THE BETIC NEOGENE BASINS (S. SPAIN)

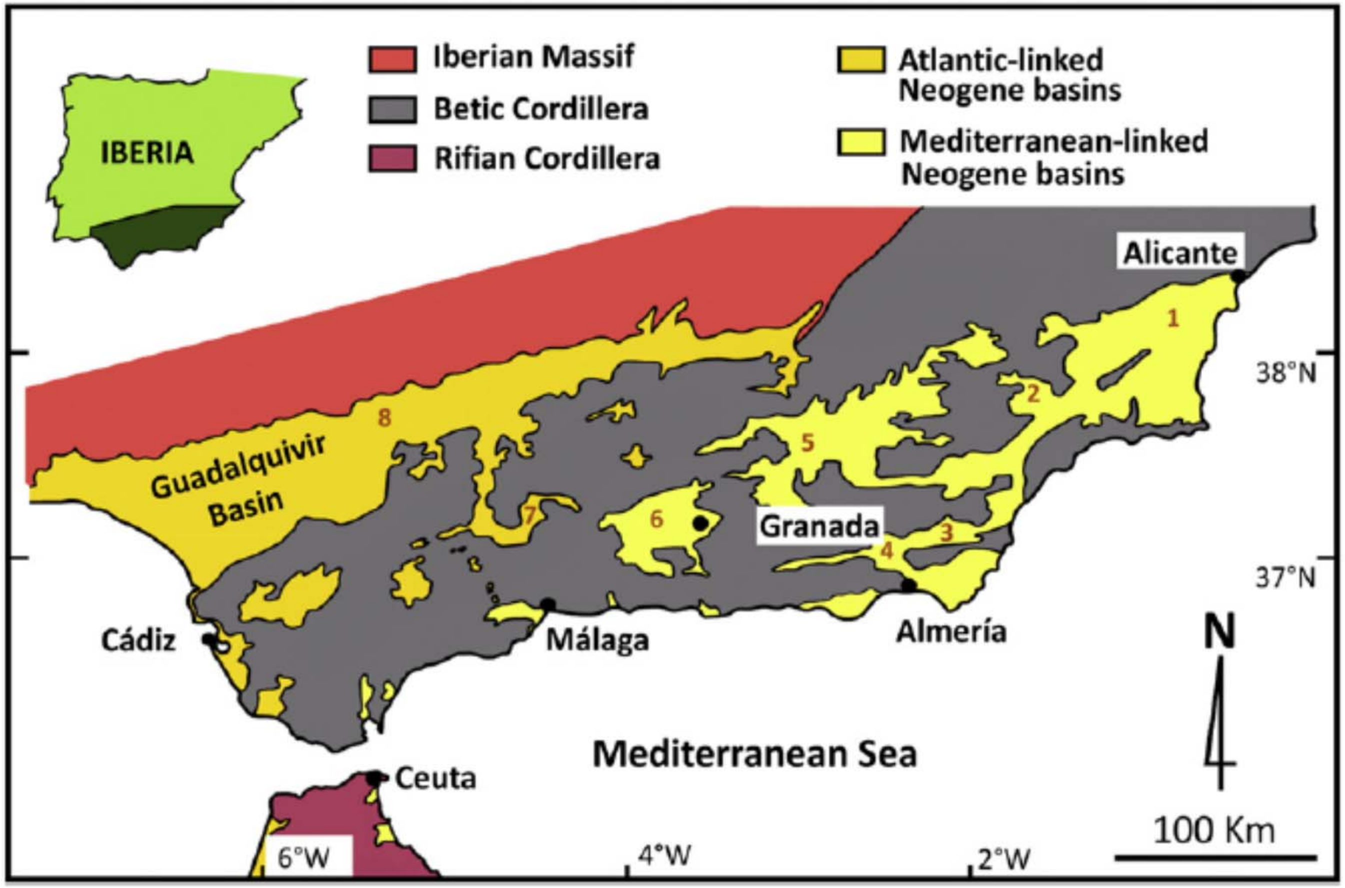
José M. Martín

Departamento de Estratigrafía y Paleontología
Universidad de Granada

Martín, J.M. The Betic Neogene Basins (S. Spain). Universidad de Granada (2016). [http://hdl.handle.net/10481/41548]

TWO TYPES

ATLANTIC-LINKED AND MEDITERRANEAN-LINKED BASINS



ATLANTIC-LINKED BASINS

Exemplified by the Guadalquivir basin, and some minor basins to the south

The Guadalquivir basin is the foreland basin of the Betic Cordillera. Mass-flows and olitostromes were the dominant type of deposits in Middle Miocene times

MEDITERRANEAN-LINKED BASINS

Two types: the “inner basins” (the most distant from the present-day Mediterranean Sea), and the “outer basins” (the nearest to the present-day Mediterranean Sea)

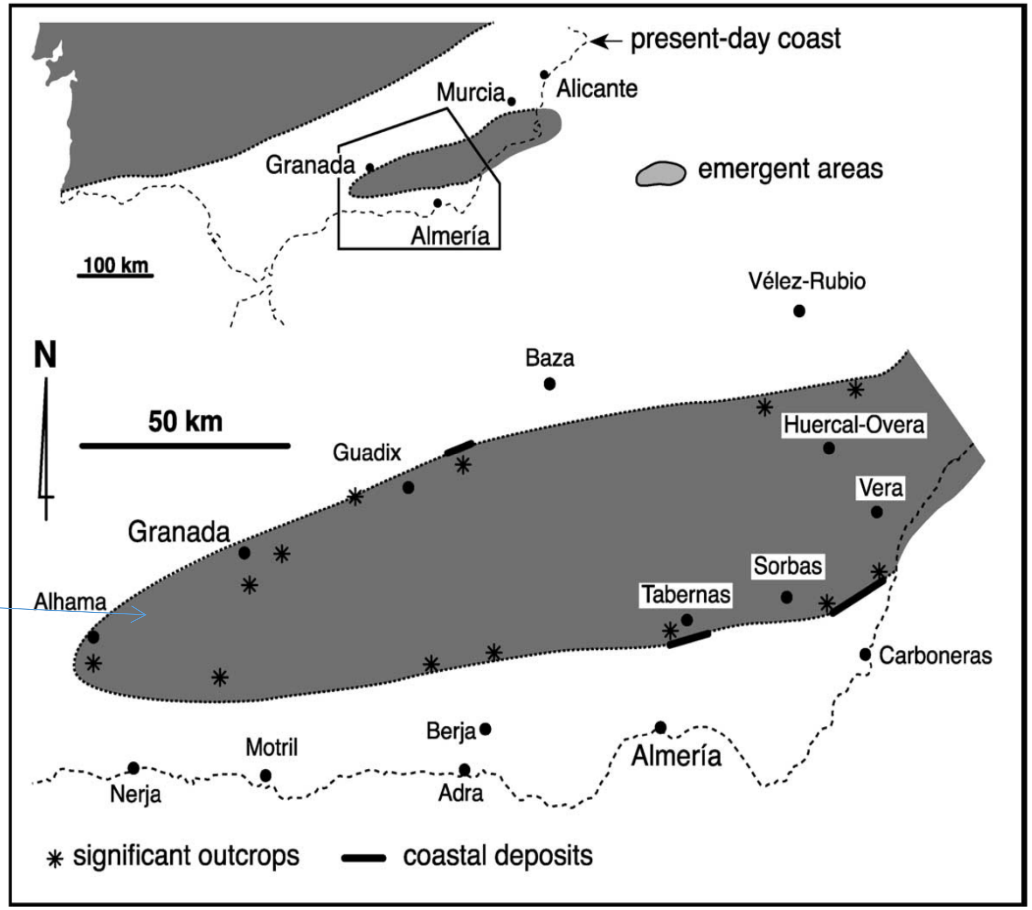
The Granada basin and the Sorbas basin will be used as study cases to exemplify the “inner” and the “outer basins” respectively

BASIN CONFIGURATION

THE BETIC BASINS DIFFERENTIATED AS SUCH IN THE COURSE OF THE TORTONIAN

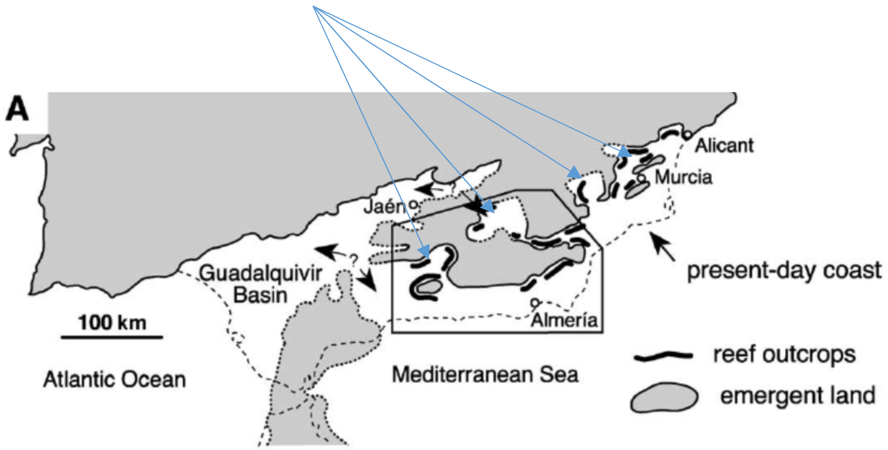
THE EARLY HISTORY

In Middle Miocene times only a single, major Betic relief existed to the South of the Iberian Massif



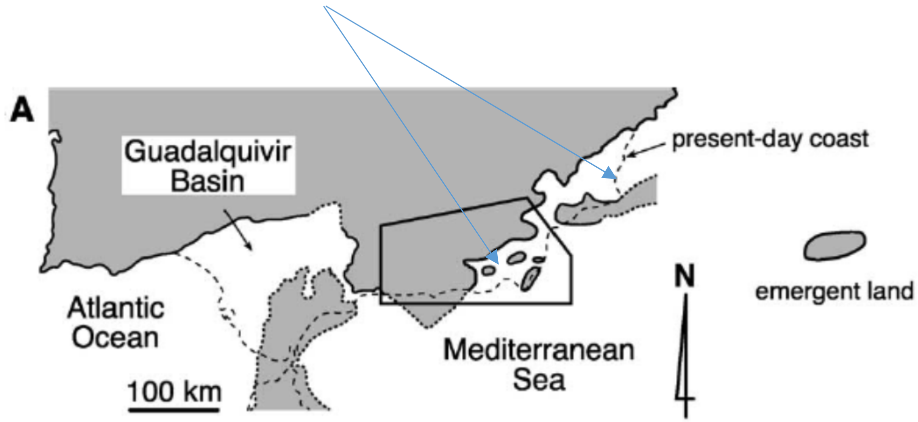
LATE TORTONIAN

(the "inner Mediterranean-linked basins" differentiated)



LATEMOST TORTONIAN

(the "outer Mediterranean-linked basins" differentiated)

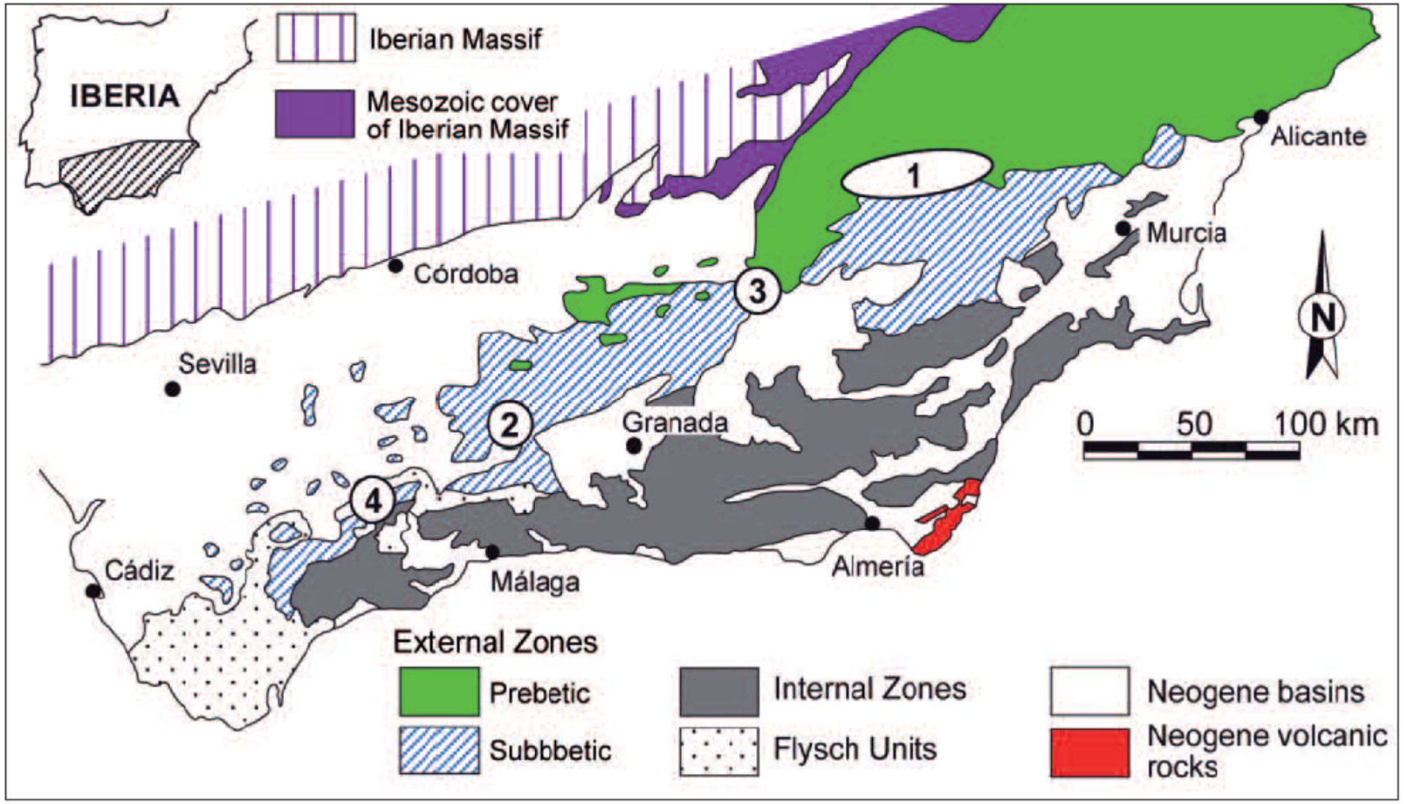


TORTONIAN HISTORY AND PALAEOGEOGRAPHICAL EVOLUTION

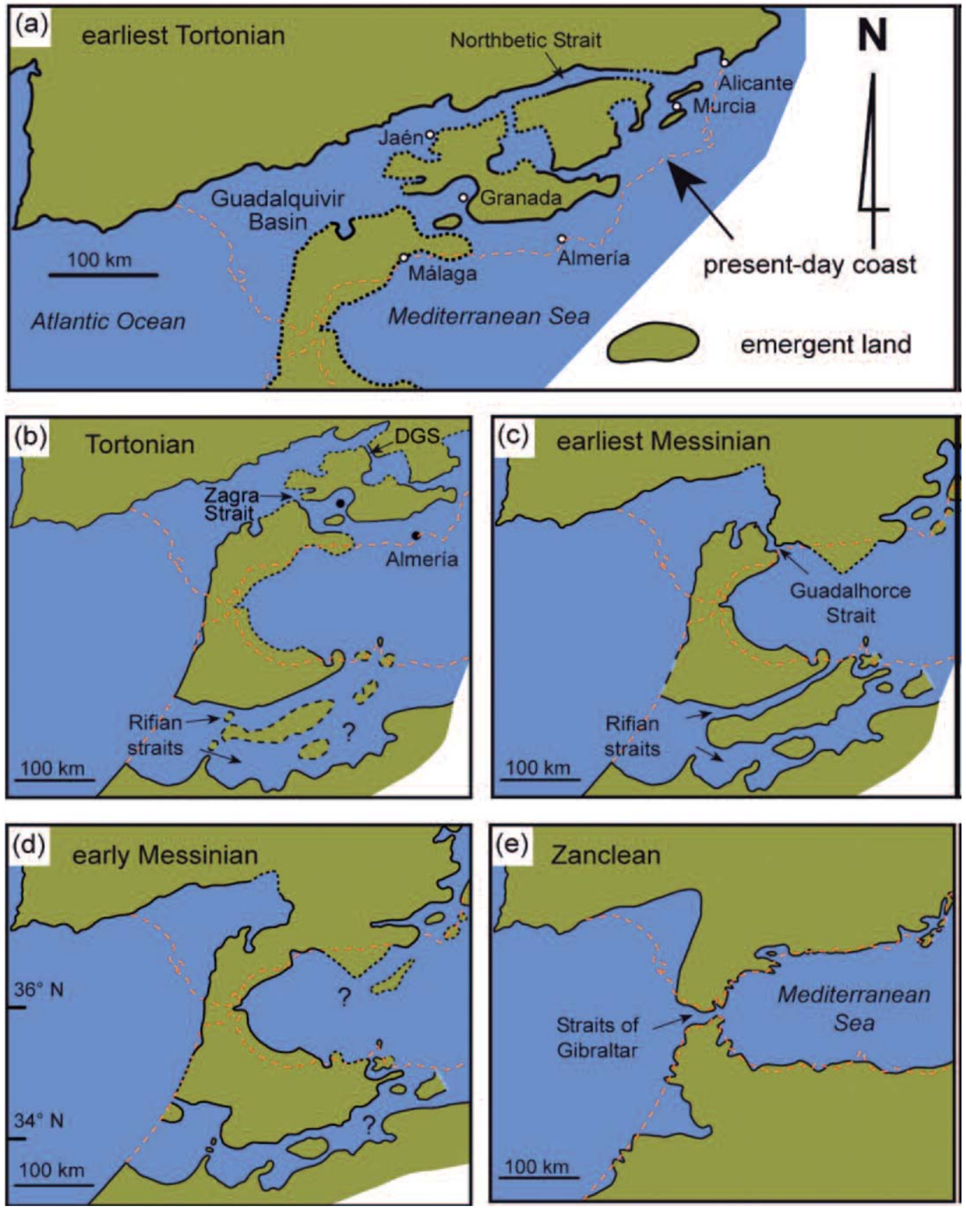
The "inner basins" lost their marine connection at the end of the Tortonian,
while the "outer basins" remained connected to the Mediterranean Sea

