SEDIMENTOLOGY OF THE NEOGENE ALMERÍA BASINS: AN ILLUSTRATED GUIDE.

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Sorbas basin

Stratigraphy. Neogene Sorbas Basin: infilling units and geometrical relationships

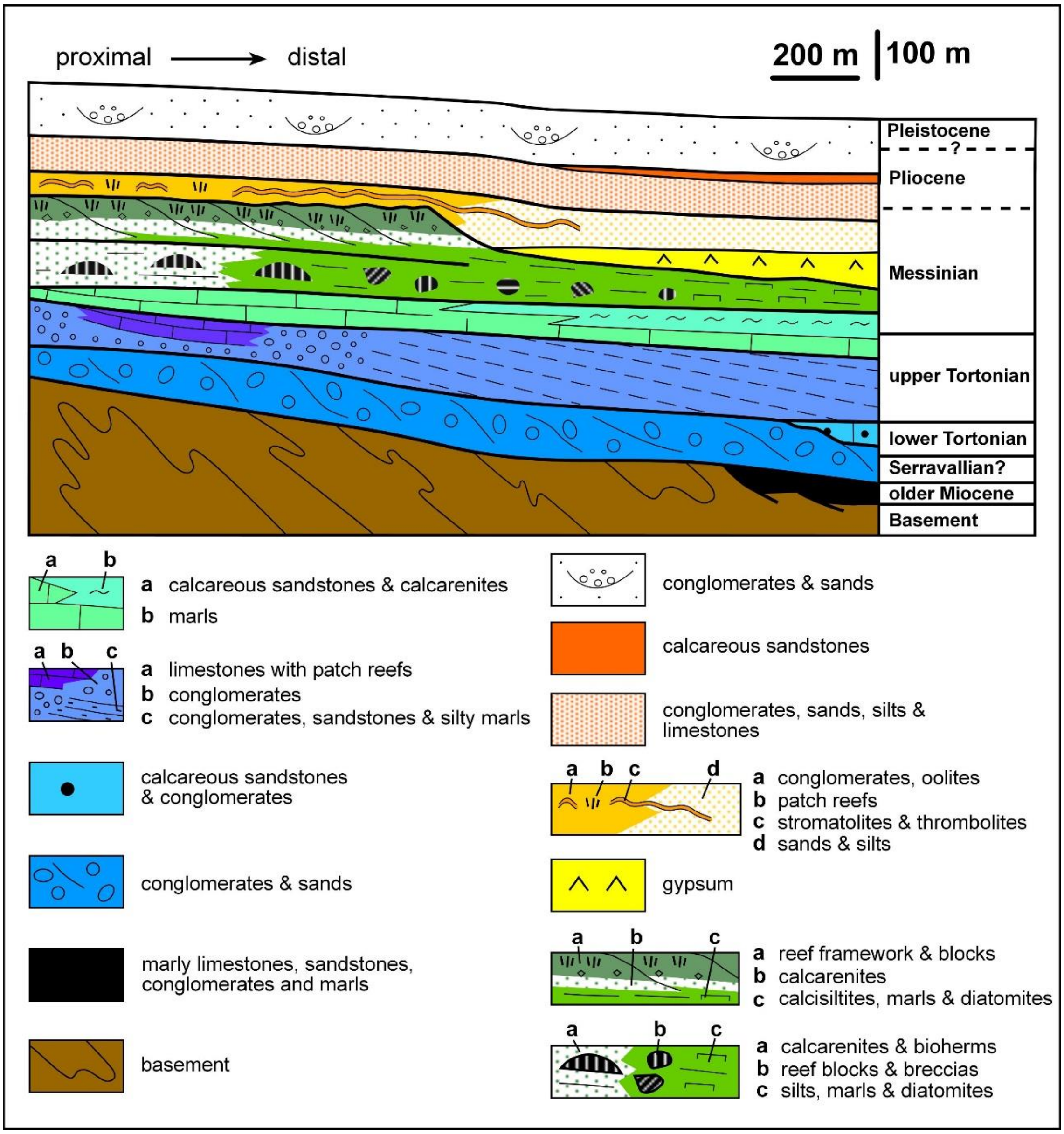


Figure 1. Miocene to Quaternary stratigraphy of the Sorbas Basin (modified after Martín and Braga, 1994).

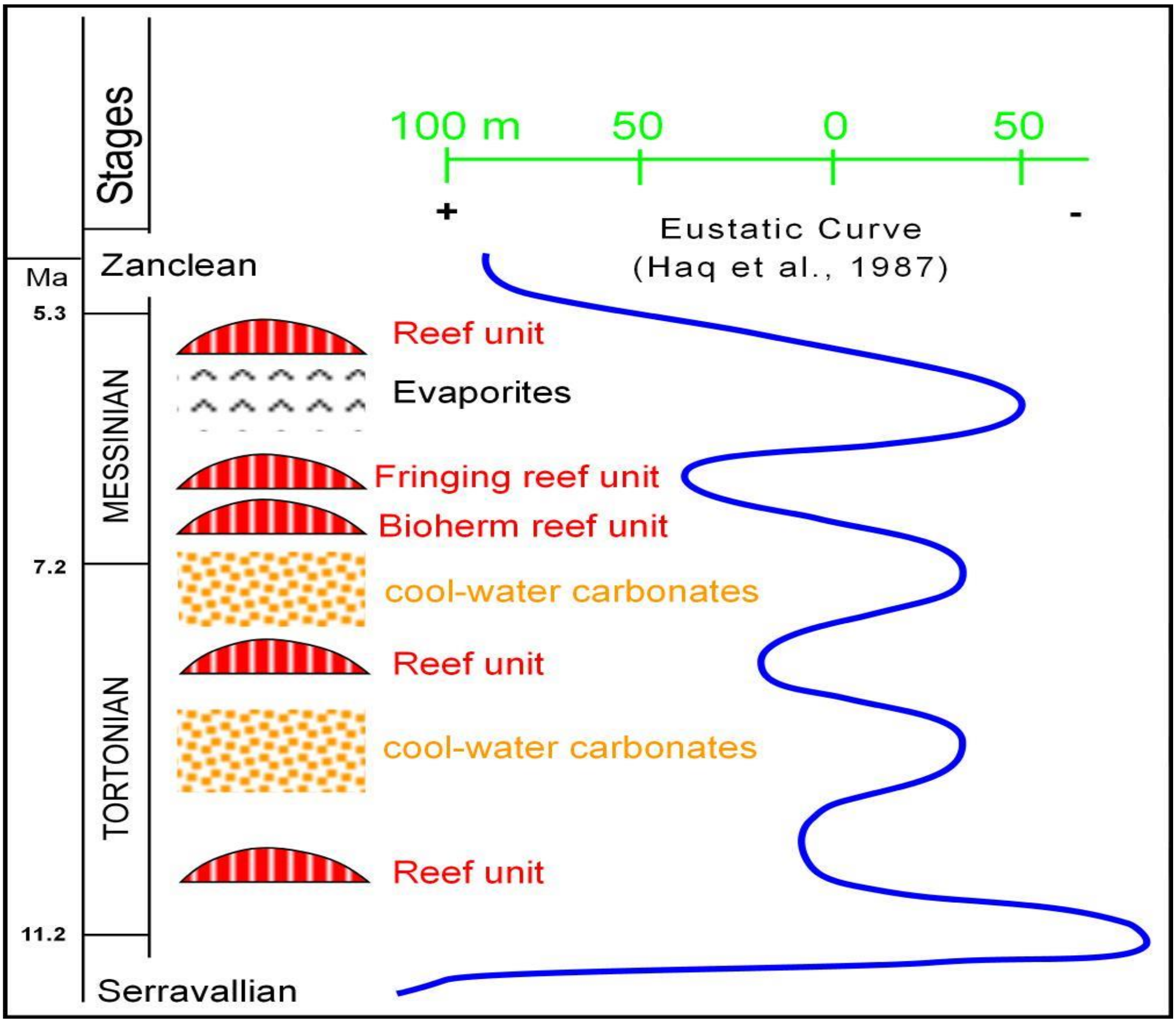


Figure 2. Temporal distribution of temperate and tropical (reef) carbonates in southern Spain during the Neogene (modified after Brachert et al. 1996 and Braga et al. 1996), and their correlation with the eustatic curve of Haq et al. (1987). Temperate carbonates were deposited during low sea-levels of third-order cycles whereas coral reefs grew during high sea-levels. Note that Messinian evaporites formed during the cold phase (low sea-level stand) of a third-order cycle.

Photograph 1.- Upper Tortonian marls (a) outcrop in the valley. Small hills within the valley correspond to sand (conglomerate) intercalations (b). A thick carbonate bar (c), from the Tortonian-Messinian transition, stands out in the middle of the most prominent hills, at the background. Messinian marls (d) occur on top, crowned by gypsum deposits (e), and those, in turn, by the uppermost Messinian carbonates (f), outcropping in the topmost part of the “El Cerrón de Hueli” (Sorbas Basin. Peñas Negras).

Photograph 2.- Turbidite sandstone layers make up the bulk of the small hills in the valley. They intercalate within the upper Tortonian marls (Sorbas Basin. Peñas Negras).

Photograph 3.- Azagador Member carbonates (a) (from the Tortonian-Messinian transition) appear in the foreground. Abad Member marls (Messinian), first grey in colour (b) and then yellow (c), occur on top. Yesares Member Messinian gypsum (d) overlie them. Light-grey, soft sediments belonging to the upper Messinian Sorbas Member (e) can be distinguished in the valley behind, crowned by the red-coloured Zorreras Member sediments (f) (uppermost Messinian-Pliocene). All these sediments are dipping to the North (Sorbas Basin. Los Molinos del Río Aguas). →

Photograph 4.- Río Aguas river canyon has been sculptured in the Messinian gypsum. Gypsum banks are up to 20 m thick. The base of the gypsum is irregular (erosive). Note how the lowermost gypsum bank thins out and disappears laterally to the West (Sorbas Basin. Los Molinos del Río Aguas)

Photograph 5.- The view to the North shows a similar stratigraphy. Motorway bridge is sitting on the Azagador carbonates. The middle-ground platform area corresponds to the Messinian gypsum. Sierra de los Filabres appears at the background. Metamorphic rocks belonging to the Nevado-Filábride Complex from the Internal Zones of the Betic Cordillera make up the bulk of this Sierra (Sorbas Basin. Barranco del Tesoro).

Photograph 6.- Gypsum base seen in detail. The lowermost gypsum bank infills an incised, erosional relief which was excavated in the underlying marls. It thins and thickens accordingly, following the erosion surface irregularities (the black, solid line marks the base of the gypsum) (Sorbas Basin. Barranco del Tesoro).

Photograph 7.- The irregular (erosive) gypsum base stands out clearly in the picture as well as the underlying yellow and grey marls (Sorbas Basin. Los Molinos del Río Aguas).

Photograph 8.- The yellow/grey marls appear below the Messinian gypsum (Sorbas Basin. Cerrón de Hueli).

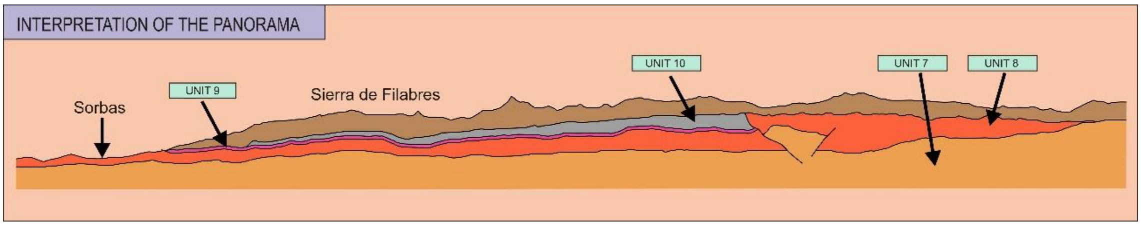
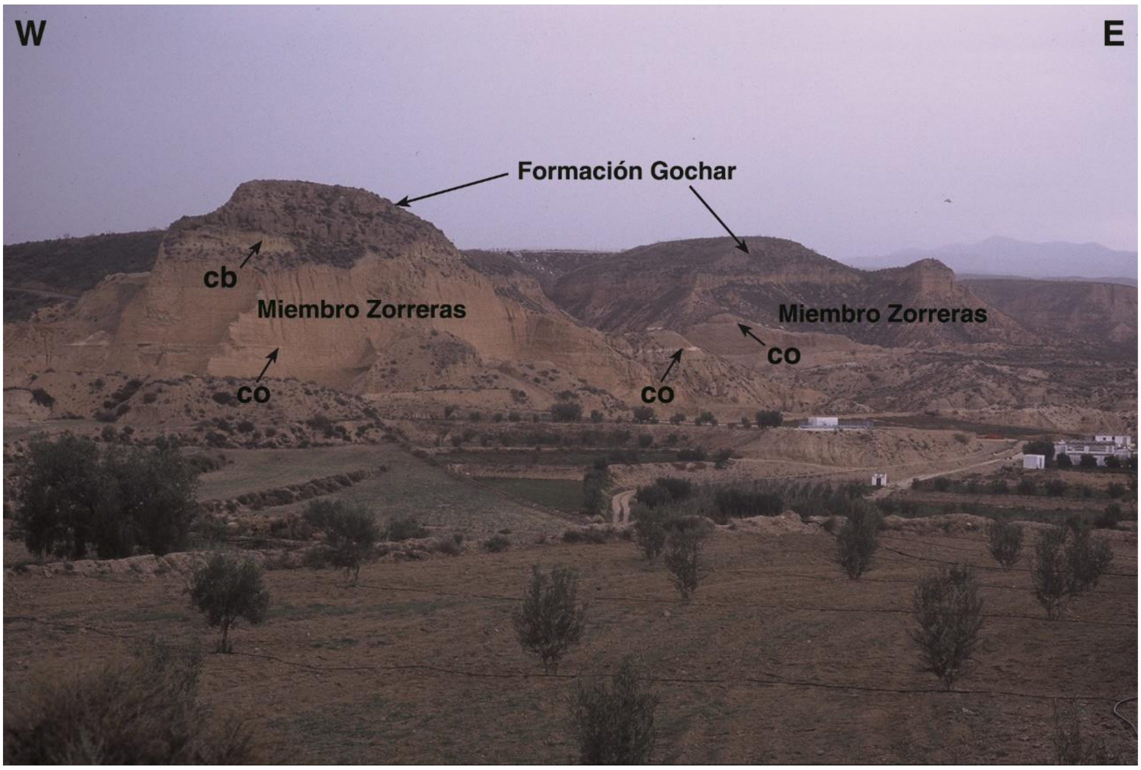
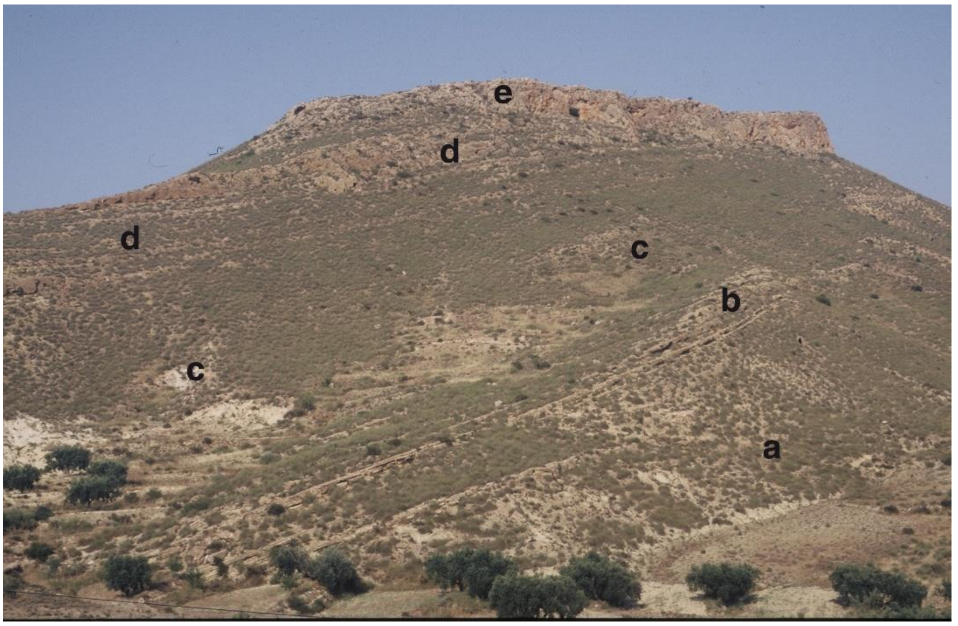


Figure 3. Urra Mirador view to the north: 1, Nevado-Filabre basement of Sierra de los Filabres; 2, sandstones, siltstones and claystones from the Sorbas Member; 3, clays, silts, sands and limestones from the Zorreras Member; 4, marine bioclastic sandstones from the Lower Pliocene; and 5, Plio-Pleistocene Góchar Formation conglomerates. Vertical scale is exaggerated by 1.5.

