Palaeogeography, Palaeoclimatology, Palaeoecology 499 (2018) 45–55

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

Biostratigraphy, carbon isotopes and cyclostratigraphy of the Albian-Cenomanian transition and Oceanic Anoxic Event 1d in southern Tibet

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ARTICLE INFO

Keywords:
ACBI
OAE 1d
Cretaceous
Spectral analysis
Youxia
Eastern Tethys

ABSTRACT

During the Albian and Cenomanian, the Earth underwent profound climatic and oceanographic changes that were recorded in sedimentary successions on a global scale. Carbon isotope records spanning this time interval have been established in the western Tethys, eastern Pacific and North Atlantic Oceans, but not yet in the eastern Tethys Ocean. In this paper, we present biostratigraphic, chemostratigraphic and cyclostratigraphic characteristics of the uppermost Albian–lowermost Cenomanian in an eastern Tethyan section (Youxia, southern Tibet). Based on calcareous nannofossil biozones and the bulk rock $\delta^{13}C$ curve, the Albian-Cenomanian boundary interval (ACBI) was identified and correlated to the western Tethys and Atlantic Oceans. In the Youxia section, $\delta^{13}C$ values range from approximately 0‰ to +1.3‰ (−0.03‰ to +1.31‰). Four subevents (a, b, c and d) were distinguished in the ACBI carbon isotope curve via correlation with other sections. Based on a spectral analysis of the carbonate content, we recognized Milankovitch short eccentricity (~100 kyr) and precession (22.2 kyr) cycles, suggesting that orbital variations modulated depositional processes. The duration of the ACBI was estimated at ~311 kyr, while OAE 1d lasted for ~233 kyr in the eastern Tethys Ocean, consistent with the duration calculated from Atlantic Ocean records.

1. Introduction

The Cretaceous is marked by several positive high-amplitude carbon isotope excursions that record changes in the carbon cycle and global climate (Valanginian to early Turonian, 135 to 89 Ma; Leckie et al., 2002; Jenkyns, 2010). Aptian-Albian and Cenomanian-Turonian excursions coincide with oceanic anoxic events (OAEs) as defined by Schlanger and Jenkyns (1976). Numerous studies of the Cretaceous OAEs at global and regional scales have focused on OAE 1a and OAE 2 (e.g., Jenkyns, 1980; Weissert, 1989; Menegatti et al., 1998; Tsikos et al., 2004; Föllmi, 2012). The focus of this study is the Albian-Cenomanian boundary interval (ACBI) with OAE1d at its base. OAE 1d correlates with the organic-rich Breistroffer Level in the Vocontian Basin of southeastern France (Bréhéret, 1988; Gale et al., 1996; Kennedy et al., 2004) and the Black Pialli Level in the Umbria-Marche Basin of Italy (Coccioni et al., 1987; Coccioni and Galeotti, 2003; Gambacorta et al., 2015). To date, OAE 1d or the Breistroffer Level and its equivalents have been identified in the western Tethys (e.g., Gale et al., 1996; Bornemann et al., 2005; Gambacorta et al., 2015; Melinte-Dobrinescu et al., 2015), in the Atlantic Ocean (Wilson and Norris, 2001), in the Pacific Ocean (Navarro-Ramirez et al., 2015), in North America (Western Interior Basin, Gröcke et al. (2006)) and in the Boreal realm (Bornemann et al., 2017), but only limited information on the ACBI, including OAE 1d, is available from the eastern Tethys of southern Tibet.

Moreover, OAEs were periods when oceanographic conditions favoured increased organic carbon burial rates. Most prominent black shales during OAE 1a and OAE 2 are documented from basinal settings in the western Tethys and North Atlantic Oceans and from depositional environments within the Cretaceous oxygen-minimum zone in the Pacific Ocean (e.g., Menegatti et al., 1998; Ando et al., 2008; Jenkyns, 2010; Blättler et al., 2011; Jarvis et al., 2011). Recent investigations of Cretaceous pelagic sediments from a deep basin in the eastern Tethys, the Hawasina Basin (Oman Mountains), indicate that the basin remained oxygenated during OAE 1a and during the Valanginian. Red radiolarian chert deposits record high productivity and a shallow calcite compensation depth (CCD) during these times of carbon cycle perturbation (Wohlwend et al., 2017). Available data from Cretaceous

