Investigating warm climatic conditions through bulk and clay mineralogy in the Alano Section (Neo–Tethys) during the Middle Eocene Climatic Optimum (MECO, ~40 Ma)

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1. Introduction & Aims

Why is the MECO important?

- Occurred ~ 40 M.a during a global cooling trend
- Lasted ~ **500 kyr – much longer than early Eocene hyperthermals**
- Likely driven by sustained pCO2 increase and complex Earth system feedbacks

MECO-warm but long-lived!

Aims

- Reconstruct **weathering regimes and geochemical changes**
- Contribute new mineralogical data for MECO modeling
- Highlight **continental feedbacks during prolonged warming**

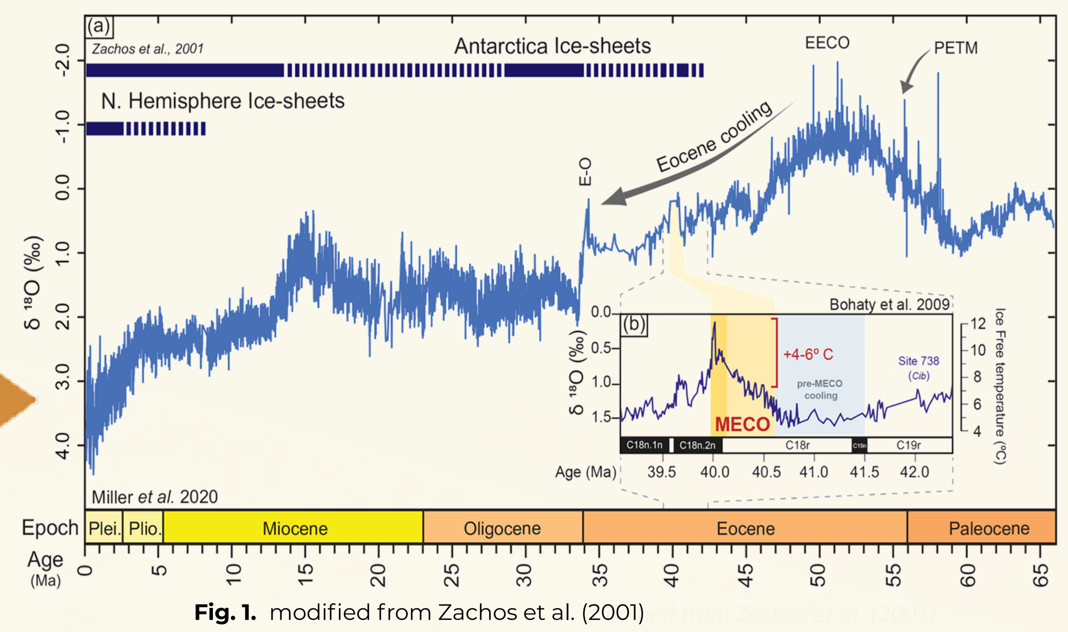


Fig. 1. modified from Zachos et al. (2001)

2. Study Area & Methodology

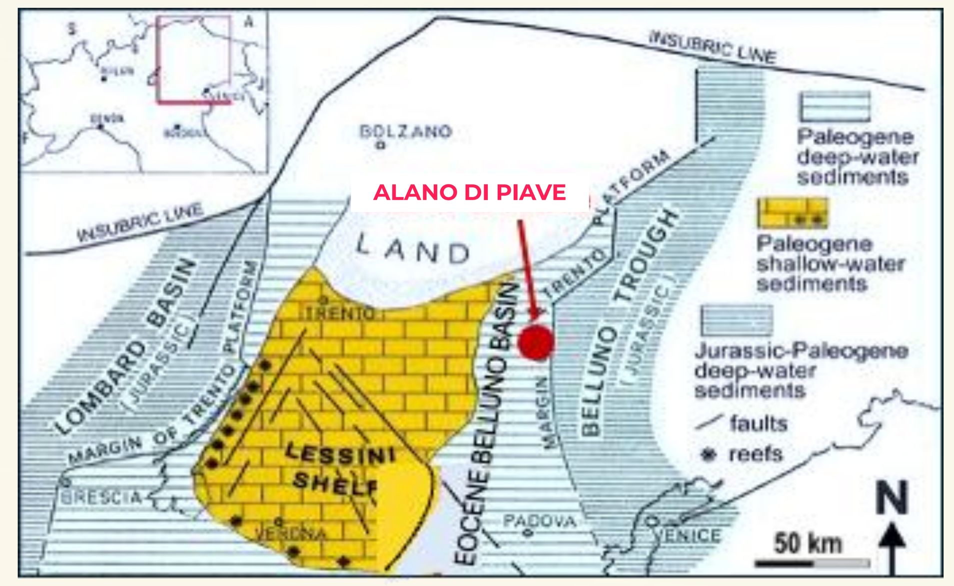


Fig. 2. Geological context of the sections (modified from Bosellini et al. 2020).

