Annales de la Société Géologique de Belgique, T. 95, 1972, pp. 403-406 1973

RECENT ARAGONITIC ENCRUSTATIONS & PSEUDO-STROMATOLITES OF THE TRUCIAL COAST, PERSIAN GULF

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I. Aragonitic encrustations.

Aragonitic crusts exhibiting various morphologies coat both discreet grains and beach rock within the supratidal zone of the Trucial Coast. They are best developed in lagoonal settings and, although invariably lithified, have many features in common with algal stromatolites. They resemble, even closer, certain non-marine spring and cave tufas.

1. *General observations.*

These strontium-rich (8000-9000 ppm), aragonitic encrustations have been examined in detail at two localities in W Abu Ahabi, at the extreme W. end of the Trucial Coast.

a. *Khor Odaid Lagoon.* The SW shores of this 5-10 km wide coastal lagoon consist of oolitic sand often lithified to beach rock, and low cliffs of Tertiary dolomite. Both Recent and Tertiary rocks are encrusted locally with various types of aragonite.

In the *lower parts of the supratidal zone* fragments of rock are completely enveloped in a thin (1-5 mm) pellicle of beige, laminated, enamel-like aragonite with a highly polished surface which, in thin slide, is virtually identical in structure to tho cortex of classic marine ooids. These coated blocks attain 50 cm in diameter and when sub-rounded in shape, could be regarded as pisoliths. Elsewhere in the same environment this same polished aragonite pellicle coats beach rock thus forming a sheet along the lower parts of the supratidal zone. It is especially well developed on impermeable rocks exposed to wave action. SEM studies (by J-P. Loreau) show that the aragonite is a mixture of minute (1-2 microns) prisms, equant nanograins and elongate rods, the latter generally arranged tangentially with respect to the rock substrate.

In the *uppermost parts of the supratidal zone* at Khor Odaid Tertiary outcrops forming small cliffs along the shoreline, are also coated with unpolished aragonite whose morphology, in contrast to the lower supratidal crusts, is highly irregular. It closely resembles spring or cave tufa; its surface is modified into a series of ridges and lobes which exhibit clearly developed drip-stone effects, especially on the steeply inclined substrates.

b. *Jebel Dhanna Lagoon.* A 1 km wide coastal lagoon is almost completely enclosed by a coastal spit of coarse bioclastic sand. The inner (lagoonal) side of this spit is extensively lithified to beach rock which, together with various lithoclasts and other grains, is coated with aragonite. Individual grains in the *lower parts of the supratidal zone* have a well developed (2-10 mm) cortex consisting of laminated microcrystalline or fibrous aragonite crystals, the latter frequently oriented radially with respect to the nucleus. When this nucleus is round (e.g. a quartz grain) the resultant coated grain is ovoid and may be classified as an ooid or pisooid, depending on size. Irregular nuclei (e.g. gasteropods) result in irregularly shaped grains resembling algal oncoids. In the lower parts of the supratidal zone the external morphology, although frequently irregular, is always smooth. However, in the *upper parts of the supratidal zone* the surface is highly irregular being decorated with a complicated micro-system of ridges and depressions which gives these grains a distincly « vegetable » appearance. These grains may attain 30 cm in diameter.

Coated grains generally lie close to, or directly upon inclined beach rock layers which are also encursted with aragonite. These aragonitic sheets are identical in microstructure to the grains and also exhibit similar change from smooth morphologies in the lower parts of the supratidal zone to highly irregular morphologies in the upper parts of this zone.

Sections through grains and beach rock crusts show that the numerous surface depressions which constitute the complicated morphology typical of the uppermost parts of the supratidal zone, truncate laminations within the crust. This indicates that at least part of this surface morpholcgy is due to destructional processes. Most depressions contain abundant minute, black fungae or algae which tend to bore into the crust suggesting that they may be responsible for part of this surface relief. These depressions also contain detrital sediment grains and are clearly small, but effective, sediment traps. Many of the small ridges also exhibit a distinct drip-stone morphology indicating the effects of running water.

2. *Processes involved in the formation of aragonitic crusts.*

The essential problem is to determine whether these encrustations, particularly those around Jebel Dhanna lagoon, are lithified algal growths or whether, on the contrary, they form by precipitation of aragonite and are subsequently inhabited by various micro-floras. The following observations suggest that the latter is most probable :

(1) The aragonite invariably encrusts a hard substrate — either a discreet grain or a layer of beach rock; algae, on the contrary, do not require a hard substrate.

(2) These crusts are invariably lithified, there being no soft spongiostrome equivalents.

(3) SEM examination (by J-P. Loreau) indicates that algal or fungal filaments tend to perforate these crusts and do not resemble the felt of filaments which constitute algal stromatolites.

(4) Individual laminae may be traced around the nucleus, especially on grains in the lower parts of the supratidal zone; algal oncoids generally show a marked asymmetry with discontinuous laminations often thickest on the top of the grain.

(5) These crusts are best developed within the upper parts of the *supratidal* zone; algal mats, a characteristic feature of the Trucial Coast, attain maximum development in the upper parts of the *intertidal* zone, those around Jebel Dhana lagoon being 30 cm topographically lower than the adjacent lithified crusts.

