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Carbonate platform crisis in the Carnian (Late Triassic) of Hanwang (Sichuan Basin, South China): Insights from conodonts and stable isotope data

Xin Jin[a,b,*], Zhiqiang Shi[c], Manuel Rigo[a], Marco Franceschi[a], Nereo Preto[a]

[a] Dipartimento di Geoscienze, Università degli Studi di Padova, Via G. Gradenigo 6, Padova, Italy
[b] Shandong Provincial Key Laboratory of Depositional Mineralization & Sedimentary Minerals, Shandong University of Science and Technology, Qingdao, Shandong 266590, China
[c] State Key Laboratory of Oil and Gas Reservoir Geology and Exploitation, Chengdu University of Technology, Chengdu, Sichuan 610059, China

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ABSTRACT

During the Carnian, the Hanwang area in the northwestern Sichuan Basin (South China) was characterized by shallow water carbonate sedimentation that underwent an abrupt demise associated to a sudden input of terrigenous sediments. This major facies change was considered to be the expression of the onset of the Carnian Humid Episode, a most remarkable environmental crisis in Late Triassic that is well recognized in northwestern Tethys margins and coincides with a major global perturbation of the carbon stable isotope record. However, the lack of detailed biostratigraphic constraints have so far prevented a precise dating of the carbonate platform demise in western Sichuan Basin.

In this work, the Qingyan Gou (HWQ) section, cropping out in Hanwang, was investigated for its facies and microfacies, carbonate carbon and oxygen isotopes on brachiopods, microbial grains and bulk matrix. Facies analysis shows a marine transgression from inner ramp oolitic shoal to middle ramp siliceous sponge mound, then overlain by shale and calcareous siltstone with interbedded silty mudstones. Refined biostratigraphic data from HWQ and Guanyin Ya (HWG) sections imply that the demise of sponge mounds occur in the late Tuvalian or later.

A negative carbon isotope perturbation was found in the bulk matrix immediately below the sponge mounds demise, but it was not found on the isotope record from brachiopods. This suggests that the negative shift in the bulk carbonate was probably related to diagenesis. Given the late Tuvalian (last substage of Carnian) age attributed to the demise of the sponge mounds and the absence of a carbon isotopic excursion, we infer that the carbonate platform crisis and strong terrigenous input in Hanwang cannot be related to the onset of the Carnian Humid Episode. These the demise of the carbonate platform and the facies deepening trend could be rather due to the interplay between accelerating subsidence rates, environmental chants and enhanced siliciclastic input related to the formation of a foreland basin during Indosinian orogenesis.

1. Introduction

During the Mesozoic, siliceous (Hexactinellida) sponges played an accessory role in carbonate reefs, in contrast to calcareous sponges, which were widely distributed in carbonate platforms and constructed carbonate buildups (Pratt, 1995; Stenzel and James, 1995; Wendt et al., 1997). The first reports of hexactinellid sponges as major Mesozoic reef builders were made by Wendt et al. (1989) and Wu (1989) in Hanwang and Jushui areas, within the northwestern Sichuan Basin (Carnian, Late Triassic, China). Since then, hexactinellid sponges spread continuously in the geological record and are found commonly on continental shelves (Krautter et al., 2006).

The Sichuan Basin hosts a thick Middle to Upper Triassic sedimentary succession, deposited in a foreland basin related to the Indosinian orogenesis (Luo and Long, 1992; Li et al., 2003, 2014). Hexactinellid sponges formed spectacular mounds in Hanwang and Jushui areas, which soon underwent an abrupt demise and were overlain by a thick terrigenous succession. Their age so far was constrained to the Carnian only by scarce fossils (Wu, 1989; Wang, 1992; Shi et al., 2017). The disappearance of sponge mounds coincides with a sharp transition to terrigenous sedimentation that was correlated to the Carnian Humid Episode (Shi et al., 2009, 2017; Wang et al., 2015). The Carnian Humid

* Corresponding author at: Dipartimento di Geoscienze, Università degli Studi di Padova, Via G. Gradenigo 6, Padova, Italy.
E-mail address: xin.jin@studenti.unipd.it (X. Jin).

