium grained; subangular; moderately sorted; non-calcareous; well indurated; massive.	0.3
11	Claystone; light greenish gray (5 GY 8/1) to light gray (N 7); slightly silty; slightly calcareous; mostly covered.	9.7
10	"Agate bed"; medium dark gray (N 4), moderate red (5 R 4/6) and pale reddish brown (10 R 5/4) nodular chert.	0.9
	Disconformity	
	Bell Ranch Formation:	
9	Sandstone; pale yellowish orange (10 YR 8/6) to grayish orange (10 YR 7/4) unweathered; weathers to moderate yellowish brown (10 YR 5/4); quartzose; very fine to fine grained; rounded to subrounded; well sorted; slightly calcareous; well indurated; laminar and ripple laminar.	1.2
8	Clayey, gypsiferous sandstone; pale yellowish brown (10 YR 6/2) to grayish orange pink (5 YR 7/2) (gypsum masses are moderate orange pink [5 YR 8/4]); quartzose; fine grained; rounded, well sorted; gyspum masses as much as 5 cm in diameter; slightly calcareous; friable; laminar; mostly covered.	7.3
7	Sandy siltstone; yellowish gray (5 Y 8/1); sand is quartzose, very fine grained, subangular to subrounded and well sorted; slightly calcareous; intensively bioturbated.	0.9
6	Clayey sandstone; yellowish gray (5 Y 8/1) and grayish yellow (5 Y 8/4); quartzose; fine and medium grained; subrounded; poorly sorted; very calcareous; friable; massive.	0.9
5	Sandstone; very pale orange (10 YR 8/2) and dark yellowish orange (10 YR 6/6); quartzose; medium grained; subrounded; well sorted; hematite coating of some grains; very calcareous; friable; intensively bioturbated.	0.8
	Entrada Sandstone:	
4	Sandstone; same colors as unit 3; quartzose (minor chert); fine and medium grained; subangular to subrounded; poorly sorted; slightly clayey; friable; very calcareous; large-scale trough crossbeds; base of unit is topographic notch that is more oxidized (pale reddish brown [10 R 5/4]) than overlying sandstone.	4.0
3	Sandstone; pale yellowish orange (10 YR 8/6) and very pale orange (10 YR 8/2) with specks (chert) of dusky yellowish brown (10 YR 2/2); quartzose; fine grained; subrounded; well sorted; slightly clayey; very calcareous; friable; laminar.	3.3
2	Sandstone; mottled very pale orange (10 YR 8/2) and pale reddish brown (10 R 5/4); quartzose; fine and medium grained; poorly sorted; subrounded and rounded; slightly clayey; very calcareous; hematitic; friable, massive.	4.0
	Disconformity	
	Travesser Formation (Upper Triassic):	
1	Siltstone; moderate reddish brown (10 R 4/6); non-calcareous.	not measured

Section B

Measured in the SW¼ SE¼ SW¼, SE¼ SW¼ SW¼ and NW¼ SW¼ SW¼, sec. 12, T31N, R33E, Union County, New Mexico.

unit	lithology	thickness (m)
	Lytle Sandstone:	
29	Sandstone; white (N 9) to very light gray (N 8) with hematitic spots of grayish orange (10 YR 7/4) unweathered; weathers to dark yellowish orange (10 YR 6/6); quartzose; medium and coarse grained; subangular-subrounded; poorly sorted; non-calcareous; hematitic; planar crossbeds.	3.5
	Disconformity	
	Morrison Formation:	
28	Sandy siltstone and silty sandstone; siltstone is dusky yellow (5 Y 6/4) and grayish yellow (5 Y 8/4) with quartzose, fine-grained, well sorted sandstone and non-calcareous; sandstone is light gray (N 7), weathers light brown (5 YR 5/6) quartzose, very fine and fine-grained, subangular, moderately sorted, non-calcareous and massive; bentonite in upper 0.3 m.	1.5
27	Sandstone with minor interbedded claystone; sandstones are dark yellowish orange (10 YR 6/6) and grayish orange (10 YR 7/4) unweathered, weather to moderate yellowish brown (10 YR 5/4); subarkosic, medium grained, subangular, well-sorted, slightly calcareous, and trough-crossbedded lenticular bodies that extend about 30 m on strike; claystone is grayish red (10 R 4/2) and greenish gray (5 GY 6/1).	21.5
26	Sandy claystone with minor clayey sandstone: claystone is grayish red (10 R 4/2) and greenish gray (5 GY 6/1) with quartzose, fine grained, subrounded, well sorted sand and is non-calcareous; sandstone is yellowish gray (5 Y 8/1) to light greenish gray (5 GY 8/1), quartzose, fine grained, subangular, well sorted and slightly calcareous; lenticular and massive.	14.6
25	Sandstone; medium light gray (N 6); fine-grained; well sorted; subangular, non-calcareous; massive.	0.1
24	Sandy siltstone; grayish yellow green (5 GY 7/2) to greenish gray (5 GY 6/1); sand is quartzose, very fine grained, subrounded and well sorted; non-calcareous.	4.4
23	Limestone with wavy algal laminae; same color and lithology as unit 21.	1.2
22	Interbedded siltstone and claystone; same color and lithology as unit 20.	9.7

