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NORIAN SPONGE AND CORAL BIOSTROMES IN THE ANTIMONIO FORMATION, NORTHWESTERN SONORA, MEXICO

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ABSTRACT

A diverse marine invertebrate fauna has previously been documented from the Norian carbonate interval of the Antimonio terrane. However, little research has been aimed at understanding its paleoecology, fine scale stratigraphy, and depositional environments. Preliminary field work by the authors represents the first attempt to characterize the lithofacies and paleoecological associations in this sedimentary interval. The authors of the present paper have documented four sedimentary rock types: (1) argillites and mudstones, (2) lime-cemented sandstones, (3) sandy limestones, and (4) massive limestone. Each of these lithofacies contains distinct associated biofacies. The coincidence of lithofacies and biofacies indicates that these biostromes were dominated by physical processes which, to a large extent, controlled their biological development. In addition to the similarity of faunal components of these biostromes of Sonora with the Luning Formation in west-central Nevada, the paleoecological patterns and biotic structure are also remarkably coincident. This observation suggests that the relationship of the Antimonio Formation to units farther north in the United States requires more investigation.

Key words: Triassic, Norian, Antimonio Formation, biostromes, sponges, coral, Sonora, Mexico.

RESUMEN

El terreno Antimonio de Sonora contiene un intervalo de carbonatos nóricos, del cual se ha consignado una fauna diversa de invertebrados marinos. Sin embargo, muy poco se ha investigado respecto a su paleoecología, estratigrafía de detalle y ambientes de depósito. Este artículo presenta resultados preliminares de una investigación en curso por los autores, la cual tiene el objetivo de caracterizar las litofacies y la asociación paleoecológica de ese intervalo sedimentario. Se reconoce cuatro litofacies dentro del intervalo nórico: (1) argilitas y lodolitas, (2) areniscas calcáreas, (3) calizas arenosas, y (4) calizas masivas. Cada una de éstas contiene biofacies asociadas que le son distintivas. La asociación de ambas facies indica que la formación de los biostromas que están presentes en dicho intervalo estuvo dominada por procesos físicos que en gran medida controlaron su desarrollo biológico. Los biostromas que están en la Formación Antimonio muestran una gran similitud faunística con otros que están presentes en la Formación Luning del centro-oriente de Nevada y, del mismo modo, presentan un gran parecido en sus patrones paleoecológicos y estructura biótica. Estas observaciones sugieren que se debe continuar investigando la relación de la Formación Antimonio con unidades que están presentes más hacia el norte, dentro de los Estados Unidos de América.

Palabras clave: Triásico, Nórico, Formación Antimonio, biostromas, coral, Sonora, México.

INTRODUCTION

A rich assemblage of shallow-water, Late Triassic marine invertebrates has been reported in carbonate intervals in the upper portion of the Antimonio Formation, northwestern Sonora (Stanley *et al.*, 1994). This includes corals, sponges and mollusks which occur in lenticular, bedded biostromes. While the taxonomic composition of the biostromes is known, little work has been focused on the stratigraphy, paleoecology, and depositional processes responsible for the resulting stratigraphic sequence. The Sonora biostromes also bear a great resemblance to roughly coeval deposits found in the Pilot Mountains of west-central Nevada (Stanley, 1979; Senowbari-Daryan and Stanley, 1992). Like the Nevada site, examples from Sonora consist of a rich variety of marine invertebrate groups. The composition and biotic structure of the fossil organisms occurring in the biostromes appear important in understanding paleogeographic, paleoecologic, and tectonic problems.

The best fossils are known from the Sierra del Álamo site (Figure 1), where the stratotype of the Antimonio Formation is located (Stanley *et al.*, 1994). The biostromal associations at Sierra del Álamo have been assigned to the mid- to upper Norian stage based on characteristic ammonoid taxa and the planktonic hydrozoan *Heterastridium* (González-León *et al.*, 1996). *Pinacoceras* cf. *Pinacoceras metternichi*, *Catenohalorites* and *Sagenites* cf. *Sagenites schaubachi*, and *Heterastridium conglobatum* indicate assignment to the middle to upper Norian, Columbianus or Cordilleranus Zones (Stanley *et al.*, 1994). Late Triassic fossils at Sierra del Álamo range from the middle to the upper part of the Norian and the uppermost Triassic, Rhaetian stage (González-León *et al.*, 1996).

