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Messinian coral reefs and erosion surfaces in Cabo de Gata (Almeria, SE Spain)

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SUMMARY

Excellent exposures in Cabo de Gata area reveal two major Messinian depositional sequences, the Reef Complex and the Terminal Complex, which are overlying a complicated erosional morphology with several terraces on the volcanic basement. A typical *Porites* reef developed on the 200 m platform and originated extense fore slope deposits adosed to the terraced volcanic basement. This Reef Complex is severely truncated by an important erosion surface, which also presents a terraced morphology (80, 160, 220 m) and follows similar trends than the erosion surface on the volcanic basement. This intra-Messinian erosion surface is onlaped by the Terminal Complex, consisting in alternating layers of oolites, stromatolites and *Porites* thickets. Hypothetically, layers of evaporites could had been associated to the stromatolites in the lower section of the Terminal Complex before the pre-Pliocene erosional episode.

RESUMEN

Arrecifes coralinos messinienses y superficies de erosión en el Cabo de Gata (Almería, SE de España).

Los excelentes afloramientos de este area revelan dos grandes secuencias deposicionales en el Messiniense, el Complejo Arrecifal y el Complejo Terminal, las cuales recubren una complicada morfología erosional con varias terrazas sobre el basamento volcánico. En la plataforma de 200 m se desarrolló un típico arrecife de *Porites* que originó extensos depósitos de talud adosados a las terrazas del basamento volcánico. Este Complejo Arrecifal está profundamente truncado por una importante superficie de erosión, la cual también presenta una morfología de terrazas (80, 160, 220 m) siguiendo una tendencia similar a la superficie de erosión sobre el basamento volcánico. Esta superficie de erosión intra-Messiniense está solapada expansivamente (onlapada) por el complejo Terminal, el cual consiste en capas alternantes de oolitos, estromatolitos y biostromas de *Porites*. Hipotéticamente, en las partes más bajas del Complejo Terminal, capas de evaporitas pudieran haber estado asociadas con los estromatolitos antes del episodio erosional pre-Plioceno.

INTRODUCCIÓN

Upper Miocene coral reefs in SE Spain have been briefly mentioned by several authors (Völk and Rondeel 1964, Perconig 1973, Montenat 1973, 1975, 1977, Addicott et al. 1978, and others) with the main emphasis on their stratigraphic situation. These coral reef exposures are of maximum interest because they have recorded the succession of events related to the widely debated «Messinian crises», and also because of the excellent exposure conditions allowing detailed sedimentological analyses to be made. Only few authors attempt to study the sedimentological (Dabrio 1974, 1975) or diagenetic (Armstrong et al. 1977) particularities of a few small reef localities in Almería Province.

Joint field work started in 1975 as part of a large scale project with other collaborators in the areas of Balearic Islands, Alicante and Murcia and the first results were published in Esteban et al. (1977 a,b), Esteban and Giner (1977 a, b), Dabrio and Martin (1977). The main point was the uniformity of the reef facies model in spite of the variety of ecologic settings, and the presence of so-called «aberrant» paleoecological features related to the Messinian crises. Esteban (1979) enlarged the area of study to all the western Mediterranean showing: (1) the generalized reef models, (2) the importance of erosional episodes before, during and after the Messinian, (3) geometric relationships of the Reef Complex and evaporites, (4) the presence of a distinctive carbonate unit, the Terminal Complex, formed by oolites and stromatolites (and other lithologies) onlapping the eroded Lower Messinian Reef Complex and truncated by the Pliocene. The most common type of Messinian reef is described by Dabrio et al. (in press) in Níjar (Almería), a locality adjacent to Cabo de Gata.

The purpose of this note is to present our first results in Cabo de Gata, namely: (a) a first recognition of the total extension of the reef complexes in the area; (b) the particularities of the morphology of the Messinian erosion surfaces; (c) the influence of the erosion morphology of the basement in the development of Messinian facies; (d) the complexity in detail of the Messinian facies pattern in contrast to the simplified model of Esteban (1979).

GEOLOGIC SITUATION

Cabo de Gata is a Neogene volcanic complex (fig. 1) in the internal Betic Cordillera (see Julivert et al. 1974; Montenat 1973, 1975, 1977, for an introduction to general geology of the area). External volcanic forms, cones and volcano-sedimentary products are abundantly well preserved. Few wedges of the Triassic Betic basement (and Jurassic?) are locally present. Some volcanic eruptions occurred as late as Upper Miocene affecting the basal part of the Neogene marine sediments in a few localities. For the most part, the Neogene marine sediments onlap an irregular erosion

