TEMPERATE AND TROPICAL SHELF-CARBONATE SEDIMENTATION IN THE WESTERN MEDITERRANEAN DURING THE NEOGENE: CLIMATIC AND PALAEOCEANOGRAPHIC IMPLICATIONS

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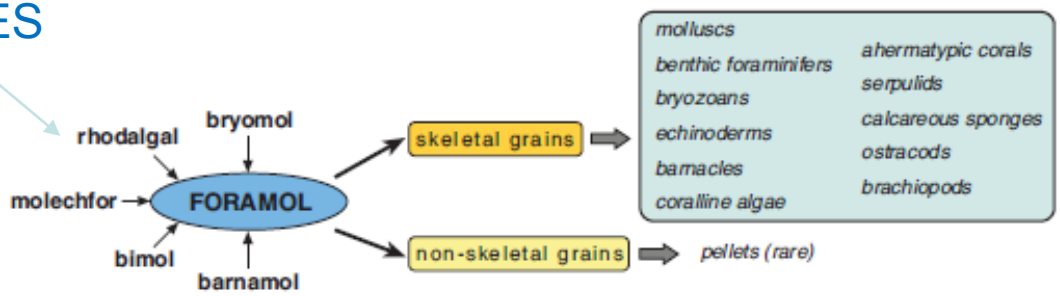
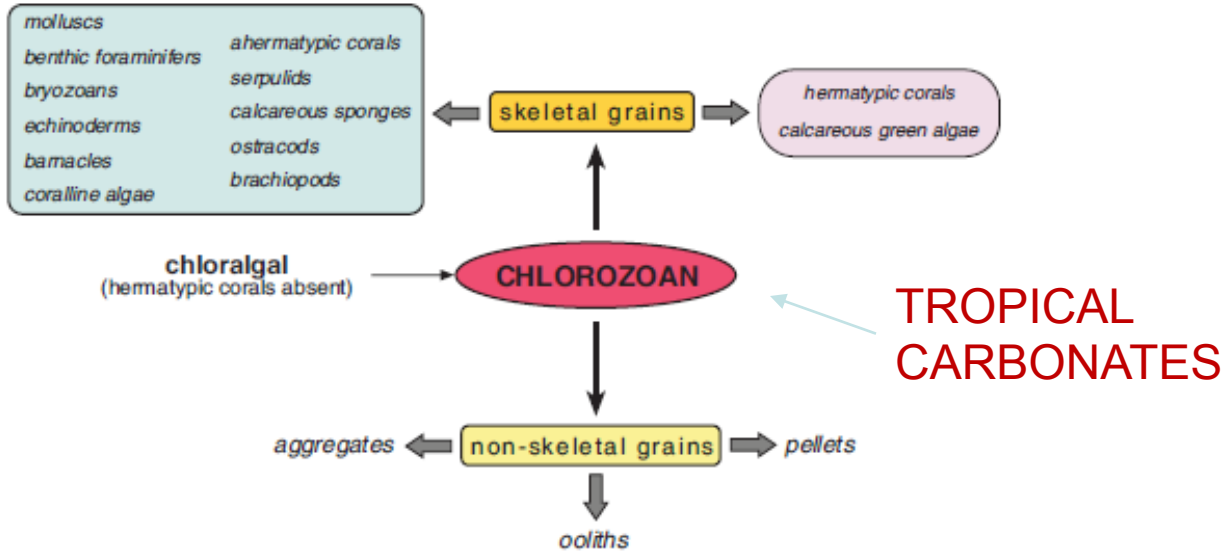
Key paper: Martín, J.M., Braga, J.C., Sánchez-Almazo, I.M. & Aguirre, J. (2010). Temperate and tropical carbonate-sedimentation episodes in the Neogene Betic basins (southern Spain) linked to climatic oscillations and changes in Atlantic-Mediterranean connections: constraints from isotopic data. In: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

TEMPERATE AND TROPICAL CARBONATES CONSTRASTED
THE TEMPERATE (FORAMOL) AND TROPICAL (CHLOROZOAN) ASSOCIATIONS

TEMPERATE CARBONATES





TROPICAL CARBONATES

James, 1997 (Check in reference list of key paper)

TEMPERATE AND TROPICAL CARBONATES CONSTRASTED OTHER MAJOR DIFFERENCES

Micrite is neither chemically or biochemically precipitated **in temperate-carbonate environments**. If present, it **forms as result of bioclast grinding**

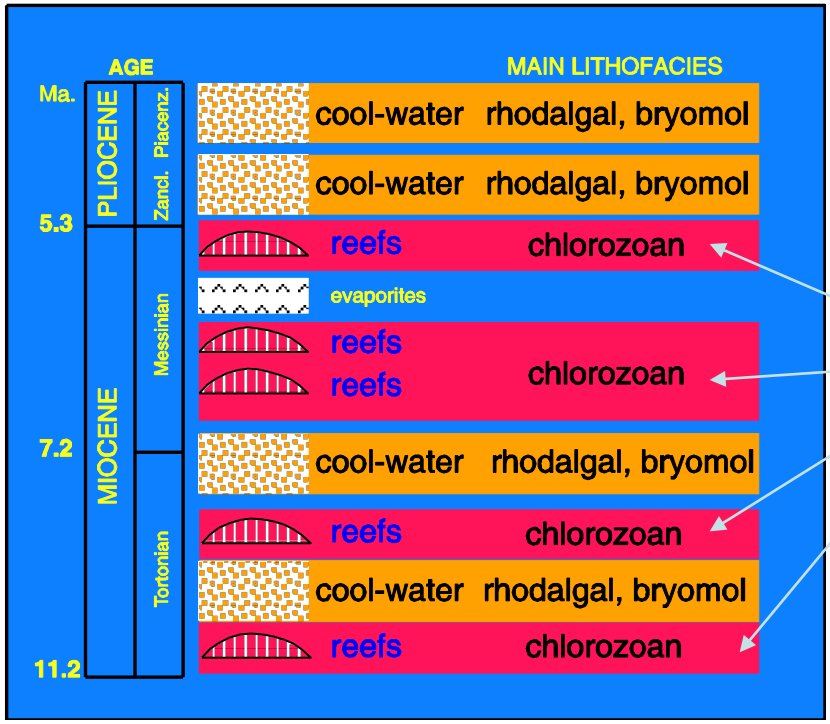
Early sea-floor lithification is a significant feature in tropical carbonates but is almost absence in temperate carbonates. As a result **temperate-carbonate particles are loose on the sea-floor and can be easily remobilized**. In this respect **temperate carbonates can be compared with and behave very much like siliciclastic sediments**