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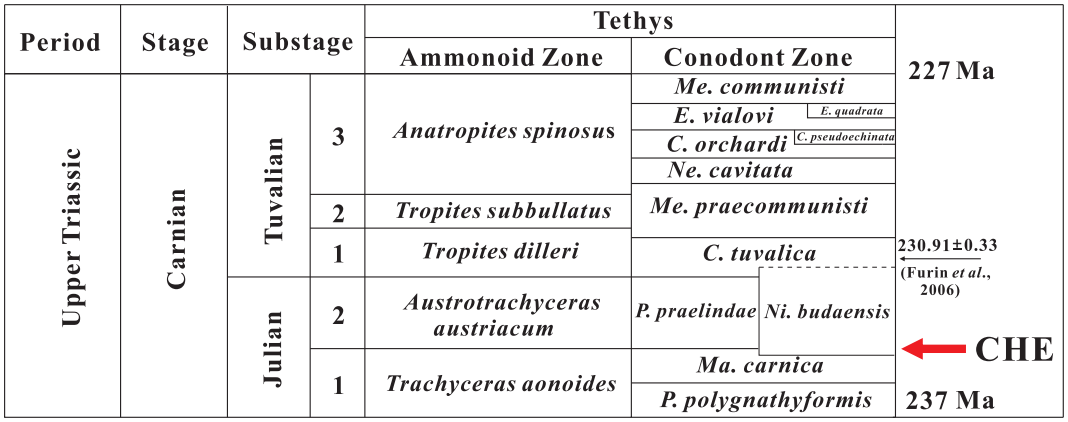

Fig. 1. Tethysian Carnian chronostratigraphy. Ammonoid biozonation follows Gallet et al. (1994), conodont biozonation follows Rigo et al. (2018). The top and base of Carnian age are based on Cohen et al. (2013). "CHE" = Carnian Humid Episode.

Episode (CHE sensu Ruffell et al., 2015), also known as Carnian Pluvial Event, is a major global Triassic climate event which was recognized in shallow carbonate platforms (Ogg, 2015; Ruffell et al., 2015, and references therein), and in deep-water environments (Rigo et al., 2007; Nakada et al., 2014). The CHE testifies to an increase in rainfall that caused input of terrigenous sediments and black shales deposition into sedimentary basins (e.g., Simms and Ruffell, 1989). At the same time, carbonate production crises occurred worldwide (e.g., Keim et al., 2006; Hornung et al., 2007a, 2007b; Breda et al., 2009; Lukeneder et al., 2011).

The onset of the CHE was found coincident with a major negative $\delta^{13}C$ perturbation (CIE) recorded by bulk organic matter and n-alkanes (e.g., Dal Corso et al., 2012, 2015; Mueller et al., 2016a, 2016b; Sun et al., 2016; Miller et al., 2017). This led to interpret the climate change towards wetter conditions as related to an injection of CO_2 in the atmosphere-ocean system, possibly triggered by massive volcanism (Furin et al., 2006; Dal Corso et al., 2012, 2015). Biochronostratigraphic investigations allowed dating the CHE to around the boundary between Julian 1 (*Trachyceras* ammonoid zone) and Julian 2 (*Austrotrachyceras* ammonoid zone, Fig. 1) in most locations of northwestern Tethys (e.g., Hornung and Brandner, 2005; Hornung et al., 2007c; Breda et al., 2009; Dal Corso et al., 2015), in southern Tethys (Spiti basin, Hornung et al., 2007b) and in eastern Tethys (Nanpanjiang Basin, Sun et al., 2016). These studies suggest synchronicity of climate change, terrigenous input and demise of carbonate platforms. This synchronicity was questioned by Lukeneder et al. (2011), who found that the carbonate platform crisis in Turkey has been younger, at the boundary between Julian and Tuvalian.