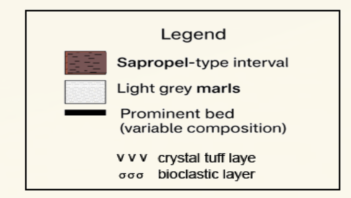
Why Alano di Piave?

- **Global Stratotype section** and Point of the Bartonian-Priabonian boundary
- Continuous, well preserved Neo-Thetyan succession
- Ideal location to study paleoclimatic conditions, **especially in relation to continental weathering**

Alano section

Our approach

- Use **major and minor element chemistry** and **clay & bulk mineralogy** to trace environmental change
- SEM imaging to distinguish between
  → **Detrital inputs**
  → **Authigenic clays**



Methodology

Studied Interval: ~4–33 m (Mantegna to Canova)

Resolution sampling: every 20 cm

Bulk XRD analyses: 134 samples

XRD clay mineralogy: 48 samples

XRF analyses: 52

3. XRF and isotopes data

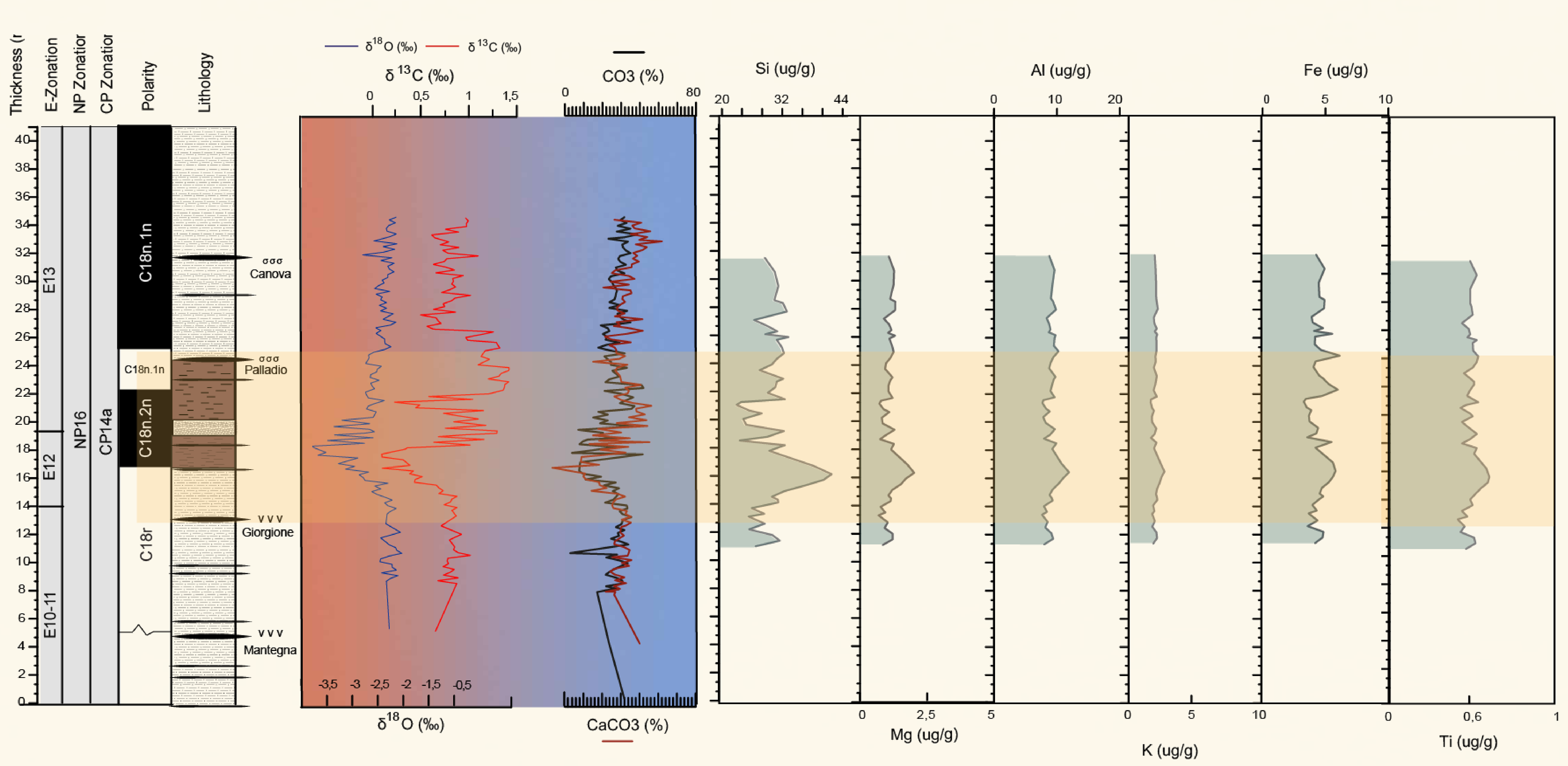


Fig.3. Stable isotope curves ($\delta^{13}C$ and $\delta^{18}O$), XRF geochemical data and $\%CO_3$ are from Spofforth et al. (2010). The $CaCO_3$ curve is based on our bulk XRD analyses. A marked decline in calcite content is observed at the MECO interval, shaded by the band.

4.1 Results: bulk clay mineralogy

Clay minerals

Elements such as **Si, Al, Fe, Mg, K, and Ti** show an increasing trend in the section (Fig.3), followed by a decrease and a subsequent rise in the upper part. This geochemical shift reflects a transition from a carbonate-dominated system to one enriched in quartz, feldspars and clay minerals, the latter incorporating elements like Fe and Mg.