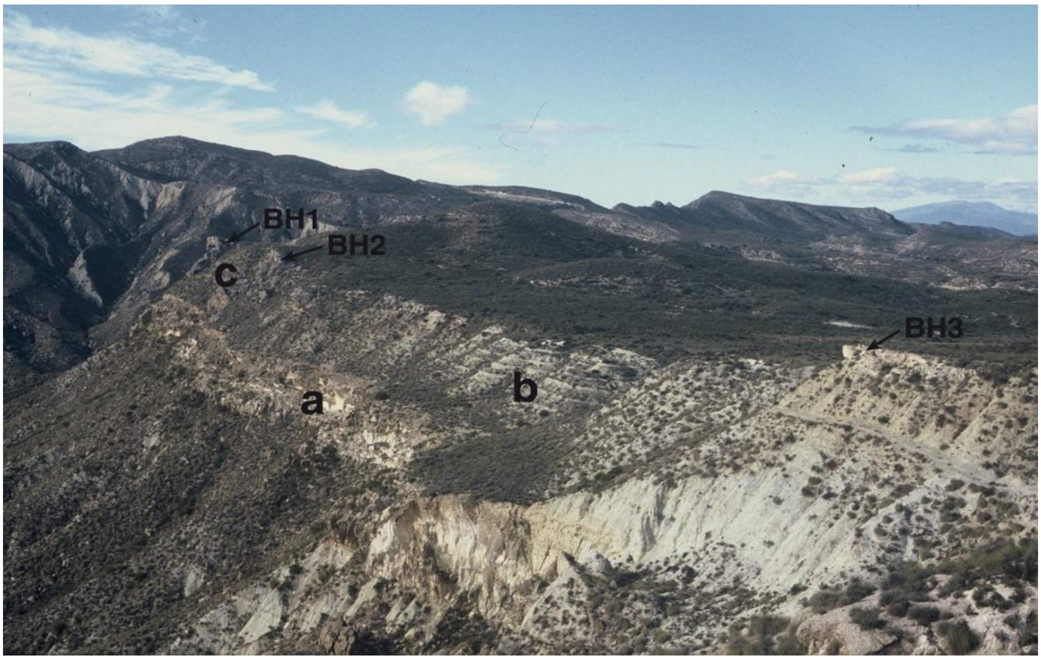


Photograph 9.- Zorreras Member (uppermost Messinian-lowermost Pliocene). Fluviatile, red clays predominate in the sequence. They are mined in quarries to make bricks and pottery. Two thin, white, lacustrine, ostracode-limestone intercalations (co), stand out in the landscape. Yellow-brown, lower Pliocene marine bioclastic limestones occur on top of the hill in the foreground. They are overlaid by the continental conglomerates (sands) of the Plio-Pleistocene Góchar Member, visible in the hills to the right at the distance (Sorbas Basin. Sorbas).



Photograph 10.- Mixed terrigenous-carbonate, Azagador Member sediments (b) occur in the foreground, covering upper Tortonian marls (a). Messinian marls (c), which appear on top, are crowned by the reef units: the Bioherm Unit (d) and the Fringing Reef Unit (e). Successive units are limited, in most cases, by unconformities. Messinian marls thin out and disappear laterally to the East (Sorbas Basin. Lucainena).

Photograph 11.- Reef-slope facies interfingering with the Messinian marls (Sorbas Basin. Lucainena).



Photograph 12.- Messinian grey marls (b) wedging out to the West between the Azagador Member bioclastic limestones (a), from the Tortonian-Messinian transition, and the Messinian reef limestones of the Bioherm Unit (c). Bioherms at the distance (BH1 y BH2) are made up of corals and algae (*Halimeda*). Bioherm at the foreground (BH3), which is intercalated between yellow marls, consists exclusively of *Halimeda* plate accumulations (Sorbas Basin. Cerrón de Hueli).

Temperate carbonates from the Tortonian-Messinian transition

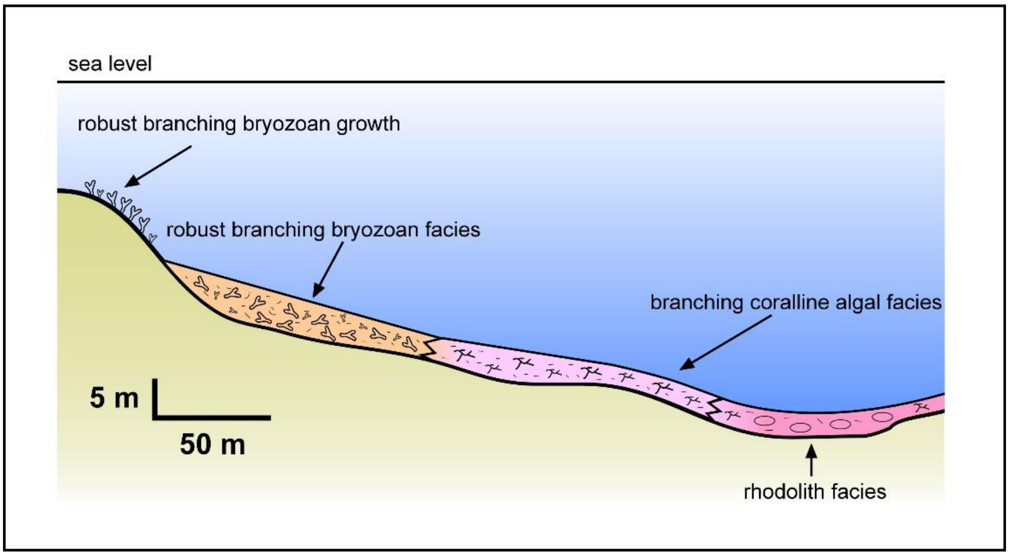
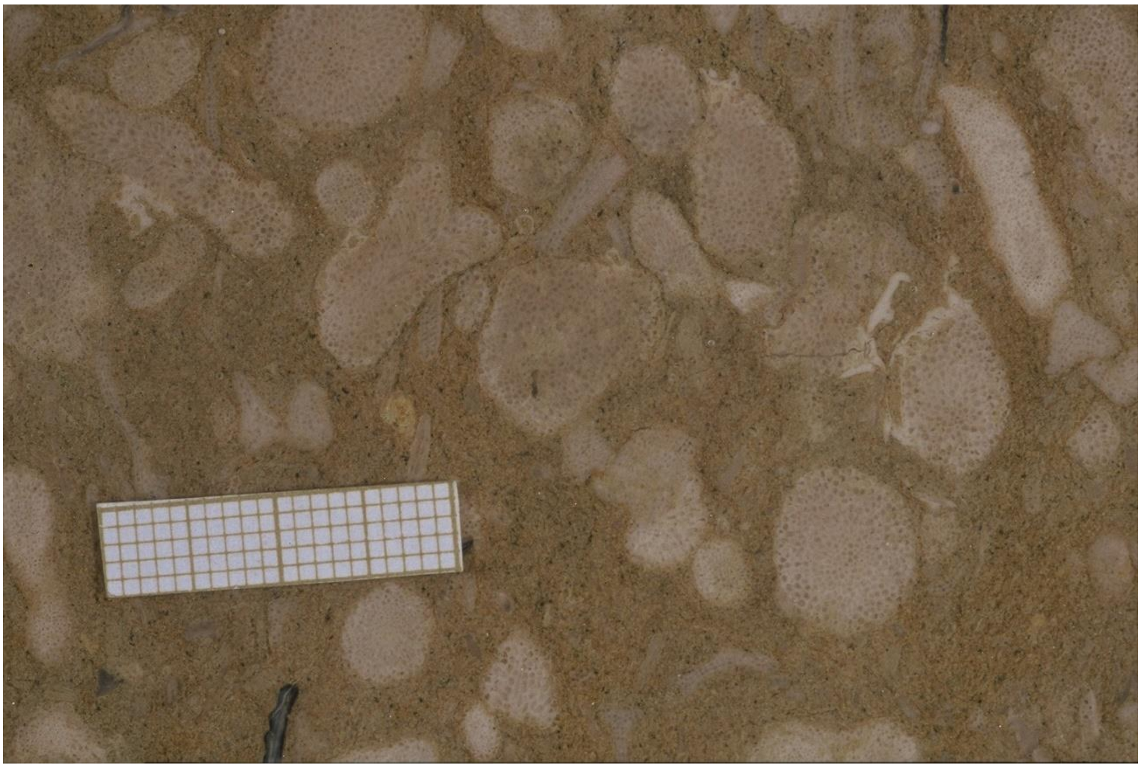


Figure 4. A: Depositional model of the temperate-carbonate ramp at the northern margin of the Sorbas Basin. Prolific robust branching bryozoan growth took place on the walls of submarine cliffs and their remains accumulated at the base of the cliffs. In deeper ramp areas branching coralline algae proliferated, whereas rhodoliths concentrated in small depressions.

Photograph 13.- Azagador Member bioclastic carbonates, from the Tortonian-Messinian transition, are well-exposed, and appear regularly stratified, at the northern margin of the Sorbas Basin (Sorbas Basin. Bar "Lemon").

Photograph 14.- Robust-branching bryozoan facies stand out. These deposits accumulated at the foot of submarine palaeocliffs (Sorbas Basin. Bar "Lemon").



Photograph 15.- The bryozoan internal structure can be clearly seen in some polished samples (Sorbas Basin. Bar “Lemon”). (Scale is in millimetres).

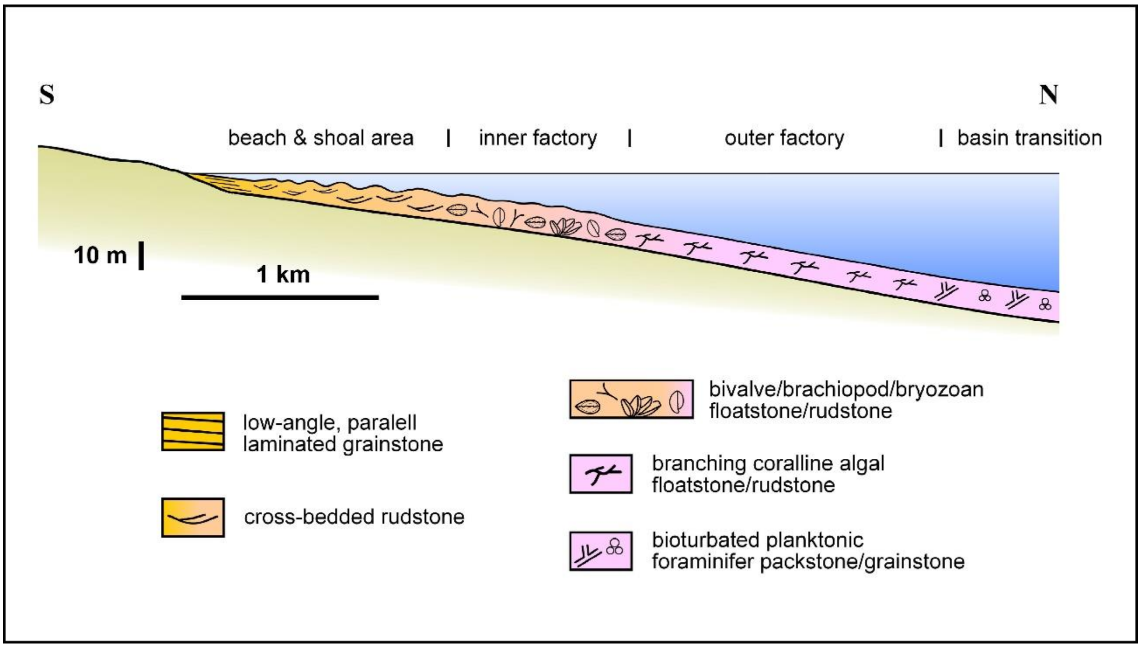
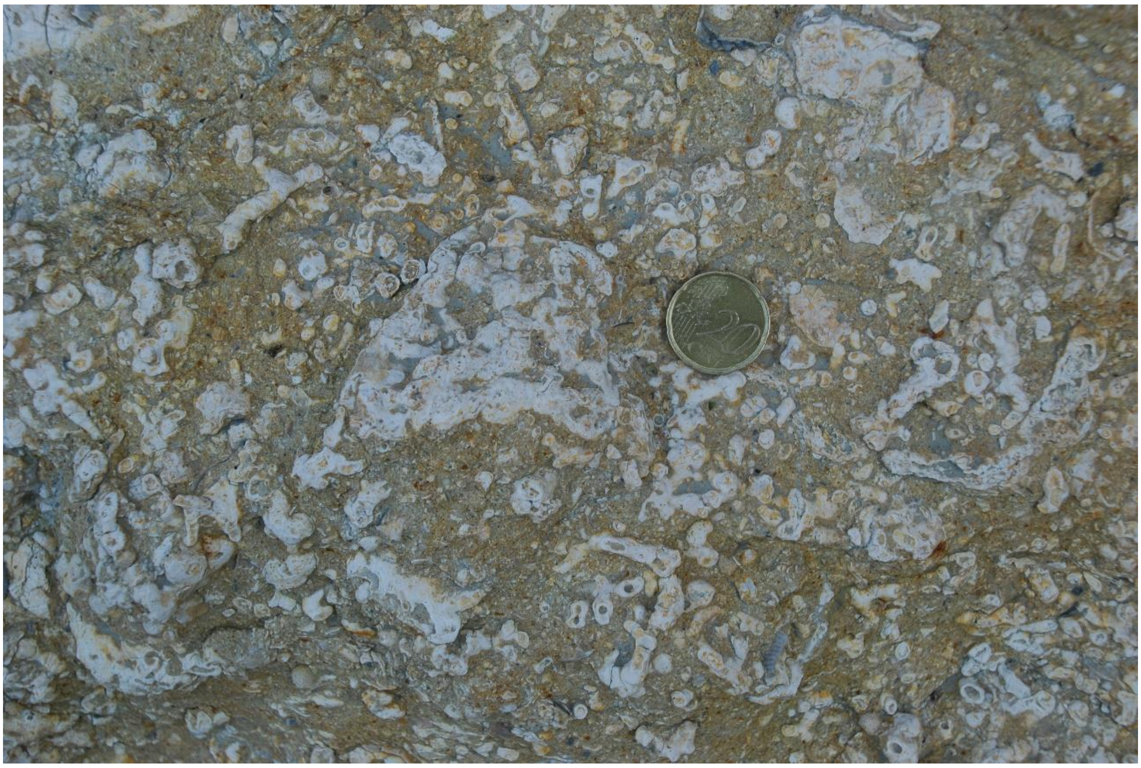


Figure 4. B: Depositional model of the temperate-carbonate ramp at the southern margin of the Sorbas Basin. *In-situ* carbonate production took place in middle (inner-factory) and outer (outer factory) ramp positions (from Puga-Bernabéu et al. 2007).

Photograph 16.- Another representative facies, well exemplified at the southern margin of the basin, near the Cantona hill, are the oyster banks. They developed in shallow and protected, inner-platform areas (Sorbas Basin. Collado de los Molinos).

Photograph 17.- Branching, red-algal (coralline) accumulations are also characteristic facies from Azagador Member limestones of the Sorbas basin. They developed in outer-platform areas (Sorbas Basin. Los Molinos del Río Aguas).



Photograph 18.- Rhodolitic nodular growths appear locally associated with the branching coralline growths (Sorbas Basin. Los Molinos del Río Aguas).

Photograph 19.- *Thalassinoide*s burrows abound in the fine-grained calcarenites from the platform-basin transition (Sorbas Basin. Los Molinos del Río Aguas).