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https://doi.org/10.1016/j.palaeo.2018.03.005
Received 6 December 2017; Received in revised form 7 March 2018; Accepted 8 March 2018
Available online 15 March 2018

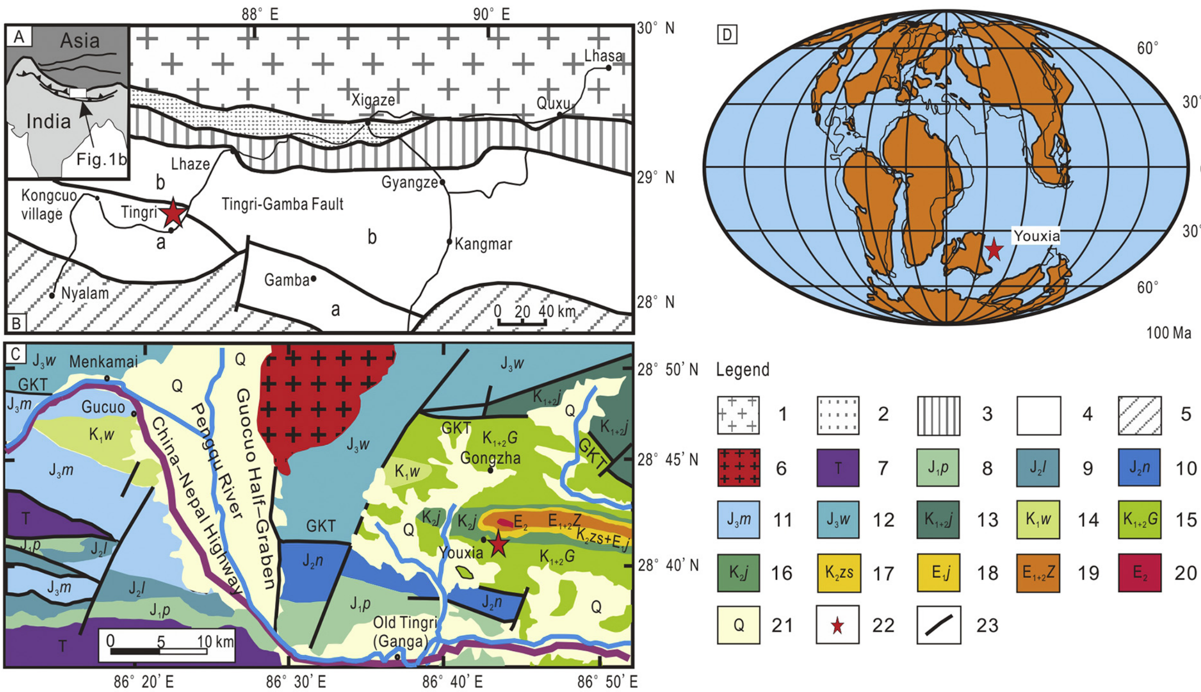

Fig. 1. A- Location of the studied area; B- The tectonic framework of central southern Tibet and the location of the section studied (modified from Li et al., 2006). a-The southern subzone of the Tethyan Himalayas; b-The northern subzone of the Tethyan Himalayas; C- Geological map of the Tingri area (modified from Hu et al., 2010). 1-Gandese Arc; 2-Xigaze forearc basin; 3-Yanglung Zangbo suture zone; 4-Tethys Himalayas; 5-High Himalayas; 6-Leucogranite; 7-Triassic; 8-Pupuga Formation; 9-Lanongla Formation; 10-Nieniexiongla Formation; 11-Menkadun Formation; 12-Weimei Formation; 13-Jiabula Formation; 14-Wolong Volcaniclastic; 15-Gamba Group; 16-Jiubao Formation; 17-Zhepure Shanpo Formation; 18-Jidula Formation; 19-Zongpu Formation; 20-Enba Formation and Zhaguo Formation; 21-Quaternary; 22-Location of section; 23-Fault; GKT-Gyirong-Kangmar Thrust; D- Paleogeographic reconstruction at 100 Ma (modified from Hay, 2009).

oceans suggest that deep water anoxia during OAEs was restricted to the small basinal settings of the Atlantic and Tethys Oceans (Bornemann et al., 2017; Wohlwend et al., 2017).

