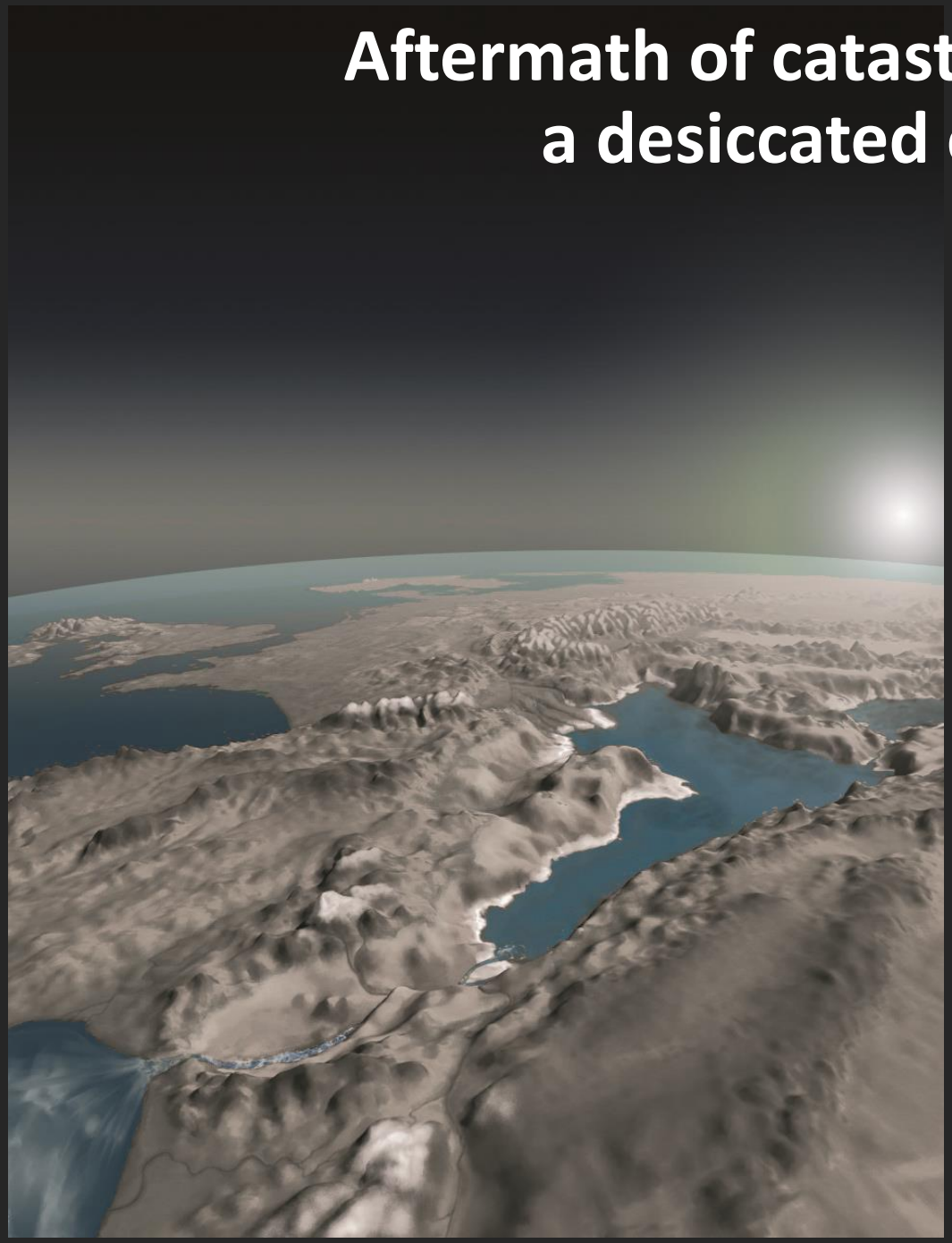
Aftermath of catastrophic flooding of a desiccated ocean basin



(**Nature Geoscience**, accepted – in press)

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[1] Australian National University
[2] University of Southampton
[3] MARUM, University of Bremen
[4] Geoscience Australia

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Australian National University

Original image credits: Daniel Garcia-Castellanos
Edited by: Udara Amarathunga

The Messinian Salinity Crisis (MSC)

5.97 million years (Ma)
Atlantic-Mediterranean gateway restriction

5.60 – 5.55 Ma
Peak of the MSC

5.33 Ma
MSC termination

Figure 01: Present Mediterranean and the Gibraltar gateway
(Image was downloaded from istock)

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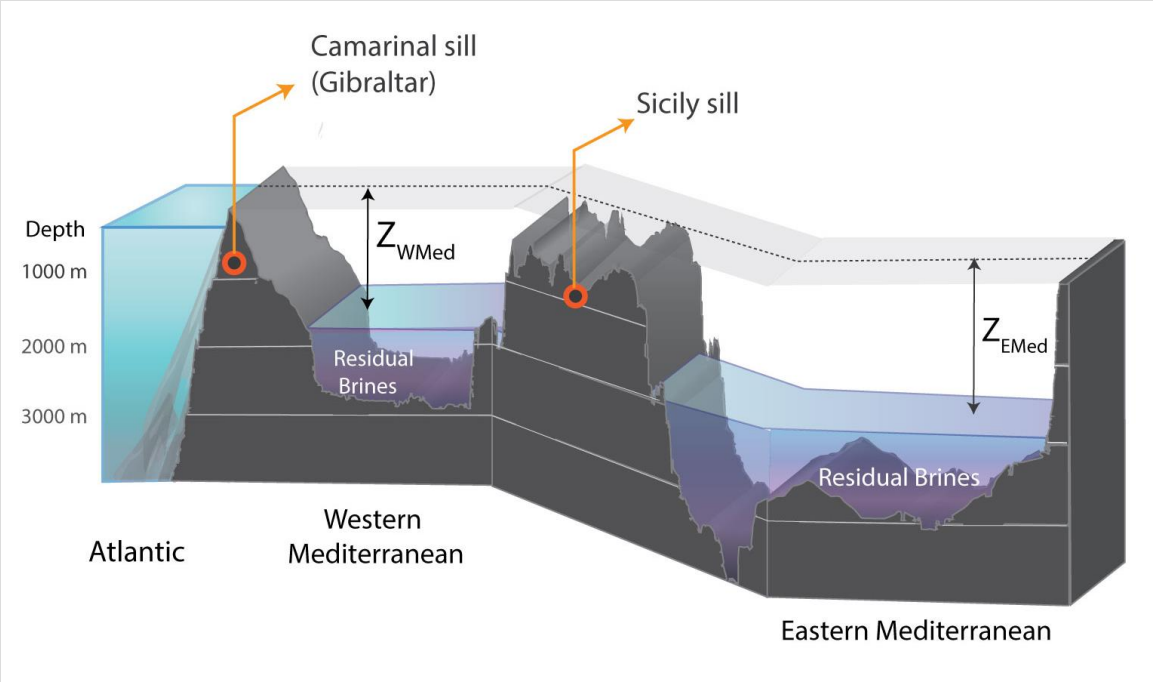

Figure 02: Partially desiccated Mediterranean at MSC peak
(Z_{WMed}, Z_{EMed}; western and eastern basin drawdown)
(Amarathunga et al., 2022 [in press])

