Glacial-interglacial and insolation-controlled climate and environmental variability on early Pliocene deposits from the lower Guadalquivir Basin (SW Spain)

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1. Objective and methods

The main goal of this study is to reconstruct paleoenvironmental and paleoclimatic changes controlled by glacial-interglacial and insolation fluctuations in Pliocene deposits from the lower Guadalquivir Basin (SW Spain).

This study is based on micropaleontological and geochemical proxies: benthic foraminiferal assemblages; pollen (*Quercus*); foraminiferal O and C stable isotopes; and inorganic and organic geochemistry (XRF, TOC, C/N)

2. Study area

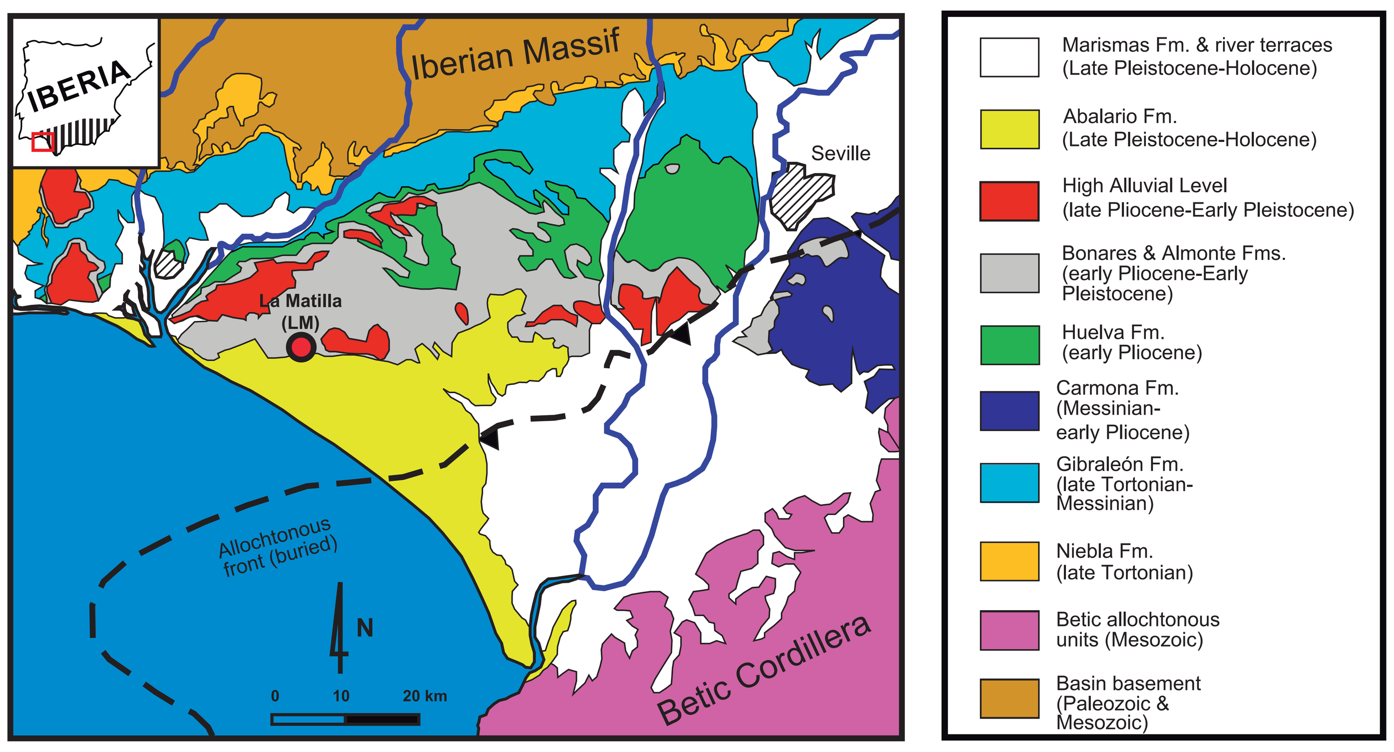


Fig. 1. Simplified geological map of the study area and location of the La Matilla core.