Sedimentation rates are one order of magnitude (ten times) higher in tropical than in temperate carbonates

MEDITERRANEAN, NEOGENE SHELF-CARBONATE RECORD

Alternating temperate and tropical carbonate episodes are common feature in the Upper Neogene stratigraphic record of the western Mediterranean

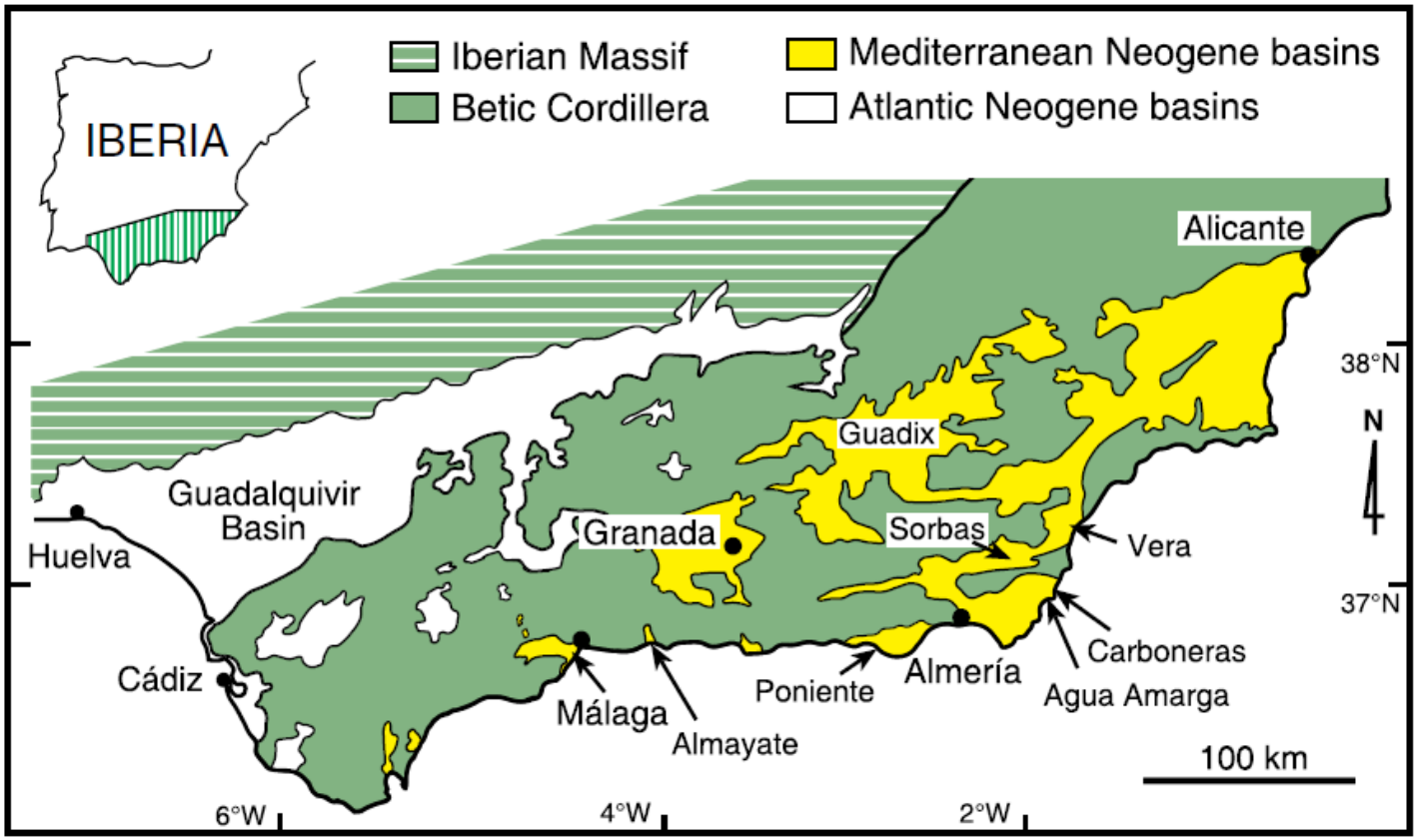
Temperate carbonates



Tropical carbonates

Temperate carbonates appear in the early late-Tortonian, latest Tortonian-earliest Messinian and in the Pliocene
Tropical carbonate formation took place in the earliest Tortonian, late Tortonian and the Messinian