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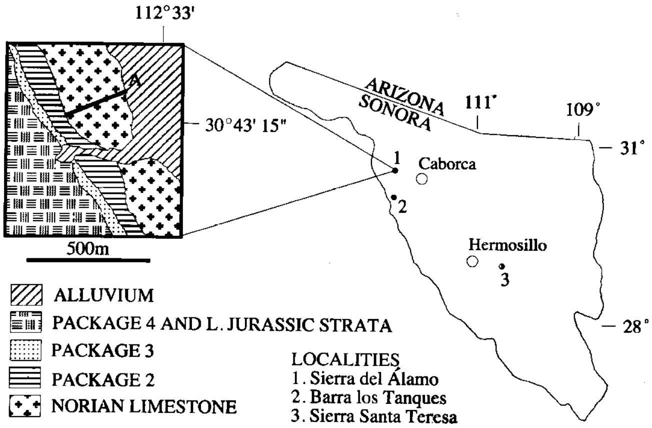


Figure 1. Locality map of occurrences of Upper Triassic coral biostromes in the Antimonio Formation. Inset geologic map shows line of section A, see Figure 2. The term "package" is used in the sense of González-León and collaborators (1996).

Fossils include thalamid sponges, disjectoporoid sponges, scleractinian corals, articulate brachiopods, bivalves, gastropods, nautiloids and ammonoids, mollusks, and crustacean microcoprolites. Additional corals occur higher in the section (Stanley and González-León, 1997) and contain some of the species found in the biostromes described below. Among the invertebrate taxa recognized from the Antimonio Formation, corals and mollusks are the most diverse and abundant. Some elements of this Late Triassic biostromal fauna have been discovered at other sites in northwestern Sonora (Figure 1), such as one located near Sierra Santa Teresa (*cf.* Stewart *et al.*, 1997). However, rocks and fossils at the Sierra Santa Teresa locality are not well preserved. Similar fossil assemblages resembling biostromes have also been found at a third site in northwestern Sonora at Barra los Tanques, suggesting possible correlations with the Antimonio Formation.

GEOLOGIC SETTING

The Triassic–Jurassic Antimonio Formation stratotype crops out in the northern foothills of the Sierra del Álamo, Sonora, Mexico (González-León, 1980, 1989, 1997). Its 3.4-km-thick section contains sandstone, mudstone, carbonate and conglomerate. The Antimonio Formation has been divided into two informal members: a lower member deposited in Early to Late Triassic time and an upper member deposited in latest Triassic to Early Jurassic time (González-León, 1997). The lower and middle portion of the lower member is composed of shallow- to deep-water marine limestone and mudstone, siltstone and fine-grained sandstone. Abundant ammonoids have been found in these beds (Stanley and González-León, 1995). The upper portion of the lower member contains an interval of distinctively deep-water mudstone and limestone. A fauna of ammonoids, coleoids, brachiopods, bivalves (Stanley *et al.*, 1994) and ichthyosaur bones (Callaway and Massare, 1989)

