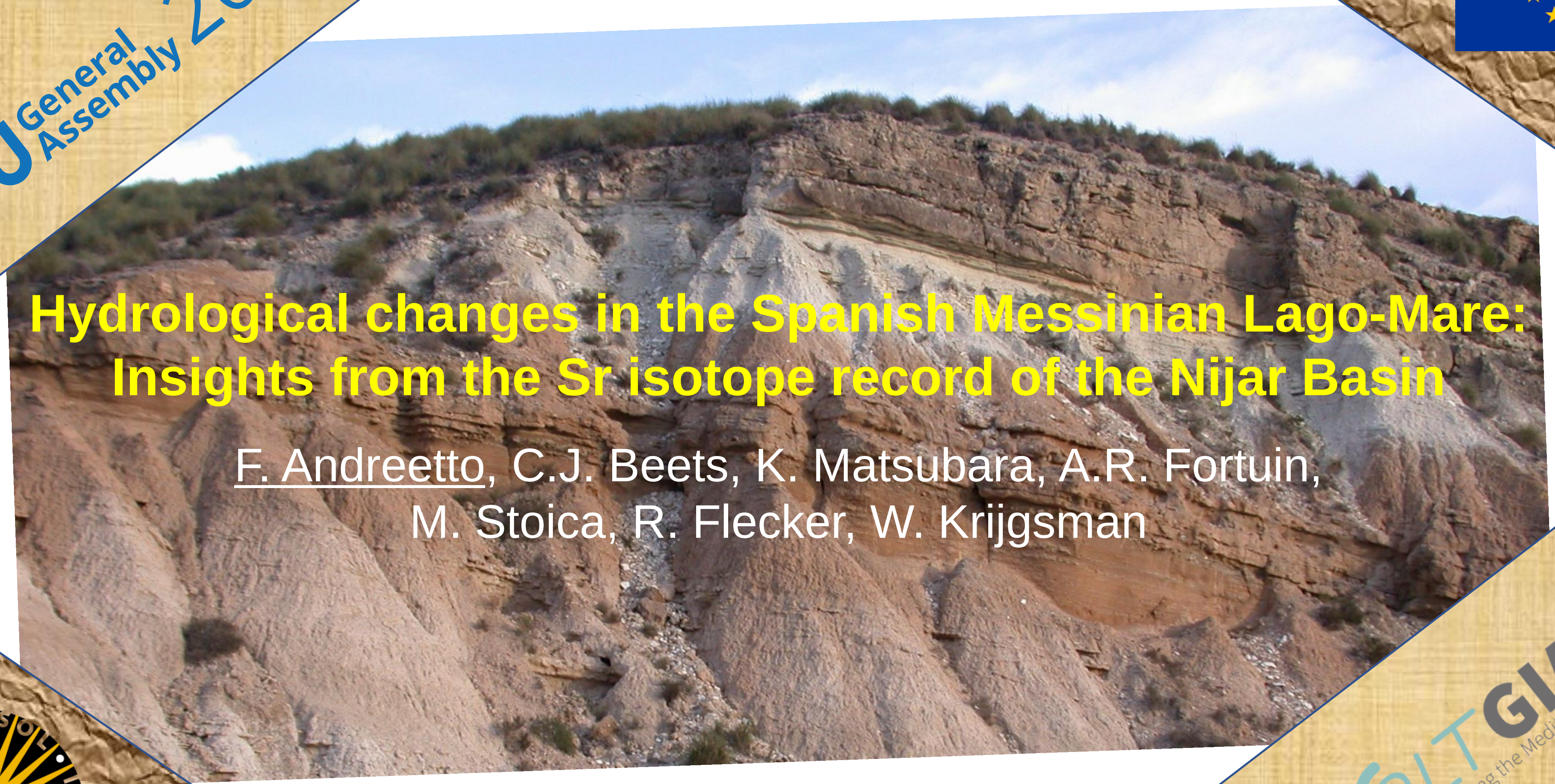

Hydrological changes in the Spanish Messinian Lago-Mare: Insights from the Sr isotope record of the Nijar Basin

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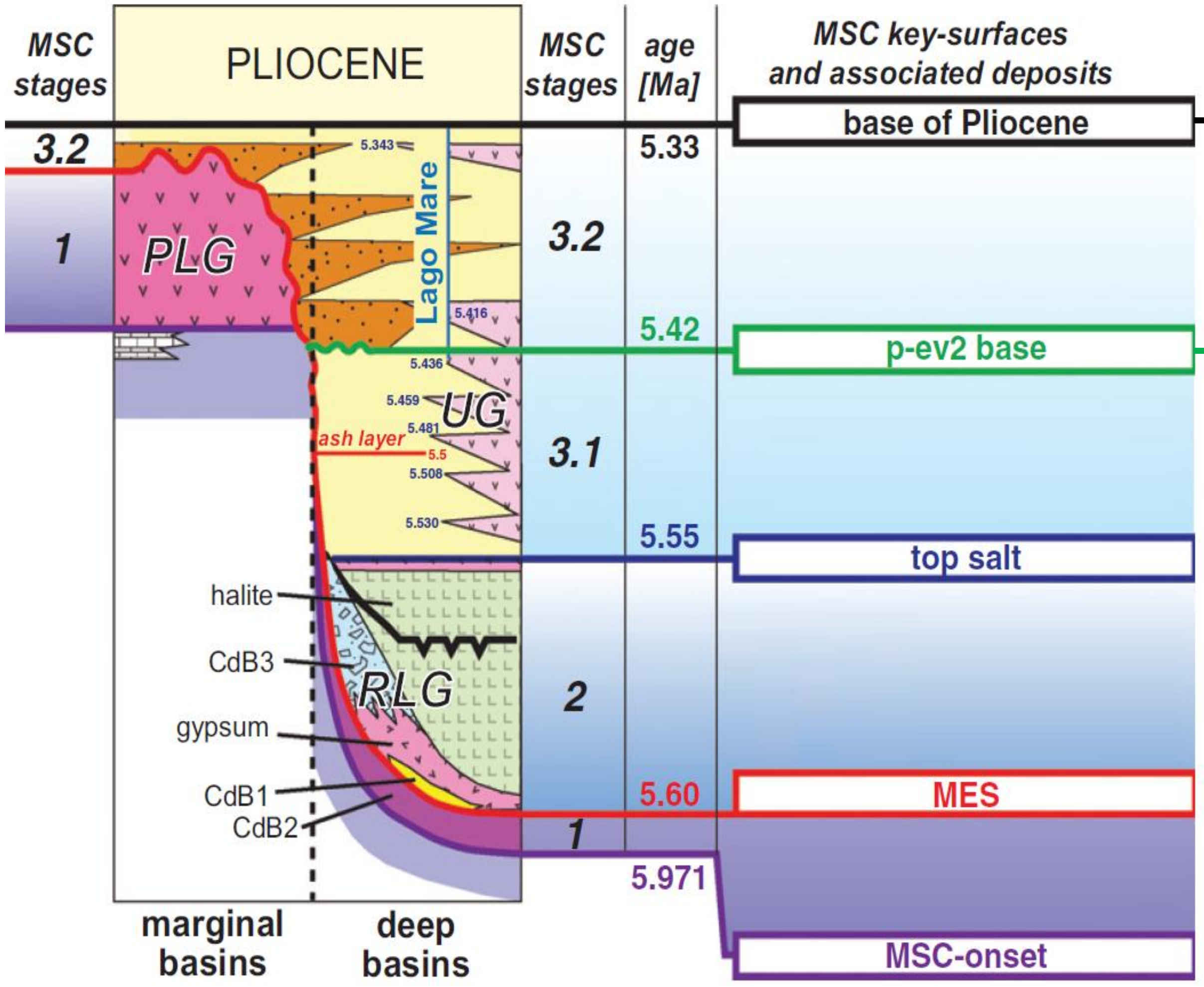
EGU General Assembly 2020

SALTGIANT Understanding the Mediterranean Salt Giant

INTRODUCTION



Consensus chronostratigraphic model for MSC (modified from [Manzi et al., 2013](#)). PLG: Primary Lower Gypsum; RLG: Resedimented Lower Gypsum; UG: Upper Gypsum; MES: Messinian Erosional Surface

5.42-5.33 Ma: Mediterranean-wide freshening

- Conglomerate to sandstone-laminated pelites alternations
- Pelites are featured by an brackish microfauna (ostracods, molluscs, dinoflagellates, fish) with Paratethyan affinity

Whitish laminated pelites capped by a sandstone bed (Nihar Basin).