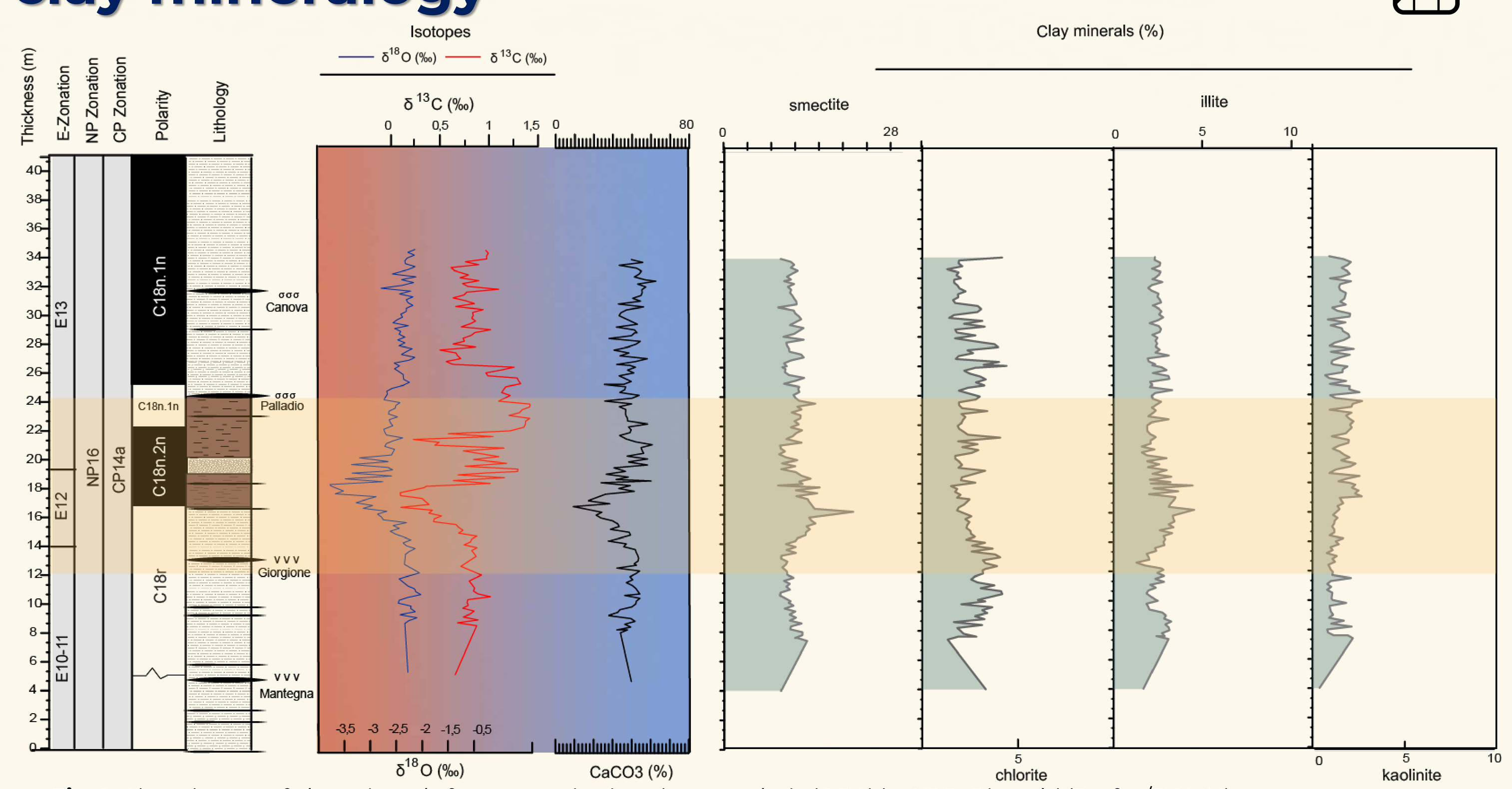


Fig.4. Abundances of clay minerals form quantitative phase analysis (QPA) by XRD-Rietveld (Profex/BGMN)

- Clay mineral assemblages are dominated by **smectite** (17 to 43%) and **illite** (4 to 10 %) while **chlorite** (2 to 4%) and **kaolinite** (0,7 to 3%) are minor components. Increases in **illite** and **smectite** during the sapropel interval suggests enhanced terrigenous input.

4.2 Results: clay mineralogy

- **Post-MECO:**
  - Higher **kaolinite** contents
  - Sustained chemical weathering in **more stable**, with **humid and cooler** conditions.
- **MECO interval:**
  - Increase in **smectite** and **illite**, followed by increase in **kaolinite**
  - Transition from physical weathering, in **warm** and **yet less humid** conditions to **enhanced chemical weathering in warmer and more humid** climate
- **Pre-MECO:**
  - Increase in **chlorite**.
  - **Physical weathering,** possibly of mafic rocks, **cooler and drier climate.**