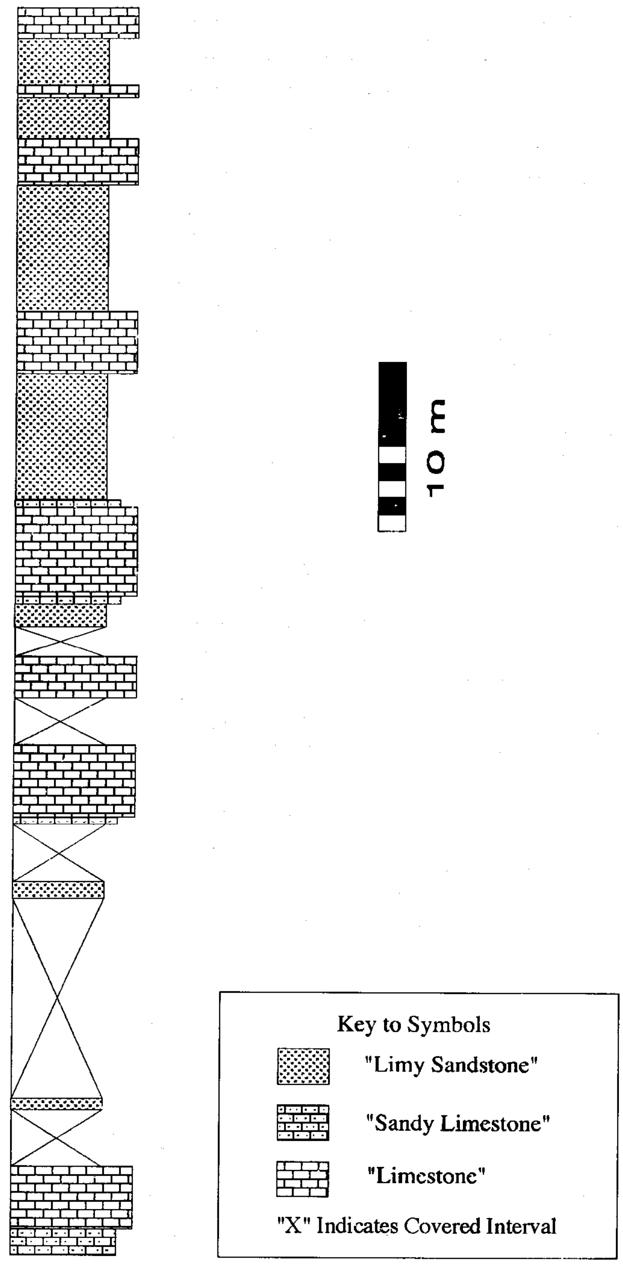


Figure 2. Stratigraphic section measured trough the Norian carbonate interval at Sierra del Álamo, see Figure 1.

has been found in this interval. Ammonoids (identified by N.J. Silberling) from these beds have been placed in the Upper Triassic Carnian stage Dilleri Zone (Stanley and González-León, 1995). The uppermost portion of the lower member contains distinctive shallow-water carbonate sponge and coral biostromes. The upper member, more than 2,000-m thick, contains Upper Triassic and Lower Jurassic rocks. Approximately 40 m of uppermost Triassic (Rhaetian) strata are recognized from the lowermost part of the upper member based on the occurrence of Rhaetian ammonoids. Early Jurassic (latest Hettangian or early Sinemurian) ammonoids have been located in the lower portion of the upper member above the Rhaetian ammonoids. The lower portion of the upper member is dominated by siltstone, mudstone and limestone. This member grades upward into sandstone, siltstone and conglomerate. The upper half of the upper member is composed almost entirely of sandstone and conglomerate. The contact between the upper and lower members is complicated by thrust faults and unconformities (González-León *et al.*, 1996; González-León, 1997).

The Triassic-Jurassic sedimentary strata of the upper lower member and the lower upper member have been subdivided into five informal lithostratigraphic sedimentary divisions referred to as packages (Figure 1) (González-León *et al.*, 1996). These packages range in age from the middle Norian Columbianus Zone to the upper Hettangian or lower Sinemurian Canadensis Zone (González-León *et al.*, 1996). The contact between the upper and lower member is placed at the boundary of packages one and two (González-León *et al.*, 1996). A Triassic-Jurassic boundary is present in the Antimonio section. Although originally believed to contain a fairly continuous transitional sedimentary record from the uppermost Triassic into Lower Jurassic rocks (González-León *et al.*, 1996), the Sierra del Álamo section instead has been found to contain a major disconformity amounting to most, if not all, of the lowest Jurassic Hettangian stage (González-León, 1997). The Triassic-Jurassic boundary is now placed in the base of the upper member, at the top of package four (González-León, 1997).

