Palaeogeography, Palaeoclimatology, Palaeoecology 473 (2017) 41–56

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

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

Marine to brackish depositional environments of the Jurassic–Cretaceous Suowa Formation, Qiangtang Basin (Tibet), China

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ARTICLE INFO

Article history:
Received 29 November 2016
Received in revised form 21 February 2017
Accepted 21 February 2017
Available online 24 February 2017

Keywords:
Black shales
Organic matter
Tethys
Marine–continental transition
Transgression

ABSTRACT

The Late Jurassic to Early Cretaceous depositional environments of the Qiangtang Basin in Tibet have the potential to provide significant insight into mechanisms of black shale deposition, organic matter accumulation, and the timing of closure of the Mesotethys Ocean. However, the depositional setting has not been well constrained. Here we apply multiple geochemical proxies and petrologic analyses to representative samples of black shale, marl, and micrite collected from a section in the region. These indicate a transitional marine–continental environment, with brackish to saline water. Redox conditions were weakly oxic to suboxic. Environments represented by the studied section varied over time. The lowermost marls were deposited in a low-salinity, weakly oxic shore to shallow lake environment, under a warm and humid climate regime. The micrites in the middle part of the section were deposited in a lagoonal environment, with intense evaporation, high salinity, and water column stratification. The uppermost shales were deposited in a reducing, semi-enclosed lagoon environment during a marine transgression. These results suggest that the Late Jurassic–Early Cretaceous succession was deposited in a tidal-flat or lagoonal environment.

1. Introduction

The Qiangtang Basin, located in the north–central Qinghai–Tibet Plateau, preserves a sedimentary record of the eastern Tethys and has been the subject of research for decades (Kapp et al., 2000, 2007; Zhang et al., 2006a, 2006b, 2006c, 2011; Pullen et al., 2008; Zhang and Tang, 2009; Zhu et al., 2011a). The Late Jurassic to Early Cretaceous was an important interval in the geologic history of this region, because this is when the critical shift from marine to continental settings (i.e., the closure of the Mesotethys Ocean) is thought to have occurred (Zhang, 2000, 2004; Zhang et al., 2002, 2004a, 2007a, 2012, 2014; Skelton et al., 2003). However, the timing of this transition is debated, with proposed closure ages ranging from the Late Jurassic to the Early Cretaceous (Zhang, 2000, 2004; Zhang et al., 2002, 2004a; Lu et al., 2003; Mo and Pan, 2006; Shi, 2007), and even into the Late Cretaceous (Zhang et al., 2012, 2014). Therefore, whether the Late Jurassic–Early Cretaceous environment of the Qiangtang Basin was marine or continental is of critical importance for constraining the timing of closure of the Mesotethys.

As tectonic events are typically reflected in sedimentological responses, sedimentary analysis can be used to improve our understanding of this issue (Blair and Bilodeau, 1988; Zhang, 2000, 2004; Zhang et al., 2002, 2004a, 2006c; Herrle et al., 2003; Brumsack, 2006; Sha et al., 2008; Yang, 2013). Sedimentological studies of the Bangong Mesotethys, with implications for the Jurassic–Cretaceous tectonic evolution of the Mesotethys Ocean, have been conducted since the 1980s (Yin et al., 1988; Leeder et al., 1988; XZBGM, 1993; Zhang, 2000, 2004; Zhang et al., 2002, 2004a, 2007a, 2012; Yi et al., 2003; Baxter et al., 2009). However, the Jurassic–Cretaceous marine sedimentary succession has not been fully described, and requires additional research.

Recently, a widespread and continuous succession of Upper Jurassic or Lower Cretaceous black shales and oil shales was described cropping out along the Shengli River, in the northern part of the Qiangtang Basin (Fu et al., 2009; Yang et al., 2015). Based on the regional geology, these shales were deposited in a marine embayment (Fu et al., 2010, 2011). These strata provide a new opportunity to study the Late Jurassic–Early Cretaceous depositional environment of the basin, further constraining the timing of closure of the Mesotethys. Previous studies have not investigated these issues, instead focusing primarily on the depositional age, provenance, and hydrocarbon potential of the shales (Wang et al., 2007, 2009; Fu et al., 2010, 2011, 2012; Yang et al., 2015). Environmental interpretations may have been avoided in the past due to the poor preservation of the section, and particularly sedimentary structures (Fu et al., 2010, 2011), caused by high maturity (Yang et al., 2015).

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http://dx.doi.org/10.1016/j.palaeo.2017.02.031
0031-0182/

Using samples from a representative section of these shales, we conducted a preliminary study to characterize the Late Jurassic–Early Cretaceous paleoenvironments of the Qiantang Basin. Our interpretations are based on a combination of multiple petrologic and geochemical approaches, and the results of this study have broader implications for mechanisms of black shale deposition, organic matter accumulation, and hydrocarbon resource potential.

2. Geologic setting

2.1. Tectonic setting

The Qiangtang Basin, which has an area of approximately 180,000 km^2, is located in the northern–central part of the Qinghai–Tibet Plateau (32–35°N, 83–93°E). The basin is situated between the Hoh Xil–Jinshajiang and Bangonghu–Nujiang suture zones (Fig. 1A), and consists of three secondary structural units: the Northern Qiangtang Depression, the Central Uplift, and the Southern Qiangtang Depression (Fig. 1A).