OUTSTANDING HYDROLOGICAL SWITCH

5.97-5.42 Ma: Dominantly evaporative conditions

- Massive (i.e. in the order of some million cubic km) deposition of evaporites (gypsum and halite) both in marginal and deep settings.
- Strong impact on eukaryotes

Halite (Realmonte mine)

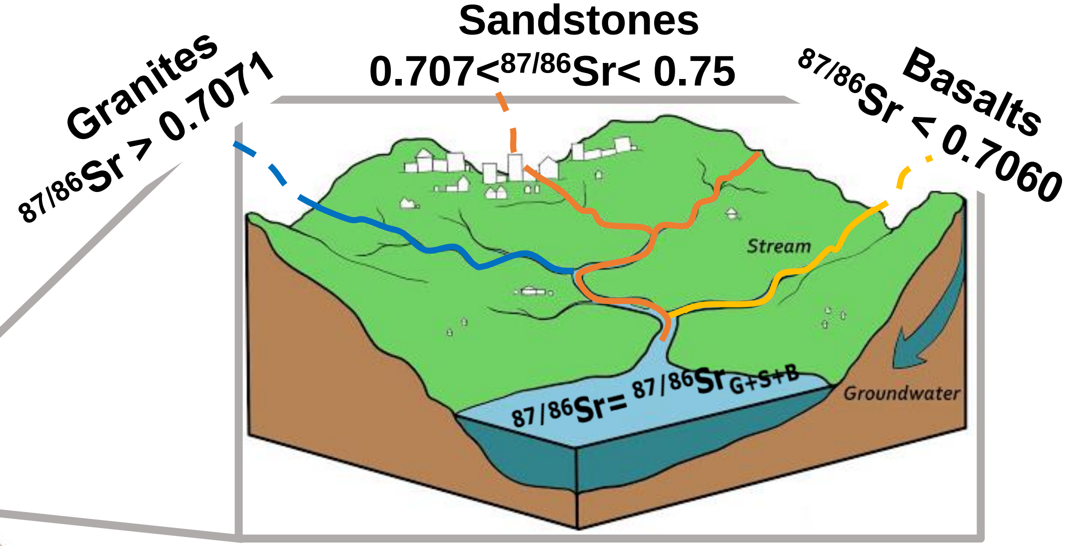
Bulk of the Lago-Mare conundrum:

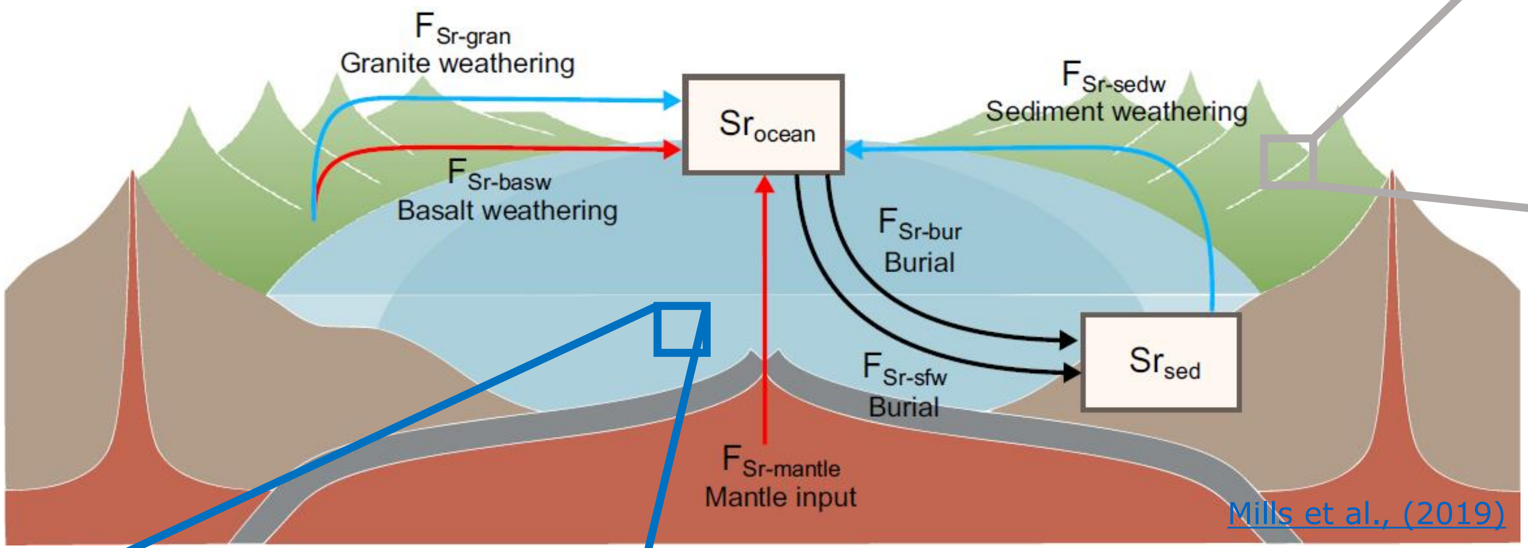
- Did the transition to the Lago-Mare phase happen in disconnected basins variously elevated above a desiccated Mediterranean (e.g. Orszag-Sperber et al., 2000) or in basins intra-connected at high sea level (e.g. Stoica et al., 2016)?

- As for the full Mediterranean model, what was the hydrochemistry of the water mass?
  - Fully marine (e.g. Aguirre and Sánchez Almazo, 2004; Carnevale et al., 2008)?
  - Fully brackish (i.e. Caspian Sea-like Mediterranean; McCulloch and De Deckker, 1989)?
  - Density-stratified (i.e. Black Sea-like Mediterranean; e.g. Marzocchi et al., 2016)?

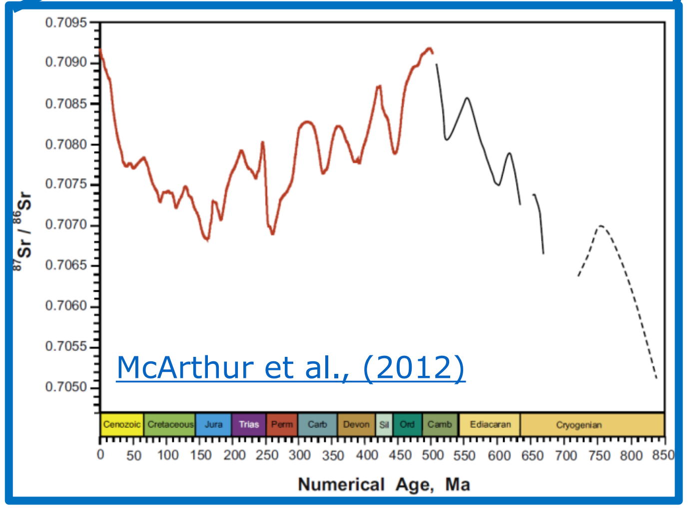
Here we look into Mediterranean base level and hydrology during the Lago-Mare phase by means of the $^{87}Sr/^{86}Sr$ isotope record of the spanish Nijar (new data), Sorbas and Vera (published data) basins.

Why do we use $^{87}Sr/^{86}Sr$ isotope ratios?





Schematic representation of the strontium cycle



Sr isotopes in oceans

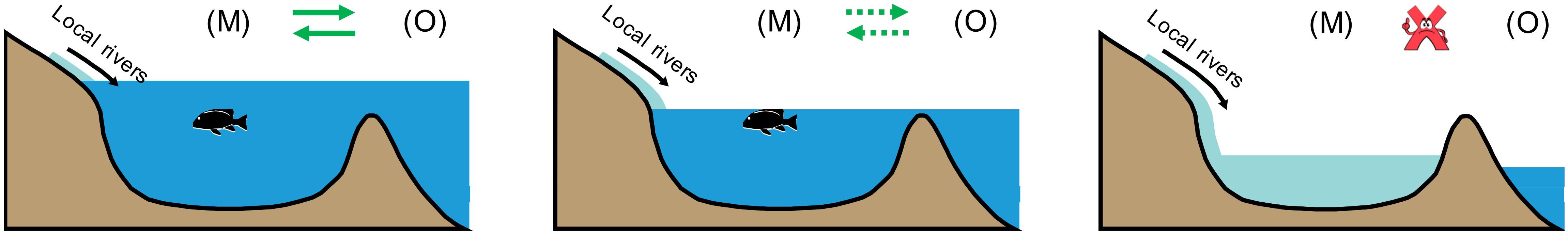
- Oceans store continental (high $^{87/86}Sr$, i.e. > 0.71) and mantle-derived (low $^{87/86}Sr$, i.e. < 0.703) Sr
- $^{87/86}Sr_{ocean}$ varied through time
- $^{87/86}Sr_{ocean}$ spatially homogeneous at any specific time

Variation of seawater 87Sr86Sr ratio through time

Sr isotopes in rivers

Rivers are featured by large variations of $^{87/86}Sr$ isotope ratios, which are related to the signature of the local bedrock

This makes the provenance of non-oceanic sources traceable (in restricted and endhoreic settings only, as the Mediterranean during the MSC)

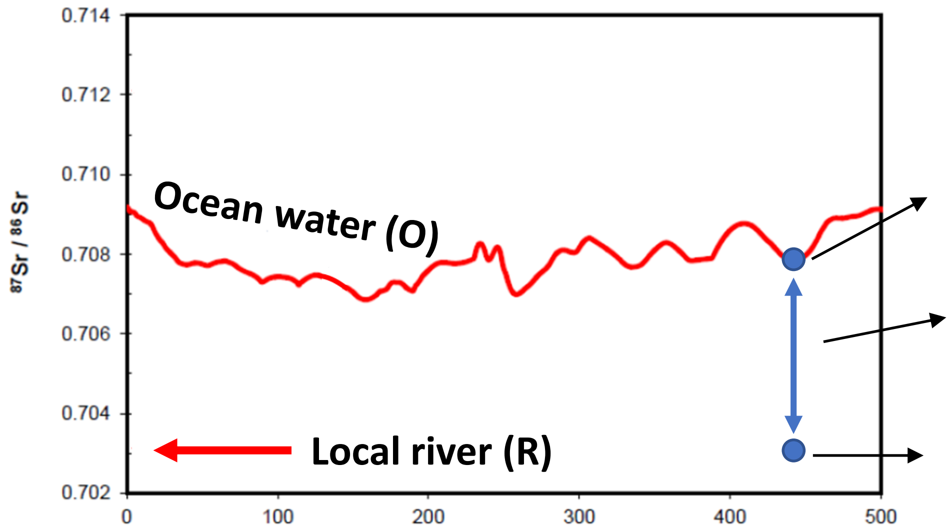


M = OPEN MARINE	M = RESTRICTED BASIN	M = ENDORHEIC BASIN

M= Marginal Basin (e.g. Mediterranean or Mediterranean subbasin) *O= Ocean (e.g. Atlantic)*

INCREASE SENSITIVITY TO CONTINENTAL RUNOFF

Isotopic fingerprint of the marginal basin (M)?



