Mississippian coral assemblages from Tabainout mud-mound complex, Khenifra area, Central Morocco

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ABSTRACT. Analysis of Mississippian coral assemblages from the Khenifra region of Central Morocco has demonstrated the presence of a rich and diverse coral fauna. Rugose coral assemblages from the Tabainout mud-mound complex comprise abundant colonial and solitary taxa, particularly in the basal bedded limestones, as well as the upper bedded flank and coquina capping beds. The massive core facies with stromatopoid cavities in contrast has rare solitary corals. The overlying shales, marls and limestone bands which buried the mud-mound are dominated by small non-disseminated solitary rugosans. The age of the Tabainout mound based on foraminifers is established as upper Viséan (late Asbian-late Brigantian). The coral assemblage strengthens correlations with the Adarouch area in the northern part of the Azrou-Khenifra Basin where similar mud mounds occur. These assemblages also show similarity with coeval coral faunas from the Jerada Basin (NE Morocco) and together represent part of the same palaeobiogeographic province (Western European Coral Province).

KEYWORDS. Morocco, Azrou-Khenifra Basin, Mississippian, upper Viséan, mud-mounds, rugose coral assemblages, palaeoecology, palaeobiogeography.

1. Introduction

In North Africa, especially Morocco and Algeria, coral-bearing mud-mounds and biherms are not all that well known from the Carboniferous. The exceptions are the upper Viséan mud-mounds of the Erfoud region, eastern Morocco (Wendt et al., 2001) and biherms from the Béchar Basin, W. Algeria (Pareyn, 1959, 1961; Semenoff-Tian-Chansky, 1974, 1985; Bourque et al., 1995). Recently, mud-mounds (buildups) containing rugose corals have been described from the Jerada Basin (NE Morocco) (Aretz & Herbig, 2008; Aretz, 2010), as well as corals from mud-mounds and platform limestones in the Adarouch area of north central Morocco in the northern part of the Azrou-Khenifra Basin (Saïd, 2005; Saïd & Rodríguez, 2007; Saïd et al., 2007, 2010, 2011; Cözar et al., 2008) (Fig. 1A). A brief summary of corals recorded from platform limestones and mud-mounds from the Azrou-Khenifra Basin (Central Morocco) have been recently noted (Aretz & Herbig, 2010).

Previous coral collecting from Carboniferous rocks in Morocco has been very limited, with occasional samples collected as part of reconnaissance mapping by the Moroccan Geological Survey (Termier, 1936; Owodeno, 1946; Termier & Termier, 1950). The dating of the Mississippian limestone successions in the Khenifra area of Central Morocco was established subsequently as upper Viséan, based on microfaunal and microfloral studies (Chanton-Güvenç et al., 1971; Chanton-Güvenç & Morin, 1973; Verset, 1988; Huvelin & Mamet, 1997). In 1995, a suite of coral specimens were collected from the Khenifra region (Aretz & Herbig, 2010), but these authors acknowledged that the results of this reconnaissance sampling probably under-represented the coral diversity present in the region.

In this study, we present a detailed description of coral faunas obtained from upper Viséan (Mississippian) limestones in the Khenifra area of central Morocco (Fig. 1B), which lies 70 km SSW of the Adarouch area. The aim of the paper is to document the coral diversity present in the region.

2. Geological setting of coral sections at Tabainout

The Palaeozoic Meseta of north central Morocco is divisible into three regions: in the west, near Rabat, the mostly Carboniferous siliciclastic rocks of the Sidi Bettache Basin; a central belt of mainly pre-Carboniferous rocks; and in the east, the Azrou-Khenifra Basin, extending from Azrou in the north to Jebel Hadid in the south (see Aretz & Herbig, 2010, fig. 1). This latter basin comprises Carboniferous siliciclastic and carbonate rocks resting unconformably on, and in thrust contact with, Ordovician and Devonian rocks, all affected by the later Variscan Orogeny (Allary et al., 1976; Hollard, 1978; Piqué, 1983; Hoepfner, 1987; Beauchamp & Izart, 1987; Bouabdell & Piqué, 1996; Hoepfner et al., 2005).