The basin is part of the Qiangtang Block, which is believed to represent a large-scale anticlinorium (XZBGM, 1993). The central part of the block is an anticline composed of pre-Jurassic sedimentary strata and metamorphic rocks, while the northern and southern depressions are synclines composed mainly of Mesozoic sedimentary rocks (XZBGM, 1993; Zhang et al., 2002, 2006c).

The central Qiangtang metamorphic belt is ~500 km long and up to 100 km wide, and is made up of blueschist- (Kapp et al., 2000, 2007; Zhang et al., 2006a) and ecoligite-bearing rocks (Zhang et al., 2006b; Pullen et al., 2008; Zhang and Tang, 2009) which represent the in situ expression of the paleo-Tethyan suture (Shuanghu suture; Zhang et al., 2006a, 2006b, 2006c). During the Early and Middle Triassic, this metamorphic belt was underthrust by the Hoh Xil–Jinsha suture, leading to the exhumation of the interior of the Qiangtang Block (Kapp et al., 2000, 2007; Pullen et al., 2008). This belt separates the Qiangtang block into northern and southern sections. During the Late Triassic to

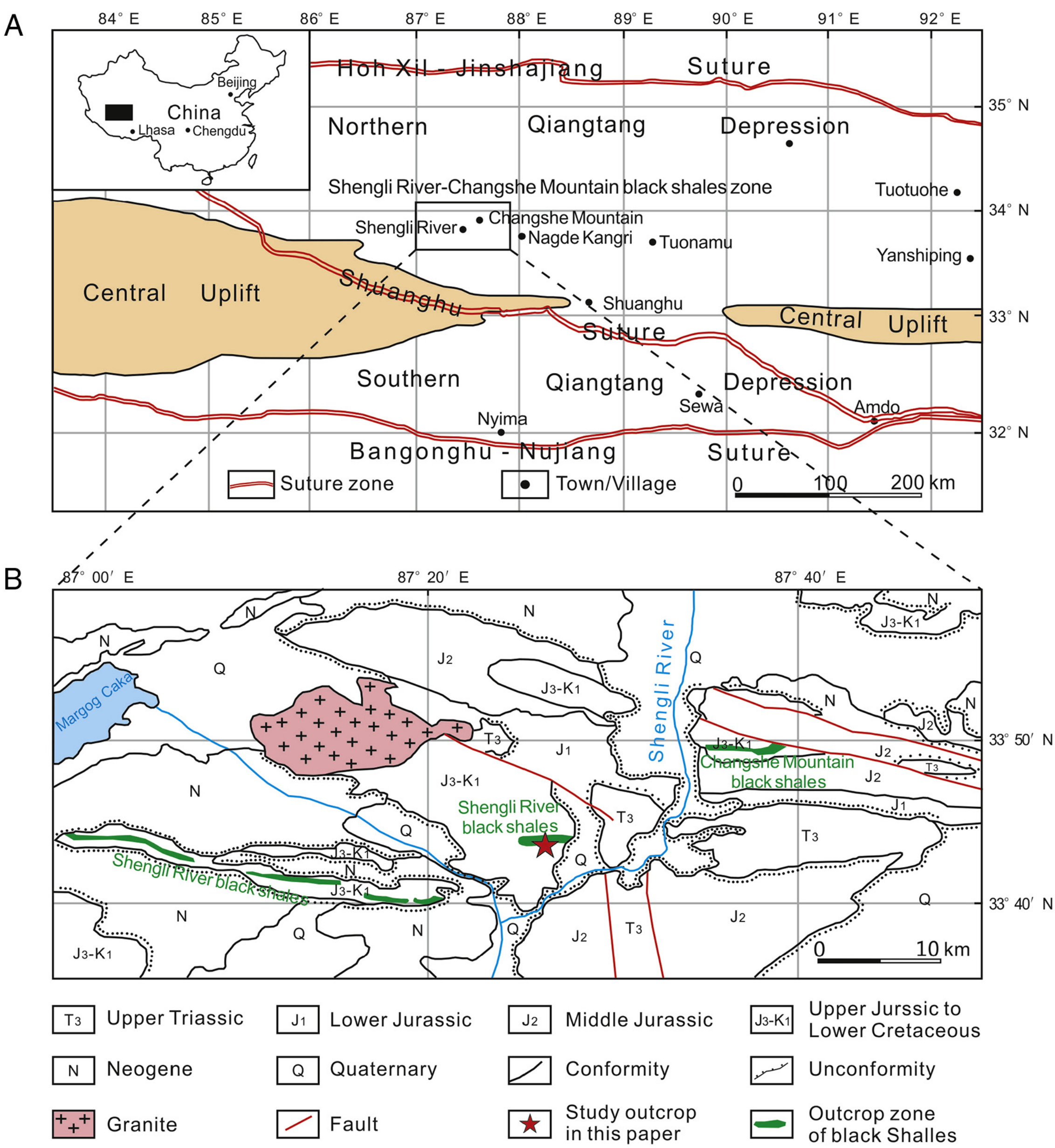

Fig. 1. Geological map of the study area. (A) Structural units of the Qiangtang Basin. (B) Simplified geological map of the sampling area. (Modified after Fu et al., 2010)