THE CONNECTIONS BETWEEN THE ATLANTIC-LINKED AND THE MEDITERRANEAN-LINKED BASINS: THE BETIC STRAITS

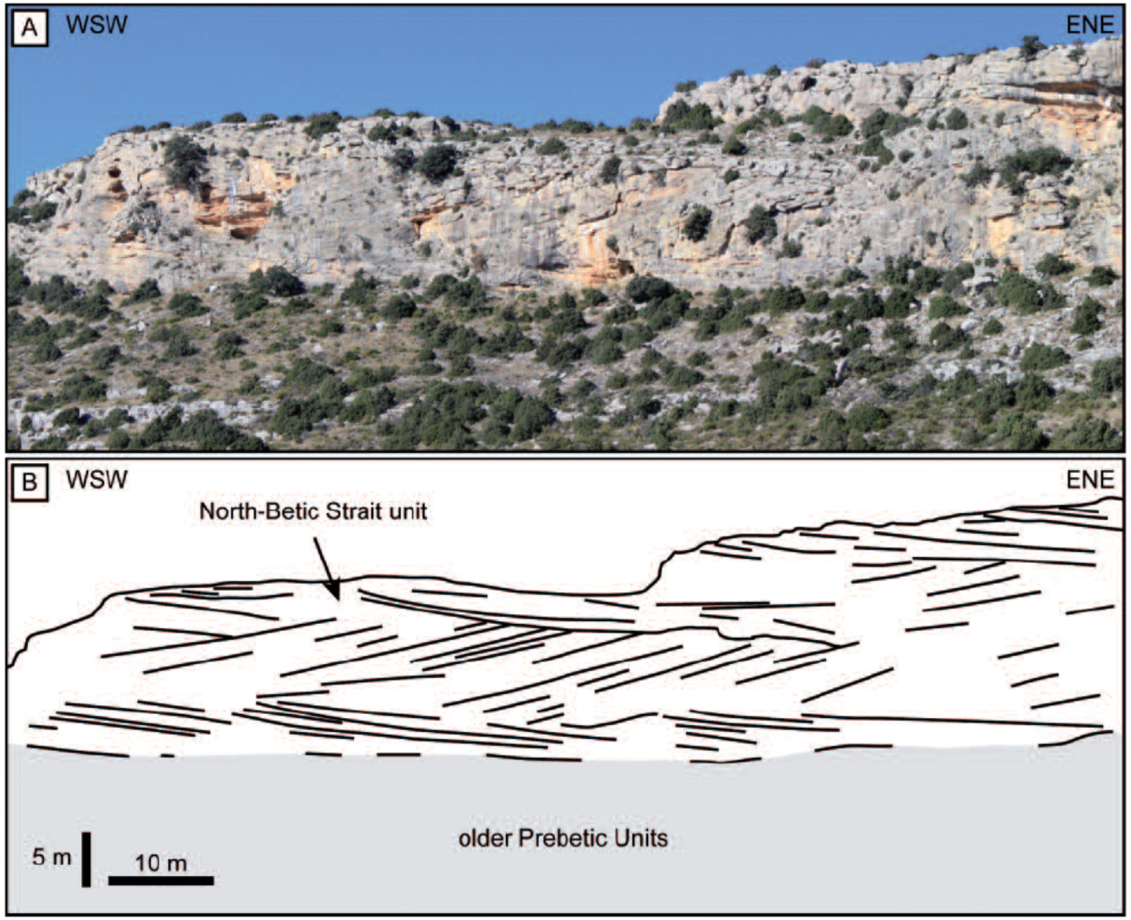
Seaway locations: 1: North-Betic Strait (early Tortonian); 2: Zagra Strait (Tortonian); 3: Dehesas de Guadix Strait (late Tortonian); 4: Guadalhorce Strait (early Messinian)

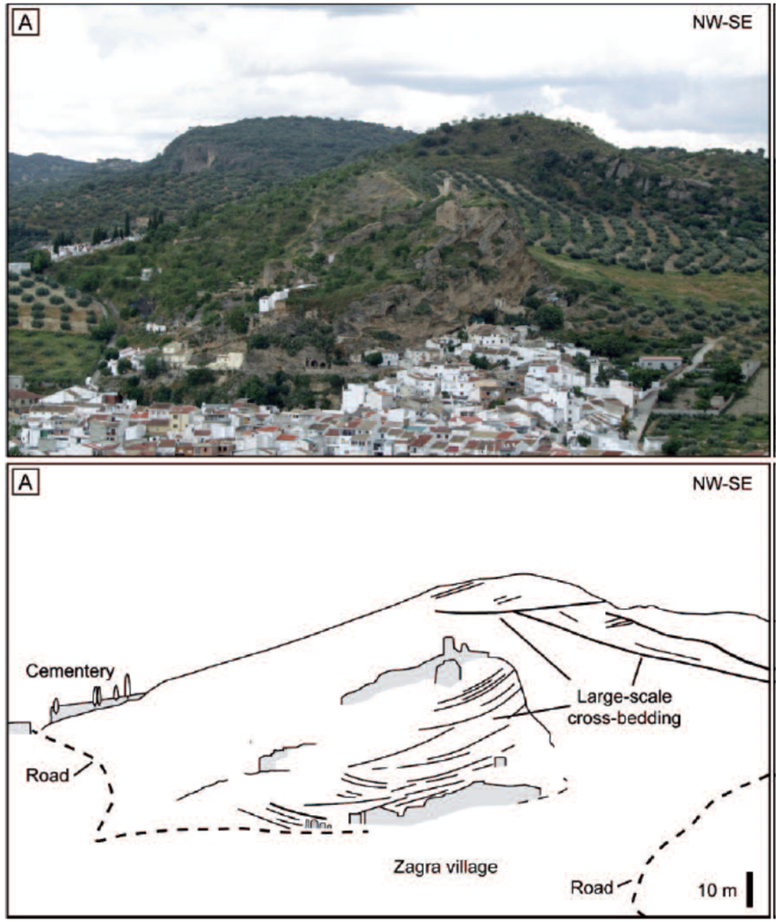


PALEOGEOGRAPHICAL MAPS SHOWING THE CHANGES IN THE ATLANTIC-MEDITERRANEAN CONNECTIONS (SEAWAYS) FROM THE TORTONIAN TO THE PLIOCENE



Strait deposits exhibit ubiquitous, large-scale cross-bedding
THE NORTH-BETIC AND ZAGRA STRAITS WERE TIDE DOMINATED





THE DEHESAS DE GUADIX AND GUADALHORCE STRAITS WERE CURRENT DOMINATED

(with bottom currents flowing from the Mediterranean Sea to the Atlantic Ocean)

ATLANTIC-LINKED BASINS
THE GUADALQUIVIR BASIN

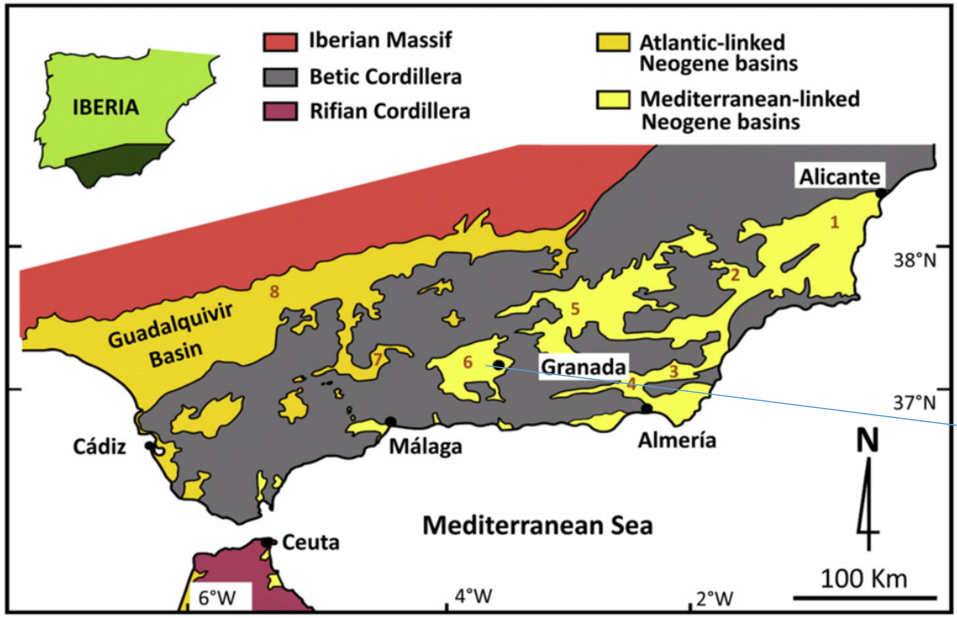
After the disappearance of the North-Betic Strait, the area farther west (its former Atlantic side), the so-called Guadalquivir Basin, remained as a wide, open marine embayment facing west

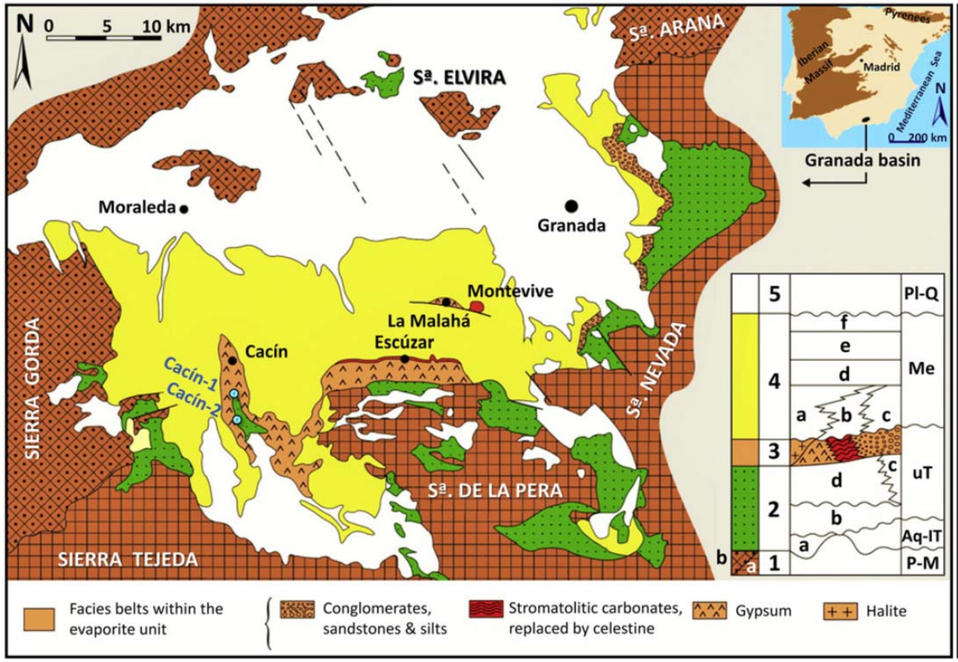
After that event, upper Tortonian/Messinian (Pliocene) shallow-water, temperate (cool-water) carbonates and mixed siliciclastic-carbonate platform-sediments were deposited at the margins of the Guadalquivir Basin. They changed laterally to, and prograded on top of, basinal marls filling in the embayment to the west

MEDITERRANEAN-LINKED BASINS
(“INNER BASINS”)