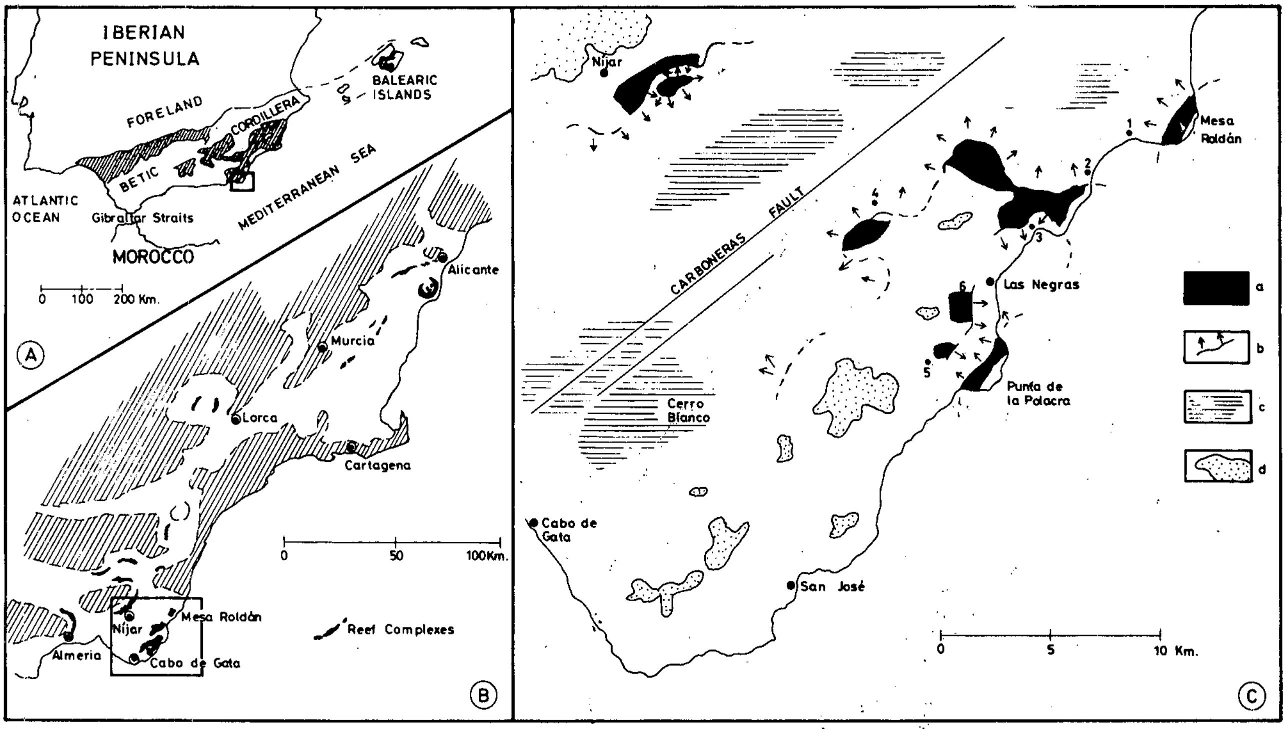

Fig. 1. Location of the Messinian Reef Complex of Cabo de Gata.
A: The area of Cabo de Gata (square block) in the Betic Cordillera. Shadowed areas correspond to major Neogene basins.
B: Messinian Reef Complexes in SE Spain.
C: Schematic Messinian paleogeography of the Cabo de Gata. a: Reef platform, b: fore-reef slopes, c: basinal marls and gypsum, d: volcanic hills over 300 m. 1: Agua Amarga, 2: El Plomo, 3: San Pedro, 4: Fernán Pérez, 5: Rodalquilar, 6: La Molata.

surface on the volcanic basement. The age of these sediments is sufficiently documented in Montenat 1973, 1975, 1977; Perconig 1973, Addicott et al. 1978, as Messinian and Pliocene, although older Miocene ages could be attributed to some volcano-sedimentary products.

The volcanic complex of Cabo de Gata was partly emergent during the Early Messinian, forming a complicate archipelago surrounded by deeper waters. The NW boundary of Cabo de Gata is a major fracture zone (trending NE-SW) active during the Neogene and Pleistocene, (Bousquet et al. 1975).

Fig. 2 is an adaptation of the generalized model of Esteban (1979) to the case of Cabo de Gata. In the coastal areas the Messinian section is subdivided into two depositional sequences separated by a regional erosion surface: (1) the Reef Complex, and (2) the Terminal Complex. In the basinal areas, Decima and Wezel (1973) and Montadert et al. (1978) recognized a Marine Unit (pelagic and turbiditic sediments) overlaid by an Evaporite Unit. The Evaporite Unit is subdivided into a Lower Evaporite Unit (with thick halite deposits, gypsum, turbidites, etc...) and the Upper Evaporite Unit (gypsum cycles with marine and brackish water marls). The Lower Evaporite grades upslope into the «Calcare di base» of the Italian authors (i.e. Decima and Wezel, 1973) and the Upper Evaporite Unit according to Esteban (1979) grades upslope into the Terminal Complex, onlapping the eroded Reef Complex. At least in the coastal areas, the Messinian deposits were emerged and severely eroded before the Pliocene transgression.

Considerable effort and polemic discussion has been devoted to the interpretation of the Messinian events, particularly to the problem of the Mediterranean paleodepths in the Upper Miocene. Data presented in this paper are not directly relevant to these questions, but show the complexity of the erosional episodes related to the Messinian. For that purpose, we offer a brief description of the Reef Complex of Cabo de Gata, followed by some key sections illustrating the position of the Terminal Complex and the erosion morphologies.

THE REEF COMPLEX

The Messinian Reef Complex of Cabo de Gata is exposed over a much wider area than previously considered. Fig. 1c, shows our provisional sketch on the paleogeography of the area. There are two major discontinuous reef alignments trending NE-SW, fringing circular to elongated volcanic highs. Most probably their NE-SW trends are structurally controlled, sensibly parallel to the major fracture of Carboneras. Of these two reef alignments, the western one is better preserved, while the eastern alignment is partly below the present day coastal waters.

The Reef Complex is partly dolomitized and consists of three major depositional facies, very similarly to most of the other Messinian Reef Complexes in the Western Mediterranean (see Esteban 1979):

(1) *Reef-wall framework:* Flat-lying, massive, mostly dolomitic limestone with the characteristic vertical sticks of *Porites* cf. *lobatosepta* with laminar horizontal expansions. Micrite submarine cements are volumetrically important contributors to the reef framework. In some protected areas or

towards the reef-flat there are abundant sticks of *Tarbellastrea eggenburgensis andalousiensis* (determination by Wells, in Addicott et al. 1978). The reef-flat and the rear zone of the reef contain small coral heads of *Tarbellastrea* and Porites.

