Palaeogeography, Palaeoclimatology, Palaeoecology 304 (2011) 184–193

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

Genesis and internal architecture of the Middle to Upper Devonian Gwirat Al Hyssan reef-mound (Western Sahara)

Eberhard Schindler [a,*], Achim Wehrmann [b]

[a] Senckenberg Forschungsinstitut und Naturmuseum Frankfurt, Dept. of Palaeontology and Historical Geology, Senckenberganlage 25, 60325 Frankfurt am Main, Germany
[b] Senckenberg am Meer, Dept. of Marine Research, Suedstrand 40, 26382 Wilhelmshaven, Germany

ARTICLE INFO

Available online 16 October 2010

Keywords:
Initial reef growth
Givetian
Frasnian
Reef builders
Global sea-level rise
Gondwana

ABSTRACT

On the southern flanks of the Tindouf Basin (Western Sahara) reefal complexes of various sizes were developed, mostly of Givetian age but possibly reaching into the early Frasnian. Surrounding sedimentary rocks were dominantly sandstones, siltstones and marls. The larger reef complexes in the northeastern part of Western Sahara show three reef cycles within the Givetian and lowermost Frasnian, interrupted by marly sedimentation. Farther to the west, more isolated reef structures in open shelf settings occur often showing smaller dimensions.

The present study focuses on one of these western reefal build-ups. Besides large-scale reefs dominated by stromatoporoids (NE), several smaller bioherms have been investigated, such as the Gwirat Al Hyssan reef-mound near Smara. Initial reef growth was of late Givetian age as indicated by corals (e.g. *Heliolites*). The main reef builders were the corals *Alveolites*, *Thamnopora*, *Aulopora*, *Frechastraea*, *Phillipsastrea*, and, to a lesser degree, *Heliolites, Scoliopora,* and *Roemerolites*. Stromatoporoids also contributed, but were less frequent. Chaetetids (e.g. *Rhaphidopora*) acted as pioneer stabilizers on bare sediment surfaces. Preservation in life position was frequently observed in both groups of organisms. Crinoids are not rare, but only present as debris. In distinct areas of the reef (depressions) concentrations of brachiopods and small solitary corals occur. The reef-mound has a present elevation of 17 m and measures about 370 m in diameter. Vertical as well as horizontal zonation could be recognized in detail. The initial reef growth started on a submarine shoal of siliciclastic sediments, containing various trace fossils and sedimentary structures such as cross-bedding and wave ripples; interference ripples suggest generation in very shallow water. The initial reef-building organisms were encrusting chaetetids, followed by platy *Frechastraea* colonies; thamnoporids were also present. The overlying reef limestones consist of different corals and, to a minor degree, stromatoporoids. The latter are sparsely distributed vertically as well as horizontally, depending on their position within the reef. Growth forms are more robust (bulbous) towards higher hydrodynamic conditions at the southern reef front. Reef growth is interrupted by debris limestones of thamnoporid and crinoid bioclasts, intercalated with detrital platy stromatoporoids. Generally, the debris was not transported over long distances, as demonstrated by the presence of relatively large fragments. This 'debris phase' (early Frasnian) is overlain by the last documented stage in reef development represented by medium- to thin-bedded coral-rich limestones. The onset of the carbonate production of the Gwirat Al Hyssan reef-mound is maybe related to the global transgressive Givetian–Frasnian Boundary Event.

1. Introduction

Reef structures can be found along the southern margin of the Tindouf Basin in Western Sahara, despite the fact that siliciclastic rocks greatly dominate the Middle Devonian strata of the area (Fig. 1). After the region was mapped by Spanish geologists in the 1940s and 1950s (Alia Medina, 1949; De la Viña and Muñoz Cabezón, 1958), as well as by Payan and Sendrier (1962) in an unpublished report, the reefs were documented by Dumestre and Illing (1967) in the proceedings of the 1st International Symposium on the Devonian System. During a field survey in 2002 some of the known reef complexes (Dumestre and Illing, 1967) accessible in the northeastern part of Western Sahara, were first studied in detail by the authors (for overview see Königshof et al., 2003, 2004). In a summary article, Wendt and Kaufmann (2006) published a synthetic profile showing an extended cyclic reef formation, mainly based on literature data of previous workers (see above).

