Ichnocoenoses and Paleoenvironments of the Middle Jurassic Carmel-Twin Creek Seaway, from the Carmel Formation near Gunlock, Utah

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INTRODUCTION

The Carmel Formation (Middle Jurassic) of southwestern Utah, near the town of Gunlock, consists primairly of carbonate siltstones and sandstones deposited under arid conditions in shallow marine to peritidal environments of the Carmel-Twin Creek Seaway. The upper portion of the Co-op Creek Member (informal member D of Nielson, 1990) is a complete shallowing-upwards sequence that contains a rich trace fossil assemblage with four distinct ichnocoenoses.

The Carmel-Twin Creek Seaway extended throughout the western United States as far south as Utah and as far east as Wyoming from Bathonian to Bajocian times, and possibly into Callovian time (Nielson, 1990). Extensive work done by Imlay (1980) on the Jurassic paleobiogeography of the continental United States brought to light the history this seaway. It began as a very shallow body of water which evaporated easily and formed extensive gypsum deposits now known in Utah as the Temple Cap Formation. Subsequently, sea level rose further and flooded the continent, creating the depositional environments of the Carmel Formation.

This study was conducted to answer some basic questions about the paleoenvironments represented in member D, and to expand upon the interpretations presented by Smail (1994). Varying faunal assemblages within the formation invited investigation into what made them different. Why do seemingly similar outcrops have such different assemblages of fossils? Are physical factors such as salinity differences, different prevailing energy levels, or varying depths responsible for the contrasting assemblages? Is it a combination of these factors affecting the organisms or are the differences simply preservational? Trends in the ichnocoenoses and stratigraphy of the Carmel Formation were looked at and compared to other similar assemblages from around the world to produce a paleoenvironmental analysis with higher resolution than previously conducted studies.

METHODS

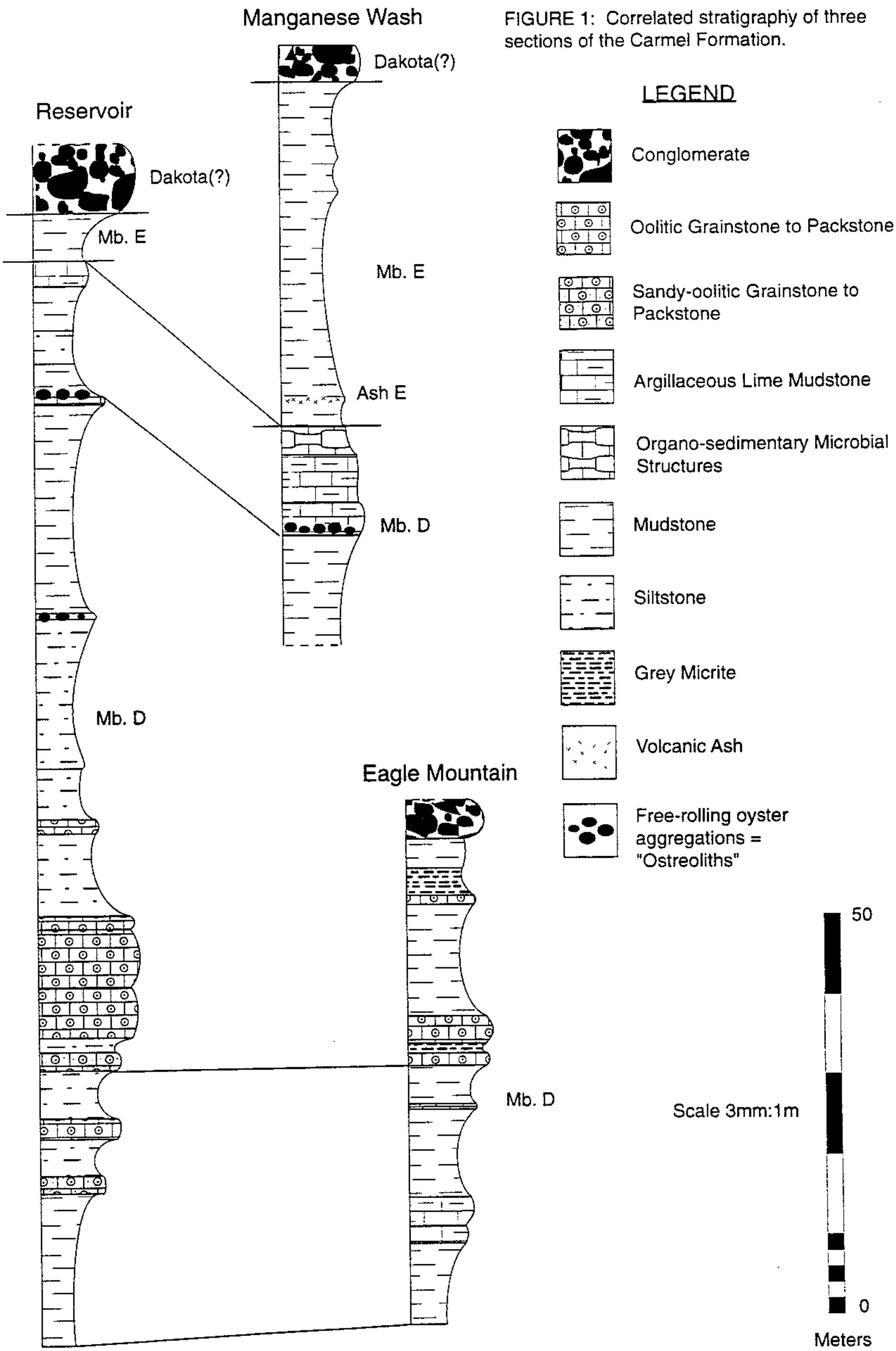
Field methods. Samples for this study were taken from three separate stratigraphic sections in the Gunlock area. The stratigraphy of each section was recorded, and the samples were collected by stratigraphic unit. An effort was made to collect samples of as many different trace fossils as possible, while the relative abundance of each taxon was noted in the field. At all three locations, at least part of the section was talus slope, making stratigraphic correlation more difficult. A reasonably accurate stratigraphic location was determined for the samples by comparing lithologies and operating under the assumption that any sample found on the slope came from above.