DESCRIPTION OF THE NORIAN CORAL AND SPONGE BIOSTROMES

Four sedimentary rock types are recognized within the Late Triassic biostromes of package 1. These exposures are dominated by carbonates but are interbedded with argillites, mudstones, and lime-cemented sandstones. This unit extends approximately 6 km in an east-west direction in the northern foothills of the Sierra del Álamo. However, in many locations the section is covered, faulted, recrystallized, and intruded by small dikes and sills. The effects of recrystallization are most pronounced in the west, where Cretaceous intrusives cut the Norian carbonates. The best preserved biostromes are found at the east end of the exposure (Figure 3). Here, a diverse fauna of Late Triassic age is found. Stanley and collaborators (1994) reported sponges, corals, spongimorphs, disjectoporoids, bivalves, brachiopods, gastropods, and anomurian microcoprolites from this interval. Additional corals are reported in this volume *(cf.* Stanley and González-León, 1997). The sedimentary rock types of package 1 and their associated faunas were deposited in direct response to changing sea levels and the influx of clastic sediments during Late Triassic time. Based on the coincidence of litho- and biofacies, the authors believe that the first order faunal changes are a direct response to changes in the depositional environment. These changes in the depositional environment are most often expressed as increases or decreases in siliciclastic input. Thus, biofacies and their associated faunas are roughly coincident with the lithofacies discussed below.

