Preliminary data on the coral distribution in the Upper Visean (Mississippian) succession from Adarouch area (NE Central Morocco)

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Abstract: The Early Carboniferous (Mississippian) sequences of the Adarouch area (NE Central Morocco) are subdivided into four lithostratigraphic units: the Oued Amhares Formation, the Tizra Formation, the Mouarhaz Formation and the Akerchi Formation (BERKHLI, 1999). Rugose corals are present throughout most of the succession but they are abundant only in the Tizra and Akerchi formations. Only the second and third members (TZ2, TZ3) of the Tizra Formation, that were sedimented on a ramp, yielded abundant corals. TZ2 yielded *Lithostrotion, Siphononodendron* and *Palaeosmilia*. TZ3 yielded *Siphononodendron, Lithostrotion, Diphyphyllum, Lublinophyllum?, Clisiophyllum, Palaeosmilia, Palastraea, Dibunophyllum, Arachnolasma, Koninckophyllum, Siphonophyllia, Haplolasma, Pseudozaphrentoides, Corwenia, Aulokoninckophyllum, Axophyllum* and tabulates micheliniids and syringoporoids. TZ2 is Asbian in age and TZ3 is Brigantian in age. The assemblage from Akerchi Formation, that was sedimented in a shallow platform, is composed of *Siphonodendron, Diphyphyllum, Lithostrotion, Palastraea, Paleosmilia, Clisiophyllum, Dibunophyllum, Axophyllum, Arachnolasma* and *Koninckophyllum*. This assemblage is Brigantian in age. An isolated outcrop located east of Akerchi, at Idmarrach, provided a rich coral assemblage composed of *Lithostrotion, Siphonodendron, Diphyphyllum, Palastraea, Palaeosmilia, Dibunophyllum, Arachnolasma, Clisiophyllum, Koninckophyllum, Aulophyllum, Siphonophyllia, Axophyllum* and common syringoporoids. The presence of *Palastraea regia* establishes the age of the Idmarrach section as Brigantian or younger.

Key words: Upper Visean, Mississippian, rugose corals, Morocco

Contents

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1. INTRODUCTION

The objective of this paper is to describe the Mississippian coral assemblages in the Adarouch area of NE Central Morocco. The Early Carboniferous sequences in this region crop out in a broad area to the south of the city of El-Hajeb (Fig. 1). These Palaeozoic rocks have a NE-SW orientation and are bounded by Mesozoic rocks (Triassic and Jurassic; Fig. 1). Palaeozoic outcrops comprise Ordovician, Devonian, Mississippian and Pennsylvanian rocks. The Mississippian rocks are subdivided into four lithostratigraphic units: the Oued Amhares Formation (at the base), the Tizra Formation, the Mouarhaz Formation and the Akerchi Formation (at the top), comprising Upper Visean to Serpukhovian sediments (BERKHLI, 1999; BERKHLI & VACHARD, 2001). Micropaleontological data suggest that Serpukhovian sediments are only present in the upper part of the Akerchi Formation and probably at the top of the Idmarrach Formation.

The Oued Amhares Formation is about 500 m thick and is divided into three members. The lower member is composed of 140 m of terrigenous sediments that contain metre-sized limestone and sandstone boulders. The upper part of the lower member is composed of interbedded sandstones and shales containing plant remains; a channelized conglomerate with polygenetic pebbles overlies it. The middle and upper members are composed of black shales and black bioclastic limestones.

The Tizra Formation is about 300 m thick. It consists of greenish to black shales with three intercalated limestone intervals. The lowest limestone interval is composed of polygenetic conglomerates with a calcareous matrix and bioclastic limestones. The second limestone interval is composed of massive microbial limestones overlain by well-bedded bioclastic limestones (Fig. 2). The third limestone interval consists of well-bedded black limestones interbedded with marls and large massive microbial mounds.

The Mouarhaz Formation is about 500 m thick and is divided into two members. The lower member consists of well-bedded bioclastic and oolitic limestones. The upper member is composed of black shales that contain metre- to decametre-sized olistoliths.

The Akerchi Formation is 100 m thick and is divided into two members. The lower member is composed of bioclastic and oolitic limestones (Fig. 2). They are overlain by marly limestones that pass progressively upward into shales and sandstones with calcareous cement (sandy limestones).