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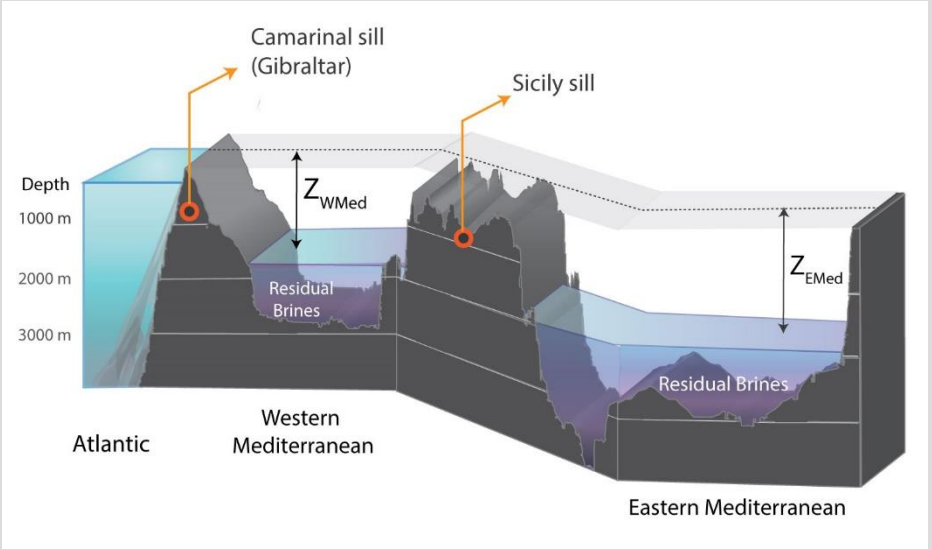


Multiple hypotheses

- A catastrophic termination - Flooding of a partially desiccated Basin (Zanclean megaflood)
- A gradual reconnection of a largely refilled basin in the Late Messinian
- A two-step process of refilling (a gradual refilling step followed by a rapid refilling event)

ODP Site 967 (Eastern Mediterranean)

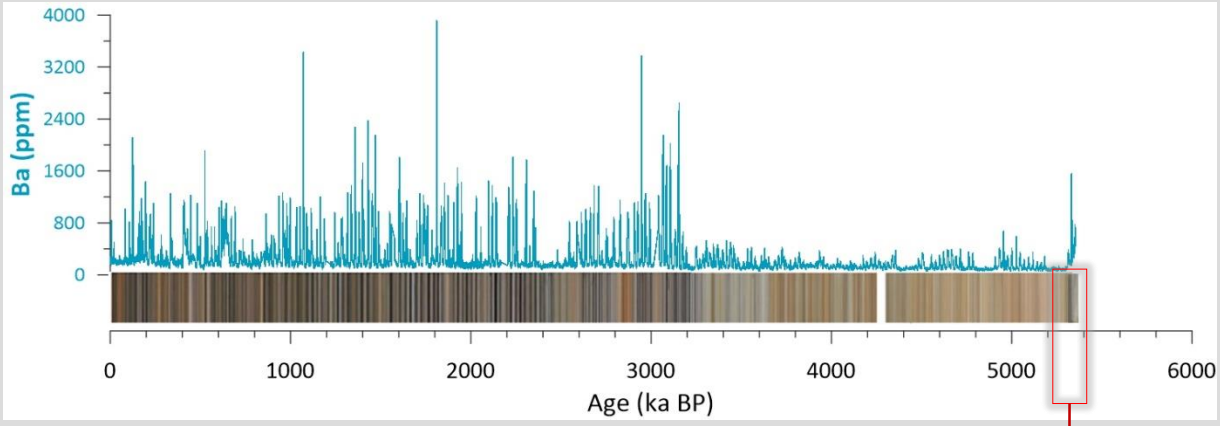


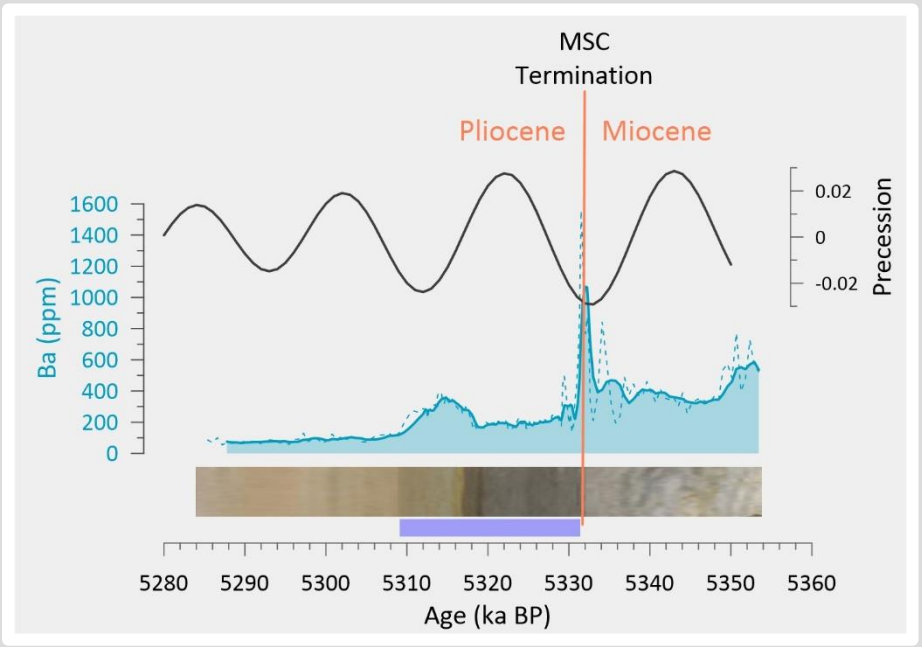
Figure 03: ODP 967 sapropel record (Amarathunga et al., 2022 [in press])

Barium:

A proxy for organic carbon burial

Sapropel:

A dark, organic-rich layers in sediment record compared to the surrounding sediments.



- ODP 967 sapropel record begins ~3.2 Ma
- However, there's a **sapropel** immediately after the M/P boundary
- Extends across two precession minima (~26,000 years long sapropel deposition)

The ‘mystery sapropel’