The Tabainout complex, 20 km west of Khenifra (Figs. 1B-1D), represents an isolated exposure of Mississippian limestones bordered to the west and north by Ordovician siliciclastics and to the south and west by Mississippian shales. The Tourmaisian and lower-middle Viséan rocks (where present) are composed mainly of sandstones and conglomerates, with the oldest limestones dated as late Viséan age, associated with a widespread transgression throughout the region (Chanton-Güvenç et al., 1971; Chanton-Güvenç & Morin, 1973; Verset, 1988; Huvelin & Mamet, 1997). The Khenifra area formed part of a larger basin, the Azrou-Khenifra Basin, which is elongated NE-SW for c. 100 km and is c. 40 km wide (Aretz & Herbig, 2010). This basin has been affected by Variscan tectonics, in particular thrusting, on the eastern side. The Adarouch area lies some 40 km NW of Azrou at the northern end of the basin, where it is surrounded by younger Mesozoic and Cenozoic rocks (Berkhli, 1999; Berkhli & Vachard, 2001, 2002; Berkhli et al., 2001; Cozar et al., 2008).

3. Tabainout complex: lithofacies and microfacies

The Tabainout complex (N32°56′59″-W5°50′35″) forms a prominent NNE-SSW trending ridge, approximately parallel to the Khenifra - Sidi-Lamine road, composed mainly of massive mud-mound facies (Fig. 1C-1D), and extends c. 5 km to the northeast. The base of the Carboniferous sequence is exposed north of a track cutting E-W through the mud-mound complex, and comprises 2 m of well-bedded, slightly nodular, fine-grained bioclastic wackestone and packstone with thin interbedded shales occurring below the massive mud-mound facies. These beds rest unconformably on Ordovician shales and sandstones (Figs 1D, 2). The bedded limestones are relatively rich in corals, both solitary and colonial. At the SW end of the ridge, below the mound, are massive and brecciated micritic limestones with occasional solitary corals. The base of the succession here comprises 2 m
of conglomerate, which thickens to >8 m southwestwards (Figs. 1D, 2), infilling the palaeotopography and is overlain by 1 metre of sandstone. These siliciclastic rocks are not developed below the large mound. The lowest limestone bed here contains angular sandstone clasts. The basal beds of the mud-mound are massive and bioclastic, with micritic facies containing stromatactoid cavities first appearing c. 8 m above the base. The measured thickness of the mound is c. 100 m, however, there are individual smaller mounds separated by thin intervals of bioclastic brecciated micrites and shales with solitary corals (intermound beds). The upper 20-25 m of the mound complex is bedded (cap beds) and locally rich in coquinas (shell bands encrusted with radiarial fibrous calcite cements) (Fig. 2). These contain rich horizons of brachiopods (including gigantoproductids, and productids), bivalves, goniatites, orthocone nautiloids, crinoids and, locally, concentrations of mostly solitary corals on the flanks north of the track (Figs 1C, 2). These coquinas are interbedded with massive mudstones devoid of fauna and dip 40° to SE towards the village of Tabainout, succeeded by supramound shales and marls. Further north of the village the highest beds in the mound have recently been quarried (Fig. 1C). They expose the thick-bedded, shelly coquinas, as well as coarse-grained massive crinoidal grainstones which are laterally equivalent to the coquinas.