The tsunamites: the megahumockites and the thick shell-debris bed

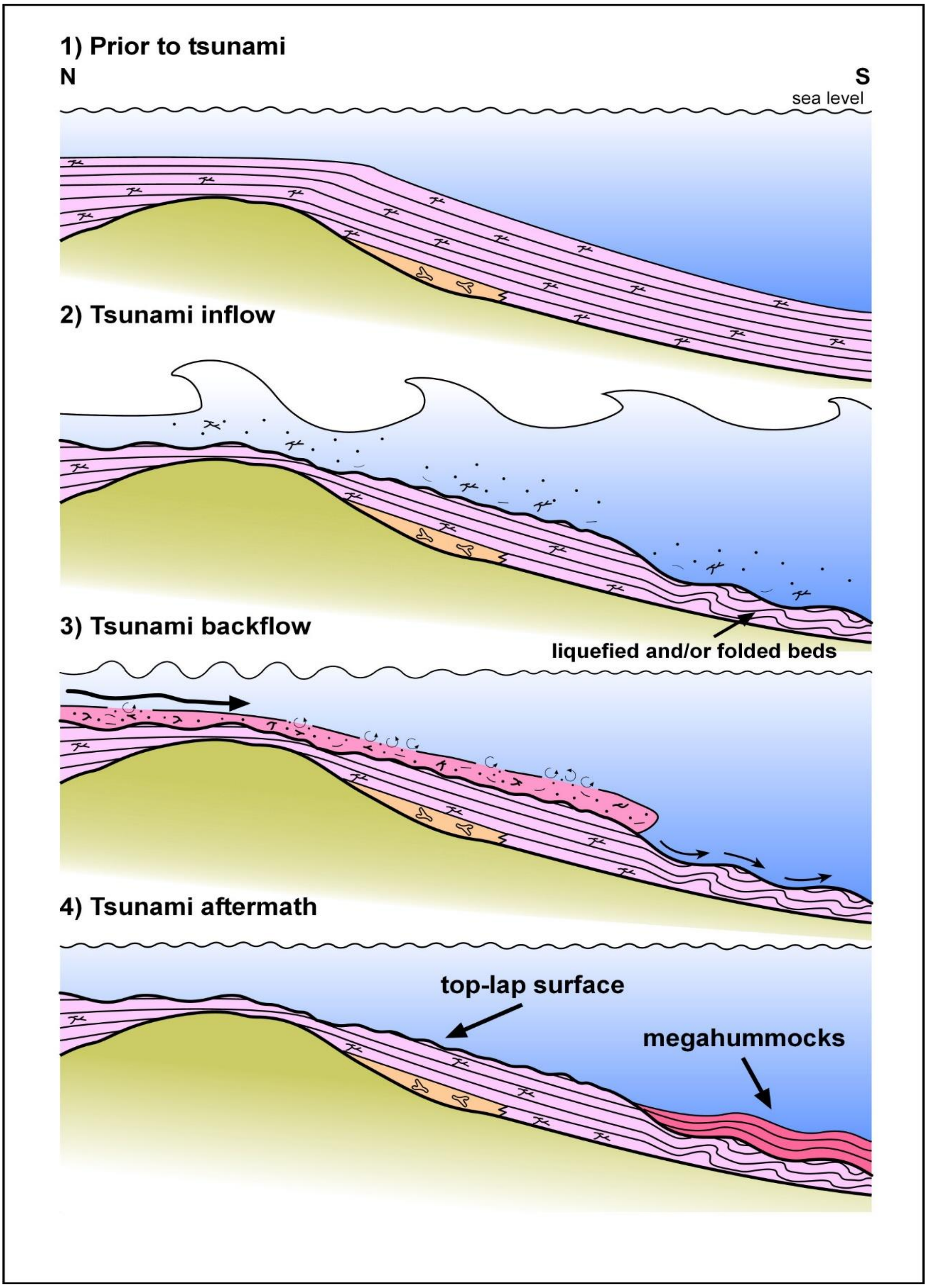


Figure 5. A: Tsunami effects on the northern ramp of the Sorbas Basin. Steep slopes were strongly eroded by the in-coming tsunami waves. The sediment brought back by the tsunami backflow was deposited in middle-outer ramp positions, on top of an irregular erosion surface, yielding the megahummocks (from Puga-Bernabéu et al. 2007).

Photograph 20.- Some deposits reflecting tsunami action appear intercalated in the stratigraphic sequence. At the northern margin they are “megahummockites” (Sorbas Basin. Bar “Lemon”).

Photograph 21.- They show metric-scale ondulations and have an irregular, erosive base. They rest on sediments which have been in turn deformed by liquefaction processes (Sorbas Basin. Bar “Lemon”).

Photograph 22.- The erosional surface at the base of the megahummockites shows upslope as a toplap surface cross cutting the underlying algal-calcarenite strata (Sorbas Basin. Bar “Lemon”).

Photograph 23.- Huge algal-limestone blocks are locally enclosed in the megahummockite (Sorbas Basin. Bar “Lemon”).

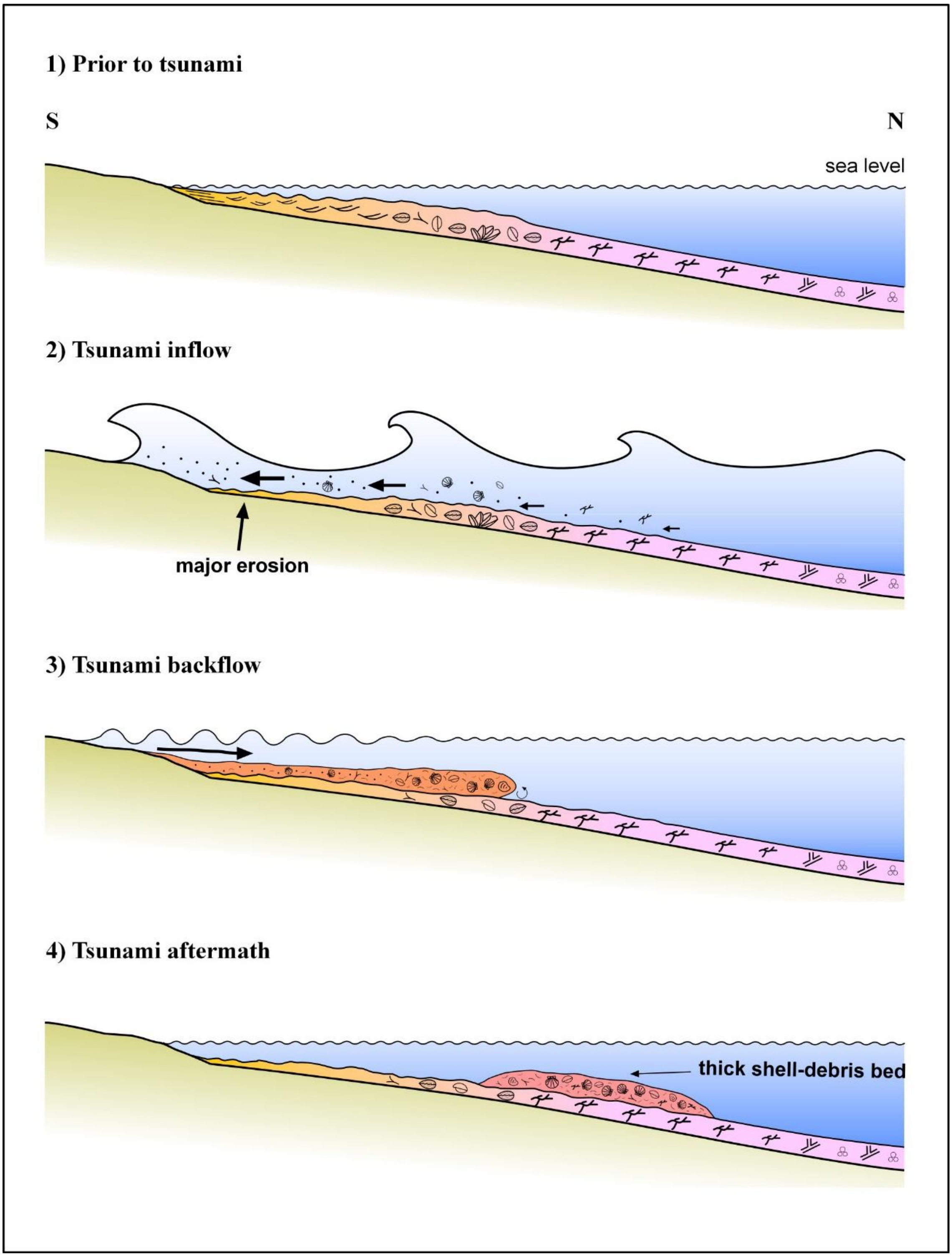


Figure 5. B: Tsunami effects on the southern ramp of the Sorbas Basin. Tsunami inflow crossed the gentle ramp eroding the sea floor to some extent. Coarse bioclasts, derived mainly from the inner factory area, were removed and mixed with some finer-grained (sand-sized) carbonate sediment from the inner ramp (shoals and beaches), generating a debrite. The tsunami backflow took the debrite bioclastic sediments back to seawards depositing a thick, shell-debris bed in outer ramp settings (from Puga-Bernabéu et al. 2007).

Photograph 24.- Tsunami action resulted in the formation of a bioclastic megabreccia with abundant pectinid remains at the southern margin (Sorbas Basin. La Molata).

Photograph 25.- Some other bioclasts mainly from red algae (branching growths and rhodoliths) and braquiopods occur together with the pectinid remains (Sorbas Basin. Los Molinos del Río Aguas).

The Messinian tropical carbonates: The Bioherm Unit

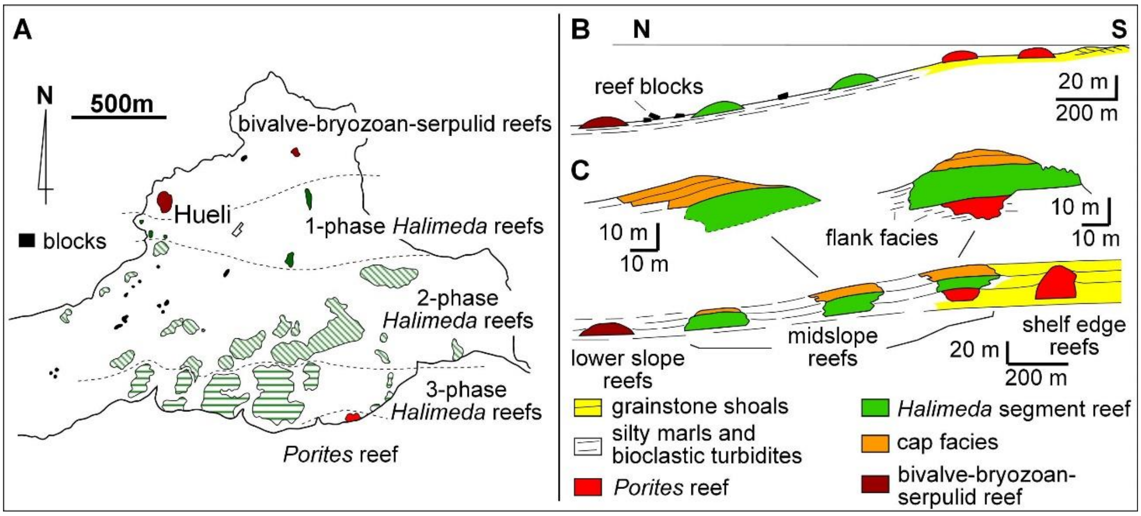
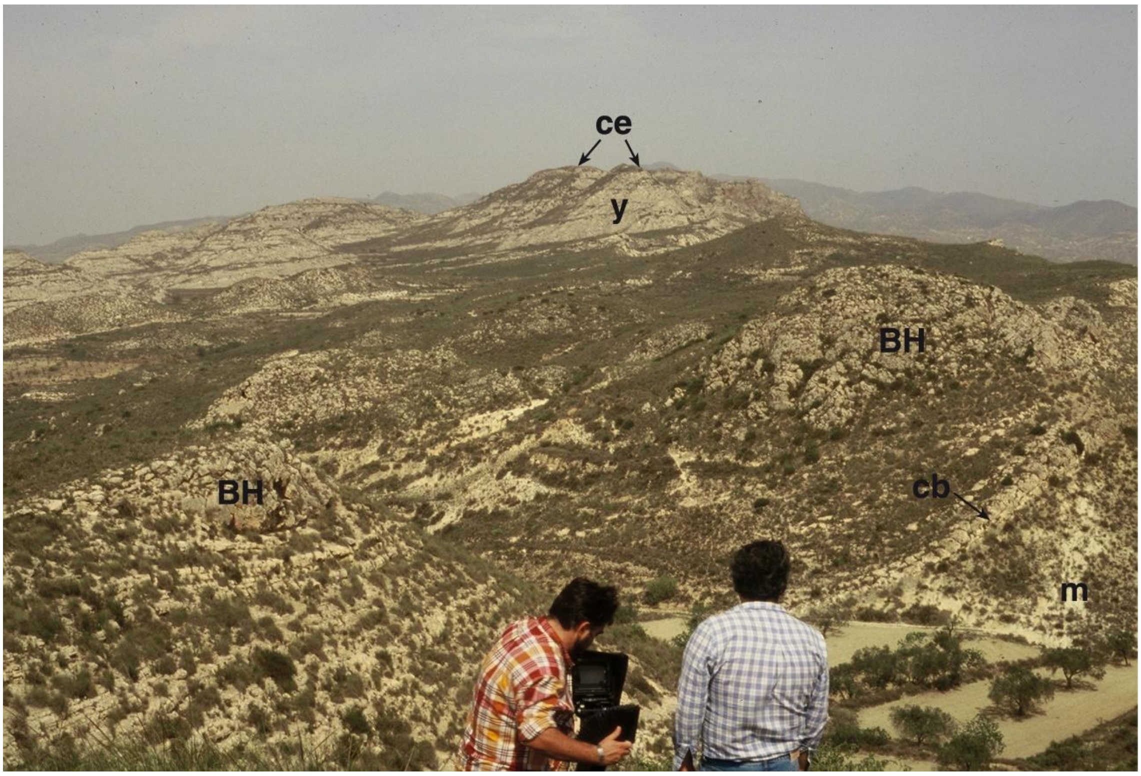


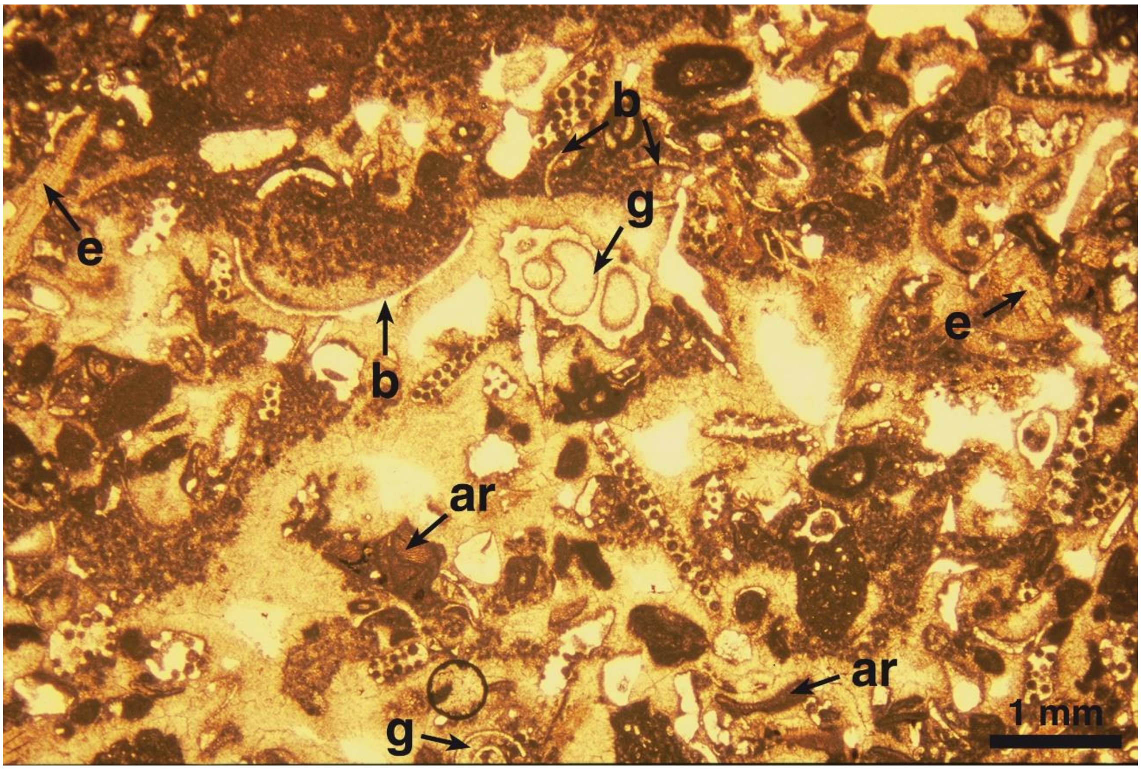
Figure 6. (A) Spatial distribution of reef types within the bioherm unit at Hueli. (b) Interpretation of the palaeoenvironmental setting of the bioherm patch reef complex at Hueli. The *Halimeda* reefs formed on the midslope at depths of 20-65 m. (C) Patch reef types and their lateral distribution. (1) Proximal shelf edge: *Porites* reefs. (2) Midslope: *Halimeda* reefs subdivided into: (a) upper midslope: three-phase *Halimeda* reefs with a coral base and bioclastic-microbial cap; (b) mid midslope: two-phase *Halimeda* reefs with a thick bioclastic-microbial cap; (c) lower midslope: one-phase *Halimeda* reefs with local, thin, bioclastic-microbial caps. (3) Lower slope: bivalve-bryozoan-serpulid reefs. The upper two diagrams show sketches of actual examples of upper midslope and mid midslope *Halimeda* reefs. Accretion (time) lines shown in the lowermost diagram separate lowstand, transgressive, and highstand stages (from Martín et al. 1997).