unit	lithology	thickness (m)
21	Limestone with wavy algal laminae; yellowish gray (5 Y 8/1) to light greenish gray (5 GY 8/1).	0.9
20	Interbedded siltstone and claystone; siltstone is light greenish gray (5 GY 8/1) and very calcareous; claystone is greenish gray (5 GY 6/1), slightly sandy and very calcareous.	6.7
19	Interbedded nodular chert ("agate bed") and claystone; chert is medium dark gray (N 4) and light gray (N 7) with moderate red (5 R 4/6) streaks; claystone is greenish gray (5 GY 6/1) and very calcareous.	0.3
18	Nodular chert ("agate bed"); same color as chert in unit 19.	0.1
17	Claystone; greenish gray (5 GY 6/1); slightly sandy; very calcareous.	3.2
16	Siltstone; same color and lithology as unit 14.	0.3
15	Clayey sandstone with minor interbedded siltstone; sandstone is moderate yellowish brown (10 YR 5/4) and grayish orange (10 YR 7/4), quartzose, fine grained, rounded, well sorted, hematitic, well indurated, very calcareous and laminar; siltstone is same color and lithology as unit 14.	3.2
14	Siltstone; pale reddish brown (10 R 5/4) to pale red (10 R 6/2); slightly calcareous.	2.1
13	Siltstone; pale reddish brown (10 R 5/4) to pale red (10 R 6/2); intensively bioturbated.	0.8
	Disconformity	
	Bell Ranch Formation:	
12	Sandstone; grayish orange (10 YR 7/4) and yellowish gray (5 Y 8/1); quartzose; fine grained; subrounded; well sorted; minor clay content; very calcareous; laminar and ripple laminar.	0.4
11	Gypsiferous sandstone; very pale orange (10 YR 8/2) to grayish orange (10 YR 7/4); quartzose; fine and medium grained; subrounded-subangular; poorly sorted; some ripple laminae; slightly calcareous.	0.9
10	Gypsiferous sandstone; grayish orange pink (5 GY 7/2) to light brown (5 YR 6/4); gypsum rossettes are moderate orange pink (10 R 7/4) to grayish orange pink (10 R 8/2); quartzose; subrounded; very fine-grained; well sorted; very calcareous; laminar.	3.3
9	Gypsiferous siltstone; light olive gray (5 Y 6/1) with grayish orange-pink (10 R 8/2) gypsum rossettes as much as 7 cm across; calcareous.	6.1
8	Sandstone; grayish orange (10 YR 7/4) and very pale orange (10 YR 8/2); quartzose; very fine grained; subrounded-rounded; well sorted; local hematitic grains; friable; very calcareous; bioturbated; forms a ledge.	0.3
7	Gypsiferous sandstone; very pale orange (10 YR 8/2) with dark yellowish orange (10 YR 6/6) specks; quartzose; fine and medium grained; rounded-subrounded; poorly sorted; slightly clayey and hematitic; slightly calcareous; friable; massive.	1.4
	Entrada Sandstone:	
6	Sandstone; moderate reddish orange (10 R 6/6) with grayish orange pink (10 R 8/2) specks; quartzose; medium grained; subrounded-rounded; moderately sorted; slightly clayey; hematitic; very calcareous; massive.	0.9
5	Sandstone; same color as unit 4; quartzose; fine and medium grained; rounded; poorly sorted; very calcareous; massive.	0.9
4	Sandstone; pale yellowish orange (10 YR 8/6) and very pale orange (10 YR 8/2) with specks of dusky yellowish brown (10 YR 2/2); quartzose; fine and medium grained; rounded-subrounded; well sorted; large-scale trough crossbeds faintly visible; calcareous.	4.0
3	Sandstone; grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6) and some moderate reddish orange (10 R 6/6); quartzose; fine and medium grained; subrounded; moderately sorted; very calcareous; friable; massive.	2.3
2	Sandstone; same color as unit 4; quartzose; medium and coarse grained; rounded; moderately sorted; very calcareous; planar crossbeds.	4.0
	Travesser Formation:	
1	Siltstone; moderate reddish brown (10 R 4/6); non-calcareous.	not measured



Ute Creek about 6 km below its headwaters. View is N5°W upstream. Here the stream is flowing on basalt and has a well defined but grassy channel studded with basalt boulders. Two small terrace remnants at left are indicated by light colored grass. Elsewhere in this reach a well defined channel is absent, and the drainageway is marked by small transverse scarplets in the thin alluvium that underlies the broad grassy valley floor. Camera station is in NW¼ sec. 6, T26N, R26E. Altitude about 2,133 m. W. Lambert photograph No. 86L117. 30 December 1986, 11:48 am., MST.