Rugose corals are present throughout the succession, but they are locally abundant only in the Tizra and Akerchi formations. Additionally, a small section located 1 km to the east of the main outcrops, at Idmarrach, yielded very abundant corals (Figs.1, 3).

The stratigraphical profile of the Idmarrach Formation is 50 m thick and is composed of well-bedded black bioclastic limestones and marly limestones (Fig. 3).

2. METHODS

We have examined the entire stratigraphical succession of Adarouch; corals occur in many beds, but only three units yielded significant amounts: Tizra Fm. (second and third members), Akerchi Fm. (transition between first and second members) and Idmarrach Fm. (entire succession). A total of five stratigraphical sections has been sampled, two in Tizra, one in Akerchi and two in Idmarrach.

We have sampled the outcrops twice: First, we took samples on a purely quantitative basis by collecting as many specimens as possible from every bed containing corals. Thin

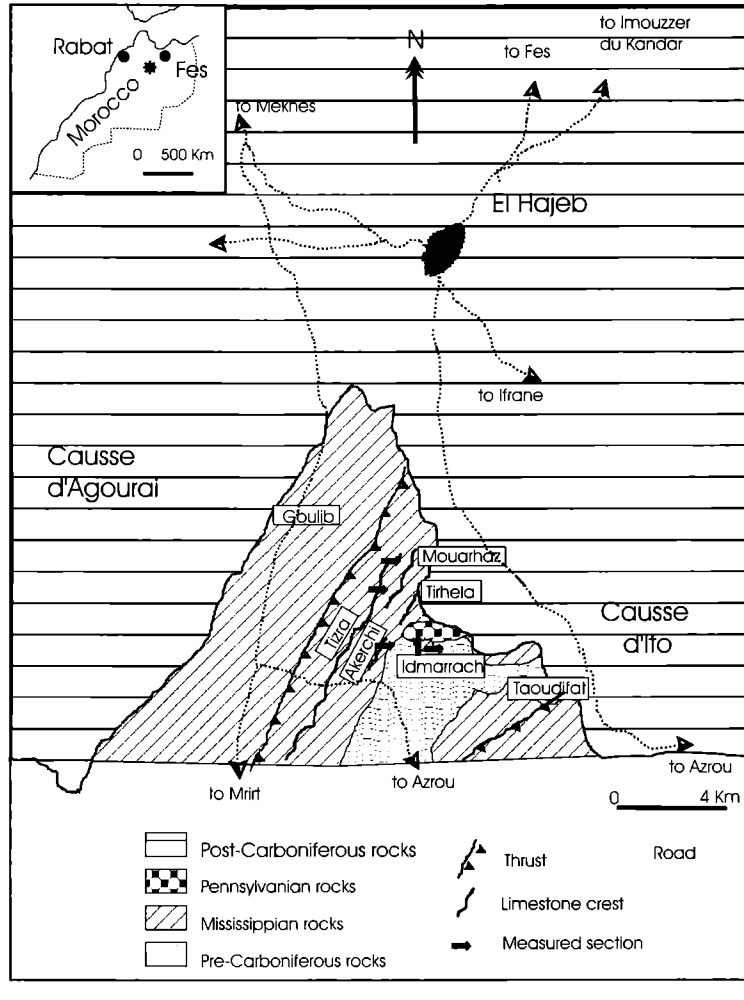

Fig. 1: Location map of the Adarouch Carboniferous outcrops (modified from BERKHLI & VACHARD, 2001)