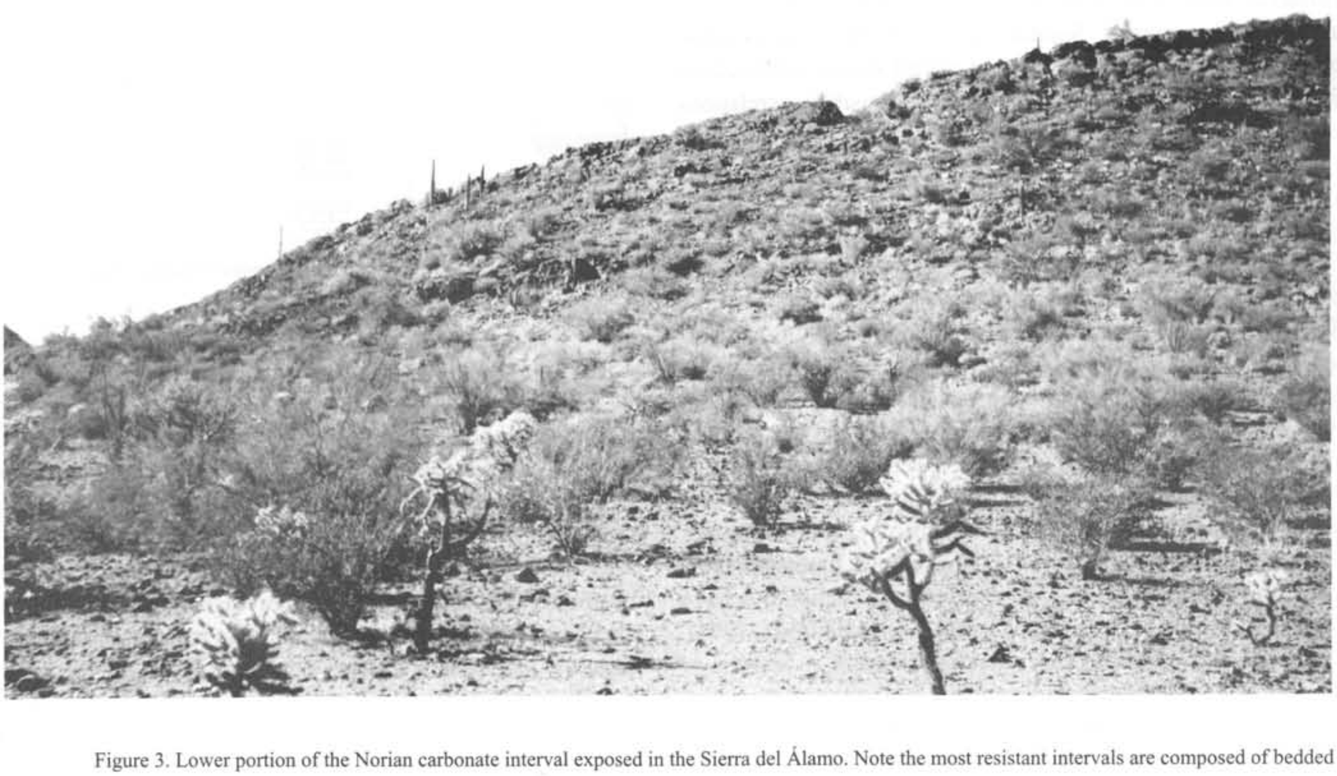


Figure 3. Lower portion of the Norian carbonate interval exposed in the Sierra del Álamo. Note the most resistant intervals are composed of bedded

LITHOFACIES AND BIOFACIES

The rock types (lithofacies) include: (1) argillite and mudstone which are exposed below the lime-cemented sandstone and often covered by float material; (2) lime-cemented sandstone; (3) sandy limestone; and (4) thick-bedded limestone which combined with the sandy limestone forms the thickest and most conspicuous units in the biostromes. This paper concentrates primarily on the carbonate rocks and the fossils contained therein. The following descriptions refer to recurring lithofacies which crop out in the Norian carbonate interval.

ARGILLITE AND MUDSTONE LITHOFACIES

This lithology is rarely exposed. Most often it is expressed as a covered interval which contains float material from all lithofacies. However, in a few places it is exposed. Exposures are commonly unfossiliferous and display one cleavage at a low angle to the bedding plane. The paucity of suitable material to sample may be due to the cleaved nature of this rock and its tendency to crumble. The authors of the present paper assume that this lithology grades conformably into the lime-cemented sandstone, although no contact has been seen.

