A Miocene (23–13 Ma) continental paleotemperature record from the northern Mediterranean region (Digne-Valensole basin, SE France)

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MOTIVATION

During the Middle Miocene the Earth's climate shifted from a warm phase, the Miocene Climatic Optimum (MCO, 16.9–14.7 Ma), to a colder phase associated with the formation of major and permanent Antarctic ice sheets. This climatic shift, the Middle Miocene Climatic Transition (MMCT, 14.7–13.8 Ma), had significant impact on the composition and structure of major biomes and impacted worldwide ocean circulation. While the MCO and the subsequent MMCT are well described in marine records, quantitative continental paleoclimate records are still lacking when it comes to constraining the magnitude and rate of terrestrial environment changes. We present **a long-term (23–13 Ma) biostratigraphically-controlled terrestrial stable ($\delta^{18}O$, $\delta^{13}C$) and clumped (Δ_{47}) isotope paleosol carbonate dataset** from the Digne-Valensole basin (SE France). To allow understanding of the dynamics and variability of terrestrial temperatures during one of the most extreme Neogene climate changes, we compare our record with time-equivalent counterparts from Central Europe (North Alpine Foreland Basin, Switzerland) and with global marine records.

STUDY AREA

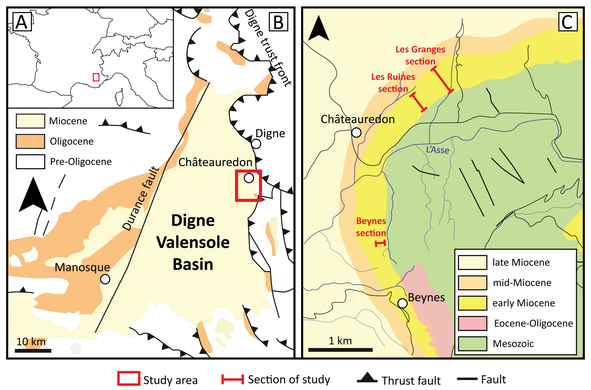

Fig. 1. Study area. (A) Digne-Valensole basin in SE France. (B) Geological map of the Digne-Valensole basin and study area at the margin of the Digne thrust front. Modified after Gillot et al. (2022). (C) Composite section of study consists of the distinct Les Granges, Les Ruines, and Beynes sections within the Digne-Valensole basin. Modified after Bauer (2006).

CLUMPED ISOTOPE (Δ_{47}) THERMOMETRY ON PEDOGENIC CARBONATES

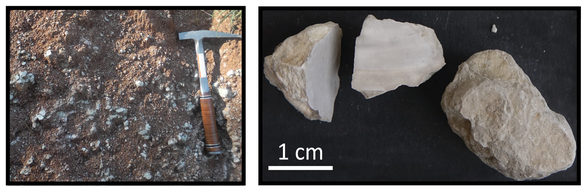

Fig. 2. Sampling material. Pedogenic carbonate nodules from the Beynes (left) and les Granges (right) sections .

What ? Pedogenic carbonate nodules from composite section

Why ? Reconstruct long-term Miocene paleotemperature record

How ? Measure carbonate nodule formation temperatures with Kiel IV carbonate device – MAT 253plus based on temperature-dependent tendency for ^{18}O and ^{13}C to bond in the same carbonate molecule ($^{13}C^{18}O^{16}O_2^{-2}$)

References

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MID-LATITUDE EUROPEAN Δ_{47} TEMPERATURE RECORDS

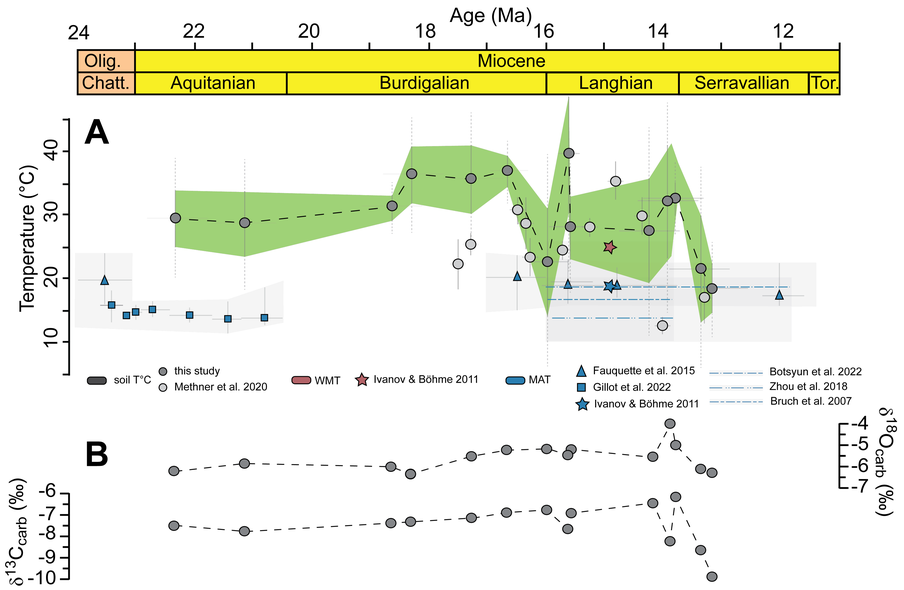

Fig. 3. Compilation of terrestrial mid-latitude European temperatures. (A) Pedogenic carbonate-based clumped isotope temperature records of the Digne-Valensole basin and the Swiss part of NAFB (in grey), mean annual temperatures of the Digne-Valensole basin and Bavarian part of the NAFB inferred from paleofloral and terrestrial data (in blue), warmest month temperature of the Bavarian part of the NAFB inferred from herpetofauna (in blue) and climate modeled temperatures for the Digne-Valensole basin (dashed blue lines). (B) Pedogenic carbonate stable isotope ($\delta^{18}O$, $\delta^{13}C$) values from the Digne-Valensole composite section.