A CASE STUDY: THE MEDITERRANEAN-LINKED NEOGENE BASINS OF THE BETIC CORDILLERA



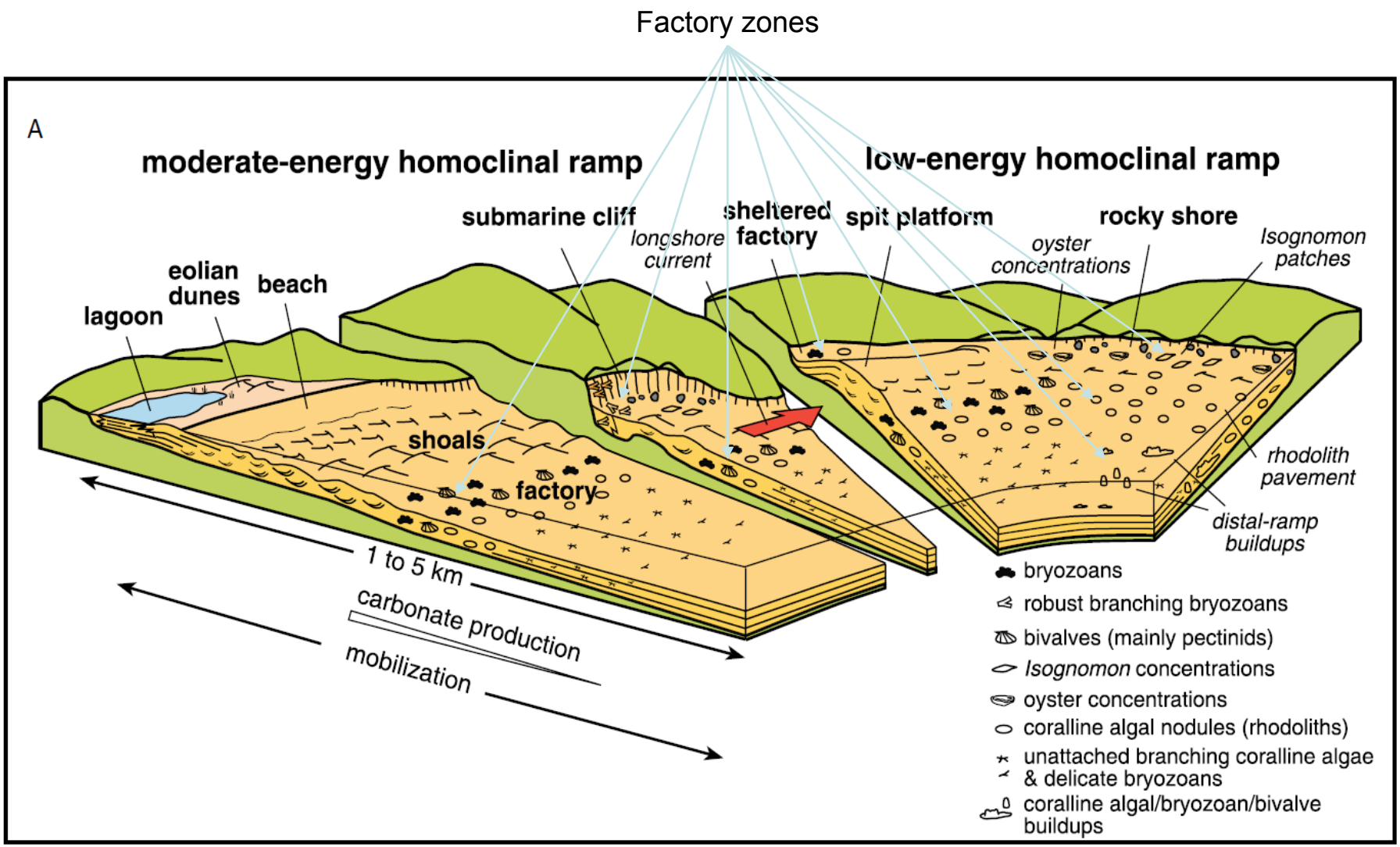
These basins, linked to the open Mediterranean sea to the S and to the E, differentiated as small, interconnected marine passages during the Alpine Orogeny in Middle-Late Miocene times

Carbonates deposited on siliclastic-free shelf areas at the margins of these basins were of two types: temperate and tropical. Both types contain abundant bioclast remains

THE TEMPERATE CARBONATES

These non-reefal, “cold-water” carbonates formed in similar conditions to those occurring on the Present-day Mediterranean sea, with mean winter, sea-surface water temperature ranging between 14° C and 17° C

DEPOSITIONAL MODELS OF TEMPERATE CARBONATES IN THE BETIC CORDILLERA



THE “FACTORY ZONE” CONCEPT

Carbonate production took place in localized, usually “shelthered”, relatively low-energy areas