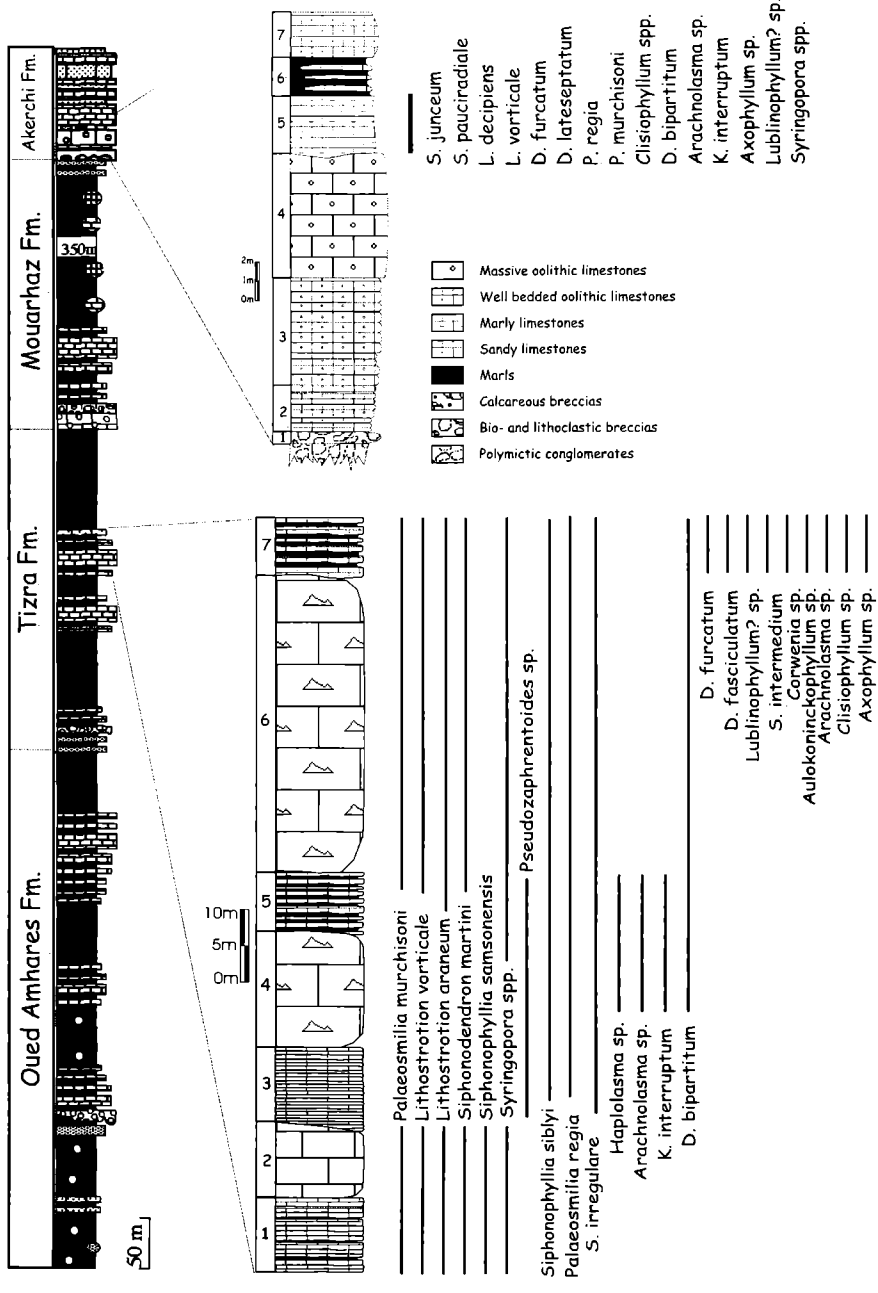

Fig. 2: General stratigraphical section of the Carboniferous from the Adarouch area (left column) with detailed stratigraphical sections from Tizra (lower right column) and Akerchi (upper right column) showing coral distributions. Note that a 350 m long section has been omitted in the Mouarhaz Formation.