- Nearly constant temperatures during Early Miocene (22.3–18.6 Ma)
- Rapid rise in temperature at 18.6 Ma
- A distinct Middle to Late Miocene (16.7–13.1 Ma) temperature pattern characterized by:
  - MCO bracketed by two warmth peaks of above 30°C at 15.6 and 13.7 Ma
  - High-amplitude fluctuations best explained by a shift in seasonality (see Fig.4 and Methner et al., 2020)
- Clumped isotope temperatures from SE France and Swiss NAFB outline a coherent climate pattern for the Alpine foreland during the Middle Miocene
- Δ_{47}-based soil temperatures are in agreement with time-equivalent WMT, MAT and modeled temperatures with European mid-latitudes

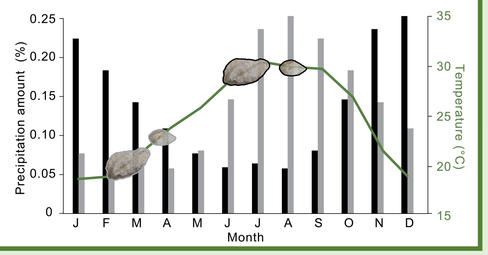

Fig. 4. Difference in pedogenic carbonate formation temperatures resulting from a shift in precipitation seasonality. Two different scenarios of precipitation amount and air temperature for the Digne-Valensole basin. Considering precipitation of carbon controlled by the interplay between soil water, soil temperature and soil CO_2, pedogenic carbonate nodules pictures represent the time of the year most favorable to their formation.

LOCAL CONTINENTAL RECORD IN A GLOBAL CLIMATIC CONTEXT

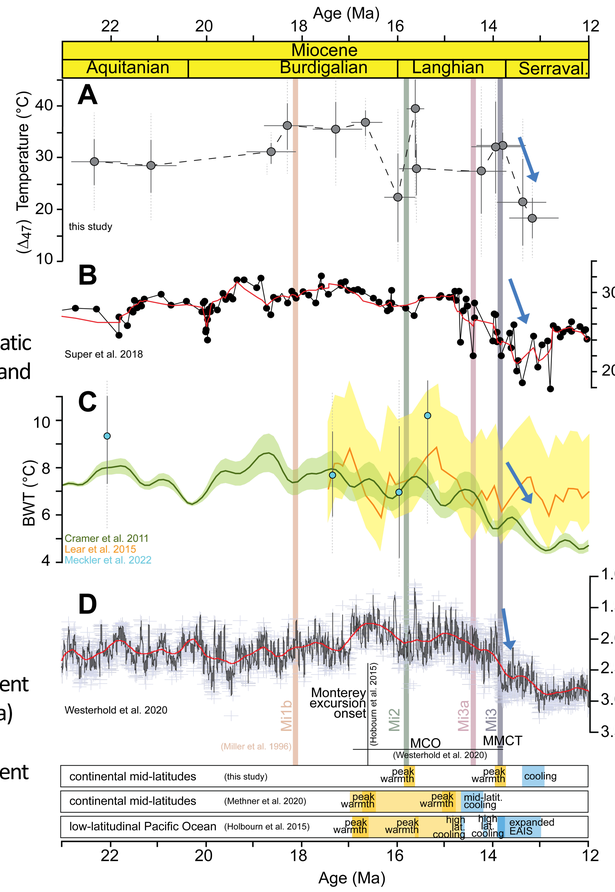

Fig. 3. Compilation of terrestrial and marine MCO-MMCT records. (A) Clumped-isotope temperature of the Digne-Valensole basin. (B) North-Atlantic TEX_{86}-based sea-surface temperatures (Super et al., 2018). (C) Pacific and Southern Ocean bottom water temperatures (Cramer et al., 2011; Lear et al., 2015; Meckler et al., 2022). (D) global benthic foraminiferal oxygen isotope values (Westerhold et al., 2020).

- Correlation of major climatic events between terrestrial and marine records:
  - Warm peak at 18.3 Ma – Mi1b
  - Warm peak at 15.6 Ma – Mi2
  - Warm peak at 13.8 Ma – Mi3
  - Monterey excursion onset
  - Onset of MCO and subsequent progressive cooling (16.7–16 Ma)
  - Onset of MMCT and subsequent global cooling (ca. 14 Ma)

CONCLUSIONS AND OUTLOOK

- Distinct circum-Alpine foreland temperature pattern during the Middle Miocene influenced by reorganization of atmospheric circulation simultaneously with change in temperatures
- Major climatic events from marine records identified in Northern Mediterranean terrestrial dataset
- Complete 16–14 Ma interval with terrestrial dataset from southern European latitudes (Löffler et al., in process) to identify potential climatic latitudinal gradient

Any comments or suggestions on the processes or interpretation are welcome !

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