SOME REPRESENTATIVE EXAMPLES

Oyster factory

Pectinid factory

FACTORY FACIES

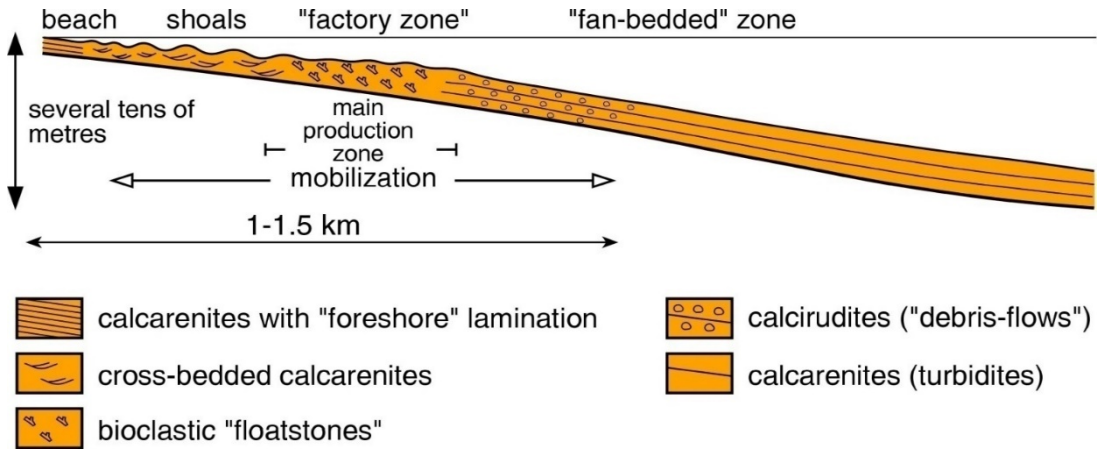
Branching bryozoan factory

Nodular bryozoan factory

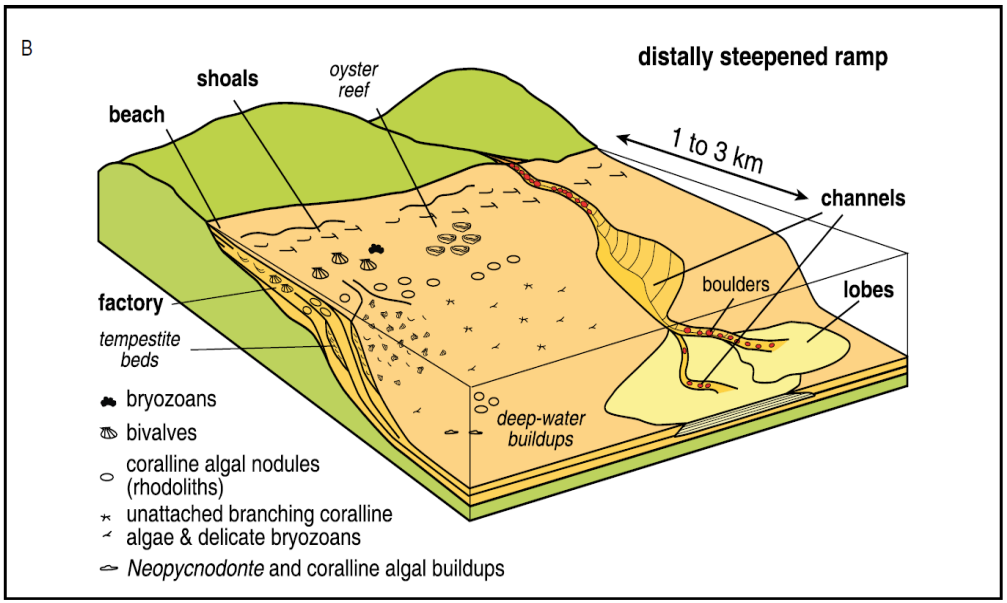
Branching coralline factory

Nodular coralline factory

REDEPOSITED TEMPERATE CARBONATES
MOBILIZATION PROCESSES



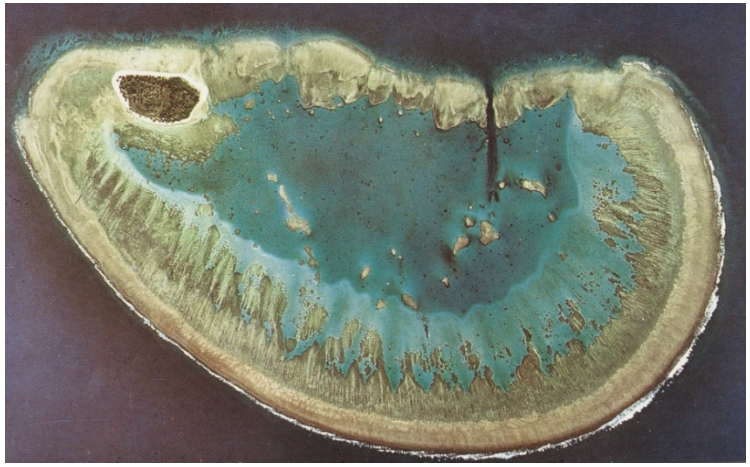
The lack of early lithification favoured mobilization of skeletal particles from the “factory”
Waves and currents accumulated bioclastic particles in shoals, spits and beaches
Skeletal grains were mobilized downslope as sediment gravity flows



Temperate-carbonate sediments were also mobilized via submarine channels and canyons

THE TROPICAL CARBONATES

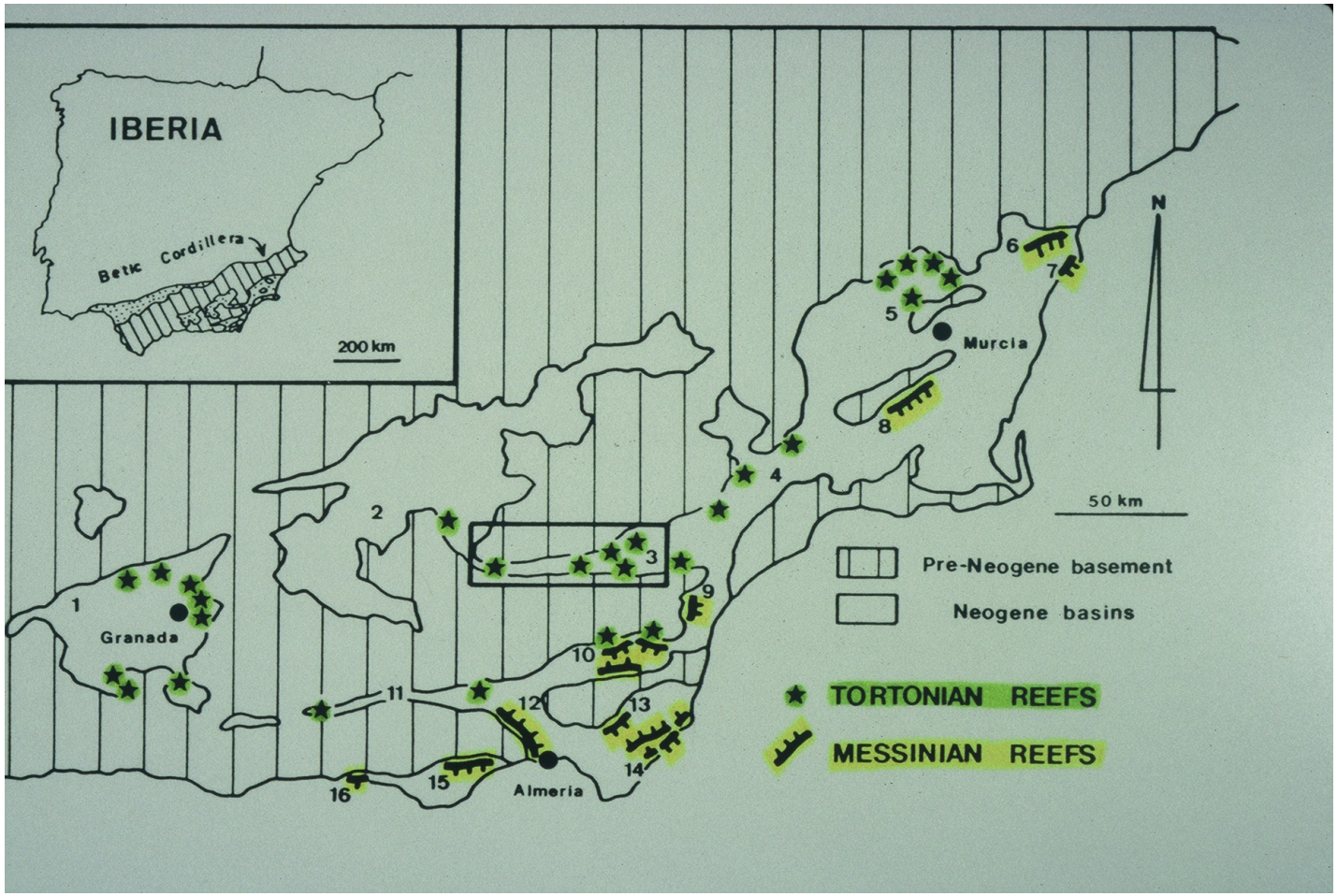
A second type of Mediterranean Neogene carbonate deposits are tropical carbonates, exemplified by coral reefs with abundant hermatypic coral remains. These reefs are strong evidence of the existence of a warm Mediterranean sea at certain times during the Neogene