The bedded limestones at the base of the section are mostly medium-grained wackestone/packstone with extensive micritisation of bioclasts. Calcareous algae and Algospongia are locally very common with kamaenids, Koninckopora, Borladella, Praedonezella cespeformis, Fasciella, Ungdarella uralica, Sparaphrylisys tanaca and Draffania. Foraminifers are relatively abundant with Tetrataxis, Endotaxis, Vissariotaxis, Howchinia and archaediscids at angulatus stage. The heterocoral Hexaphyllia is also recorded. The bulk of the Tabainout complex is composed of massive limestones, which in thin section are predominantly lime mudstone and sparse wackestone, with peloidal microbial fabrics and stromatactic cavity networks with geopetal sediment (Fig. 2). Fenestellid bryozoans and encrusting bryozoans can be conspicuous elements, but foraminifers are virtually absent, apart from very rare Tetrataxis and endothyrids. The top of the mound is more crinoid-rich with intraclasts, rare algae and foraminifers. The latter include Neoarchaediscus parvus, N. ovatus, Endostaffella, Archaediscus karreni grandis, A. at angulatus stage with tenuis sutures, Praeplectostaffella, Euxinita efremovi, E. pendleiensis, Pseudocornuspira, Asteroarchaeiscus pusulus, Biseriella parva, Endothyranopsis compressa/planus, and Planospiriscus taimyricus. Dasyclad algae include Windsoporella and Koninckopora.

In a stream section south of the main mound yellow and greenish shales, marls and thin interbedded bioclastic limestone...
bands and nodules contain a rich assemblage of zaphrentid-type corals, together with crinoids and goniatites. This sequence lies stratigraphically above, but also lateral to, the mud-mound, occupying a topographic low position (Figs. 1C, 2).

4. Age of the Tabainout mud-mound complex

Most of the foraminifers and algae at the base of the complex from the bedded limestones below the massive mud-mound facies are typical of late Asbian assemblages, and are comparable with the lower part of the Tizra Formation at Adarouch (Cózar et al., 2008). This is also supported by the presence of the rugose corals Dibunophyllum bipartitum, Clisophyllum keyserlingi, Siphonodendron sp., and Pseudokirsop. See Poty, 1981; Rodriguez & Somerville, 2007). The massive core facies is poor in corals and virtually devoid of foraminifers. The upper part of the mound in the bedded coquina grainstones and flank beds (capping beds), have a locally rich and diagnostic rugose coral assemblage, including Kizilia sp., Diphophyllum furcatum, D. lateseptatum and ‘Pseudozaphrentoides’ juddi, establishing a Brigantian age (Rodriguez & Somerville, 2007). Moreover, rare samples have a diagnostic foraminiferal assemblage including: Asteroarchaeodiscus pusculosus, Biseriella parva and Planospirodiscus taimyricus. This indicates a late Brigantian age for the uppermost capping beds in the mound. Thus, the age of the limestones in the Tabainout complex ranges from late Asbian to late Brigantian (Cf6γ-Cf6δ, Foraminiferal Zones and subzones of Conil et al., 1991). This differs from previous studies, which claimed an entirely Asbian age for the Tabainout mound (Huvelin & Mamet, 1997; Aretz & Herbig, 2010). A similar late Brigantian foraminiferal assemblage has been reported from the upper part of the Tizra Formation at Adarouch (Cózar et al., 2008, 2011).

Cephalopods collected from coquina float are dominated by Goniatites crenistria of latest Asbian-earliest Brigantian age (Pla Zone) (Dieter Korn, pers. com.). Goniatites were also recovered in situ from the marls and limestones in the stream section. They include Arnsbergites sp. and Hibernicoceras hibernicum, which establish an early-mid Brigantian age (P1b-P1c zones; Riley, 1993) for the lower part of the supramound cover mudstones (Dieter Korn, pers. com.).

The implication is therefore, that continued upward growth of the mound complex was maintained during the Brigantian, when relief of tens of metres was developed. This led to shallower-water carbonates forming on the crest and upper flanks of the mound, whereas on the lower flanks and adjacent to the mound only marls accumulated in deeper water.

5. Description of the coral faunas

A total of c. 270 coral specimens was collected from the Tabainout complex and all of the material is reposited in the Departamento de Paleontología, Facultad de Ciencias Geológicas, Universidad Complutense de Madrid (Spain).