Photograph 26.- The Bioherm Unit is very well represented in the area of Hueli. The view shows, at the foreground, the deposits from this unit which include some bioherms or reef mounds (BH). The “El Cerrón de Hueli” can be seen at the distance, consisting of Messinian gypsum (y), with some stromatolite carbonates (ce) on top from the uppermost Messinian Sorbas Member. Azagador Member bioclastic carbonates (cb), from the Tortonian-Messinian transition, underlie the Bioherm Unit. The lie in turn on Upper Tortonian marls (m) (Sorbas Basin. Hueli). →

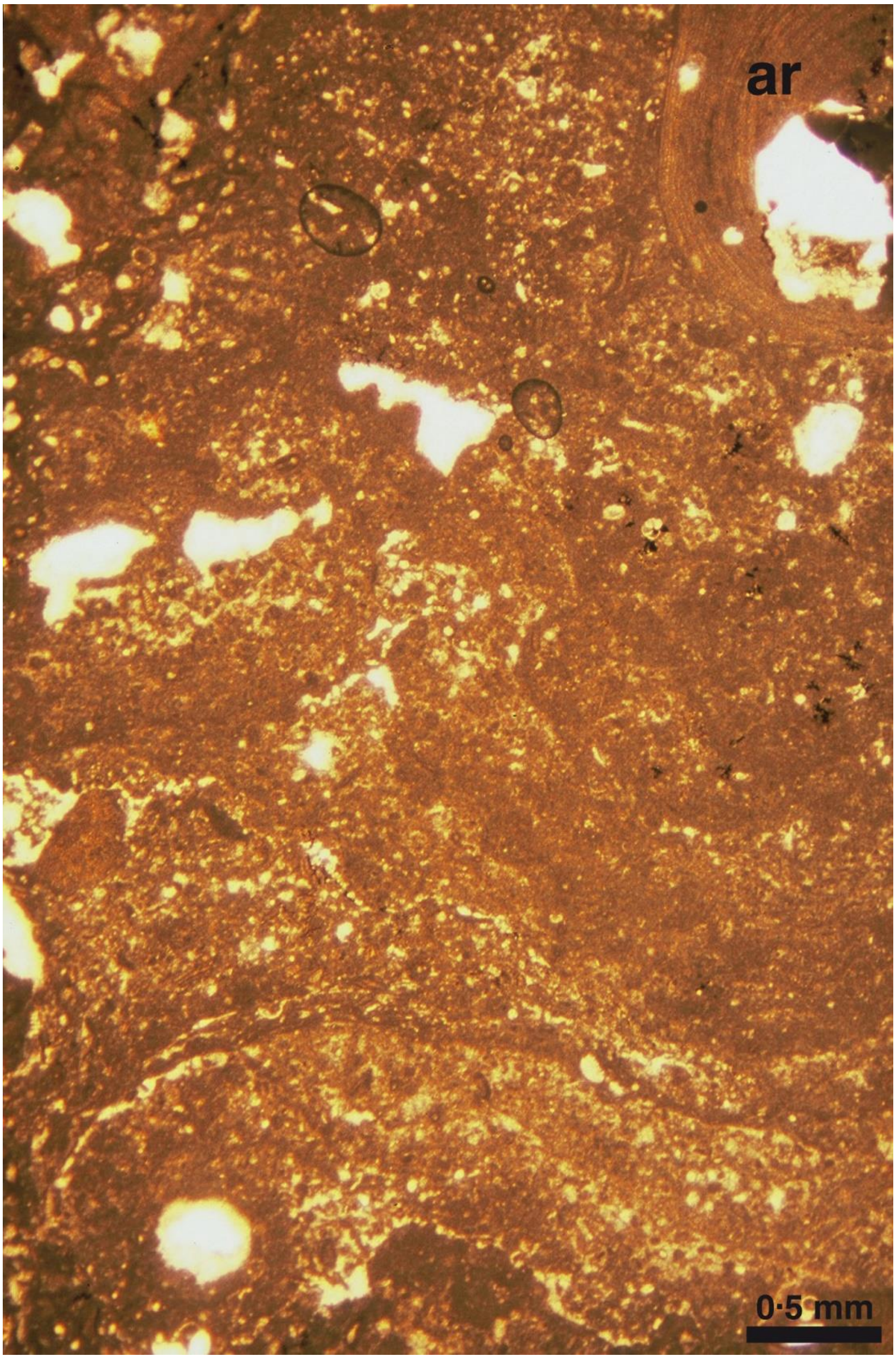


Photograph 27.- Inner-platform bioherms are made up of corals (mainly *Porites*). They intercalate within calcarenites (Sorbas Basin. Hueli).

Photograph 28.- More to the North (platform edge-platform slope transition in the sedimentary model) they are more complex and show a coral base (a), an intermediate algal-rich (*Halimeda*) zone (b) and a bioclastic-stromatolitic, relatively well stratified upper zone (c). They now intercalate between fine-grained limestones and marls (Sorbas Basin. Hueli).



← Photograph 29.- Microscopic view of the bioclastic facies from the top of the mound with abundant bivalve (b), red algal (ar), gastropod (g) and echinoderm (e) remains (Sorbas Basin. Hueli).

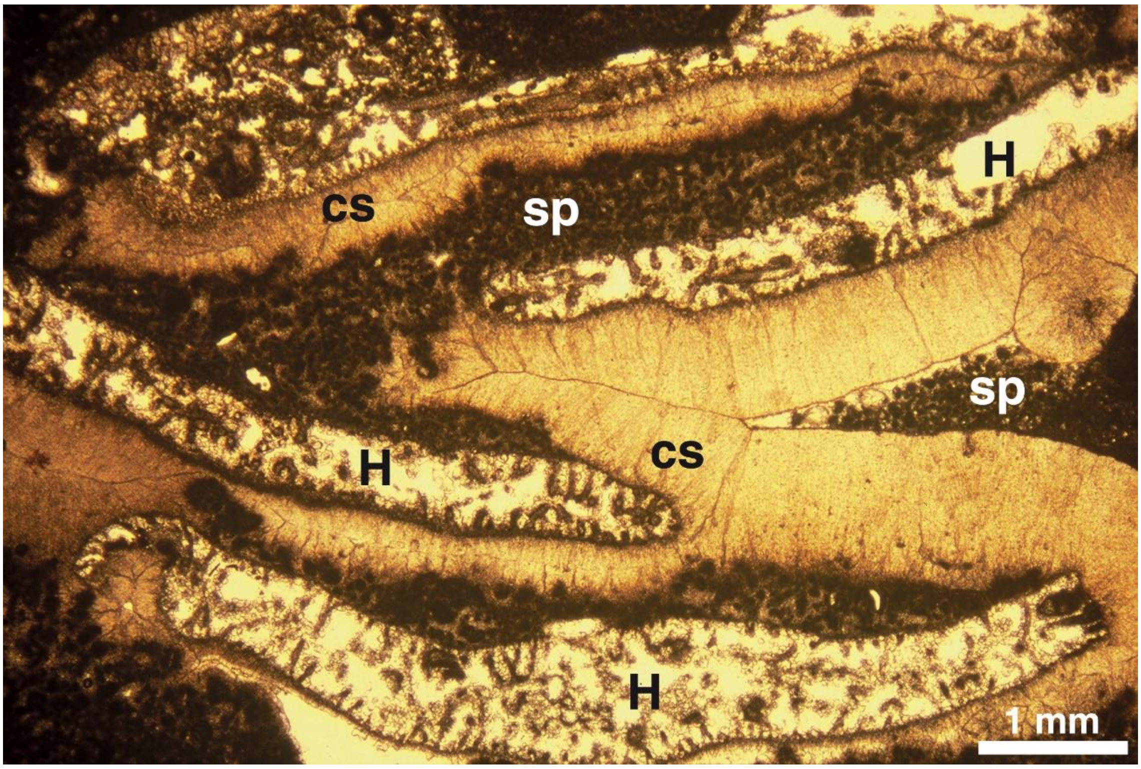


Photograph 30.- Stromatolite facies from the top of the mound seen under the microscope. The lamination is clearly visible as well as the typical pelloidal structure. Note how some red algal fragments (ar) were trapped within the stromatolite laminae (Sorbas Basin. Hueli).

Photograph 31.- More to the North (in deeper slope-areas of the former submarine carbonate ramp) the intermediate zone, rich in *Halimeda*, becomes more significant. They are still mixed bioherms but with a wider *Halimeda*-rich zone (well exemplified in the byre area) (Sorbas Basin. Hueli).

Photograph 32.- The sediment is locally a mixture of branching-coral remains (*Porites*) and *Halimeda* plates (Sorbas Basin. Hueli).

Photograph 33.- In most situations *Halimeda* plates are by far the most abundant components (Sorbas Basin. Hueli).



Photograph 34.- Microscopic view of *Halimeda* (H) facies showing abundant synsedimentary submarine cements (cs) and stromatolitic pelloidal sediment (sp) (Sorbas Basin. Hueli).

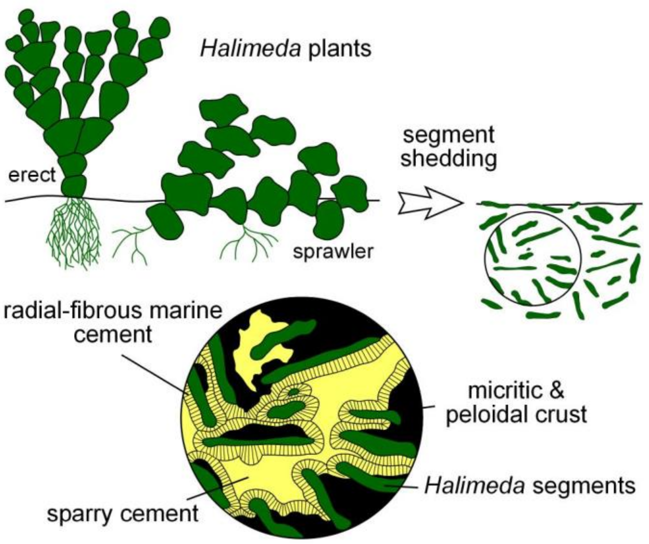
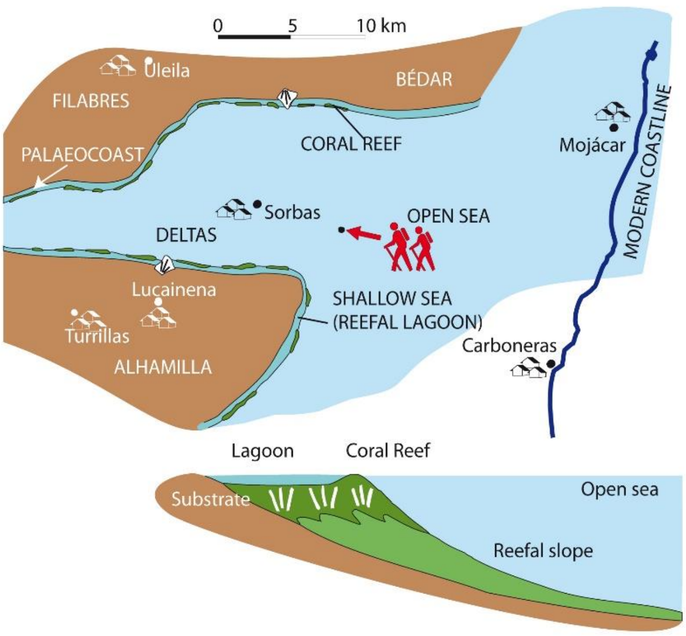


Figure 7. Development of *Halimeda* segment reef fabric, from living *Halimeda*, through segment-shedding during life and after death, to rigid segment rock, lithified by micritic and peloidal microbial crusts and marine cement. Individual segments are approximately 1 cm across (from Martín et al. 1997; modified after Braga et al. 1996).

The fringing reef



← Figure 8. A: Palaeogeography of the Sorbas Basin approximately 6 My ago, at the time of development of the Messinian fringing reefs. Reefs grew around the Sierra de los Filábres and bordered the Sierra Alhamilla at the northern and southern margins respectively. B: Symplified model for the fringing reef, with the reef slope (fore-reef) to seawards and the lagoon behind, between the reef itself and the coast.

Photograph 35.- Messinian fringing reefs bordered the Sierra de los Filabres at the northern margin of the Sorbas Basin, extending for some tens of kilometres (Sorbas Basin. Cariatiz).

Photograph 36.- Reef deposits outcrops at the top of the small hills just behind Cariatiz (Sorbas Basin. Cariatiz).

Photograph 37.- The reef-core framework facies (a) occur on top of the reef-slope facies (ta). These latter sediments are well stratified and dip strongly to the South (Sorbas Basin. Cariatiz).

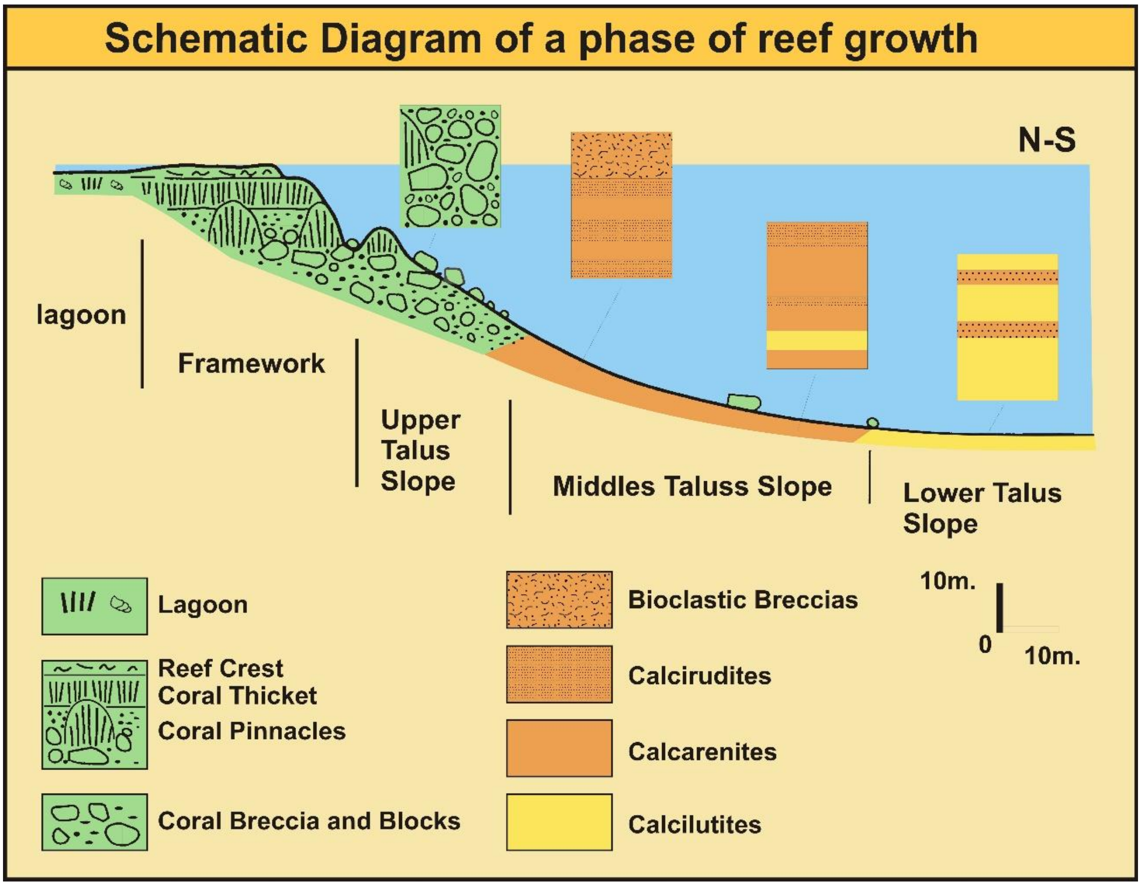
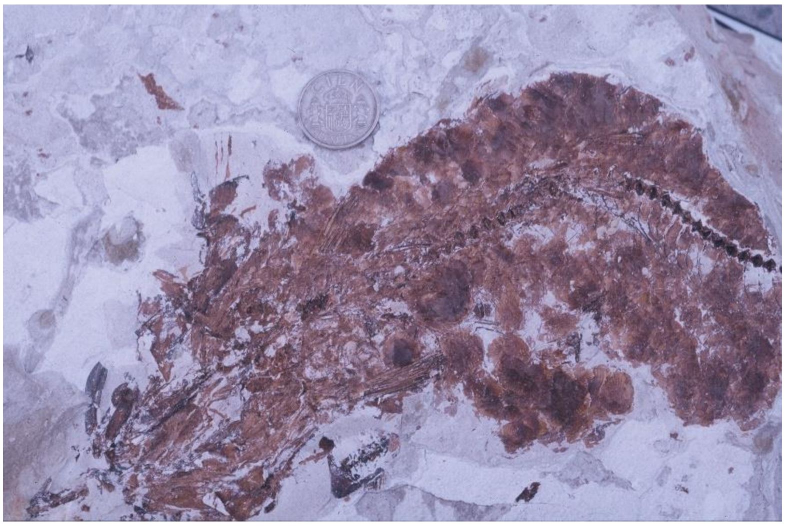


Figure 9. Facies model of the fringing reef. Slope facies: (1) Distal slope (lowermost slope): Silty marls and calcisiltites (calcarenites) intercalating with basinal marls and diatomites. (2) Proximal slope (middle slope): Bioclastic calcarenites (calcirudites). Bioclasts are mainly coralline algae, serpulids, mollusc and *Halimeda*. (3) Reef-talus slope (uppermost slope): Framework blocks and coral breccias mixed with bioclastic calcirudites (calcarenites) (from Braga and Martín, 1996).