Laboratory methods. After spending two weeks in the field, project operations moved to the College of Wooster for initial lab work. Thin sections were prepared from representative samples of each unit and an intensive literature search was initiated. Detailed discussions and descriptions were compiled for each ichnotaxon, including a selected synonymy. The thin sections were examined with a petrographic microscope to confirm lithologic interpretation. Cements, mineralogy, grain types, and fabrics were the primary attributes studied.

RESULTS

Stratigraphy. As mentioned previously, member D represents a single shallowing-upwards cycle. A correlated graphic log of the three studied sections is shown in Figure 1. Member C ends at the top of a deeply mudcracked, moderately resistant argillaceous lime mudstone, and the bottom of member D represents a flooding event. Above the contact, member D consists of a very fissile mudstone which is interrupted occasionally by oolitic grainstones. The thinnest of these grainstones is about 0.3m thick, and they become more prevalent higher in the member, often forming a prominent cliff. Above these highly resistant grainstones, grain-size decreases and mudstones and siltstones predominate. Within these fine-grained beds are thin lenses of oolitic grainstone which are from 1 to 10 mm thick. A few thicker beds of oolitic grainstone crop out at this level as well. These beds are similar to those found lower down; however, there are several hardgrounds present and some horizons contain sub-rounded aggregates of oysters (ostreoliths, see Wilson et al. 1998).

FIGURE 1: Correlated stratigraphy of three sections of the Carmel Formation.