3. Studied core (La Matilla) and age model

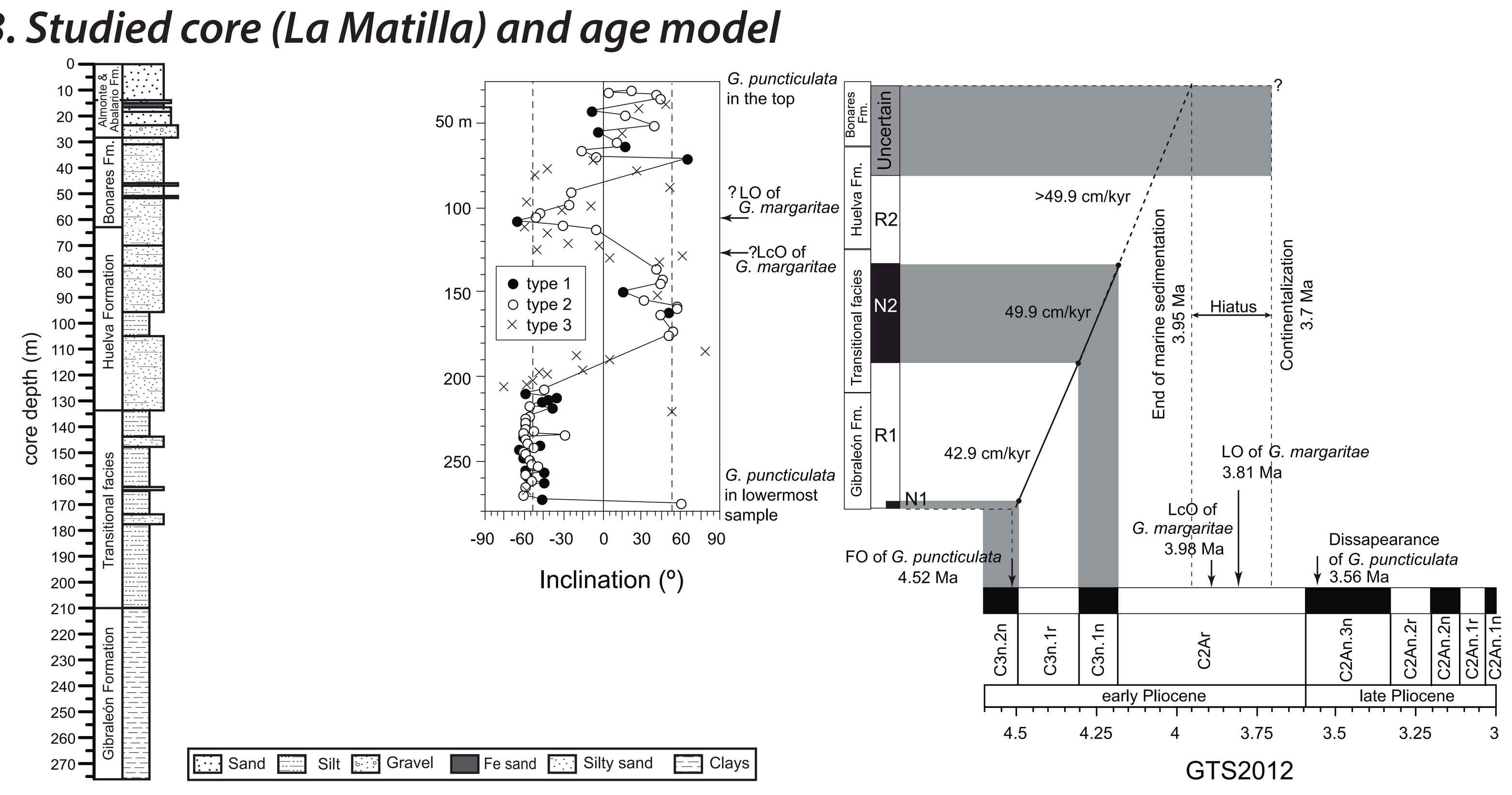
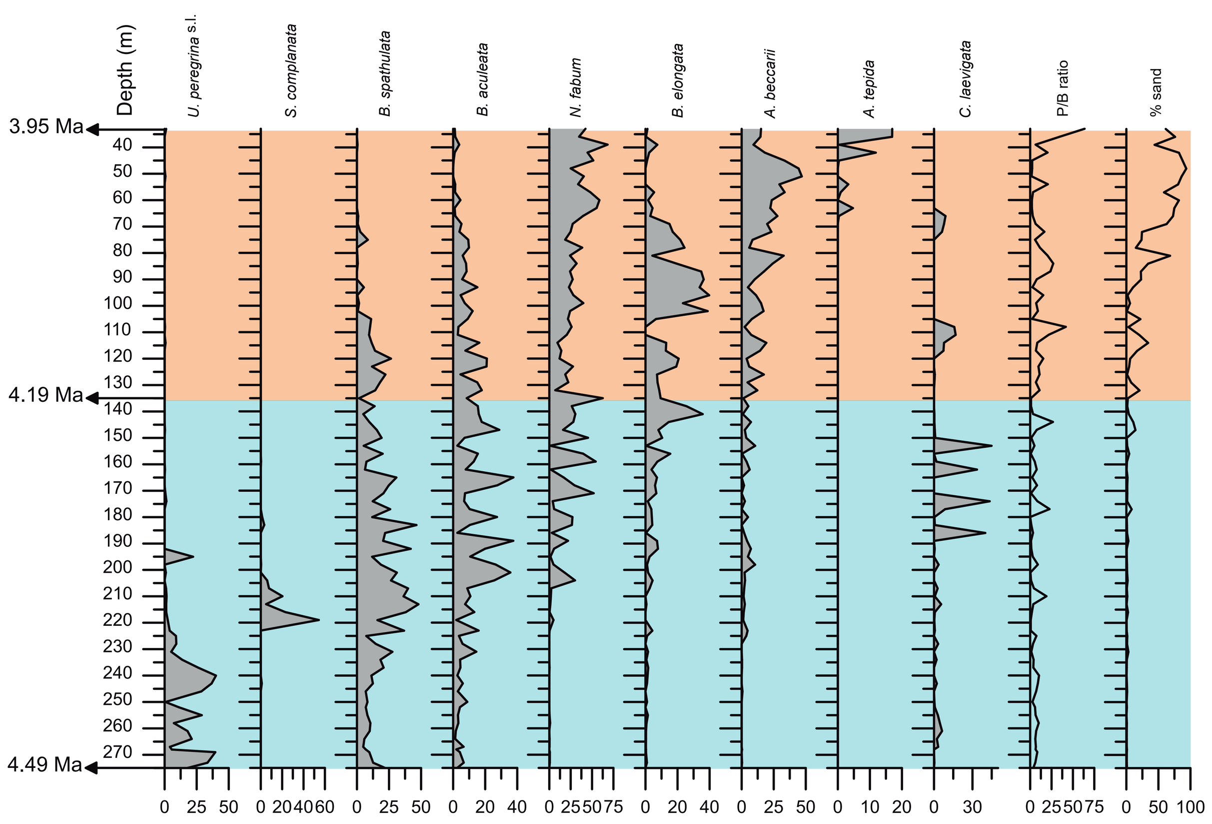


