BORINGS ASSOCIATED WITH A MIOCENE CORAL REEF COMPLEX, FORTUNA BASIN, SOUTHEASTERN SPAIN

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Borings are escavations made by organisms in consolidated or otherwise firm substrates. They are indications of behavioral activity in response to the substrate and other paleoecological parameters. Borings found in the fossil record are usually distinctive enough to be classified. Their morphological characteristics allow them to be used as important tools in the study of ancient environments. In this study, borings in cobbles from the Fortuna Basin of southeastern Spain are described and analyzed. Three aspects of this study are: 1) detailed description of the borings to identify the organisms that bored and their methods of boring; 2) analysis of the borings in terms of the types of substrates bored and their stratigraphic occurrences; and 3) interpretation of the paleoenvironment for the study.

Field Study

The area for this study, La Loma, is located about 2.2 km southeast of the town of Abanilla in southeastern Spain. The La Loma area consists of several knolls aligned approximately east/west with elevations between 200 - 240 m above present sea level. The strata studied are of late Miocene age and are located in the Fortuna Basin; the strata consist primarily of conglomerate, coral reefs, and calcarenites. Stratigraphic sections were measured and samples were collected from these knolls.

Results

Three ichnogenera and seven ichnospecies were described from the samples collected (Table 1). The descriptions were based on both macroscopic and microscopic features. Detailed descriptions of the borings were made by observing the size, shape, length, and width of the borings. Table 1 also identifies the organisms that were possibly responsible for the borings, as well as the type of substrate bored.

Ichnospecies	Organism Responsible	Substrate Bored
Entobia cateniformis	*Cliona* (a sponge)	Limestone Cobbles
E. geometrica	*Cliona*	Limestone Cobbles
E. ovula	*Cliona*	Limestone Cobbles
Gastrochaenolites dijugus	*Gastrochaena* (a bivalve)	Limestone Cobbles
G. lapidicus	*Gastrochaena* & *Lithophaga*	Limestone Cobbles
G. torpedo	*Lithophaga* (a bivalve)	Limestone Cobbles, Corals, & Coral Cobbles
Potamilla sp.	Polychaete worm	Coral Cobbles & Corals

Table 1: Ichnospecies identified at the La Loma area. "*Potamilla*" is actually a genus of polychaete worm commonly used in an ichnogeneric sense.

Discussion

Entobia is the ichnogeneric name assigned to multi-chambered sponge borings that resemble those of the living sponge *Cliona* (Bromley, 1970). These borings are common in Mesozoic and Tertiary nearshore sequences. Cobb (1969) and Warburton (1958) suggested a chemical hypothesis for the means of boring. The sponge possesses mesenchymal cells that project part of their cytoplasm onto the substrate. These cells release a substance in minute quantities through cytoplasmic threads which dissolve or etch the substrate around its edges. The cytoplasmic films work their way into the dissolved or etched areas and excavate a hemisperical chip which is later displaced, leaving a convex-shaped separation surface. The end result is a anastomosing network of galleries within the substrate. *Gastrochaenolites* includes borings that are constructed today by some species of the bivalves *Lithophaga* (Kelly and Bromley, 1984) and *Gastrochaena* (Bromley, 1978). Hodgkin (1962) concluded that *Lithophaga* species bore by some sort of chemical means because no abrasive effects are produced in the boring walls. Jaccarini (1968) hypothesized that a calcium chelating agent, secreted from the pallial glands of *Lithophaga*, is responsible for the penetration of the substrate. The manner in which *Gastrochaena* bores has been assigned to either a chemical method, a mechanical method, or a combination of both (Carter, 1978). Mechanical boring is achieved by the projecting comarginal shell ridges and by the aragonitic periostracal spikes. However, the precise manner of the mechanical boring has never been observed. *Gastrochaena* can also bore by chemical methods using the pedal, siphonal, and anterior mantle epithelium, but the nature of the boring agent is presently unknown. The manner in which the *"Potamilla"* boring was excavated is not understood.