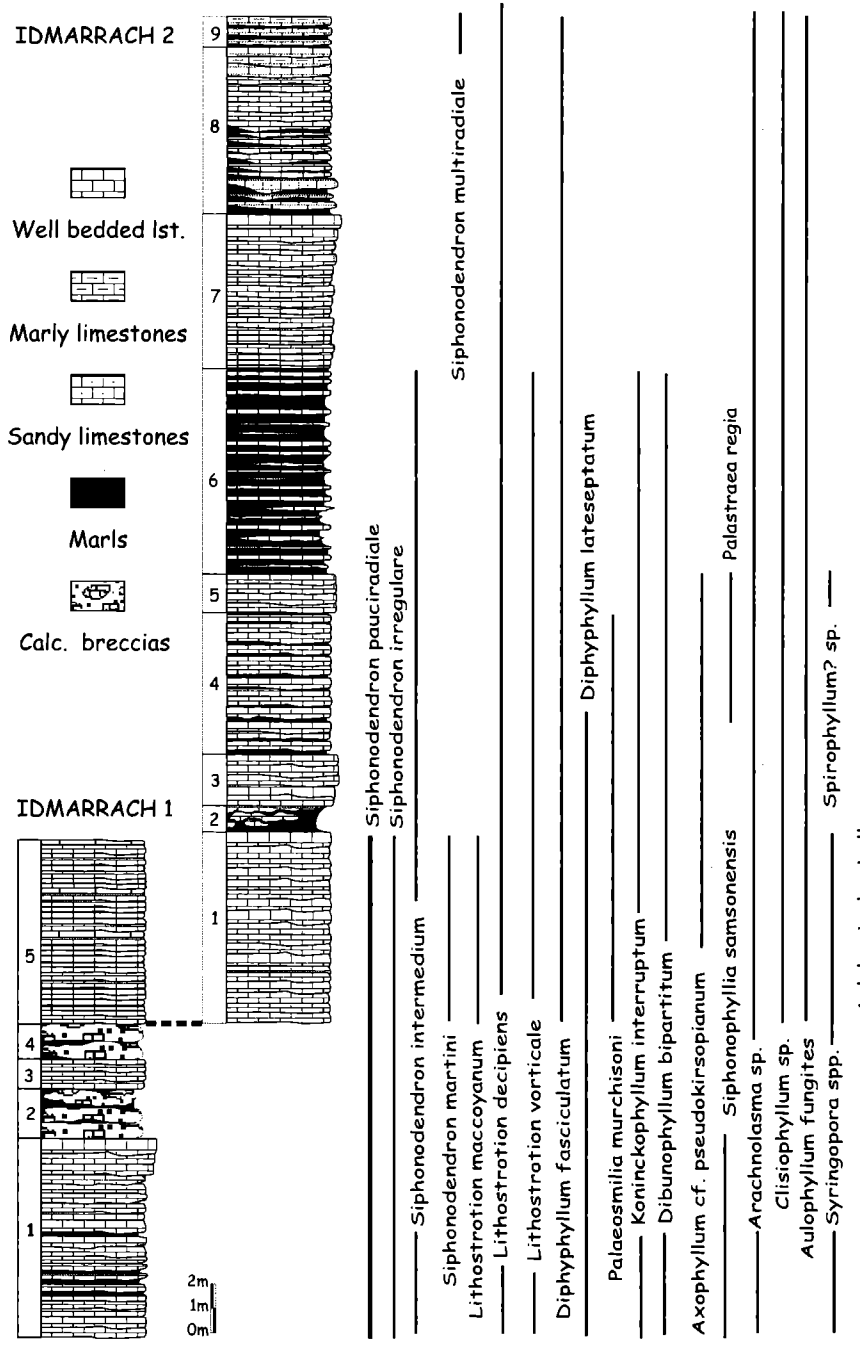

Fig. 3: Stratigraphical sections from Idmarrach with distribution of corals. Distance between Idmarrach1 and Idmarrach 2 is only 300 m (Fig. 1).

sections were then made from all coral specimens and a preliminary identification of rugose corals provided a guide for the second collection of samples. This time, we took samples on a selective basis by sampling only those species of which we had initially collected less than three specimens. Significant species of which we did not find at least three specimens were carefully investigated to determine their precise horizons and range. Additionally, petrographic samples were taken at 2 m intervals, in order to obtain detailed sedimentological information on the beds that contain corals.

During the sampling procedure, we made many field observations on the orientation of corals and their relationship with the surrounding sediments and other fossil groups, in order to determine as precisely as possible the taphonomical evolution of the coral skeletons and the ecological relationships of corals before they were buried

3. CORAL ASSEMBLAGES

At the time of writing this paper, the majority of specimens have been identified at the generic level. Although our work is still ongoing, it has progressed to the point that we can now attempt a preliminary summary of the assemblages from Adarouch and determine the age of the rocks with some certainty.

3.1. Tizra Formation

The Tizra Formation is subdivided into three members (TZ1–3). Each member is composed of a succession of basal limestones and upper shales. Only the second and third members (TZ2 and TZ3) yielded abundant corals. Two sections have been sampled in the Tizra Fm.. The first one comprises the upper beds of the second member and the complete carbonate succession of the third member. This section has been described as type section by BERKHLI (1999) and BERKHLI & VACHARD (2001) and is not presented here in detail. The second section was measured about 2 km south of the type section where many variations in detail occur in the carbonate units of the third member. The second section comprises only the base of the third member and contains several intervals of silts, well-bedded bioclastic limestones and massive microbial limestones. The investigation of the Tizra Fm. is far from complete; additional stratigraphical sections need to be sampled to complete the analysis of this very complex unit.