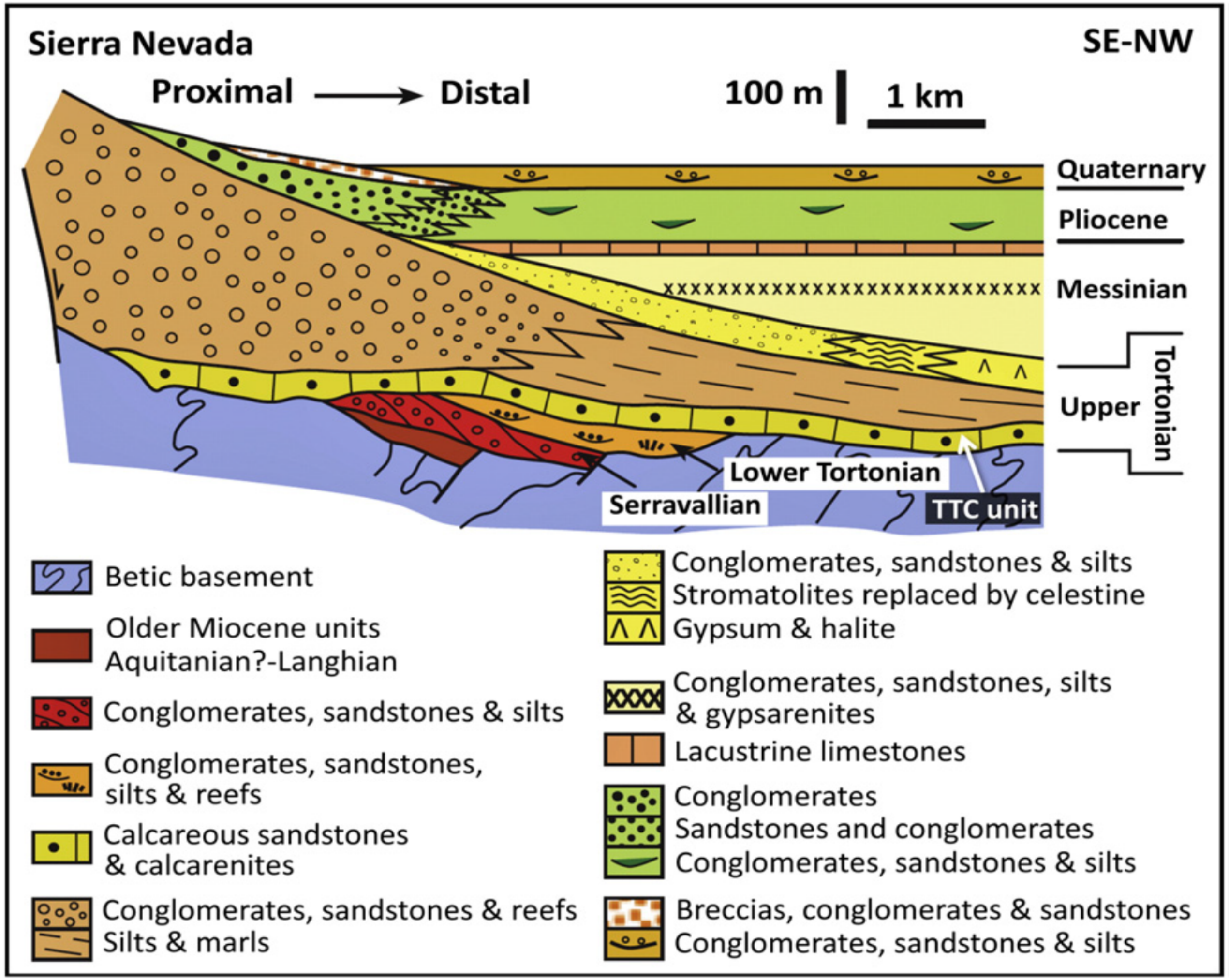
THE GRANADA BASIN

LOCATION OF THE GRANADA BASIN AND SIMPLIFIED GEOLOGICAL MAP





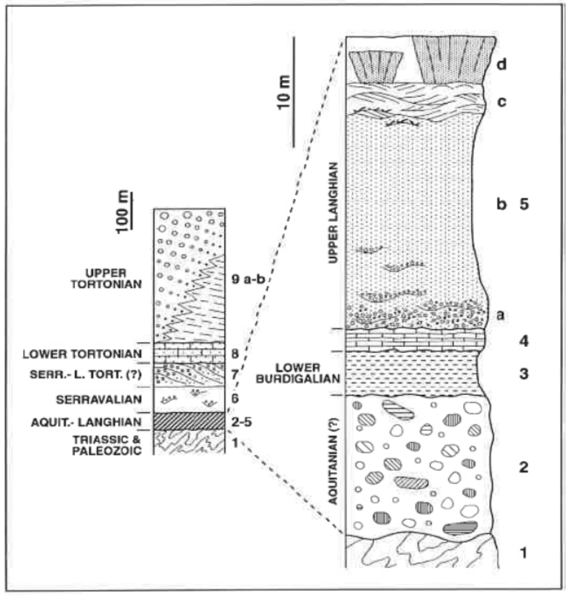
STRATIGRAPHY OF THE GRANADA BASIN

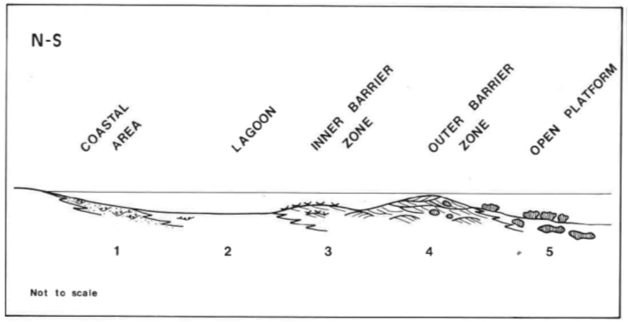


OLDER NEOGENE DEPOSITS

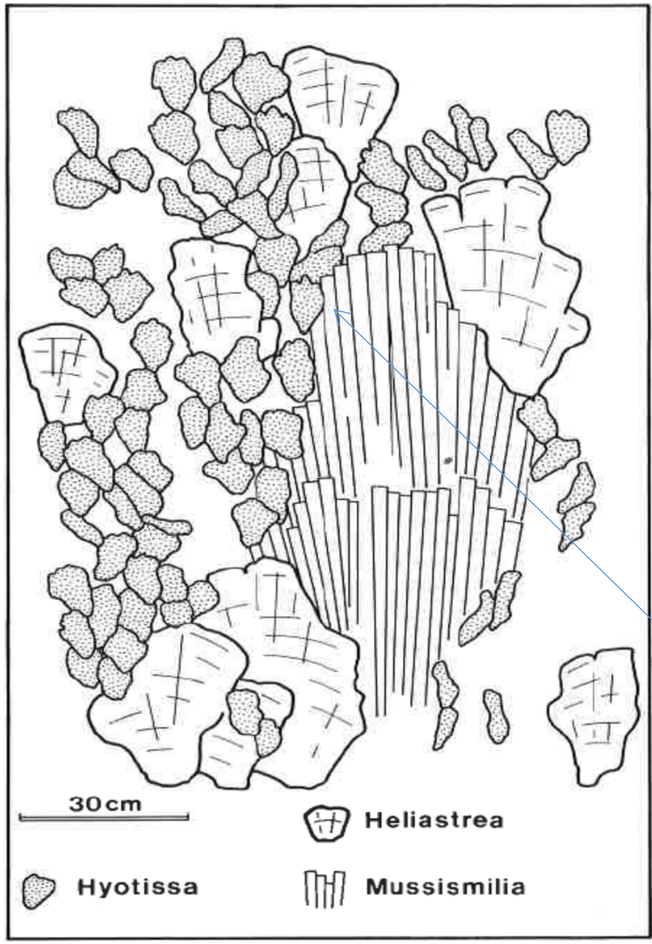
THE LANGHIAN CORAL-OYSTER PATCH-REEFS

Stratigraphic position and sedimentary model

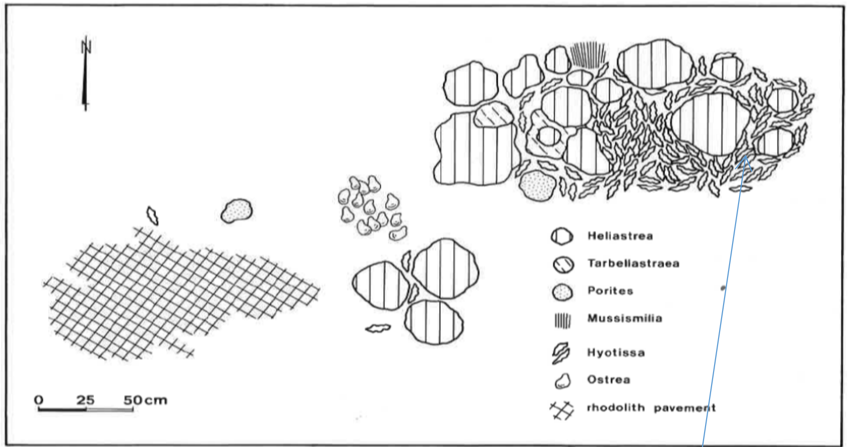


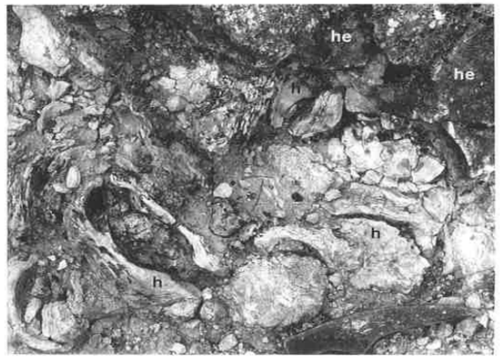


Vertical view



Horizontal view



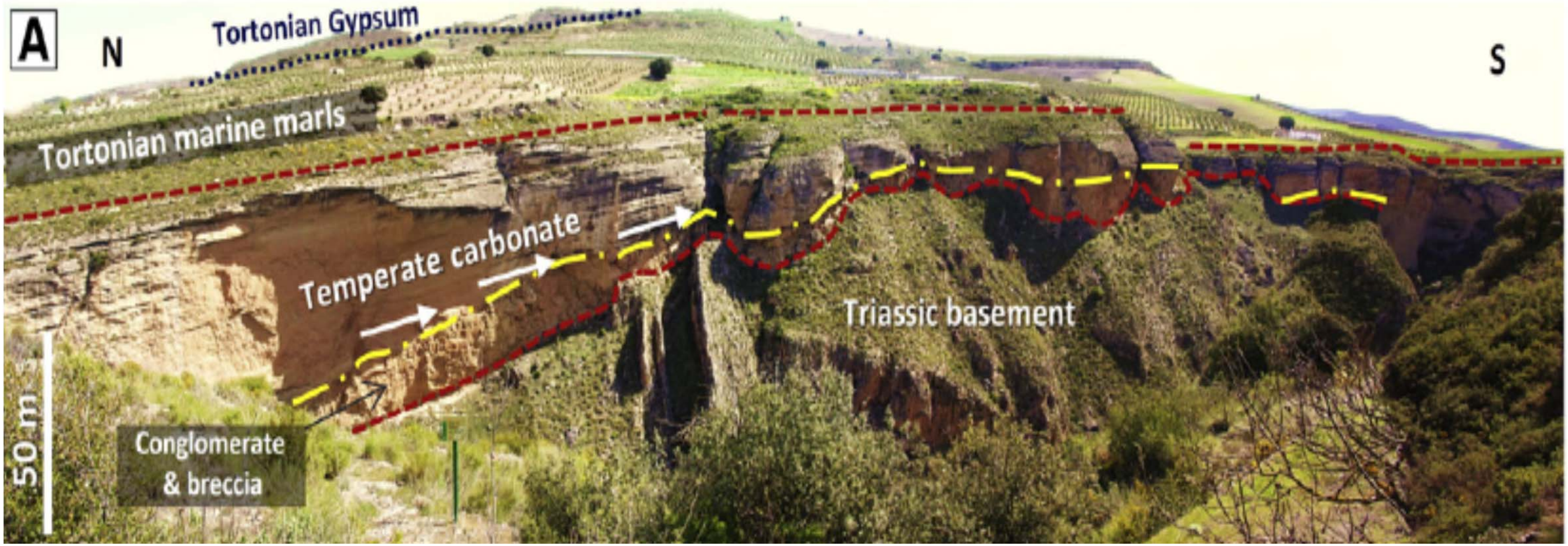


THE GRANADA BASIN INFILLING

THE UPPER TORTONIAN (8.3 to 7.8 Ma) TEMPERATE CARBONATES

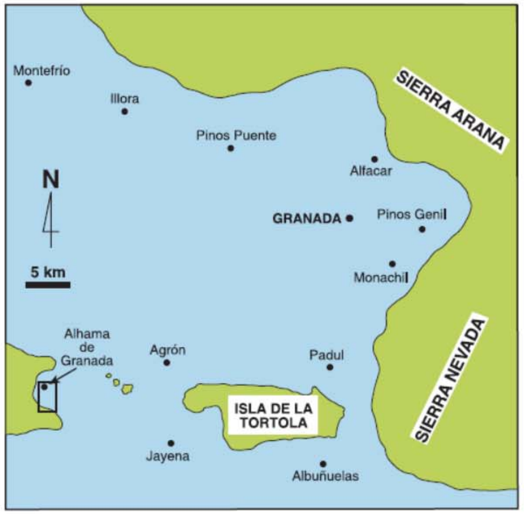
They are made up of carbonates (calcarenites), and mixed siliciclastic-carbonate sediments, containning abundant skeletal remains of bryozoans, bivalves and coralline algae

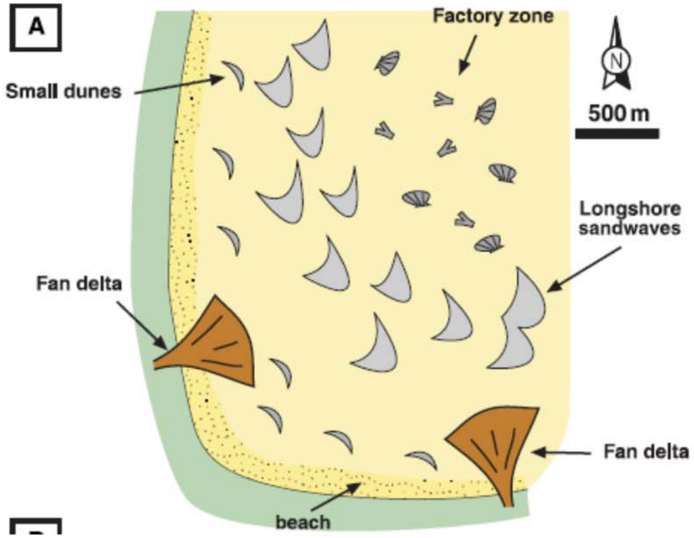
They are shallow-water (shelf) deposits formed on a temperate (cool-water) sea



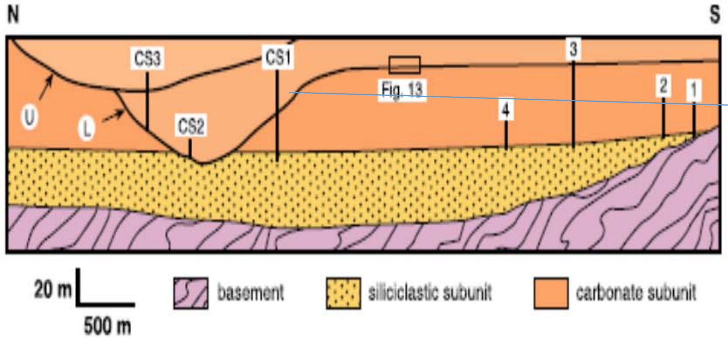
A STUDY CASE: THE ALHAMA SUBMARINE CANYON

Paleogeographical location and sedimentary model

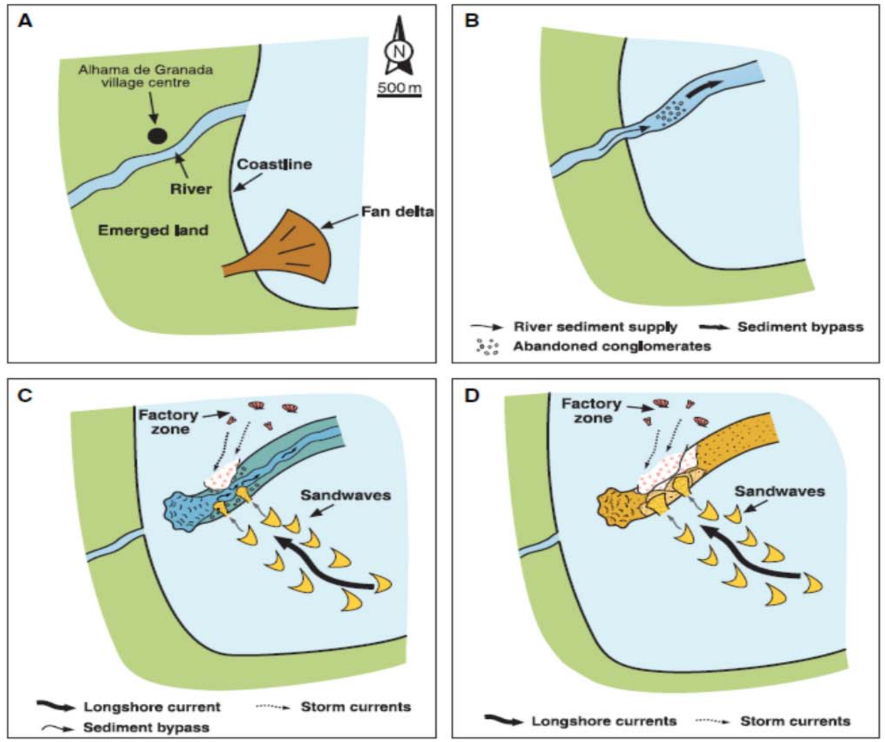




North-South cross section

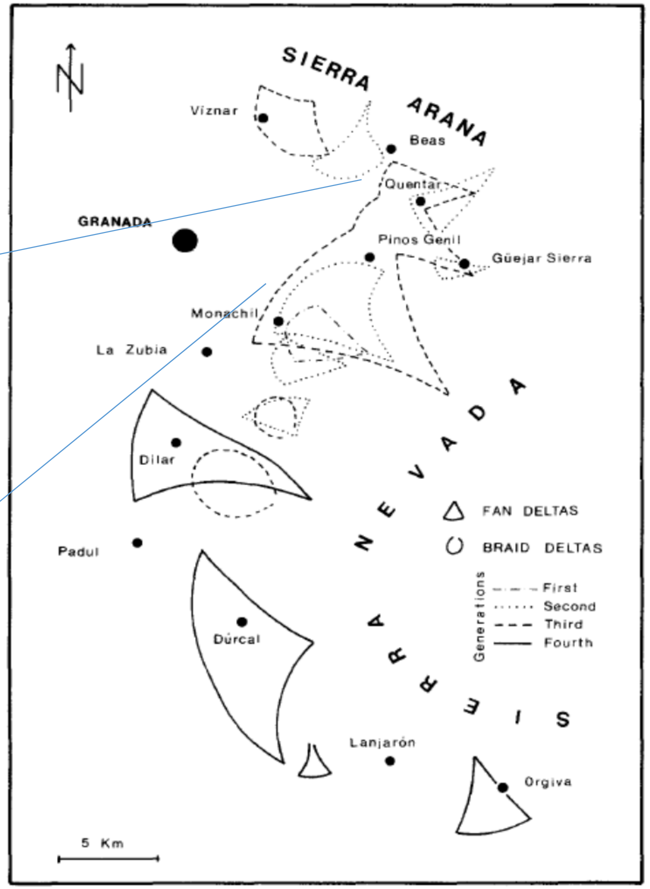


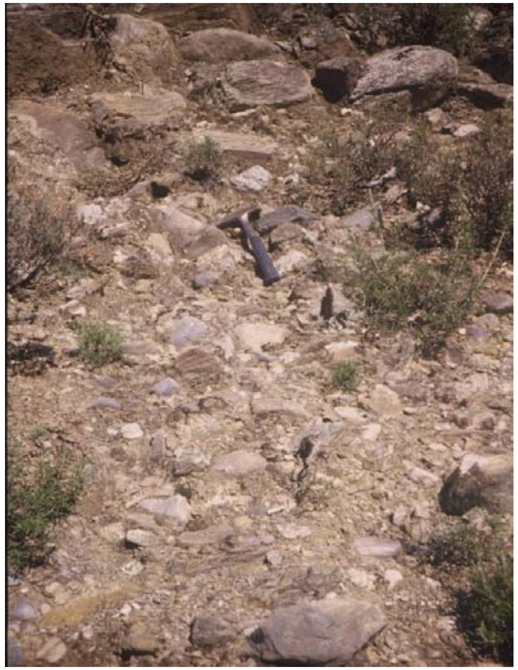
Submarine channel evolution



THE UPPER TORTONIAN CONGLOMERATES

Several generations of conglomeratic fan and braid deltas developed at the active eastern margin of the Granada basin during the upper Tortonian (7.8 to 7.3 Ma), at the foot of the Sierra Arana and Sierra Nevada reliefs