In this study, we use C-isotope stratigraphy as a tool for identifying C-cycle perturbations during the ACBI in eastern Tethyan shelf sediments that currently outcrop in southern Tibet. These sediments contain no prominent black shale deposits and C-isotope geochemistry serves as the only tool for tracing the depositional history of the ACBI in this part of the eastern Tethys Ocean. We combined bio- and cyclostratigraphy with carbon isotope stratigraphy to (i) provide a high-resolution ACBI carbon-isotope reference curve for the eastern Tethys of southern Tibet and (ii) establish a composite orbital chronology based on geochemical data sampled across the ACBI.

2. Geological setting

Tectonically, southern Tibet is composed of five distinct zones (Fig. 1B): the Higher Himalayan Crystalline Belts, the Tethyan Himalaya tectonic zone, the Indus-Yarlung Zangbo suture, the Xigaze forearc basin and the Gandese Arc (Ganser, 1991). Cretaceous marine deposits in southern Tibet are mainly exposed in the Tethyan Himalaya tectonic zone. The Gyirong-Kangmar intracrustal thrust (Fig. 1C) subdivides the Tethyan Himalaya into distinct northern and southern subzones (Liu and Einsele, 1994). Our study area (Fig. 1) formed the northern margin of the Indian continent during the Early Cretaceous and was separate from Eastern Gondwana (Hu et al., 2010; Du et al., 2015). During the mid-Cretaceous, the study area was located at the 21°S paleolatitude (Patzelt et al., 1996) and was part of an ocean that connected the Pacific Ocean with the western Tethys (Scotese, 1991).

The mid-Cretaceous marine strata in the Tingri area (Fig. 1C) are mainly composed of calcareous shales, marls and marly limestones, underlain by volcanoclastic sandstones and organic carbon-rich shales of Aptian-Albian age (Hu et al., 2010). The Youxia section was investigated for this study; it is ~150 m thick and located along the southern limb of a syncline, formed by Cretaceous to Paleogene marine strata (Fig. 1C).

3. Materials and methods

A total of 49 samples from the whole ~150-m-thick Youxia section were investigated for calcareous nannofossil analysis (Fig. 3). Calcareous nannofossils were collected from the 2–30 μm fraction and were initially separated via the decantation method, using a 7% solution of H_2O_2. Due to the poor quality of the calcareous assemblages recovered via decantation, the samples were successfully reprocessed using ultrasound techniques. Smear-slides were mounted with Canada balsam and analysed using an Olympus transmitting light microscope at 1200× magnification. Taxonomic identification of calcareous nannofossils was based on Perch-Nielsen (1985) and Burnett et al. (1998), with assemblages interpreted using the UC zones of Burnett et al. (1998). The first occurrence (FO) refers to the stratigraphically lowest occurrence of a species, and the last occurrence (LO) refers to the stratigraphically highest occurrence.

A total of 116 samples from the lower part of the section (0–26.8 m) were collected for carbon and oxygen isotopic analyses with an average sampling interval of 23 cm. The carbon and oxygen isotopic composition of bulk carbonate was measured at the Carbonate Reservoir Key Laboratory, of the PetroChina Hangzhou Institute of Geology, using a GasBench II system coupled to a Delta V mass spectrometer (Thermo Fisher Scientific, Bremen, Germany). For quality control, an internal reference standard was run every eight to ten samples. Approximately 900 μg of the powdered sample was placed in a 12 ml vacutainer, flushed with helium, and then reacted with 5 drops of 99% phosphoric acid at 25 °C. The instrument was calibrated with Chinese national carbonate standard GBW04405 ($\delta^{13}C = +0.57‰$, $\delta^{18}O = -8.49‰$). Values are reported in the conventional delta notation, relative to