The second member of the Tizra Fm. (TZ2) in the type section is mainly composed of massive bioclastic limestones containing many crinoids, brachiopods and coral fragments. Well-bedded limestones containing some corals that are not in growth position overlie the massive limestones. The most common species are *Lithostrotion vorticale* (PARKINSON) and *Palaeosmilia murchisoni* MILNE-EDWARDS & HAIME. Rare specimens of *Siphonodendron* MCCOY, have also been found.

The basal beds of the TZ3 member are well-bedded sandy to marly limestones that contain solitary corals of the genera *Palaeosmilia* MILNE-EDWARDS & HAIME and *Siphonophyllia* SCOULER, lying parallel to the surface of the strata. They are overlain by breccioid massive limestones containing many fragmentary colonies of *Lithostrotion vorticale* PARKINSON , *L. araneum* (MCCOY) and *Siphonodendron martini* (MILNE-EDWARDS &

HAIME); *Siphonophyllia samsonensis* (SALÉE) and tabulate syringoporoids and micheliniids are also present.

The upper beds in the same section are composed of massive microbial limestones overlain by well-bedded black limestones with cherts that provided *Lithostrotion vorticale* PARKINSON, *Dibunophyllum bipartitum* MCCOY, *Arachnolasma* sp., *Koninckophyllum interruptum* THOMSON & NICHOLSON and *Haplolasma* sp.

A section sampled 2 km south of the type section yielded abundant corals (Fig. 2). The lower beds of that section correspond to the base of TZ3 and yielded *Lithostrotion vorticale* PARKINSON and *Siphonophyllia samsonensis* SALÉE. The upper beds in the same section (Fig. 2, units 3–5 in the lower section) provided *Palastraea regia* (PHILLIPS), *Siphonophyllia siblyi* SEMENOFF-TIAN-CHANSKY, *Pseudozaphrentoides* sp., *Siphonodendron irregulare* (PHILLIPS), undissepimented rugose corals and micheliniids. These beds are overlain by thick masses of microbial limestones that built a microbial mound. It is covered by well-bedded limestones containing a rich assemblage of colonial corals in growth position dominated by fasciculate species: *Siphonodendron intermedium* POTY, *S. irregulare* (PHILLIPS), *Diphyphyllum furcatum* HILL, *D. fasciculatum* FLEMING, *Corwenia* sp., *Lublinophyllum?* sp. and *Syringopora* sp. Massive and solitary rugosans are also common, namely, *Lithostrotion vorticale* PARKINSON, *L. araneum* (MCCOY), *Palastraea regia* (PHILLIPS), *Palaeosmilia murchisoni* MILNE EDWARDS & HAIME, *Aulokoninckophyllum* sp., *Arachnolasma* sp., *Dibunophyllum bipartitum* (MCCOY), *Clisiophyllum* sp. and *Axophyllum* sp.

3.2. Akerchi Formation

Corals are only abundant at one specific level in the lower part of the Akerchi Formation. A dominant feature of this formation are massive oolitic limestones that form a crest. Corals occur in a 3 m thick bed composed of marly limestones that occur just on that crest. Corals are very abundant (more than 50% of the total composition of the rock) and quite diverse. Many of the colonies are in growth position, others are reworked. The most conspicuous feature of this bed is the presence of large masses of *Siphonodendron junceum* (FLEMING) that locally form more than 80% of the rock. Other species recorded from this bed are *Siphonodendron pauciradiale* (MCCOY), *Lithostrotion decipiens* MILNE EDWARDS & HAIME, *L. vorticale* PARKINSON, *Diphyphyllum furcatum* THOMSON, *D. lateseptatum* MCCOY, *Lublinophyllum* sp., *Palastraea regia* (PHILLIPS), *Paleosmilia murchisoni* MILNE EDWARDS & HAIME, *Clisiophyllum* sp., *Dibunophyllum bipartitum* (MCCOY), *Arachnolasma* sp., *Koninckophyllum interruptum* THOMSON & NICHOLSON, *Axophyllum* sp. and *Syringopora* sp..