The reef-slope: Photograph 38.- Basinal marls (mc) occur at the bottom of the sequence (at the foot of the hill). Upwards they intercalate with distal reef-slope facies (td), consisting of very fine to fine-grained calcarenites. Light-coloured carbonates, belonging to the Sorbas Member (MS), occur on top, overlaid in turn by red-coloured, detrital sediments from the Zorreras Member (MZ). Both Members are Upper Messinian in age (Sorbas Basin. Cariatiz).



Photograph 39.- Some diatomite layers with well-preserved fish remains appear intercalated within the marls (Sorbas Basin. Cariatiz).

Photograph 40.- Reef-slope facies, containing abundant *Halimeda*-plate remains, occur upslope (Sorbas Basin. Cariatiz).

Photograph 41.- As we moved upslope towards the reef, we come across a coral block and breccia zone (the reef talus-slope), with a chaotic internal structure. All these fragments fell off from the reef and accumulated just in front of it, in the upper part of the reef-slope (Sorbas Basin. Cariatiz).

The reef-core framework →

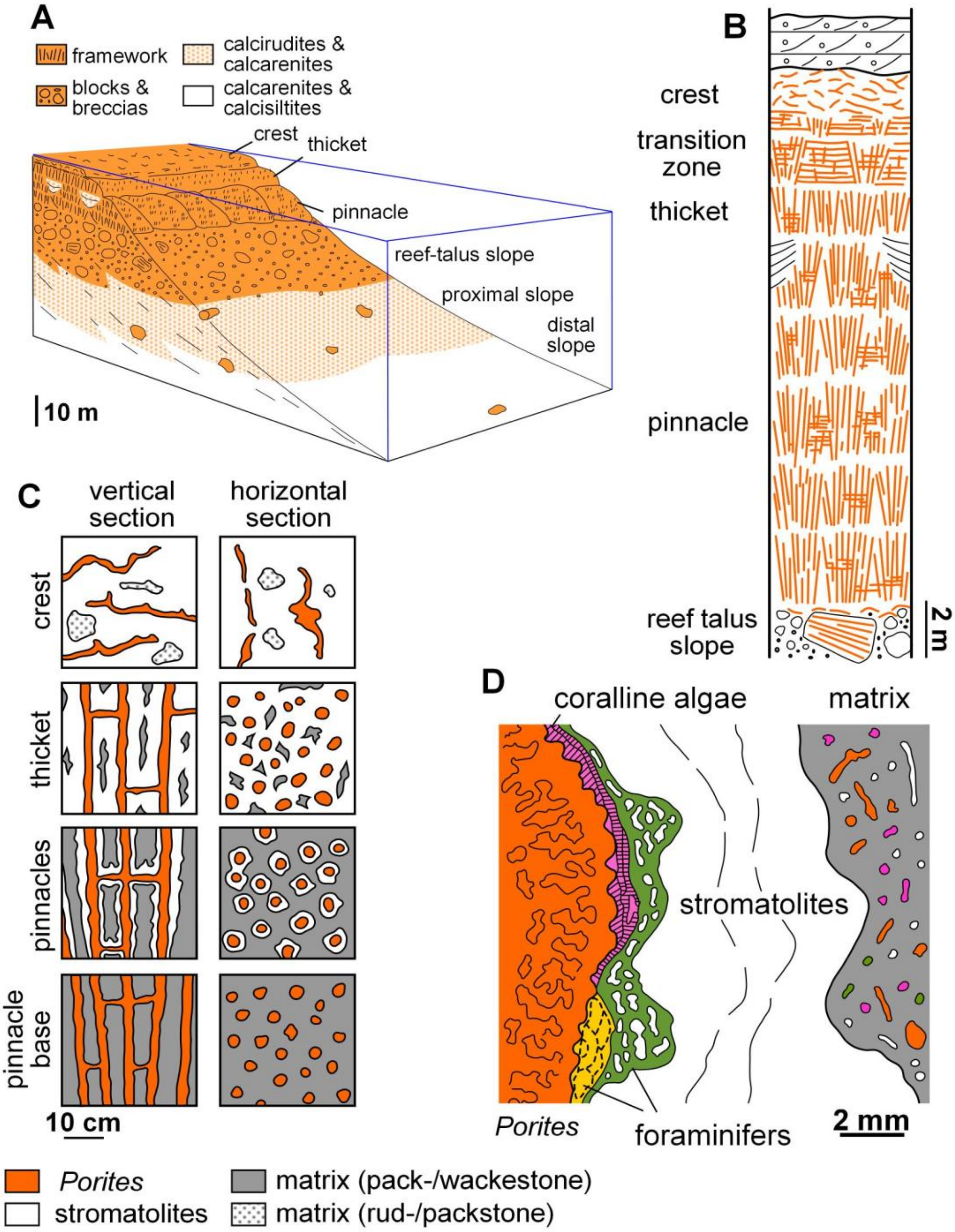
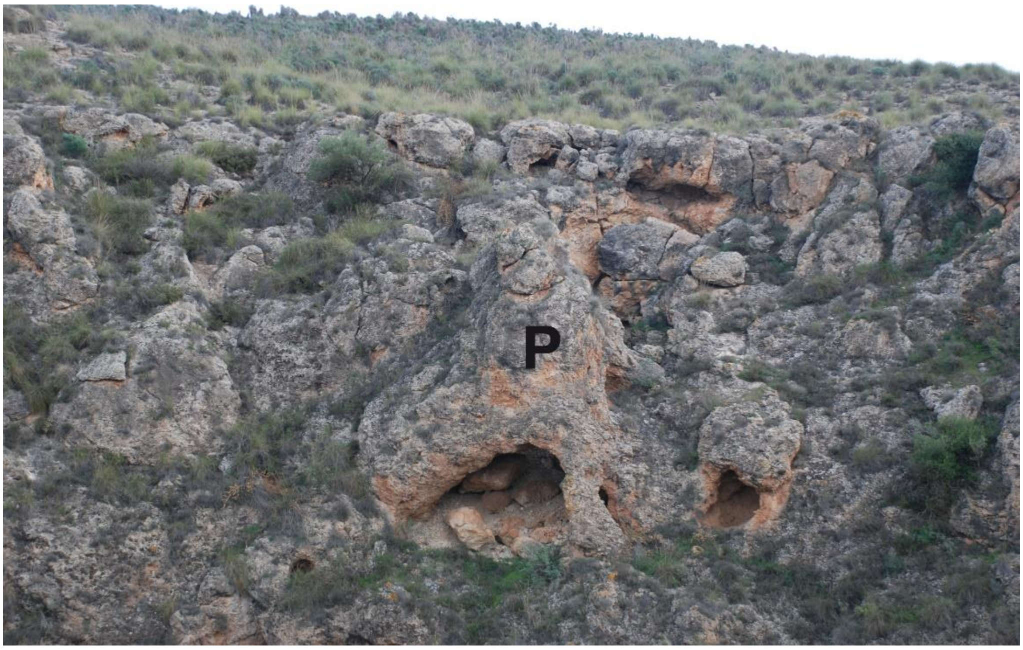


Figure 10. (a) Reconstruction of the coral-stromatolite reef showing the pinnacle, thicket and reef-crust zones and reef-derived blocks on the fore-reef slope. (b) Fringing reef sequence. The reef shows a thick pinnacle zone overlain by a thinner thicket zone, both of which were constructed principally by erect stick-like *Porites* coated with stromatolitic crusts. This erect form of *Porites* passes upwards at the reef crest into a laminar platy form. (c) Vertical increase in crust development and change in style of coral growth from base of pinnacle zone to reef crest. (d) Sequence of reef-frame sedimentation from coral to bioclastic matrix. Stromatolitic crusts are often preceded by layers of coralline algae and foraminifers (from Riding et al. 1991).

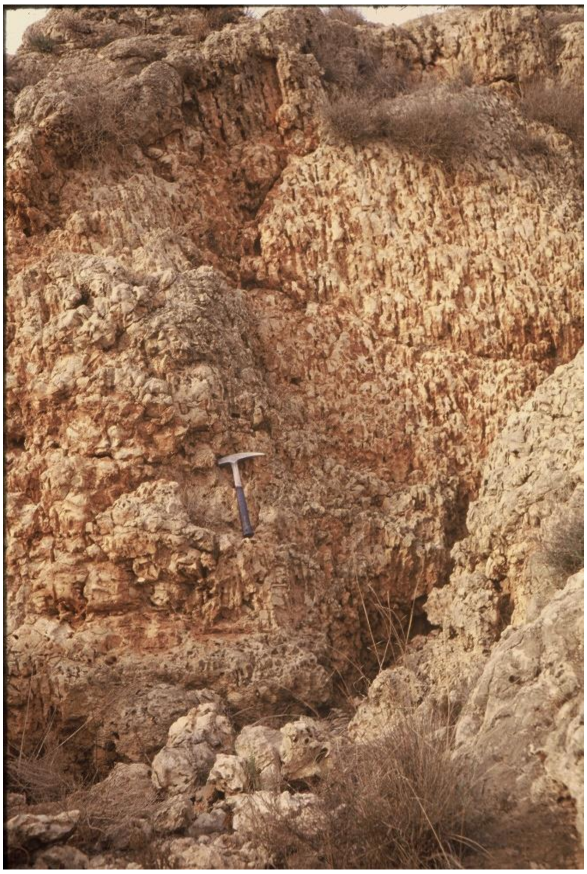
Photograph 42.- The reef settled on top of the coral blocks and breccias (Sorbas Basin. Cariatiz).

Photograph 43.- In the deepest part of the reef occur the pinnacles as disconnected, mound-like growths (P). The sediment in between is a mixture of calcarenites and coral blocks and breccias (Sorbas Basin. Cariatiz).

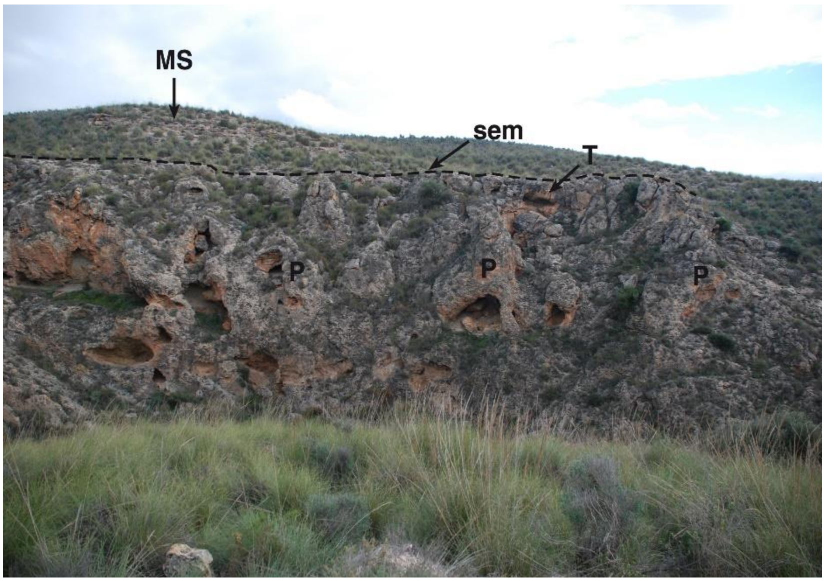


Photograph 44.- Coral pinnacle (P) (Sorbas Basin. Rambla de Góchar).

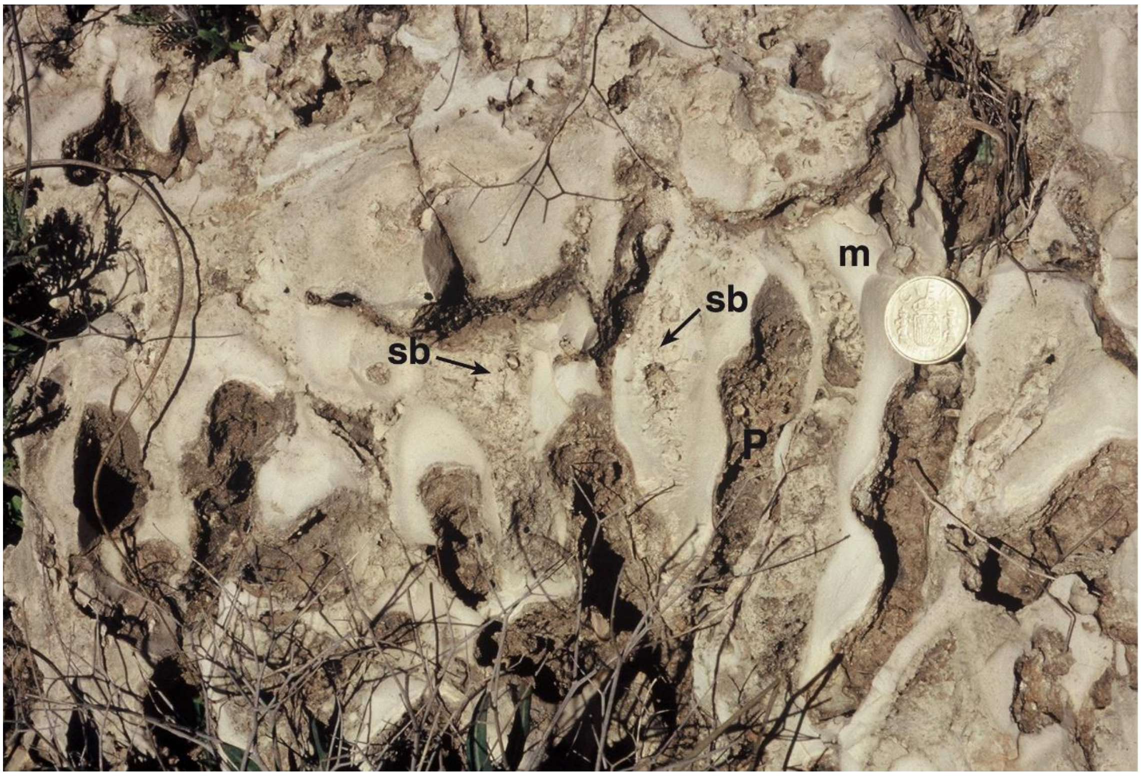
Photograph 45.- *Porites* is the dominant coral in the pinnacles. It is partially leached and it shows up at the outcrop as voids and dark brown areas. The predominat morphology is that of long and thin, vertical sticks, connected by very thin, subhorizontal laminar-colony bridges (Sorbas Basin. Cariatiz).



