

EARLY DIAGENETIC FEATURES OF THE SCLERACTINIANS, PLEISTOCENE CORAL REEF, DAHAB (SINAI, EGYPT)

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ABSTRACT

Two kms north-east of Dahab, the northernmost remnant of emerged Pleistocene terraces display well preserved coral-reef and associated peri-reefal facies. The Scleractinian corals within the reef sequence display a series of diagenetic features formed by the alteration of the original micro-structures under different diagenetic conditions. Evidence from cement fabrics (aragonite and high-Mg calcite) suggests that the cementation took place exclusively in a phreatic marine environment. Meteoric diagenesis is indicated by traces of minor leaching and sparry calcite cement. Formation of microcrystalline dolomite and halite might take place in a sabkha environment. This suggests under various diagenetic alternation conditions.

Keywords: Sinai, Dahab, Pleistocene, reef terraces, Scleractinian corals, early diagenesis.

INTRODUCTION

The Egyptian coasts of the Gulf of Aqaba are characterized by a series of spectacular Quaternary and recent coral-reef terraces. The emerged Pleistocene coral reefs along the southern Sinai coast occur in two major sequences. They form two morphologically well defined reef terraces. They are situated at altitude ranging from +3 to +30m above the present sea level. The aspects of the diagenesis, geochemistry and carbonate facies of the Pleistocene reefs of the Red Sea and south Sinai coastal plain have been presented by a number of works (FRIEDMAN, 1968; GVIRTZMAN and FRIEDMAN, 1977; GVIRTZMAN et al. 1992; DULLO 1984, 1986, 1990; AL RIFAII and CHERIF, 1988; YOUSSEF, 1988; STRASSER et al. 1992, 1997; HEISS et al. 1993; FATHY and HAAS, 1994,1997). This publication contributes to the study of the northernmost small remnants of the younger Pleistocene reef sequence, 2 kms north-east of Dahab (*Fig. 1*). The study area is limited to a band of about 10 km in length, starting from Wadi Abu Ma' in the south and stretching northward toward El-Qardud. A corresponding younger reef sequence of south Sinai has been dated by STRASSER et al, 1992 between 140 and 60 ka BP which corresponds to isotope stage 5.

The identification of diagenetic alterations of Scleractinian corals in the emerged sequence which is in the focus of present study may allow the highlighting of sea level fluctuations and climatic changes which prevailed during the formation and diagenesis of the coral-reef system.

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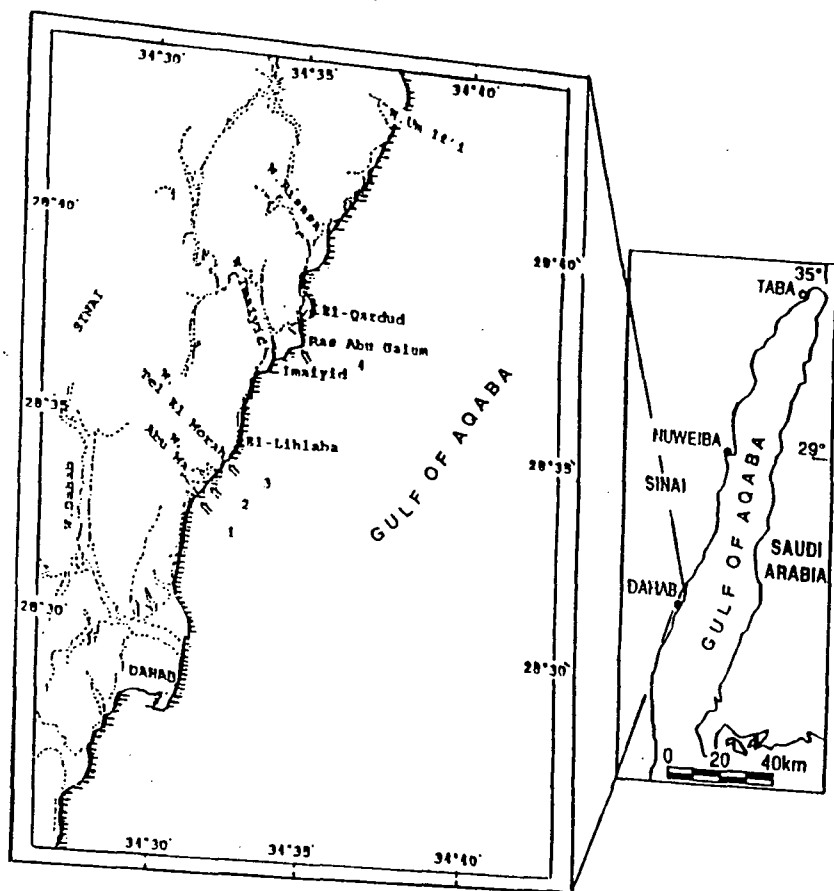


Fig. 1. Location map of the studied cross-sections

STRUCTURAL AND GEOMORPHOLOGICAL SETTINGS

The Red Sea system is generally referred to be a typical rift coast. The rifting has begun in the Late Oligocene. The Gulf of Suez has been started to form by extension and subsidence in the Early Miocene, but the extensional movements slowed down by the Middle Miocene. A left-lateral transform fault was then initiated along the Dead Sea - Gulf of Aqaba fault system (MAKRIS and RIHM, 1991). Some E-W extensional tectonics of Aqaba deformation occurred during the Plio-Quaternary (LYBERIS, 1988). In association with these movements uplift of the graben shoulders and block-faulting occurred and these are still active today (PURSER et al., 1990). GVIRTZMAN (1994) estimated the average uplift rate as $0.085 \text{ mm year}^{-1}$.