3.3. Idmarrach Formation

The outcrops of Idmarrach are isolated from the main outcrops in Adarouch. They occupy about 1 km^2 and are located about 1 km east from Akerchi. Two sections were sampled in Idmarrach; they can easily be correlated in the field. The Idmarrach 2 section is more complete, but the Idmarrach 1 section exhibits the basal beds that are not found

in the second section. The stratigraphical succession is composed of black well-bedded limestones interstratified with marls. They are very rich in corals and brachiopods (mainly gigantoproductids). Gigantoproductids are in some cases in growth position, but sometimes they show the concave brachial valve downwards. In both cases they frequently provide the attachment for solitary and colonial corals. Corals are commonly in growth position. Units 2 and 4 of the Idmarrach 1 section are composed of masses of reworked corals.

Corals are abundant and very diverse. The basal beds contain *Siphonodendron pauciradiale* (McCoy), *S. irregulare* (Phillips), *S. intermedium* Poty, *Lithostrotion decipiens* Milne Edwards & Haime, *L. vorticale* Parkinson, *Diphyphyllum lateseptatum* McCoy, *Koninckophyllum interruptum* Thomson & Nicholson, *Dibunophyllum bipartitum* McCoy, *Arachnolasma* sp., *Siphonophyllia samsonensis* Salée, and *Syringopora* sp.

The upper beds of the Idmarrach1 section and the basal beds of the Idmarrach 2 section are the richest in corals (Fig. 3). They contain the same assemblage as the lower beds, additionally *Siphonodendron martini* Milne Edwards & Haime, *Lithostrotion maccoyanum* Milne Edwards & Haime, *Diphyphyllum fasciculatum* (Fleming), *Axophyllum* cf. *pseudokirsopianum* Semenoff-Tian-Chansky, *Clisiophyllum* sp., *Aulophyllum fungites* (Fleming) and *Palaeosmilia murchisoni* Milne-Edwards & Haime. The upper beds in the Idmarrach 2 section yielded a somewhat impoverished assemblage containing *Siphonodendron intermedium* Poty, *Lithostrotion decipiens* Milne-Edwards & Haime, *Lithostrotion vorticale* Parkinson, *Diphyphyllum fasciculatum* Fleming, *Diphyphyllum lateseptatum* McCoy, *Palaeosmilia murchisoni* Milne-Edwards & Haime, *Koninckophyllum interruptum* Thomson & Nicholson, *Dibunophyllum bipartitum* (McCoy), *Arachnolasma* sp., *Clisiophyllum* sp., *Aulophyllum fungites* (Fleming), *Aulokoninckophyllum* sp., *Palastraea regia* (Phillips) and *Axophyllum* cf. *pseudokirsopianum*. Single specimens of *Spirophyllum?* sp. and *Siphonodendron multiradiale* Nudds & Somerville occur in the units 5 and 9 of the Idmarrach 2 section (Fig. 3).

4. DISCUSSION

The Tizra Formation is mainly composed of siliciclastic rocks (interbedded shales and sandstones) that show typical features of turbiditic sedimentation in a ramp (Berkhli 1999). The carbonate intervals that represent breaks in the siliciclastic sedimentation show also turbiditic features. Well-bedded black limestones show grading and parallel lamination, dewatering structures and common chert. They are regarded as distal turbidites and are interbedded with bioclastic limestones and massive breccioid limestones containing blocks of coral colonies and intraclasts that are regarded as proximal turbidites. These beds contain common corals that are not in growth position. They are clearly reworked in the debris-flow breccias (allochthonous) but only partially transported in the bioclastic beds (paraautochthonous). The breccioid and bioclastic beds seem to form a good foundation for the development of microbial mounds that show facies similar to those described in Algeria (Bourke et al., 1995; Madi et al., 1996) and SW Spain (Cózar et al., 2003; Rodríguez-Martínez et al., 2000, 2003). The size of these mounds vary from 5 m thickness and 30–40 m diameter to 50 m thickness and 400–500 m diameter. Marly beds around the mounds contain high concentrations of crinoids and some solitary undissepi-

mented corals. Shallow water depth on top of the mounds facilitated the development of coral assemblages composed mainly of large colonies of fasciculate rugosans, similar to the one in Ardagh Quarry (Ireland) described by SOMERVILLE (1997).