Ichnology. Initial field work revealed two distinct ichnocoenoses (coeval tracemakers), and further examination established two more (Figure 2). Ichnocoenosis I is characteristically limited in both diversity and numbers, and it is similar to Ichnocoenosis III. The only trace found with any regularity is *Gyrochorte comosa*, although other traces include *Chondrites* (?) type 1, *Diplocraterion* sp., *Lockeia* sp. and *Neonereites uniserialis.* This ichnocoenosis can be found within the bottom most mudstone, before any of the resistant grainstone units. Ichnocoenosis II is dominated by *Planolites beverlyensis* type 1 and a large species of *Thalassinoides. Diplocraterion* sp. and *Chondrites* are relatively uncommon in these beds, but neither is found commonly elsewhere, thus they are considered to be typical of this ichnocoenosis, if not diagnostic. The few other taxa found in Ichnocoenosis II are minor in occurrence and more common elsewhere. They appear to take advantage of local environmental change and do not coexist with the dominant traces for long, therefore they do not define this ichnocoenosis. The ichnofabric index of rocks in Ichnocoenosis II averages 3.5 (Droser-Bottjer scale). Ichnocoenosis III is found in the upper half of member D. It is characterized by having a variety of different taxa including *Asteriacites lumbricalis, Chondrites* (?) type 2, *Gyrochorte comosa, Lockeia* sp., *Neonereites uniserialis, Planolites beverlyensis type 2, Skolithos* sp. *Teichichnus, Thalassinoides* (?), and *Neonereites uniserialis.* As is the case in Ichnocoenosis I, *G. comosa* is the only trace fossil that is found abundantly throughout this ichnocoenosis. The other taxa are distributed much more sporadically, and there is no order to their distribution. Compared to trace fossil assemblages from other areas, Ichnocoenosis III has very limited diversity, although it is the most diverse ichnocoenosis in member D. Ichnocoenosis IV is the most limited ichnocoenosis of the member. It contains only *Copeza propinquata*, which is considered to be the track of an insect (Hitchcock, 1865). The sediments have been interpreted as a supratidal, sabkha-like facies by Nielson (1990).

DISCUSSION

To determine the paleoenvironments represented in member D of the Carmel Formation, it was necessary to study both the lithologies of the rocks as well as their trace fossils. Wave energy, salinity, and water depth were the main factors examined. An interpretation of the sea-level changes apparent in member D is shown graphically in Figure 3.

Ichnocoenosis I begins just above the base of the member, and represents a tracemaker colonization phase. The sediments deposited were fine-grained mudstones indicating a very low energy environment, possibly a restricted bay. The occurrence of Ichnocoenosis II corresponds with an increase in grain-size, which indicates a slightly higher energy level than before. However, the high amount of bioturbation preserved in the rocks shows that the depositional environment had a low energy level and a low sediment influx which allowed for reworking of the sediments. Water depths above wave-base but well off shore from the intertidal zone and any protective barriers could satisfy these conditions. The oolitic grainstones in the area have been interpreted by Nielson (1990) as being oolite shoals that formed a barrier. The thinner oolitic grainstones in the lower portion of the member likely represent remnants of the outer edges of that shoal. *Planolites beverlyensis* and *Thalassinoides* sp. of Ichnocoenosis II became less prevalent above as wave-ripples and crossbedding indicative of the oolite shoal became more common. Ichnocoenosis II is replaced by Ichnocoenosis III as the oolitic grainstones terminate and finer-grained stiltstones dominate. The grain-size reduction indicates a decrease in wave energy. This sudden change in depositional environment is attributed to a sea-level drop accompanied by the formation of a protected lagoon. The restricted diversity of Ichnocoenosis III is indicative of a relatively harsh environment, although the presence of some trace fossils, especially *Asteriacites lumbricalis* indicate normal or near normal marine salinity. Modern brittle stars burrow to avoid light, and if the Jurassic ophiuroids burrowed for the same reason, it can be inferred that the water was not deep or turbid enough to shade them. No traces were found in part of the section containing Ichnocoenosis III; however, because the lithologies are similar to the surrounding units, I attributed the absence of trace fossils to insufficient searching, rather than an absolute lack of trace fossils. Ichnocoenosis III gradually disappears and is not replaced immediately by any other organisms, thus indicating a gradual change to inhospitable conditions. Salt hopper casts and microbial laminations are evidence for a continued regression and a change to a supratidal environment. The last and most important evidence of this terrestrial environment is the presence of the arthropod track *Copeza propinquata.* Throughout this stratigraphic section, sea level (depth), salinity, and wave-energy levels have been shown to restrict the distribution of trace fossils.