Open $^{87/86}Sr_M = {}^{87/86}Sr_O$

Restricted $^{87/86}Sr_M = {}^{87/86}Sr_{O+R}$

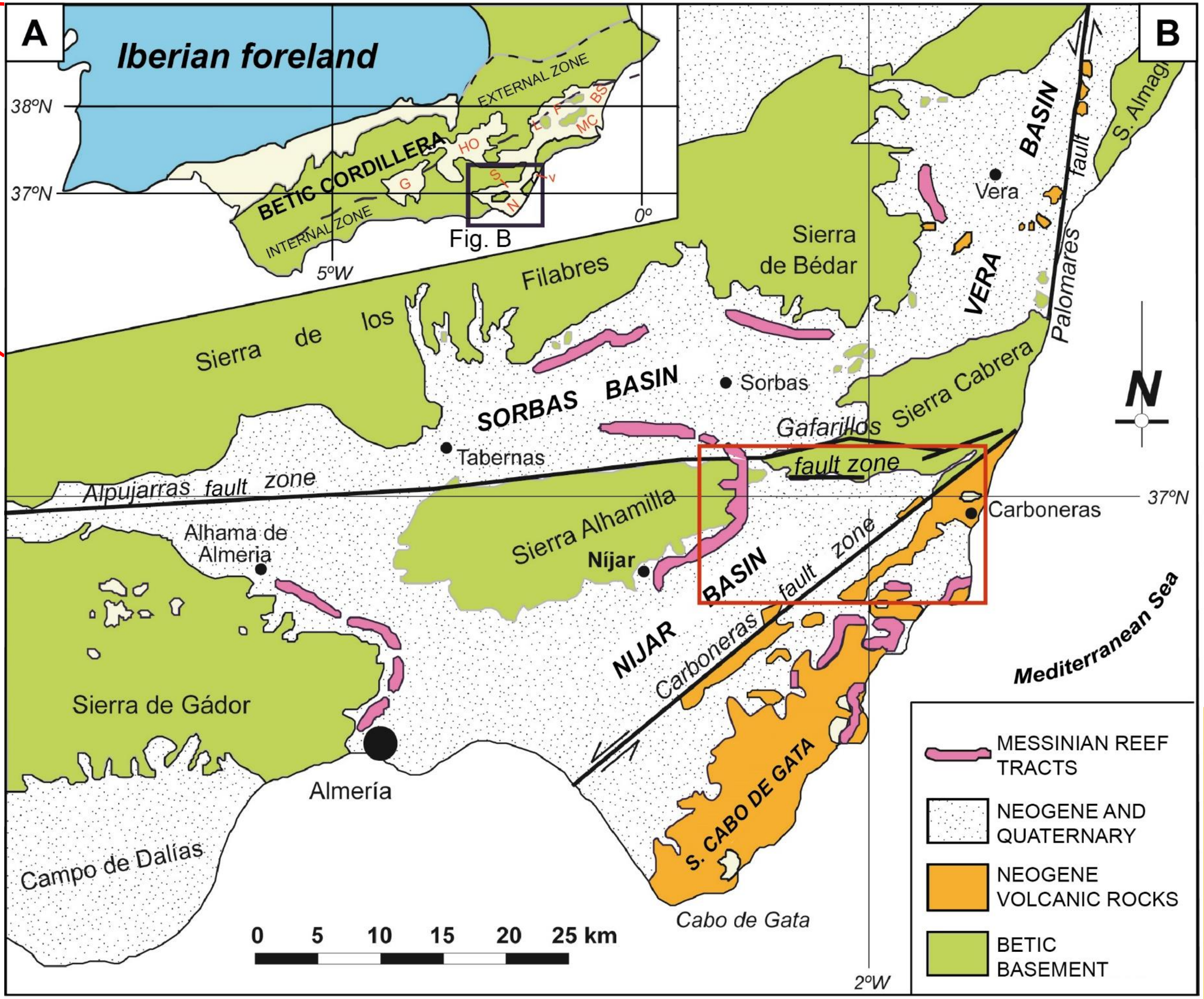
Endorheic $^{87/86}Sr_M = {}^{87/86}Sr_R$

Implications for Mediterranean base-level issue:

SUB-BASINS-MED HIGH-SEA LEVEL CONNECTION (Full theory)

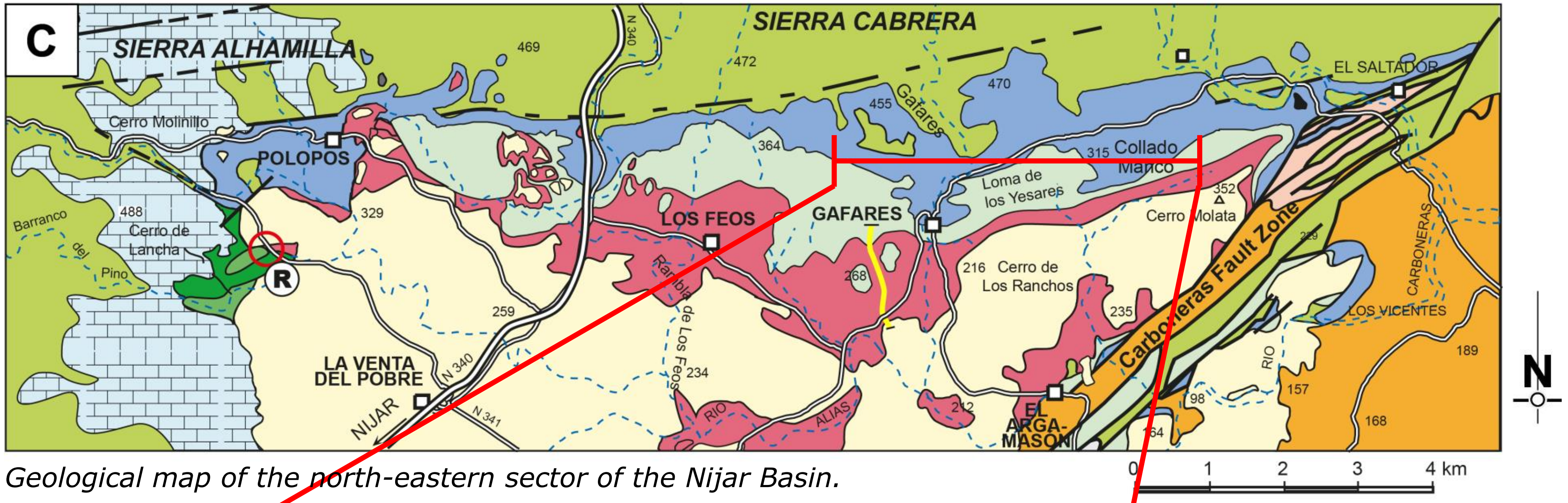
ISOLATED MED SUBBASINS (Desiccation theory)

STUDY AREA
Geological setting...

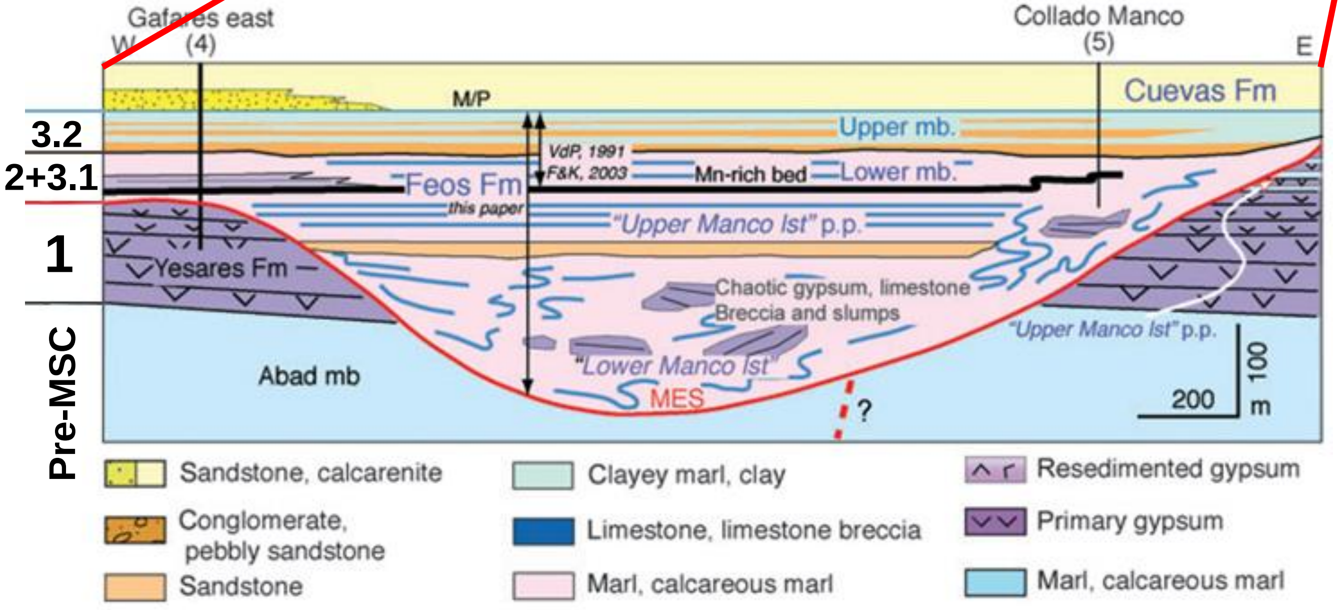


A) Geological map of the Betic Cordillera showing the location of the internal (G=Granada, HO=Huércal-Overa, L=Lorca, F=Fortuna) and external (N=Nijar, S=Sorbas, V=Vera, MC=Murcia-Cartagena, BS=Bajo Segura) Neogene basins. B) Schematic geological map of the eastern end of the Betic Cordillera.

