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Campanian to Eocene dinoflagellate cyst biostratigraphy from the Tahar and Sekada sections at Arba Ayacha, western External Rif, Morocco

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ABSTRACT

Our detailed palynological study of the Upper Cretaceous–Lower Eocene marly succession from the Sekada and Tahar sections in southern Arba Ayacha, westernmost External Rif Chain (northwestern Morocco), has provided precise age determinations based on dinoflagellate cyst biostratigraphy. Dinoflagellate cysts (dinocysts), which are the dominant palynomorphs, allowed us to recognize the following ages: Late Campanian, Early and Late Maastrichtian, Danian, Selandian, Thanetian and Early Ypresien. Published studies on the western External Rif based on lithostratigraphy, show conflicting ages of Late Cretaceous (Senonian) and Early Eocene. Our age determinations are based on dinocyst events, which are more reliable. We recognize the Late Campanian on the First Occurrence (FO) and Last Occurrence (LO) of *Exochosphaeridium*? *masureae*, and the FO of *Cerodinium* spp., and the LOs of *Cribroperidinium wilsonii* subsp. wilsonii, *Odontochitina porifera* and *Trithyrodinium suspectum*. The Early Maastrichtian is denoted by the FOs of *Alterbidinium varium* and *Palaeocystodinium golzowense* and the LO of *Alterbidinium acutulum*. We define the Late Maastrichtian on the FOs of *Disphaerogena carposphaeropsis* and *Glaphyrocysta perforata*, and the LOs of *Alisogymnium euclaense*, *Dinogymnium* spp., *Isabelidinium cooksoniae*, and *Pterodinium cretaceum*, plus the worldwide latest Maastrichtian acme of *Manumiella seelandica*. Marking the Danian is the overall range of *Senoniasphaera inornata*, the FOs of *Carpatella cornuta*, *Damassadinium californicum* and *Membranilarnacia*? *tenella*. Species having LOs in the Selandian incude *Cerodinium diebelii*, *Manumiella seelandica*, *Senoniasphaera inornata*, *Palaeocystodinium australinum* and *Cerodinium speciosum*. We recognize the Thanetian mainly on the FO of *Homotryblium tenuispinosum* and based the worldwide terminal Thanetian acme of *Apectodinium* spp. The Early Ypresian is characterized by the FO of *Deflandrea phosphoritica* and a high abundance of *Apectodinium* spp. and *Kenleyia* spp. Thus, we now know that the rocks outcropping in the Sekada and Tahar sections are Late Campanian to Early Ypresian in age.

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1. Introduction

At Arba Ayacha in Larache Province (Fig. 1), the well exposed outcrops of the Sekada and Tahar sections, are ideal for investigating the age of this part of the western External Rif Chain of northern Morocco, which has previously been considered to be either Senonian or Early Eocene (Suter, 1980a; Asebriy, 1994). Using dinocysts for age control, Guédé et al. (2014) determined the Cretaceous–Paleogene boundary and a lower Paleocene (Danian) interval for the first time in the Tahar section. Other studies on dinocysts (Slimani et al., 2008, 2010, 2012; Slimani and Toufiq, 2013) have been focused on the Cretaceous–Paleogene transition in the eastern part of the External Rif. Our present study represents the first detailed palynological investigations based on quantitative and qualitative dinocyst analyses undertaken in the Upper Cretaceous–Lower Eocene marly and marly limestones succession from the Sekada and Tahar sections. We have found that the palynological assemblages change across the Cretaceous–Paleogene (K–Pg) and Paleocene–Eocene (P–E) boundaries: these are generally thought to reflect the global chemical anomalies and bio-events defining these boundaries, but there is still considerable debate on this topic. The Cretaceous–Palaeogene boundary is defined by the global iridium anomaly and mass extinctions of many marine and terrestrial biota, marking at the end of the Cretaceous period (the last period of the Mesozoic Era) and the beginning of the Paleogene period of the Cenozoic Era. But what caused these mass extinctions and global chemical anomalies? Most geologists attribute the changes to the massive asteroid that collided with the Earth and formed the Chicxulub impact (Alvarez et al., 1980; Hildebrand et al., 1991). But other hypotheses have been advanced, such as intense volcanism, multiple impacts, sea level fluctuations and climate change (Courtillot et al., 1986; Courtillot, 1990). Dinocysts did not undergo mass extinction at the Cretaceous–Paleogene boundary (Hansen, 1977; De Coninck and