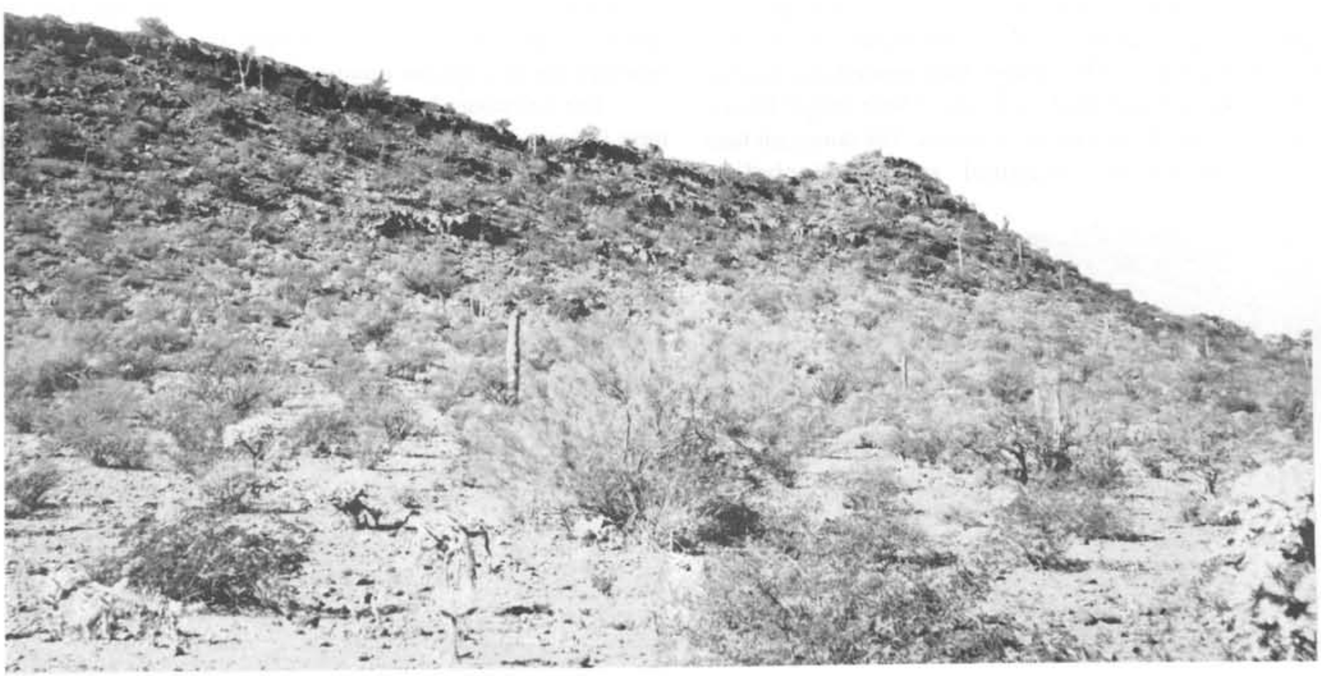
LIME-CEMENTED SANDSTONE LITHOFACIES

This unit thickens and thins laterally and ranges in thickness from 0.4 to 1.0 m. The average grain size increases vertically from fine- to medium-grained sand at the base to coarse-grained sand at the top. Examination of this lithology in thin sections reveals poorly sorted, angular quartz sand in a calcite matrix. No sedimentary structures were observed in this lithology. Any such structures may have been erased by the burrowing activity of bivalves found in this unit (Figure 4). Bivalve shells are most often found disarticulated and concave downward. However, both articulated and concave upward specimens have been observed.

The first faunal association at Sierra del Álamo is found in this interval and is composed of bivalves and gastropods. The authors have termed this the Mollusk biofacies. Mollusks are most common in the mudstone/siltstone intervals and they consist of diverse gastropods and the bivalves *Myophorigonia* and *Palaeocardita*. This biofacies is found predominantly in the lime-cemented sandstone. The bivalves are interpreted to have lived as infaunal components within the sandstone prior to lithification. Bivalve shells are most often found disarticulated which indicates that there has been *post mortem* transportation. Based on rock and faunal associations, a shallow distal siliciclastic shore environment is indicated.

SANDY LIMESTONE LITHOFACIES

The sandy limestone lithology lies above the lime-cemented sandstone and below the thick-bedded limestone. Laterally, this unit shows little variation in thickness, averaging 1 m. It consists of limestone with abundant sand-sized



limestone and calcareous sandstone. Biofacies described in text are found within the resistant intervals. Exposed section is approximately 30-m thick.

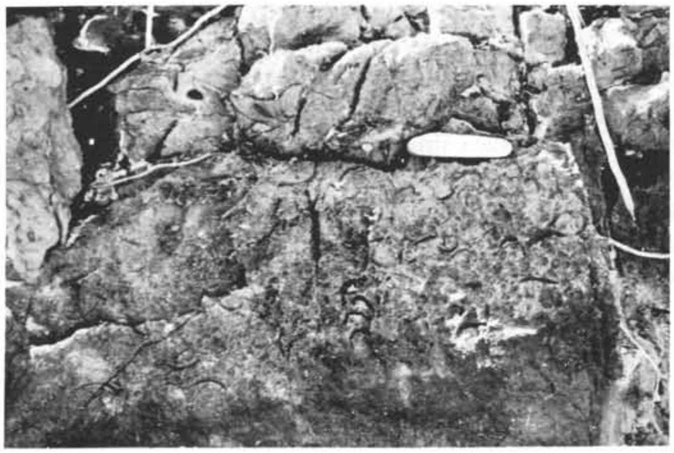


Figure 4. Lime-cemented sandstone lithofacies and the Mollusk biofacies. Bivalves dominate this faunal association within this tabular to lenticular unit. Note also that generally bivalves are found both concave upward and downward.

quartz grains. Profuse subparallel dissolution residues, stylolites, and geopetal structures are characteristic. Thalamid sponges are the most abundant constituents preserved in these beds (Figure 5). Many of the identified sponges have been found in the Luning Formation of western Nevada (Stanley, 1979; Senowbari-Daryan and Stanley, 1992). Recent field investigations have led to the discovery of new probable sponge taxa and are currently under investigation. Corals, gastropods, bivalve fragments, and ?*Lopha cordillerana* (McRoberts, 1997) are present but less volumetrically important in this unit.

