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Timing, cause and impact of the late Eocene stepwise sea retreat from the Tarim Basin (west China)

Roderic Bosboom [a,*], Guillaume Dupont-Nivet [a,b,c], Arjen Grothe [d], Henk Brinkhuis [d], Giuliana Villa [e], Oleg Mandic [f], Marius Stoica [g], Tanja Kouwenhoven [d], Wentao Huang [a,b,c], Wei Yang [b,c], ZhaoJie Guo [b]

[a] *Paleomagnetic Laboratory Fort Hoofddijk, Faculty of Geosciences, Utrecht University, Budapestlaan 17, 3584 CD Utrecht, The Netherlands*
[b] *Key Laboratory of Orogenic Belts and Crustal Evolution, Ministry of Education (Peking University), Beijing 100871, China*
[c] *Géosciences Rennes, UMR 6118, Université de Rennes1, Campus de Beaulieu, 35042 Rennes Cedex, France*
[d] *Marine Palynology and Palaeoceanography, Laboratory of Palaeobotany and Palynology, Department of Earth Sciences, Faculty of Geosciences, Utrecht University, Budapestlaan 4, 3584 CD Utrecht, The Netherlands*
[e] *Dipartimento di Fisica e Scienze della Terra, University of Parma, Viale Usberti, 157A, 43100 Parma, Italy*
[f] *Geological-Palaeontological Department, Natural History Museum Vienna, Burgring 7, A-1010 Wien, Austria*
[g] *Department of Geology and Paleontology, Faculty of Geology and Geophysics, Bucharest University, Bălcescu Bd. 1, 010041, Romania*

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ABSTRACT

A vast shallow epicontinental sea extended across Eurasia and was well-connected to the Western Tethys before it retreated westward and became isolated as the Paratethys Sea. However, the palaeogeography and the timing of this westward retreat are too poorly constrained to determine potential wider environmental impacts, let alone understanding underlying mechanisms of the retreat such as global eustasy and tectonism associated with the Indo-Asia collision. Here, an improved chronostratigraphic and palaeogeographic framework is provided for the onset of the proto-Paratethys Sea retreat at its easternmost extent in the Tarim Basin in western China is provided. Five different third-order sea-level cycles can be recognised from the Cretaceous–Palaeogene sedimentary record in the Tarim Basin, of which the last two stepped successively westwards as the sea retreated after the maximum third incursion. New biostratigraphic data from the fourth and fifth incursions at the westernmost margin of the Tarim Basin are compared to our recent integrated bio-magneto-stratigraphic results on the fourth incursion near the palaeodepocentre in the south-western part of the basin. While the fourth incursion extended throughout the basin and retreated at ~41 Ma (base C18r), the last and fifth incursion is restricted to the westernmost margin and its marine deposits are assigned a latest Bartonian–early Priabonian age from ~38.0 to ~36.7 Ma (near top C17n.2n to base C16n.2n). Similar to the fourth, the fossil assemblages of the fifth incursion are indicative of shallow marine, near-shore conditions and their widespread distribution across Eurasia suggests that the marine connection to the Western Tethys was maintained. The lack of diachronicity of the fourth incursion between the studied sections across the southwest Tarim Basin suggests that the sea entered and withdrew relatively rapidly, as can be expected in the case of eustatic control on a shallow epicontinental basin. However, the westward palaeogeographic step between the fourth and fifth incursions separated by several millions of years rather suggests the combined long-term effect of tectonism, possibly associated with early uplift of the Pamir-Kunlun Shan thrust belt. The fourth and fifth regressions are time-equivalent with significant aridification steps recorded in the Asian interior, thus supporting climate modelling results showing that the stepwise sea retreat from Central Asia amplified the aridification of the Asian interior.

1. Introduction

A vast shallow epicontinental sea extended across Eurasia during the Cretaceous and Palaeogene from Europe to the Tarim Basin in western China, before it retreated westward and became isolated as the Paratethys Sea in the Oligocene, of which nowadays only the Caspian and Black Seas remain (e.g. Báldi, 1984; Rusu, 1985; Tang et al., 1989; Dercourt et al., 1993; Lan and Wei, 1995; Burtman et al., 1996; Robinson et al., 1996; Rögl, 1999; Burtman, 2000; Popov et al., 2004; Schulz et al., 2005; Vincent et al., 2005; Allen and Armstrong, 2008; Bosboom et al., 2011). The timing and palaeogeography of the long-term westward retreat of the proto-Paratethys Sea are however still poorly constrained and hamper understanding of the mechanisms controlling the sea retreat, as well as its palaeoenvironmental impact on the Eurasian continent. The retreat has originally been attributed to progressive tectonic overthrusting of the Pamir-Kunlun Shan thrust belt in the south and the Tian Shan in the north in response to the

* Corresponding author. Tel.: +31 30 253 5246.
E-mail address: R.E.Bosboom@uu.nl (R. Bosboom).