Despite the broad coincidence in terms of age between the CHE and the facies changes observed in the Carnian of the Sichuan Basin, the precise temporal relationship is still unclear. Thus, the causes and time of the demise of the hexactinellid sponge reefs and potential relationships with the ongoing Indosinian orogenesis are obscure. A discussion of these open questions would require a precise correlation of the Carnian of Sichuan Basin with the western Tethyan domain, and a finer biostratigraphic framework, which are still lacking. Moreover, a stable isotope record was not retrieved yet that could confirm the presence of the major isotope shift at the onset of the CHE. These data are provided in this paper.

2. Geological setting

The Sichuan Basin is a portion of eastern Tethys, located on the northern margin of South China Plate (Fig. 2A). Sedimentation on this plate was dominated by extensive carbonate platforms during the Triassic. Two sections are studied in this work and are situated in Hanwang region, in the middle of the Longmen Shan Thrust Belt at the boundary between the Sichuan Basin and Tibetan Plateau (Fig. 2B). The first section is named Qingyan Gou (HWQ) (N31°27′46.85″/E104°09′35.40″) and is located at 7 km SSW of Mianzhu city, northwestern Sichuan Basin. The other is named Guanyin Ya (HWG) which is around 1.5 km to the northwest of HWQ (Fig. 2C). Due to the collision between North China and South China plates (Zhang et al., 1996), which was considered the first stage of the Indosinian orogenesis (Li et al., 2003), an extensive unconformity formed between Middle and Upper Triassic sediments (Li et al., 2003). During the Late Triassic, a carbonate ramp dipping west and surrounded by local uplifted areas formed in the middle to western Sichuan Basin (Wu, 2009). In the meantime, the Middle Triassic carbonates suffered intense karst dissolution in the shallow parts of the Sichuan Basin (Li et al., 2003). A second phase of the Indosinian orogenesis at the end of Carnian caused a minor and local unconformity between Carnian and Norian (Zhang et al., 2013). Some consider this minor unconformity as the initiation of the western Sichuan foreland basin (Zeng and Li, 1995). According to these authors, the entire Sichuan Basin could have been mainly subjected to extension, not compression, during the early Carnian (Liu et al., 1995; Li et al., 2011b).

In the early Carnian, seawater from the eastern Tethys Ocean was entering the western Sichuan Basin from the Ganzi deep marine basin, which thus became a large bay (Wu, 1984). This bay was the only channel connecting the Sichuan Basin with the eastern Tethys Ocean through an island chain (Deng et al., 1982; Wu, 1984). Because of the complex sea level changes during the Carnian (e.g., De Zanche et al., 1993; Gianolla et al., 1998; Li et al., 2011a) and the inherited rugged landforms, the thickness and lithological features of Carnian rocks are extremely variable both laterally and stratigraphically in the Sichuan Basin (Shi et al., 2015).

3. Carnian/Norian stratigraphy of Hanwang area in Sichuan Basin

The subaerial unconformity between Middle and Upper Triassic is well documented in the Hanwang region, and is exposed at the base of the HWG section. Above the unconformity, the Upper Triassic succession is divided into three formations: the Ma'antang Formation (T_3m) consists of oolitic limestones, bioclastic limestones and microbial – sponge mounds, subsequently overlain by dark grey shales, calcareous silty mudstones and muddy siltstones. It is interpreted as being deposited on a carbonate ramp (Wu, 2009). This formation is subdivided into 4 lithozones (unit 1–4 in Shi et al., 2017). Above, the Xiaotangzi Member (T_3xt) is assigned to the lower Xujiahe Formation (T_3x) and dated to Norian (Li et al., 2003), on the basis of limited biostratigraphic data (Deng et al., 1982). It mainly consists of quartz arenite, coarse lithic arenite with calcite cement and is widely distributed in the Sichuan Basin. Its sedimentary environment is thought to be transitional