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Clay mineralogical and geochemical expressions of the "Late Campanian Event" in the Aquitaine and Paris basins (France): Palaeoenvironmental implications

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ABSTRACT

Campanian sediments from two French sedimentary basins were studied, using clay mineralogy and stable isotope ($\delta^{13}C$ and $\delta^{18}O$) geochemistry, in order to investigate the Late Campanian Event. The clay fraction of the Campanian sediments from the Tercis-les-Bains section (Aquitaine Basin) and from the Poigny borehole (Paris Basin) is mainly composed of smectite. This background sedimentation was, however, interrupted during the Upper Campanian in the two basins by a substantial increase in detrital inputs, including illite, kaolinite, and chlorite at Tercis-les-Bains, and illite at Poigny. This detrital event, resulting from the enhanced erosion of nearby continental areas triggered by increasing runoff, has also been recognized in the Tethys and South Atlantic oceans. It coincided with a global negative carbon isotope excursion, the Late Campanian Event (LCE). Carbon isotope stratigraphy was used to correlate the two basins with previously studied sections from distant areas. Spectral analysis of the bulk $\delta^{13}C$ from Tercis-les-Bains suggests a duration of *ca.* 400 kyr for a pre-LCE negative excursion and *ca.* 800–900 kyr for the LCE *sensu stricto*. The detrital event, as characterized by clay mineralogy, spans the interval that comprises the pre-LCE and the LCE, with a duration of 1.3 Myr. Intensification of continental erosion during the LCE may have resulted either from the Late Campanian *polyplocum* regression and/or from a regional tectonic pulse that triggered the emersion of previous submerged shelf areas and the increase of silicate erosion. As the LCE seems to be recorded at a large geographic scale, it is proposed here that enhanced chemical weathering and an associated decrease in atmospheric pCO_2 levels could have contributed to the long-term Late Cretaceous cooling trend.

1. Introduction

The Cretaceous is a "greenhouse" period with maximum sea-surface temperatures recorded around the Cenomanian to Turonian interval (Jenkyns et al., 1994; Clarke and Jenkyns, 1999; Pucéat et al., 2005; Friedrich et al., 2012). Following this climatic optimum, isotopic data highlight a long-term cooling during the remainder of the Late Cretaceous (Huber et al., 1995; Clarke and Jenkyns, 1999; Friedrich et al., 2012; Linnert et al., 2014). This cooling trend accelerated during the beginning of the Campanian (Friedrich et al., 2012, Linnert et al., 2014), but its mechanisms and dynamics are not yet well understood. The Campanian is also characterized by significant fluctuations of the sea level (Haq et al., 1987; Barrera et al., 1997; Jarvis et al., 2002), a major shift in the $\delta^{15}N$ of marine organic matter (Algeo et al., 2014), clay mineralogical changes, and the occurrence of positive and negative carbon isotope events: the Santonian–Campanian Boundary Event (SCBE) (Jarvis et al., 2002, 2006), the Mid Campanian Event (MCE) (Jarvis et al., 2002, 2006; Thibault et al., 2012a), the *conica* Event (Perdiou et al., 2015), the Late Campanian Event (LCE) (Jarvis et al., 2002, 2006; Voigt et al., 2012; Thibault et al., 2012a, b), the Epsilon Event (EE) (also called C1- Event) (Thibault et al., 2012a, 2015), and the Campanian–Maastrichtian Boundary Event (CMBE) (Barrera, 1994; Barrera and Savin, 1999; Friedrich et al., 2009; Jung et al., 2012; Voigt et al., 2012; Thibault et al., 2012a, 2015). Mineralogical changes expressed by detrital inputs of kaolinite and illite have been observed in many sedimentary basins, including the South Atlantic Ocean (Chamley et al., 1984), the Umbria-Marche Basin (Deconinck, 1992), the Saharan Platform (Li et al., 2000), and in the Paris Basin (Deconinck et al., 2005). As these mineralogical changes are stratigraphically poorly constrained, they cannot be associated with isotopic events. The objective here is to better understand the Campanian palaeoclimatic cooling by an integrated study of clay mineralogy and

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isotope geochemistry ($\delta^{13}C$ and $\delta^{18}O$). In addition, a cyclostratigraphic study was conducted in order to estimate the duration of the clay mineral change during the LCE.

We focus on two French sedimentary basins, the Aquitaine and the Paris basins. Isotopic data from the Tercis-les-Bains section (Aquitaine Basin) published by Voigt et al. (2012) are compared with new clay mineralogical data, while clay mineralogical data from the Poigny borehole (Paris Basin) published by Deconinck et al. (2005) are compared with new isotopic data. The whole data set is used to better constrain the timing of clay mineralogical changes and isotopic events that occurred in both basins.

2. Palaeogeography and geological settings

During the Campanian, the Atlantic Ocean was widening, while the Tethys Ocean was in the process of closing due to the counterclockwise motion of Africa (Smith, 1971; Dewey et al., 1973; Blakey, 2008). This period corresponded to the development of epicontinental seas in the Tethyan realm. Western Europe was an archipelago, whose islands corresponded to emergent Hercynian massifs (*e.g.,* Armorican, Central, and Rhenian Massifs) separated by epicontinental seas (Fig. 1). These emergent lands locally contributed to terrigenous sedimentation, although most Campanian sediments in the studied basins are composed of chalk and bioclastic limestone beds.