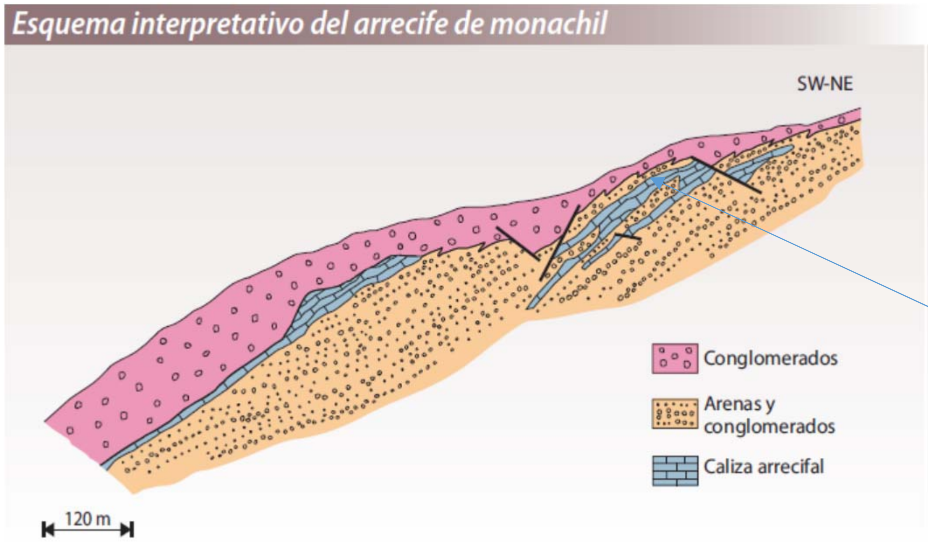


Debris-flow, conglomerate deposits are dominant in the fan deltas

THE CORAL REEFS

Coral-reef growth took place simultaneously to conglomerate deposition

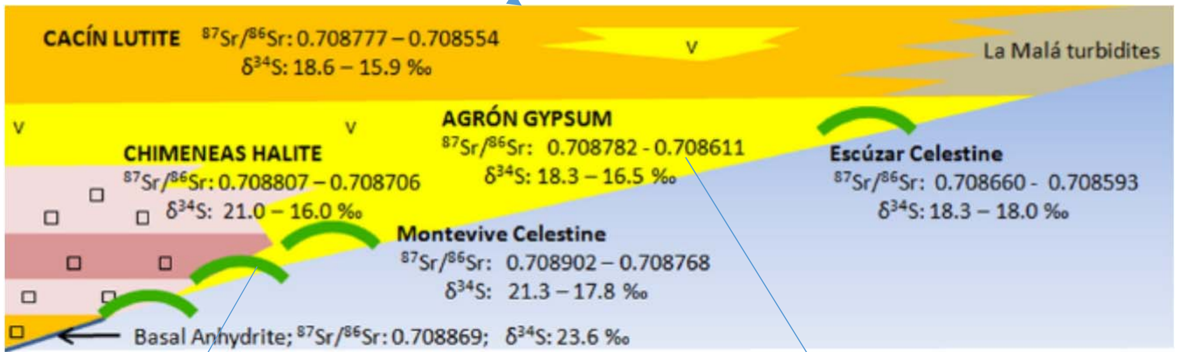
Reefs developed as fringing reefs, at stable basin margins, and as patch-reefs in conglomeratic fan and braid deltas

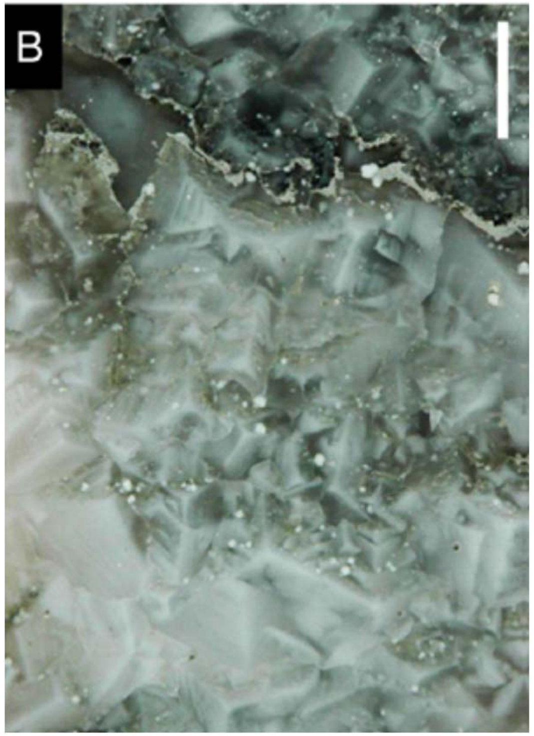


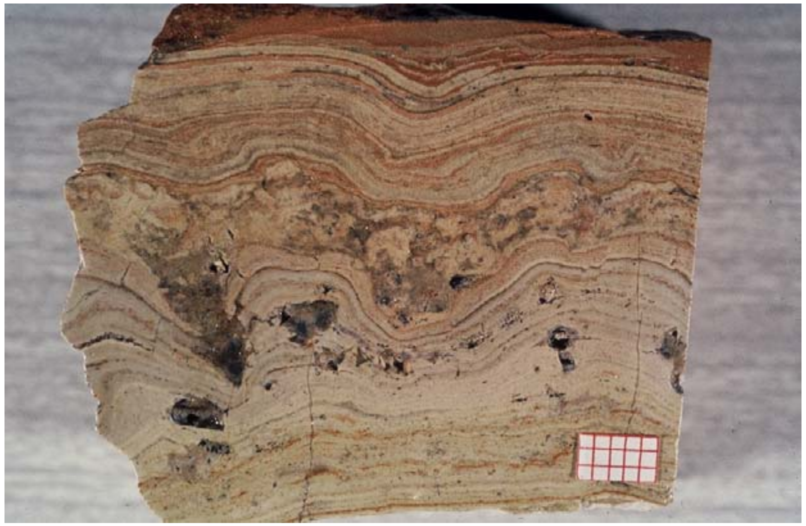
THE UPPERMOST TORTONIAN (7.3-7.2 MA) EVAPORITES

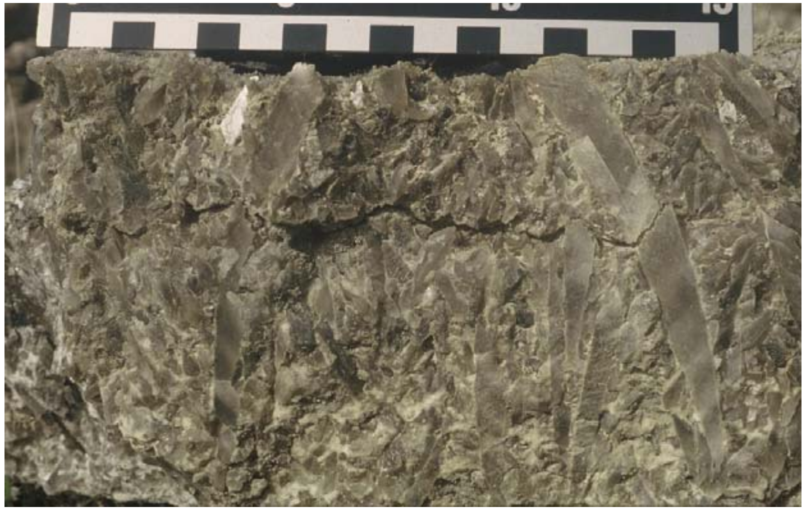
The marine Granada basin desiccated in the latest Tortonian. As a result, an evaporitic basin developed with stromatolites at the margin (replaced by celestine), selenite gypsum accumulating in its shallow-water areas and halite in its centre