DESCRIPTION OF THE STUDIED SITES

The coast is a relatively narrow strip (from 100-600 m wide north of Dahab). At some places the basement relief is located in close vicinity of the shore. The coastal zone is generally covered by unconsolidated pebbles and coarse-grained beach rock. The composition, morphology and elevation of the beach rock indicates clearly its old origin. Locally it is composed of fanglomerates of the nearby crystalline rocks. They could be transported by floods of older wadis (for examples; wadi Abu Ma', wadi Tel El Morah and wadi Imaiyyid). The present occurrence of beach rock (at about 50 cm above the present sea level) suggests that the cementation process has been active during the latest period too. Remnants of the beach rock mark the old shore. Beach rock and unconsolidated pebbles cover the Holocene fossil reef flat which is about 50 cm to 1 m above the mean sea level (*Fig. 2* and *Fig.-s 3a* and *b*). By now both the reef flat and the beach rock are strongly eroded and bored by intertidal organisms. The studied coast is of particular importance as a clear indicator of the previously higher sea level or a regional tectonic uplifting in the last few thousand years. Unfortunately, radiometric dating has not been done for the Scleractenian corals.

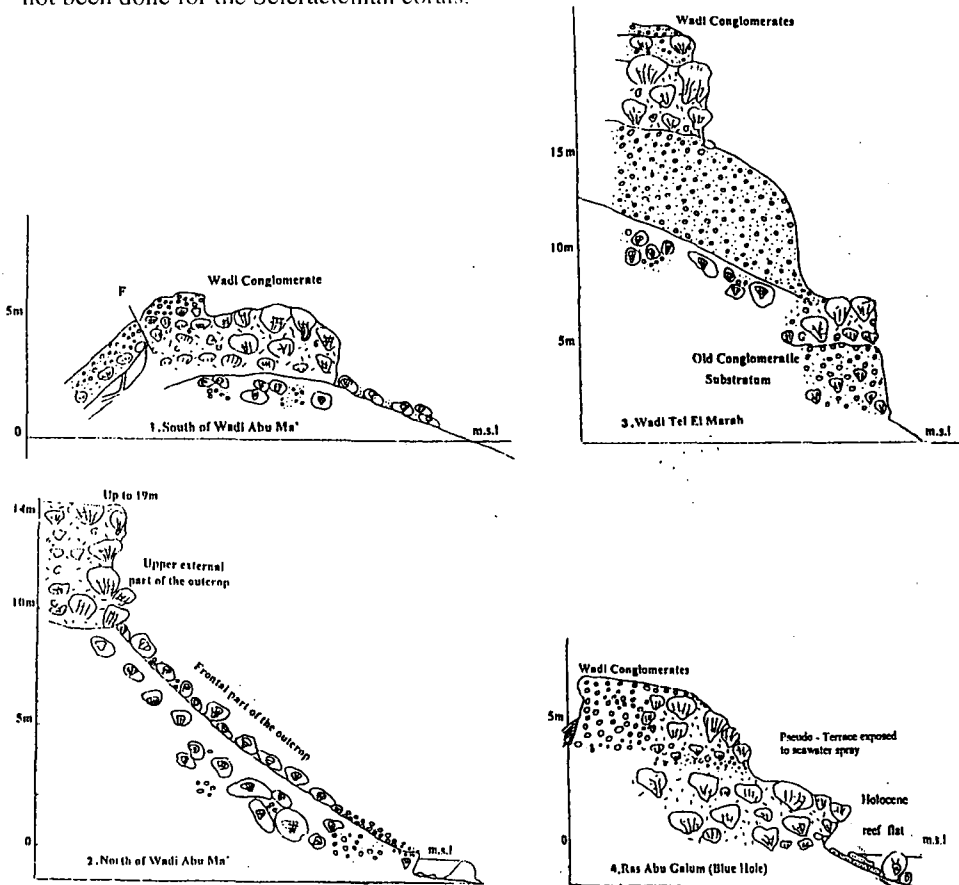


Fig. 2. Sketches of studied cross sections for the last Pleistocene terrace and Holocene reef flat, Dahab, Sinai



Fig. 3a (explanation is on the page)



Fig. 3b (explanation is on the page)