2.1. The Tercis-les-Bains section

The studied section is located in an abandoned quarry near Tercis-les-Bains (north-west of Dax) and belongs to the Aquitaine Basin (south-west France, Fig. 1). This basin was in an intermediate position between the North Atlantic and the Tethyan oceans (Fig. 1). The Tercis-les-Bains quarry, opened on the side of a diapir, shows vertically oriented Late Campanian to Maastrichtian beds (Bilotte et al., 2001; Odin, 2001). The 116-m-thick Campanian succession is composed of bioclastic limestone beds with common glauconitic horizons, flint nodules, and occasional marly levels (Fig. 2). The relatively homogeneous facies, microfacies, and faunal associations reflect deposition on the outer shelf in lower offshore environments (Berthou et al., 2001). The section is defined as the Global boundary Stratotype Section Point (GSSP) of the base Maastrichtian Stage (Odin, 2001), ensuring a well-defined magnetostratigraphic and biostratigraphic framework for the middle and upper part of the Campanian (Fig. 3).

2.2. The Poigny borehole

A thick succession of chalk (about 700 m), deposited from the Cenomanian to the Campanian, was drilled at Poigny, south-east of Paris (Craie 700 project, Mégnien and Hanot, 2000; Fig. 1). The Paris Basin was surrounded by the London-Brabant Massif to the north, by the Massif Central to the south and by the Armorican Massif to the west (Fig. 1). During the Late Cretaceous, the Paris Basin was an epicontinental sea where chalk accumulated. It was connected with the Tethys to the south-east, with the Boreal Ocean to the north and with the North Atlantic to the west. The lithological description of the borehole includes marker beds and biostratigraphic data based on benthic foraminifera, dinoflagellates, ostracods, nannofossils, and bivalves (Fig. 4), which allowed a detailed stratigraphic framework of the ~250-m-thick Campanian succession to be established (Robaszynski et al., 2005). Unfortunately, planktonic foraminifera cannot be studied in the Campanian succession of the Poigny borehole due to their poor preservation,

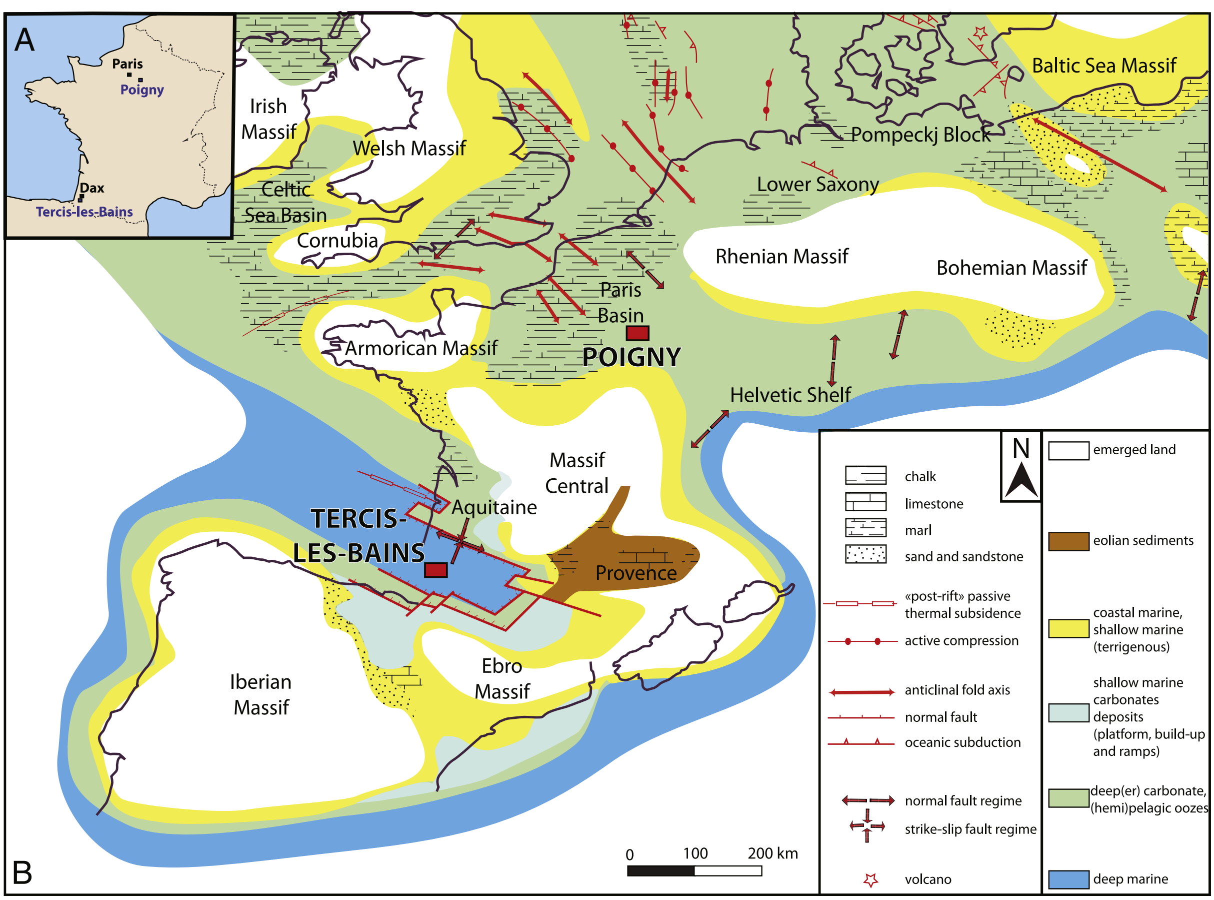

Fig. 1. Studied sites located on (A) a geographic map and (B) on a palaeogeographic map of the Western Peri–Tethyan Realm during the Early Campanian (modified after Philip and Floquet, 2000).