Overlying lacustrine deposits





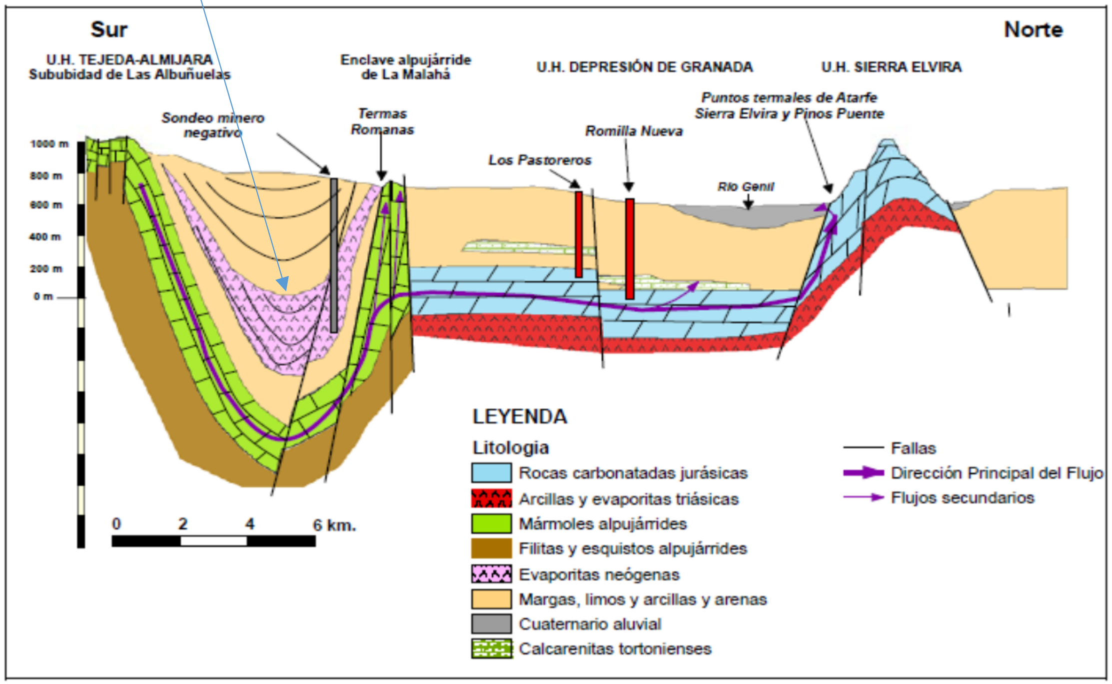


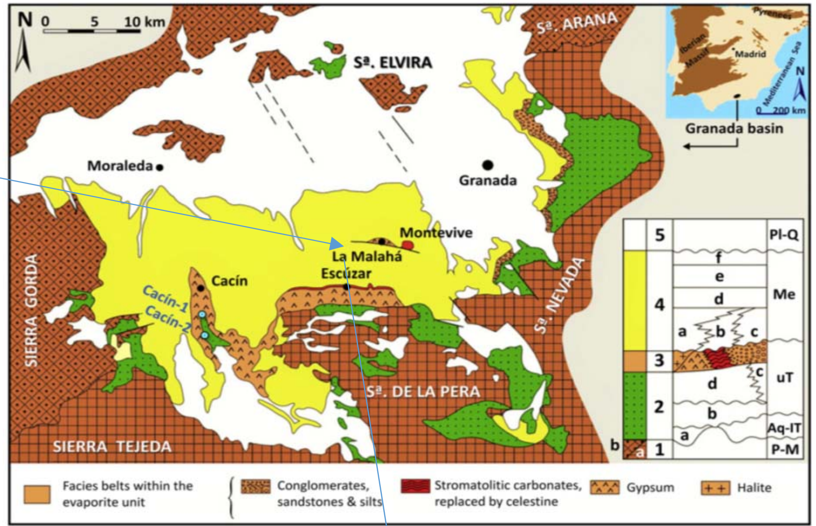


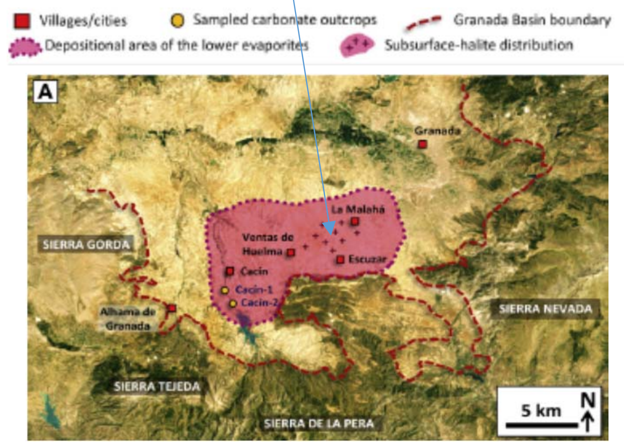
THE EVAPORITE DEPOCENTRE

The evaporite depocentre locates at the southern part of the basin

Up to 500 m of salt (halite) accumulated

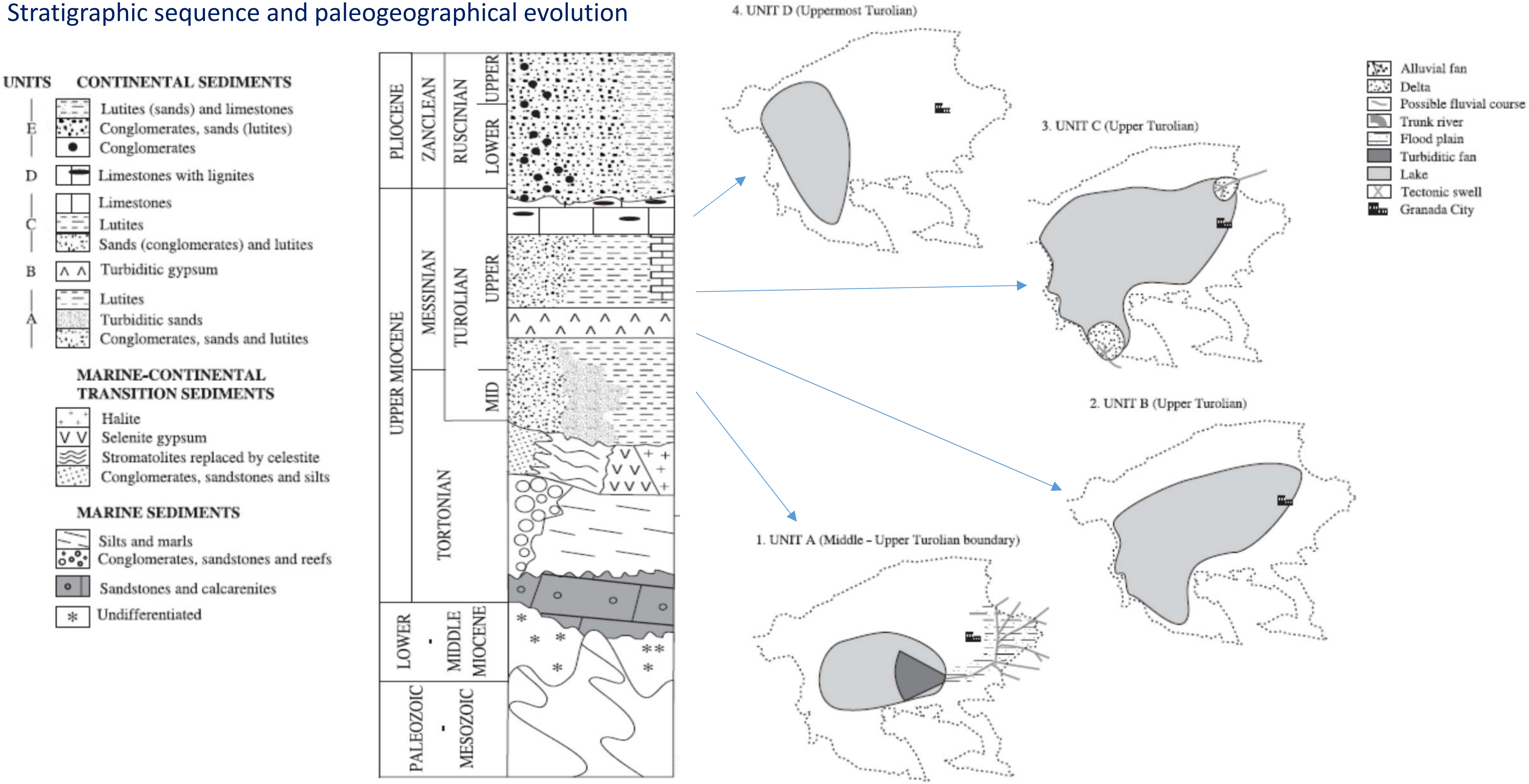






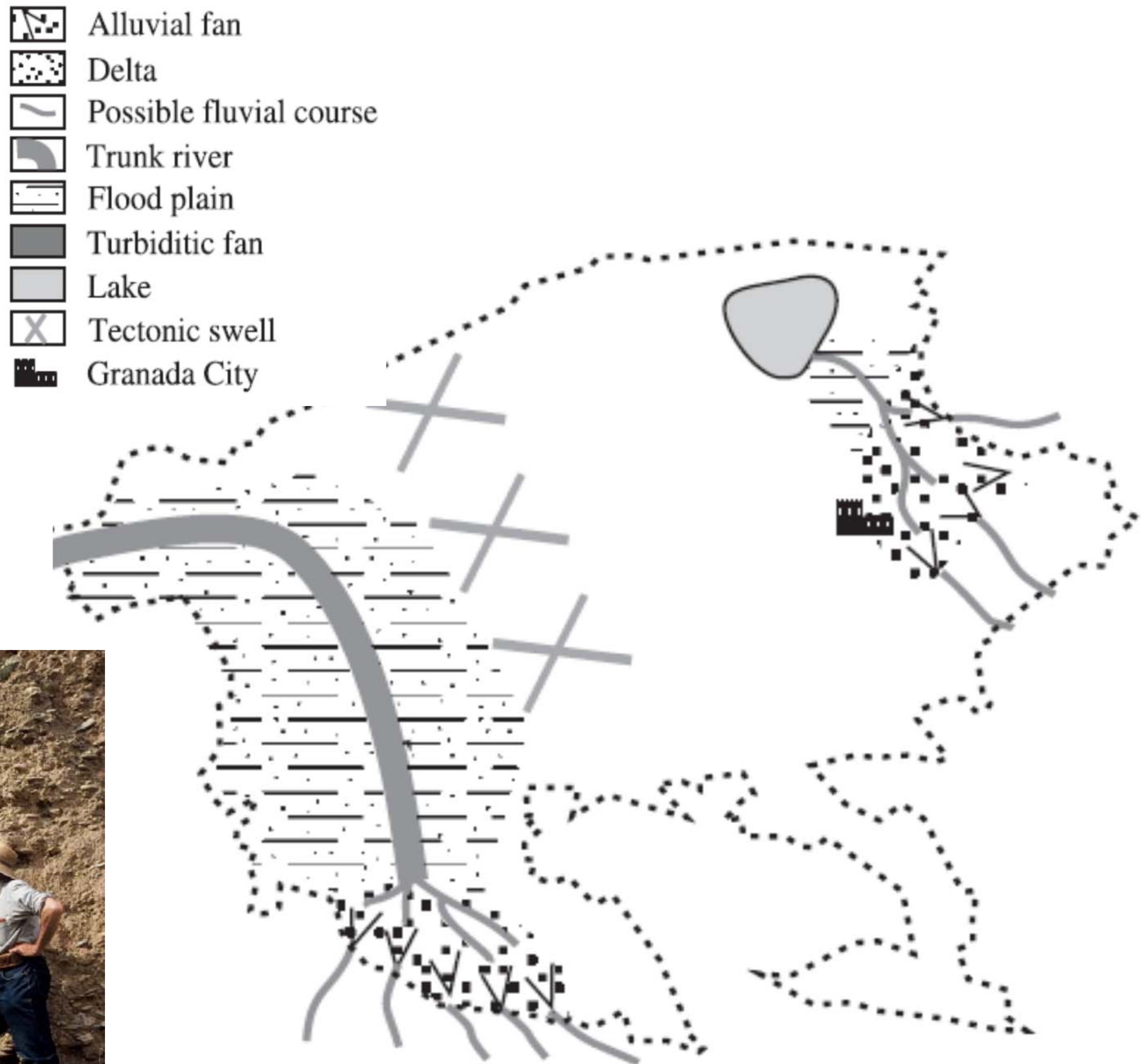
THE "MESSINIAN" LACUSTRINE SEDIMENTATION

Stratigraphic sequence and paleogeographical evolution



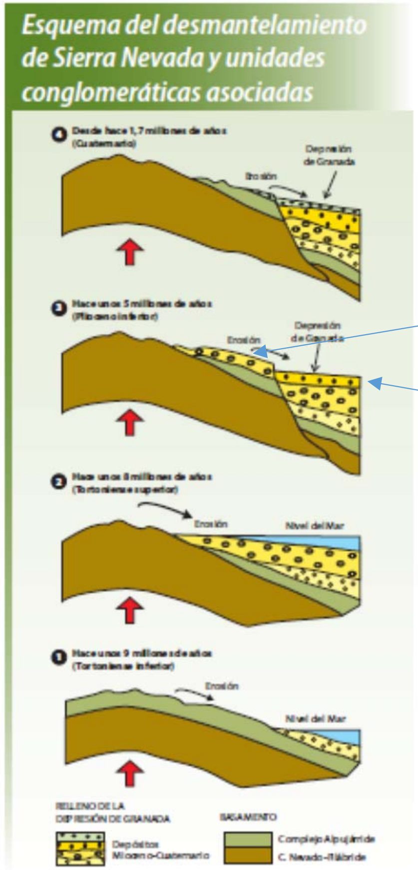
THE EARLY PLIOCENE SITUATION

In the early Pliocene a NW-SE trending swell formed in the middle of the basin. Two independent fluvial systems developed: the Alhambra and the Moraleda systems. The Alhambra system, in the Eastern side, was endorheic with a lake to the North and some alluvial fans bordering the southern Sierra Arana and Sierra Nevada active margins. The conglomerate of the southernmost fans (known as “the Alhambra conglomerate”) contains some alluvial gold



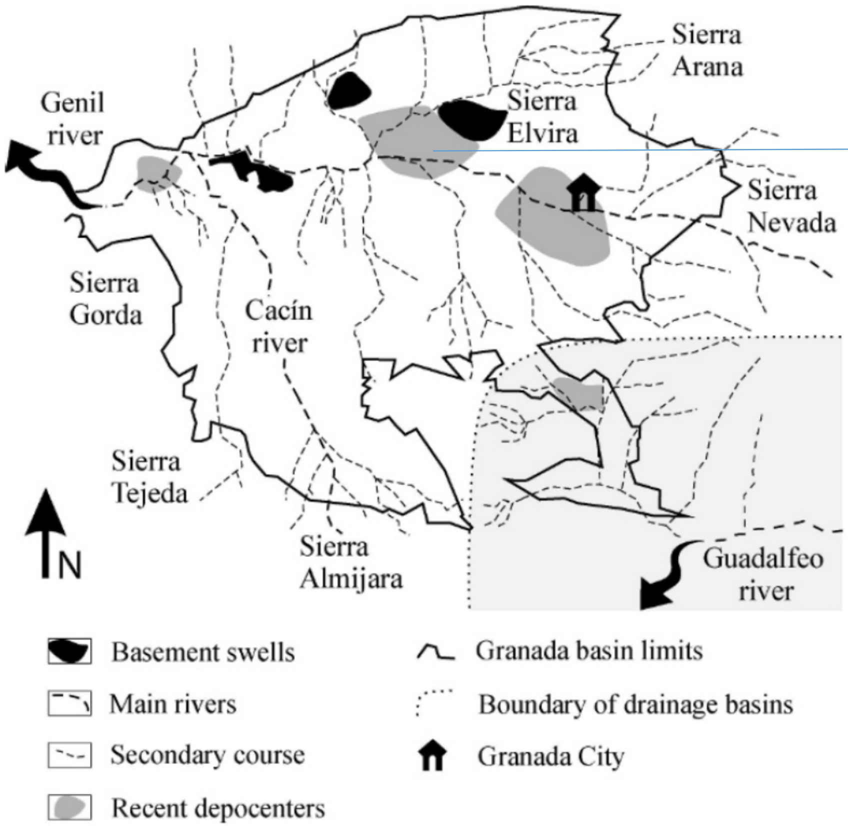
THE GENESIS OF THE ALHAMBRA CONGLOMERATE

The Alhambra conglomerate (lower Pliocene) formed by recycling of an older (upper Tortonian) conglomerate

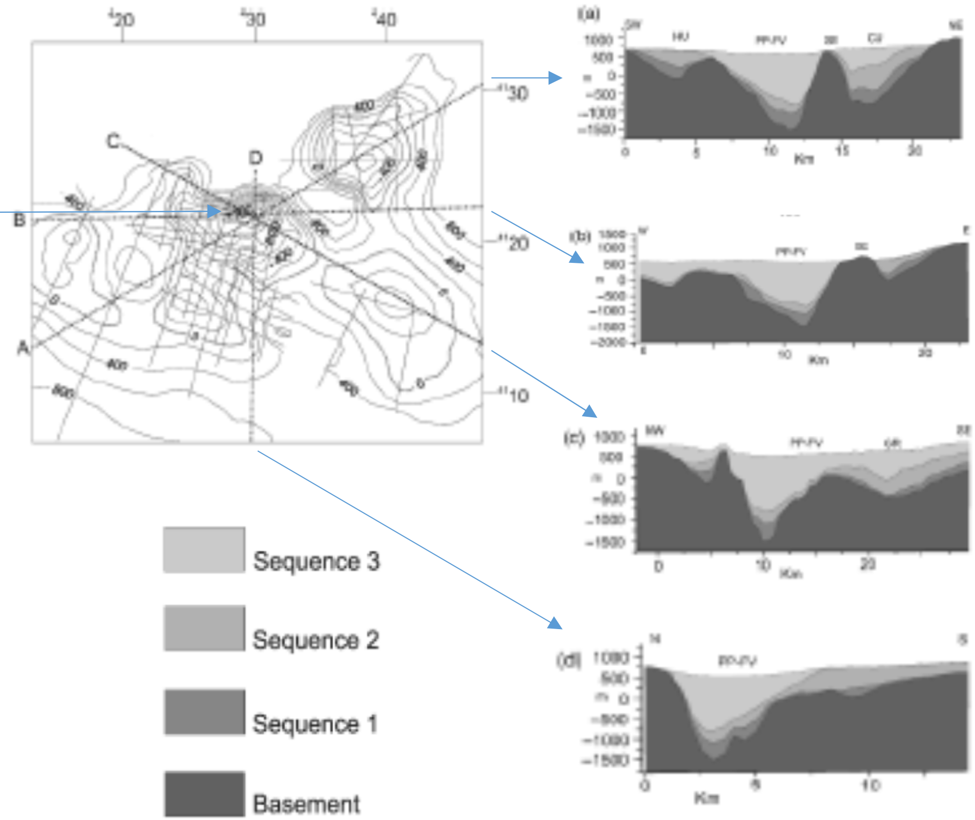


RECENT SEDIMENTATION

Cuaternary sedimentation concentrates in some active depocentres controlled by NW-SE and E-W trending faults. It mainly consists of fluviatile conglomerates, sands and silts. Alluvial-fan and lacustrine deposits are also locally present



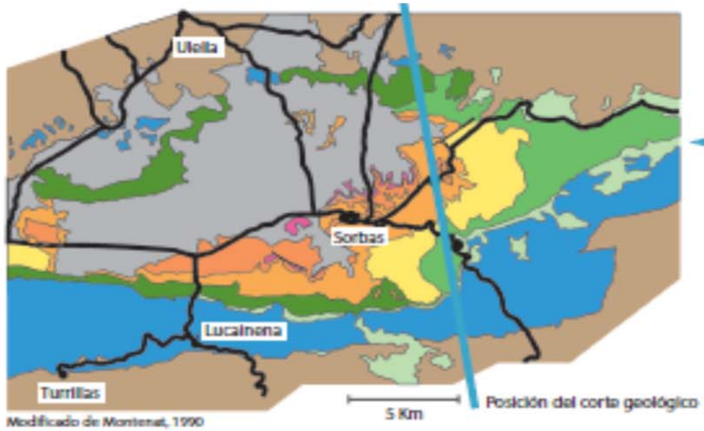
In some of these depocentres more than 500 m of Pliocene-Quaternary deposits (Sequence 3) are found, as deduced from seismic-profile interpretations

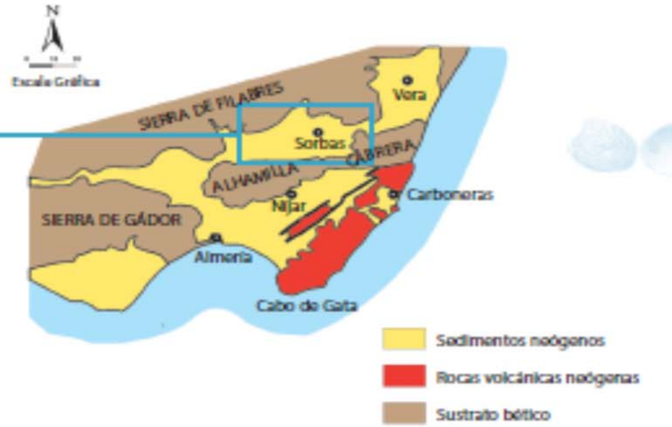


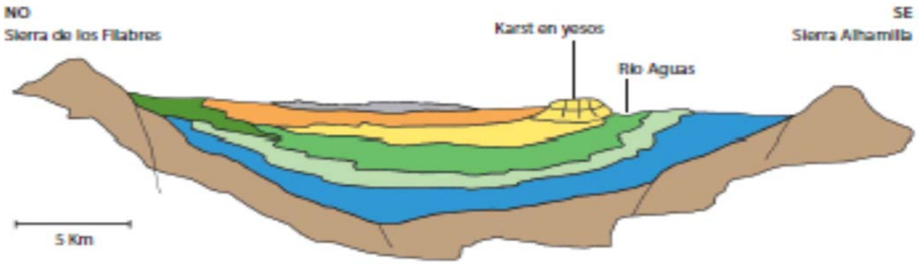
MEDITERRANEAN-LINKED BASINS
(“OUTER BASINS”)