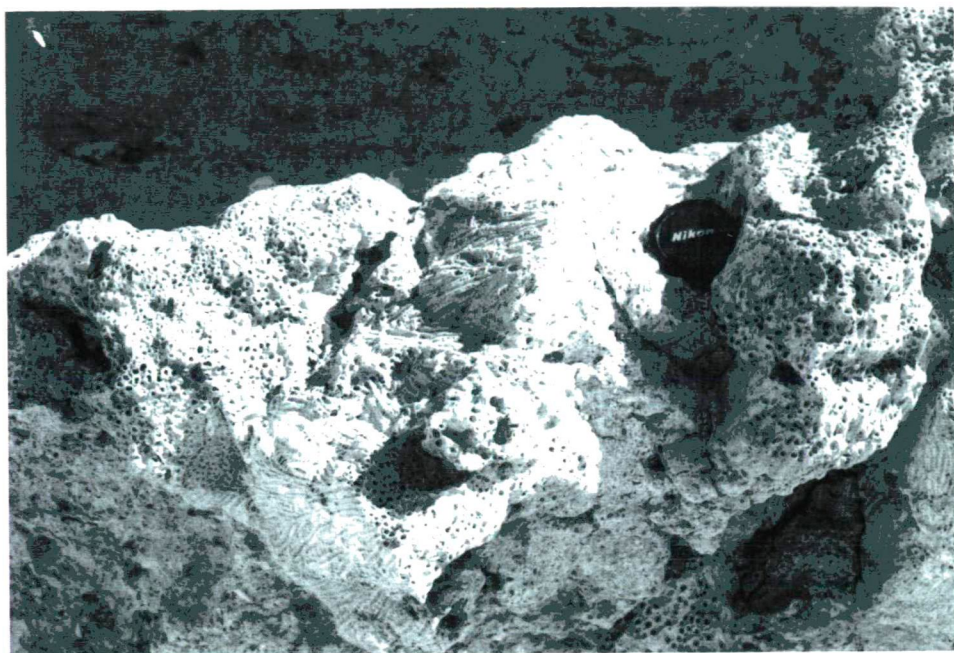


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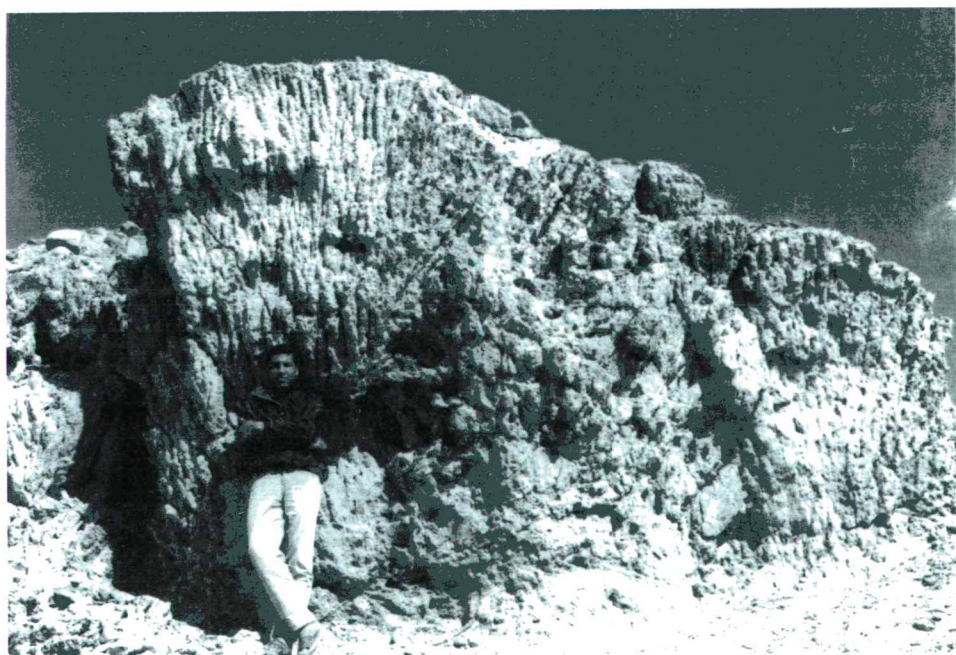


Fig. 3d (explanation is on the page)

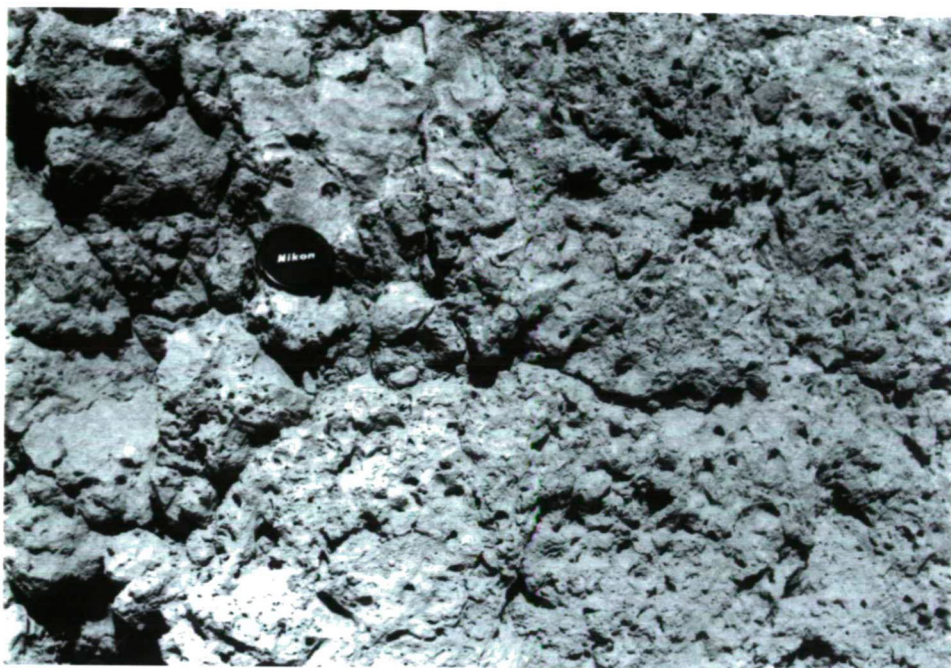


Fig. 3e (explanation is on the page)