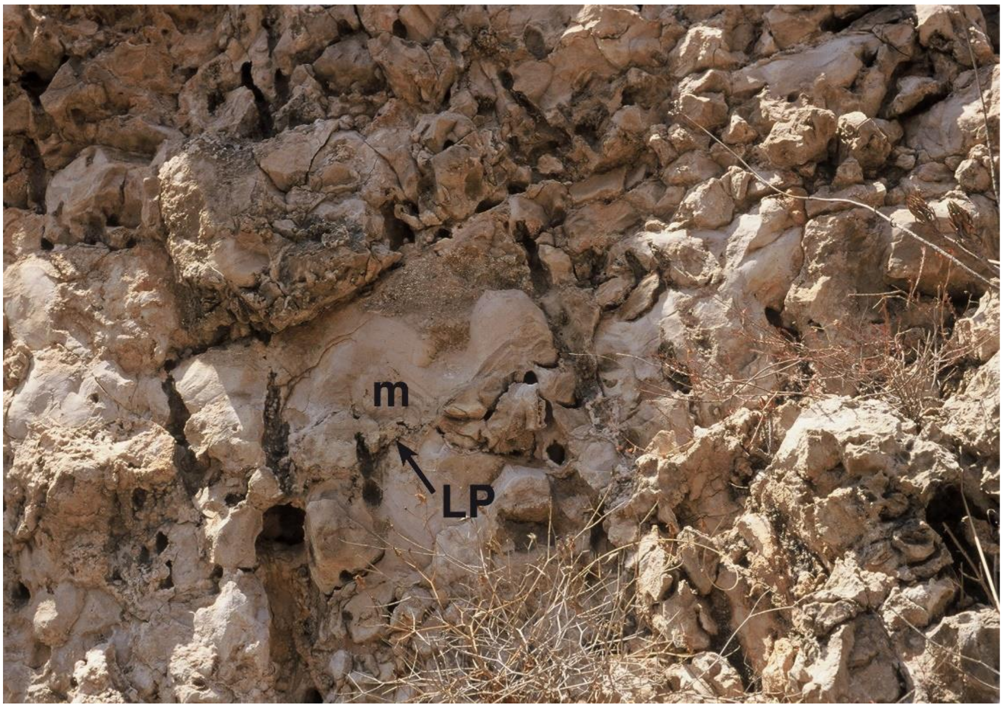
Photograph 46.- On top of the pínnacles *Porites* growths extend as dense palisades, with a predominance of vertical morphologies (stick-like morphologies). It is the so-called “thicket”, with a horizontal (stratiform) arrangement (Sorbas Basin. Cariatiz).



Photograph 47.- Reef pinnacles (P) covered by the thicket (T). The intramessinian erosion surface (sem) (linked to the Mediterranean desiccation) has removed the reef crest. Sorbas Member conglomerates, sands and oolites (MS) were deposited on top of the erosion surface (Sorbas Basin. Rambla de Góchar).



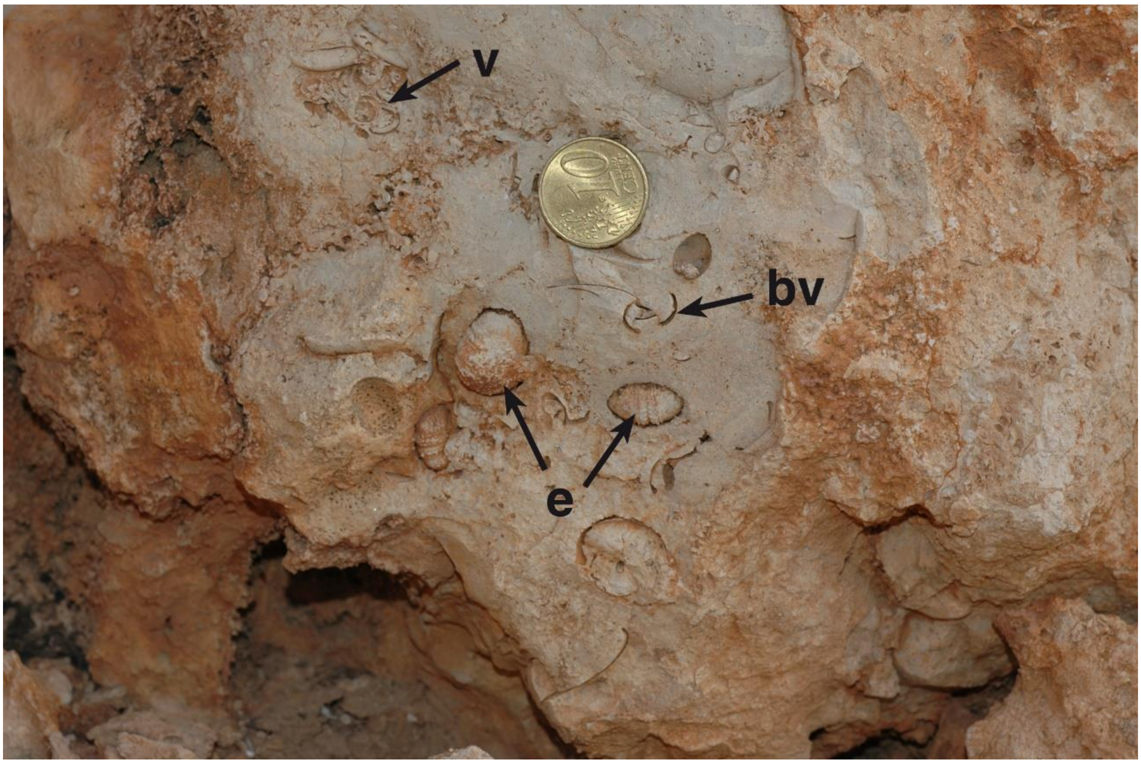
Photograph 48.- Coral (*Porites*) (P) skeletons were coated by micrite crusts (m). Bioclastic sediments (sb) filled the remaining open spaces (Sorbas Basin. Cariatiz).



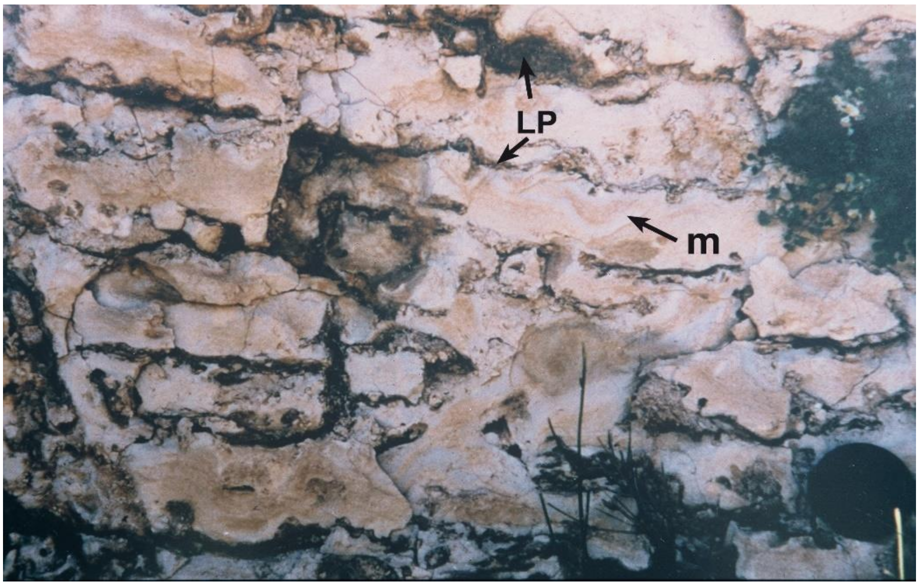
Photograph 49.- Micrite crusts (m) are of microbial origin. Dome morphologies and stromatolitic lamination are sometime very evident, as in the case here exemplified on laminar *Porites* (LP) (Sorbas Basin. Cariatiz).

Photograph 50.- Micrite (stromatolitic) crusts coating *Porites* sticks are very thick in the upper part of the “thicket” (Sorbas Basin. Cariatiz).

Photograph 51.- *Clionia* borings are very notorious and conspicuous in the corals (*Porites*) (Sorbas Basin. Cariatiz).



Photograph 52.- Well-preserved echinoderm (*Arbacia*) (e), small bivalve (bv) and vermetid (v) remains are part of the components found in the internal sediment filling in the remaining spaces between the micrite-encrusted coral branches (Sorbas Basin. Cariatiz).



Photograph 53.- The reef crest is at the top of the bioconstruction. It consists of very thin and irregular, subhorizontal laminar Porites growths (LP) coated by thick micrite (stromatolitic) crusts (m) (Sorbas Basin. Cariatiz).

Fringing-reef progradation and cyclicity

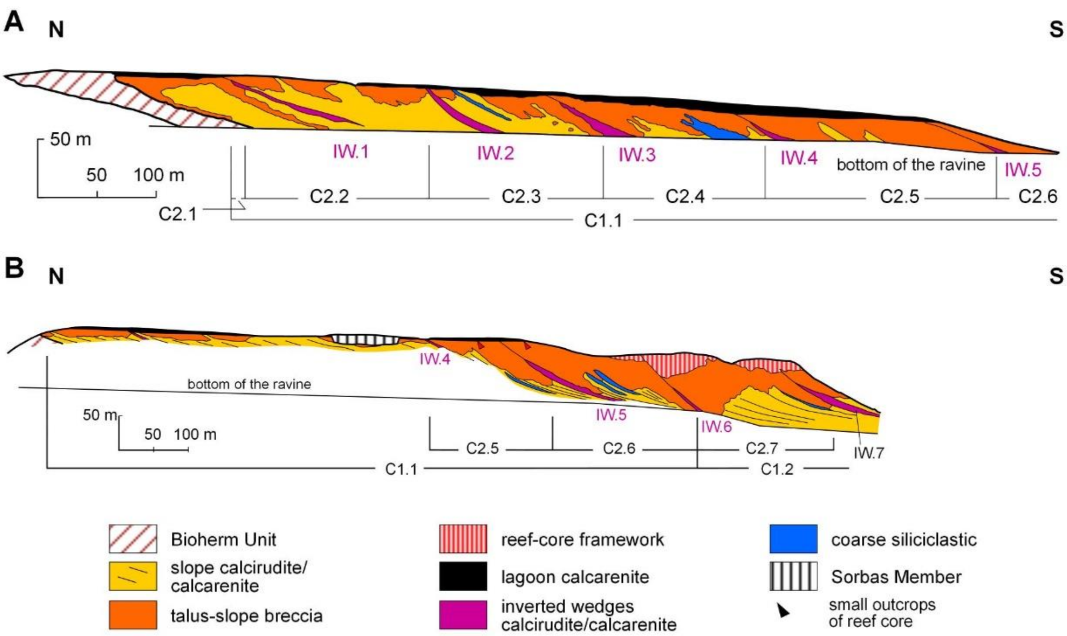
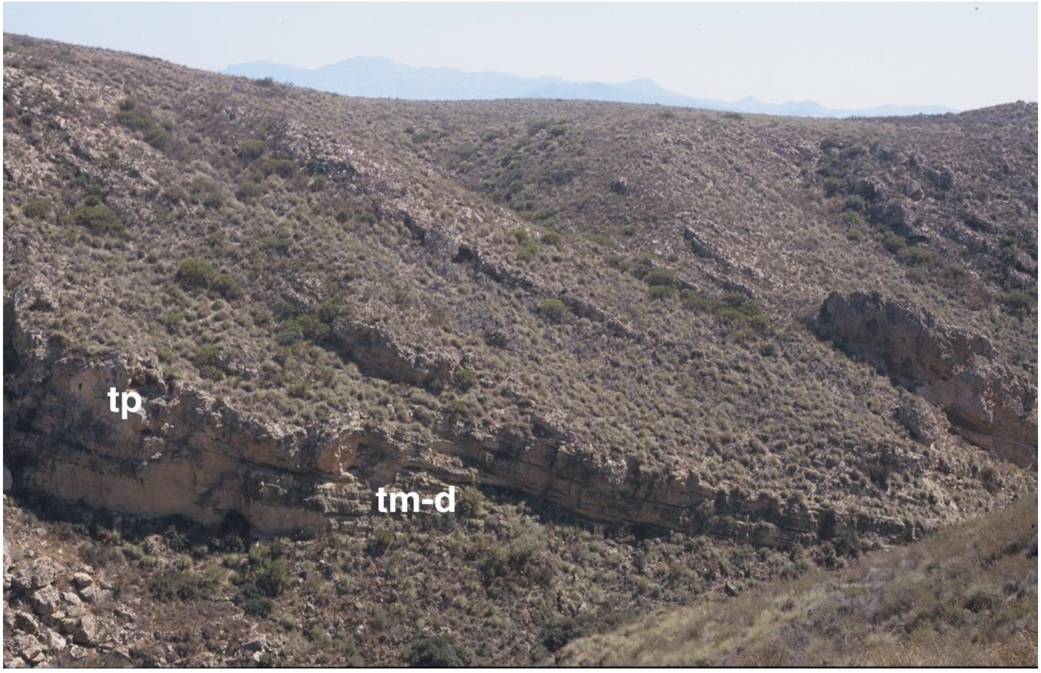


Figure 11. (a) Barranco de los Castaños section. Vertical shifts of reef facies during reef advance are evident at two orders (C1 and C2) of cyclical relative sea-level change. (b) Barranco de la Mora section (from Braga and Martín, 1996).



Photograph 54.- Fringing-reef progradation pattern. Massive, steeply-dipping block and breccia facies from the reef-talus slope (tp) stand out. Downslope they interfinger with regularly-bedded calcarenites (tm-d) from the proximal reef-slope. This change can be perfectly traced laterally within a single layer (Sorbas Basin. Barranco de los Castaños).

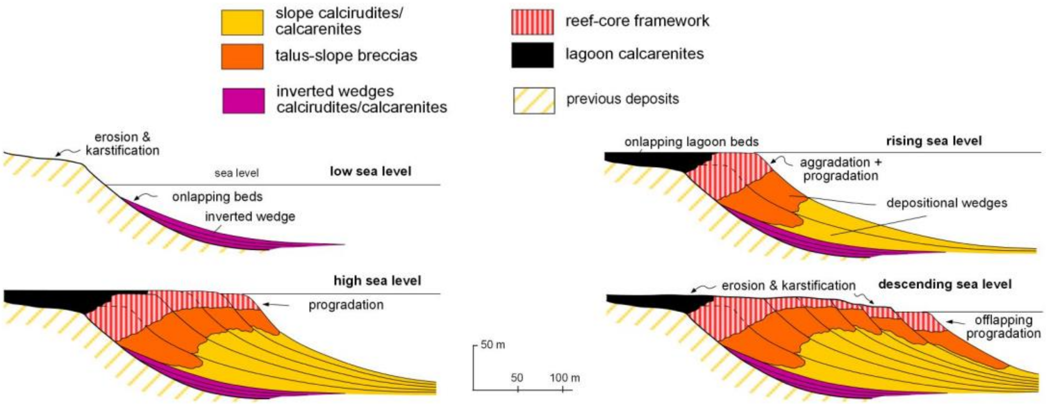


Figure 11. (c) Model of reef-advance geometries in C2 cycles. Inverted wedges (IW) mark the beginning of cycles and are the deposits that formed at lowest sea-level. Reef aggradation combined with progradation took place during sea-level rise. Lagoon beds onlapped the eroded and karstified previous deposits. Reefs prograded during highest sea-level, and offlapped during sea-level fall, at which time reef deposits from former phases started to be eroded (from Braga and Martín, 1996).

Photograph 55.- Final stages of progradation of the Messinian Cariatiz fringing-reef. Sigmoidal carbonate bodies comprise both the reef core (a) and the frontal reef-slope (t). They reflect the successive growth-phases of the reef system. Downslope, reef-slope beds thin out and interfinger with basinal yellow marls (m). The Messinian-gypsum quarries can be seen at the distance (Sorbas Basin. Barranco de los Castaños).

Photograph 56.- “Lowstand” wedge (cl) onlapping reef-slope facies (ta). These wedges are made up of non-reefal carbonates. They developed during lowstands of high-frequency, eustatic sea-level cycles (Sorbas Basin. Barranco de la Mora).

