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Estimating the impact of early diagenesis on isotope records in shallow-marine carbonates: A case study from the Urgonian Platform in western Swiss Jura

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ABSTRACT

The poor preservation of sedimentological and geochemical evidence often hampers the identification of subaerial exposure surfaces in carbonate platform successions. Such discontinuities may represent significant time gaps, justifying the quest for diagnostic indications. We investigated a lower Hauterivian to upper Barremian sedimentary succession from Switzerland to highlight the stratigraphic impact of meteoric diagenesis on platform carbonates. Petrographic observations revealed the presence of five generations of calcitic cements. Spot measurement of carbon and oxygen stable isotope compositions ($\delta^{13}C$ and $\delta^{18}O$ values, respectively) measurements relate them to specific diagenetic environments: selected blocky calcite cements exhibit an enrichment in light isotopes (^{12}C, ^{16}O), indicative of meteoric eogenesis, whereas very negative $\delta^{18}O$ values link the last phase of cementation to mesogenesis. Meteoric calcitic cements formed during karstification of the top of the upper Barremian succession; burial diagenetic phases overlap these eogenetic phases, which thus cannot be related to recent telogenesis. We estimated the ratio of early meteoric versus burial cements within the studied succession: its stratigraphic repartition reveals that lower Aptian eogenesis influenced the geochemistry of platform carbonates as deep as 45 m below the exposure surface. In this interval, negative whole-rock $\delta^{13}C$ values do not reflect contemporaneous variations of the $\delta^{13}C$ curves documented in sections devoid of strong diagenetic impact. Such an impact is a function of the amount of meteoric cement filling pore space as well as of the primary carbon isotope composition of the carbonate sediments and of the meteoric cement. The vertical influence of a karst event is not restricted to the first metres directly below the exposure surface. Although meteoric diagenesis may not significantly alter microfacies, it may strongly perturb isotope systems. Building onto this case study, the application of $\delta^{13}C$ chemostratigraphy to platform carbonates can only be performed with great caution and after a careful examination of diagenetic features.

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1. Introduction

Variations in the stable carbon and oxygen isotope composition of Lower Cretaceous carbonate rocks have been used for palaeoenvironmental reconstructions (e.g., Weissert, 1989, 2000; Weissert and Erba, 2004; Millán et al., 2009), as well as for correlation purposes (e.g., Scholle and Arthur, 1980; Ferreri et al., 1997; Menegatti et al., 1998; Godet et al., 2006; Weissert et al., 2008). The application of chemostratigraphy to ancient platform carbonates is often hampered by the propensity of these rocks to be altered by diagenesis. Sequence stratigraphic models predict that shallow-marine sediments may be subaerially exposed during times of low sea level (e.g., Vail et al., 1977; Sarg, 1988; Schlager, 1999). Rhizoturbation, development of palaeosols, dessications, epikarstic cavities may characterize emersion surfaces (James and Choquette, 1984; Dickson and Saller, 1995; Rameil et al., 2012) but in slowly subsiding basins, gullying processes during early transgression usually destroy these superficial patterns. In such cases, arguments for an exposure event may be provided by early meteoric diagenesis (dissolutions, neogenesis or cementations), which may extend well below the air-sediment interface and develop deep enough to escape from subsequent erosion (Durlet and Loreau, 1996). Among such early diagenetic features, meteoric low-magnesium calcite (LMC) cements are usually enriched in both light carbon and oxygen isotopes (^{12}C, ^{16}O; e.g., Allan and Matthews, 1982; Lohmann, 1988; Joachimski, 1994). To identify such key cements, a detailed cement stratigraphic investigation must be conducted on numerous samples

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coming from both the supposed exposure itself, and from the underlying/overlying layers. In the case of series that are or have been buried, the superimposition of successive diagenetic histories corresponding to the eogenesis (early, shallow diagenesis), mesogenesis (burial diagenesis) and telogenesis (erosion and weathering induced by exhumation) renders difficult the straightforward identification of emersion surfaces.

Remains of a Barremian–early Aptian carbonate platform are preserved in various regions of Europe, including eastern France (e.g., Arnaud-Vanneau and Arnaud, 1990; Masse and Fenerci-Masse, 2013) and Switzerland (e.g., Föllmi et al., 1994; Blanc-Alétru, 1995) where the diagenetic history of Urgonian-type, rudist-bearing carbonates unravelled the frequent subaerial exposure of the platform during periods of low sea level. Features indicative of an emersion include early phases of dissolution, epikarstification, rhizoliths, and pendant cements (Carrio-Schaffhauser, 2005). In France and Switzerland, the development of the Urgonian platform ultimately ends as a response to a major drop of sea level and the subsequent karstification of these shallow marine carbonates in the early Aptian (Arnaud-Vanneau and Arnaud, 1990; Föllmi and Gainon, 2008). In the western Swiss Jura, previous authors agree on the presence of stratigraphic hiati associated with sequence boundaries (Blanc-Alétru, 1995; Godet et al., 2010); their stratigraphic location is hampered by their complex sedimentological expression. Ultimately, a karstified surface developed on top of the 'Urgonien Blanc', a local formation that designates rudist-bearing facies (Desor and Gressly, 1859).

With this contribution, we firstly aim at identifying subaerially-exposed sequence boundaries and to estimate the vertical extent of associated diagenetic modifications. Such surfaces may have been misinterpreted as submarine erosional surfaces due to an inadequate or incomplete dataset that hampers the accurate reconstruction of the evolution of this innermost portion of the Urgonian platform. Moreover in this region of the western Swiss Jura, repeated emersions may have led to the superimposition of several sequence boundaries. Finally, the correlation of the Swiss succession with contemporaneous series (e.g., Subalpine Chains, Vercors, Vocontian Basin) will help assessing the degree of meteoric overprint on the whole-rock stable isotope signal.