The assemblage from TZ2 Member appear to be Asbian in age, because none of the typical Brigantian corals occur there. The presence of *Palastraea regia* (PHILLIPS) and *Corwenia* sp. in TZ3 Member indicates that this unit belongs at least to the Zone 8 of POTY (1985), Zone I of MITCHELL (1989), Zone 4 of RODRÍGUEZ & SOMERVILLE (this volume). They mark the Brigantian and are approximately equivalent to the foraminifera zone Cf6δ. Consequently, the boundary Cf6γ/Cf6δ that was located at the top of Tizra Formation by BERKHLI & VACHARD (2001) should be relocated at a lower stratigraphical level, approximately between TZ2 and TZ3 at the base of the TZ3 Member.

The marly bed containing abundant corals in the Akerchi Fm. is related to the oolitic limestones. The lowest colonies lie in growth position, directly in contact with the irregular upper surface of the oolitic massive limestone. Nevertheless, most colonial and solitary corals in the Akerchi Fm. are slightly transported. There are large colonies of *Siphonodendron junceum* (FLEMING) that are not moved, but thousands of small broken branches of this species bind colonies and solitary corals within the bed. The corals from the Akerchi Fm. probably flourished in a quiet platform protected by oolitic sand bars, but they were exposed to strong waves during storms.

The coral assemblage is typically Brigantian. Thus, our dating of the lower beds from the Akerchi Fm. agrees with the age determined by BERKHLI & VACHARD (2001).

The most conspicuous feature of the limestones from Idmarrach is the abundance of gigantoproductid brachiopods and corals. The gigantoproductids are in some cases in growth position. Occasionally, they lie with the concave side downward. Very rarely do they show a chaotic distribution in beds. In some cases the beds contain broken fragments of corals around the transported gigantoproductids, but more commonly the latter form the base for the coral growth (solitary and colonial) in a manner similar to Los Santos de Maimona (RODRÍGUEZ et al., 1992, 1994). Nevertheless, the coral colonies are more diverse at Idmarrach and do not show any vertical control of their growth. Some beds consist of higher quantities of silt and contain more solitary corals showing curved skeletons, adapted to muddy bottom (NEUMAN, 1988; RODRÍGUEZ, 2000). In some cases, breccioid beds display masses of broken corals and brachiopods that show typical features of storm beds. The facies associations and the distribution of gigantoproductids and corals indicate that the sediments from Idmarrach were deposited in a shallow platform or ramp dominated by storms.

The presence of *Palastraea regia* (PHILLIPS) proves that most the Idmarrach Fm. belongs to the Brigantian (at least from the unit 4 of the Idmarrach 2). It may be equivalent in age to the third member of the Tizra Fm. (TZ3), but was probably deposited in shallow water facies. This assumption supports the model of BERKHLI (1999, p.255, figs 3–4) because of the eastern location of Idmarrach.

5. CONCLUSIONS

Three lithostratigraphic units in the Mississippian from the Adarouch area (Morocco) are rich in corals: the Tizra Fm., the Akerchi Fm., and the Idmarrach Fm.

The Tizra Fm. carbonates were deposited on a ramp. Microbial mounds are common there. At least three different coral assemblages can be distinguished:

(1) Allochthonous to paraautochthonous assemblages composed of broken colonies and large solitary corals in debris-flows and in bioclastic beds.

(2) Autochthonous assemblages composed of undissepimented rugosans and michelinids (tabulate corals).

(3) Autochthonous assemblages located at the top of microbial mounds composed mainly of fasciculate corals, but also by large solitary dissepimented corals.

The assemblage from TZ2 member is too poor to determine the age of this unit. Nevertheless our observations agree with the late Asbian age provided by BERKHLI & VACHARD (2001) based on foraminifers.

The assemblage presence of *Palastraea regia* (Phillips), *Corwenia* sp. etc. in the TZ3 member indicates a Brigantian age.

Corals from the Akerchi Formation developed on a platform protected by oolitic sand shoals. The assemblage is very rich and diverse, but it is clearly dominated by large colonies of *Siphonodendron junceum*.

The coral assemblage from the Akerchi Fm. indicates also a Brigantian age because of the presence of *Palastraea regia* (PHILLIPS) and extreme abundance of *Siphonodendron junceum* (FLEMING).

The sedimentation from Idmarrach took place in a shallow platform dominated by storms. The corals are commonly associated with gigantoproductids.

The assemblage from the Idmarrach also indicates a Brigantian age (at least in its upper part) because of the presence of *Palastraea regia*.

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