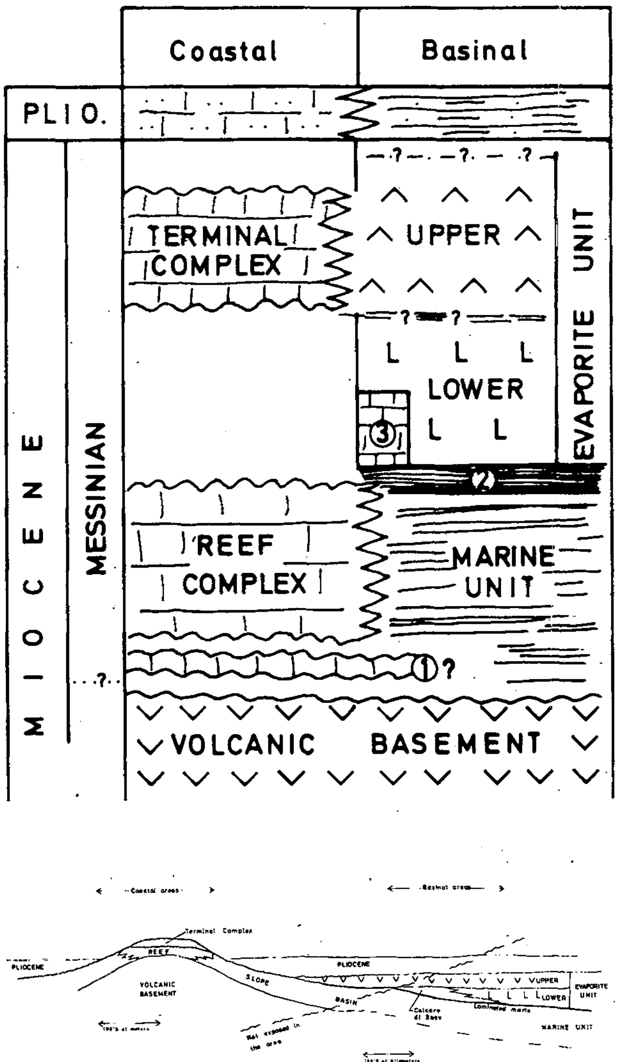

Fig. 2. Lithostratigraphic model of the Messinian of Cabo de Gata. A: Lithostratigraphic terminology. 1: bryozoan-rich wedge, 2: laminated marls, 3: «calcare di base». B: Inferred geometric relationships.

(2) *Fore-reef slope facies:* Giant-scale, cross-bedded strata with coral breccias, *Halimeda* packstones, abundant red algal sands and rhodoliths, shell layers with serpulids and vermetids... interfingering and grading down into bioturbated fine grained, white skeletal calcarenites and calcisiltites. At the toe-of-the-slope and basin transition, bioturbated calcisiltites and calcilutites predominate. The deep fore-reef slope usually contains fallen blocks from the reef-wall and upper reef-slope (fig. 3B). These blocks are pebble to large boulder in size (up to 20 m or more in diameter) and are typically confused with in place reef (patch-reef) framework (as in Addicott et al. 1977; see the correct interpretation of the same locality in Roux and Montenat, 1977). The reef-slope is up to 200 m in most of the area, indicating minimum water depths of this order. This is corroborated by the conclusions of Roux and Montenat (1977) studying the paleoecology of pedunculate crinoids in the reef-slope of El Plomo (200-500 m in water depth). Good exposures of the reef-slope occur practically all over the area, but the best are at La Molata and El Playazo (south of Las Negras), at Mesa Roldán and Rellana de San Pedro.

(3) *Back reef lagoon facies:* This depositional unit is poorly represented, absent in most of the Cabo de Gata, perhaps some small coral heads in La Molata and La Rellana could be considered as relicts of lagoonal (or upper reef-wall) deposits. The absence of good back-reef lagoonal exposures can be explained by the intense erosional episode at the base of the Terminal Complex, although in any case their original dimensions probably were very reduced (mostly fringing reef types).

The reef-wall framework is established on flat, subhorizontal erosional platforms directly overlying the volcanic basement, although in some localities there is a previous bryozoan-rich wedge (discussed below).

Our data reveal a remarkably constant altitude of these erosional platforms: 210-220 m along the coastal reef alignment, near 300 m in the internal trend. All our evidences suggest a gentle tilting to SE of the entire Cabo de Gata basement. It is interesting to note that the last reef-wall exposures in the area of Nijar (see Dabrio et al. in press) also occur at an altitude of 300 m; all these constant altitudes imply that since the Messinian time the activity of the Carboneras fault is mainly horizontal (as deduced in Bousquet et al. 1975). Several minor fractures occur across the Volcanic Complex of Cabo the Gata, but they do not seem to affect the position of the Reef Complex.

The extension and regular distribution of the Reef Complex in the northern half of Cabo de Gata is in contrast with the apparent lack of reef exposures to the SW of Rodalquilar. Volcanic hills of similar heigths are also present in the southern half of Cabo de Gata, but Messinian sediments seem to be predominantly deeper water in origin. A good exposure is Cerro Blanco, described by Montenat (1975, 1977) consisting of pelagic marls, diatomites, turbidites and Messinian evaporites. As a working hypothesis we assume that during the Messinian the southern half of Cabo de Gata was deeply submerged in relation to the northern half.

THE TERMINAL CARBONATE COMPLEX

This unit, defined in Esteban et al. (in prep.) and widely used by Esteban (1979), is a distinctive depositional sequence delimited, at its base and top, by two important emersion and erosion surfaces. The Terminal Complex overlies unconformably the Messinian Reef Complex in many localities all over the Mediterranean (see also Bossio et al. 1978; Catalano and Esteban, 1978; Pedley, 1979; Rouchy, 1979; Dabrio et al. in press.), and is itself overlaid by onlapping coastal marine Lower Pliocene sediments. Although there is no positive age determination, a Messinian age is attributed to the Terminal Complex on the basis of its lateral (downslope) relationship to the Messinian Upper Evaporite Unit (Esteban, 1979). A wide variety of lithologies can be present in the Terminal Complex, but the most common and characteristic are alternating strata of cross-bedded ooliths and layers (mostly biostromal) of large stromatolites (1-2 m in diameter).

