Sedimentation, stratigraphy, and paleoenvironments of the lower members of the Carmel Formation (Middle Jurassic, Southwestern Utah)

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INTRODUCTION

The Middle Jurassic Carmel Formation in southwestern Utah is composed of shallow marine to peritidal sedimentary rocks, including complexly interbedded limestones, siltstones, sandstones, and evaporites. Only Nielson (1990) has done the primary work on the sedimentation and stratigraphy of the Carmel Formation in the Gunlock area. Nielson (1990) separated the Carmel in to six members (A-F), each of which represents a portion of the shallow marine peritidal system. Members A through C were studied for this report. Nielson's (1990) work correlates and supports as well as differs from my own observations. The purpose of my project is to interpret sedimentary environments of the Carmel Formation as reflected by macro- and micro-textures and fossils, in order to place the Carmel Formation into the larger context of the geologic and sedimentologic history of the Colorado Plateau.

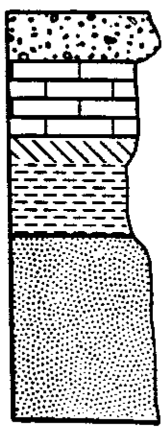
GEOLOGIC SETTING

The Carmel Formation accumulated during two major transgressive cycles (Nielson, 1990). The Carmel is composed of seven, second-order shallowing upward cycles and is believed to have been deposited in off shore and shoreline environments near the southern margin of the Middle Jurassic Western Interior seaway (Carmel Seaway) that extended into southern Utah from Canada (Caputo, 1980; Blakey, Havholm, and Jones, 1996). Overall, the Carmel Formation represents the margins of a much larger, intra-cratonic marine basin and records periods of high to low energy conditions and normal to hypersaline marine to peritidal environments.

Deposition of the lower Carmel in southwest Utah began due to the downwarping of the Carmel-Twin Creek Trough resulting in a series of southerly transgressions of the seaway (Imlay, 1967). The presence of interbedded limestone, dolomite, gypsum, and red bed facies characteristic of the lower Carmel indicate arid nearshore conditions which prevailed in southwest Utah during the Middle Jurassic (Blakey et al., 1983).

The Carmel Formation and its stratigraphic relationships vary greatly throughout the region. In the Gunlock Reservoir area of southwest Utah, the gypsum rich mudstone of the Temple Cap Formation overlies the Navajo Sandstone and underlies the Carmel Formation (Figure 1). The massive Cretaceous pebble conglomerate of the Dakota Formation lies unconformably over the Carmel Formation.

Figure 1: Generalized stratigraphic relationships of Mesozoic rocks of southwestern Utah showing the position of the Carmel Formation.



METHODS

Four separate sites of the Carmel Formation were examined in detail (Figure 2). Each site was previously divided into 37 separate units by Nielson (1990), whose paper was used to locate each member. A Trimble Scout Global Positioning System receiver was used to determine each site location. Total unit thickness was measured with meter transect tapes and Jacob staffs. Brunton compasses were used to determine paleocurrent direction of ripple marks. Color, grainsize, composition, sedimentary structures, contact relationships, sketches, and photographs were made from units A2-C37. Samples were collected from each of the primary units within each member. Several sections within each member were more thoroughly examined because they differed from Nielson's (1990) work or were laterally extensive and easy to identify at all sites. 85 thin sections were made from hand samples and examined under a binocular dissecting microscope for microsedimentary structures and fossils. Complete stratigraphic columns have been made of each of the four study sites. Using modern analogues and evidence presented in the field and in thin sections, I made interpretations of the depositional system of the lower Carmel in the Gunlock area.