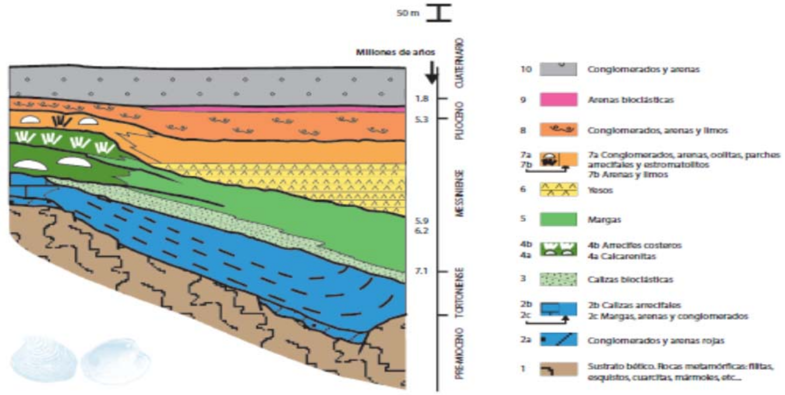
THE SORBAS BASIN

LOCATION OF THE SORBAS BASIN: SIMPLIFIED GEOLOGICAL MAP AND CROSS SECTION

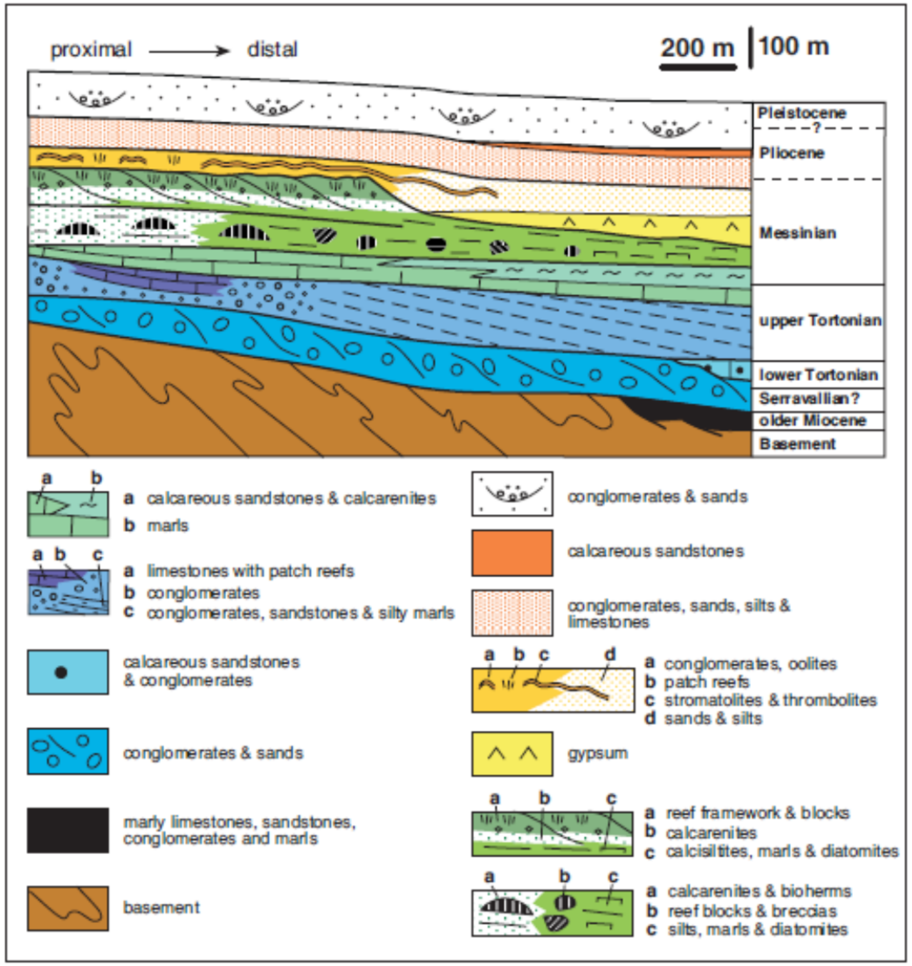








DETAILED NEOGENE STRATIGRAPHY OF THE SORBAS BASIN



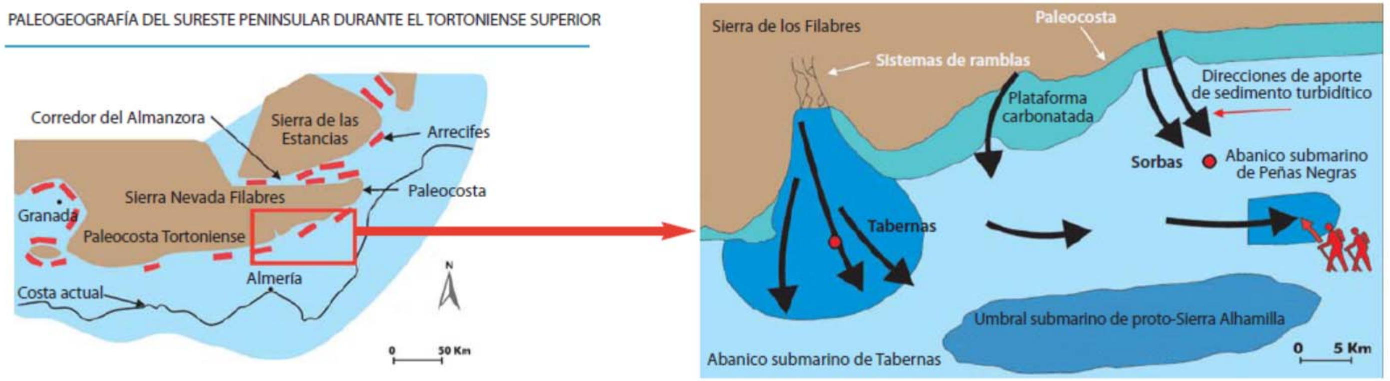
OLDER NEOGENE DEPOSITS

Thick sequences (a few hundred metres in thickness) of red Serravallian conglomerates occur at the southern margin of the Sorbas basin. They are of continental origin and were originally deposited on the southern flank of the single, large Betic relief, comprising present-day Sierra Nevada and Sierra de los Filabres, existing in Middle Miocene times

THE PRE-CONFIGURATION OF THE BASIN

THE UPPER-TORTONIAN (~ 8. MA) SEDIMENTS

In the upper Tortonian a carbonate platform, with coral reefs, developed at the northern margin of the Sorbas basin. A submarine swell (the proto-Sierra de Alhamilla) existed some kilometres to the South

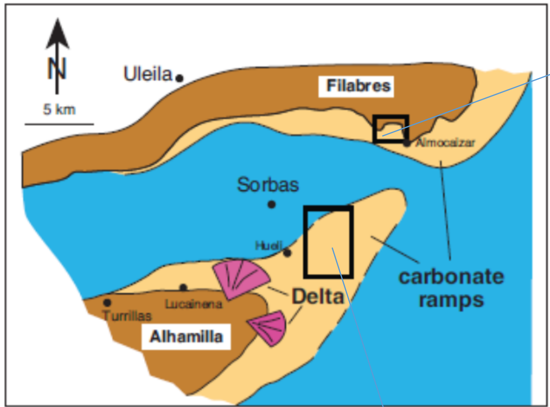


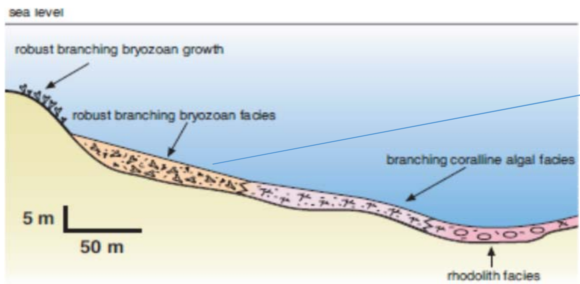
Turbidite currents, coming from the northern margin and flowing S, were diverted to the E. Turbidite deposits (mainly lobes) intercalate with marls. A several hundred metres thick sequence resulted

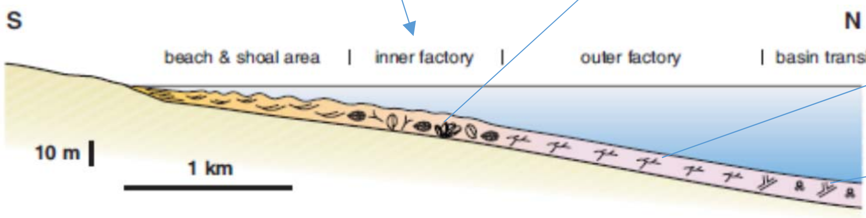
THE SORBAS BASIN INFILLING

THE UPPERMOST TORTONIAN-LOWERMOST MESSINIAN TEMPERATE CARBONATES (~7.5 to 7.2 Ma)

The Sorbas basin differentiated as such in the latemost Tortonian with the emersion of its southern margin (Sierra Alhamilla). Bioclastic-rich, temperate (cool-water) carbonates were deposited in shallow-water, platform areas at both margins of the basin

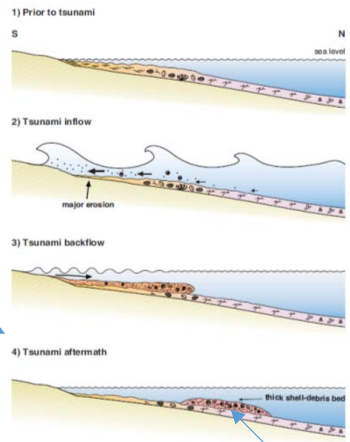


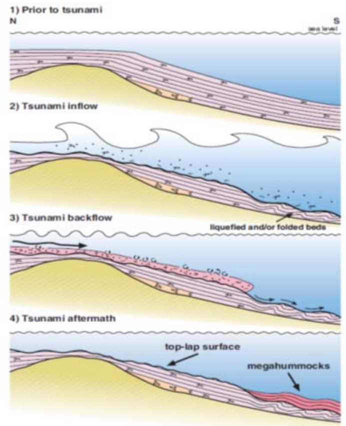


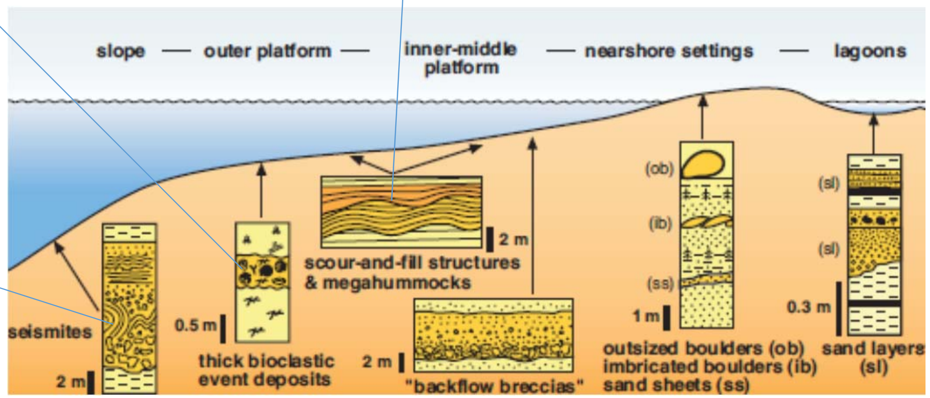


A STUDY CASE: THE TSUNAMI DEPOSITS

A large tsunami affected the carbonate platforms resulting in the formation of megahummock structures at the northern margin, a thick bioclastic debrite at the southern margin, and a huge seismite deposit in the nearby Tabernas basin

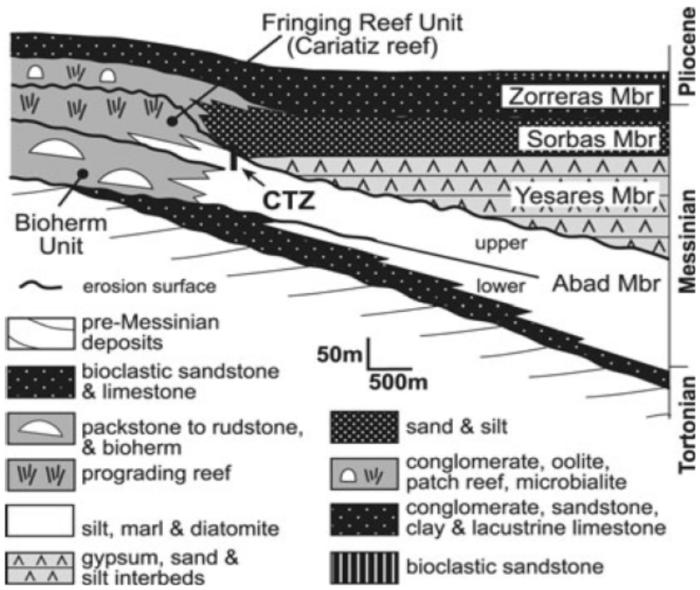




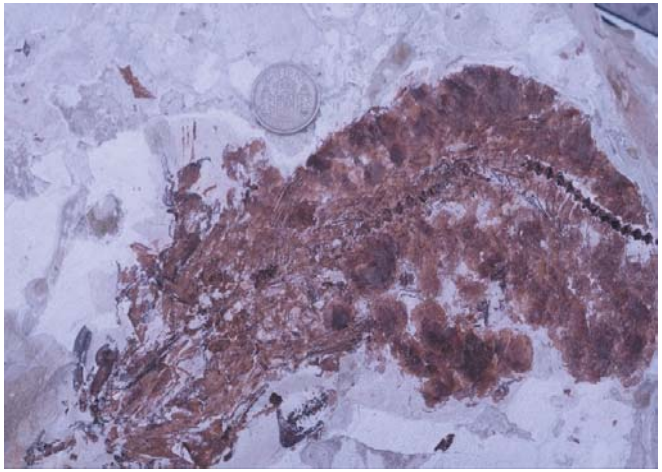


THE MESSINIAN REEF UNITS

They comprise two units: the Bioherm Unit and the Fringing Reef Unit



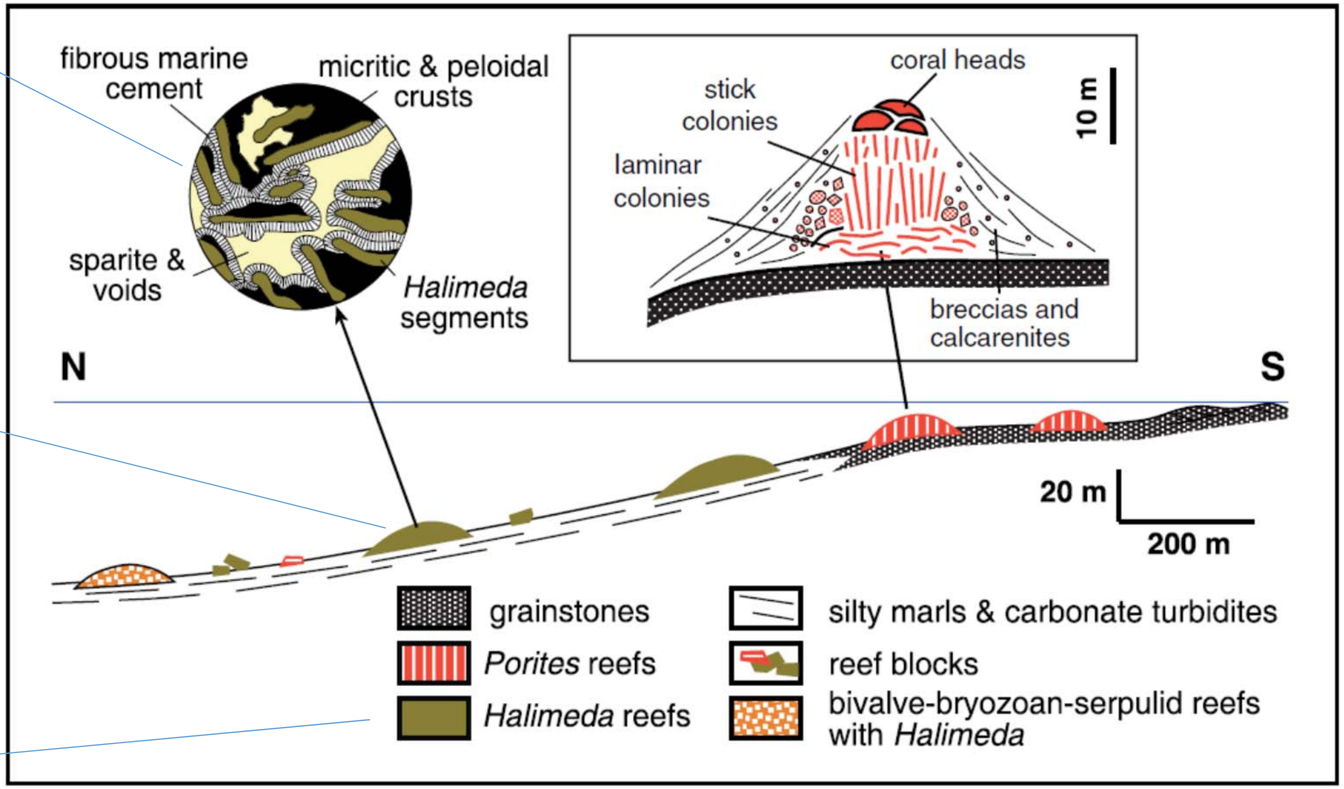
Reef carbonates change laterally basinwards to yellow marls with intercalated diatomites