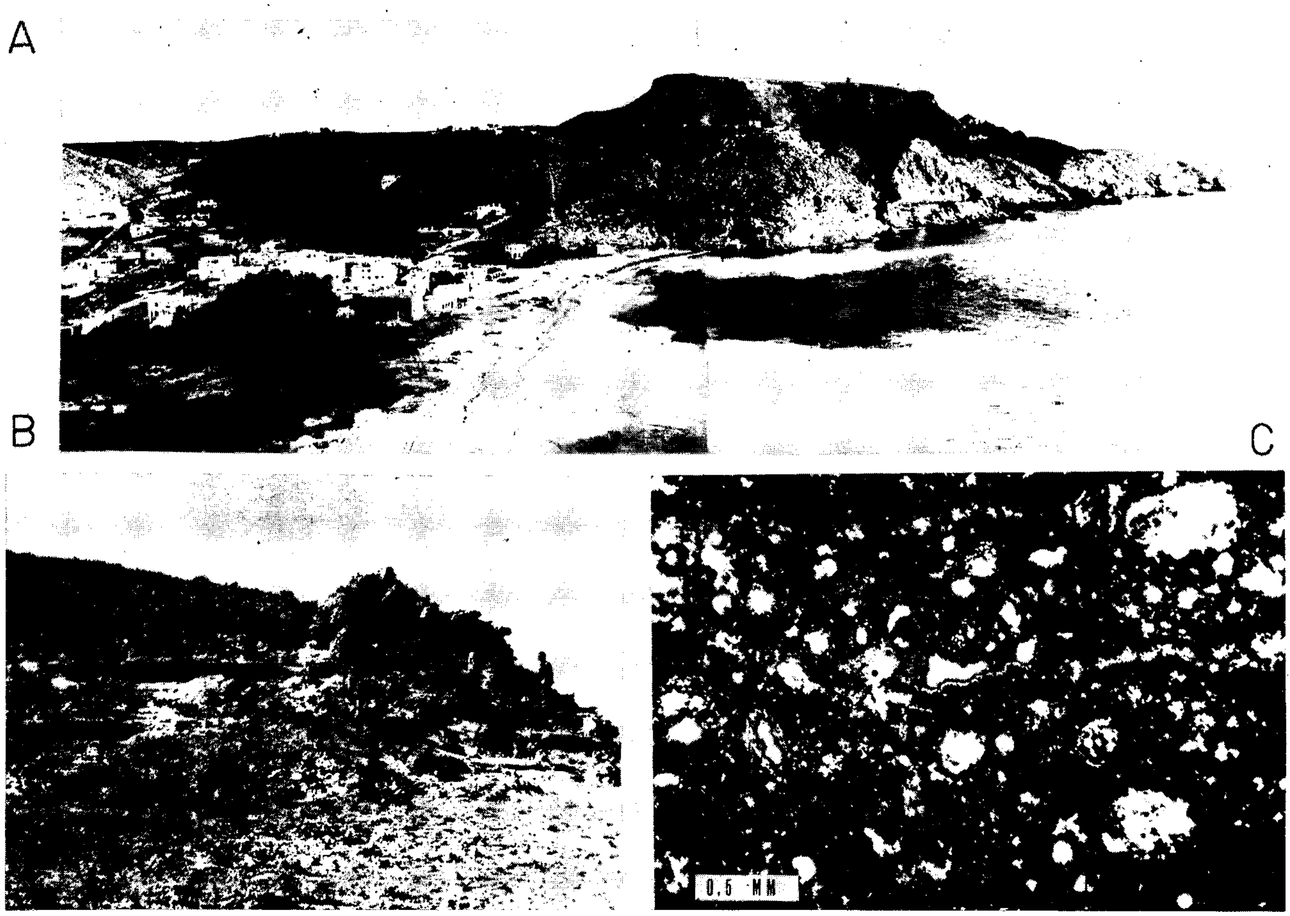

Fig. 3. Aspects of the Reef Complex in the area of Mesa Roldán -- Agua Amarga.
A: View of Mesa Roldán from Agua Amarga, see fig. 5 for geologic interpretation. Note the well developed plateaus at the top (220 m) and the terrace at 80 m. B: Flat-lying distal fore-slope basin transition with a large block slumped from the reef-wall. West of Agua Amarga. C: Rhizoliths in a pebble from the basal conglomerate of the Terminal Complex in peak 222 (fig. 4). The circular to elongated voids and sparry fabrics correspond to rootlet molds and partly calcified rootlets which are considered diagnostic of subaerial exposure.

In Cabo de Gata, exposures of the Terminal Complex are intensively dolomitized and rarely show more than 20 m in thickness due to intense erosion since its deposition. The erosional basal contact with the Reef Complex shows clear evidences of emersion such as pockets of terra-rossa, rhizoliths (fig. 3C), as for example in peak 222 of Mesa Roldán, La Molata, El Playazo. This basal contact is followed by a thin (less than 20 cm) conglomeratic layer formed by pebbles of the Reef Complex and the volcanic substrate. An interesting particularity is the presence of well-developped *Porites* thickets (biostromes) as occassional episodes in the sequence of oolite and stromatolite strata (Mesa Roldán, La Rellana). The general aspect of these *Porites* reefs in the Terminal Complex is undistinguishable from the reef-wall of the underlaying Reef Complex; however, their geometry and facies relationships are different (see cross-sections below). Silicified breccias and stromatolites, gastropod packstone and lamellibranch layers are other lithologies also present in minor amounts in the Terminal Complex of Cabo de Gata. Several erosion surfaces (more or less conspicuous) occur within the Terminal Complex, apparently separating stromatolite strata from the other lithologies.

The Terminal Complex of Cabo de Gata (and elsewhere) presents several features bearing important relationships with the Messinian crises. This are some of the major considerations:

A) The sedimentary structures of the oolithic calcarenites appear suggestive of effective tidal currents. Similar structures and interpretations occur in Mallorca, Malta and Turkey. This tidal interpretation would change the present day conception of a restricted Mediterranean basin in the Messinian time. However, Dabrio and Martin (1977), Roep et al. (1979) and Dabrio et al (in press), studying comparable sedimentary structures in the adjacent basins of Níjar and Sorbas, conclude that they originated in high energy shoals during storms. According to these authors, there is no need of a tidal interpretation.

