Earth and Planetary Science Letters 499 (2018) 95–106

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

www.elsevier.com/locate/epsl

Late Cretaceous–Palaeogene topography of the Chinese Tian Shan: New insights from geomorphology and sedimentology

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ARTICLE INFO

Article history:
Received 12 April 2018
Received in revised form 25 June 2018
Accepted 1 July 2018
Available online xxxx
Editor: A. Yin

Keywords:
topographic heritage
Central Asia
Tian Shan
geomorphology

ABSTRACT

The Cenozoic growth of the intra-continental Tian Shan Range initiated during the late Eocene–Oligocene, and led to a tectonic reactivation of the complex Palaeozoic and Mesozoic lithospheric structure. Due to the very low erosion rates linked to the semi-arid climate that characterised the Tian Shan region during most of the Cenozoic, the topography of the range is not at equilibrium with deformation. Fragments of pre-orogenic low relief surfaces are preserved among the Late Cenozoic Alpine-type topography. Using field observations and satellite image mapping of those fragments, as well as sedimentology and biostratigraphic analysis, we show that the pre-Oligocene topography of the Tian Shan region was indeed complex, combining hundreds of metres to one-and-a-half kilometre-high reliefs with a multi-phased Mesozoic planation surface incised by Late Mesozoic paleo-valleys. The occurrence of several metres-thick Late Cretaceous–Palaeogene calcareous paleosols, in the basins surrounding the range further implies a semi-arid climate, very low subsidence rates and no uplift at that time. Late Cretaceous and early Miocene fossil records in the northern Tian Shan suggest a possible connection, even if episodic, between the drainage system of the south Junggar foreland basin and the proto-Paratethys Sea to the west. A renewed late Eocene–early Oligocene sedimentation probably marks the onset of the Tian Shan uplift. We argue that in addition to the growth of the Pamir and Western Kunlun ranges, this incipient uplift was one of the driving mechanisms for the final retreat of the proto-Paratethys Sea from the Tarim Basin. This regression apparently did not change the climate in the studied area because semi-arid conditions seem to prevail at least since the Late Cretaceous. Finally, the Tian Shan uplift remained very limited up to the Miocene as revealed by the occurrence of Burdigalian lake deposits preserved in the paleo-valleys inside the present day range. In contrast, post-early Miocene deformation of the northern Tian Shan has produced 4000 to 5000 m of differential vertical movement between the uplifted range and the subsiding proximal foreland basin.

1. Introduction

Many studies dealing with the topographic evolution in active mountain ranges focus on understanding and quantifying the distribution of surface uplift and erosion through time (Clark et al., 2006; Finnegan et al., 2008; Liu-Zeng et al., 2008; Ouimet et al., 2010; Sugai and Ohmori, 1999; Wang et al., 2014). These constraints are also crucial to decipher the feedbacks between tectonics, erosion and climate. However, the occurrence of a pre-existing relief or an antecedent hydrographic network within a range has implications on the calculated amount of surface uplift and erosion. These initial topographic features also influence the assessment of rock uplift, drainage evolution and sediment sources, as well as of the regional climate dynamics (e.g. orographic effects linked to inherited relief may pre-date the studied period). Consequently, documenting the initial topography of an orogen brings valuable insights on range evolution and landscape dynamics (Burbank et al., 1999; Hetzel et al., 2011).

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https://doi.org/10.1016/j.epsl.2018.07.004