2. Geological setting

During the Early Cretaceous, the western Swiss Jura was located in the innermost part of the northern Tethyan margin (Fig. 1B), where reduced accommodation space led to a thin sedimentary succession and to gullying processes during early transgressive phases. An exposure is accessible in the quarry of Eclépens (LafargeHolcim CH©), 25 km northward from Lausanne, Switzerland (A in Fig. 1). Previous studies showed that sediments from the Hauterivian up to the late Barremian, and potentially the early Aptian, are cropping out (Blanc-Alétru, 1995; Godet et al., 2010, 2011). From the base to the top, lithostratigraphic units encountered at Eclépens are the lower and upper Pierre Jaune de

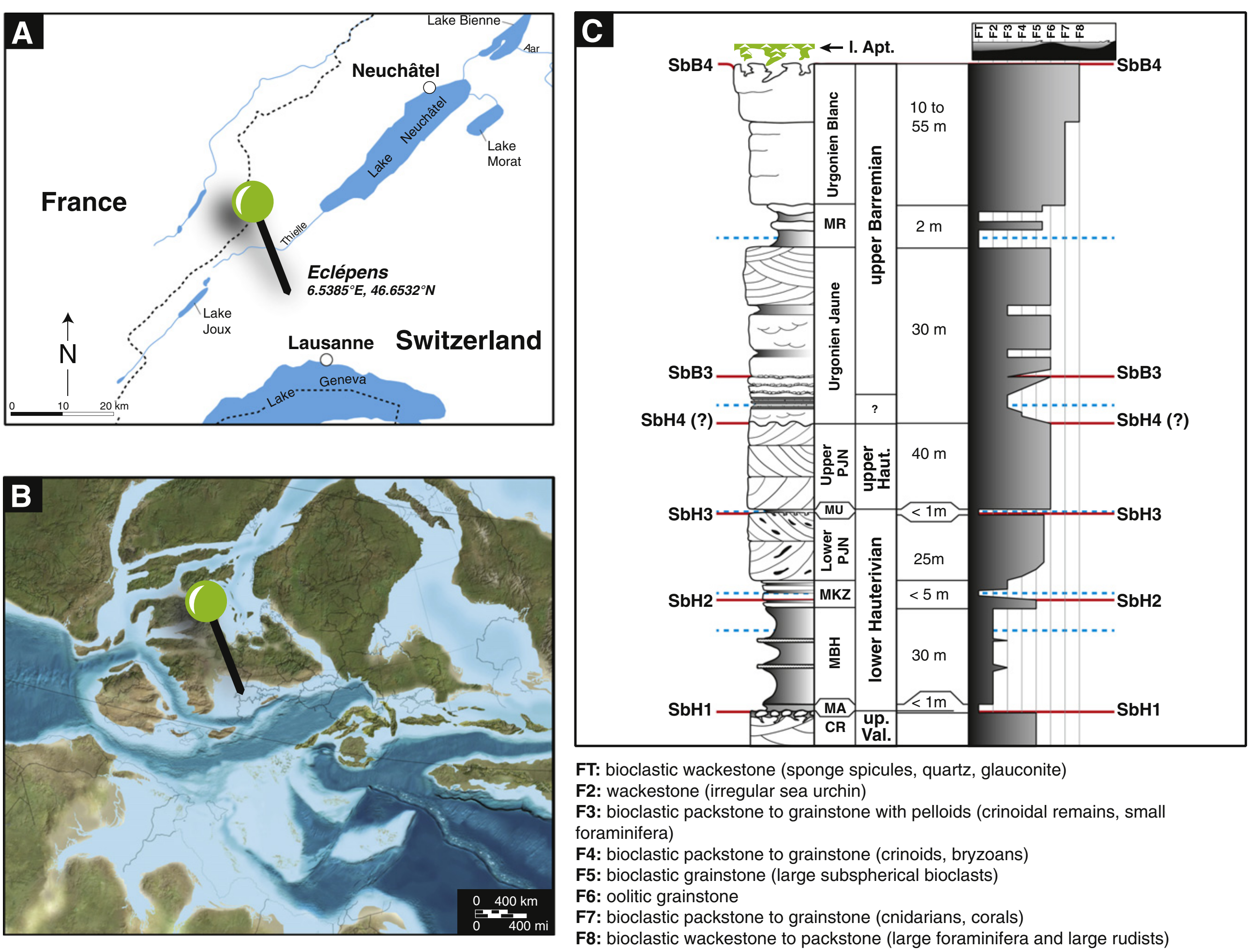

Fig. 1. (A) Location of the studied section on present-day geography (Godet et al., 2011), as well as on a (B) palaeogeographical map for the Early Cretaceous (125 Ma; Blakey and Geosystems, 2014). (C) A schematic representation of the upper Valanginian–Barremian sedimentary succession from the western Swiss Jura is modified after Godet et al. (2010), where the stratigraphic evolution of microfacies and sequence stratigraphic interpretation is reported (Godet et al., 2010, 2011). Abbreviations of the lithostratigraphical units are: CR, Calcaire Roux; MA, Marnes à Astieria; MBH, Marnes bleues d'Hauterive; MKZ, Mergelkalk Zone; PJN, Pierre Jaune de Neuchâtel; MU, Marnes d'Uttins; MR, Marnes de la Russille.