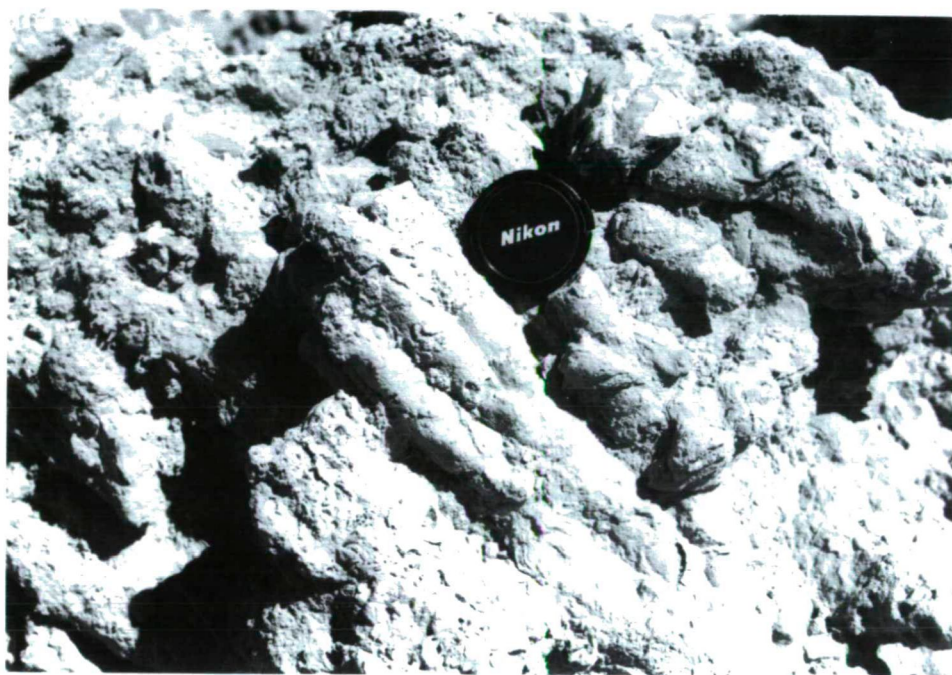


Fig. 3f (explanation is on the page)

Fig. 3. Outcrop Photographs. (a) General view to the south, north of Blue Hole. Holocene fossil reef flat completely emergent at low tide. Rocky beach backed by Late Pleistocene reef. (b) Ras Abu Galuuni. The whole outcrop belongs to only one reef but cementation of the lower 2m by sea water spray produced a bench or a pseudo-terrace by differential erosion. (c) Constructed reef facies, with massive coral colonies of *Favia Pallida*, more or less in-situ., section 3. (d) The giant coral colonies of the upper part of the outcrop indicate the fastest rise of relative sea level and maximum flooding, section 1. (e) Fine grained facies rich in encrusting red algae (arrow) which show white in the outcrop, section 3. (f) Constructed reef facies with corals and vermetid gastropods (arrow) indicate the beginning of the transgression, section 2.

The present study is based on four examined cross-sections from Wadi Abu Ma' to El-Qardud (Fig. 2). They belong to one major coral reef sequence which corresponds to the lower (younger) reef sequence in South Sinai and Ras Mohammad area attaining an altitude of 3-15m above the mean sea level (FATHY and HAAS, 1994, 1997). In the studied sections, at Dahab the sequence contains two small, sub-sequences of meter scale: (1) Reefal facies which comprises large coral communities, reflecting the maximum transgression and elevation of sea-level (Fig. 3c and d) (2) Lagoonal facies with isolated corals, bivalves, gastropods and red algae, indicating sedimentation in a low-energy area, in a lagoon on the reef flat (Fig 3e and f). Coral rubbles and/or terrigenous beds (gravel- and boulder conglomerates) separate the sub-sequences from each other and their presence indicates a lowering sea-level. Vermetid gastropods typically occur at the transgressive surface.

South of Wadi Abu Ma', the coral terrace is estimated at 6 m above the mean sea level. The top of this terrace is covered with 1 m of terrigenous fanglomerate. The thickness of the siliciclastic input decreases seaward. This section is cut by a recent faulting (N20W/75SE) which caused the drop of the western block (Fig 2). To the North the reef terrace attain up to 19 m in altitude above the mean sea level. At Wadi Tel El Marah site the section was uplifted to higher altitudes than elsewhere on the studied coast. It begins with a 3m thick coarse old conglomerate bed which is possibly the substrate of the reef sequence. The terrace is located at about 8 m above the mean sea level at Ras Abu Galum. In all sections (Fig. 2), the fanglomerates prograde over the carbonates which are replaced seaward by coral rubbles.