Fish remains are found in the diatomites

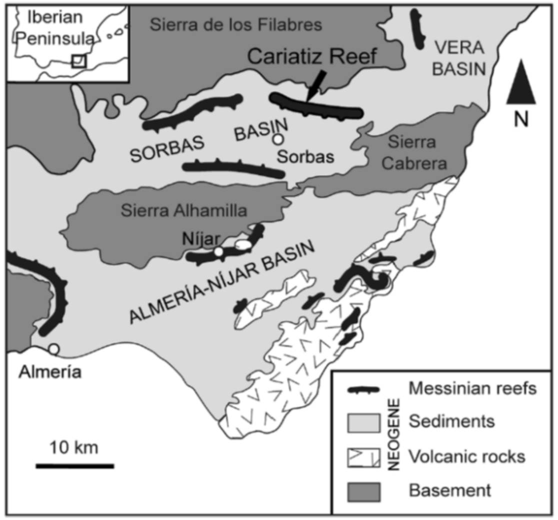
THE BIOHERM UNIT(~ 6.5 Ma): THE HALIMEDA BIOHERMS

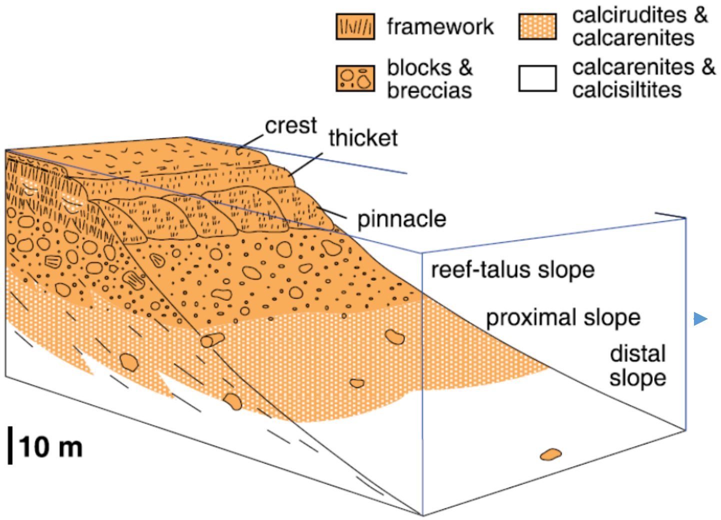
The Halimeda bioherms developed at depths between 30 and 60 m

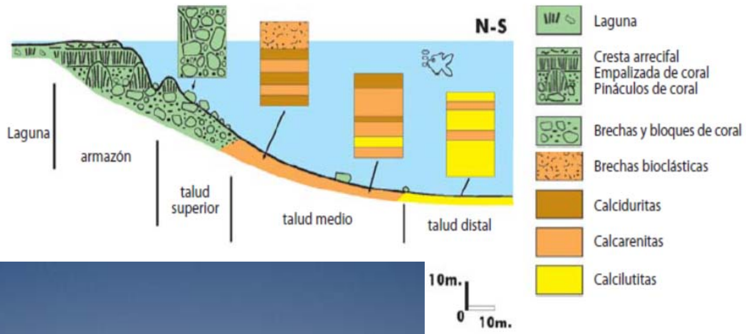


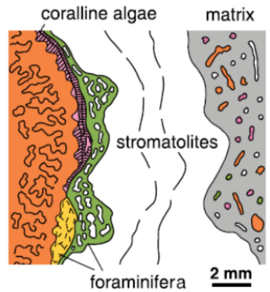
THE FRINGING REEFS (~ 6 Ma): the Porites-stromatolite reefs

Porites is the dominant and almost exclusive coral. Porites coral skeletons are encrusted by stromatolites





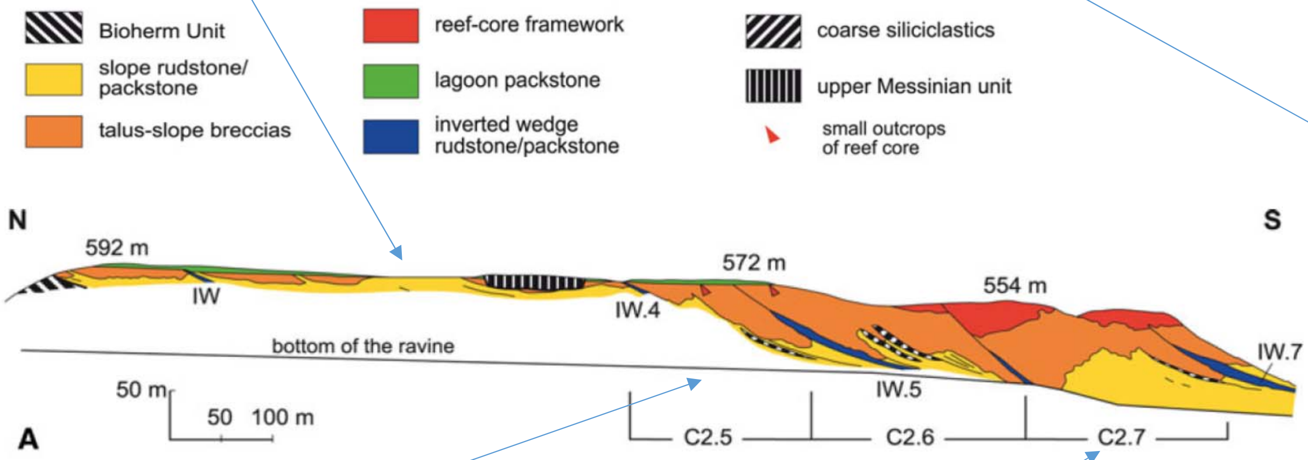


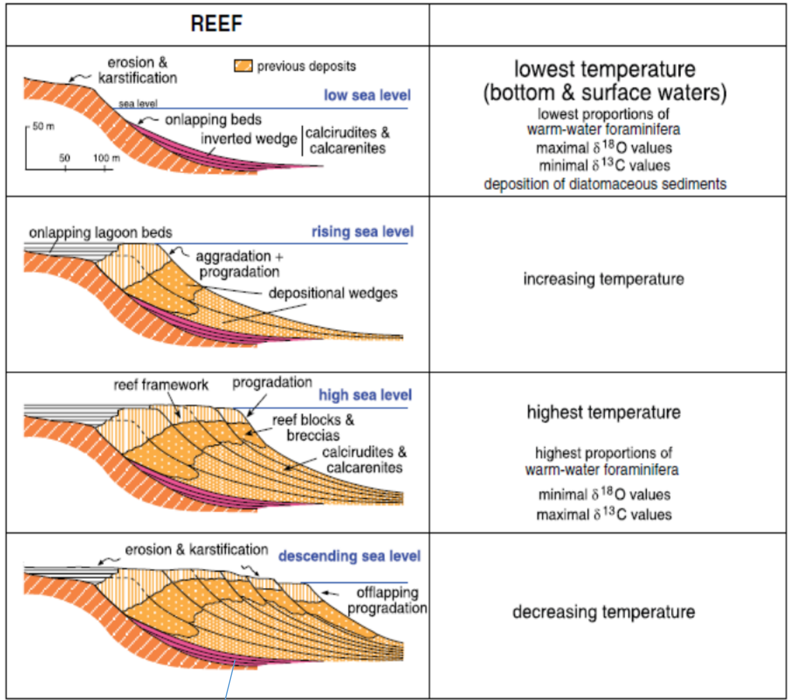


CYCLICITY IN THE FRINGING REEF

Reef progradation exhibits two orders of cyclicity related to sea-level fluctuations

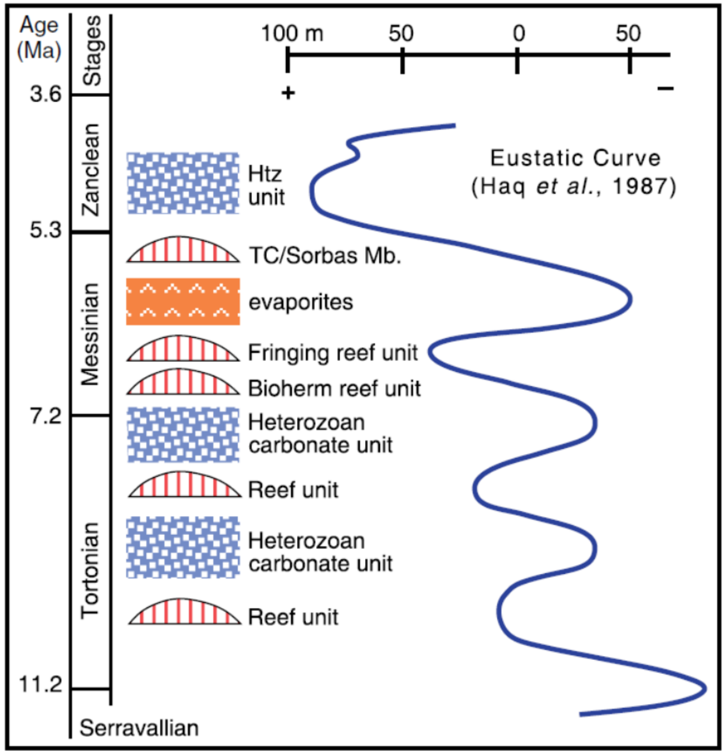
Higher-order cycles: resulting geometries, major related features and controlling factors

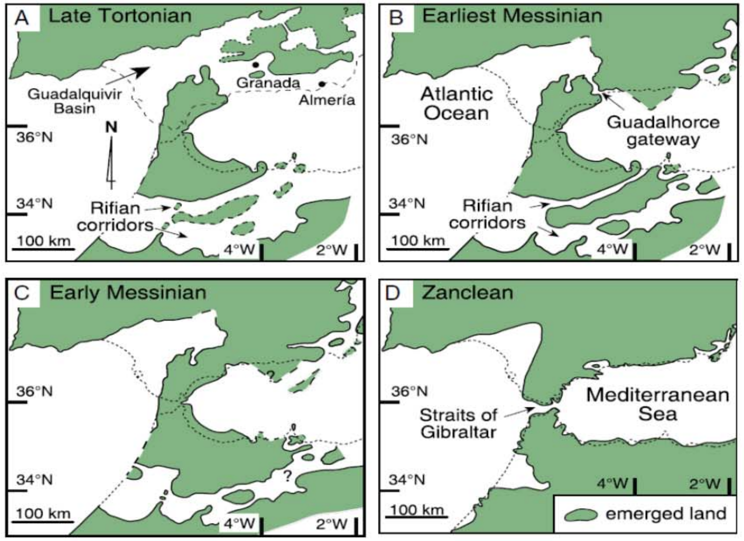


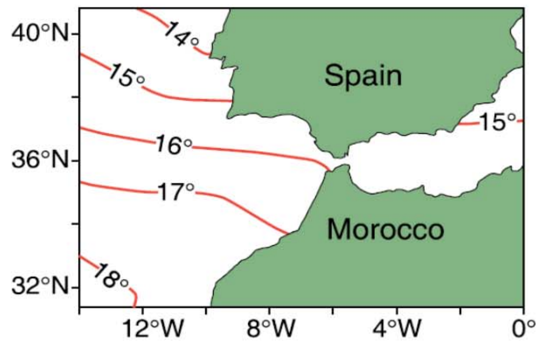


THE TEMPERATE-TROPICAL CLIMATIC ALTERNATIONS

Temperate (cool-water) and tropical shelf-carbonate deposits are found alternating in the Mediterranean-linked Neogene Basins. During the Late Miocene, temperate carbonates accumulated in the cold stages of third-order eustatic sea-level cycles, during sea-level lowstands. Tropical carbonates formed in warm periods, during rising and high sea levels. During the Early Pliocene, in constrast with the subtle global warming, the closure of the Rifian Straits and the opening of the Gibraltar Straits induced the flowing of temperate surface waters into the Mediterranean Sea from a more northern, cooler source area, resulting in the deposition of temperate carbonates. Present- day winter surface-water temperatures on the Atlantic-side position of the Rifian corridors are about 1.5 C higher than on the western side of the Straits of Gibraltar

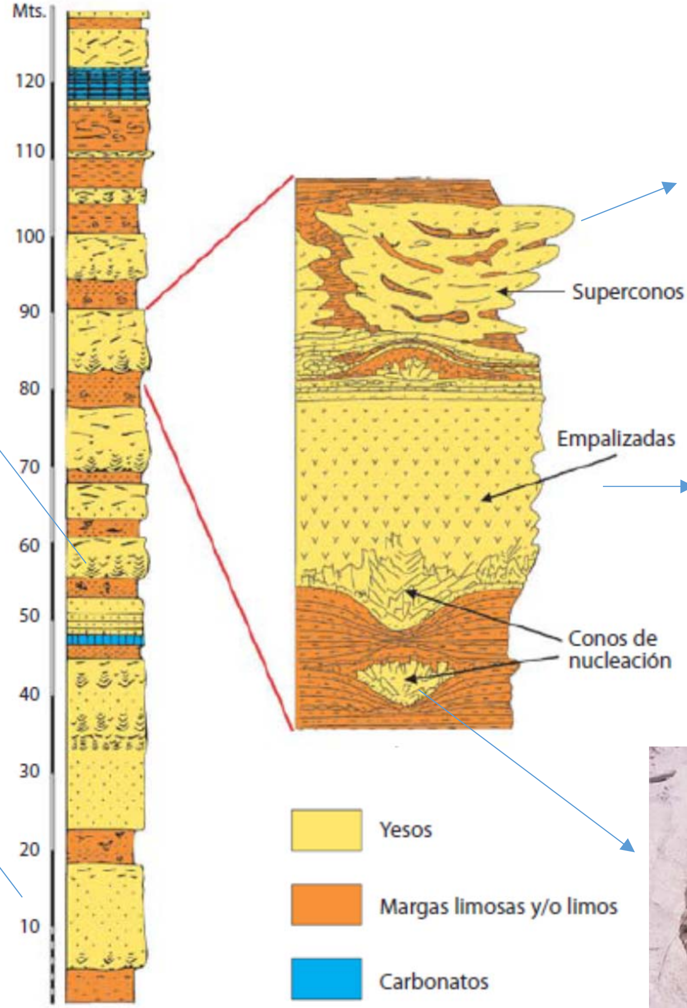






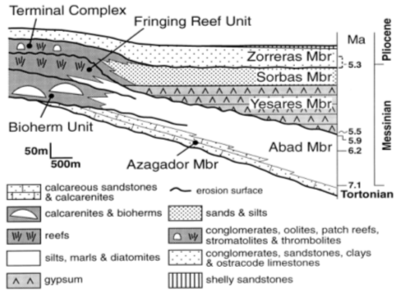
THE EVAPORITES OF THE SORBAS BASIN: THE GYPSUM DEPOSITS (~ 5.5 Ma)

Isotopic data indicate that the gypsum is of marine origin. Fossil remains from the marl-silt interbeds are as well from a normal marine biota



THE EROSION SURFACE AT THE BASE OF THE GYPSUM

The gypsum was deposited on top of an irregular, erosional (bad-land) surface excavated into the underlying Messinian marine marls



It fills in small ravines

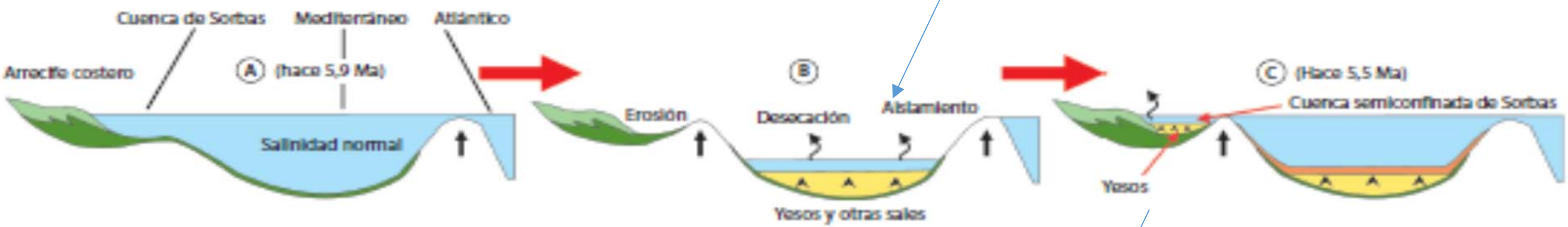
as well as large canyons

TIMING OF GYPSUM DEPOSITION IN THE SORBAS BASIN

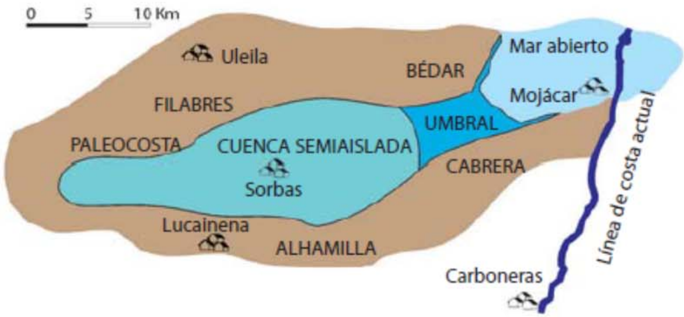
Evaporite formation in the Sorbas basin

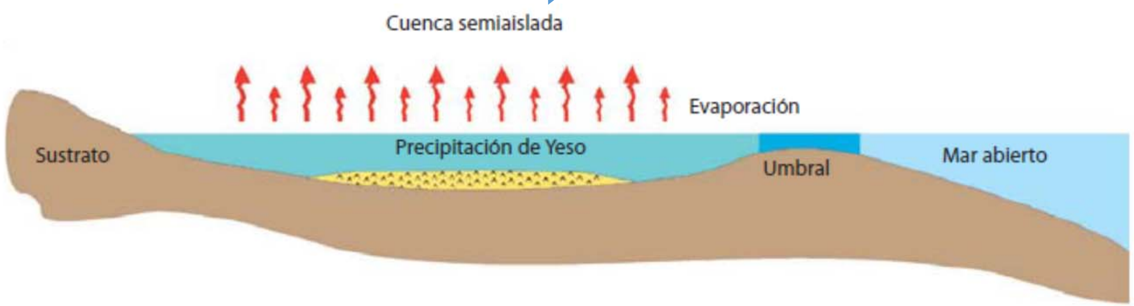
post-dates massive-salt precipitation

in the Mediterranean Messinian, deep-basin depocentres



Gypsum precipitation took place in a small, tectonic semi-isolated Mediterranean Sea embayment