According to widely accepted palaeogeographic reconstructions (Copper, 2002; Golonka, 2002; Scotese, 2003), the Devonian reefs of Western Sahara developed on the northern shelf margin of Gondwana

* Corresponding author. Tel.: +49 69 970751132; fax: +49 69 970751137.
E-mail addresses: eberhard.schindler@senckenberg.de (E. Schindler), achim.wehrmann@senckenberg.de (A. Wehrmann).

0031-0182/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.palaeo.2010.10.017

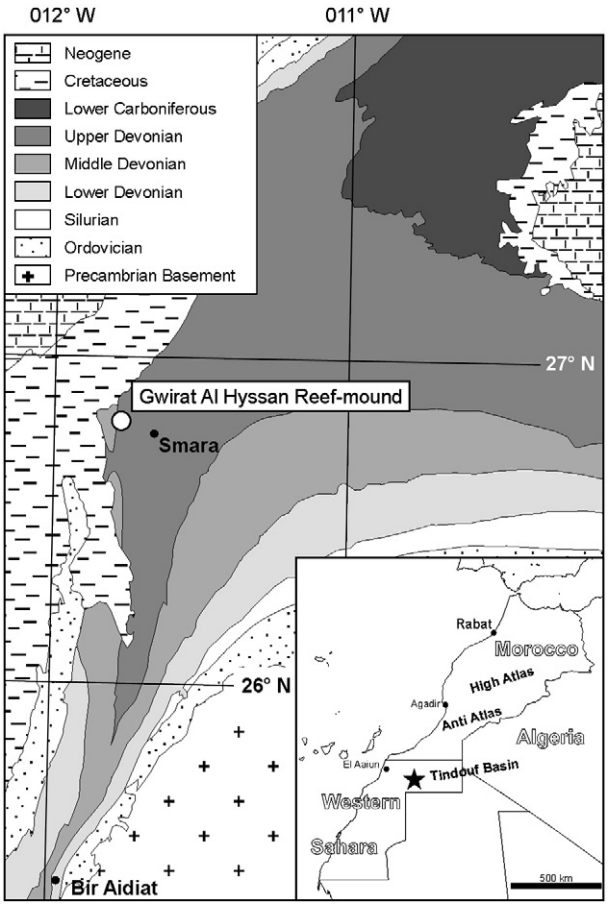

Fig. 1. Simplified geological map of the southwestern Tindouf Basin (Western Sahara). White dot indicates study area west of Smara. Modified after Carte Géologique du Maroc 1/1000000, Service Géologique du Maroc, 1985.

at latitudes of ~40–45° S. The aim of this study was, (i) to document the internal architecture of reefal structures in different settings in order to interpret bathymetry and hydrodynamics, (ii) to investigate the initial phases of reef growth, and (iii) to date the onset and extension of the reefs in this area. Owing to the absence of tectonic deformation, diagenetic alteration, and vegetation, the preservation and exposure of the reef structures of this area are extraordinary.

2. Material and methods

Detailed mapping and section logging were carried out in the field (Fig. 2). Mapping of lithological units was done using a 3D-GPS (WGS 84), post-processed by analysis of high resolution satellite images. Topographic elevations and dips of beds were measured with standard geodetic methods. Samples for microfacies analysis (polished slabs and thin sections) were mainly taken from in-situ beds. To indicate directions, abbreviations are partly used (N, W, NE, etc.). Fossils, hand specimens, and thin sections are stored in the collections of the Senckenberg Forschungsinstitut und Naturmuseum Frankfurt.