The second fossil assemblage is recognized in the sandy limestone lithofacies. It is composed of inozoan and sphinctozoan sponges, gastropods, bivalves, the oyster ?*Lopha* and minor coral fragments. The authors have named this assemblage the Sponge-Gastropod biofacies. These larger fossils occur in a wackestone or packstone matrix. The dominant taxa in this biofacies are thalamid sponges including *Nevadathalamia*, *Fanthalamia*, and *Cinnabaria* (Figure 5). This assemblage represents a fauna less tolerant of coarse-grained siliciclastic input than that of the Mollusk biofacies. This suggests a major change in depositional environment. This lithofacies and its associated fauna marks the onset of a small scale transgression and the retreat of the shore facies and associated clastic material.

THICK-BEDDED LIMESTONE LITHOFACIES

This thick-bedded pure to impure limestone lithofacies lies depositionally above the sandy limestone. This unit is by far the most fossiliferous found in the Norian carbonates. The biota consists of upright-growing, encrusting, binding and high-growing, constructional corals and large upright and encrusting chambered thalamid sponges as well as the massive, encrusting red alga *Solenopora*. Also present are spongiomorphs and stromatoporoid sponges.

Corals are the most volumetrically important component of these beds. The branching colonies of the coral *Retiophyllia* form distinctive patches. Single coral colonies can measure 2 m across and over half a meter in thickness (Figure 6). Lateral facies often contain overturned partial colonies of *Retiophyllia*. The encrusting coral *Astraeomorpha* is also abundant in this lithofacies and is found above the *Retiophyllia* patches. *Astraeomorpha* displays distinctive growth interruption morphology (Figure 7) similar to that defined by Miller and West (1997). Bivalves, gastropods, brachiopods, and coral debris are found overgrown by *Astraeomorpha*. Also present are unusual, giant alatoform bivalves with wing-like extensions. These are endemic forms related to Triassic megalodontids (Stanley *et al.*, 1994; Yancey and Stanley, in press). In addition to Sphinctozoan sponges, inozoan sponges are also found in this lithology but they are not volumetrically important.

The limestone shows dissolutional cavities and other features indicative of vadose diagenesis. Microcoprolites occur in some cavities. The upper part of the Norian biostrome interval

Figure 5. Sponge-Gastropod biofacies found in the sandy limestone lithofacies.

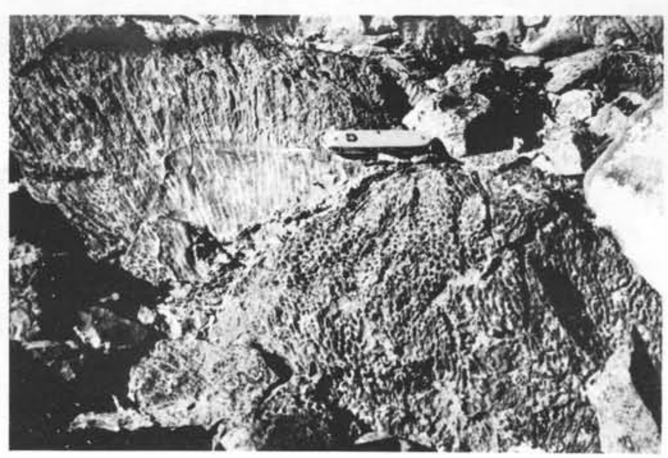


Figure 6. Colony of the coral *Retiophyllia* found in the thick-bedded limestone lithofacies.

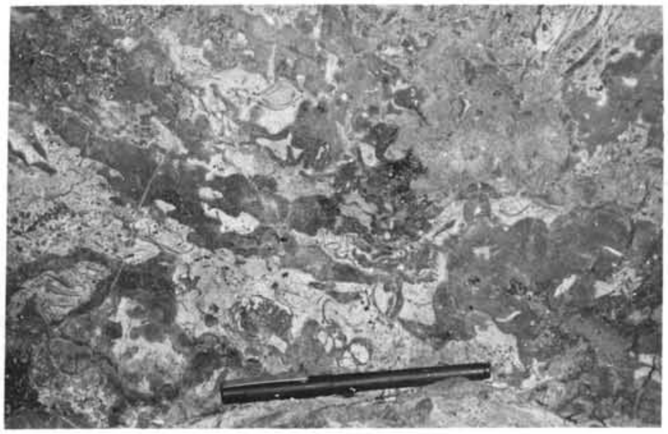


Figure 7. *Astraeomorpha* colony found depositionally above *Retiophyllia* in Figure 6. Note the distinctive growth pattern of the coral. The debris is composed of bivalves, coral fragments, brachiopods and sponges.