Fig. 2. Lithostratigraphy, age model and sedimentation rates (cm/kyr) based on the magnetobiostratigraphic data. The age model indicates that the studied interval ranges from 4.52 to 3.95 Ma.

4. Benthic foraminifera, P/B ratio and sand content vs. depth

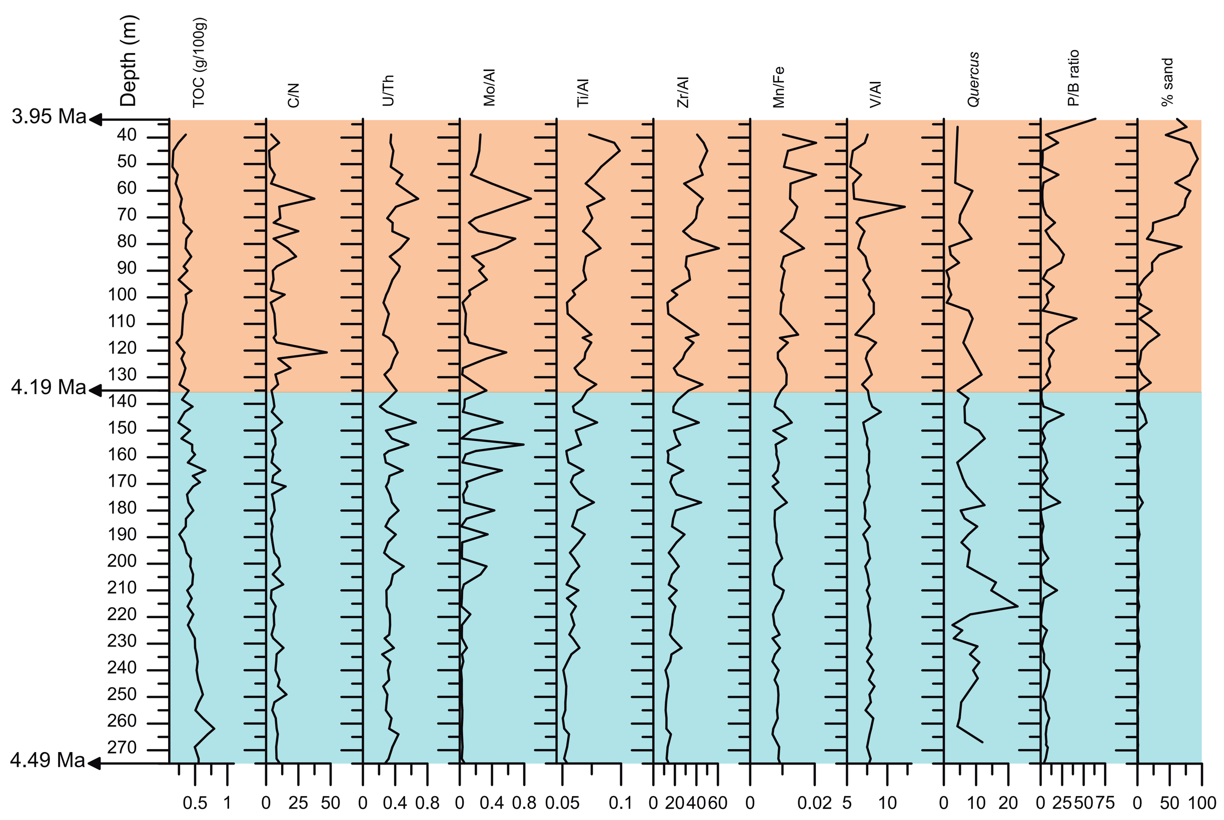


135 to 33 m (4.19-3.95 Ma): Inner shelf, <100 m water depth (high sand content, more *Ammonia beccarii* and *Ammonia tepida*).

275 to 135 m (4.52-4.19 Ma): Outer shelf or deeper setting, >100 m water depth (low sand content, more *Uvigerina peregrina* s.l. and *Brizalina spathulata*).

Fig. 3. Benthic foraminiferal relative abundances (%), P/B ratio and sand content (%) of the La Matilla core