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Indo-Asia collision (e.g. Hao and Zeng, 1984; Tang et al., 1992; Burtman and Molnar, 1993; Jia et al., 1997; Lan, 1997; Burtman, 2000; Yin and Harrison, 2000; Coutand et al., 2002; Cowgill, 2010). More recently, it has been proposed that fluctuations in the retreat of this sea may have been simultaneously paced by global climate and associated eustatic effects during the shift from greenhouse to icehouse conditions in the late Eocene, culminating at the Eocene–Oligocene Transition (EOT) at ~34 Ma (e.g. Browning et al., 1996; DeConto and Pollard, 2003; Dupont-Nivet et al., 2007; Zachos et al., 2008; Bosboom et al., 2011; Gasson et al., 2012; Bosboom et al., in press). Climate modelling studies have suggested that the sea functioned as a major moisture source for the Asian continental interior (Ramstein et al., 1997; Zhang et al., 2007), such that its disappearance from Central Asia may have amplified the intensification of the Asian monsoons and the Asian aridification (Bosboom et al., 2011; Bosboom et al., in press). An opportunity to further test these hypotheses is provided by the Cretaceous and Palaeogene marine records of the easternmost extent of this sea in the Tarim Basin. These deposits indicate a peculiar pattern of five successive marine incursions, i.e. after the maximum extent reached during the third transgression, the sea retreated stepwise westward paced by the fourth and fifth transgressions (Tang et al., 1989; Lan and Wei, 1995). Using integrated bio-magnetostratigraphy our previous study focussed on the Aertashi, Kezi and Keliyang sections along the West Kunlun Shan (Fig. 1) and showed that the sea completely withdrew from the palaeodepocentre of the southwest depression after the fourth regression at ~41 Ma (base C18r; Bosboom et al., in press). This new study aims to extend the established chronological framework of the stepped westward retreat by more accurate biostratigraphic dating of the succeeding fifth and last regression from the Tarim Basin at the Bashibulake Mine section along its westernmost margin (Fig. 1), in order to discuss the long-term palaeogeographic dynamics of the proto-Paratethys Sea with respect to early tectonic uplift of the Tibetan Plateau, regional palaeoenvironmental changes in the Asian interior and the deterioration of global climate in the late Eocene.

2. Geological setting

The Tarim Basin is part of a relatively undeformed crustal block within the Indo-Asia collision system (e.g. Yin and Harrison, 2000). The sedimentary infill on top of the oceanic crustal basement is primarily composed of Palaeozoic and Mesozoic clastic sediments, which were folded by successive distal accretion of continental terranes along the southern margin of Asia from the late Triassic until the Eocene Indo-Asia collision at ~50 Ma (Tian et al., 1989; Hendrix et al., 1992; Yin and Harrison, 2000; Robinson et al., 2003; Jia et al., 2004; van Hinsbergen et al., 2012). Marginal overthrusting and tectonic loading of the Tian Shan, the Pamir Mountains and the Kunlun Shan by the Cenozoic northward movement of India into Eurasia, probably initiated the Late Cretaceous formation of two major distal foreland basins, the Kuche depression along the southern margin of the Tian Shan and the southwest depression along the West Kunlun Shan with its palaeodepocentre near Yarkand (Fig. 1; Burtman and Molnar, 1993; Jia et al., 1997; Yin and Harrison, 2000; Yang and Liu, 2002; Cowgill, 2010). A period of relative tectonic quiescence followed with successive shallow marine incursions in the two depressions. This study focuses on the marine history of the westernmost margin of the Tarim Basin, part of the southwest depression and situated where the present-day Kunlun Shan and Tian Shan meet (Fig. 1).