B) The presence of *Porites* reefs in the Terminal Complex, also known from other areas (Tuscany, Santa Pola), poses many questions. As discussed in Esteban and Giner (1977 a,b) and Esteban (1979) the *Porites* of the Terminal Complex had to survive the generalized Lower Evaporite deposition in the Mediterranean, or migrated elsewhere. Alternatively, this survival of *Porites* could suggest that evaporite deposition was not synchronous all over the Mediterranean. These authors also indicated that the Terminal Complex has a marked cyclic character (from normal marine to hypersaline) and that 3-15 erosional episodes delimitate those cycles.

Deposition of the gypsum layers of the Upper Evaporite Unit probably occurred during these erosional episodes or during stromatolite growth.

C) The geometry of the Terminal Complex is more complicated than previously considered. The area of Cabo de Gata provides good exposures for extense lateral observation of the Terminal Complex and allows some important conclusions. For this purpose, we will study the main cros-sections of Cabo de Gata in the next chapter.

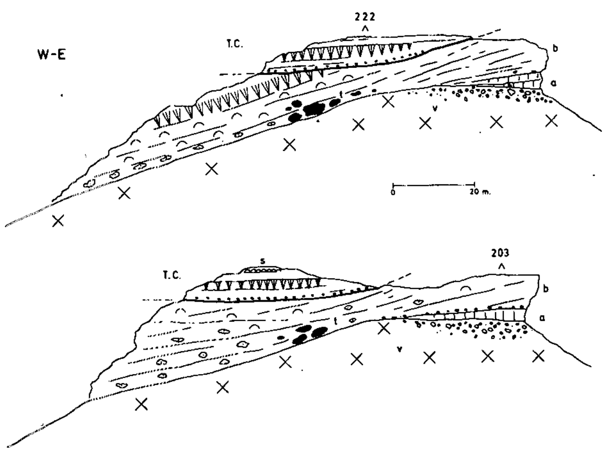

Fig. 4. Two cross-sections of Mesa Roldán: volcanic basement with conglomerates, a: bryozoan-rich wedge, b: fore-reef slopes of the Reef Complex, with *Halimeda* sands, slumped blocks of *Tarbellastrea,* (t), rhodoliths, shell layers and in-place *Porites.* T.C.: Terminal Complex, with *Porites,* oolitic skeletal sands and stromatolites (s).

KEY CROSS-SECTIONS

Most of the features of the Reef Complex and Terminal Complex, their geometry and related erosional episodes can be studied in three key cross-sections in Cabo de Gata, as detailed in the following paragraphs.

– *Mesa Roldán (fig. 4).* This outstanding volcanic promontoire offers very instructive sections of the Messinian carbonates. The Reef Complex is deeply eroded and only the fore-reef slopes remain in most of Mesa Roldán. However, reef-talus breccia and the lower part of the reef-wall are well exposed in the southern margin of Mesa Roldán along the access road to lighthouse. Fore-reef slopes consist of the characteristic sloping beds consisting of skeletal packstones with *Halimeda,* blackened rhodoliths, shell layers, coral rubble. In particular, this section illustrates:

(1) The contact between the volcanic basement and the Messinian carbonates. This is an irregular, undulating surface overlain by up to 1 m of volcanic pebbles (10-30 cm in diameter) embedded in lamellibranch-rich carbonates (also with organic borings, solitarian corals...). The character of this contact is quite constant all over the area, showing practically no variation between volcanic highs and valleys.

(2) The bryozoan-rich wedge. This unit occurs between the volcanic basement and the Reef Complex. Branching and nodular bryozoans are extremely abundant, together with different morphologies of red algae and a variety of lamellibranchs, oysters, gastropods and ahermatypic corals. Rock is a poorly cemented wackestone with interbedded white limemudstone layers. At the upper part, at the contact with the Reef Complex, burrowing is very intense and a thin (less than 10 cm) conglomeratic layer of volcanic and bryozoan pebbles is usually present. The bryozoan-rich wedge seems to occur in high volcanic plateaus and it is absent of the volcanic flanks.

(3) The pre-Terminal Complex erosion surface truncating the reef slopes. This erosion surface occurs as a flat surface and rapidly changes into a 30° dipping surface. The Terminal Complex overlaps this surface with a basal conglomerate (0.2-1 m thick) derived from the underlying Reef Complex and some volcanic pebbles. This conglomerate is coastal marine in origin with red algae incrustations and blocky spar cement, but also presents evidence of previous subaerial exposure (fig. 3c).

– *Mesa Roldán – Agua Amarga – La Rellana Section* (fig. 5). This is a long section following coastline exposures and allows a better understanding of the relationships between the morphology of the volcanic basement and the Reef and Terminal Complexes. The volcanic basement is eroded as a wide valley with erosional terraces; the highest terrace (200 m) supports the reef-wall framework and the reef slopes are adosed to the flanks of the erosional valley. In the area of Agua Amarga – Cala de Enmedio reef slopes show a practically flat bedding, but reef derived sediments (sands and blocks) are still common (Fig. 3B). Remains of the flat-lying Terminal Complex (with stromatolites, *Porites* reef and oolites) appear at the tops of the reef-wall and at lower positions truncating the reef-slopes at well-defined heights (220, 160, 80 m) progressively higher towards the NW. Fig. 5 illustrates the erosional morphology (terraces) on the volcanic basement controlling facies development of the Reef Complex. The pre-Terminal Complex erosion surface inherits a similar terraced morphology.

The Terminal Complex was intensively eroded before the deposition of the Pleistocene. The thin (1-3 m) layers of calichified coral and stromatolite breccia of fig. 5 are interpreted as relics of this erosional period. Most exposures of the Terminal Complex (mainly in low depositional sites) are intensively brecciated and silicified.

