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Neritic isotope and sedimentary records of the Eocene–Oligocene greenhouse–icehouse transition: The Calcare di Nago Formation (northern Italy) in a global context

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ABSTRACT

From the Middle Eocene to Early Oligocene, the Earth experienced the most significant climatic cooling of the Cenozoic era. The Eocene–Oligocene transition (EOT) represents the culmination of this climatic cooling, leading to the onset of the Antarctic glaciation and, consequently, to the beginning of the present-day icehouse world. Whereas the response of deep-sea systems to this climate transition has been widely studied, its impact on the shallow-water carbonate realm is poorly constrained. Here, the sedimentary expression of the EOT in two shallow-marine carbonate successions (Nago and San Valentino, northern Italy) belonging to the Calcare di Nago Formation is presented. The chronostratigraphic framework was constructed by integrating litho-, bio-, and isotope-stratigraphic data (C and Sr isotopes), allowing to correlate these shallow-marine successions with pelagic sections in central Italy (Massignano), Tanzania (TDP Sites 12 and 17), and the Indian Ocean (ODP Site 744). Within several sections in northern Italy, including Nago and San Valentino, a Priabonian (Late Eocene) transgression is recorded. Oxygen isotopes of ODP Site 744 show a coeval negative shift of 0.4‰, suggesting a glacio-eustatic origin for this transgression. In the Nago and San Valentino sections, no prominent sequence boundary has been detected that would indicate a rapid sea-level drop occurring together with the positive shift in $\delta^{18}O$ defining the EOT-1 cooling event. Instead, a gradual shallowing of the depositional environment is observed. At TDP Sites 12 and 17, the EOT-1 is followed by a negative shift in $\delta^{18}O$ of around 0.4‰, which correlates with a relative deepening of the environment in the studied sections and suggests a melting pulse between EOT-1 and the Oligocene isotope event 1 (Oi-1). The positive $\delta^{18}O$ shift related to the Oi-1 translates in San Valentino into a change in carbonate factory from a photozoan association dominated by larger benthic foraminifera, corals, and red algae to a heterozoan association dominated by bryozoans. The same bryozoan facies occurs in several Italian localities near the Eocene–Oligocene boundary. This facies is interpreted to represent an analogue of modern cool-water carbonates and results from a cooling pulse of at least regional scale, associated to the Oi-1 event.

1. Introduction

The Eocene–Oligocene transition (EOT) marks the transition between a greenhouse and an icehouse world. In deep-sea records, it is expressed by prominent positive shifts in stable oxygen- and carbon-isotope values (Kennett and Shackleton, 1976; Miller et al., 1991; Zachos et al., 1996, 2001; Coxall and Pearson, 2007; Coxall and Wilson, 2011). The positive shift of oxygen isotopes occurred in two steps: a precursor step (~0.5‰) leading to the EOT-1 event (Katz et al., 2008), and a second, more pronounced step (~1‰) leading to the Oligocene isotope event 1 (Oi-1), also referred to as the Eocene–Oligocene glacial maximum (EOGM). The duration of this shift is estimated at around 500 kyr (Coxall et al., 2005; Coxall and Pearson, 2007; Katz et al., 2008; Miller et al., 2008; Coxall and Wilson, 2011; Wade et al., 2012). An additional but less clear precursor step has been reported only from the St. Stephen Quarry in Alabama (Katz et al., 2008; Miller et al., 2009). The Eocene–Oligocene boundary (Global Boundary Stratotype Section and Point = GSSP) as defined at Massignano (Italy) by the last appearance of the planktonic foraminifer *Hantkenina* (Nocchi et al., 1988; Premoli Silva and Jenkins, 1993) occurs within the EOT. The GSSP falls within magnetochron C13r but cannot be correlated to any stable isotope event.

While it is widely accepted that large ice sheets first formed in Antarctica during the EOT, there is increasing evidence that smaller transient glaciations already occurred during the Middle and Late Eocene (Tripati et al., 2005; Peters et al., 2010; Dawber et al., 2011). However, fluctuations in oxygen-isotope composition measured in deep-sea sediments do not allow differentiating between changes in temperature, salinity, and ice-volume, and alone do not permit to

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reconstruct in detail the formation of ice-sheets in Antarctica. Shallow-marine successions, on the other hand, where changes in water depth affect sedimentation, can be used to reconstruct local and regional sea-level history. Where such relative sea-level changes occur together with global shifts in oxygen isotopes, they can be interpreted in terms of glacio-eustatic sea-level fluctuations linked to waxing and waning of glaciers and ice sheets. In this respect, neritic deposits have been studied on the New Jersey shelf (Pekar et al., 2002; Miller et al., 2005a, 2009), at St. Stephens Quarry in Alabama (Katz et al., 2008; Miller et al., 2008, 2009; Wade et al., 2012) (Fig. 1A), and in Priabona in northern Italy (Houben et al., 2012) (Fig. 1A and B). However, due to the scarce and often incomplete shallow-water records spanning the EOT, open questions regarding the climatic and oceanographic evolution during this time interval remain.