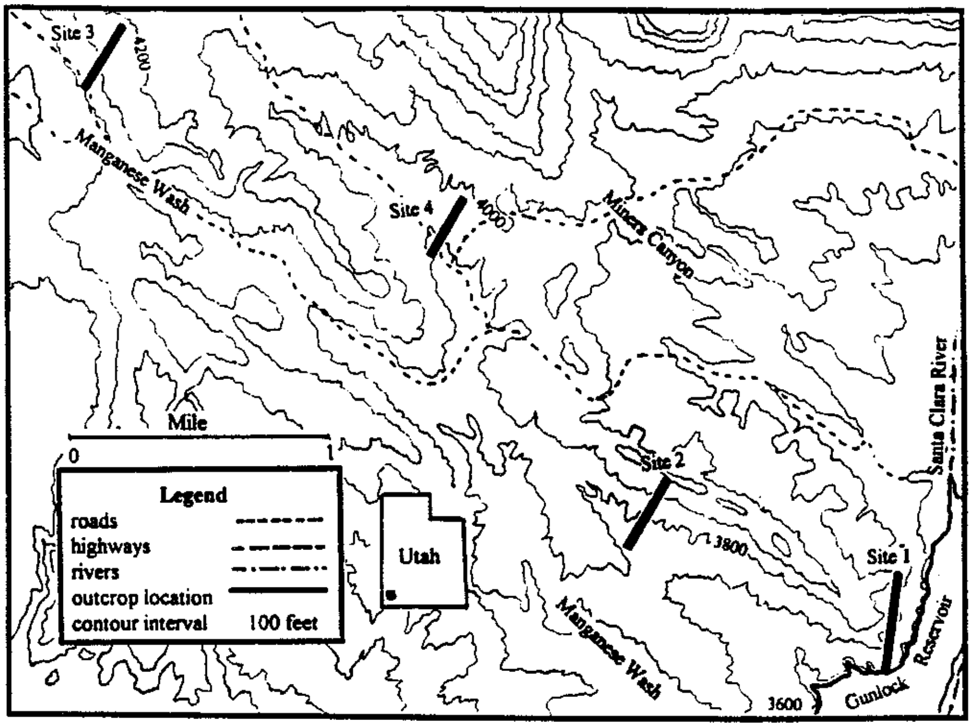


Figure 2. Map of the Gunlock Reservoir Region (Gunlock, Utah 15' Quadrangle, 1972)