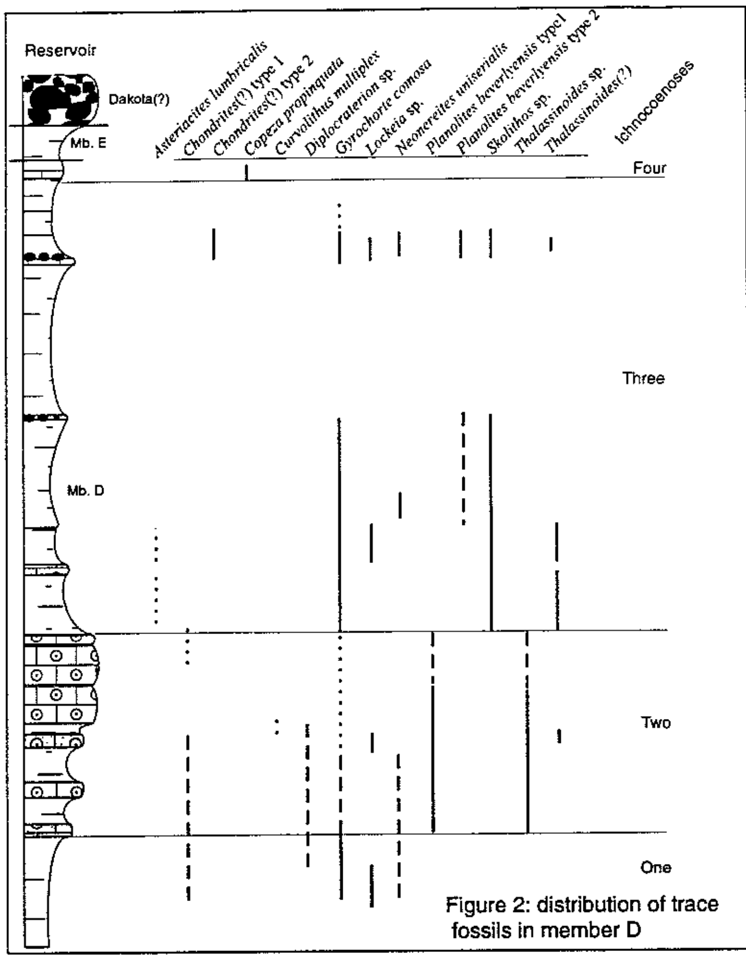


Figure 2: distribution of trace fossils in member D

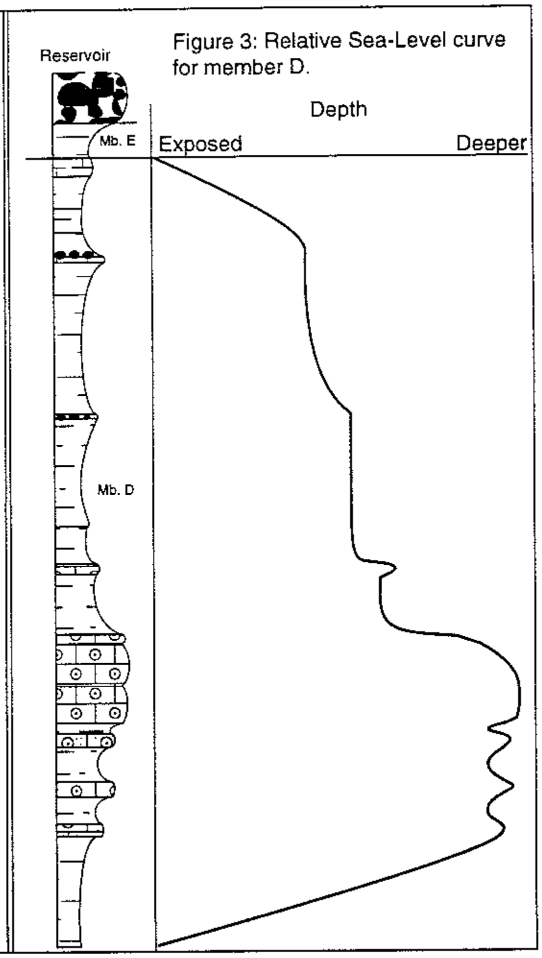


Figure 3: Relative Sea-Level curve for member D.

CONCLUSIONS

The combination of stratigraphic and ichnologic evidence provides the following depositional history of member D in the Carmel Formation near Gunlock, Utah. After a period of low sea level, there was a rapid transgression that culminated with depths well within the limits of fair-weather wave-base. Intense bioturbation by two types of organisms occurred in the relatively quiet waters. Sea level began to shallow slightly, bringing with it increased wave energy and oolite shoals. As the regression continued, the shoal moved farther off shore allowing quiet water back-barrier muds and silts to be deposited under fairly normal marine salinity conditions. A relatively diverse, although still limited group of organisms lived in the lagoon until sea level dropped more, and evaporation caused hypersalinity. At this point, the area became inhospitable to marine life but after further evaporation, terrestrial organisms ventured onto the newly exposed land.

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