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Bioevents and redox conditions around the Cenomanian–Turonian anoxic event in Central Mexico

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ABSTRACT

The Xilitla section of central Mexico (western margin of the proto-North Atlantic) is characterized by pelagic sediments enriched in marine organic matter. Using biostratigraphic and radiometric data, it was dated at the latest Cenomanian–earliest Turonian transition. We identified an interval coeval with the faunal turnover associated with the Oceanic Anoxic Event 2 (OAE 2), recording the *Heterohelix* shift and the "filament event" for the first time in Mexico. An integral analysis of sedimentary facies, pyrite and geochemical proxies reveals vertically variable redox conditions, with prevailing anoxic to dysoxic bottom waters. Along with phosphorous and manganese depletion, the highest content of total organic carbon and of certain redox-sensitive trace elements (RSTEs) is found during part of the anoxic event, confirming more uniform and constant oxygen-depleted conditions. This interval is also characterized by a significant enrichment in biogenic barium and elevated TOC/N_{TOT} ratios, suggesting a link between productivity and anoxia. Sulfur isotope fractionation has a maximum value within the anoxic event, favored by the increase in the flux of organic matter and intensified through sulfur recycling. Highly bioturbated beds representing short-lived episodes of oxic conditions are intermittent within the OAE 2 and become more frequent in the early Turonian. This study proposes a model similar to that of modern upwelling regions. High marine productivity controlled organic matter burial and oxygenation at the seafloor, varying between anoxic (laminated facies with small pyrite framboids) and dysoxic conditions (bedding-parallel bioturbated facies with inoceramid bivalves and large pyrite framboids), interrupted by short-term well-oxygenated episodes (thoroughly bioturbated facies with common benthic foraminifera). General low-oxygen conditions led to the formation of glauconite and pyrite (bacterially mediated); the enrichment of redox-sensitive trace elements in sediments (Cd, Zn, V and Cr scavenged by organic matter and Ni, Mo, Pb, Co and Re by pyrite) and resulted in Mn and P depletion.

1. Introduction

Throughout the Mesozoic, several short-lived episodes of marine anoxia caused profound imprints on life and the environment, termed Oceanic Anoxic Events (OAEs; Schlanger and Jenkyns, 1976). The Cenomanian–Turonian anoxic event (OAE 2) is one of the most dramatic episodes of accelerated global change to have occurred throughout the Cretaceous, during a major global sea-level rise. Water column oxygen depletion in the course of this event caused a significant faunal turnover and enhanced the deposition of organic-rich sediments leading to a prominent positive carbon isotope excursion (Leckie et al., 2002; Caron et al., 2006; Jiménez Berrocoso et al., 2008; Hetzel et al., 2009; Gambacorta et al., 2015). In addition to affecting the global carbon cycle, the increased delivery of organic carbon to the seafloor drove an expansion of the oxygen minimum zone, elevated trace metal abundance in sediments, and favored high bacterial sulfate reduction (BSR) rates that, in turn, increased sedimentary pyrite burial and led to important modifications in seawater sulfur isotope composition (Coccioni and Luciani, 2004; Denne et al., 2014; Lowery et al., 2014; Poulton et al., 2015; Reolid et al., 2015).

The precise driving mechanisms behind the OAE 2 are still under debate; however, proposed hypotheses for the widespread ocean anoxia/dysoxia related to this event include the release of large quantities of CO_2 into the atmosphere through massive submarine volcanic activity during the formation of the Caribbean Plateau. Seawater chemistry changed radically due to the introduction of large quantities of sulfate and biolimiting metals that enhanced primary marine productivity (Snow et al., 2005; Trabucho Alexandre et al., 2010). Additionally, the associated CO_2 outgassing favored global warming, thus accelerating the hydrological cycle and increasing continental runoff and nutrient delivery into surface waters, which also contributed to increase productivity. Moreover, enhanced recycling of phosphorous from sediments overlain

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by anoxic waters has likely been an active mechanism further sustaining marine productivity (Mort et al., 2007; Poulton et al., 2015). While this event is well recorded in the Tethys, Central Atlantic and the Western Interior Seaway (WIS) in North America (e.g., Hetzel et al., 2009; Bomou et al., 2013; Eldrett et al., 2014), it is poorly understood in the Mexican Sea, a key area representing the transition between the WIS and the open ocean.

The Xilitla section of the Tampico-Misantla Basin, central Mexico, contains organic-rich sediments of the Agua Nueva Formation. It offers a good opportunity to study paleoenvironmental response to OAE 2 global perturbation in this particular site of the western margin of the proto-North Atlantic. In the present study, we present a multi-proxy approach to the stratigraphic section, correlating information from biostratigraphy, sedimentary facies, pyrite framboids content and size, carbon and sulfur isotopes, and total organic carbon and redox-sensitive trace elements (RSTEs) contents. The goals of this contribution are to: (i) identify the bioevents linked to the global turnover across the Cenomanian–Turonian (C–T) transition, (ii) provide information illustrating the redox conditions of the depositional environment; (iii) decipher the causes of such conditions and explore their genetic link with OAE 2; and (iv) construct a general depositional model considering the analytical results of the different proxies. This investigation is critical to developing a better understanding of the impact of OAE 2 on the deposition and preservation of organic matter in the study area.