3. Geological setting

There are two main "clusters" of Devonian reefs (Uein Terguet and Gor Loutad) distributed along the northern margin of the Precambrian Shield in the southeast of the study area. The reefs are situated in an area that was not affected by Palaeozoic tectonic movements, and there has been no later deformation. Unfortunately, however, research was hampered due to the presence of the Moroccan "Ligne de défense", making access impossible to most of the two reef clusters (including the most spectacular ones) since the 1970s. Some reefs, however, were accessible with the permission and help of the Moroccan military forces, and the local administrative authorities.

The reefal deposits of the Smara region comprise isolated carbonate complexes within a depositional environment characterized by the accumulation of siliciclastics derived from the nearby Gondwanan coast to the southeast (Fig. 1). The strata beneath of the Gwirat Al Hyssan reef-mound consist of thin-bedded silt-/sandstones (Fig. 3A-C). Sedimentary structures (e.g., oscillation ripples, interference ripples, and hummocky cross-stratification [HCS]) indicate deposition in shallow water, within the storm-wave base (Fig. 3A, B). Trace fossils most probably produced by worm-like organisms occur frequently on sedimentary surfaces of these silt-/sandstones (Fig. 3A,C). The lateral equivalents of the reef deposits are dark bluish grey, very resistant, micritic limestones only a few meters in thickness (Fig. 3D). The sedimentary rocks directly capping the reef structure have been removed by post-depositional erosion. With respect to the original size of the entire reef-mound, a larger structure than that preserved today must be assumed (Fig. 2; for detailed description see 5.3). About 10 km NE of the Gwirat Al Hyssan reef-mound (N 26°54.19, W 011°45.49) cephalopod limestones with manticoceratid goniatites of Late Devonian (Frasnian) age are exposed (Fig. 3E; pers. comm. R.T. Becker, Münster).

4. Stratigraphy

Reef growth of the Gwirat Al Hyssan reef-mound started in the Givetian. This is documented by the initial occurrence of chaetetids within the underlying siliciclastics. Following the siliciclastics, reef carbonates prevail to the top of the reef-mound. A Givetian age is indicated by its characteristic reef-builders and associated organisms (Table 1), such as the corals *Heliolites porosus, Scoliopora* sp. (Givetian form of the *S. denticulata* group), typical late Givetian *Frechastraea*, and the brachiopods *Aulacella eifeliensis* and *Tropidoleptus carinatus freuloni*. The brachiopods *Cyrtospirifer* cf. *verneuili* and *Douvillina* cf. *dutertrei* represent the Givetian/Frasnian transition and the Frasnian (reef debris phase), respectively. They originate from the thamnoporid rudstones (see 5.2.2).

5. The Gwirat Al Hyssan reef-mound

The Gwirat Al Hyssan reef-mound (N 26°49.38, W 011°46.96) was mapped in detail with respect to morphology, lithologic and genetic units, colonization strategies, pre-reef strata, stratigraphy, and small-scale tectonics. The present spatial extent of the reef body is about 370 m in diameter, with a maximum height above the surrounding terrain of 17 m (see Fig. 2 and 5.3 for assumed original extension). Its external morphology strongly reflects an internal structure of a siliciclastic shoal built up by underlying silt-/sandstones, as can be seen in an erosional window in the northwestern part. This pre-existing submarine shoal was colonized by pioneer reef-building organisms that were able to stabilize sediment surfaces. Reefal deposits enveloped this shoal with a thin cover of 4–5 m of bioclastic carbonates (Fig. 2). In the southern and western parts, the original synsedimentary steep dip of the beds is still recognizable. The Gwirat Al Hyssan reef-mound is dissected by minor faults (Fig. 2A,B), which run SSE–NNW reflecting the overall regional pattern of larger-scale tectonic direction. However, the faults did not cause significant vertical displacement.

5.1. Basal siliciclastic deposits

The underlying siliciclastics are composed of thin-bedded, platy siltstones to fine-grained sandstones yielding shallow water sedimentary structures (Fig. 3A,B). Nevertheless, well-preserved and distinct trace