(6) Although superficially resembling algal growths these crusts locally have a preferred downward orientation suggesting a drip-stone effect; the micro-ridges developed in the upper parts of the supradital zone often have steeper down-slope flanks resembling the tufas at Khor Odaid, and certain non-marine spring tufas.

3. *The sequence of formational processes.*

The processes leading to the formation of supratidal aragonitic crusts at Jebel Dhana include :

(1) the formation of a hard nucleus, often a fragment of beach rock, or mollusc.

(2) precipitation of aragonite in concentric layers around this nucleus, or as layers on beach rock. Although a biochemical influence can not be excluded it is more probable (in view of the preceeding observations) that the aragonite is precipitated directly from sea water.

(3) local organic destruction, especially within small surface depressions. This leads to a deepening of these depressions and an increase in surface relief.

(4) local trapping of sediment within the surface depressions, the subsequent precipitation of aragonite resulting in the incorporation of this sediment into the crust.

4. *Similarities and differences between marine tufas and algal stromatolites.*

It should be evident from preceeding observations that the aragonitic encrustations in W. Abu Dhabi have much in common with lithified algal stromatolites. Similarities include :

(1) external morphologies, with numerous surfaces inclined at angles exceeding 40°,

(2) irregular internal laminations which reflect the external morphology,

(3) detrital sediment trapped within these laminations,

(4) very similar environment of formation,

(5) variation in morphology as one crosses the supratidal zone.

Characteristics which may permit the distinction between marine tufas essentially of chemical origin, and algal stromatolites are the following :

(1) Because aragonitic crusts coat a hard substrate the contact may often be discordant (a « hard ground » or unconformity); grains directly below the crust may be truncated, bored or micritised. Stromatolites most frequently encrust a soft substrate, although oncoids often coat a hard nucleus.

(2) Aragonite crusts frequently have a drip-stone morphology with downward growth around the edges.

(3) Aragonite crusts, although they may fracture, do not exhibit the dessication features characteristic of many stromatolites.

(4) Because the aragonitic tufa is always lithified it does not include « birds eye » (fenesrate) structures typical of many stromatolites.

(5) Although marine tufa effectively traps sediment, detrital grains are generally isolated in small pockets; algal stromatolites are composed mainly of detrital material which often constitutes distinct layers.

(6) Marine tufas, at least in Abu Dhabi, have a dense micritic fabric; algal stromatolites frequently have a porous fabric.

II. MICROSTALACTITIC ENCRUSTATIONS UNDER BEACH ROCK.

Beach rock layers are generally 20-30 cm in thickness and are underlain by non-cemented sediment which is excavated locally by crabs etc... to produce small micro-caverns beneath the resistant rock layers. The roofs of many of these supratidal micro-caverns are decorated with two types of aragonitic micro-dripstone.

(1) « *Crystalline micro-dripstone* » consist of 1-3 mm thick layers of laminated aragonite with numerous stalactitic lobes several mm in length composed of acicular aragonite. This type is common in the *lower* parts of the supratidal zone.

(2) « *Sedimentary micro-dripstone* » occurs under beach rock mainly in the *upper* parts of the supratidal zone and consist of earthy textured, irregular layers, micro-ridges and lobes composed of detrital sediment – generally faecal pellets, cemented with fibrous aragonite. Individual stalactites attain 5 mm in length.

Both types of microstalactites would seem to be formed, at least in part, from marine sediment and sea water by processes related to a fluctuating water-table, this latter probably due to tidal movements or storms. Porous sediment particles float on a rising water surface within the micro-cavern and are plastered against the roof of the cavern. Following a lowering of the water-table some of these grains remain attached to the roof by surface water tension and are subsequently fixed by precipitation of aragonite cement. Droplets of water suspended from the roof of the micro-cavern create crystalline micro-dripstone.

III. SIMILARITIES AND DIFFERENCES BETWEEN MARINE AND NON-MARINE TUFAS.

The marine encrustations on the Trucial Coast, both above and below beach rock layers, are very similar to those found around springs and within caves, their formation, in spite of the contrasting environments, probably having much in common. The association of sheet-like crusts, often with irregular drip-stone morphologies, and discreet grains, recalls the association of cave tufa and cave pearls. These latter, in common with the coated grains found in the supratidal zone, have irregular shapes which reflect the form of the nucleus. These marine encrustations differ from cave tufa in the following respects :

i. They are composed of microcrystalline or acicular aragonite; cave tufa most frequently consist of somewhat larger, bladed crystals of calcite (and occasionally of aragonite).

ii. The marine tufas have numerous micro-perforations made by endolithic algae or fungae; although similar perforations occur in cave tufa they seem to be much rarer.

iii. Marine tufa generally, but not invariably, encrust a marine substrate such as skeletal gravel or beach rock, and its setting is marine.

Both marine encrustations and those within caves and other terrestrial environments are forming in a vadose environment above the water table, and consequently both types exhibit drip-stone effects. The discovery of *marine vadose* encrustations indicates that one should not automatically equate vadose fabrics with a non-marine environment; the confusion may lead to the creation of non-existant unconformities and to interpretation of excessive degrees of paleo-emergence.