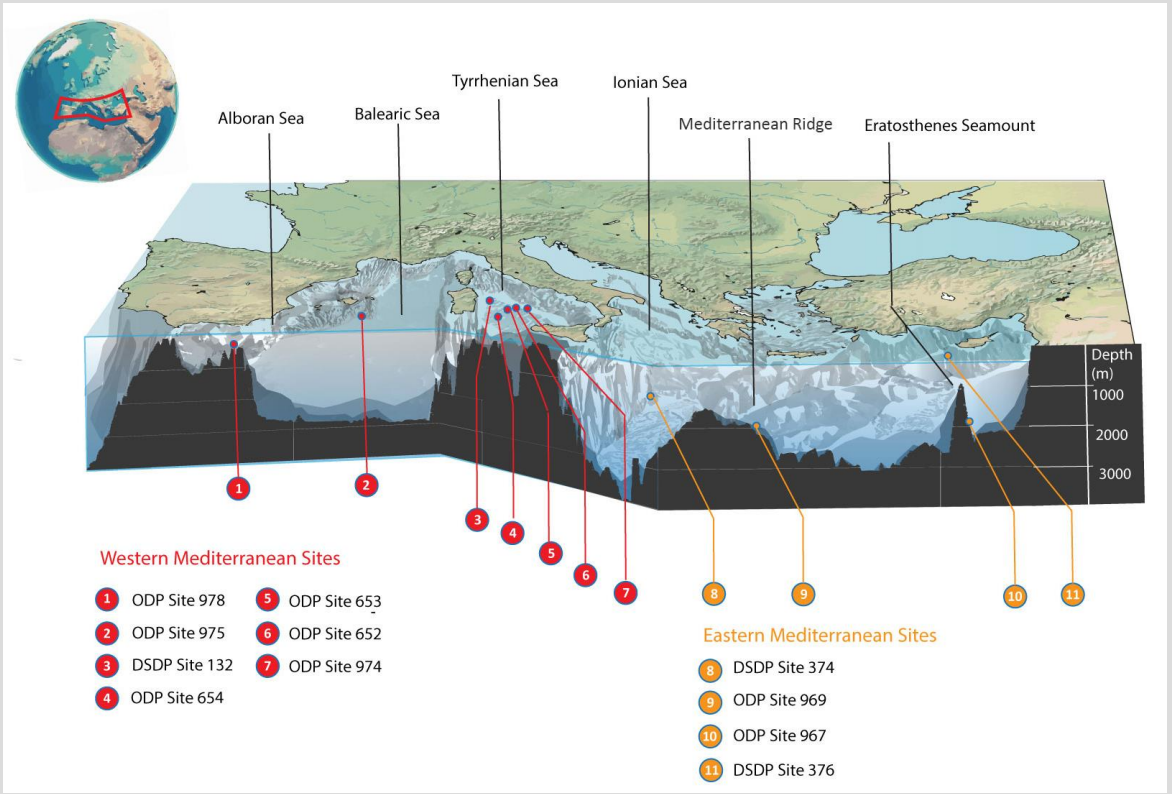


Figure 04: ODP and DSDP sites across the Mediterranean, which penetrate the M/P boundary (11 out of 46 total) (Amarathunga et al., 2022 [in press])

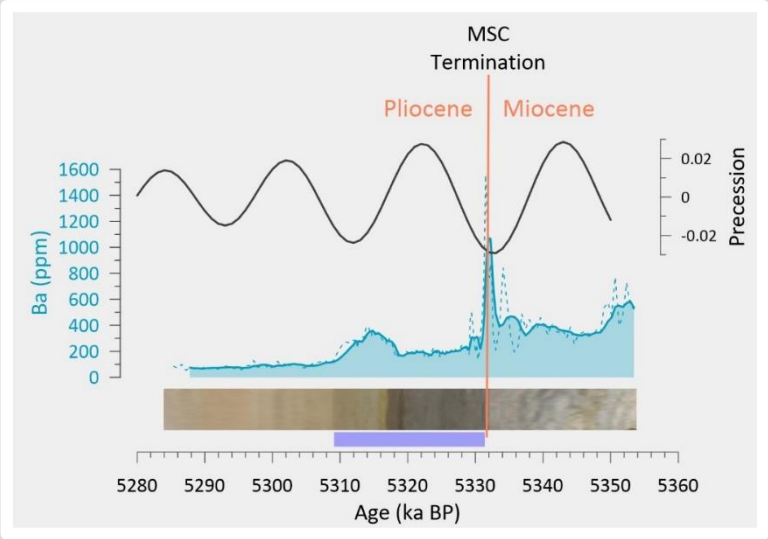
No sapropels in the western basin at the M/P boundary

All eastern basin sites contain a sapropel at the M/P boundary

Western basin Productivity > Eastern basin productivity

DSDP 376 initial reports (*1973*) coined this the ‘**mystery sapropel**’

Sapropel formation



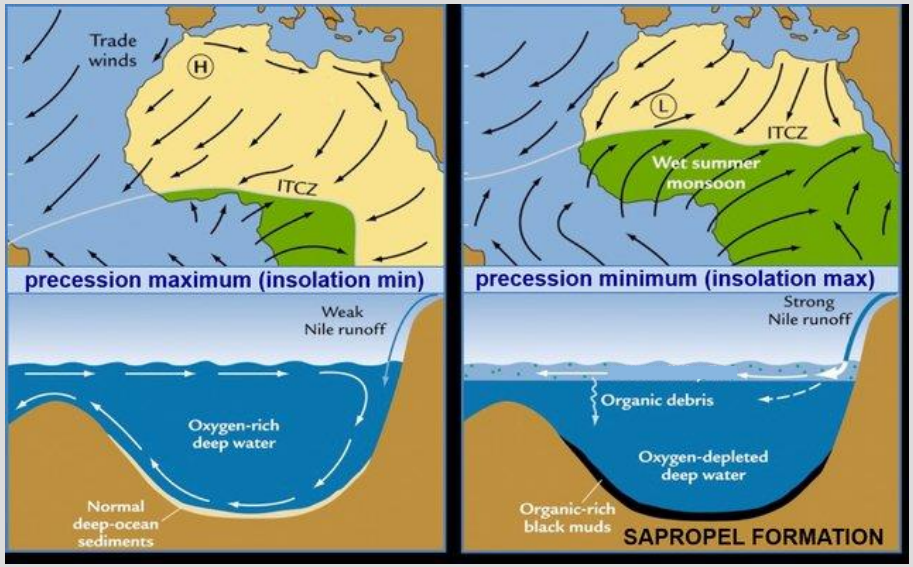
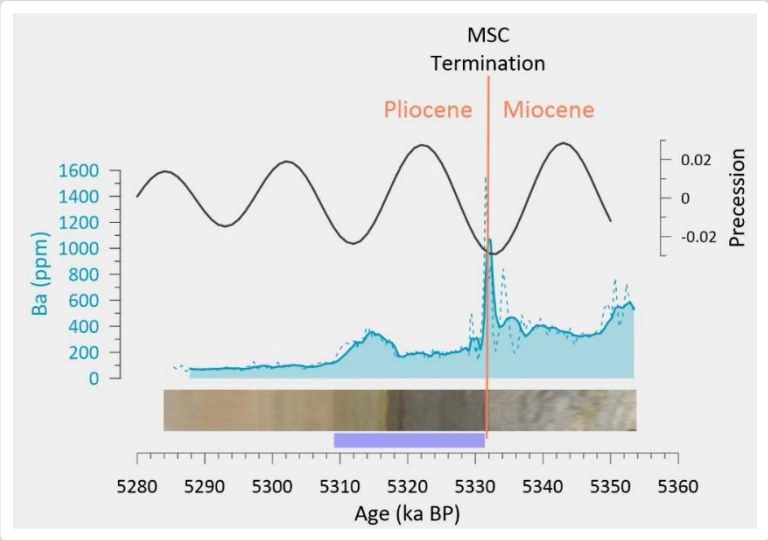


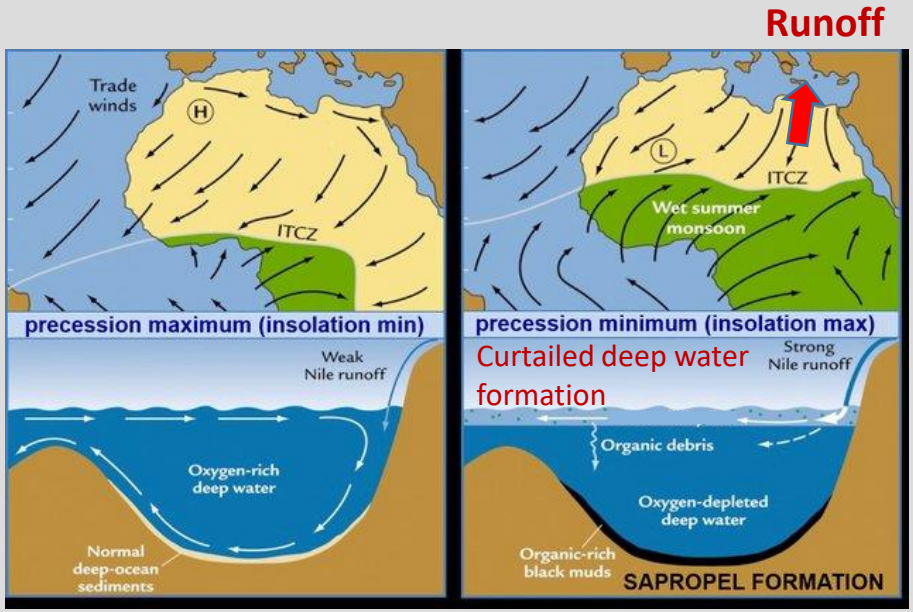
Figure 05: Sapropel formation during precession minima (Marzochchi, 2016)

- Sapropel formation requires basin **stratification** and **anoxic** bottom waters.