The framework of the reefs usually consists of very large coral colonies in growth position, showing a coarsening trend upwards. Giant coral colonies (0.5-2m in length) are common at the upper external part of the succession. Coraline algae are the dominant frame-building organisms in the sequence, beside a mixture of bioclastic grains, detrital quartz and granitic grains. The most abundant Scleractinians are the following: *Porites lutea*, *P. solida*, *Goniastrea pectinata*, *Favia Pallida*, *F. speciosa*, *Galaxea aspicularis*, *Stylophora pistillata*, *Platygeria dedalae*.

LABORATORY METHODS

25 coral samples have been taken from the examined cross-sections. Thin sections were made from all samples and stained with Feigl's solution for distinction between aragonite and calcite and with Alizarine Red-S for separation of calcites and dolomites (FRIEDMAN, 1959). Ten samples of the selected corals were broken, cleaned with distilled water and pressured air and coated with gold for scanning electron microscopy. For SEM investigations AMRAY- 1830I was applied, EDAX detector, PV 9800. The mineralogy of cements was confirmed with the energy dispersive spectrometer (EDS) on samples prepared for SEM.

Bulk X-ray analyses were performed on all samples with X-ray diffractometer Philips PW 1710 Goniometer, employing CuK α radiation at 40 kV/30 mA (scanning speed: 2° min⁻¹).

For the geochemical investigations major and trace element analyses were carried out on 6 samples. The carbonate fraction of the bulk-rock samples was extracted by 1N HCL, following the procedure worked out by ROBINSON (1980). The solutions were analysed for major elements (Ca, Mg) and trace elements (Sr, Na, Fe, and Mn) using JY-70 ICP-OEs spectrometer.

DIAGENETIC FEATURES

The selected Scleractinian corals were collected along the whole sections. Most of them are located directly at the coast, exposed to the sea water spray and storm waves. The studied Scleractinians show no alteration of the primary microstructure. The marine aragonitic fibrous cement has also been preserved. This cement consists of aragonitic needles, which were grown either onto the trabecular structure of the corals or syntaxially, projecting from the micritic envelopes into the primary pore spaces. The high Mg-calcite and aragonite cements strongly suggest that the early cementation took place exclusively in a phreatic marine environment.

The change from the marine depositional environment to the meteoric diagenetic environment was due to subaerial exposure of the reefs, it is indicated by minor leaching of the trabecular centers (*Fig. 4a*). Subsequently, the vugs, that had been formed by leaching, were lined by newly formed sparry calcite and the relics of the primary aragonite microstructure in the periphery of the septa (*Fig.-s 4b,c*). In some interseptal pores, original aragonite needles, peloids and trapped terrigenous grains were preserved. The sediment infilling generally avoided the dissolution, although a few of the particles have been dissolved. The thin micritic envelopes, that form a thin substratum for the micritic cements were resistant against dissolution.

Microcrystalline calcian dolomite crystals appear as small surfacial rhombs, of about 5-10 μ m in size. They grow over the earlier Mg calcite and developed in the interstitial voids among the trapped terrigenous grains (*Fig.-s. 4d,e*). The association of aragonite, Mg calcite and microcrystalline dolomite with halite (*Fig.-s 4d,e and f*) suggest an evaporative-sabkha origin of these dolomites.

GEOCHEMISTRY OF CORAL SKELETONS

The most significant properties of the Pleistocene Scleractinian corals from Dahab's sequence (IBTEHAL, in press), are:

(1) In the studied fossil corals, carbonates (*Fig. 5*) were represented mainly by aragonite, low and high Mg-calcite, and protodolomite. The amount of protodolomite is relatively low (4-6%). Evaporites (halite and gypsum) were also identified (2-26%).

(2) Sr ranges between 8,000 and 9,500 ppm, 8,575 ppm in average. It falls within the field of values reported for marine aragonite (7700-10,000 ppm, AISSAOUI, 1985). It means that the Sr content in corals was influenced by Sr content of the precursor carbonates.

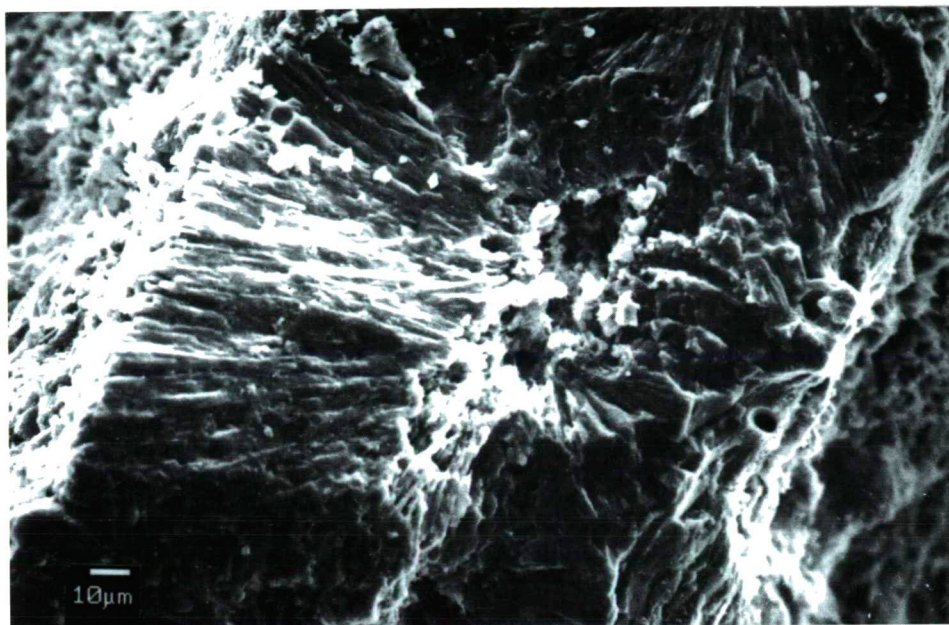


Fig. 4a (explanation is on the page)