5. Inorganic and organic geochemistry, pollen, P/B ratio and sand content vs. depth

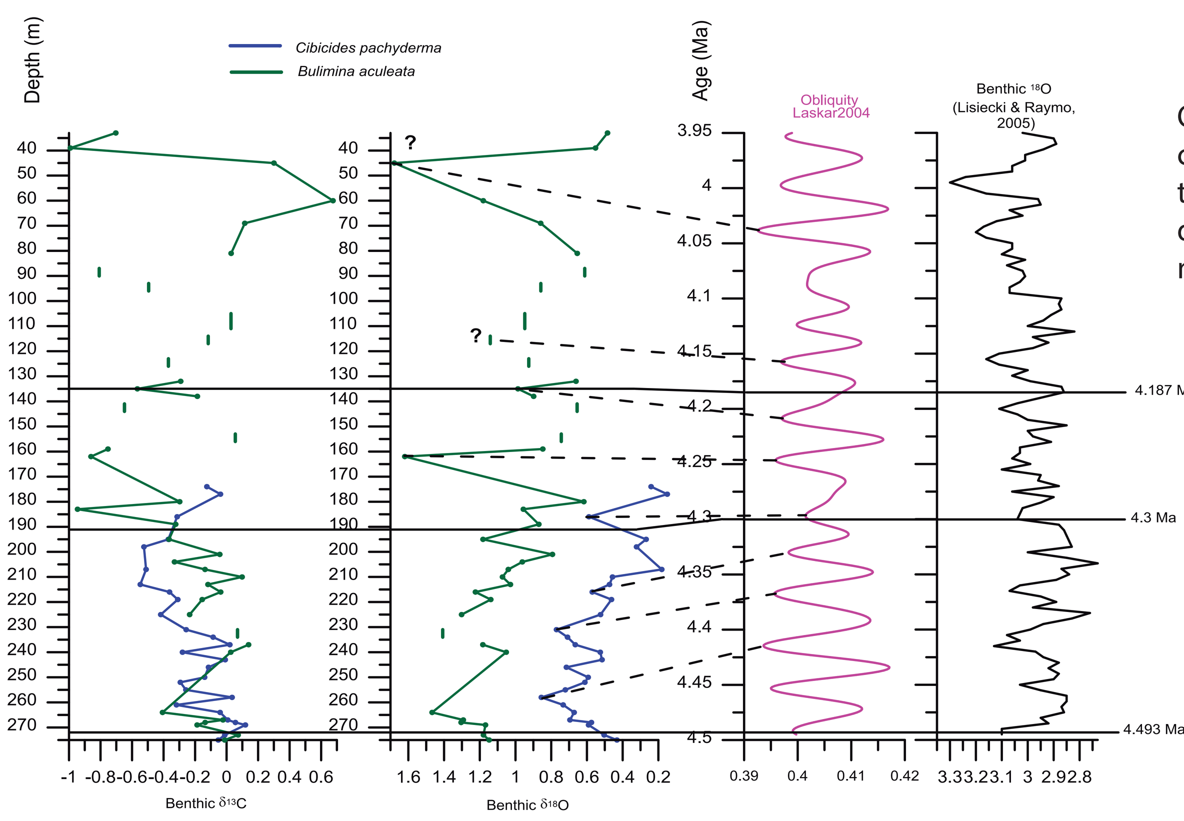


135 to 33 m (4.19-3.95 Ma): more continental organic matter and higher riverine discharge in shallow setting (higher C/N, Ti/Al, and Zr/Al ratios, more sand content).

275 to 135 m (4.52-4.19 Ma): more marine organic matter and lower river runoff in deep setting (lower C/N, Ti/Al, and Zr/Al ratios, less sand content).

Fig. 4. Inorganic and organic geochemistry (ppm), pollen (%), P/B ratio and sand content (%) of the La Matilla core