- Remember – Messinian brine columns (>gypsum saturation [140 PSU]) remained in the Mediterranean during the MSC.
  If **normal sea-water** is added to the basin during refilling, it will be **stratified** (and **anoxic,** eventually).

Sapropel formation





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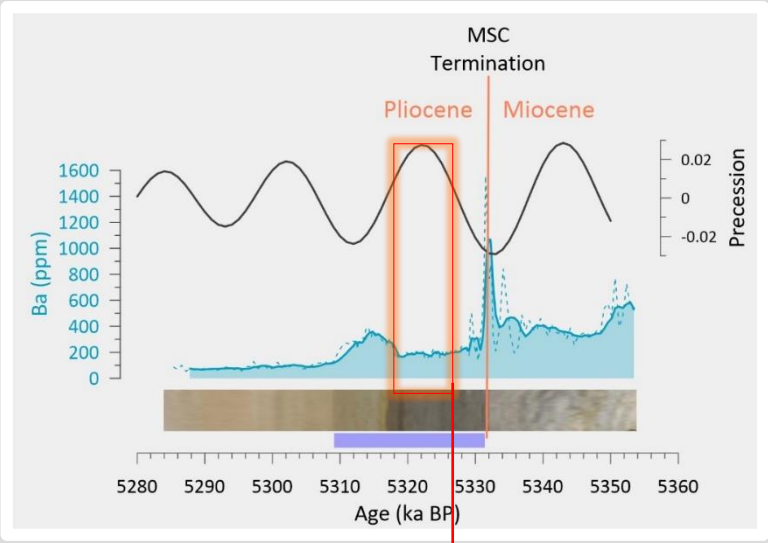
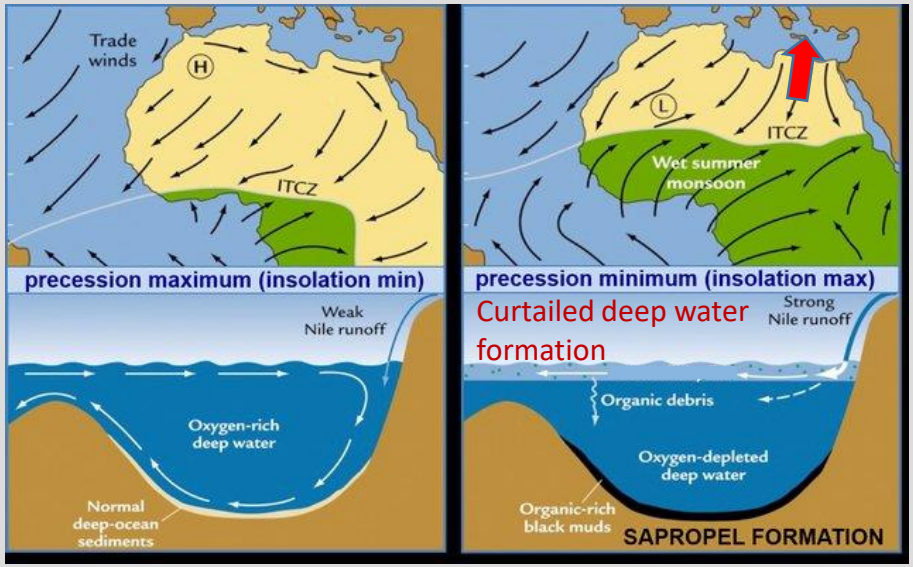


Continued deposition through precession maximum

WHY ?

Runoff



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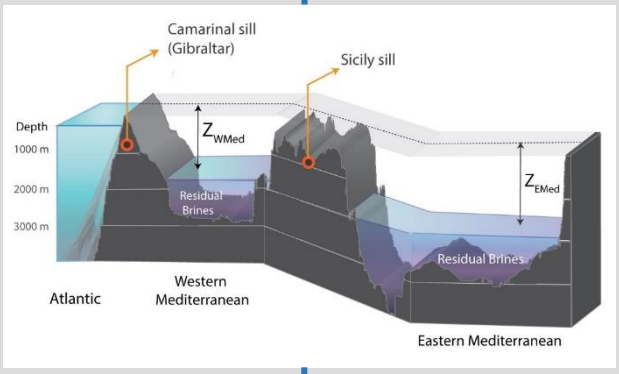
Refilling the Mediterranean