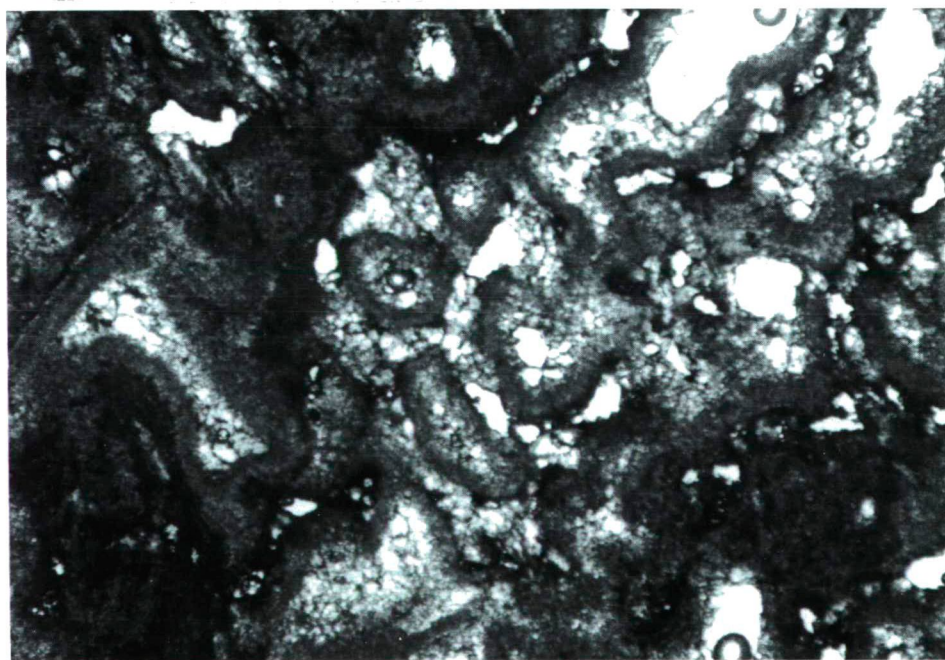


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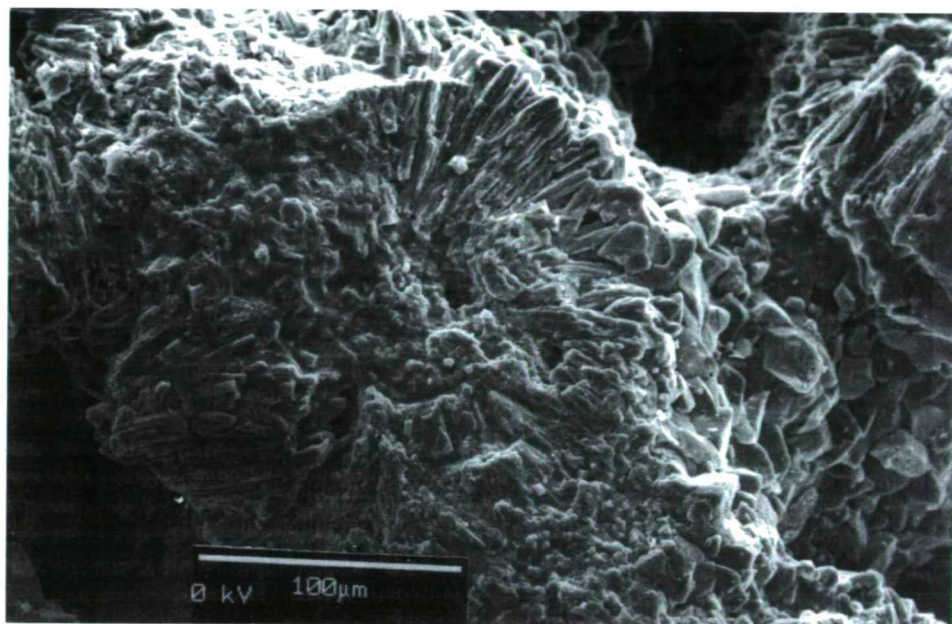