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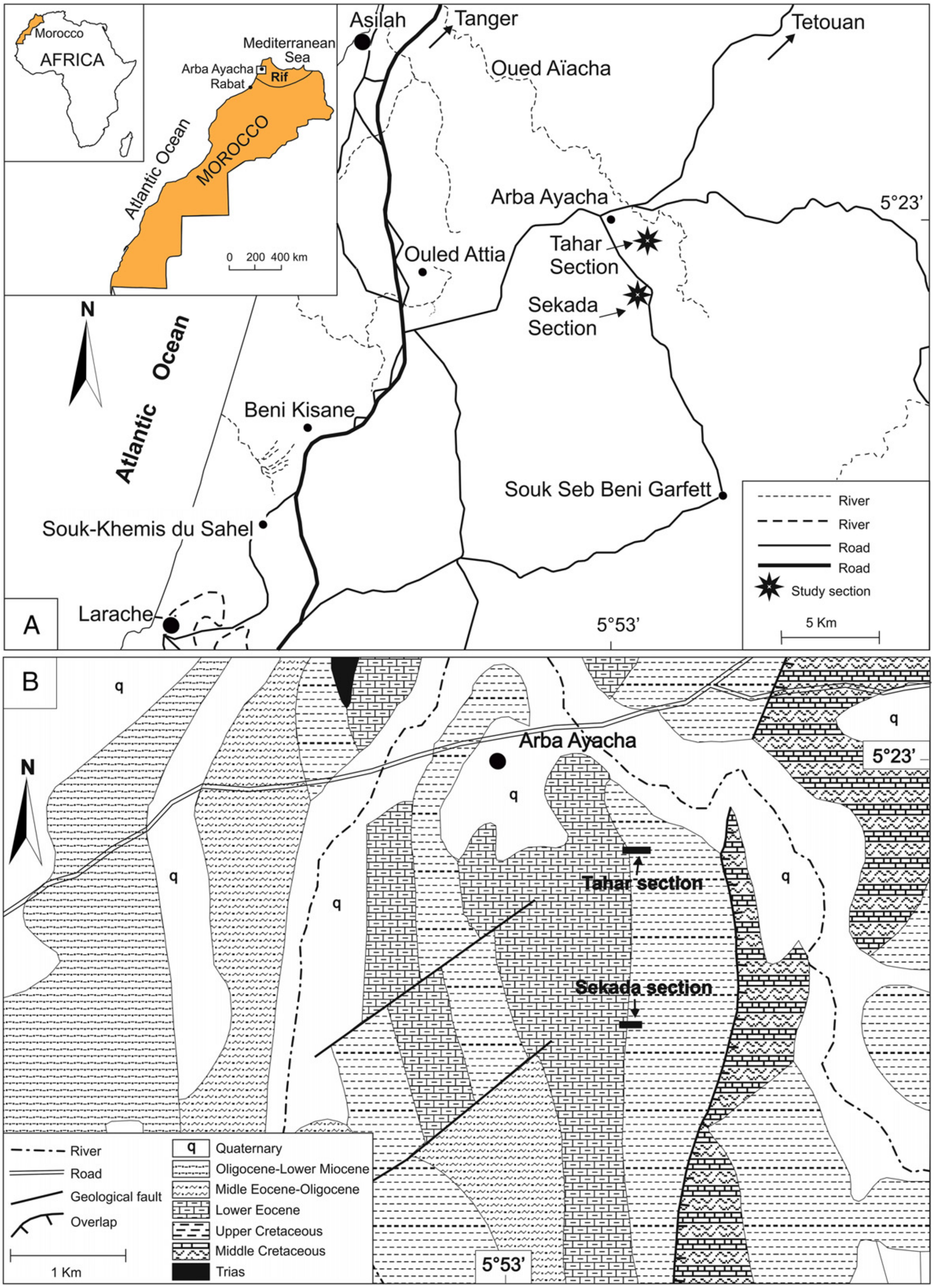

Fig. 1. Location map (A) and geological setting (B) of the Sekada and Tahar sections, Arba Ayacha, western External Rif, northwestern Morocco. B is adapted from the geological map of Rif and South-Rif Corridor 1/500 000 (Suter, 1980a).

Smit, 1982; Firth, 1987; Brinkhuis and Zachariasse, 1988; Habib et al., 1996; Slimani et al., 2010). However, there are notable changes in relative abundances of taxa, the most significant of which is the worldwide acme of *Manumiella seelandica*, indicating cool global climatic conditions (Hultberg, 1986; Firth, 1987; Habib and Saeedi, 2007; Slimani et al., 2010).

In contrast to the K–Pg interval, the P–E (Paleocene–Eocene) transition is marked by a worldwide Paleocene–Eocene thermal maximum (PETM), the most pronounced hyperthermal period in the Paleogene (Zachos et al., 2001, 2008). The PETM was coeval with a large negative carbon isotope excursion (CIE) recorded globally in both marine and continental strata (Koch et al., 1992; Zachos et al., 1993, 2005;

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