Coral species are recorded at several distinct stratigraphic levels within the Tabainout complex. Below the massive mounds in thick-bedded bioclastic limestones (Table 1, col. 1) was recorded a relatively rich assemblage of solitary and colonial rugose corals: Amplexizaphrentis sp., ‘Amplexocarina’ sp., Arachnolasma cylindricum Yu, 1934 (Fig. 3E), Clisophyllum keyserlingi M’Coy, 1849, Dibunophyllum bipartitum (M’Coy,

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Table 1. Comparison of coral taxa recorded from the Tabainout complex (columns 1-5) with Adarouch in the northern part of the Azrou-Khenifra Basin and Jerada (NE Morocco). The coral data from Adarouch is from the Tizra Fm (Said et al., 2007; Said & Rodriguez, 2007; Cózar et al., 2008). The coral data from Jerada is from the youngest Viséan Koudiat Es-Senn Fm containing mud-mounds (Aretz, 2010). The corals recorded from the Tabainout complex are: col. 1 = lower bedded limestones and strata below the lower part of the massive core facies, col. 2 = mass core facies, col. 3 = upper strata in the mounds (bedded coquina horizons and flanking beds), col. 4 = supramound shales, col. 5 = combined data for columns 1-4. N.B.: The listing of genera follows the order in Hill (1981).
Mississippian coral assemblages from Tabainout Mud-Mound Complex

1849), Lithostrotion vorticale (Parkinson, 1808) (Fig. 3C), Palaeosmilia murchisoni Milne-Edwards & Haime, 1851 (Fig. 3D), Pseudozaphrentoides sp., Rotiphyllum sp., Siphonodendron irregulare (Phillips, 1836), S. martini (Milne-Edwards & Haime, 1848) (Fig. 3B), S. intermedium Poty, 1981, S. pauciradiale (M’Coy, 1844) (Fig. 3A), S. sociale (Phillips, 1836) (Fig. 3G), and Siphonophyllia samsonensis (Salée, 1913).

In the lower part of the massive limestones, particularly in the brecciated micritic facies that is interbedded with thickly-beded bioclastic limestones, occur solitary corals, notably Amplexus sp., Axophyllum sp., Rotiphyllum and Palaeosmilia, with the tabulate Michelinia (Fig. 3F), and rare fragments of colonies of Lithostrotion araneum (M’Coy, 1844), L. vorticale, Siphonodendron martini and S. sociale. In addition, was recovered the heterocoral (Hexaphyllia sp.) (Table 1, col. 1).

In the main massive mud-mound facies characterised by the presence of stromatactid cavities were recorded rare Amplexus sp. (Fig. 4F), Axophyllum aff. pseudokirsopianum Semenoff-Tian-Chansky, 1974 and Michelinia (Table 1, col. 2).

In the upper part of the mud-mound which shows layers of bivalve/brachiopod and goniatite-rich coquinas interbedded with microbial limestones with stromatactoid cavities, are locally, rich pockets of rugose corals including Diphyphyllum furcatum (Hill, 1940) (Fig. 4B), Lithostrotion araneum, Palaeosmilia

1849), Lithostrotion vorticale (Parkinson, 1808) (Fig. 3C), Palaeosmilia murchisoni Milne-Edwards & Haime, 1851 (Fig. 3D), Pseudozaphrentoides sp., Rotiphyllum sp., Siphonodendron irregulare (Phillips, 1836), S. martini (Milne-Edwards & Haime, 1848) (Fig. 3B), S. intermedium Poty, 1981, S. pauciradiale (M’Coy, 1844) (Fig. 3A), S. sociale (Phillips, 1836) (Fig. 3G), and Siphonophyllia samsonensis (Salée, 1913).