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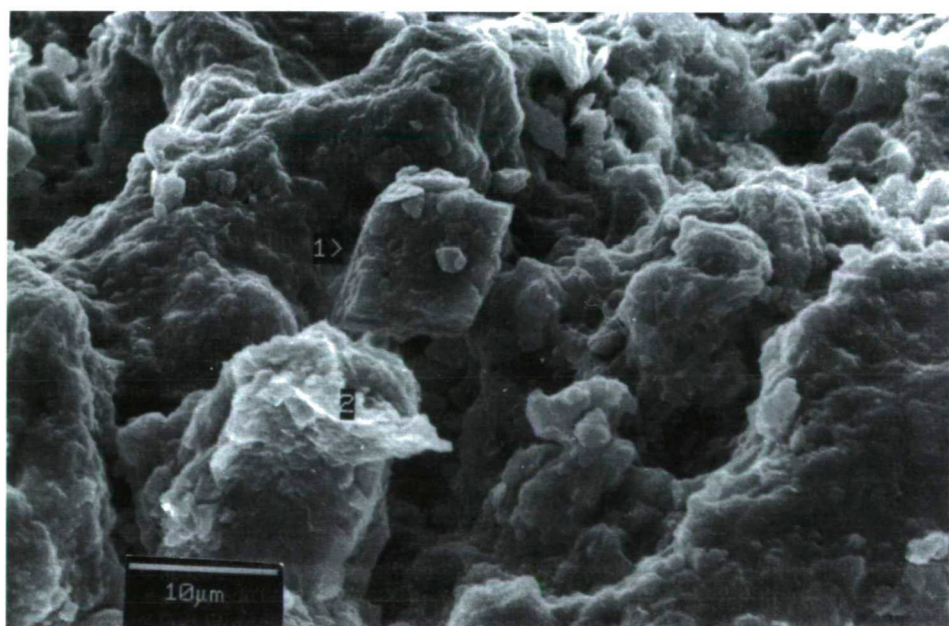


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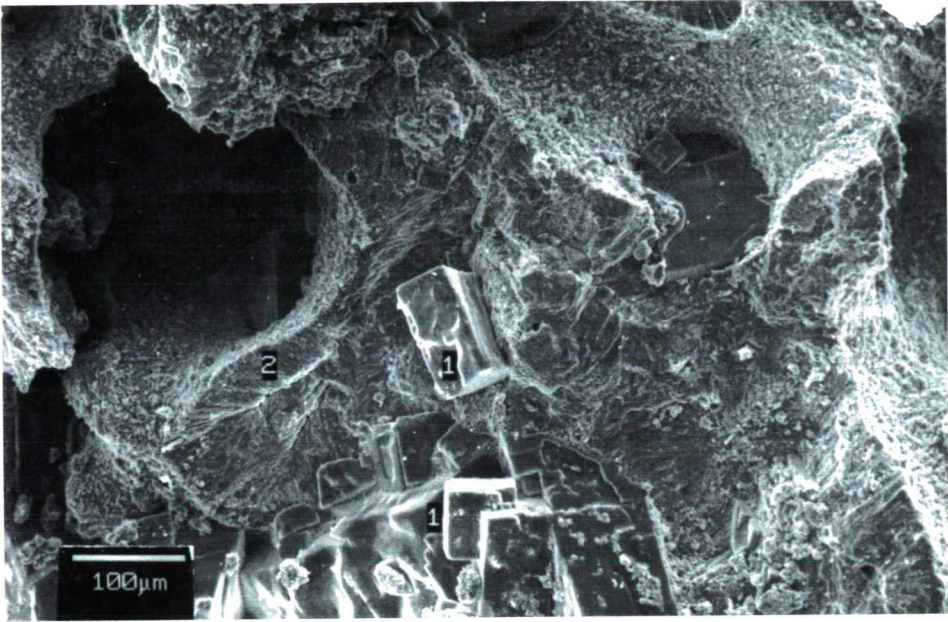


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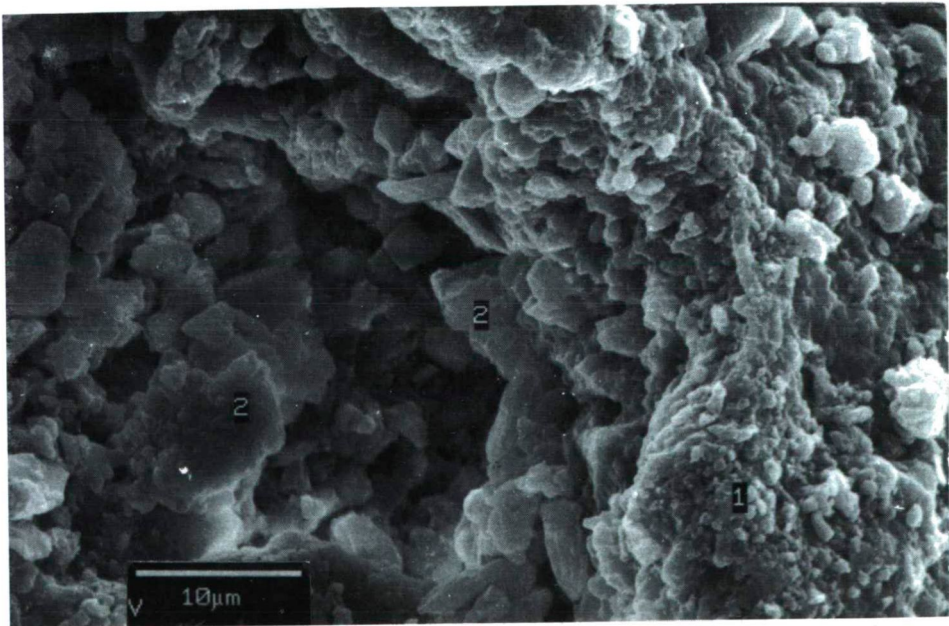