STUDY AREA
… and stratigraphy

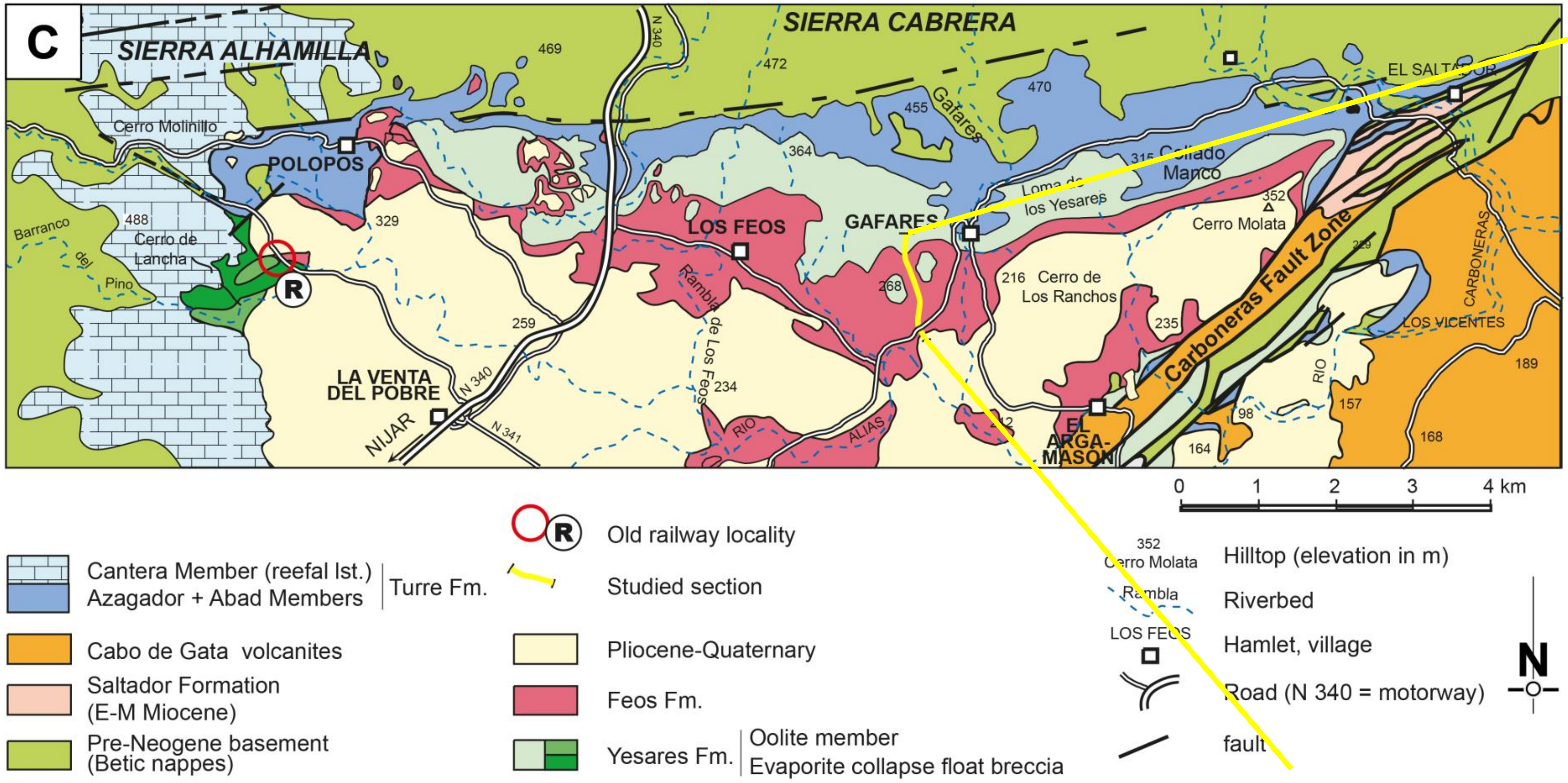


Geological map of the north-eastern sector of the Nijar Basin.

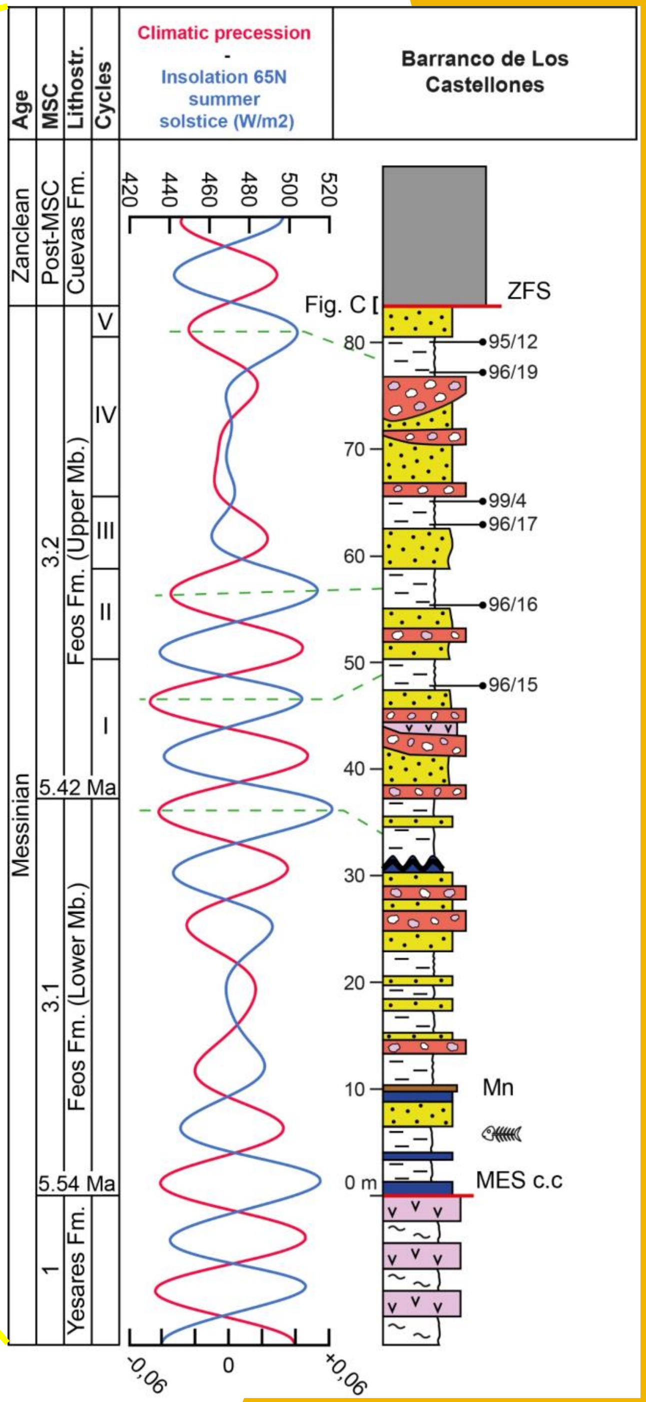


The Nijar Basin exceptionally preserves a nearly continuous upper Messinian record from pre-MSC sediments (Abad Fm.) to the overlying neritic Early Pliocene deposits (Cuevas Fm.), passing through evaporites (Yesares Fm.) and terrigenous facies (Feos Fm.) representing the MSC.

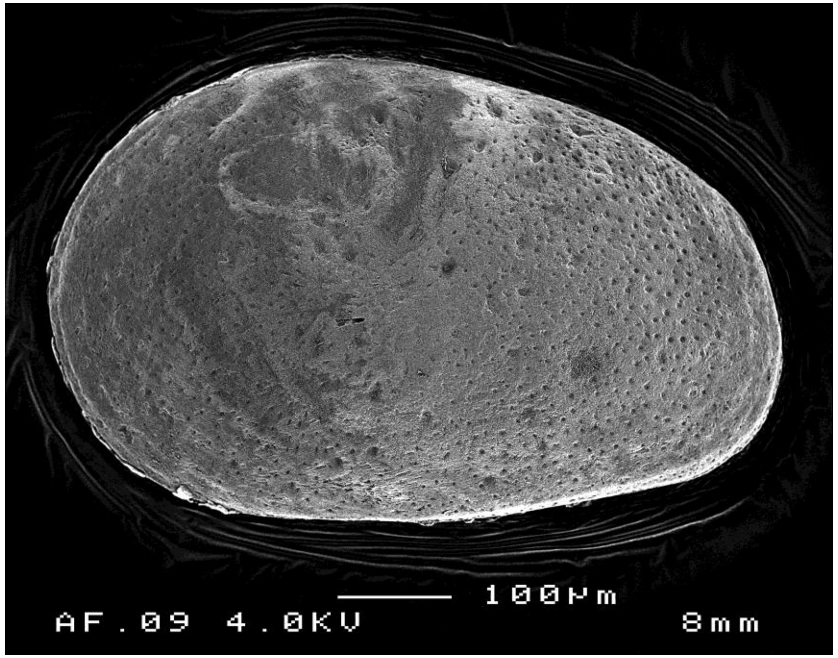
Schematic W-E cross-section showing the relationship between the Messinian unit. Numbers on the left side correspond to the MSC stages (modified from Omodeo Salé et al., 2012).



The Upper Member of the Feos Formation, considered the sedimentary expression of the Lago-Mare phase following the astronomical tuning of the Barranco de los Castellones section by Omodeo Salé et al., (2012), consists of four conglomerate to sandstone-laminated pelite alternations thought to be precession controlled. The pelitic beds host a microfaunal assemblage mainly composed of oligohaline, Black Sea-type ostracods mixed with marine foraminifera of struggled in-situ (Aguirre and Sánchez Almazo, 2004) and reworked (Bassetti et al., 2006) provenance.