Present-day reefs formed by hermatypic corals only develop in shallow marine environments, with mean winter sea-surface water temperatures of 20° C or higher

THE TROPICAL EPISODES

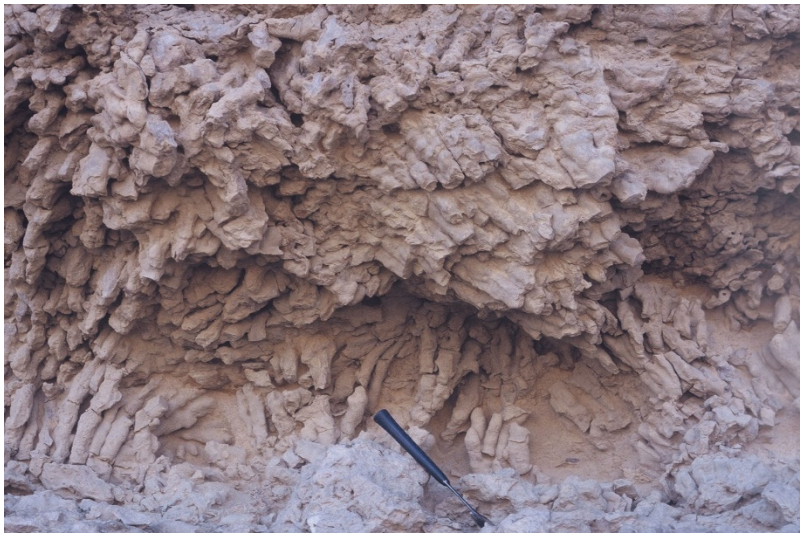
THE NEOGENE CORAL REEFS IN THE MEDITERRANEAN-LINKED BASINS



Field views

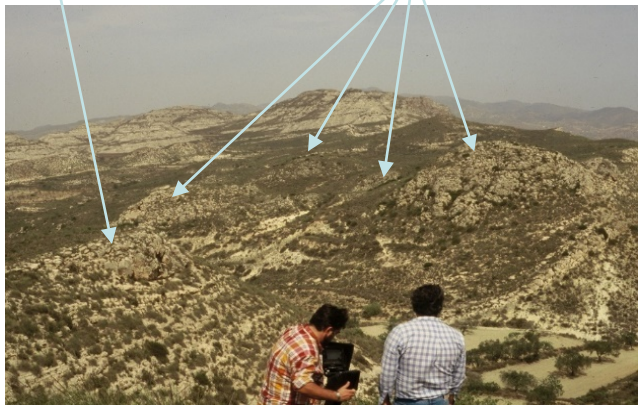
THE TORTONIAN REEFS

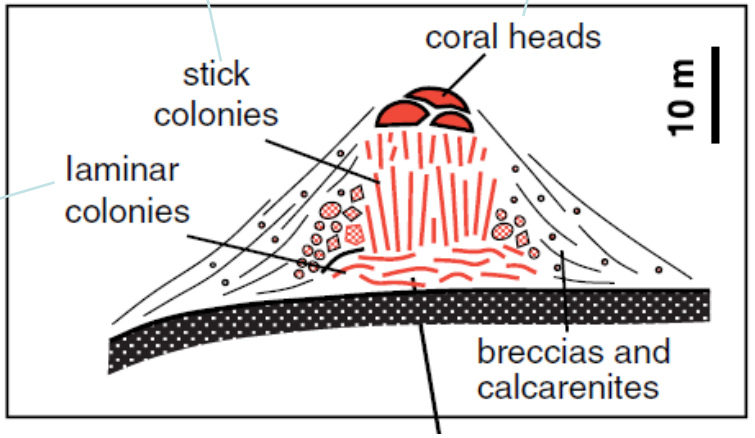
The corals



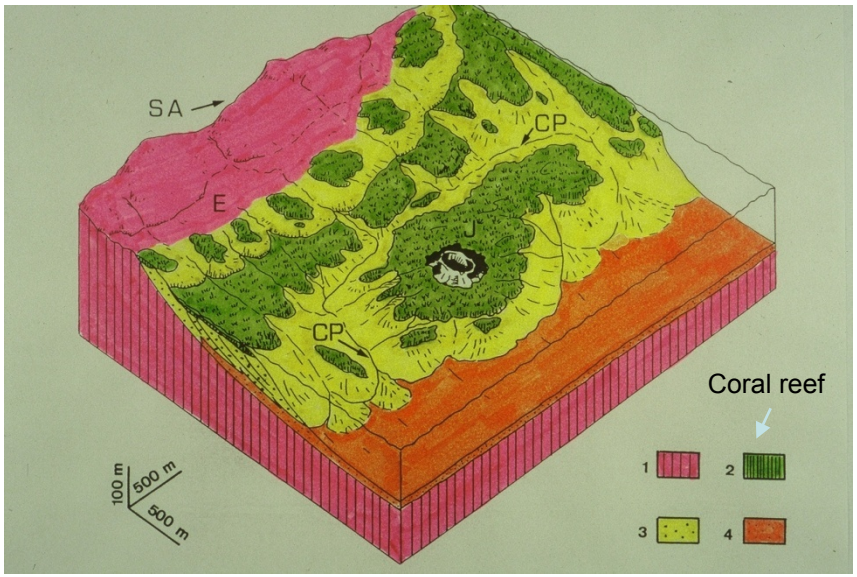
THE MESSINIAN REEFS

MOUND-LIKE BIOHERMS





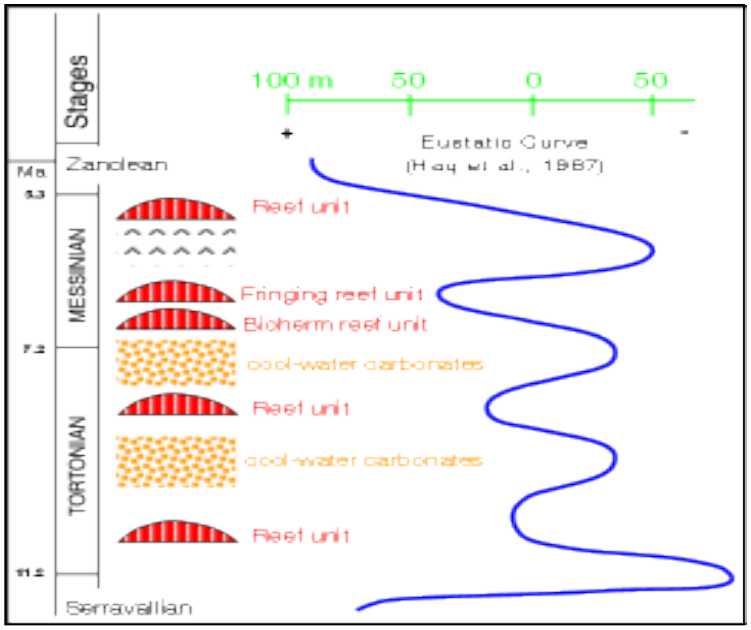
FRINGING REEFS



TEMPERATE AND TROPICAL CARBONATE EPISODES IN THE UPPERMOST MIOCENE

In the uppermost Miocene, temperate and tropical carbonate episodes follow each other and alternate in time. These alternations can be correlated with the Late Neogene global sea-level curve