Gradual refilling

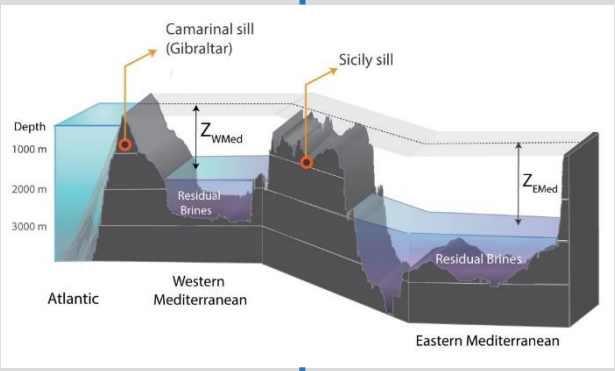


Catastrophic refilling

Refilling the Mediterranean

Less flow energy
Reduced mixing

Gradual refilling



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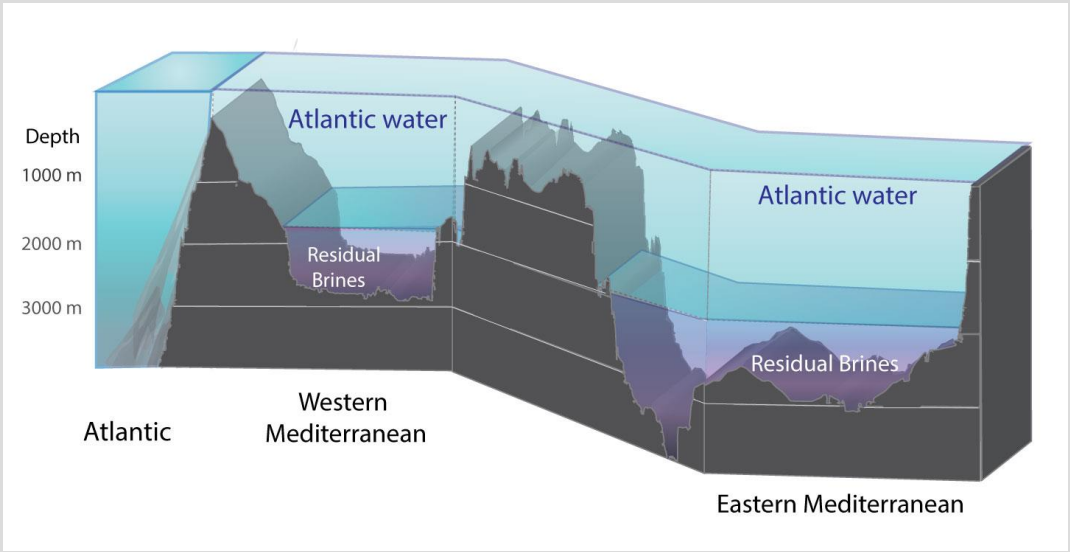
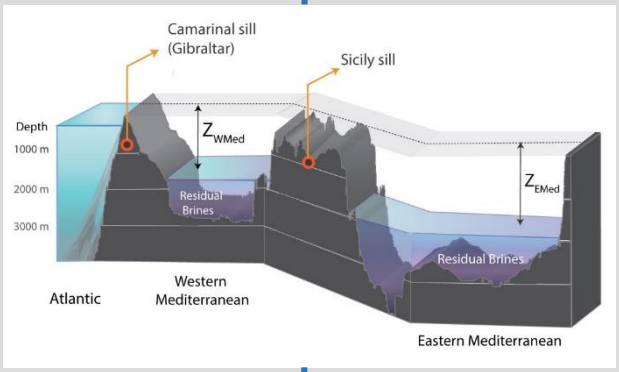
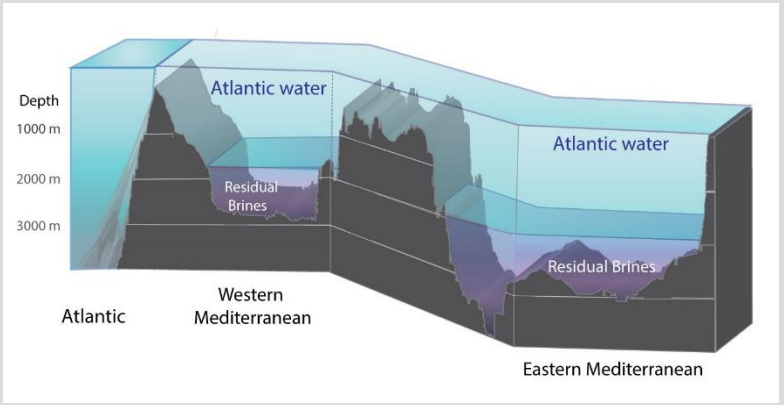


Figure 06: Gradual refilling of the Mediterranean.
(Amarathunga et al., 2022 [in press])

Refilling the Mediterranean

Gradual refilling





Catastrophic refilling

High flow energy

Energetic mixing

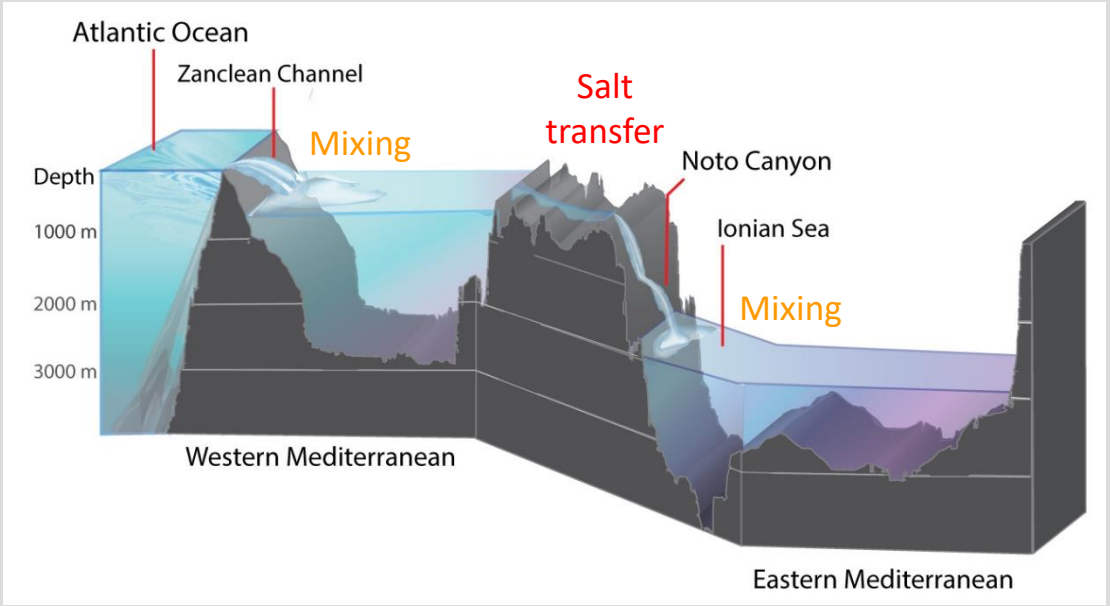


Figure 07: Rapid refilling of the Mediterranean.
(Amarathunga et al., 2022 [in press])

Modelling results

A sill-incision model(Garcia-Castellanos et al., 2009) combined with our fluid-dynamics/mixing-dynamics based model

Gradual refilling:

Not enough energy to erode the western basin stratification.

Stratification & sapropels expected in **both basins**.

Catastrophic refilling:

All the Messinian salt from the western basin transferred to the eastern basin.

Stratification & sapropel deposition **only** in the **eastern basin**. **(Agrees with proxy data)**

Modelling results for a catastrophic termination

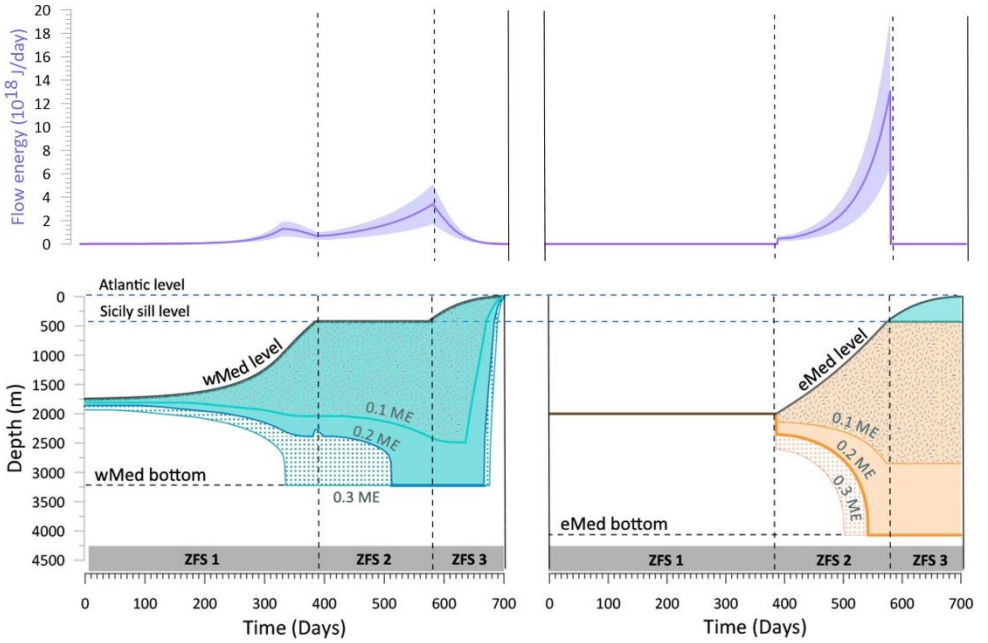


Figure 08: Flood energy and mixing depth evolution (ME; Mixing efficiency).
(Amarathunga et al., 2022 [in press])