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murchisoni, Siphonodendron irregularare, S. martini, S. pauciradiale, S. sociale, and a rare gregarious form of Axophyllum with budding (Fig. 4A). In the mound flank on the northern side close to the E-W track, similar capping bed facies are locally rich in large solitary corals, especially ‘Pseudozaphrentoides’ juddi (Thomson, 1893) (Fig. 4J) and Palacosmilia murchisoni. In addition, were recorded ’Amplexocarinia’ sp. (a gregarious form showing microbialite encrustation) (Fig. 4G), Arachnolasma cylindricum, Diphyphyllum lateseptatum (M’Coy, 1849) (Fig. 4C), Kizilia sp. (Fig. 4D), Lithostrotion vorticale, Haplolasma sp., Rotiphyllum sp., Siphonodendron martini, S. pauciradiale, as well as the tabulates Michelinia spp. (two species; one with a large diameter corallite and the other with a smaller diameter corallite) and Syringopora sp. (Table 1, col. 3).

In the stream section above the mud-mound within the shales, marls and interbedded limestone bands were recorded mostly non-dissepimented solitary rugose corals including ’Amplexus’, Bradyphyllum (Fig. 4H), Claviphyllum? sp. (Fig. 4I), Cyathaxonia cornu Michelin, 1846 and Rotiphyllum sp. (Fig. 4E). Occasional tabulate corals recorded include Michelinia sp., and Syringopora sp. (Table 1, Col. 4).

6. Analysis of Tabainout coral faunas

6.1. Comparison with previous coral studies in the region

In Tabainout there is a marked difference in the coral records presented here and in Aretz & Herbig (2010). The latter authors did not record any rugose corals from the massive mound core (‘reefal limestone’) and only three taxa below the ‘reef’ (Axophyllum martini, Siphonodendron martini, S. pauciradiale, Axophyllum sp. and Amygdalophyllum sp. in the ‘bedded limestones’). Our recent sampling of the mud-mound complex has recorded 13 genera and 18 species of rugose corals from beds below the massive core facies of the mound, 2 rugosan genera and species from the massive core facies, and 11 genera and 16 species of solitary rugosans from the flank beds and coquinas (capping beds) in the upper part of the mud-mound complex (Table 1). In addition, the shales, marls and limestones above the mound have yielded 5 genera and 5 species of solitary rugosans, and 2 genera and species of tabulate corals. Thus in total, 19 rugose genera and species of tabulate corals. Thus in total, 19 rugose genera and species of solitary rugosans, and 2 genera and species of rugosans from the flank beds and coquinas (capping beds) in the upper part of the mud-mound complex (Table 1). In addition, the shales, marls and limestones above the mound have yielded 5 genera and 5 species of solitary rugosans, and 2 genera and species of tabulate corals. Thus in total, 19 rugose genera and species of solitary rugosans, and 2 genera and species of rugosans from the flank beds and coquinas (capping beds) in the upper part of the mud-mound complex (Table 1). In addition, the shales, marls and limestones above the mound have yielded 5 genera and 5 species of solitary rugosans, and 2 genera and species of rugosans from the flank beds and coquinas (capping beds) in the upper part of the mud-mound complex (Table 1). In addition, the shales, marls and limestones above the mound have yielded 5 genera and 5 species of solitary rugosans, and 2 genera and species of rugosans from the flank beds and coquinas (capping beds) in the upper part of the mud-mound complex (Table 1). In addition, the shales, marls and limestones above the mound have yielded 5 genera and 5 species of solitary rugosans, and 2 genera and species of rugosans from the flank beds and coquinas (capping beds) in the upper part of the mud-mound complex (Table 1). In addition, the shales, marls and limestones above the mound have yielded 5 genera and 5 species of solitary rugosans, and 2 genera and species of rugosans from the flank beds and coquinas (capping beds) in the upper part of the mud-mound complex (Table 1). In addition, the shales, marls and limestones above the mound have yielded 5 genera and 5 species of solitary rugosans, and 2 genera and species of rugosans from the flank beds and coquinas (capping beds) in the upper part of the mud-mound complex (Table 1).