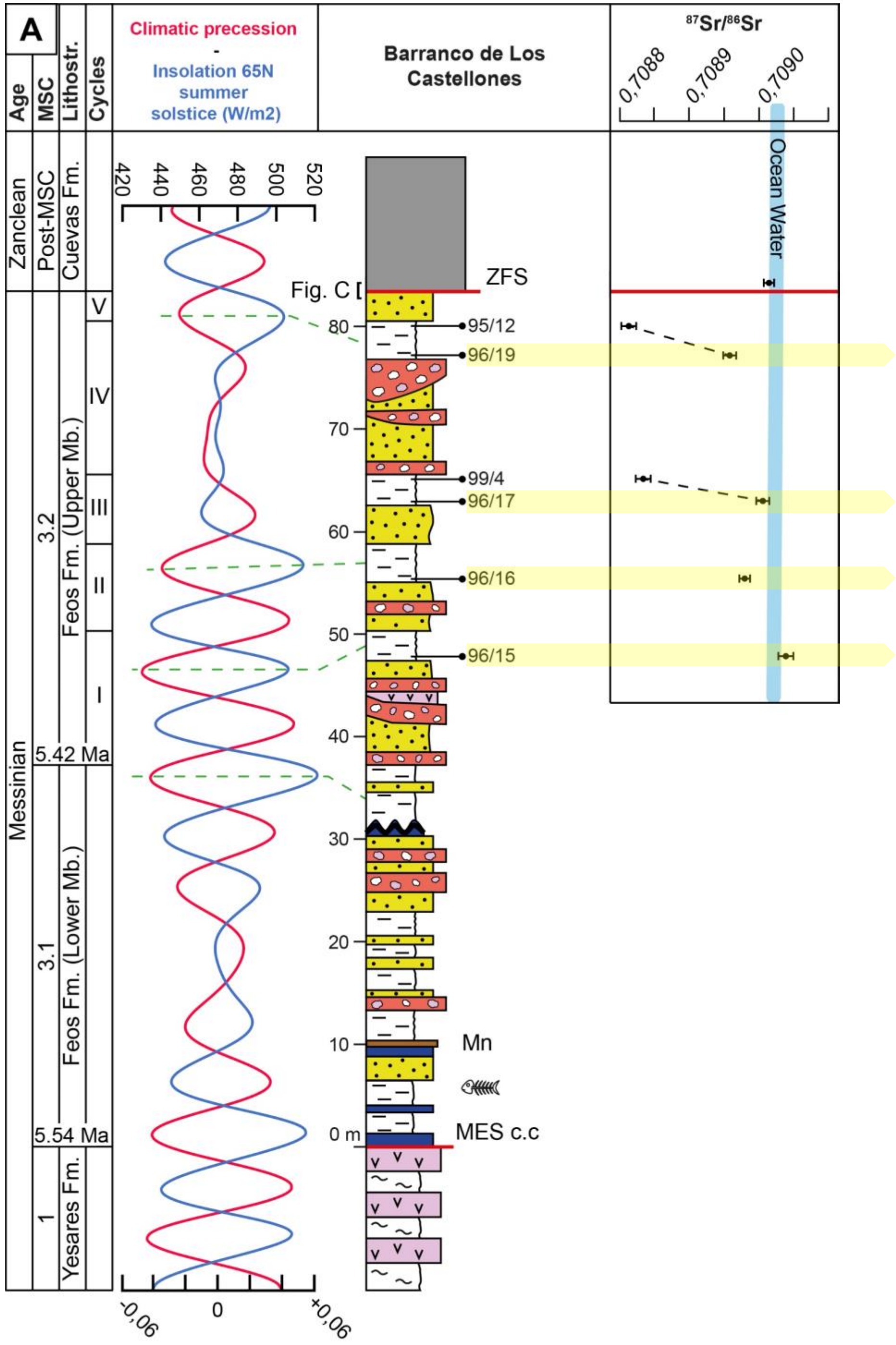


METHODS

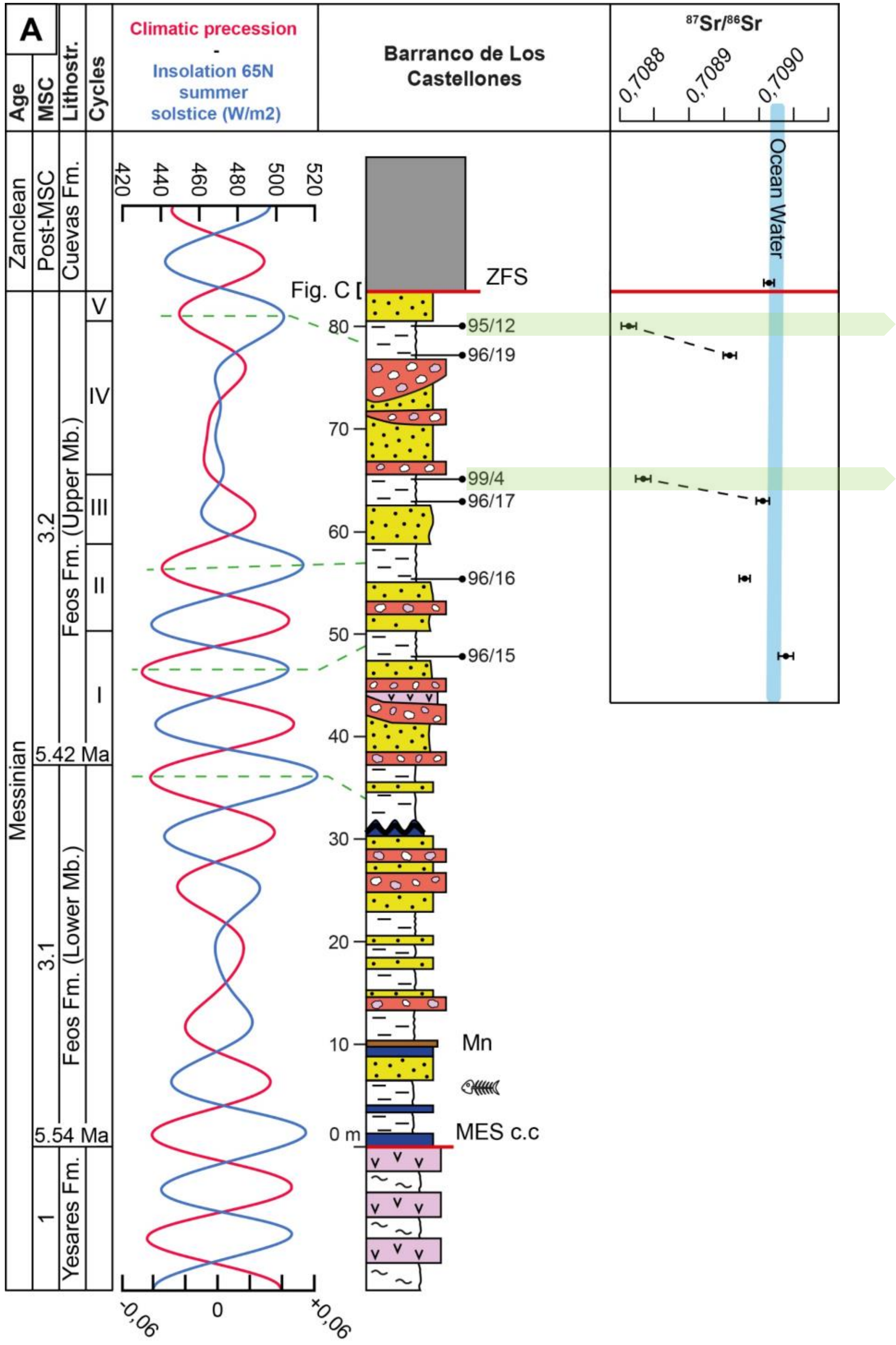


We measured the strontium ($^{87}Sr/^{86}Sr$) isotope composition of the calcitic valves of the ostracod *Cyprideis pannonica* (picture above) from the uppermost four pelitic strata of the Upper Member of the Feos Formation. Six samples of the pelitic intervals of the Feos Fm. contained sufficient (e.g. 4) well-preserved ostracod valves to permit Sr isotope analysis to be carried out.