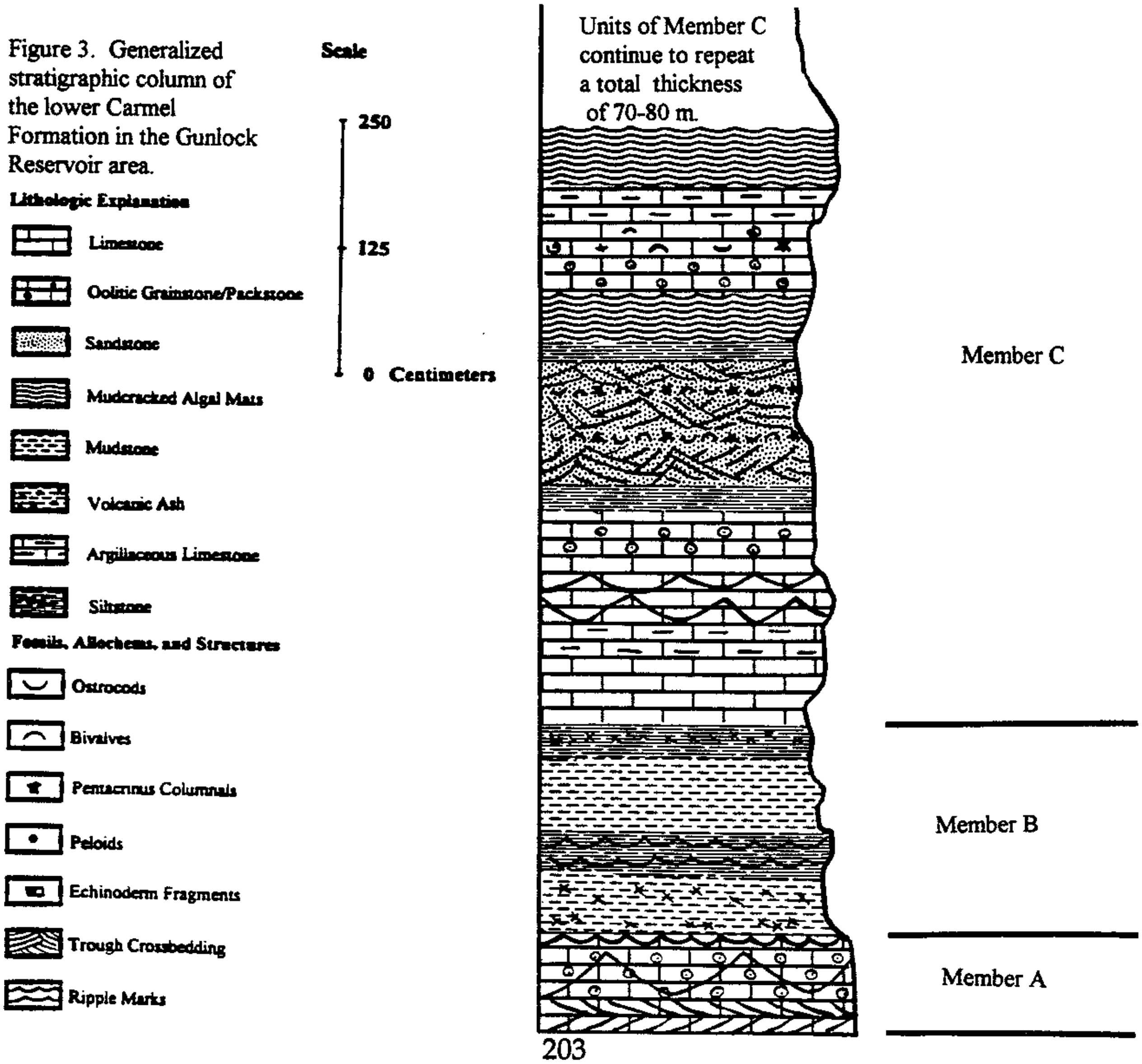
RESULTS

Member A. Member A, the lowermost member of the Carmel Formation, overlies the Temple Cap Formation as thickly bedded limestone blocks. Sedimentary structures found in Member A at sites one and two include large and small scale cross bedding, large rip up clasts (25 X 40 cm), hummocky cross stratification, and well preserved ripple marks (Figure 3). At site three, well developed siliceous rinds thinly coat the uppermost ripple marks an enigmatic phenomenon that might be explained by an early diagenetic process. Paleocurrent determinations suggest a southwest current, supportive of previous work conducted on the Carmel Formation (Rigby, 1986; Caputo, 1980; Voorhees, 1978). Fragments of fossil gastropods and bivalves are included in this oolitic grainstone member. The orientation and concentration of the fossils in this member suggest that they are most likely transported and reworked remains derived from elsewhere in the system by storms. Member A, an oolitic shoal assemblage (Figure 4), represents the highest energy environment preserved in the Carmel Formation.

Member B. Members B and C indicate a restricted lagoonal environment grading into an intertidal sequence (Figure 4). Member B was studied in greatest detail at site 1 which had the highest degree of preservation and exposure. This member consists of three distinct gypsum and volcanic ash-rich mudstone units and three siltstone units (Figure 3). Due to the highly weathered characteristic of this member, thin sections could not be made from the brittle hand samples. Each unit lacks both body and trace fossils, and supports the possibility that these rocks were formed by processes associated with supratidal sedimentation characteristic of an arid environment (sabkha). As pools of hypersaline seawater evaporated on mudflats, gypsum hopper crystals (3-5 cm wide) developed throughout the sabkah region and permeate the laminated siltstone and mudstone. Small scale ripple marks and planar bedding characterize a single unit of siltstone and represents a restricted shallow (less than 1 meter depth) lagoon. Paleocurrent information suggests sediment transport was in a southeast direction. Of special interest is a 2-3 cm thick caliche horizon found separating Member B from Member C. The caliche horizon is well developed at Site 1 and suggests a long period of stability and arid conditions and is the best evidence to support the idea that transgression of the Carmel Sea was not occurring at that time. Based upon sedimentologic data, Member B represents a hypersaline lagoon and an arid lagoon with little or no water circulation.