Temperate carbonates accumulated on ramps during sea-level lowstands of third-order, eustatic sea-level cycles. Tropical carbonates formed on shelves during rising and high sea levels



All this suggests that the change in the type of carbonate was driven by seawater temperature variations related to global sea-level fluctuations

OXYGEN STABLE-ISOTOPE DATA

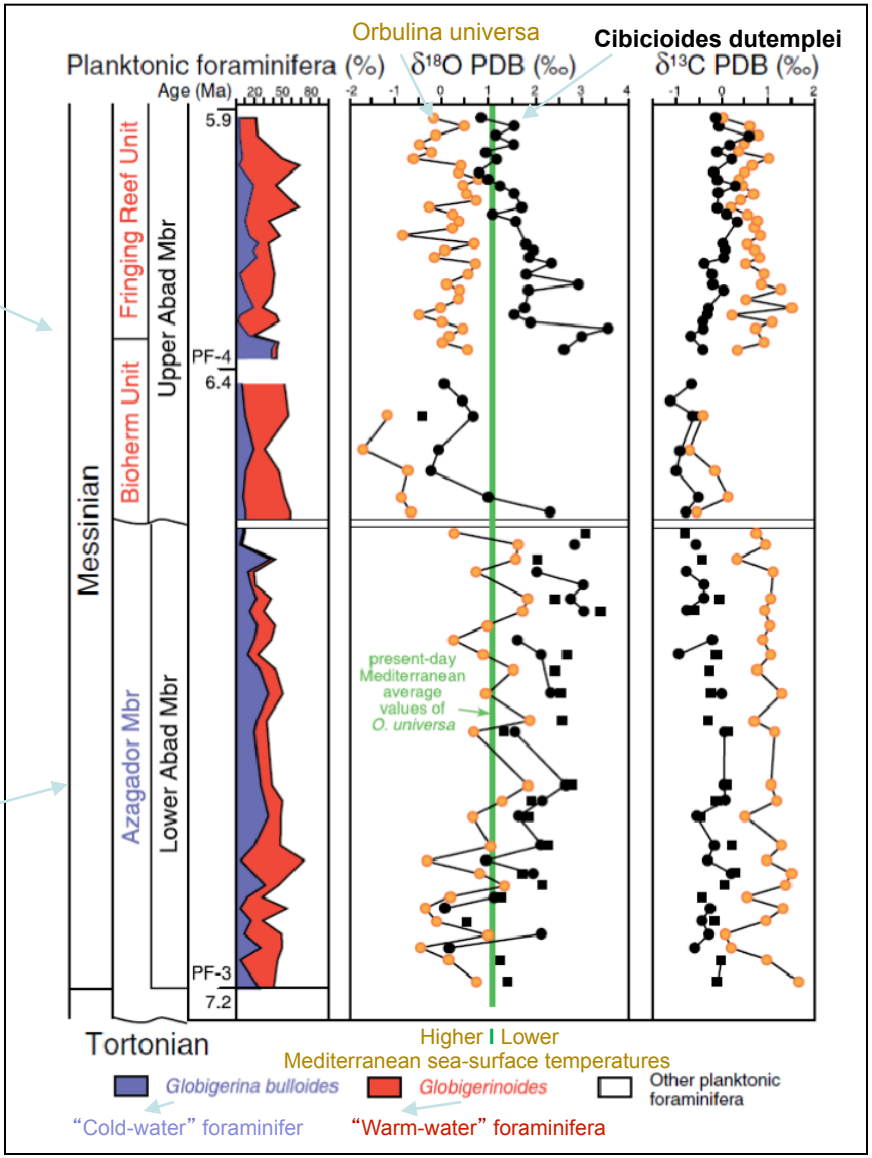
OXYGEN-ISOTOPE DATA CONFIRM THE CLIMATE ALTERNATIONS IN THE UPPERMOST MIOCENE

Reef units

$d^{18}O$ values, together with planktic-foraminiferal assemblages, suggest a rise in sea-surface temperatures in the early Messinian as the change from temperate to tropical, reef carbonate deposition took place

Temperate-carbonate unit

SEA-SURFACE TEMPERATURE IS THE MAJOR FACTOR CONTROLLING CARBONATE TYPE



TEMPERATE AND TROPICAL ALTERNATIONS REFLECT CYCLICAL CLIMATE CHANGES, OF PRESUMABLY GLOBAL SIGNIFICANCE, AFFECTING ALL THE WESTERN MEDITERRANEAN AREA