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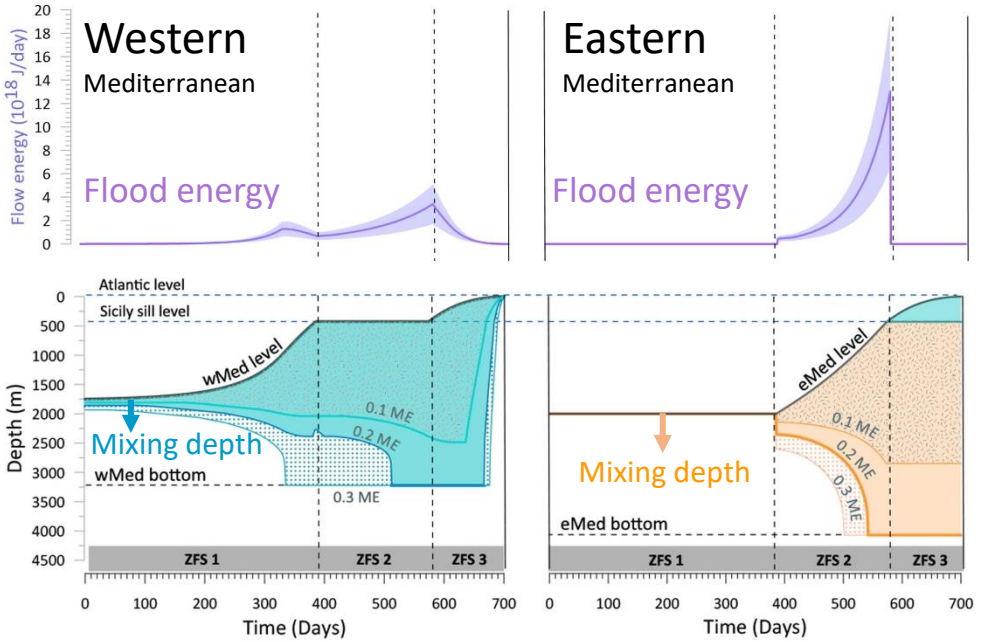

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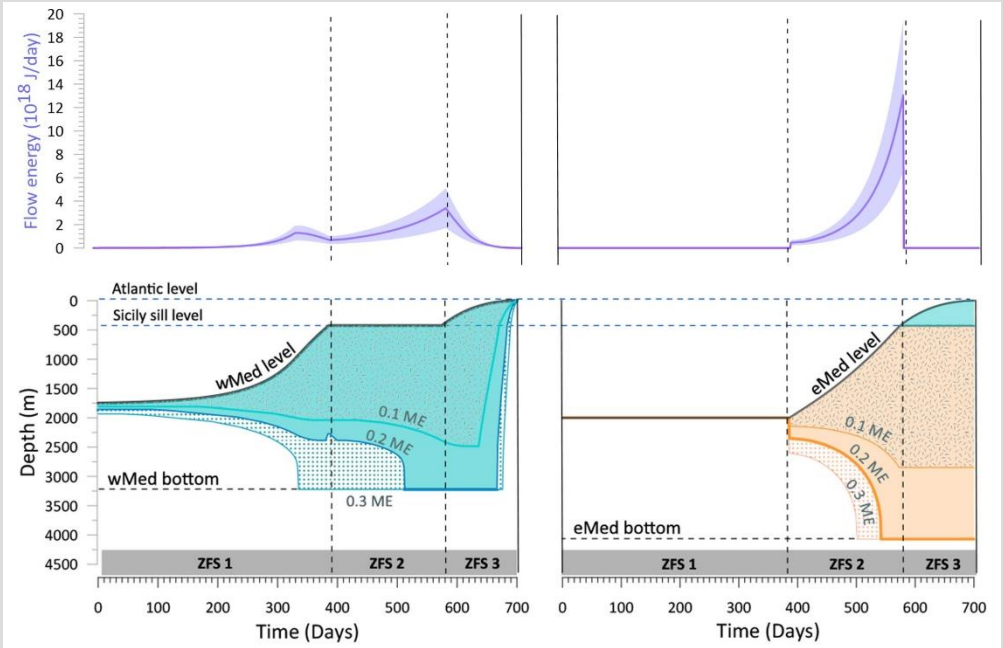

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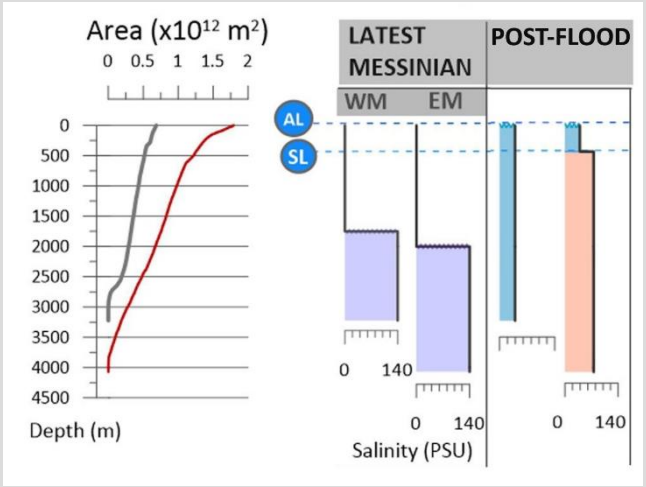


Figure 09: Western & eastern basin salinity profile evolution.
(Amarathunga et al., 2022 [in press])

Modelling results – post-flood evolution

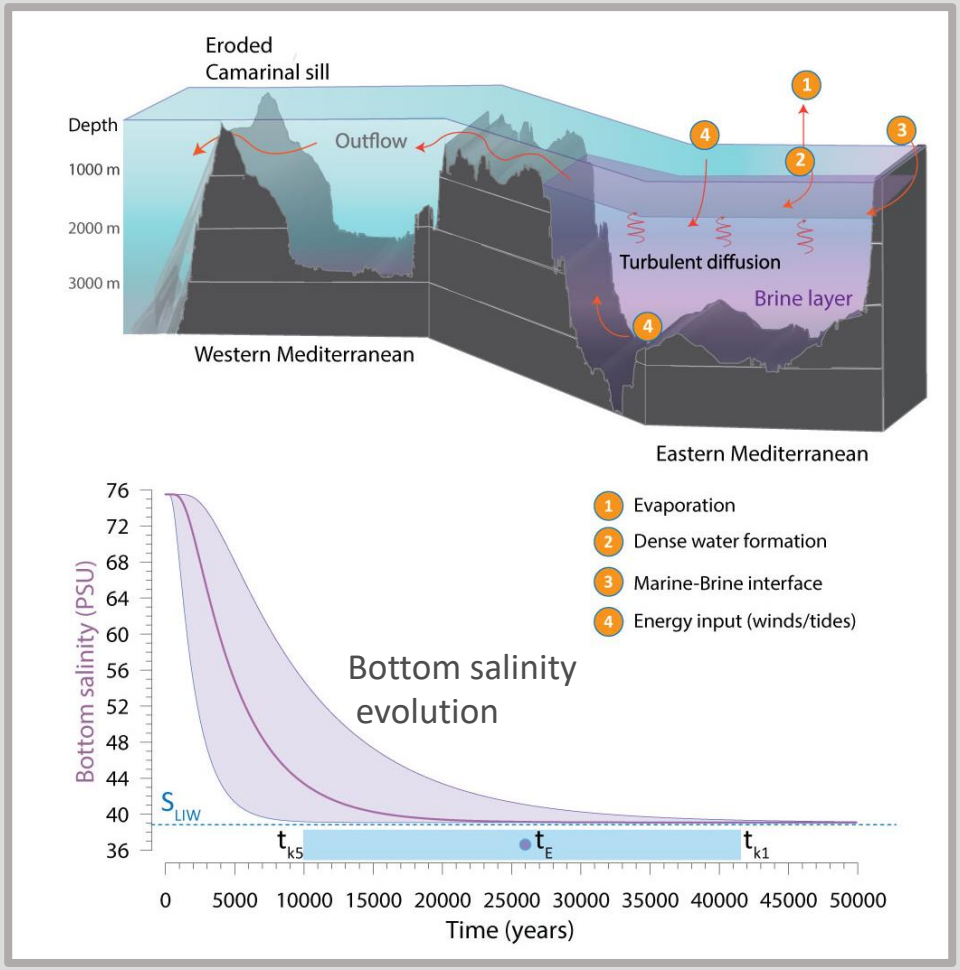
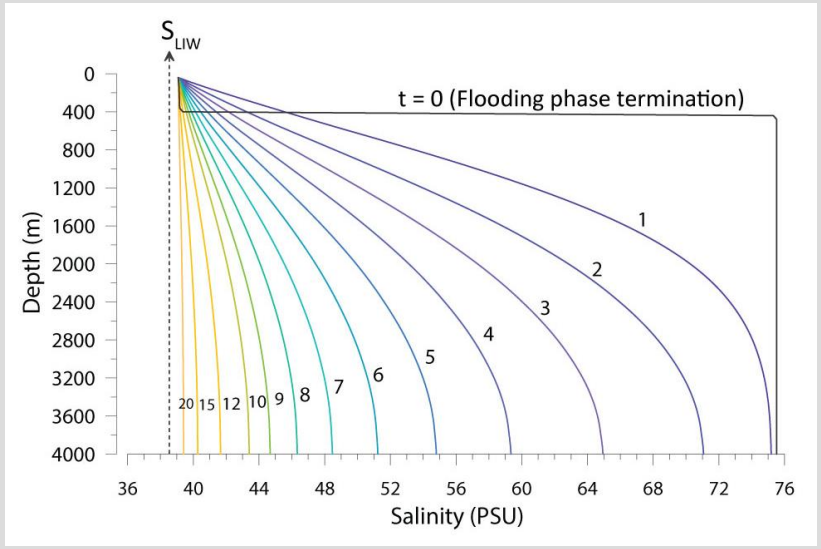