Member C. Member C is the thickest of all members of the Carmel Formation and consists of four depositional cycles. The lowermost contact of Member C places it as the first thick series of carbonate limestones following the red bed mudstones and siltstones of Member B. The distinct yellow-gray color of this member is characteristic of the units throughout the 70-80 meters of measured section. The cycles generally consist of blocky gradational oolitic grainstone and fossiliferous limestone with few sedimentary features, brittle argillaceous limestone, and a resistant and thick series of algal mats capped with siltstone and mudstone (Figure 3). One unique cycle includes large scale trough cross bedded siltstone grading into a well sorted medium bedded quartz-rich sandstone. Unique to Member C, this unit was characterized by its massive unit thickness and spheroidal weathering. The large scale trough cross bedding represents a migration of large scale ripples in a higher energy environment such as that of a beach or dune. Petrographic analysis of Navajo Sandstone and this unit (C13) show distinct similarities and suggest that the Navajo Sandstone was the source rock for this unit. Within the three meter thickness of unit C13 are two concentrations of fossil fragments that are laterally extensive at three sites, and includes bryozoans, crinoids, and bivalves. The death assemblage represents two different storm accumulations. Member C includes sedimentary structures and fossils representing an intertidal onshore zone (Figure 4).

Figure 3. Generalized stratigraphic column of the lower Carmel Formation in the Gunlock Reservoir area.



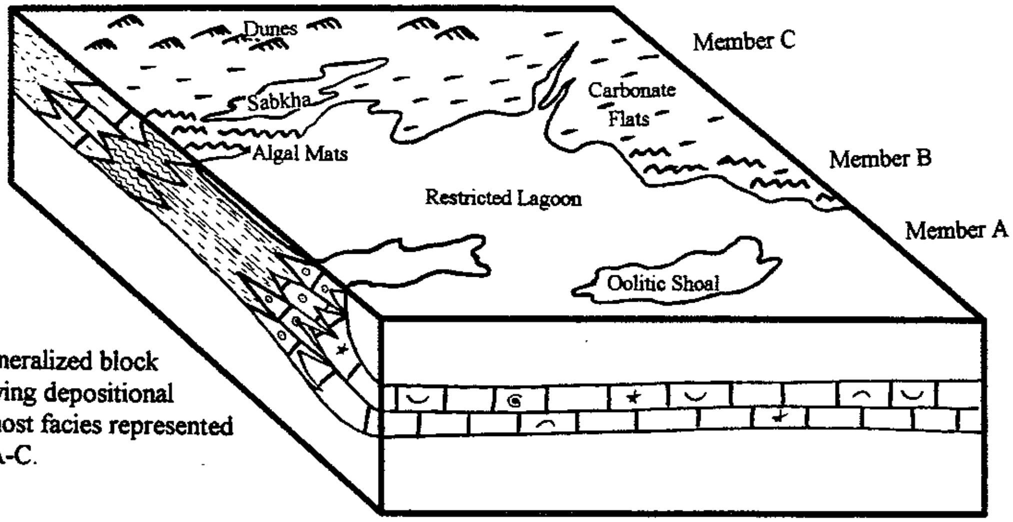


Figure 3: Generalized block diagram showing depositional systems for most facies represented in Members A-C.

CONCLUSIONS

The lower members of the Carmel Formation generally represent low energy depositional environments. Member A, however, includes large scale hummocky cross-stratification, storm deposits, and large rip up clasts and reflects the high energy environments characteristic of a shoaling zone or storm deposit of a restricted sea. The gypsum-rich units of mudstone and siltstone of Member B represent a very low energy restricted lagoon. The presence of hopper crystals in several units suggest sabkha conditions which may have resulted from evaporation as sea level dropped and exposed the mudflats to arid conditions. The rock units and structures that compose Member C represent an intertidal to onshore zone and reflect four similar depositional cycles within the Carmel Formation.

Algal mats, argillaceous limestone, and siltstone lithologies often include common sedimentary structures of lenticular bedding, small scale ripple marks and cross bedding and comprise a majority of the lower Carmel Formation. These lithologies and structures indicate arid shallow marine to peritidal environments. Nearly all of the units are laterally extensive and can be found varying slightly in thickness and sedimentary features, suggesting an irregular coast line and fluctuating sea level.

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