RESULTS

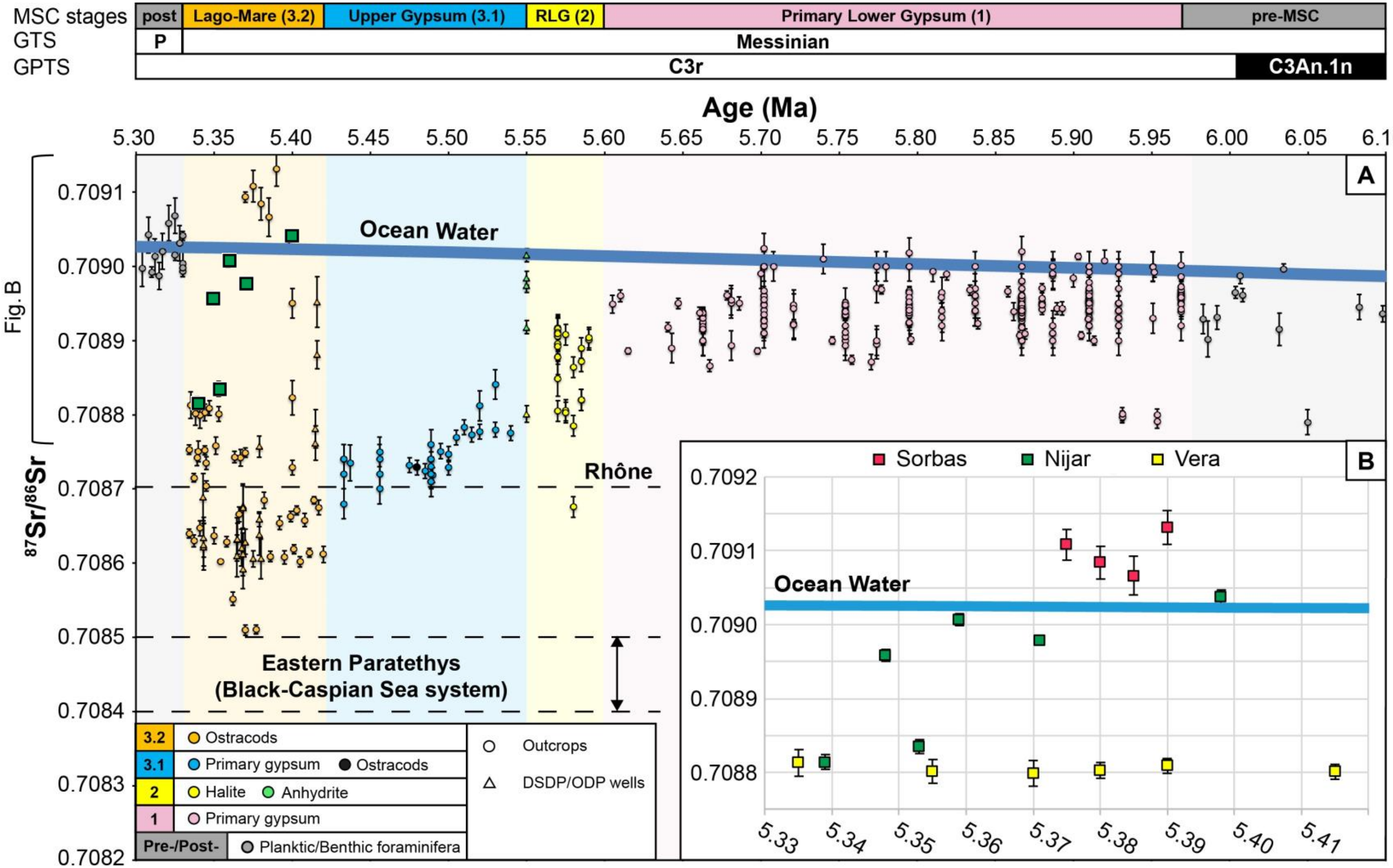


Samples collected from immediately above the transition from the underlying continental conglomerates plots within error (cycle I) of coeval global seawater Sr isotope ratios or below it (cycles II-IV).



Samples from the upper part of cycles III and IV are substantially lower than the rest of the Nijar data.

When examined alongside published Lago-Mare values from elsewhere in the Mediterranean:

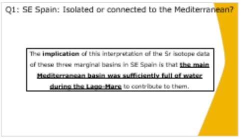


Compilation of $^{87}Sr/^{86}Sr$ isotope data for the Mediterranean during the MSC. A cyclostratigraphic age has been assigned to each sample according to the chronostratigraphic framework of Roveri et al., (2014a) for outcropping sections and Roveri et al., (2014b) for DSDP and ODP cores. B) Detailed $^{87}Sr/^{86}Sr$ record for Lago-Mare data from the Sorbas, Nijar and Vera basins and the coeval ocean ratio.

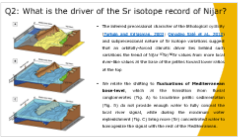
- Values from the base of the pelitic beds (0.708958-0.709037) are significantly higher (<0.708850).
- Values from the upper parts of cycles III and IV (0.708814-0.708835) are similar to values measured from substage 3.2 ostracods that inhabited the neighbouring Vera Basin (0.708799-0.708813) and slightly higher than other Mediterranean values (~0.7088-0.7085).

DISCUSSIONS

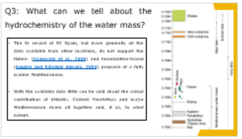
Q1: What was the hydrological setting of SE Spain and its relation with the Mediterranean?



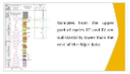
Q2: What can we tell about the hydrochemistry of the Mediterranean water mass?

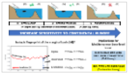


Q3: What about the driver of the Sr isotope record of Nijar?

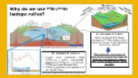


Q1: SE Spain: Isolated or connected to the Mediterranean?



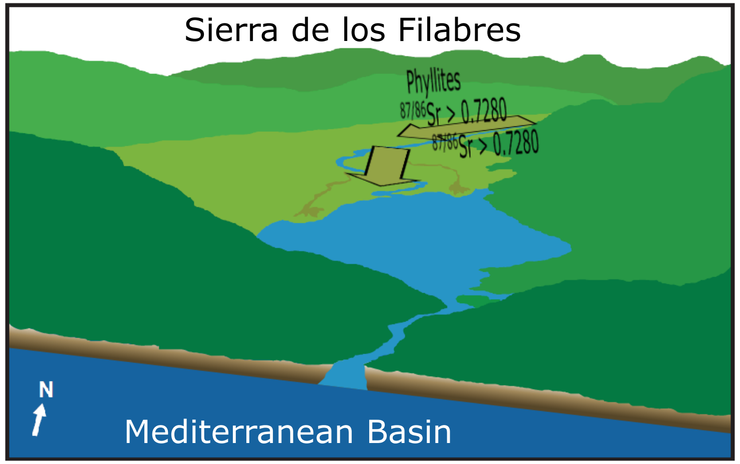


The pattern of non-oceanic Sr isotope ratios could, in principle, be consistent with the presence of three isolated lakes, one in each sedimentary basin, with its Sr signature mostly driven by the geochemistry of their catchments.

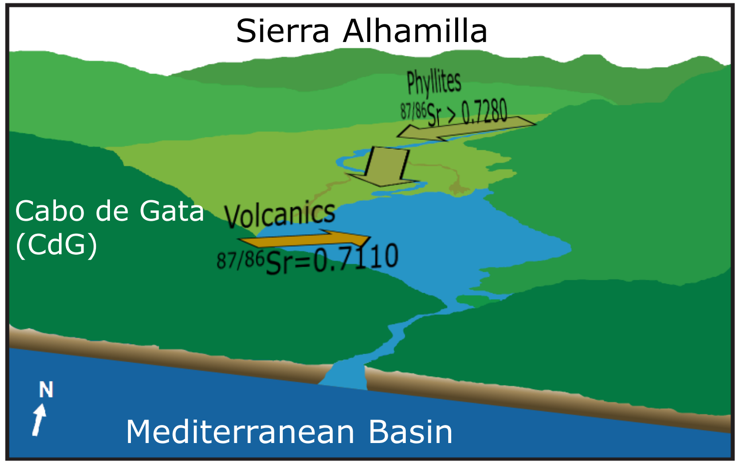


Paleogeography

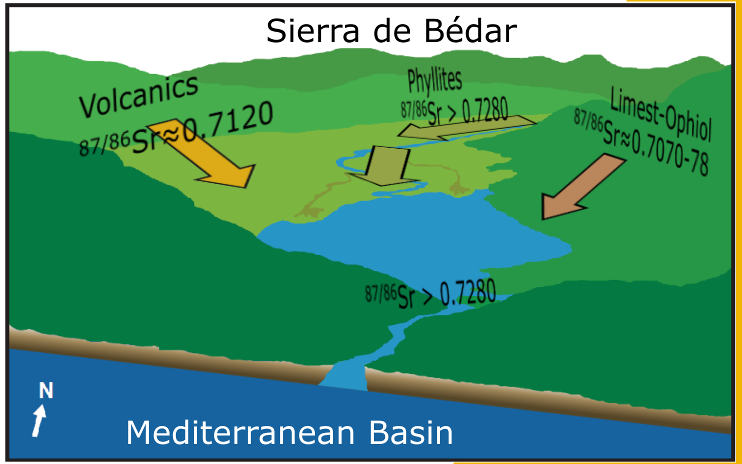
Sorbas Basin



Nijar Basin



Vera Basin

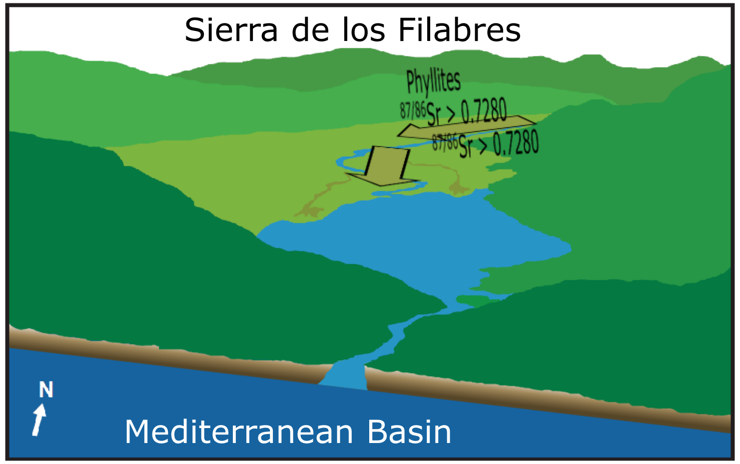


Expected $^{87}Sr/^{86}Sr$ ratios based on rivers' catchment:	0.7280	0.7110	> 0.7070

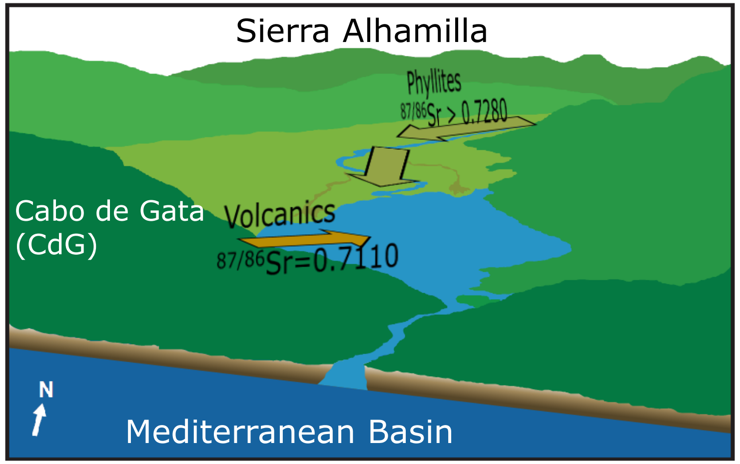
Despite the big uncertainty surrounding the Vera Basin and related to the unknown proportion of high (i.e. shales and volcanics) and low (ophiolites and limestones) radiogenic rocks weathered by the local streams, the range of **^{87}Sr/^{86}Sr values** from these three Spanish basins **does not encompass the inferred Sr signature for the local rivers, but requires an additional water source ([of compelled external provenance](#)).** This is not compatible with the hypothesis that these were three isolated lakes perched above a deeply desiccated Mediterranean.