ADDITIONAL DATA

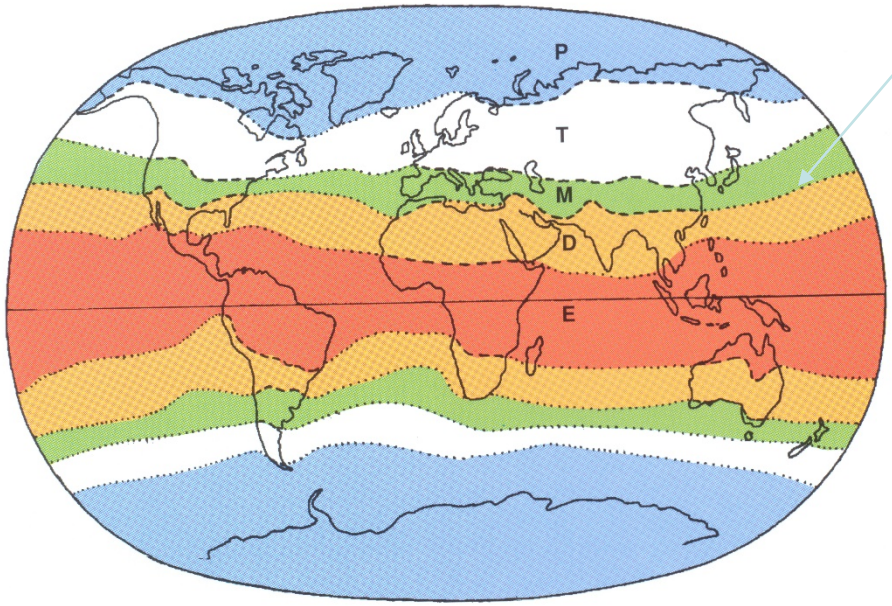
A cooling of Mediterranean waters at the Tortonian-Messinian boundary has also been detected with the d^{18}O record of planktic and benthic foraminifers in the Monte Casino section **in Italy** (Kouwenhoven *et al.,* 1999*), **and** in the Salé Briquetiere section in the Rifian Corridor **in Morocco** (Hodell *et al.,* 1994*)

Increase in global ice volume has been invoked as a possible causal mechanism (Hodell *et al.,* 1994*). Ice cap expansion has been reported from the southern hemisphere (Warnke *et al.,* 1992*), and from the northern hemisphere (Thiede *et al.*, 1998*), at about 7 Ma, near the Tortonian-Messinian boundary

*Check in reference list of key paper

THE CLIMATE CHANGES IN THE UPPERMOST MIOCENE
THE CLIMATIC-BELT FLUCTUATIONS

The diagram exemplifies the Present-day ("cold stage") situation

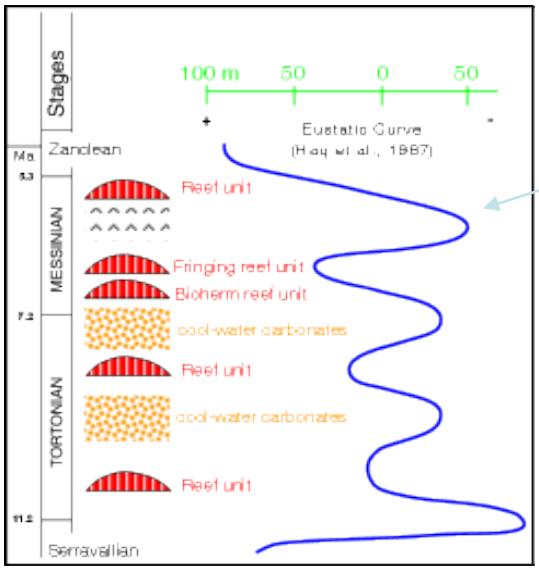


P: Polar belt
T: Temperate ("cold-Temperate") belt
M: Mediterranean ("warm-Temperate") belt
D: Tropical ("Desert") belt
E: Equatorial belt

Key line: the temperate-tropical boundary

In cold stages polar ice-cap expansion resulted in the displacement of the temperate-tropical boundary to the South. Consequently, **the western Mediterranean sea area fell within the temperate climatic belt. In** contrast, during **warm periods** ice caps significantly melted, the tropical belt extended to the North, and **the Mediterranean sea area was within the (sub)tropical belt**

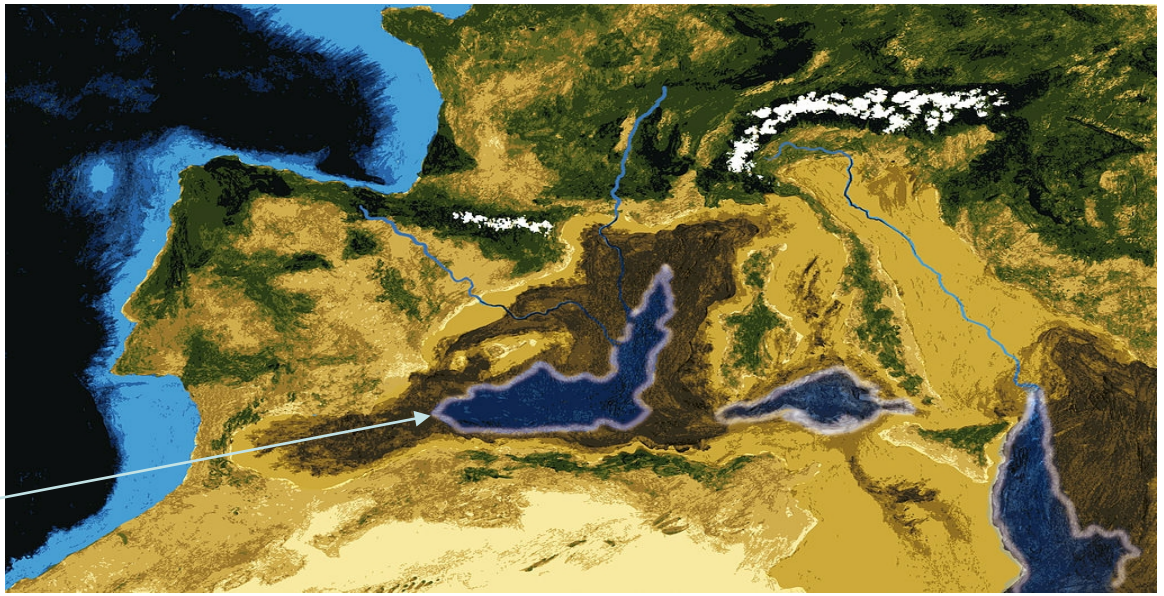
THE “LOST”, LATE MESSINIAN TEMPERATE-CARBONATE EPISODE



During the last Messinian sea-level fall evaporites formed in the Mediterranean sea instead of temperate carbonates