Figure 10: Mediterranean evolution after the megaflood
(Amarathunga et al., 2022 [in press])



Eastern basin salinity profile evolution
(each number is in thousand years)
(Amarathunga et al., 2022 [in press])

According to the model:

Salt removal by **diapycnal diffusion** requires 11,000-40,000 years to erode the stratification

Agrees with

Proxy-based age = 26,000 years

Conclusion

- Sapropel occurrence only in the eastern basin provides strong **evidence for a catastrophic Termination**
- A gradual reconnection should have resulted in 'mystery sapropel' deposition in both basins.
- Only a catastrophic flood can erode the western basin stratification.
- Most of the western basin salt were transferred to the eastern basin due to the energetic flood.
- Eastern Mediterranean was stratified at the level of the Sicily sill (expected salinity ~80 PSU).
- Stratification persisted for 20,000+ years until got broken down by diapycnal diffusion.

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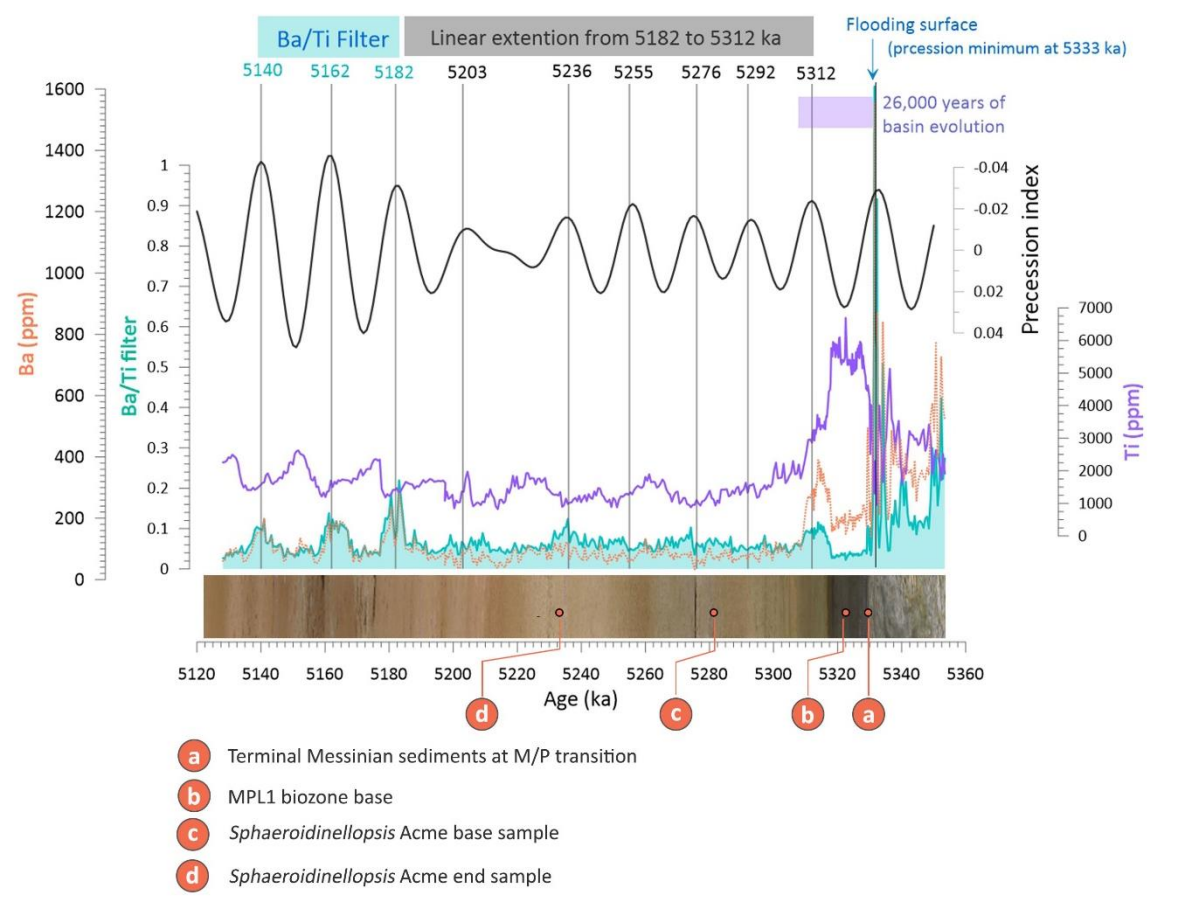
Thank you !