[Paleogeography](#)

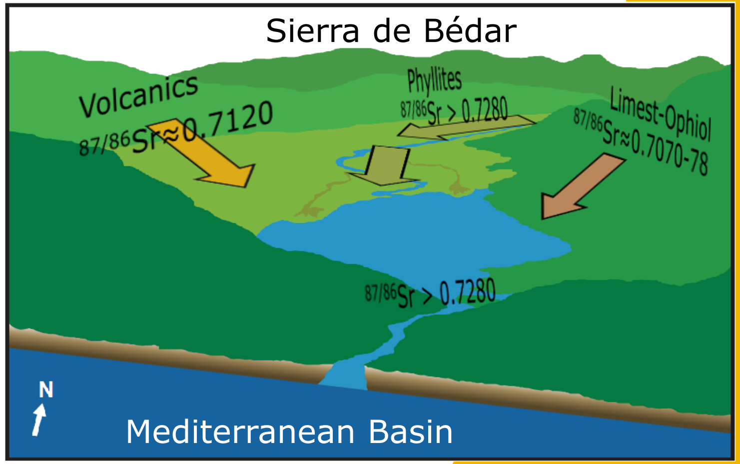
Sorbas Basin



Nijar Basin

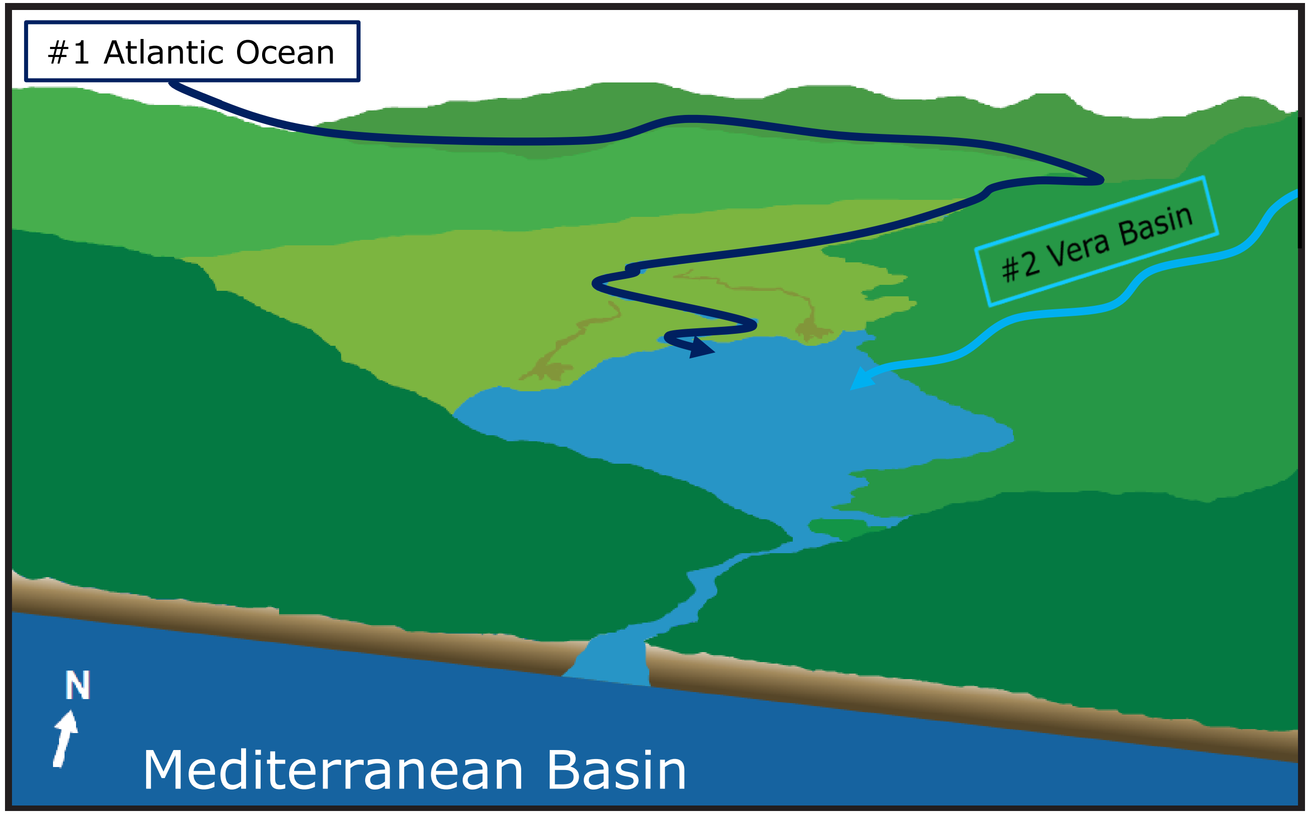


Vera Basin



	Sorbas Basin	Nijar Basin	Vera Basin
Expected ^{87}Sr/^{86}Sr ratios from isolated lakes:	0.7280	0.7110	> 0.7070
Measured ^{87}Sr/^{86}Sr ratios	0.709066-709131	0.708814-709037	0.708799-0.708813

Within the desiccated scenario, only two contributors external to both Nijar and Sorbas could have lowered their $^{87}Sr/^{86}Sr$ ratios to the measured values:



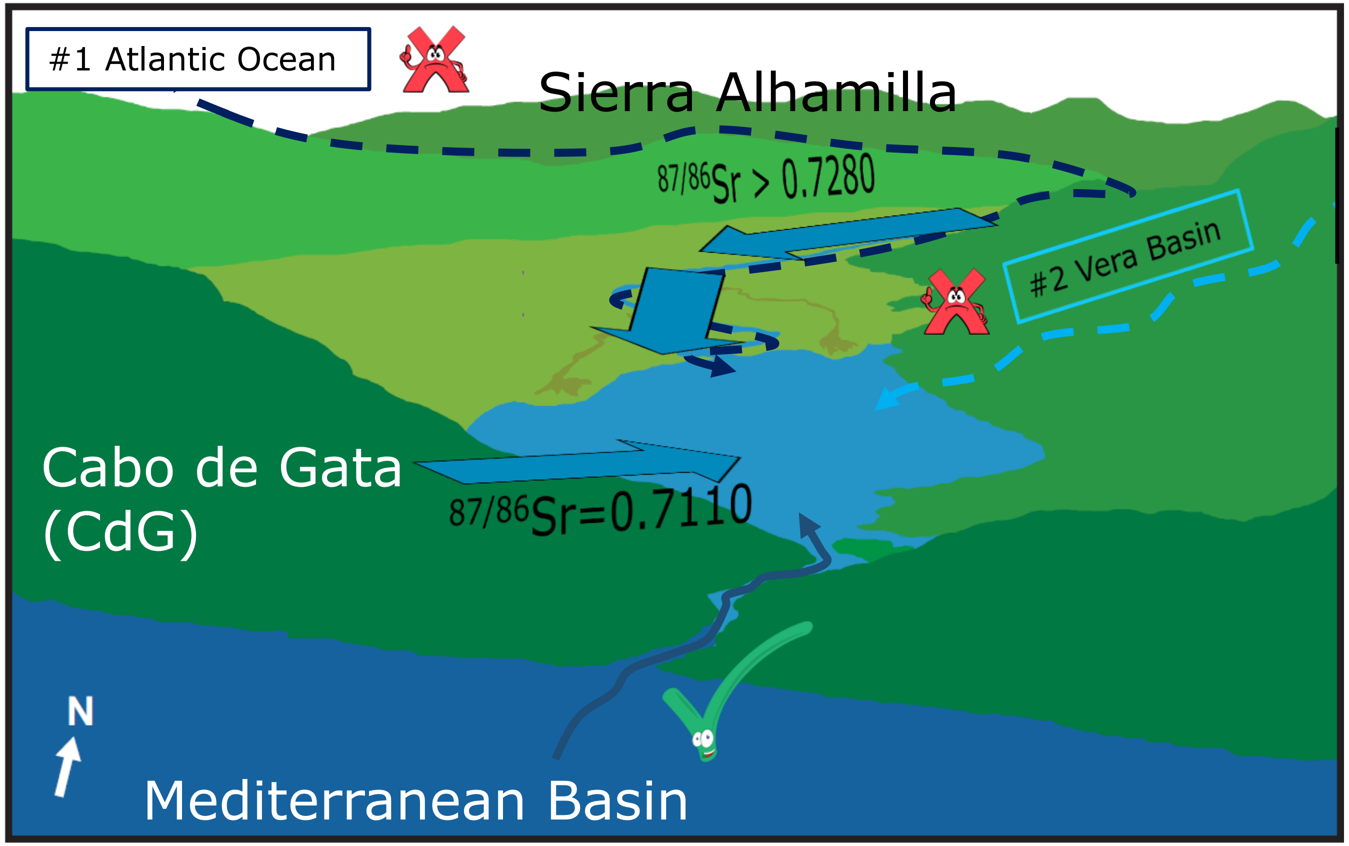
#1: Direct contribution from the Atlantic?