Marine deposition in the underfilled southwest depression supposedly initiated in the Cenomanian, though marine trace fossils have been described from Barremian to Albian sediments (Guo, 1991; Lan and Wei, 1995). The sea entered the Tarim Basin from neighbouring

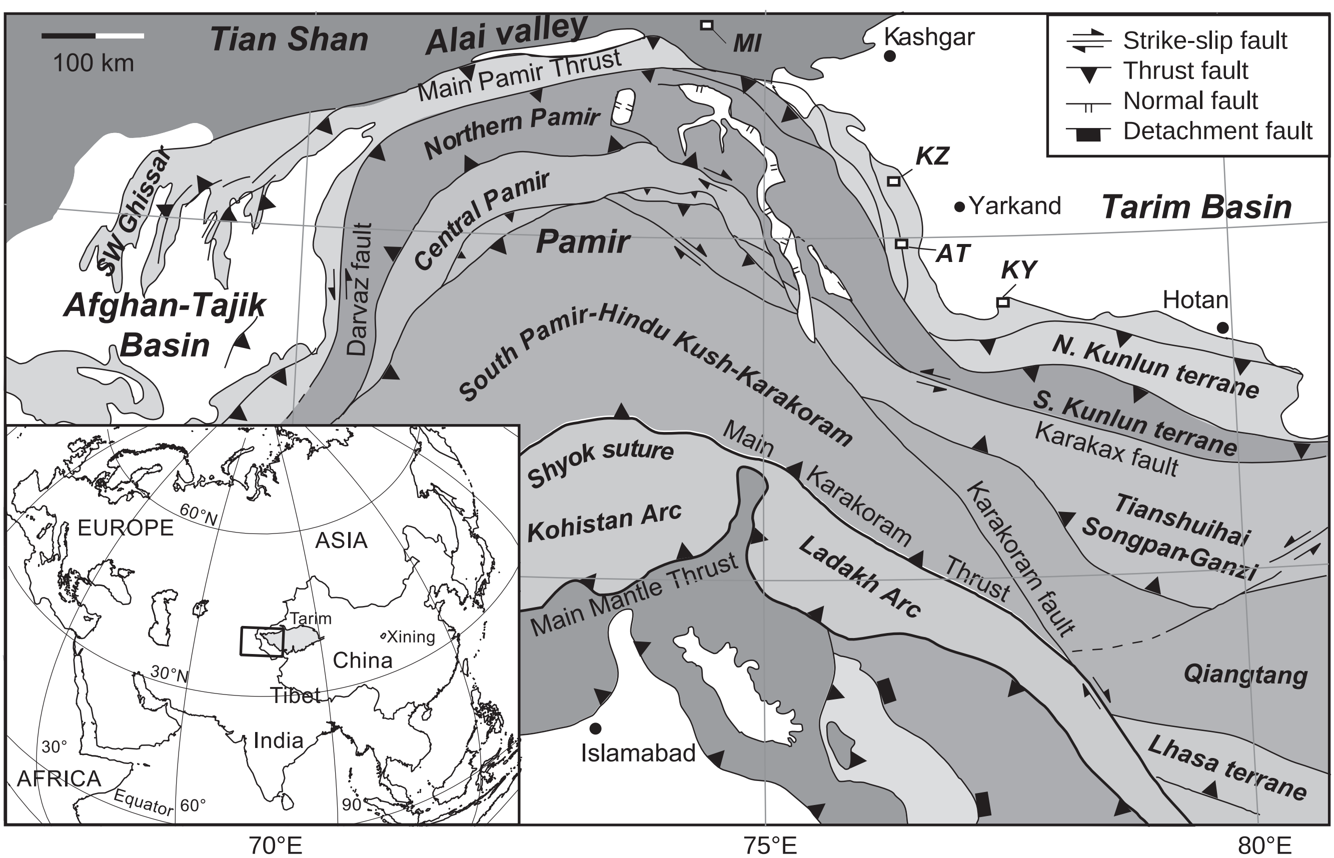

Fig. 1. Locations of the lithostratigraphic sections (MI = Bashibulake Mine; KZ = Kezi; AT = Aertashi; KY = Keliyang) are displayed on the schematic geological map of Central Asia displaying major tectonic features (modified from Cowgill, 2010). The inset shows the locations of the Tarim and Xining Basins on a large-scale map of Eurasia (present-day coastal outline obtained from GPlates 0.9.7.1).