6.2. Variations in coral diversity in the Tabainout complex and palaeoecological interpretations

The studied outcrops in the Tabainout complex show a high variation in coral diversity, as each section shows different palaeoecological settings and environmental conditions (water depth, substrate, turbidity, turbulence and light levels), providing different possibilities for adaptation and settling of colonial and solitary corals. The Tabainout complex exhibits large mud-mounds with clear differentiation of basal bedded limestones, massive microbial mound core facies, bedded coquina grainstones and flank beds in the upper part of the mound (capping beds) and supramound shaly facies (Fig. 2). The bedded limestones below the massive part of the mound contain a rich and diverse assemblage of both solitary and colonial rugosans. In particular, Siphonodendron and Lithostroton colonies are abundant, as well as large disseminated solitary taxa (Dibunophyllum, 'Pseudozaphrentoides', Siphonophyllia, Clisophyllum and Palaeosmilia). These bedded limestones which are dominated by solitary rugosans are typical of Rugose Coral Assemblage (RCA) 5 of Somerville & Rodríguez (2007). These packstones are also characterised by the presence of abundant dasycladacean algae, foraminifers, heterocorals and micritised grains, indicative of shallow water, moderately turbulent, eutrophic conditions.

In contrast, the massive core facies has very rare corals, comprising small axophyllids and Amplexus. The absence of calcareous algae and foraminifers in the fine microbial lime mud sediment and the lack of allochems obviously inhibited coral attachment, and only specialist corals could adapt to the presumed deeper and quieter water conditions associated with the transgression.

The upper part of the mud-mound shows a significant increase in coral diversity, and locally, corals are very abundant in the coquina horizons, along with productid brachiopods, bivalves and goniatites. Large solitary corals can be locally conspicuous in these beds (Palaeosmilia, 'Pseudozaphrentoides'). In the flank beds colonial corals are present (Diphyliphyllum, Lithostrotion and Siphonodendron). Interestingly, a gregarious form of Axophyllum with buddings is recorded from the upper part of the mound, which is distinguished from Lonsdaleia by its simpler axophyllid axial structure and disseminatment, and from Howthia by its larger size, more prominent axial structure and wider lonsdaleoid disseminatment. This taxon, together with gregarious 'Amplexocarinia', suggests that potential evolutionary opportunities were present in a shallower-water phase of later mound growth (cf. Rodriguez & Somerville, 2010; Somerville & Rodriguez, 2010). Interestingly, Mundy (1994) recorded abundant Amplexocarinia and Cyathaxonia in the upper part of the late Viséan Stebden Hill buildup in N. England. These solitary rugosans, that were encrusted in microbialite, were interpreted as forming a framework in a shallow-water niche.

The upper part of the mud-mound facets with its high diversity and abundance of rugose corals (11 genera and 16 species) is typical of RCA6. (Somerville & Rodríguez, 2007), and is characteristic of large upper Viséan (late Asbian-Brigantian) mud-mounds (c. 100 m thick) which grew up into shallower water, where colonial corals in particular could flourish (see Somerville et al., 1996; Somerville, 1997; Rodriguez & Somerville, 2007; Denayer and Aretz, 2011). A shallower-water setting for the upper part of the mound is also suggested by the presence of dasycladacean green algae.

The solitary corals of the supramound shales are typical of the RCA8 of Somerville & Rodríguez (2007), and characterised by small, undisseminated taxa (the Cyathaxonia fauna). They are representative of the basinal or flysch-type sediments that buried the mounds, particularly on their lower flanks and introduced much deeper water conditions into the Tabainout area, where colonial corals, apart from tabulates, are absent, and goniatites and crinoids are the only other distinctive faunal elements. A similar assemblage dominated by solitary corals was identified by Sando (1980) as having a very low indication of a shallow-water habitat.