Fig. 4f (explanation is on the page)

Fig. 4. Diagenetic features, stained thin section photomicrographs are taken in non-polarized light. (a) Leached trabecular centers of *Porites Lutea*, suggesting a meteoric diagenetic environment. (b) The centers of the leached septa were lined by newly formed blocky calcite. The relics of the primary aragonite microstructure occur in the periphery of the septa. Thin section, 25X. (c) Coarse low-Mg calcite cement binds the partial preserved coral sclerodermite. SEM. (d) Microcrystalline dolomite crystals 1 developed in the interstitial voids between the trapped terrigenous grains (2, clay minerals) SEM. (e) Microcrystalline Mg calcite 2 are overgrown by microcrystalline dolomite crystals 1, SEM. (f) The original aragonitic structure of sclerodermite disappeared and has been replaced by large crystals of halite. This is the same sample as in (e), thus showing co-existence of aragonite, dolomite and halite.

(3) Na values are surprisingly high (between 7,000 and 7,900 ppm, with average 7,425 ppm); this was certainly influenced by the precipitation of halite cement, derived from evaporation of marine water during dolomitization.

(4) Ca (with average 46.7 %) and Mg contents (with average 0.38 %) show a negative correlation with each other.

(5) Fe ranges between 140 and 322 ppm, 240 ppm in average. Mn content ranges between 8 and 23 ppm. Fe and Mn values are relatively low at the Dahab fossil corals in accordance with surface dolomitization where Fe and Mn are locked up as oxide/hydroxide compounds.

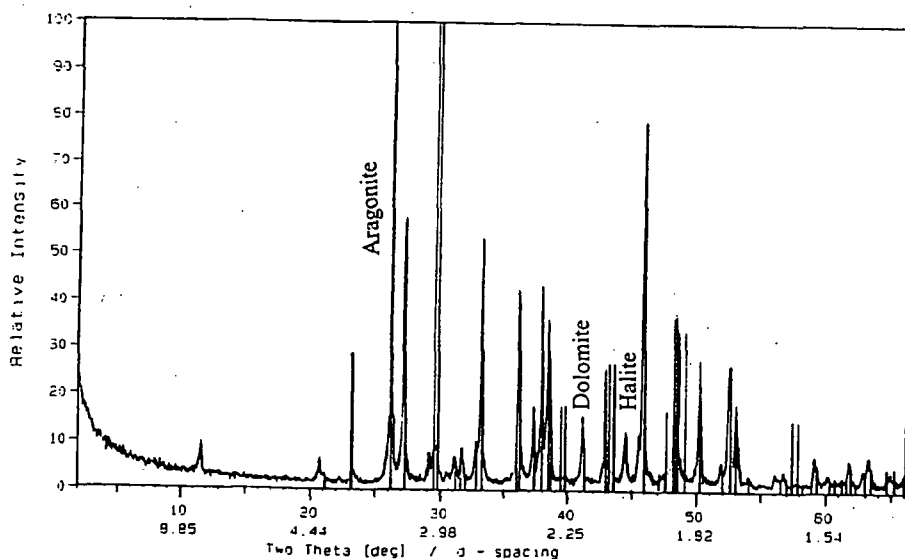


Fig. 5. X-Ray powder diffraction analysis of coral skeleton

CONCLUSIONS

At the Egyptian shoreline of the Gulf of Aqaba, 2 kms NE of Dahab, remnants of Pleistocene coral reefs are preserved. They represent one major depositional sequence corresponding to the lower reef sequence of South Sinai which was formed during the eustatic sea-level high of isotope stage 5 (HAYS et al., 1976 and STRASSER et al., 1992). Tectonic elevation of the Dahab's sequence may also be supported. It exhibits planations at 6 m, 8 m, 15 m, and 19 m, which are traceable all over the studied coast. The latter

two steps were probably formed by tectonic erosion (with respect to a reference level of +6 or +8 m). Planation within the contemporaneous lower reef sequence of South Sinai occur at 3 m, 5 m, 8 m, 10 m, 13 m and 15 m above the present sea level (FATHY and HAAS, 1994, 1997). This suggests a slow recent uplift of the Gulf of Aqaba coast.

The Scleractinian corals within the emerged Pleistocene reef sequence reveal a complex pattern of early diagenetic features. The general succession of diagenetic events indicates several short-term sea level oscillations and low-grade climatic changes. Main types of diagenetic evolution are as follows:

a. Precipitation of marine cements (aragonite and high-Mg calcite) occurred contemporaneously or just after the construction of the reefs during the major sea-level highstands.

b. Minor leaching and precipitation of meteoric low-Mg calcite cements took place mainly at a lower sealevel.

c. Poorly ordered and calcium-rich dolomites in association with evaporites (halite and gypsum) formed under the surface of the wide tidal flat. It means that during stillstand or slight fall of sea-level, and under arid climate, intertidal/supratidal evaporative and reflux dolomitization by marine water took place. Such short-term regression with arid climate were favourable for the precipitation of evaporites.

It is likely that the reefs developed during sea level highstands. The diagenesis of coral reefs took place under warm and arid climatic condition which was punctuated by wet periods.

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