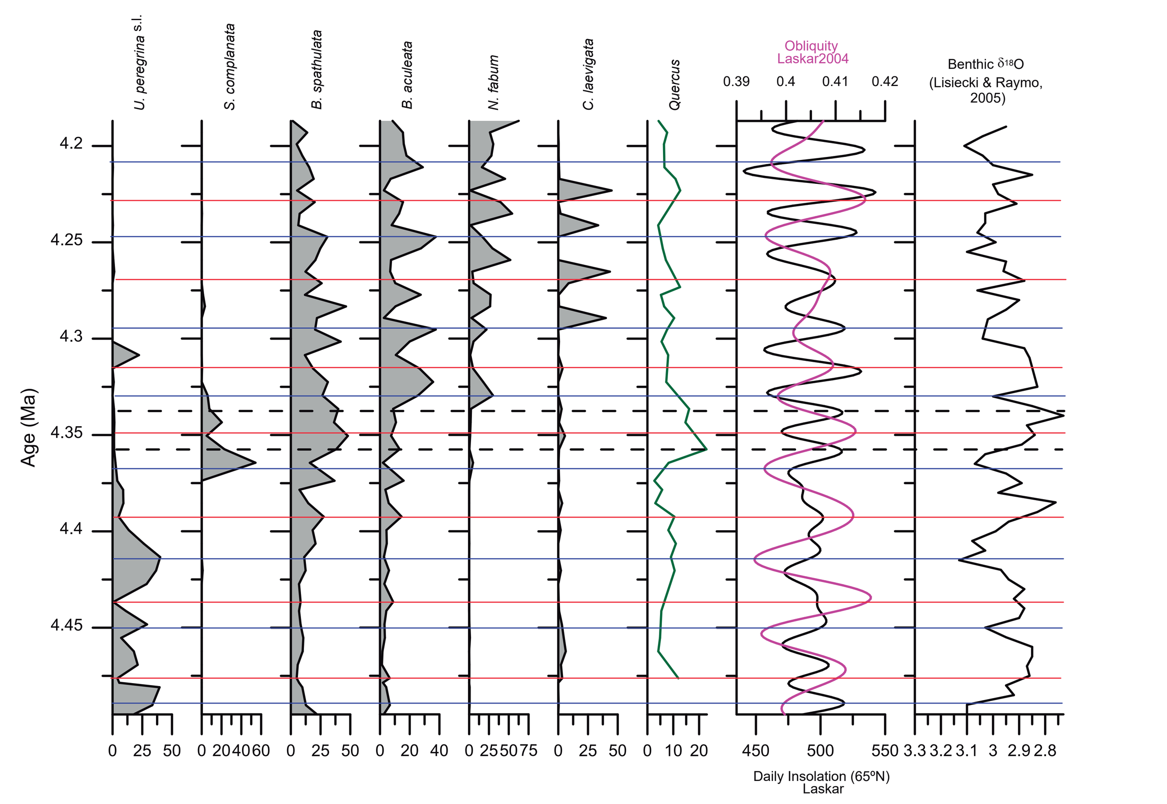
6. Foraminiferal stable isotopes correlation to obliquity and global isotopic curve



Orbital obliquity is the main forcing for glacial-interglacial fluctuations recorded on the studied early Pliocene marine sediments.

Fig. 5. Foraminiferal O and C stable isopes correlation to obliquity (Laskar2004) and global benthic $\delta^{18}O$ stack

7. Benthic foraminifera, pollen, obliquity and global isotopic curve vs. age



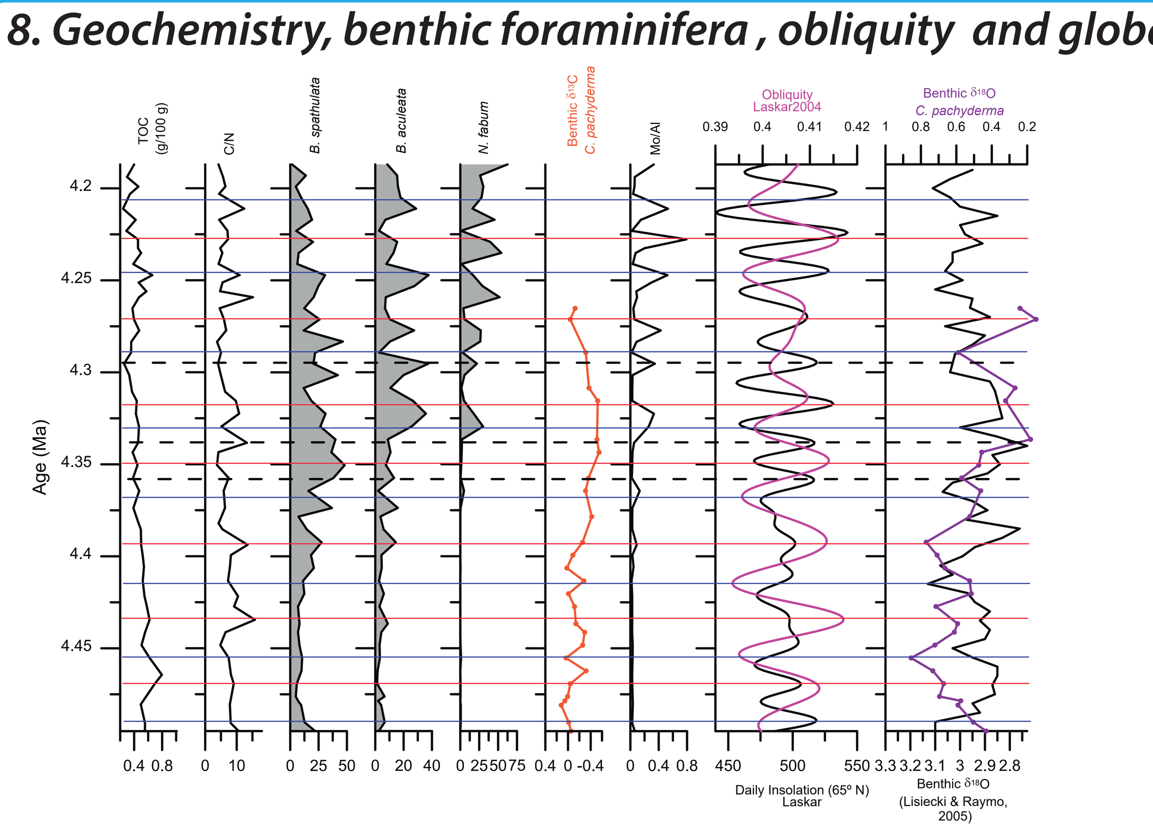
Glacial conditions (obliquity minima): more marine organic matter related to upwelling or phytoplankton blooms (more *Uvigerina peregrina* s.l.).