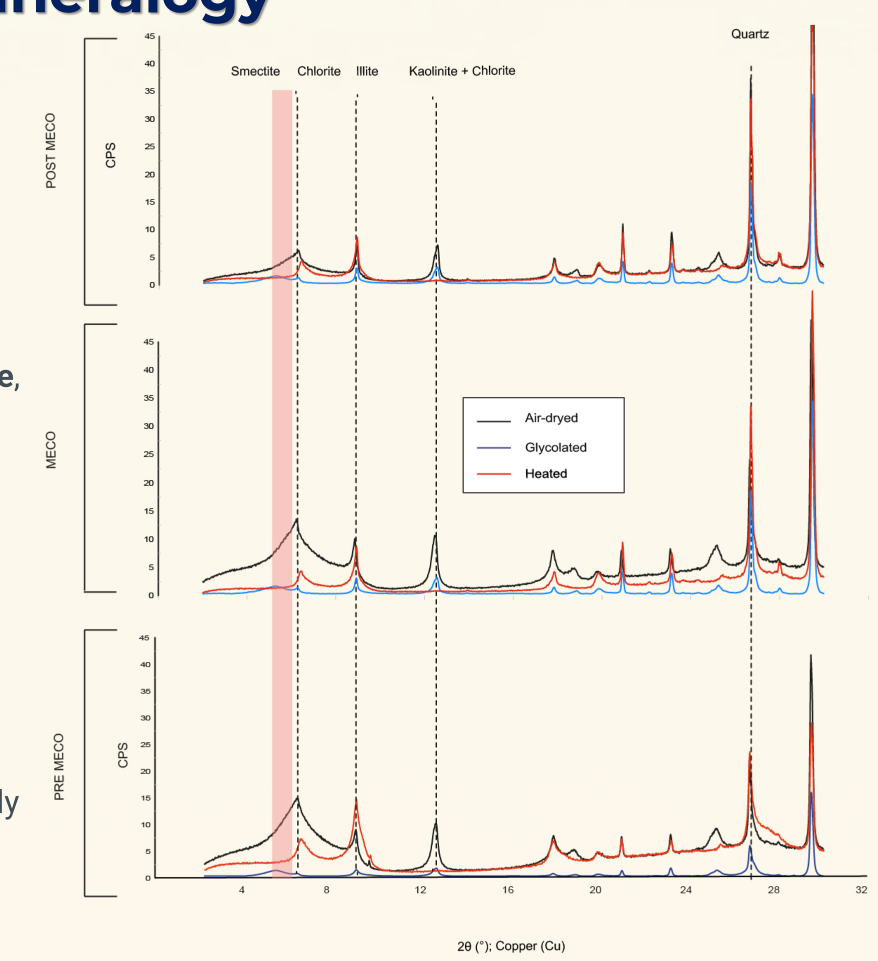
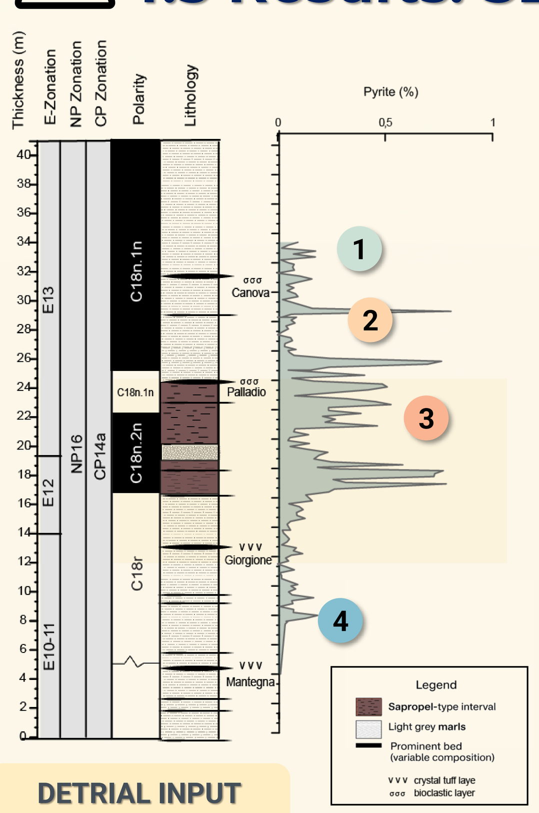
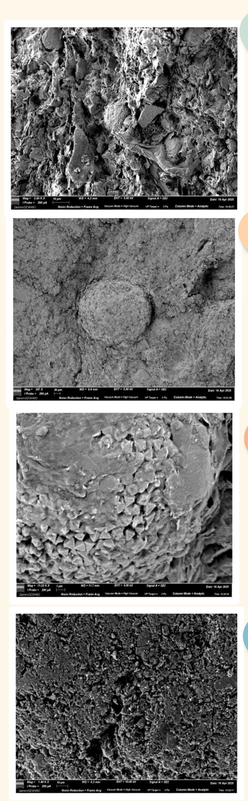


Fig.5. A set of XRD clay patterns representative of the studied section across the MECO interval