is often found with distinctive red mottling. This infilling may be attributed to post-depositional vadose diagenesis and/or karstification with resultant redeposition of insoluble residues derived from carbonate dissolution.

These associations are interpreted as shallow-water biostromes within a shallow offshore lagoonal environment. This lithofacies represents the purest carbonate end member in the Norian biostromal interval, indicating that siliciclastic input was minimal. Lithologic and faunal relationships indicate that the massive limestone lithofacies marks the point of maximum transgression within the Norian biostromal interval.

PALEOGEOGRAPHY

Stanley and González-León (1995) reviewed the paleogeographic significance of the diverse invertebrate fossils from the Antimonio Formation and a list is presented in the introduction to this volume. The fauna of our study reveals mixed paleogeographic relationships but seems dominated by taxa with Tethyan affinities, especially the corals, disjectoporoids and gastropods. Interestingly, several taxa are known exclusively from the western Tethys (central Europe). The rest of the taxa occurs in South American and/or Cordilleran terranes of North America, including Nevada, Stikinia and Eastern Klamath terranes. The giant alatoform bivalves probably represent a new species in the Antimonio biostromes and a related species has been found in the Yukon (Stikine terrane) and the Wallowa terrane of Oregon (Yancey and Stanley, in press). The bivalve *Myophorigonia salasi* (Alencáster, 1961), is no longer recognized from the Antimonio (McRoberts, 1997).

Chambered sponges appear useful for paleogeography. Many species appear endemic to inbound terranes of North America. Taxa such as *Nevadathalamia cylindrica* and *Fanthalamia polystoma*, previously were known only from Nevada (Senowbari-Daryan and Stanley, 1992). Corals first described from the Antimonio such as *Astraeomorpha sonorensis* and possibly *Cuifastraea granulata* also have been recognized in Nevada but do not appear in other displaced terranes. For a discussion of displaced terranes and their paleobiogeographic significance, see Stanley (1996).

These findings, coupled with geologic correspondence from other parts of the Antimonio sequence, led Stanley and González-León (1995) to postulate that the Antimonio terrane could have been displaced tectonically southward by left-lateral faulting from original depositional settings in the southwestern United States. While the Antimonio terrane is viewed as an allochthonous block resting above the Caborca terrane, during Triassic times it could have been associated with a continental island arc system situated at subtropical paleolatitudes near the North American craton. Subsequent post-Triassic faulting, perhaps along the Mojave-Sonora megashear (Anderson and Silver, 1979), is postulated to have transported these rocks southward to their present location in northwestern Sonora. It is hoped that further field work and discussion will facilitate a better understanding of the relationship of the Antimonio terrane to units farther north.

CONCLUSIONS

The Norian carbonate strata of the Antimonio Formation represent a dynamic sedimentary environment. Shifting sedimentary facies are expressed as a change in sediment types and associated faunas. The rapid change from carbonate deposition to a shale and quartz dominated environment suggests that these biostromes were deposited close to a siliciclastic source. The remarkable coincidence of sedimentary facies with specific associated fauna demonstrates strong physical control over the fauna in contrast to biological accommodation.

Similar paleoecological patterns also are found in the Luning Formation in west-central Nevada. The coincidence of fauna, paleoecological patterns, and the general sequence stratigraphy suggests a link between the Antimonio and the Luning Formations. As discussed above, the Antimonio terrane that contains this Norian carbonate is postulated to have moved south along a northwest-southeast trending left-lateral strike-slip fault, the Mojave-Sonora Megashear. This hypothesis, however, is still inconclusive and needs further corroboration from paleontological, sedimentological, paleomagnetic and structural investigations.

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