Extra slides - Chronology



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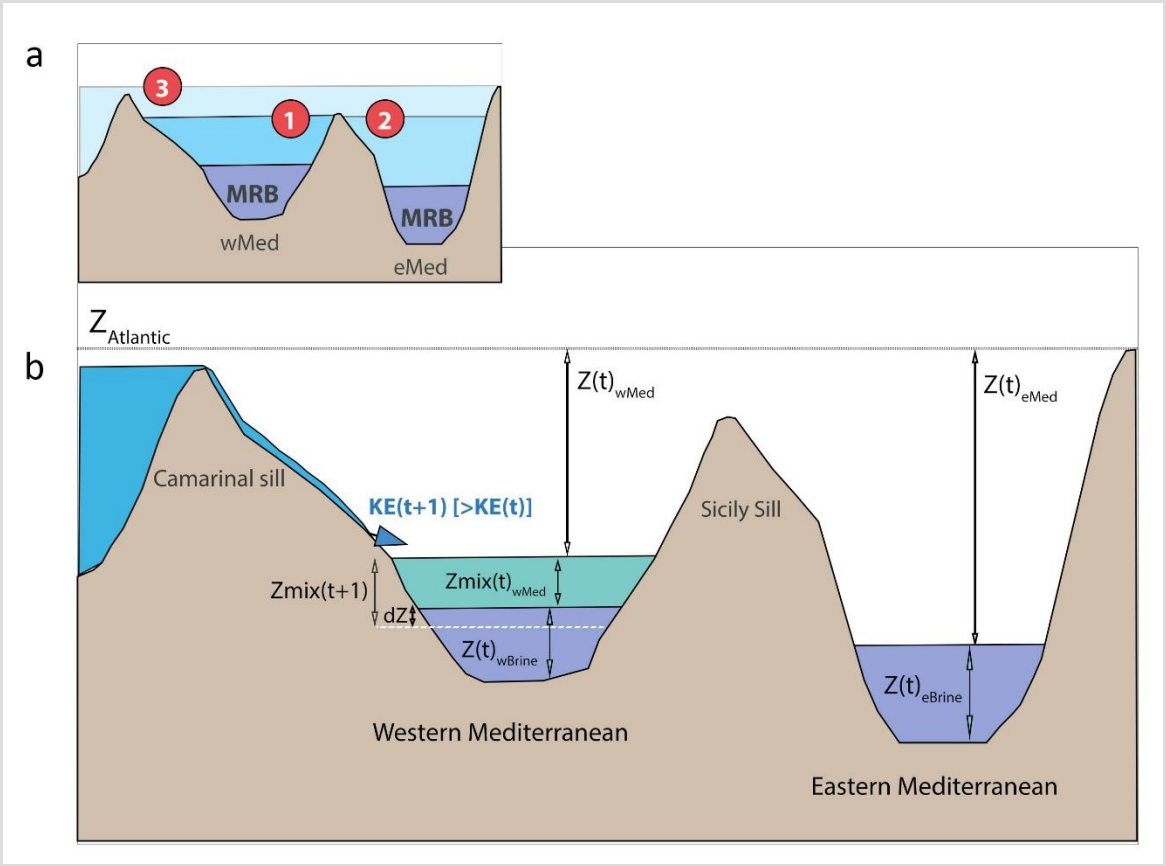
Chronology. (Amarathunga et al., 2022 [in press]).

Extra slides – conceptual model



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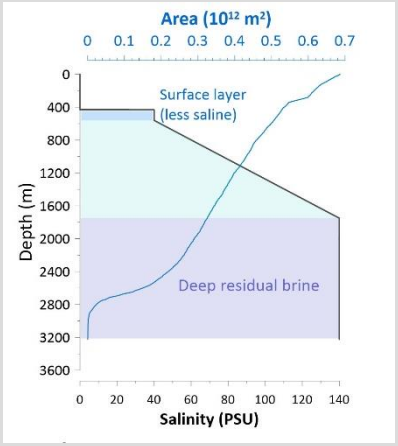
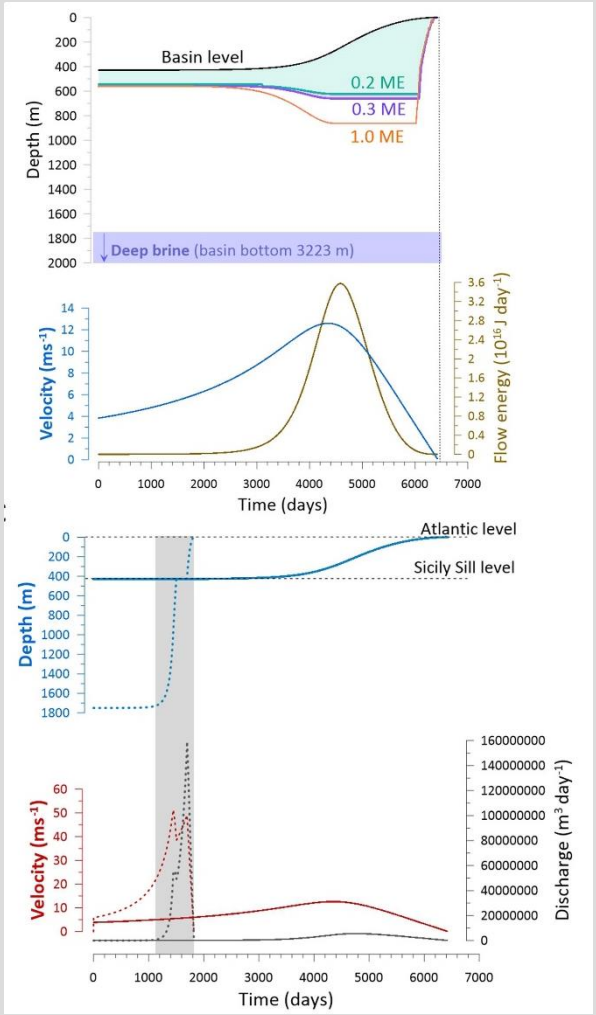
Conceptual model for Mediterranean refilling (Amarathunga et al., 2022 [in press]).

Extra slides – sensitivity tests



Mediterranean evolution for a largely refilled Mediterranean
(Amarathunga et al., 2022 [in press])



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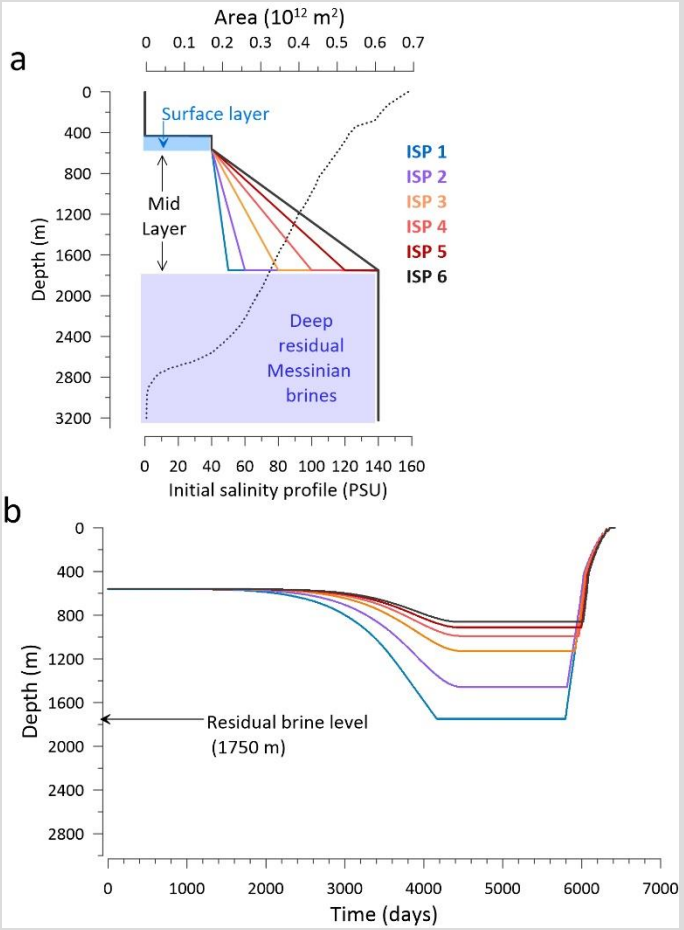

Testing for different initial salinity profiles for a largely refilled Mediterranean
(Amarathunga et al., 2022 [in press])

Extra slides

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