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Fish tooth and rudist δ^{18}O records indicate short-term temperature variations during the Valanginian: a basin and platform example in the Western Tethys

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The Early Cretaceous is punctuated by perturbations of the carbon cycle as evidenced by δ^{13}C excursions in carbonates and organic matter and by black shale deposits (Weissert et al., 1998; Menegatti et al., 1998). This period is also marked by carbonate production crises (Masse, 1993; Erba et Tremaloda, 2004; Föllmi et al., 1994) and important biotic turnovers (Erba et al., 2004; Melinte and Muterlose, 2001). It has been suggested that these events could be related to climate fluctuations (Kemper, 1987; Walter, 1991; Hochuli et al., 1999; Melinte and Mutterlose, 2001). In recent studies, the occurrence of cooling episodes has been identified during the Valanginian and the Aptian stages (Pucéat et al., 2003; Steuber et al., 2005). However, the resolution of existing marine temperature records remains insufficient to determine the relationships between climate, perturbations of the carbon cycle, and biotic events. Higher resolution palaeotemperature curves exist for this period but data are based on belemnite δ^{18}O, whose significance is still discussed (Podlaha et al., 1998; Dutton et al., 2007).
The aim of this study is to produce a higher resolution record of marine surface temperatures for the Valanginian. We analysed both fish teeth and rudist bivalves from the Western Tethys for their oxygen isotope composition. Infra-millimeter fish teeth have been recovered from the >500 micrometers fraction of degraded sandstones and marls from "La Charce" section which is biostratigraphically well-constrained (Vocontian Basin, France; Reboulet and Atrops, 1995; Reboulet, 2001). This section presents deposits dated from the Campylotoxus biozone to the end of the Upper Valanginian. The recovered fish teeth belong to benthic fish. Rudist bivalves have been sampled from a Provencal platform outcrop ('Gorges d'Ollioules', Southern France) and their shell were checked by cathodoluminescence before analysis. This section corresponds to inner platform environments and presents several discontinuities that may be associated to subaerial exposure. These emersion surfaces are expected on tethysian platform especially during the Upper Valanginian as proposed Gréselle (2007). The Upper Valanginian is not well preserved on platforms in the Tethyan realm. However, in the Ollioules section, one hundred meters thick deposits of uncertain age are intercalated between the Lower Valanginian and Lower Hauterivian sediments. In order to constrain the age of these deposits, we analysed bulk rock samples for their carbon isotope composition. The δ^{13}C record is compared to those of biostratigraphically well-dated sections of the Vocontian Through. The comparison indicates that at Ollioules the Upper Valanginian would be recorded at least up to part of the Pertransiens Zone. These isotope analyses are coupled with a detailed palaeoenvironmental study in order to characterize the importance of discontinuities and their diagenetic effect on sedimentation and isotope records. The Ollioules facies evolving between lagoonal to shoal palaeoenvironments seem to be homogenised with open environments by storm waves. However, few episodes of restricted lagoon conditions are recognized which are considered while interpreting rudist δ^{18}O values with respect to temperature record.
The oxygen isotope values of benthic fish tooth apatite show only moderate variations, with temperatures of 12

to 13°C for the Campylotoxus biozone and 9 to 10°C for the Pertransiens-Furcillata interval. These temperatures are similar to those derived from δ^{18}O of belemnite calcite recovered from the Vocontian Through (McArthur et al., 2007; Van de Schootbruges et al., 2000). By contrast, palaeotemperatures inferred from rudist calcite display a significant warming from 20°C at the middle of the Verrucosum Zone to 25°C during the Peregrinus Zone. These new data confirm the warming suggested by Tethyan pelagic fish tooth apatite during the Upper Valanginian (Pucéat et al., 2003). Temperatures inferred from rudist shells in this study are about 3 to 5°C higher that those derived from δ^{18}O of pelagic fish teeth (Pucéat et al., 2003). This discrepancy can reflect the different live habitats of these organisms, with rudists living in very shallow environments (less than 40 m deep) whereas pelagic fishes belong to species living in the first two hundred meters of the water column. Our work suggests a different temperature evolution of deep and surface marine waters in the southwestern Tethys during the Upper Valanginian period.