Interglacial conditions (obliquity maxima): more terrestrial organic matter due to higher river runoff in warm and humid climate, (more *Bulimina aculeata* and *Quercus*).

Insolation maxima (precession minima): more continental organic matter derived from higher riverine discharge under warm and humid conditions, (more *Bulimina aculeata* and *Quercus*).

Fig. 6. Benthic foraminifera (%), pollen (%), obliquity and global benthic $\delta^{18}O$ stack of the La Matilla core

8. Geochemistry, benthic foraminifera , obliquity and global isotopic curve vs. age



Glacial conditions (obliquity minima): higher marine organic matter due to upwelling or phytoplankton blooms (lower C/N ratios, higher benthic $\delta^{18}O$).

Interglacial conditions (obliquity maxima): more continental organic matter related to higher riverine discharge under warm and humid conditions, (higher C/N ratios, lower benthic $\delta^{18}O$).

Insolation maxima (precession minima): more terrestrial organic matter supply by higher river runoff in warm and humid climate, (more *B. aculeata*, TOC, C/N and Mo/Al ratios).

Fig. 7. Geochemistry, benthic foraminifera (%), obliquity and global benthic $\delta^{18}O$ stack of the La Matilla core

9. Discussion and conclusions

Benthic foraminifera suggest an outer shelf or deeper setting with high variable fluctuations in organic matter flux to the sea floor and related oxygen depletion for the interval between 4.49 and 4.19 Ma (early Pliocene). Marine (phytoplankton blooms, upwelling) and continental (riverine discharge) inputs are the possible sources for organic matter, which are controlled by both orbital precession (insolation) and glacial-interglacial fluctuations forced by obliquity. Strong influence of upwelling occurs at times of obliquity minima (glacial periods) as showed by the high abundance of *Uvigerina peregrina* s.l.. On the contrary, high terrestrial organic matter supply derived from river runoff take place during obliquity maxima (interglacial periods). Under these humid and warm conditions, *Bulimina aculeata*, species feeding from more degraded organic matter, and arboreal pollen (*Quercus*) increase significantly. In addition to glacial-interglacial variability, insolation controlled by precession has modulated early Pliocene paleoclimate. TOC and Mo/Al, along with *Quercus* and *B. aculeata*, increase during insolation maxima (precession minima) pointing to more humid and warmer climate and higher riverine discharge. Finally, the upper part of the study core (4.19 to 3.95 Ma) shows a clear trend towards more continental organic matter and higher riverine discharge, due to the sea-level fall reaching the inner shelf, which is recorded by benthic foraminifera and geochemical proxies (higher Zr/Al and Ti/Al).

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