2. Geologic and physiographic setting

The Tampico–Misantla Basin (TMB) is the easternmost paleogeographic feature of a set of basins that once constituted the Cretaceous Mexican Sea along the western margin of the proto-North Atlantic (Fig. 1). The basin has a continental basement, and its Jurassic (continental clastic sediments) to Early Cretaceous (basinal carbonates) filling pattern was mainly controlled by sea level changes related to the passive-margin development that resulted from the opening of the proto-Gulf of Mexico (Goldhammer and Johnson, 2001). During the late Cenomanian–early Turonian interval, as a result of the maximum global sea level rise (Hardenbol et al., 1998), the Mexican Sea expanded greatly and connected with the Western Interior Seaway (WIS) and the deep-water pelagic limestone of the Agua Nueva Formation accumulated in the TMB. This event was contemporary with volcanic activity in the western Pacific Mexico province (Goldhammer and Johnson, 2001; Centeno-García et al., 2008). As a consequence of the Sevier and

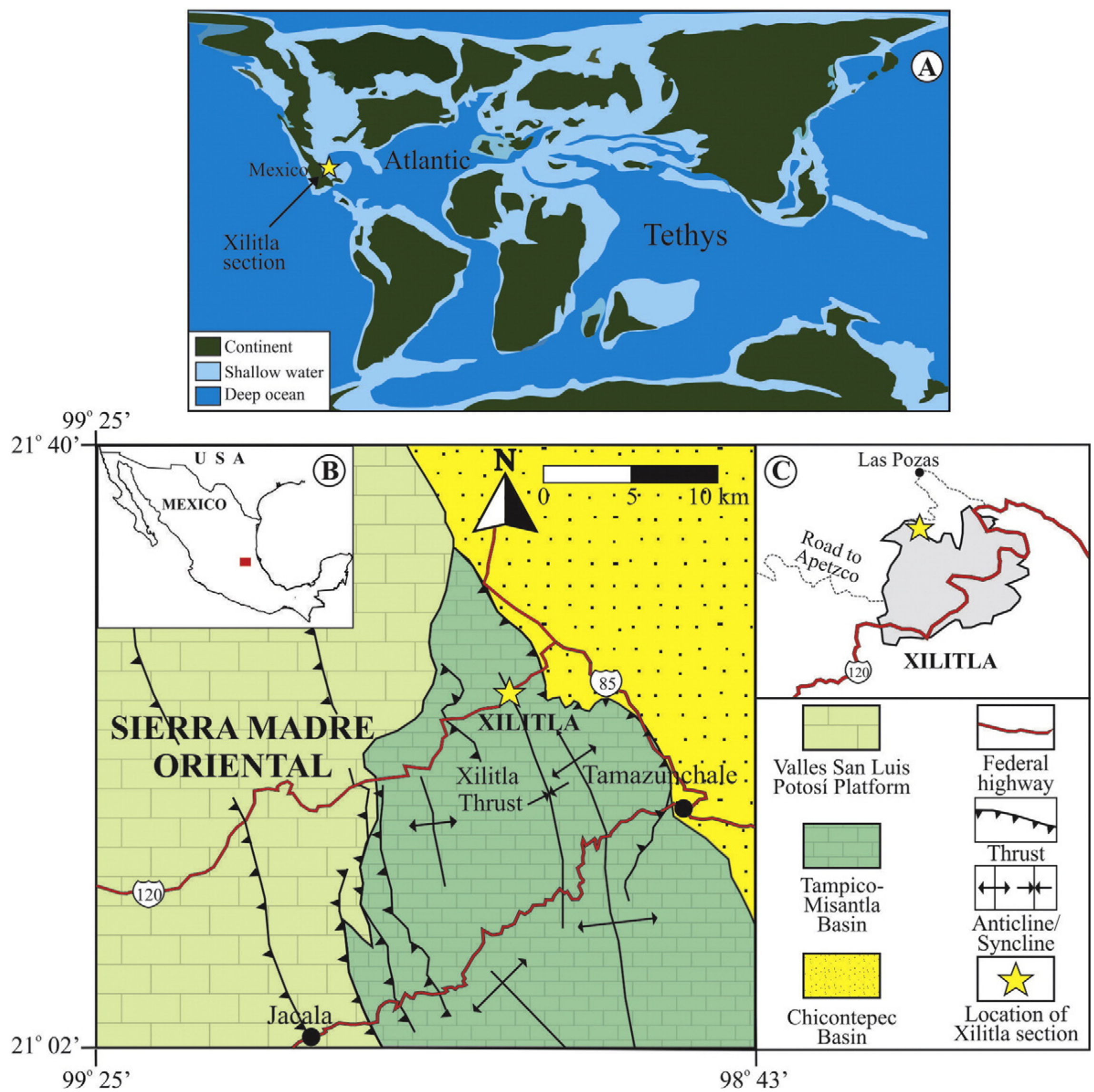

Fig. 1. (A) Paleoceanographic reconstruction of the Cenomanian–Turonian (http://jan.ucc.nau.edu/~rcb7/) showing the location of Mexico and the Xilitla section. (B). Central–northeastern portion of the Sierra Madre Oriental Fold-Thrust Belt with the major paleogeographic elements. (C) Schematic map of Xilitla.