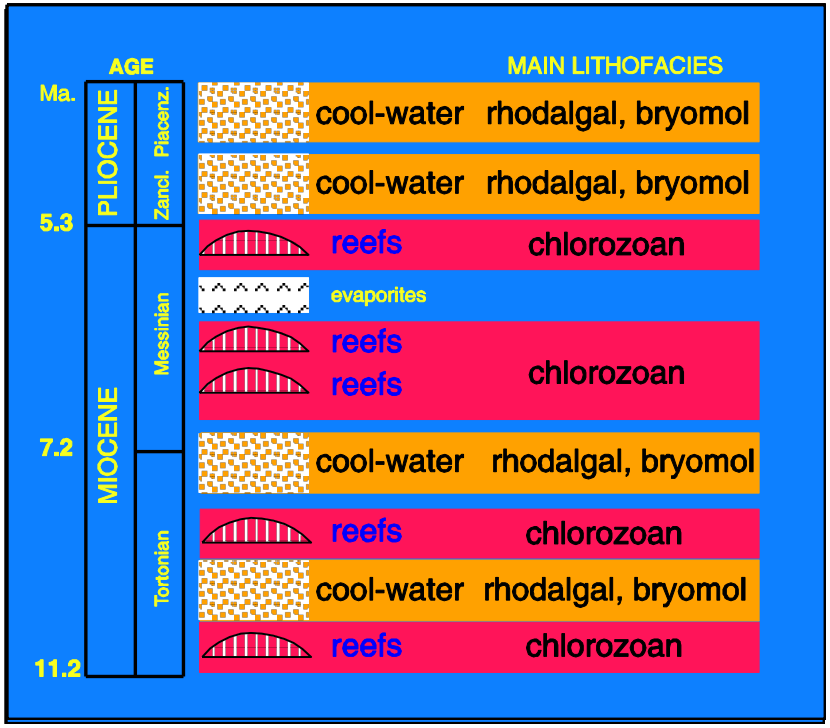
In Messinian times, at ~ 5’9 Ma, the Mediterranean sea dried out completely as a consequence of the closing of the Atlantic-Mediterranean connections

Huge salt (halite) deposits accumulated in its deepest areas



THE PLIOCENE ANOMALY

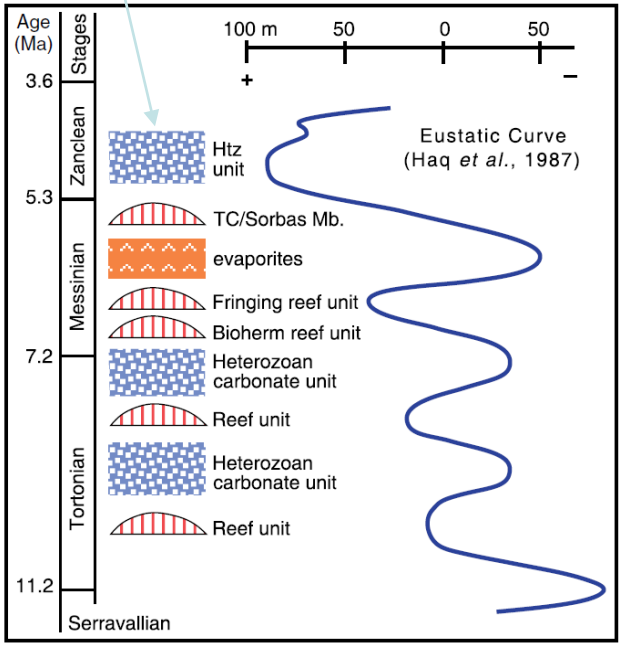
Temperate carbonates formed as well in the western Mediterranean during the Lower Pliocene, even though the global climate was warmer than during the latemost Miocene (Zachos *et al.*, 2001*)

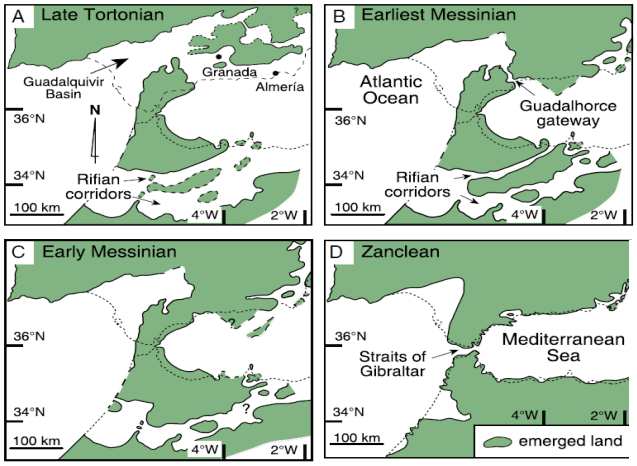


*Check in reference list of key paper

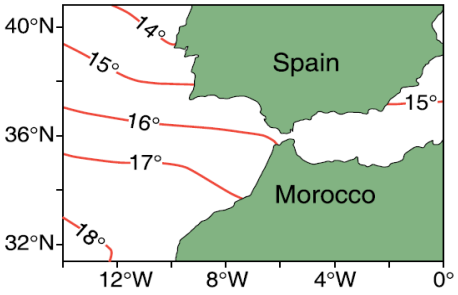
LOWER PLIOCENE,TEMPERATE-CARBONATE DEPOSITION IN THE WESTERN MEDITERRANEAN

During the Early Pliocene 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 during a global, warm high-stand stage. 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





Early Pliocene situation



EARLY PLIOCENE, OXYGEN-ISOTOPE DATA FROM THE WESTERN MEDITERRANEAN

Isotopic studies (oxygen stable isotope values), carried out on planktonic foraminifers (Orbulina universa) from a core (Hole 976B) in the western Mediterranean (ODP Leg 161, Site 976), **confirm a temperature decrease of Mediterranean surface waters during the Early Pliocene**, at about 4.9 Ma