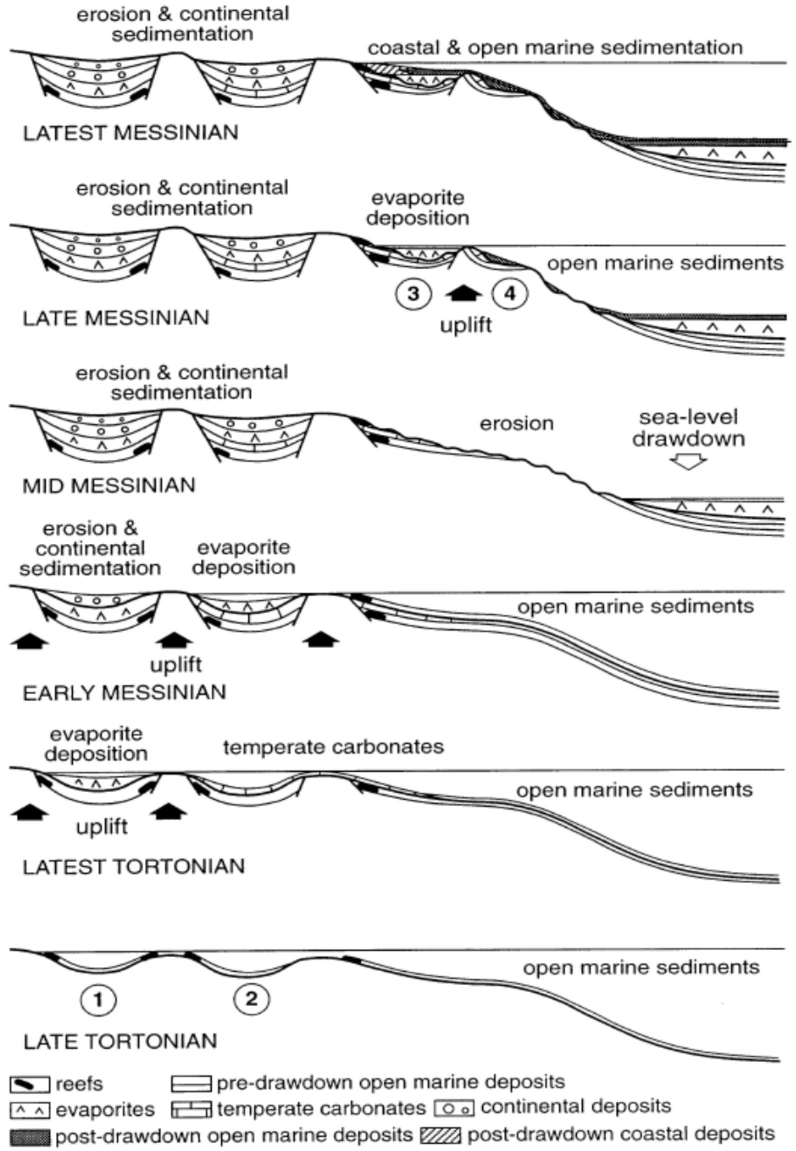


TIMING OF EVAPORITE DEPOSITION IN THE BETIC BASINS

1: GRANADA BASIN
2: LORCA BASIN
3: SORBAS BASIN
4: VERA BASIN

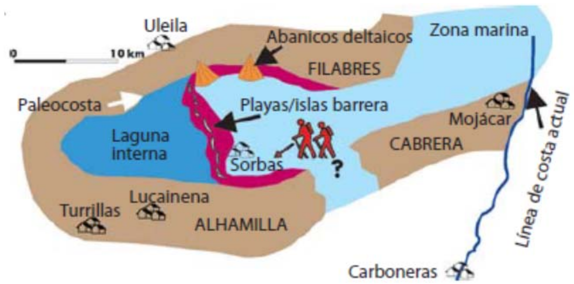
Evaporite deposition was not at the same time in the different basins

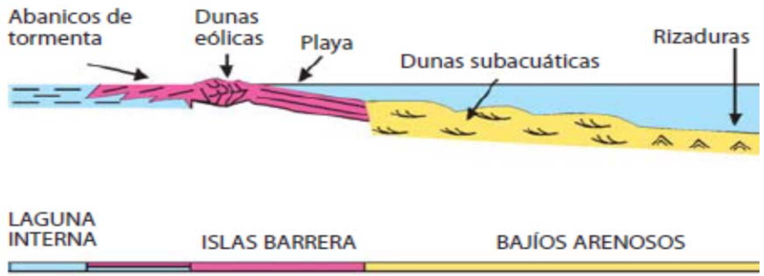
Local tectonic played a key role in the differentiation and isolation of the basins

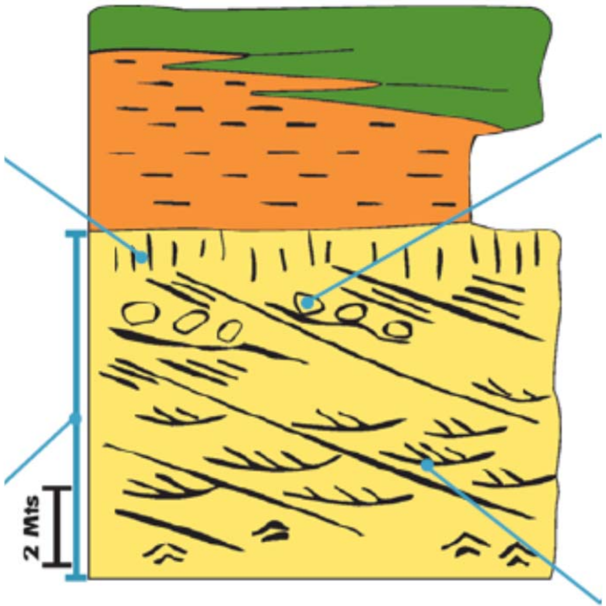


THE POST-EVAPORITIC MESSINIAN: THE BEACH DEPOSITS

Sediments from the last Messinian marine unit filled in the Sorbas embayment after deposition of the evaporites. A prograding beach system developed in the centre of the basin and some fan deltas occurred at the northern margin

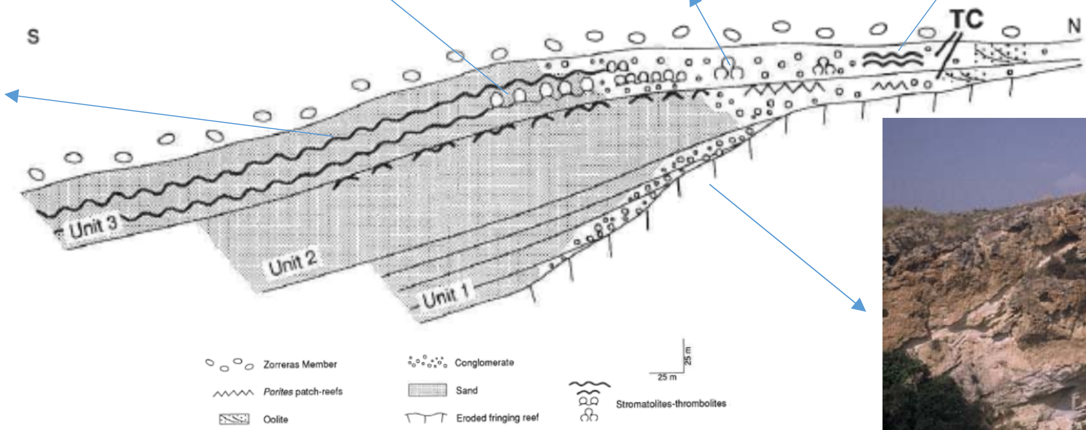






THE POST-EVAPORITIC MESSINIAN: THE GIANT MICROBIAL DOMES

Huge stromatolite and thrombolite domes are ubiquiteous in the post-evaporitic Messinian deposits. Their widespread proliferation is thought to be due to the oportunistic behaviour of the microbes colonizing the environment after deposition of the evaporites

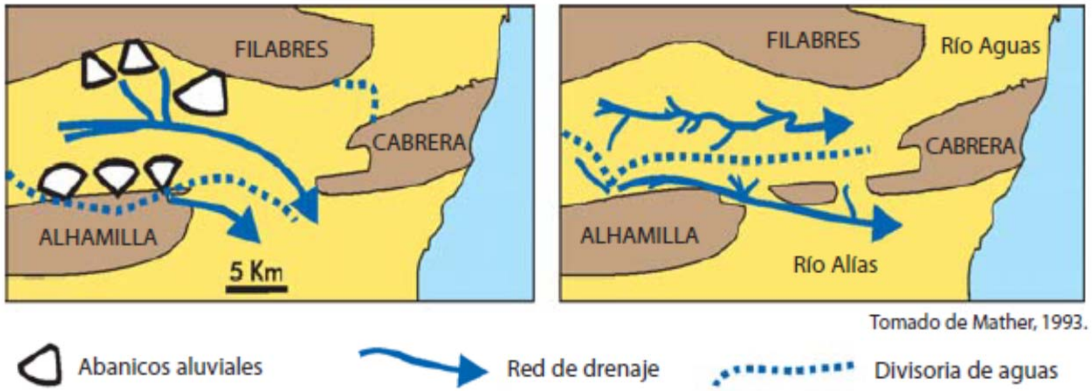


LATE CONTINENTAL SEDIMENTATION

Continental sedimentation started at the end of the Messinian and continued into the Pliocene (Pleistocene), except for a small, short interval at the beginning of the Pliocene

Alluvial-fan and fluviatile (lacustrine) deposits are dominant

In the course of the Pliocene the drainage system changed, exiting first to the South and then both to the South and to the East



Selected references

Braga, J.C. and Martín, J.M. (1996). Geometries of reef advance in response to relative sea-level changes in a Messinian (uppermost Miocene) fringing reef (Cariatiz reef, Sorbas Basin, SE Spain). Sedimentary Geology 107: 61-81.

Braga,J.C., Martin, J.M. and Alcalá, B. (1990). Coral reefs in coarse-terrigenous sedimentary environments (Upper Tortonian, Granada Basin, southern Spain). Sedimentary Geology 66: 135-150.

Braga,J.C., Jimenez, A.P., Martin, J.M. and Rivas, P. (1996). Middle Miocene, coral-oyster reefs (Murchas, Granada, southern Spain). In: E. Franseen, M. Esteban, B. Ward y J.M. Rouchy (Editors). Models for Carbonate Stratigraphy from Miocene Reef Complexes of the Mediterranean Regions. SEPM, Concepts in Sedimentology and Paleontology Series 5*,* Tulsa, Oklahoma, p. 131-139.

Braga, J.C., Baena, J., Calaforra, J.M., Coves, J.V., Dabrio, C.J., Feixas, C.,. Fernández-Soler, J.M., Gómez, J.A., Goy, J.L., Harvey, A.M., Martín, J.M., Martín-Penela, A., Mather, A.E., Stokes, M., Villalobos, M. y Zazo, C. (2003). Geología del entorno árido almeriense. Guía didáctica de campo. M. Villalobos, Editor. Consejería de Medio Ambiente de la Junta de Andalucía, 163 pp.

Braga, J.C., Martín, J.M. and Quesada, C. (2003). Patterns and average rates of late Neogene-Recent uplift of the Betic Cordillera, SE Spain. Geomorphology 50, 3-26.

Dronkert, H. (1977). The evaporites of the Sorbas basin. Revista Instituto Investigaciones Geológicas Diputación Provincial y Universidad de Barcelona 32: 55-76.

García-Alix, A., Minwer-Barakat, R., Martín, J.M., Martín-Suárez, E. and Freudenthal, M. (2008). Biostratigraphy and sedimentary evolution of Late Miocene and Pliocene continental deposits of the Granada Basin (southern Spain). Lethaia 41: 431-446.

García-Veigas, J., Cendón, D.L., Rosell, L., Ortí, F., Torres-Ruiz, J., Martín, J.M. and Sanz, E. (2013). Salt deposition and brine evolution in the Granada Basin (Late Tortonian, SE Spain). Palaeogeography, Palaeoclimatology, Palaeoecology 369: 452-465.

García-Veigas, J., Rosell, L., Cendón, D.L., Gibert, L., Martín, J.M., Torres-Ruiz, J. and Ortí, F. (2015). Large celestine orebodies formed by early-diagenetic replacement of gypsified stromatolites (Upper Miocene, Montevive–Escúzar deposit, Granada Basin, Spain). Ore Geology Reviews 64: 187-199.

Martin, J.M. (2000). Geología e historia del oro de Granada. Boletín Geológico y Minero 111-2,3: 47-60

Martín, J.M. and Braga, J.C. (1994). Messinian events in the Sorbas Basin in southeastern Spain and their implications in the recent history of the Mediterranean. Sedimentary Geology, 90: 257-268.

Martín, J.M., Braga, J.C. and Riding, R. (1993). Siliciclastic stromatolites and thrombolites, late Miocene, S.E. Spain: Journal Sedimentary Petrology, 63: 131-139.

Martín, J.M., Braga, J.C. and Riding, R. (1997). Late Miocene Halimeda alga-microbial segment reefs in the marginal Mediterranean Sorbas Basin, Spain. Sedimentology 44: 441-456.

Martín, J.M., Braga, J.C.Sánchez-Almazo, I.M. and Aguirre, J. (2010). Temperate and tropical carbonate-sedimentation episodes in the Neogene Betic basins (southern Spain) linked to climatic oscillations and changes in Atlantic-Mediterranean connections: constraints from isotopic data. In: M. Mutti, W. Piller & C. Betzler (Editors). Carbonate systems during the Oligocene-Miocene climatic transition. Int. Assoc. Sedimentol. Spec. Publ. 42: 49-70.

Martín, J.M., Puga-Bernabéu, A., Aguirre, J. and Braga, J.C. (2014). Miocene Atlantic-Mediterranean seaways in the Betic Cordillera (southern Spain). Revista de la Sociedad Geológica de España 27 (1): 175-186.

Puga-Bernabéu, A., Martín, J.M. and Braga, J.C. (2007). Tsunami-related deposits in temperate carbonate ramps, Sorbas basin, southern Spain. Sedimentary Geology 199: 107-127.

Puga-Bernabéu, A., Martín, J.M. and Braga, J.C. (2008). Sedimentary processes in a submarine canyon excavated into a temperate-carbonate ramp (Granada basin, S. Spain). Sedimentology 55: 1449-146.

Riding, R., Martín, J.M. and Braga, J.C. (1991). Coral-stromatolite reef framework, Upper Miocene, Almería, Spain. Sedimentology 38: 799-818.

Riding, R., Braga, J.C., Martín, J.M. and Sánchez-Almazo, I. M.(1998). Mediterranean Messinian Salinity Crisis: constraints from a coeval marginal basin, Sorbas, SE Spain. Marine Geology 146: 1-20.

Riding, R., Braga, J.C. and Martín, J.M. (1999). Late Miocene Mediterranean desiccation: topography and significance of the "Salinity Crisis" erosion surface on-land in SE Spain. Sedimentary Geology 123: 1-7.

Rodríguez-Fernández, J. and Sanz de Galdeano, C. (2006). Late orogenic intramontane basin development: the Granada basin, Betics (southern Spain). Basin Research 18: 85-102.

Roep, Th.B., Beets, D.J., Dronkert, H. and Pagnier, H. (1979). A prograding coastal sequence of wave-built structures of Messinian age, Sorbas, Almería, Spain. Sedimentary Geology 22: 135-163.

Rosino, J. (2008). Modelo hidrogeológico conceptual de las aguas termo-minerales de la Depresión de Granada. En: J.A. López-Geta et al (Editores). Agua y Cultura. VII Simposio sobre el Agua en Andalucía (SIAGA-08), IGME, p. 1107-1118.