The percentage of bored cobbles of coral and micritic limestone compositions are plotted in a histogram (Fig.1). It is apparent that limestone cobbles are more extensively bored than are *in situ* corals. Almost 90% of the limestone cobbles collected had some kind of boring. The most common boring is *Entobia*, followed by the clavate *Gastrochaenolites*. Cobbles which had both ichnogenera present appear to have been bored at two different times. Evidence for this is the preservation of the clavate borings, which had only part of the chambers present (the neck region and the aperture have eroded away). The cobbles are later dominated by *Entobia*. However, about 17% of the cobbles that had both ichnogenera present appear to have been bored simultaneously with *Entobia* being most common. As for the corals and coral cobbles, only 54% of total specimens had evidence of boring. These materials are extensively recrystallized. Common borings found in the coral specimens are assigned to the worm boring *"Potamilla"* (28%) followed by *Gastrochaenolites* (16%). Only 6% of the specimens had both ichnogenera present. No sponge borings are present in corals or coral cobbles. There appears to be some stratigraphic control of ichnogeneric distribution. *Entobia* is present only in the lower stratigraphic units whereas *"Potamilla"* is most common in the upper stratigraphic units. *Gastrochaenolites* appears in both the lower and upper stratigraphic units and is found in corals, coral cobbles, and cobbles. The upper stratigraphic units consist primarily of corals, where *"Potamilla"* and *Gastrochaenolities* are common. In the lower stratigraphic units, *Entobia* is common in the conglomerate beds, whereas *Gastrochaenolites* is common in both the coral reef and conglomerate beds.

Using the above information, the paleoenvironmental conditions that may have persisted at the La Loma area during this part of the Miocene can be hypothesized. Figure 2 is a paleoenvironmental reconstruction of La Loma during the Miocene. Three paleoenvironmental interpretations follow. First, the diversity of the boring fauna at La Loma indicates a shallow marine environment with some tidal influence. Second, the high diversity and occurrences of *Entobia* in the lower units suggest low depth in a tidal range (Frey, 1975). *Entobia* and *Gastrochaenolites* ichnofacies can be delineated by plotting their relative occurrences; *Entobia* is only found in the lower part of the knolls (Fig. 2). Finally, the transgression that led to the establishment of the coral reef system can be studied by plotting the distribution of *Gastrochaenolites* and *Entobia*. *Gastrochaenolites* in the coral heads of lower and upper stratigraphic units represents two levels of shallow water conditions (Frey, 1975). Therefore, the abundant *Gastrochaenolites* horizons trace two ancient shorelines. This suggests that *Gastrochaenolites* moved up stratigraphically with the rise in sea level, while the lower areas were later dominated by *Entobia* (Fig. 2). Similar patterns of the establishment of shoreline ichnofacies after transgressions are found in other areas. In southern Poland, the diversity of the near-shore ichnofauna shows a rapid transgression (Radwanski, 1964). In the Brisbane Ranges of Australia, transgression was followed closely by the establishment of a rocky shoreline biota (Bolger and Russell, 1983). In California, the development of borings in the Imperial Formation is closely associated with an

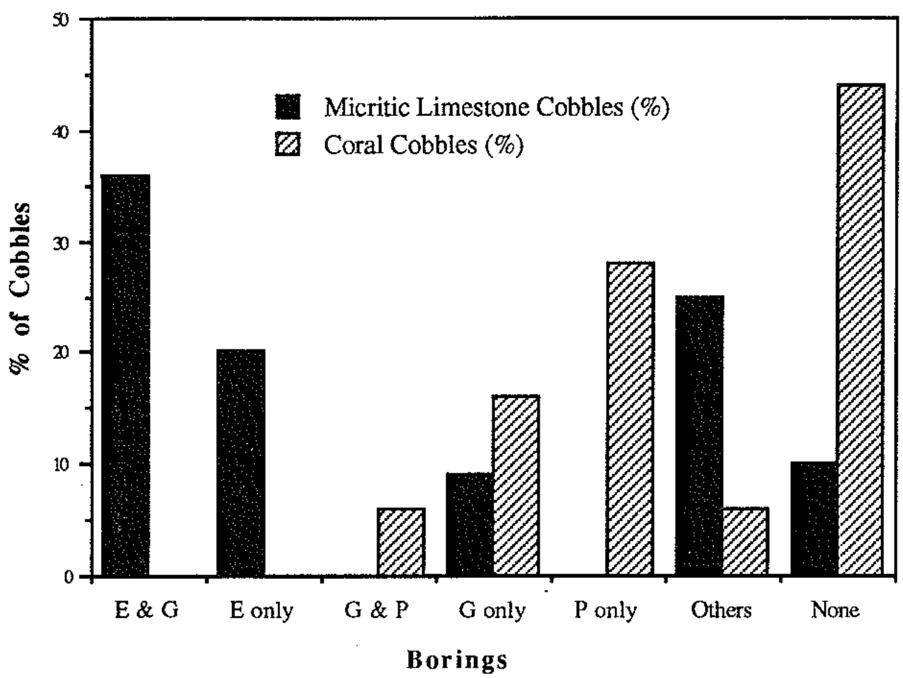

Figure 1: **Distribution of borings between cobbles composed of coral and micritic limestone. (E=*Entobia*, G=*Gastrochaenolites*, P=*"Potamilla"*)**