7. Comparison with other Moroccan areas

7.1. Adarouch

Carboniferous rugose corals have been previously studied in detail in the Adarouch region (northern Azrou-Khenifra Basin), in particular, in the age-equivalent (late Asbian-Brigantian) Tzira Formation (Said & Rodríguez, 2007; Cord et al. 2008; Said et al., 2011), which contains a development of large mud-mounds, similar to those at Tabainout. The basal bedded limestone facies of the mounds and mound core facies show similar features in both localities and, consequently, the coral assemblages have many taxa in common, notably large solitary cyathopsids, aurophyllids, colonial lithostrotiids, and axophyllids in the mound core facies (11 species, Table 1). Also, the flank beds in both regions can be locally dominated by small solitary corals and Michelinia. The main differences are related with the faeces developed in the upper part of the mounds and above them. Spectacular coquinas containing large solitary and some colonial corals are developed as flank beds in Tabainout. On the other hand, biostromal beds dominated by fasciculate corals (e.g. Siphonodendron, Diphyliphyllum and Tziraiia) occur in some metres above the mounds in Tzira (Said et al., 2011). Two of these genera are known from Tabainout, but Tziraiia, an endemic genus to Morocco (Said & Rodríguez, 2007; Aretz, 2010), is absent. However, it is recorded at Tiouinne, southeast of Khenifra (Fig. 1B, Said et al., in press). Thus, in general, there are many close similarities of the rugose coral assemblages between Adarouch and Tabainout, not only at species level, but also in the distribution of corals within and adjacent to the mud-mound complexes (Table 1).

7.2. Jerada Basin

The Jerada Basin is located in northeastern Morocco, 375 km NE of Khenifra (Fig. 1A), and shows similar lithological features to the Tabainout complex, particularly in the development of large mounds in the youngest upper Viséan rocks (Koudiat Es-Senn Fm), of probable late Asbian-Brigantian age (Vachard & Berkli, 2002; Aretz, 2010). Consequently, the coral assemblages are comparable in general, but show some differences in detail (Table 1). Fasciculate corals are dominant in Jerada, and the same genera present in Tabainout are recorded (except Tziraiia). However, Siphonodendron junceum is present in Jerada but absent in Tabainout. On the other hand, larger species such as S. sociale are absent in Jerada. Aurophyllidae, Cyathopsidae and Axophyllidae are the most common solitary corals in Jerada (as well as in Tabainout), with at least 4 species in common (Dibunophyllum bipartitum, Palaeosmilia marchisoni, Siphonophyllia samsonensis and Axophyllum aff. pseudokosgiopaniun) (Table 1). In total, 8 rugose coral genera and species (~60% of the taxa) are common to Jerada and Tabainout, demonstrating that both areas belong to the same palaeobiogeographical province (see below). However, the presence of Pareaunia splendens Semonoff-Tian-Chansky, 1974 in Jerada, which is absent in Tabainout, demonstrates some affinity with the fauna of the central Saharan basins to the south.
in Algeria e.g., Béchar Basin (Fig. 1A; Semenoff-Tian-Chansky, 1974; Aretz, 2010, 2011a).

7.3. Tafilalt Basin

In the eastern Anti-Atlas Mountains Wendt et al. (2001) described Viséan mud-mounds from the Zrigat Formation in the southeastern part of the Tafilalt Basin near Erfoud, eastern Morocco, 350 km SE of Kenitra (Fig. 1A). In the upper part of the formation the mounds are of late Viséan age (late Asbian to Brigantian) based on limited conodont and goniatite data. A sparse coral fauna was recorded from the mound and interf mound facies with rare Lithostroton (= Siphonodendron) colonies present in the massive core facies and in the interf mound facies, as well as isolated specimens of undetermined solitary rugosans. The tabulate coral Michelinia was recorded in the interf mound facies. Interestingly, below the mounds in the shaly facies, Wendt et al. (2001) recorded Cyathaxonia, lophophyllids, canniids, hapsiphyllids, as well as Dibunophyllum. Unfortunately, because of the limited identification of coral taxa from these mounds, it is not easy to make a direct comparison with the coral fauna from the Tabainout complex. However, it would appear that although some taxa are present in both areas, the overall diversity and abundance is much lower in the Tafilalt area.