– *La Molata section* (fig. 6). The area of San Pedro – Las Negras – Rodalquilar and Fernán Pérez offer excellent exposures of the Reef Complex and the volcanic basement, allowing a detailed paleogeographic analysis. La Molata is one of the most representative sections summarizing the basic pattern facies of the Messinian carbonates of Cabo de Gata. The pre-Terminal Complex erosion preserves the lower part of the reef-wall in this section and does not show a marked terraced disposition. The base of the exposure of Terminal Complex at peak 126 shows gravitational displacement.

DISCUSSION

According to our present field data, the Messinian carbonates of Cabo de Gata represent the following sequence of events:

1. Erosion of the volcanic basement, with formation of terraces. However, this erosion was not intense enough to destroy several volcanic cones which are still preserved in the area. This episode is poorly understood, with locally important volcano-sedimentary deposits and volcanic activity as well (Rodalquilar area).

2. Pre-Reef Complex deposition. Previous to the major coral reef development, some volcanic plateaus were colonized by bryozoan-rich carbonates. These deposits can be

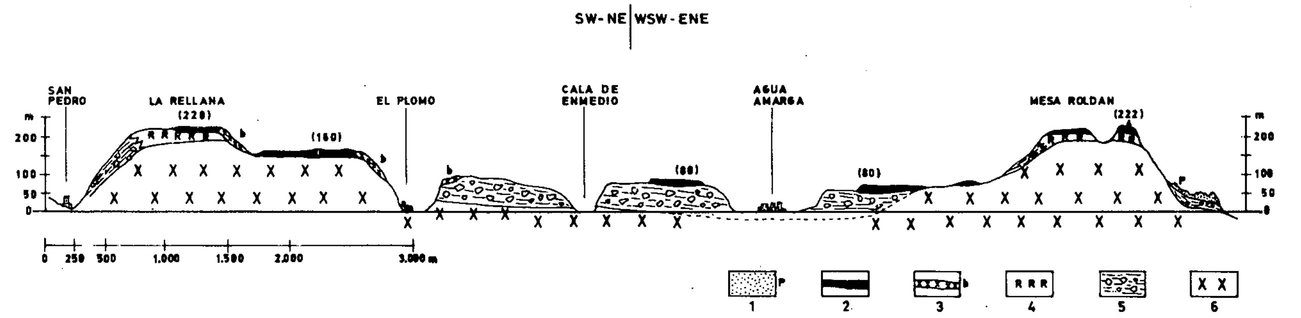

Fig. 5. Cross-section along the coast between Mesa Roldán and San Pedro. 1: Pliocene calcarenites (P), 2: Terminal Complex, 3: Pre-Pliocene breccias (b), 4: Reef-wall framework, 5: Fore-reef slopes, with slumped blocks from the reef-wall, 6: volcanic basement.

considered as originated in relatively deep water settings in the euphotic zone (submerged highs). The top of the bryozoan-rich carbonates present a 1-2 m thick reworking horizon before the development of the Reef Complex. This is interpreted as a submarine exposure surface, probably accompanied by local erosion (mainly on flanks) of the bryozoan-rich carbonates. With our present data we consider that these bryozoan-rich deposits occur simultaneously to mixed bioclastic-siliciclastic crossbedded reddish-brown sediments extensively exposed in the area W of El Plomo. These pre-Reef Complex deposits are markedly comparable in position and lithology to similar deposits in the area of Níjar (Dabrio et al. in press), and in both cases, their significance is poorly known.

3. Reef Complex development on the highest plateaus of the area (200-300 m). Reef-slopes occur adapted to the terraced morphology of the volcanic basement. Reef progradation can be recognized up to 2 km.

4. Intra-Messinian subaerial exposure. Before the deposition of the Terminal Complex, the Reef Complex was intensively eroded. Only the lower part of the reef-wall is preserved, and the upper reef-slopes are dismantled in many localities, exhuming the underlying terraced morphology of the volcanic basement. During this episode the Lower Evaporite, and perhaps part of the Upper Evaporite were deposited in the deeper parts of the Mediterranean basins. In the area here studied, we have no evidences of sediments attributable to the Lower Evaporite Unit. The references to «calcare di base-like» deposits of Dronkert et al. (1979) have to be considered in the sense of some lithologic similarities. In our intepretation they are considered as part of the Terminal Complex[1].

5. Deposition of the Terminal Complex, including *Porites* reefs, oolite shoals and stromatolites, on the intra-Messinian subaerial exposure surface. The Terminal Complex can be found overlying the truncated reef-wall, reef-slope or directly on the volcanic basement. The disposition of the Terminal Complex (figs. 4, 5) suggests a depositional onlap on the eroded Reef Complex. However, this implies the removal of large amounts of Terminal Complex deposits that would be filling up the depressions. The problem could be solved assuming that most of the Terminal Complex deposits filling up the depressions were evaporitic in nature (or mixed carbonate-evaporite) as illustrated in fig. 7. This hypothesis is in accordance with the general interpretation of the Terminal Complex in Esteban (1979). Some stromatolite strata are intensively brecciated with late replacements and infillings of chalcedony. Although we have not found length-slow varieties of chalcedony in our samples, this is not an obstacle to relate it to evaporitic environments. In contrast, some pedogenetic chalcedonies are length-slow (F. Ortí, personal communication). In our samples there are no evidences of pedogenetic fabrics associated to the silicified stromatolite breccias; we consider the brecciation and silicification in relation to evaporitic environments. Our interpretation is in contrast with the deep water interpretation of Montenat et al. (1978) for the silica-rich Messianian stromatolites in the adjacent basin of Sorbas.

6. Pre-Pliocene erosion. The Messinian carbonates were intensively eroded before the deposition of Pliocene marine sediments. This erosional episode produces deep incisions in the relict terraced morphologies. There is no record of marine Pliocene sediments at the top of the Messinian reef-wall (220 m).