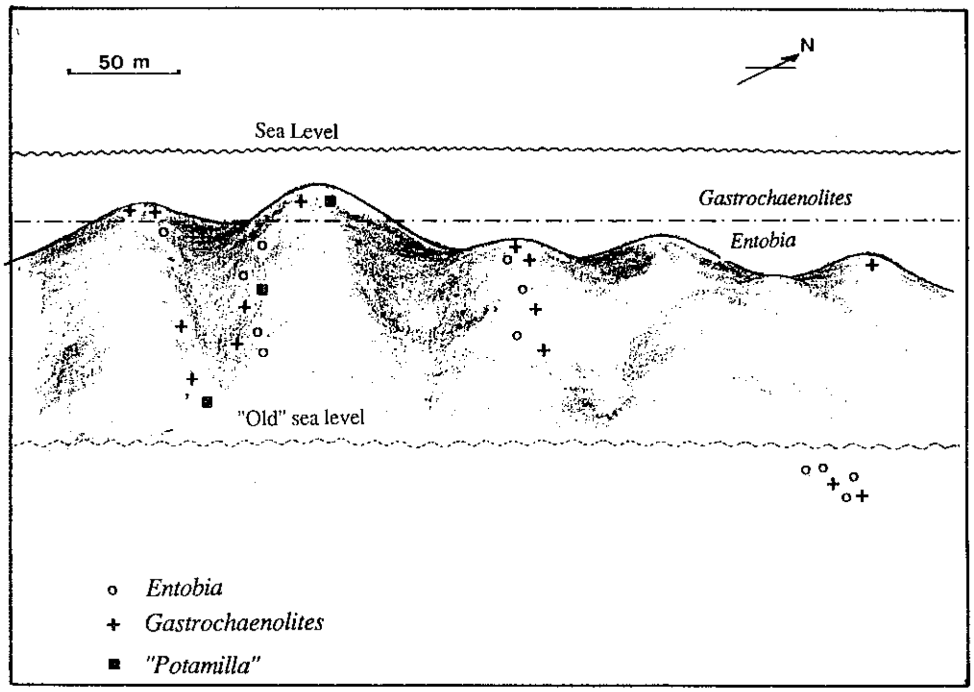

Figure 2: **Paleoenvironmental interpretation of the La Loma area, Fortuna Basin based on trace fossil distribution. The diversity of the boring fauna indicates a shallow marine environment. The distribution of *Gastrochaenolites* and *Entobia* is used to plot the transgression event.**

Early Pliocene transgression (Watkins, 1990).

Conclusions

1. Three ichnogenera and seven ichnospecies are described from limestone cobbles, coral cobbles, and corals of the La Loma area.
2. *Entobia* is the ichnogeneric name assigned to multi-chambered sponge borings. These borings were produced by chemical dissolution, for the most part. In this study, *Entobia* is only found in limestone cobbles.
3. *Gastrochaenolites* borings were constructed by some species of the bivalves *Lithophaga* and *Gastrochaena*. *Lithophaga* bores by some sort of chemical means; the manner in which *Gastrochaena* bores has been assigned to either a chemical method, a mechanical method, or a combination of both. In this study, *Gastrochaenolites* is common in limestone cobbles, coral cobbles, and corals.
4. "*Potamilla*" is a polychaete worm generic name commonly applied to worm borings. The manner in which "*Potamilla*" borings are formed is not well understood. "*Potamilla*" borings are only found in corals and coral cobbles in this study.
5. A shallow marine environment with some tidal influence is proposed for the La Loma area with respect to the boring assemblages dominated by either *Entobia* or *Gastrochaenolites*.
6. The transgression associated with the coral reef system can be plotted by studying the distribution of *Gastrochaenolites* and *Entobia*.

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