The Messinian gypsum

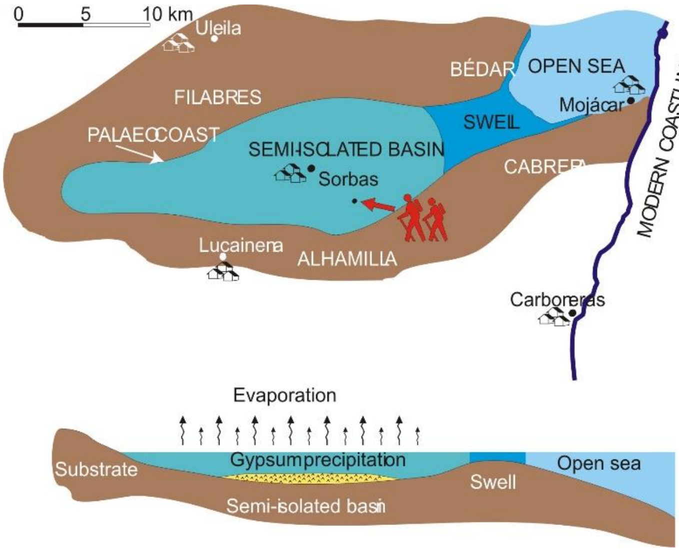


Figure 12. A: Palaeogeography of the Sorbas Basin during gypsum deposition, 5.5 My ago (from Braga and Martín, 1997). B: Sedimentation model for the Messinian gypsum in the Sorbas Basin. The confinement was probably caused by a marine area of shallow depth (a ridge) that separated the Sorbas Basin and the rest of the Mediterranean.

Photograph 57.- Gypsum banks, up to 20 m thick, at the entrance of the Río Aguas canyon. Deep scouring in the underlying soft marls has favoured the collapsing of the gypsum, and the resulting accumulation of chaotic blocks (Sorbas Basin. Los Molinos del Río Aguas).

Photograph 58.- Thick gypsum banks consisting of selenite-gypsum palisades (Sorbas Basin. Los Molinos del Río Aguas).

Photograph 59.- Selenite crystals exhibiting the typical, subvertical, V-shape, swallow-tail twinned growths (Sorbas Basin. Los Molinos del Río Aguas).

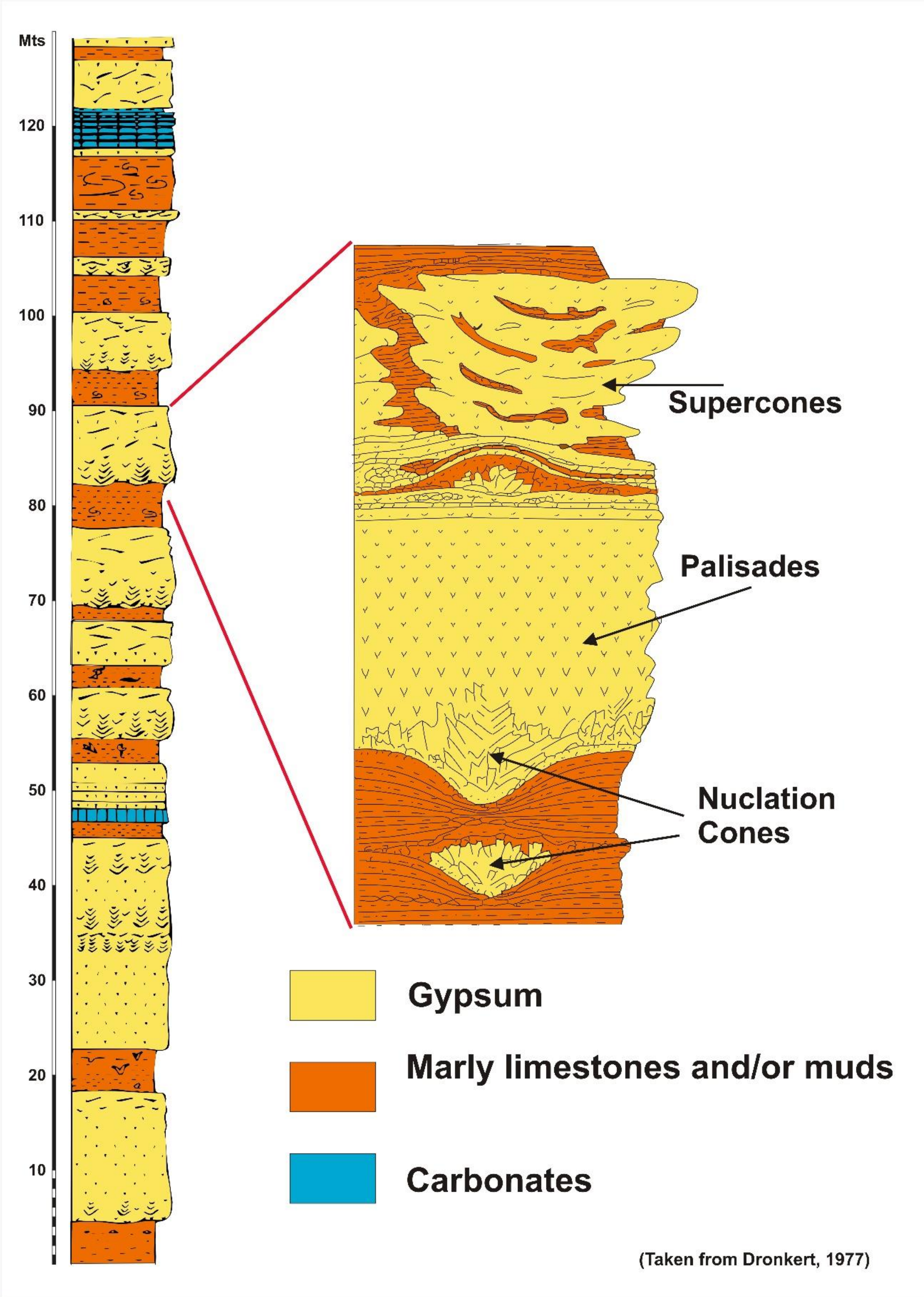


Figure 13. Stratigraphic column of the Sorbas evaporite sequence and detailed structure of one of the gypsum beds showing the nucleation cones at the base, the selenite palisades in the middle and the supercones on top, with “pockets” of silts inside the supercones and lateral to them (from Dronkert, 1977).

Photograph 60.- General view of the gypsum-supercone outcrop (Sorbas Basin. Rambla del Río Aguas).

Photograph 61.- Gypsum supercones occur at the top of very continuous and persistent gypsum banks (Sorbas Basin. Rambla del Río Aguas).

Photograph 62.- The supercones (also known as coliflower-like growths) exhibit a tree-like appearance (Sorbas. Rambla del Río Aguas).

Photograph 63.- Supercone “branches” are made up of large, selenite-gypsum crystals in the shape of a cimitar (arab sword) (Sorbas Basin. Rambla del Río Aguas).

Photograph 64.- Partially-collapsed, igloo-like gypsum structures. These structures are presumably linked to quick de-compaction, and occur on top of the gypsum outcrops (Sorbas Basin. Marchalico-Viñícas).

The lastest, post-evaporitic Messinian (Sorbas Member)

The late Messinian beaches

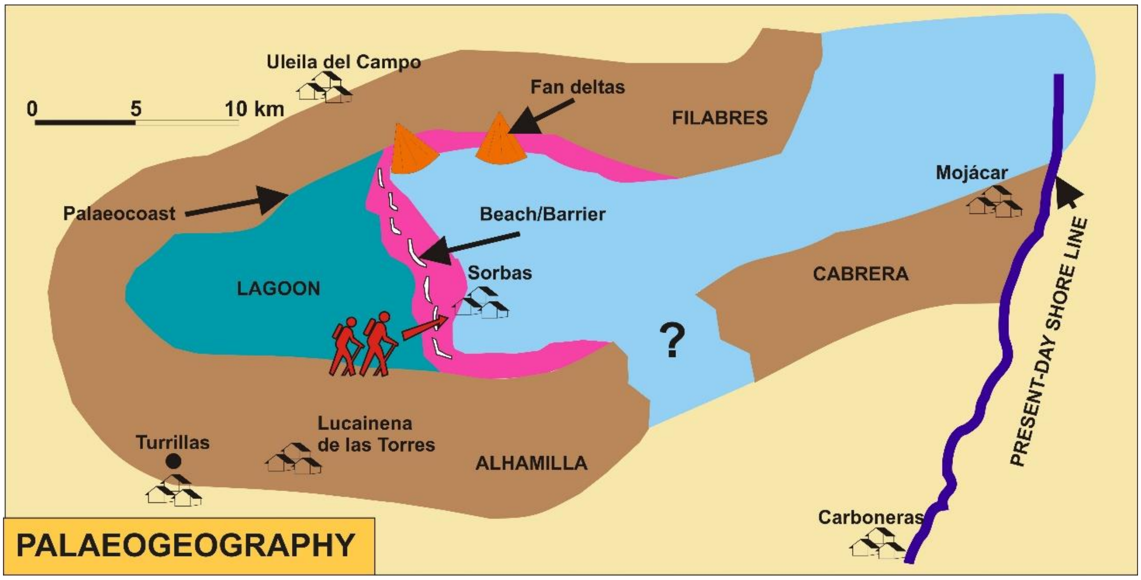


Figure 14. A: Palaeogeography of the Sorbas Basin during the formation of the Messinian beaches, 5.4 My ago (from Braga and Martín, 1997).

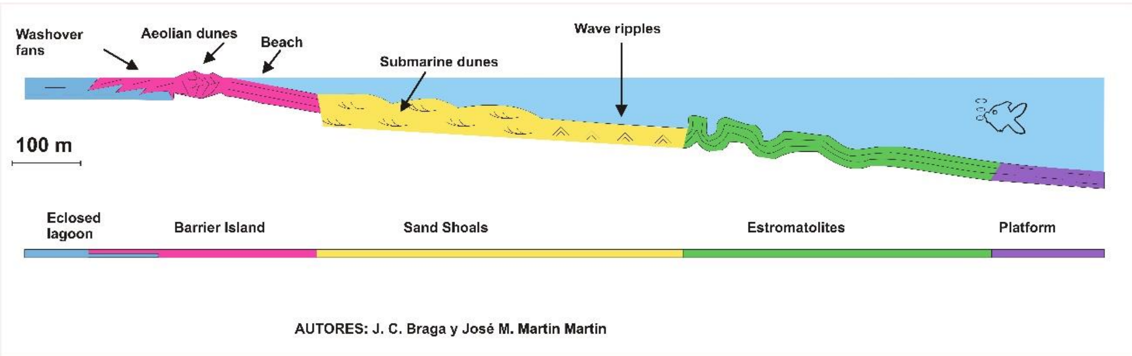


Figure 14. B: Sedimentary model and facies-belt distribution from the lagoon to the open shelf (from Braga and Martín, 2000).

Photograph 65.- Eastwards-prograding beach deposits, which infilled the uppermost Messinian Sorbas embayment. Each bank corresponds to a single beach episode. Lateral facies distribution within a single bank is the same as the one shown by successive, superimposed banks in a vertical sequence (“Walther´s law of facies”) (Sorbas Basin. Sorbas). →

Photograph 66.- Fine, weakly-cemented and bioturbated fine sands from the backshore overlaid by lagoonal silts. The latter ones interfinger laterally with and are covered by the sandy, well-cemented, washover-fan storm deposits (Sorbas Basin. Sorbas).

Photograph 67.- Highly-bioturbated sandstones from the backshore (Sorbas Basin. Sorbas).

Photograph 68.- Close view of the bioturbation probably linked to root burrows (Sorbas Basin. Sorbas).

Photograph 69.- Typical foreshore facies exhibiting low-angle, parallel lamination and intercalated beach ("beach rocks") breccias (Sorbas Basin. Sorbas).

Photograph 70.- Foreshore, low-angle parallel lamination in sandstones, from the beach deposits (Sorbas Basin. Sorbas).

Photograph 71.- Beach rock breccia, with cemented clasts from the beach deposits (Sorbas Basin. Sorbas).

Photograph 72.- Trough cross-bedding abound in the shoreface facies (Sorbas Basin. Sorbas).

Photograph 73.- Trough cross-bedding in sandstones (Sorbas Basin. Sorbas).

The fan deltas

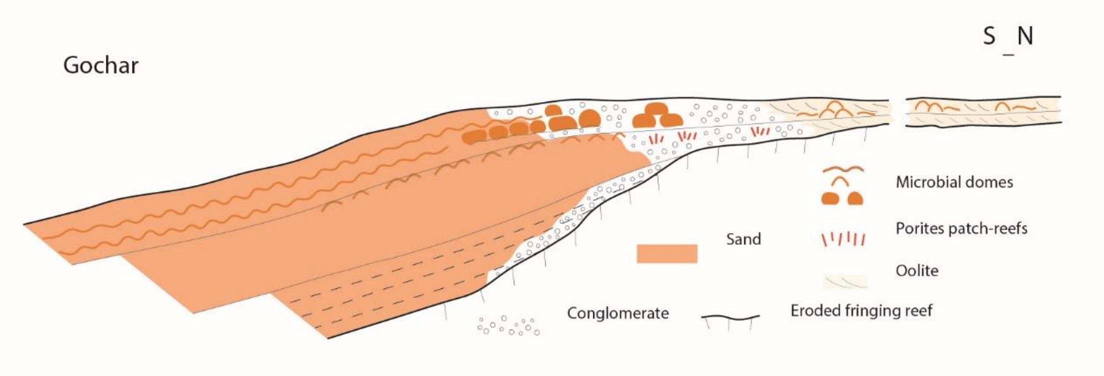
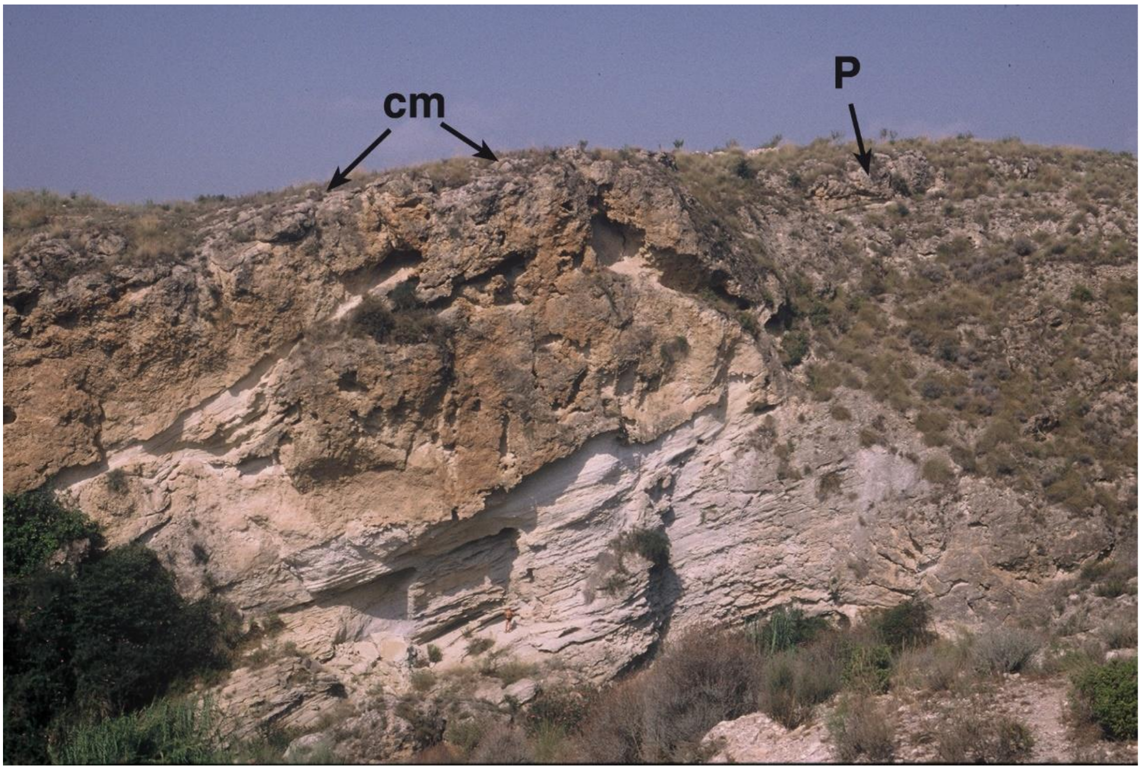


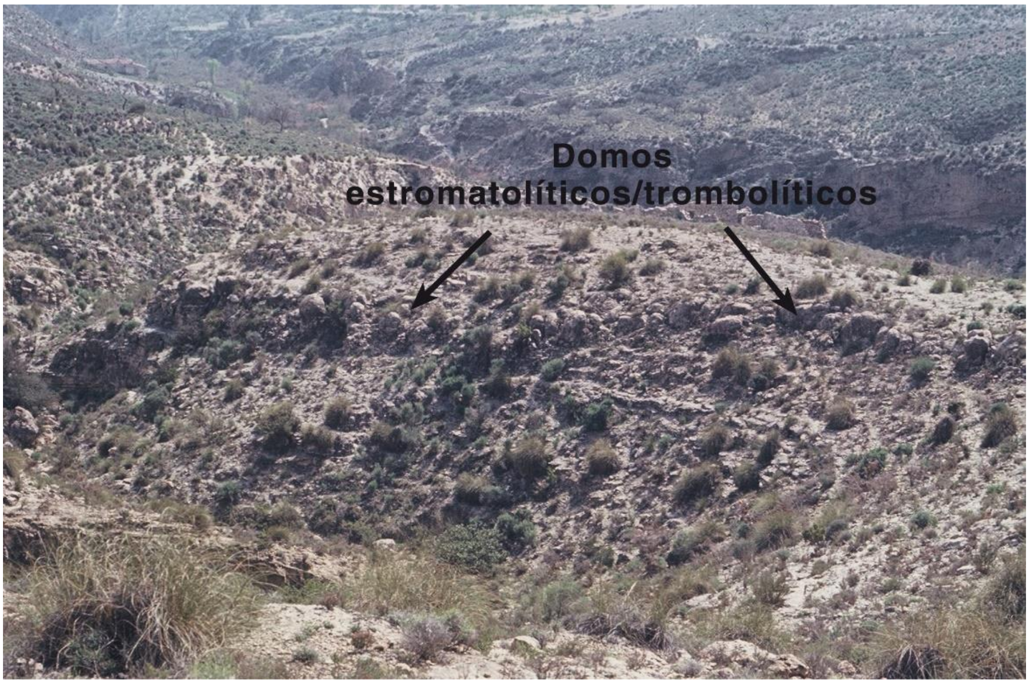
Figure 15. Góchar section showing a thin fan-delta, oolitic shoal and coral patch-reef sequence deposited on top of an eroded fringing reef. Microbial carbonate (stromatolite and thrombolite) beds extend from the shelf area, down the steep palaeoslope, into the basin for distances of 0.5 km or more (modified after Martín et al. 1993).



