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Precambrian (Ediacaran) stromatolites in the Amane-n'Tourhart (Anti-Atlas, Morocco)

The present study concerns stromatolites of the Amane-n'Tourhart outcrop (N30°47′33.4″ and W06°43′19.7″) (Fig. 1) (e.g., Choubert et al. 1952; Schmitt 1978; Raaben 1980; Beraaouz et al. 2017).

Stromatolitic limestone and dolomites are exposed along the Ouarzazate–Zagora road, 25 km from the city of Ouarzazate, Morocco. The area of interest is approximately 0.04 km^2 in extent. Stromatolites occur as 10–20 m thick units, interstratified with volcanics and volcaniclastic (rhyolites ignimbrites, tuffs, sandstones, and conglomerates) of the Late Neoproterozoic Ouarzazate Supergroup (Thomas et al. 2004; Gasquet et al. 2008).

Stromatolitic carbonates are the most common (~70%), but lacustrine sediments, minor breccia, scree, scoria, and tuff also occur lower in the succession. Fluids passing through the surrounding volcanic landscape and the volcanic ashes interbedded within the lacustrine infill supplied silica-enriched fluids, making the shallow lakes alkaline (Álvaro et al. 2010).

Calcarenites and fine-grained siliciclastic sands, containing symmetrical and asymmetrical, low amplitude, and straight crested ripples (showing tunning fork bifurcation), are common low in the succession. Ripples are associated with mud cracks, indicating very shallow-water deposition.

Stromatolites appear at three stratigraphic levels separated by volcano-clastic sandstone units. The lower stratigraphic level consists of stromatolites, pelites, and reddish fine-grained sandstones. Petrographic investigation shows filamentous cyanobacteria traces, sometimes grouped into sheaves. This differs from the upper startigraphic levels which contain large colonies of *Conophyton*.

Stromatolites in the intermediate and upper levels comprise subcircular to elliptical domes 5–60 cm in diameter and with heights up to 1 m (Fig. 1). These can form laterally linked hemispheroids or isolated domal or conical regularly spaced hemispheroids. They are weathered with a shiny black patina and ocher red colouration (colours from iron oxides). Carbonate, iron oxide, and silica cements are present. The change in stromatolite structures might be related to change in water depth.

Microscopic observations show alternating dark laminae (microbial mat) and light laminae (clay rich carbonate cement). Laminae are generally irregular and planar parallel. Dolosparite and sparite cement are present. Trapped and bound grains of quartz, plagioclase, and orthoclase are common within the lamination. Locally, the abundance of light-coloured laminae, when compared to the darker laminae, points to strong clastic input, inhibiting the growth of microbial mats. Desiccation cracks, presence of iron oxides, and micrite, associated with gypsiferous layers, are present within the lamination. The simple mat structure, trapped, and bound grains, presence of halite, and dessication cracks further reinforce a shallow-water, and possibly restricted environment of deposition.

Seasonal variation can explain the change between microbial mats and the trapped and bound light-coloured laminae. During wet periods, runoff eroded the volcanic substratum and transported grains (quartz and plagioclase) into the lake which then became trapped within the biomat. This caused an increase in turbidity, inhibiting cyanobacteria growth. During dry periods, clear water promoted photosynthetic activity by cyanobacteria that precipitated limestone.

Microscopy of the three stromatolitic levels shows an increase in the proportion of the dark beds (laminae), compared to the light beds, towards the top of the series. This can be explained by an increase in cyanobacterial activity.

The association of stromatolite and evaporites (gypsum) proves that the environment was shallow and restricted. The silica cement represents a secondary recrystallization as shown by the replacement of the carbonate cement during early diagenesis.

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Fig. 1 Plan view of stromatolitic bioherm showing cross section of *Conophyton*. Note the irregular thickening of outermost laminae forming complex pattern. Some of the columns also preserve broken outline, but show elliptical or flame shape with a rock hammer for scale

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