7.4. Discussion

The Tabainout mud-mound complex, as a whole, shows a much higher coral diversity compared to most other examples in Morocco (and Europe). However, the mound core facies (“microbial mound” facies) is particularly poor in corals, with only the occasional amplexid or axophyllid solitary rugosan, except where there are thin developments of interf mound crinoidal limestone and shale. The remarkable features of this mud-mound that are not present in other mud-mounds (e.g.,Tizra, Jerada in Morocco and in Sierra Morena, SW Spain, see Cózar et al., 2003; Rodriguez-Martínez et al., 2003) are bedded flank facies and coquinas that contain a rich rugose coral assemblage. It is not comparable to the biostromes at the top of the Tizra mounds, because they lie above the mound, whereas in Tabainout, the corals occur interbedded with horizons showing stromatolitic cavities and thus can be regarded as part of the mud-mound complex. At Tizra the mud-mounds are surrounded by marly limestone containing solitary corals and tabulates, but do not have the cemented coquinas alternating with beds having microbial textures. The total coral assemblage from the Tabainout mud-mound complex comprises 21 genera and 28 species. It represents an unusually high diversity for a mound, resulting from the presence of a diverse suite of environments of variable water depths hosting the rugose and tabulate corals.

8. Palaeobiogeography

The upper Viséan Tabainout assemblages contain many rugose genera and species that are also relatively common throughout Western Europe (SW Spain, Belgium, France, British Isles), e.g., Siphonodendron parvicicale, S. martini, S. sociale, Lithostroton vorticale, L. decipiens, Diphyliphyllum furcatum, D. latessetum, Siphonophyllia samosensis, and Dibunophyllum bipitiatum. A rare taxa including Kizilia sp. Moreover, assemblages corresponding to similar environments in Europe are dominated by the same species (cf. the standard upper Viséan assemblages of Somerville & Rodríguez, 2007). Consequently, the Tabainout upper Viséan coral assemblages indicate that the Azrou-Khenifra Basin should be considered as part of the Western European Coral Province (Fedorovski, 1981, fig. 2; Hill, 1981; Sando, 1990; Aretz & Herbig, 2010) and Western Palaeotethyan fauna (Hill, 1981; North Africa, much of North America, north of the Transform Fault, including Tabainout, Adarouch and Jerada, can be included in this same palaeobiogeographic realm. Aretz (2011b) has recently grouped together these Moroccan basins, based on a statistical study of the rugose coral faunas, and referred to them as the ‘Moroccan Meseta Province’.

9. Conclusions

Carboniferous (Mississippiian) rocks from Tabainout in the southern part of the Azrou-Khenifra Basin contain rich coral assemblages. Detailed analysis of the coral faunas from the mud-mound complex has established that they are richer and more diverse than those recorded in previous studies, especially in the bedded limestones at the base and in the upper flank beds and coquinas (cap beds).

Comparison of the upper Viséan (late Asbian-Brigantian) coral assemblages at Tabainout with those previously recorded at Adarouch, in the northern part of the Azrou-Khenifra Basin, has recognised many similarities in the composition of the rugose taxa between both areas. Moreover, similar association are recorded from different facies in the mud-mounds from Tabainout and Tizra.

Further comparison of the Azrou-Khenifra Basin assemblages with coral assemblages in other parts of the Western Palaeotethys shows recognition of close similarities with assemblages from the Jerada Basin (NE Morocco), and south-western Spain (Sierra Morena), where mud-mounds are recorded, establishing the location of all these areas within the same palaeobiogeographic province (Western European Coral Province).

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11. References


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