4.3 Results: SEM imaging



DETRIAL INPUT



1. Detrital texture
2. Pyrite framboids
3. Pyrite framboids
4. Detrital texture

5. Discussions & Conclusions

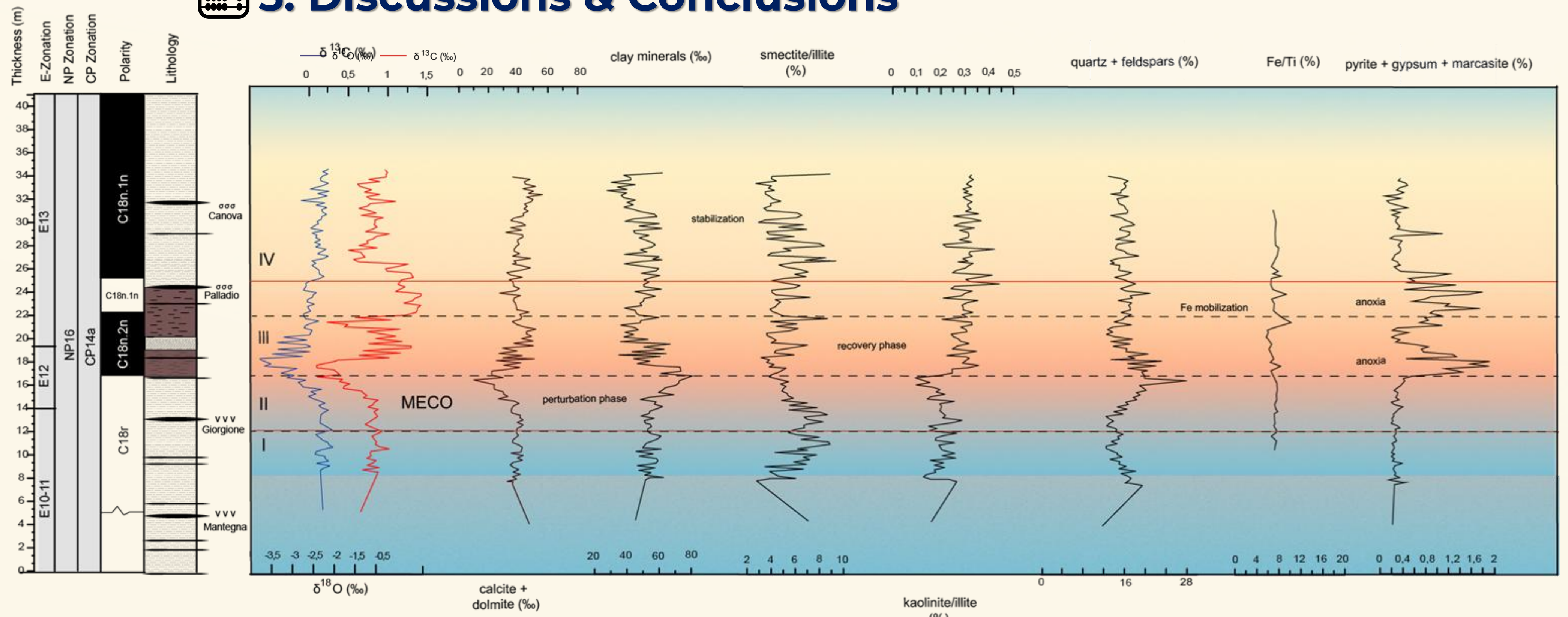


Fig.5. The dataset is divided into four phases based on key shifts in mineral ratios. Solid red horizontal lines mark the interval corresponding to the MECO while dashed lines indicate the boundaries between distinct phases (I-IV)

I Initial condition:
- △ smectite/illite △ chlorite
- → **beginning of enhanced physical weathering under drier conditions**

II Perturbation phase
- ▽ smectite/illite, kaolinite/illite, carbonates
- △ clay minerals overall
- △ quartz + feldspars (Qz + F)
- → **increased terrigenous input, changing weathering regime under warmer and less arid conditions**

III Recovery phase
- △ clay minerals △ kaolinite/illite
- ▽ Qz + F
- → **shift from physical to chemical weathering under less warm and more humid conditions**

IV Stabilization
- maintained high kaolinite/illite
- → **New equilibrium after climatic perturbation; sustained chemical weathering with humid and cooler conditions**

Enhanced Clay Formation and Reverse Weathering as a positive feedback mechanism for the MECO warming? *A missed link in our record*

Krause et al., 2023:

- Warm, humid climate
  → Enhanced weathering
- Increased clay formation (land + ocean)
- Retention of Ca^{2+} and Mg^{2+} in sediments
- Reduced carbonate formation
- Sustained high atmospheric CO_2

Spofforth et al., (2010)

Carbon cycle response dominated by organic carbon burial, indicating a potential negative feedback that may have partially mitigated CO_2 rise at Alano.

This work:

Early MECO:
- ↑ terrigenous input increases
- ↑ smectite/illite increases

Late MECO:
- ▼ terrigenous input decreases
- kaolinite/illite increases

During MECO: shift from physical to chemical wheathering

No evidence of authigen formation of incresing kaolinite

Results from this work show that the changing abundance and composition of clay minerals might have played a role on sustaining the late MECO warming. However, we did not find evidence for reverse weathering-driven feedback as proposed by Krause et al. (2023)

Bibliography

Agnini, C., et al. (2014) Paleoceanography.
Bosellini F., et al., (2020) BSPI, 59 (3).
Krause A., et al., (2023) Nature, 560(7719).
Spofforth et al.. (2010) Paleoceanography, 25(3).
Zachos, J. C., et al. (2008). Nature.