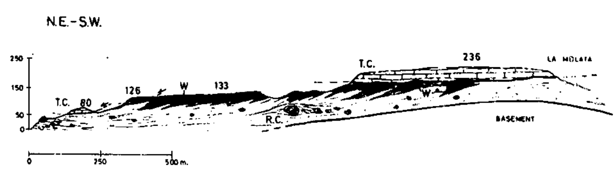

Fig. 6. Cross-section of La Molata. R.C.: Reef Complex with preservation of the Lower part of the reef-wall and the fore-reef slopes. W: Lower Reef wall-Upper Reef slope. T.C.: Terminal Complex.

The exposures of Cabo de Gata are an excellent example of facies control by erosional morphology on volcanic basement. Moreover, the major intra-Messinian erosional episode (pre-Terminal Complex), and perhaps the pre-Pliocene erosion as well, appear to reproduce a similar morphology. Due to (i) the erosional morphology of these surfaces, (ii) the scattered evidences of subaerial exposure and (iii) the abundance of coastal communities in the basal conglomerates of both Messinian sequences, it could be suggested that all these erosional surfaces originated as coastal marine planation terraces. In conclusion, sea level changes and still stands during Upper Miocene time could be the basic tool for understanding and predicting reef development in this area.

1. After acceptation of this manuscript, W. Martínez et al. (Hispanoil) presented a synthesis of the Neogene in the Mediterranean in the Meeting of Spanish Sedimentologist in Salamanca (October, 10 of 1980) concluding that there are important gypsum exposures as lateral equivalents of the Lower Evaporite Unit. Although more detailed documentation is needed, this would imply an important modification of our interpretation. On the ofther hand, comparable erosional terraces appear in their seismic profiles.

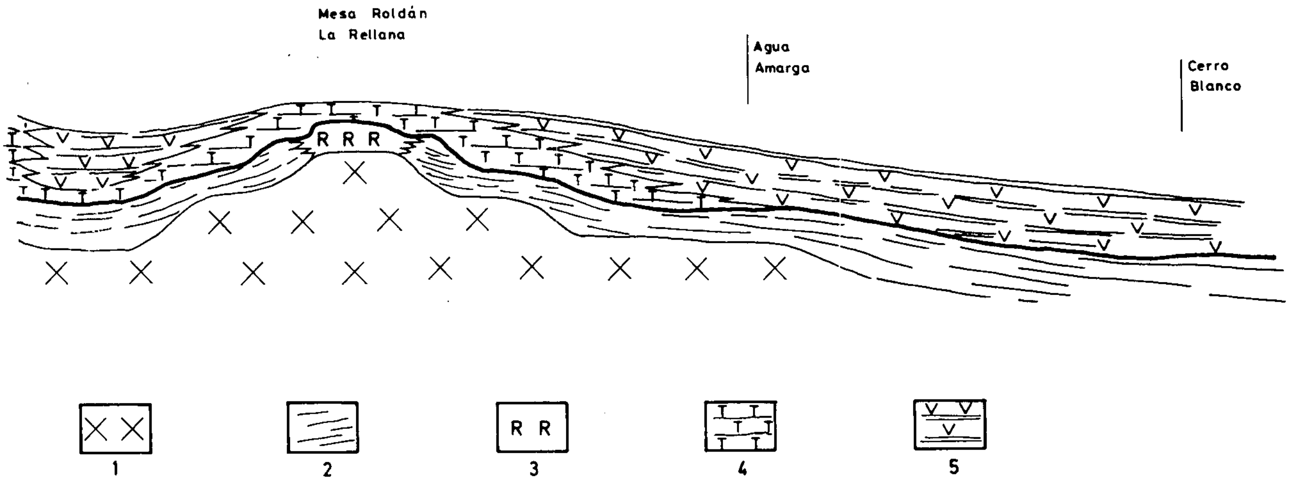

Fig. 7. Hypothetic interpretation of the relationship between the Terminal Complex and the evaporites before the pre-Pliocene erosion.
1: volcanic basement, 2: fore-reef slopes (Reef Complex), 3: Reef-wall framework (Reef Complex), 4: Terminal Complex, 5: Selenitic gypsum with alternances of marine to restricted sediments (skeletal sands, marls, stromatolites). Note the terraced morphology of the intra-Messinian erosion surface, inherited from the erosional morphology on the volcanic basement.

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REFERENCES

ADDICOTT, W. O., SNAVELY, Jr., P. D., BUKRY, D. and POORE, R. Z. (1978): «Neogene stratigraphy and paleontology of Southern Almeria province, Spain: an overview». *U. S. Geol. Survey Bull.* 1454, 49 p.

ARMSTRONG, A. L., SNAVELY, P. D. and ADDICOTT, W. O. (1977): «Porosity in late Miocene reefs, southern Spain». Abstract. *Am. Assoc. Petrol. Geol. Bull.* 61 (5): 761-762.

BOSSIO, A., ESTEBAN, M., GIANELLI, L., LONGINELLI, A., MAZZANTI, R., MAZZEI, R., RICCI-LUCCI, F. and SALVATORINI, G. (1978): «Some aspects of the Upper Miocene in Tuscany». *Messinian Seminar no. 4.* Rome, Guidebook, 88 p.

BOUSQUET, J. C., CADET, J. P. and MONTENAT, C. (1975): «Quelques observations sur le jeu quaternaire de l'accident de Carboneras (décrochement majeur senestre NE-SW des Cordillères Bétiques Orientales)». *3e Réun. Ann. Sci. de la Terre.* Montpellier, pag. 73.

CATALANO, R. and ESTEBAN, M. (1978): «Messinian reefs of Western and Central Sicily». Abstract. *Messinian Seminar no. 4.* Rome.

DABRIO, C. J. (1974): «Los niveles arrecifales del Neógeno de Purchena (S.E. Cordilleras Béticas).» *Cuadernos Geol.* 5: 78-88.

DABRIO, C. J. (1975): «La sedimentación arrecifal neógena en la región del río Almanzora». *Est. Geol.,* 31: 285-296.

DABRIO, C. J. and MARTIN, J. M., (1977): «Los arrecifes Messinienses de Almería (S.E. de España)» *Cuadernos de Geol. Univ. de Granada,* 8: 83-104.