Neritic carbonates are an excellent proxy to monitor environmental changes: carbonate-producing organisms react sensitively to changes in the environment (e.g., water depth, light intensity, nutrient input, water temperature, hydrodynamic energy). However, the correlation of shallow benthic biozones with stable-isotope, magneto-, and calcareous-plankton stratigraphy from pelagic sections, where the EOT has been characterized, is not free of uncertainties (Brinkhuis, 1994; Brinkhuis and Visscher, 1995; Luciani et al., 2002; Cascella and Dinarès-Turell, 2009; Agnini et al., 2011). One problem is the relatively poor chronostratigraphic resolution attained by benthic foraminiferal

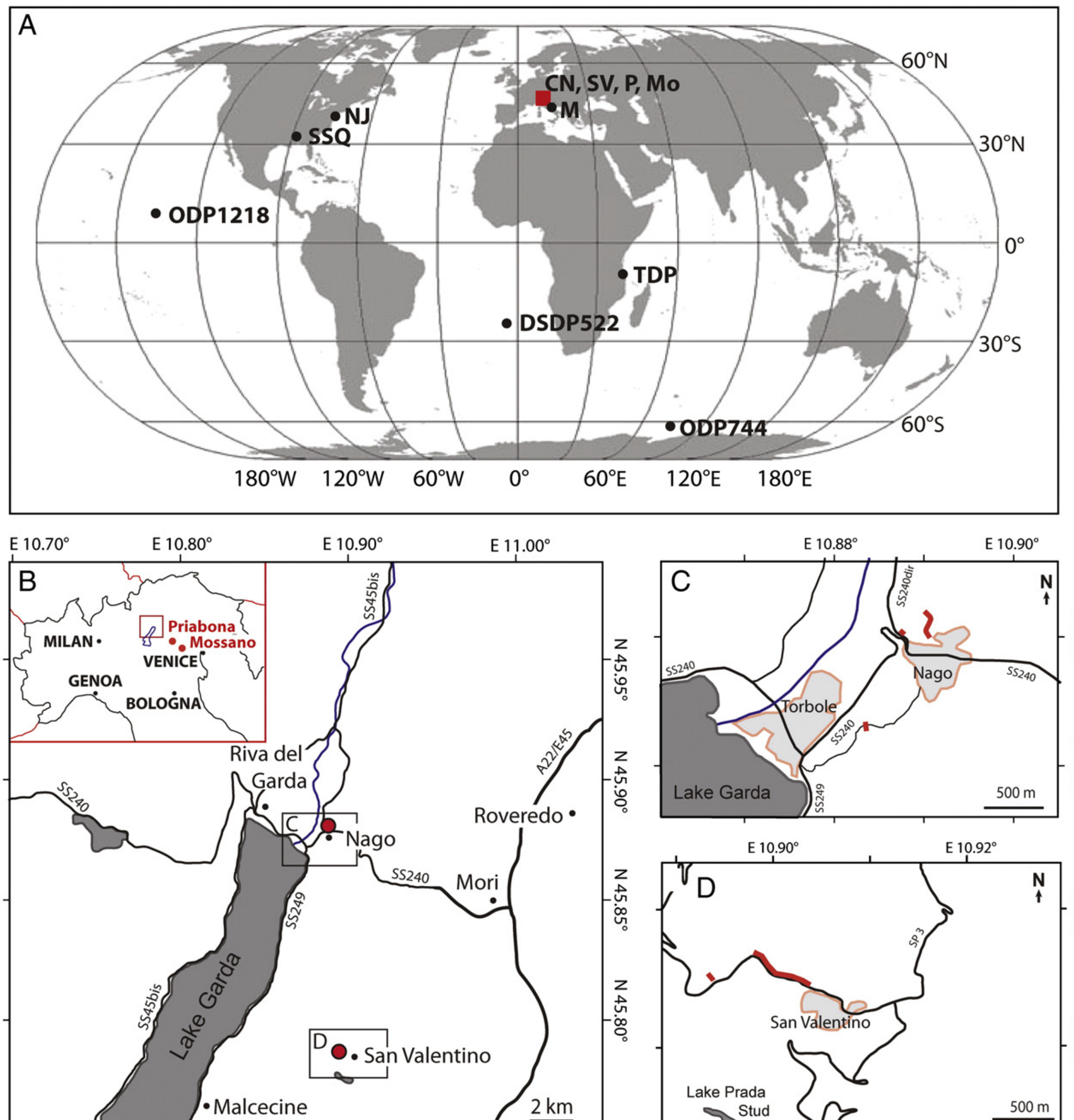

Fig. 1. A) Location of the studied sections in northern Italy (red square) and of other localities mentioned in this study containing the Eocene–Oligocene transition: Nago (CN), San Valentino (SV), Massignano (M), Priabona (P), Mossano (Mo), St. Stephens Quarry (SSQ), New Jersey shelf (NJ), Tanzania Drilling Project (TDP), ODP Sites 744 and 1218, and DSDP Site 522. B) Map of northern Italy showing the location of the Priabonian type locality at Priabona (Monti Lessini) and the Mossano section (Colli Berici). The magnification of the red square shows the area with the studied sections. C and D) Location of the measured sections in Nago and San Valentino, respectively. Red lines represent the measured sections.