Because all the Vera and much of the Nijar Sr isotope ratios are also lower than coeval ocean water, a direct contribution solely from the Atlantic cannot account for the data observed either.

#2: Overspilling of the Vera Basin?

The connection between Vera and both Sorbas and Nijar is thought to have been closed during the MSC (Fortuin and Krijgsman, 2003).

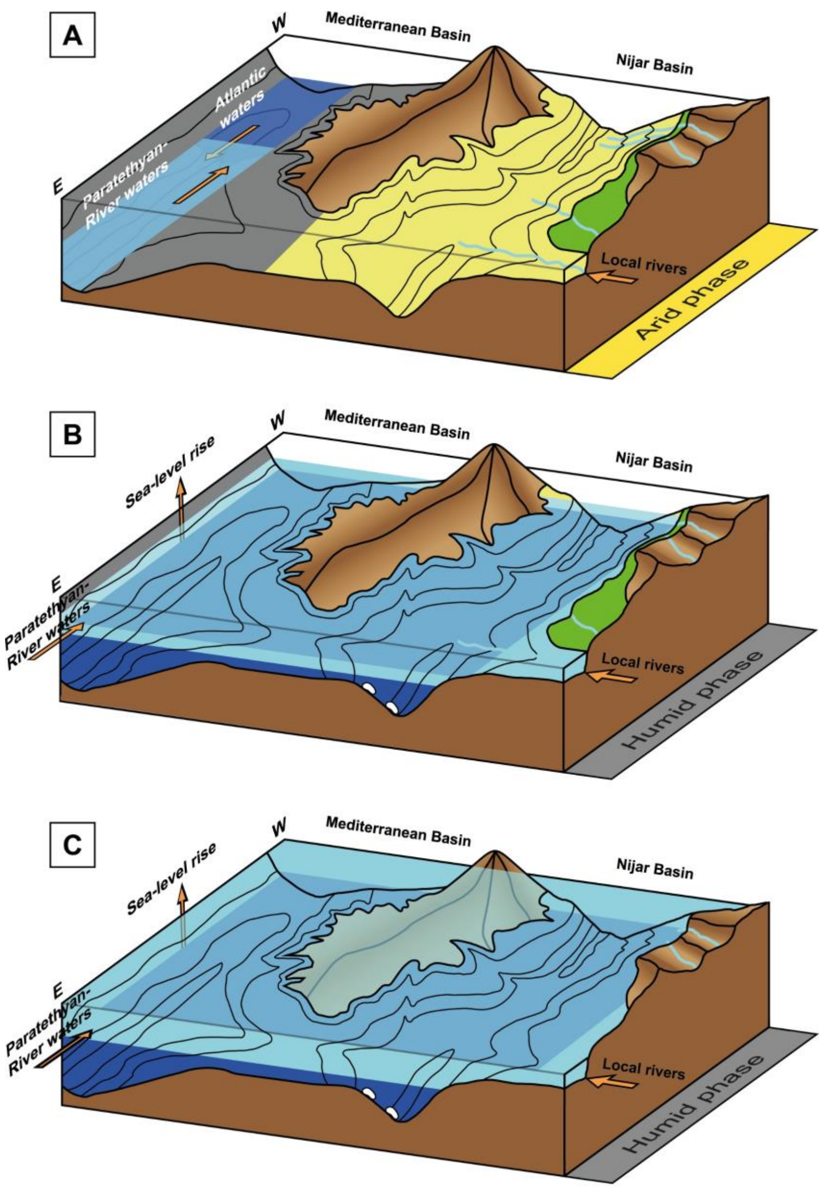
The open Mediterranean Basin, which from DSDP records had a Sr isotope ratio of ~0.7086-0.7088 (McCulloch and De Deckker, 1989), is the most likely external source of additional low $^{87}Sr/^{86}Sr$ water to these marginal Spanish basins.



Q1: SE Spain: Isolated or connected to the Mediterranean?

The **implication** of this interpretation of the Sr isotope data of these three marginal basins in SE Spain is that **the main Mediterranean basin was sufficiently full of water during the Lago-Mare** to contribute to them.

Q2: What is the driver of the Sr isotope record of Nijar?



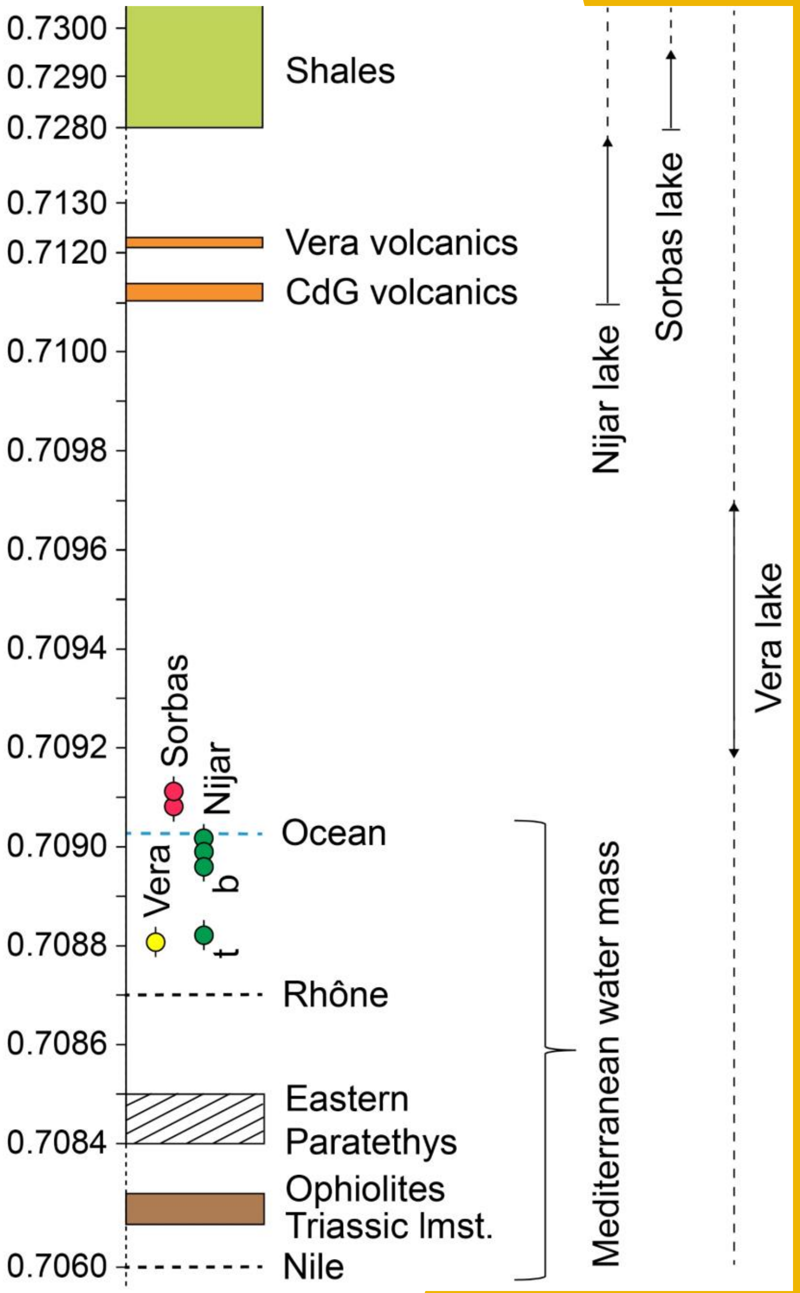
- The inferred precessional character of the lithological cyclicity (Fortuin and Krijgsman, 2003; Omodeo Salé et al., 2012) and subprecessional nature of Sr isotope variations suggest that an orbitally-forced climatic driver lies behind such variations the trend of Nijar $^{87}Sr/^{86}Sr$ values from more local river-like values at the base of the pelites toward lower ratios at the top

- We relate the shifting to **fluctuations of Mediterranean base-level**, which at the transition from fluvial conglomerates (Fig. A) to lacustrine pelitic sedimentation (Fig. B) do not provide enough water to fully conceal the local river signal, while during the maximum water replenishment (Fig. C) bring more (Sr) concentrated water to homogenize the signal with the rest of the Mediterranean.

Q3: What can we tell about the hydrochemistry of the water mass?

- The Sr record of SE Spain, but more generally all the data available from other locations, do not support the fishes- (Carnevale et al., 2008) and foraminifera-based (Aguirre and Sánchez Almazo, 2004) proposal of a fully marine Mediterranean.

- With the available data little can be said about the actual contribution of Atlantic, Eastern Paratethys and major Mediterranean rivers all together and, if so, to what extent.



CONCLUSIONS

- The range of $^{87}Sr/^{86}Sr$ values from these three Spanish basins does not encompass the inferred Sr signature for the (high radiogenic) local rivers, but requires an additional water source.

- The Mediterranean was the external source of less radiogenic Sr, meaning that sea level was at least temporarily high enough to invade these marginal areas during the Lago-Mare phase.

- Precession-modulated base-level fluctuations of the Mediterranean water body may have controlled the amount of low-radiogenic Mediterranean water entering the Nijar Basin.