DABRIO, C. J., ESTEBAN, M. and MARTIN, J. M. (in press): «The coral reef of Níjar, Messinian (Uppermost Miocene) Almería Province, SE Spain.» *Jour. Sed. Petrol.*

DECIMA, A. and WEZEL, F. C. (1973): «Late Miocene evaporites of the Central Sicilian Bassin» *in: Initial Reports of the Deep Sea Drilling Project,* 13: 1234-1244.

DRONKERT, H., VAN DER POEL, H. and GEERLINGS, L. P. A. (1979): «Gypsum deposits in the Province of Almeria. Consequences for the western Mediterranean». *Ann. Géol. Pays Hellen.* Tome hors série. (1): 345-354. VII International Congress on Mediterranean Neogene, Athens, 1979.

ESTEBAN, M. (1978): «Significance of the Upper Miocene reefs in the western Mediterranean». Abstract. *Messinian Seminar no. 4.* Rome.

ESTEBAN, M. (1979): «Significance of the Upper Miocene coral reefs of the western Mediterranean». *Paleogeography, Paleoclimatology, Paleoecology,* 29: 169-188.

ESTEBAN, M. and GINER, J. (1977a): «Field-guide to Santa Pola reef». *Messinian Seminar no. 3.* Field Trip, 5: 23-30. Málaga.

ESTEBAN, M. and GINER, J. (1977b): «El arrecife de Santa Pola» *in* R. Salas ed. *1er. Seminario Práctico de Asociaciones evaporíticas y arrecifales.* Universidad de Barcelona. Barcelona, 51 p.

ESTEBAN, M., CALVET, F., DABRIO, C. J., BARON, A., GINER, J., POMAR, L. and SALAS, R. (1977a): «Messinian (Uppermost Miocene) reefs in Spain: morphology, composition and depositional environments». *3rd. Int. Coral Reef Symp., Abstracts.* Miami, Fla.

ESTEBAN, M., CALVET, F., DABRIO, C. J., BARON, A., GINER, J., POMAR, L. and SALAS, R. (1977b): «Aberrant features of the Messinian coral reefs, Spain». *Messinian Seminar no. 3. Abstracts,* 5 p. Málaga.

JULIVERT, M., FONTBOTE, J. M., RIBEIRO, A., and CONDE, L. (1974): «Mapa tectónico de la Península Ibérica y Baleares». 1:1.000.000 Madrid. I.G.M.E. 113 p.

MONTADERT, L., LETOUZEY, J., and MAUFFRET, A., (1978): «Messinian Event: seismic evidence». In: *Initial Reports of the Deep Sea Drilling Projet,* 42 (1): 1037-1050.

MONTENAT, C. (1973): «Les formations néogènes et quaternaires du Lêvant espagnol (Provinces d'Alicante et de Murcia)». Thesis. University of Paris-Orsay. Paris. 1170 p.

MONTENAT, C. (1975): «Le néogène des Cordillères Bétiques; essay se synthèse stratigraphique et paleogeographique». *Centre. Nat. Rech. Sci. Publ.,* Paris, 187 p.

MONTENAT, C. (1977): «Les basin néogènes du levant d'Alicante et de Murcia (Cordillères Bétiques orientale – Espagne): stratigraphie, paléogéographie et évolution dynamique». *Doc. Lab. Géol. Fac. Sci. Lyon,* 69: 1-345.

MONTENAT, C., OTT, P. and VACHARD, D. (1978): «Stromatolithes silico-métalliques du Messinien d'Espagne méridionale». *Bull. Soc. géol. France.* XX (5): 773-777.

PEDLEY, H. M. (1979): «Miocene bioherms and associated structures in the Upper Coralline Limestone of the Maltese Island: their lithification and paleoenvironment». *Sedimentology,* 26: 577-591.

PERCONIG, E. (1973): «El Andaluciense». 13th Coloquio Europeo de Micropaleontología, España, 201-223.

ROEP. Th. B., BEETS, D. J., DRONKERTS, H. and PAGNIER, H. (1979): «A prograding coastal sequence of wave-built structures of Messinian age, Sorbas, Almeria, Spain». *Sediment. Geol.* 22: 135-163.

ROUCHY, J. M. (1979): «La sedimentation evaporitique messinienne sur les marges mediterraneennes» Ann. Geol. Pays Hellen, Tome hors serie III, 1051-1060 VIth Int. Cong. Medit. Neogene, Athens.

ROUX, M. and MONTENAT, C. (1977): «Sites à crinoïdes pédonculés et bathymétrie des bassins messiniens dans les Cordillières bétiques orientales (Espagne méridionale).» *Bull. Soc. géol. France.* XIX (2): 405-416.

VÖLK, H. R. and RONDEEL, H. E. (1964): «Zur gliederung des jungtertaärs in becken von Vera, Südost-Spanien». *Geol. Mijnb.* 43: 310-315.

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ADDENDA. After acceptation of this manuscript, we noticed the publication of a paper by A. K. Armstrong, P. D. Snavely and W. A. Addicott in the A.A.P.G. Bulletin, vol. 64, number 2 of 1980 entitled: «Porosity Evolution of Upper Miocene Reefs, Almeria Province, Southern Spain». This is an excellent photomicrographic description of porosity types in some Neogene carbonate sections in Cabo de Gata. We feel the need of the following comments: (i) Localities studied by these authors (northern slopes of Mesa Roldán and low sea cliffs between Agua Amarga and El Plomo) do not contain in-place coral framework nor patch-reefs, but distal fore-reef slopes with important accumulations of allochtonous blocks of reef-wall, (ii) the lithostratigraphic framework of Armstrong et al (1980) and Addicott et al (1978) is inadequate, incomplete and presents important internal contradictions (as already in part indicated by Dabrio et al. in press), and (iii) porosity evolution as discussed in Armstrong et al (1980) ignores the important role of intra-Messinian and pre-Pliocene sea level fluctuations. More detailed comments will appear in our discussion paper in the A.A.P.G. Bulletin.