Photograph 74.- At the northern margin of the Sorbas Basin, the Sorbas Member is mainly detrital in composition and consists of fan-delta conglomerates and sands. These coarse-grained terrigenous sediments intercalate small coral (*Porites*) patch-reefs (P) and huge, microbial carbonate domes (cm) (stromatolites and thrombolites) (Sorbas Basin. Rambla de Góchar).

Photograph 75.- Part of wall seen in the previous picture, consisting mostly of sands, has collapsed very recently (Cuenca de Sorbas. Rambla de Góchar).

Photograph 76.- Microbial carbonate beds can be traced laterally downslope at both sides of the ravine (Sorbas Basin. Rambla de Góchar).



Photograph 77.- Both, single stromatolite and thrombolite domes, as well as mixed stromatolite-thrombolite domes, make up the bulk of these microbial carbonate beds (Sorbas Basin. Rambla de Góchar).

The microbial carbonates

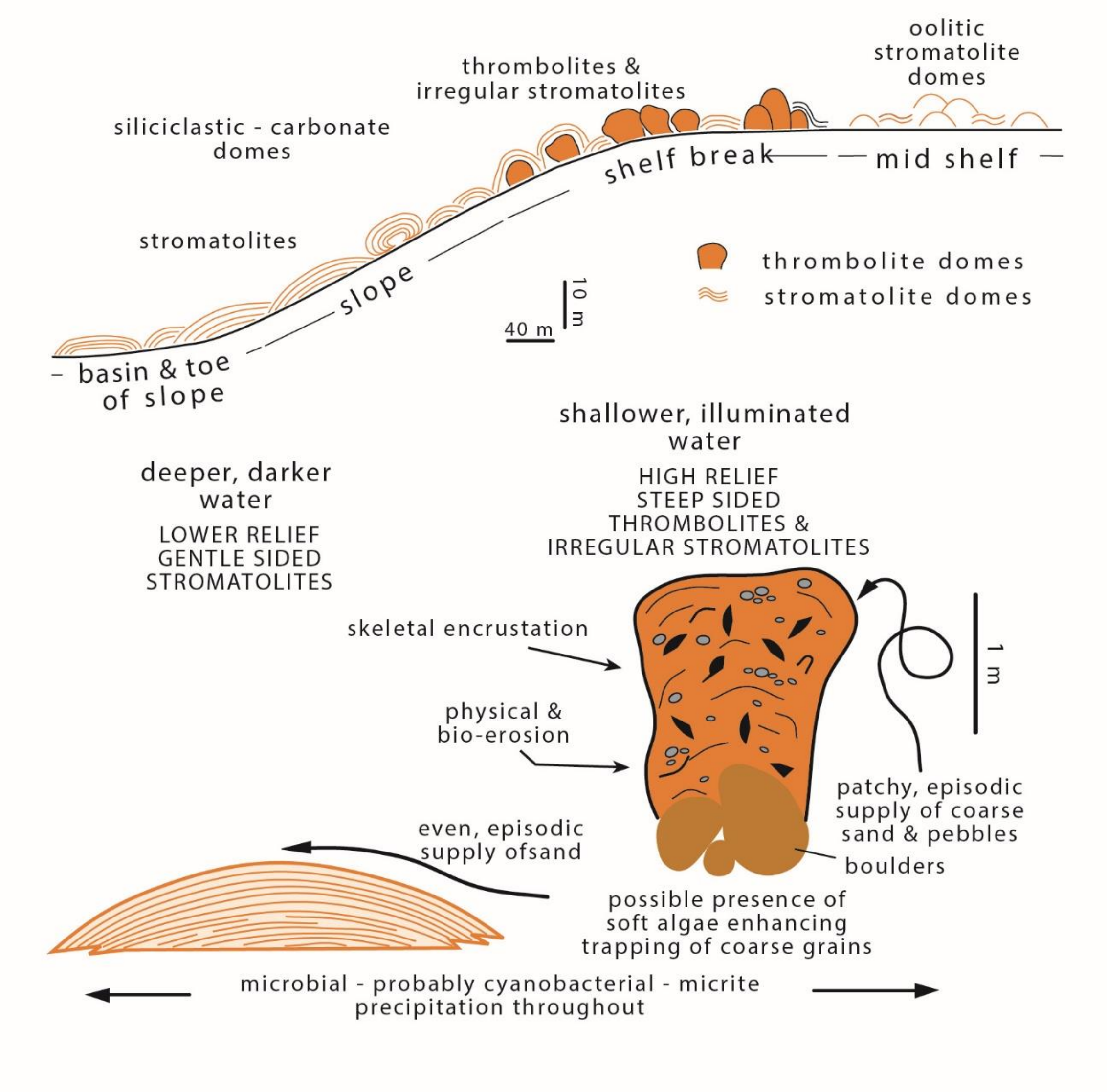


Figure 16. (a): Composite cross-section of shelf-basin dome distribution at Góchar showing variations in dome type, shape, and grain composition. (b): Deep, slope-basin stromatolite domes and shallow-water, shelf break stromatolite-thrombolite domes contrasted (from Braga et al. 1995).

Photograph 78.- Mixed, mostly thrombolitic, microbial-carbonate dome, with a thin stromatolite cap, placed on top of conglomerate blocks (Sorbas Basin. Rambla de Góchar).

Photograph 79.- Stromatolite domes (Sorbas Basin. Barranco de los Castaños).

Photograph 80.- Stromatolite dome with a bored, thrombolite core (Sorbas Basin. Rambla de Góchar).

Photograph 81.- Stromatolite dome encrusting huge conglomerate blocks (Sorbas Basin. Rambla de Góchar).

Photograph 82.- Close-view of a stromatolite. Sediment layers include small, sand clasts (Sorbas Basin. Rambla de Góchar).

Photograph 83.- Symmetric wave-ripples of significant size in fan-delta sands (Sorbas Basin. Rambla de Góchar).

RECOMMENDED ITINERARIES:

Itinerary 1.- Peñas Negras-Sorbas
Most stops are by the road. Some short walking from the car is needed in some cases.
Main subjects: Infilling sequence of the Sorbas Basin (stratigraphy), temperate carbonates from the Tortonian-Messinian transition and Messinian evaporites (gypsum deposits).
Duration: half a day.

Stop 1.- Peñas Negras:
Observed features: 1 and 2.

Stop 2.- La Molata:
Observed features: 24.

Stop 3.- Los Molinos del Río Aguas vantage point:
Observed features: 3, 4, 5, 6 and 7.

Stop 4.- Los Molinos del Río Aguas (a-b):
Observed features: (a) 17, 18, 19 y 25; (b) 57, 58 and 59.

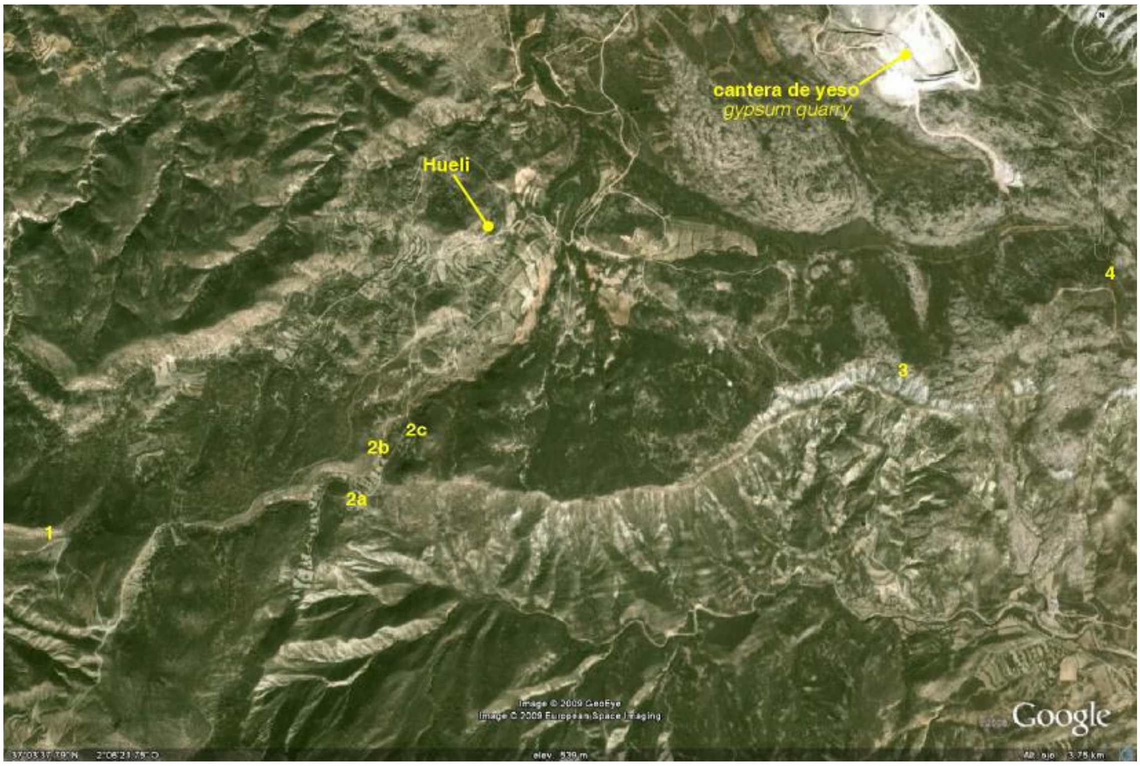
Stop 5.- Urra vantage point:
Observed features: 3.

Stop 6.- Rambla del Río Aguas:
Observed features: 60, 61, 62 and 63.

Stop 7.- Sorbas:
Observed features: 9.

Itinerary 2.- Southern margin: Cantona-Cerrón de Hueli

Most stops are only accessible by the dirt roads and 4-wheels drive vehicles are recommended. Short walking is also needed in some cases.
Main subjects: Infilling sequence of the Sorbas Basin (stratigraphy), temperate carbonates from the Tortonian-Messinian transition and Bioherm Unit (Messinian).
Duration: half a day/one day.



Stop 1.- Los Molinos hillock:
Observed features: 16.

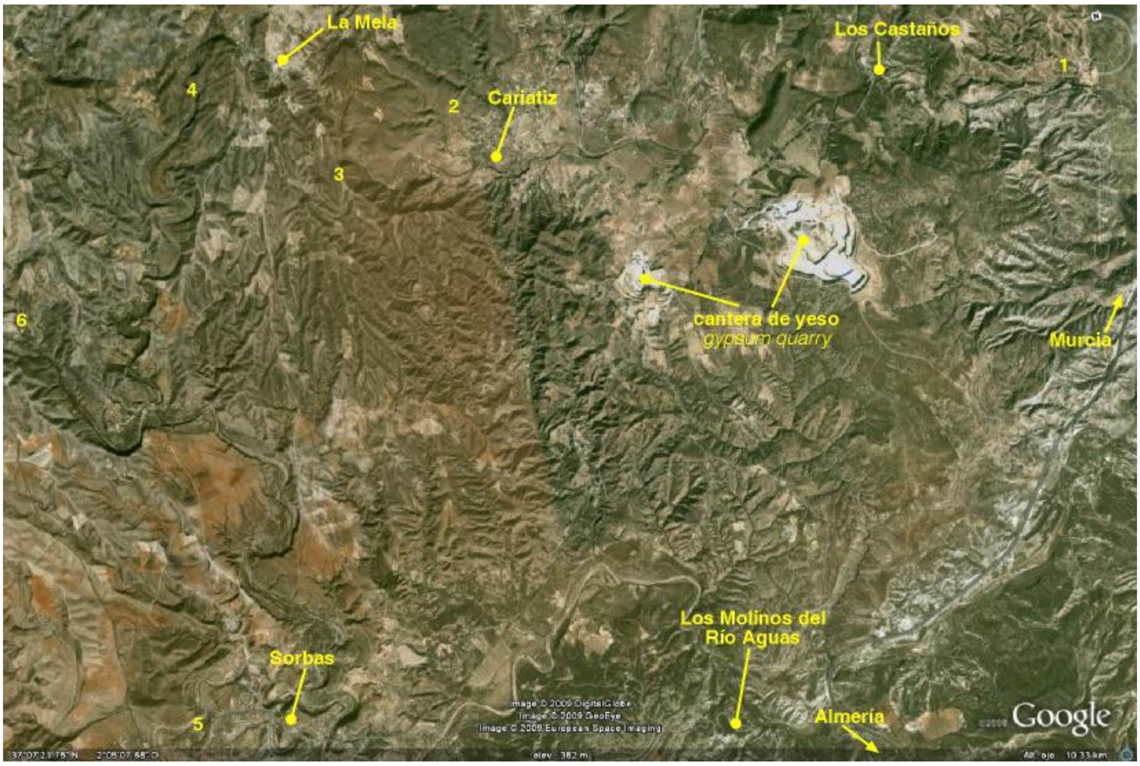
Stop 2.- Hueli (a-b-c):
Observed features: (a) 26 y 27; (b) 28 y 31; (c) 32 and 33.

Stop 3. Cerrón de Hueli hillock:
Observed features: 12.

Stop 4. Cerrón de Hueli:
Observed features: 8.

Itinerary 3.- Northern margin: Almocaizar-Cariatiz-Sorbas-Rambla de Góchar

All stops are by the road with some short walking from the car.
Main subjects: Temperate carbonates from the Tortonian-Messinian transition, Messinian fringing reefs, Messinian beach deposits and Messinian microbial carbonates (stromatolites and thrombolites).
Duration: One day.



Stop 1.- "Bar Lemon" (Almocaizar):
Observed features: 13, 14, 15, 20, 21, 22 and 23.

Stop 2.- Cariatiz:
Observed features: 35, 36, 37, 38, 39, 40, 41, 42, 43, 45, 46, 48, 49, 50, 51, 52 and 53.

Stop 3.- Barranco de los Castaños:
Observed features: 54, 55 and 79.

Stop 4.- Barranco de La Mora:
Observed features: 56.

Stop 5.- Sorbas:
Observed features: 65, 66, 67, 68, 69, 70, 71, 72 and 73.

Stop 6.- Rambla de Góchar:
Observed features: 44, 47, 74, 75, 76, 77, 78, 80, 81, 82 and 83.