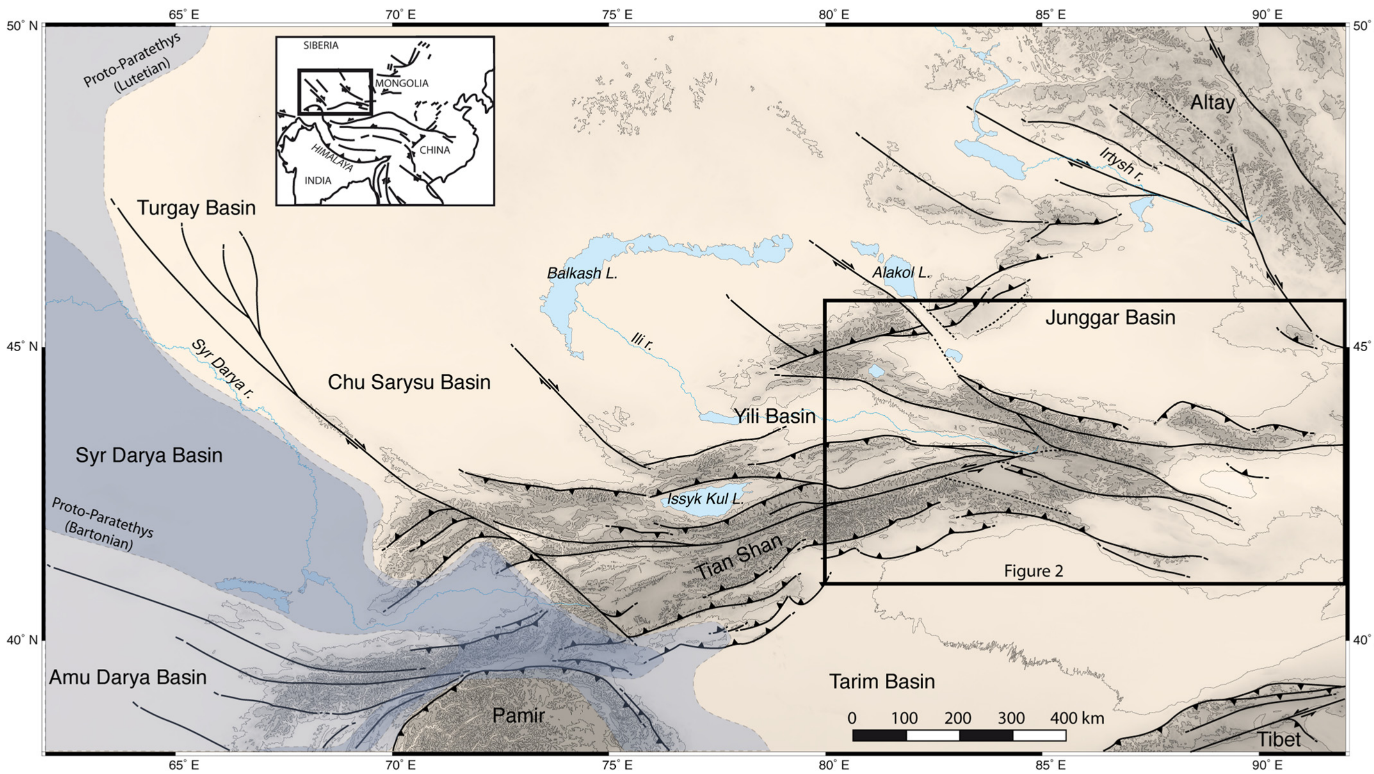

Fig. 1. General geographic and structural framework of the Tian Shan Range. The areas shaded in grey indicate the extent of the proto-Paratethys Sea during the two last transgression events in the Lutetian and Bartonian (Bosboom et al., 2014, 2017). Note that these envelopes are defined on the actual topography and that the extension of the sea towards the Pamir area is unknown. (For interpretation of the colours in the figure(s), the reader is referred to the web version of this article.)

In Central Asia, the intra-continental Tian Shan Range is a complex, multi-phased orogenic belt that was reactivated from the late Oligocene in response to the India–Asia collision (Avouac et al., 1993; De Grave et al., 2012; Dumitru et al., 2001; Tapponnier et al., 1986) (Fig. 1). The Cenozoic deformation is superimposed on and reactivates inherited Palaeozoic and Mesozoic lithospheric structures (Dumitru et al., 2001; Buslov et al., 2007; Jolivet et al., 2010 (see below)). Largely due to the semi-arid climate conditions that seem to prevail in Central Asia during most of the Cenozoic, the topography of the range still contains topographic features that existed prior to the onset of the Cenozoic orogeny (Dumitru et al., 2001; Guerit et al., 2016; Charreau et al., 2017). Our study focuses on geomorphic analysis of key relics of this paleo-topography preserved within the northern Chinese Tian Shan, as well as on analysis of Palaeogene to Miocene sediments exposed both within perched paleo-valleys in the range and in the Tarim and Junggar basins (Fig. 1). We show that the pre-Oligocene Tian Shan already had a structured topography. During the Palaeogene, thick calcrete layers indicate very low subsidence rates in the surrounding basins, a seasonal semi-arid climate and an absence of strong vertical tectonic movement.

2. Overview of the Mesozoic tectonic and topographic evolution of the Tian Shan Range

Following the Late Carboniferous–Early Permian final accretion of various continental blocks and arc-type terranes (Charvet et al., 2011; Wang et al., 2007), the paleo Tian Shan Range was affected by a major Early Permian to Early Triassic transcurrent tectonic regime that reactivated the main Late Carboniferous–Early Permian structures. This episode induced major exhumation and relief building in the range as well as the formation of pull-apart basins along the major strike-slip faults (Allen et al., 1995; Dumitru et al., 2001; De Jong et al., 2009; Jolivet et al., 2010; Yang et al., 2013). The Triassic to Jurassic period was then characterised by slow basement exhumation indicative of a progressive relief decrease (Dumitru et al., 2001; De Grave et al., 2007; Jolivet et al., 2010; Li et al., 2010). Extensive Lower to Middle Jurassic coal deposits in the Tarim and Junggar basins further suggest flat depositional landscapes with limited detrital input into the basins surrounding the range (Hendrix et al., 1992). However, the Triassic to Jurassic period was also marked in the Tian Shan region by discrete, mostly compressive tectonic events essentially linked to the accretion of the Cimmerian blocks along the southern margin of Asia (Allen et al., 1991; Hendrix et al., 1992; Allen and Vincent, 1997; De Grave et al., 2007; Yang et al., 2013). During the Cretaceous, renewed compressive deformation in the Tian Shan area is evidenced from basement cooling (De Grave et al., 2007; Glorie et al., 2010) and basin inversion (Hendrix et al., 1992; Li and Peng, 2010; Yang et al., 2013), possibly driven by the Early Cretaceous accretion of the Lhasa block along the southern margin of Tibet (Kapp et al., 2007) and by the closure of the Mongol–Okhotsk Ocean in Siberia (Zorin, 1999). Nonetheless, these tectonic movements and associated exhumation–erosion processes have been limited enough to allow the continuous development of the still preserved Mesozoic planation surface, although they most probably reworked it, leading to multi-phased nested surfaces rather than to a continuous one.

3. Preserved fragments of a Mesozoic–Early Cenozoic topography

3.1. *Basement-cut planation surfaces in the Tian Shan range: overview*

Numerous fragments of basement-cut planation paleo-surfaces are exposed within Central Asia (Berkey and Morris, 1924; Allen et al., 2001; Cunningham, 2007; Cunningham et al., 2003a, 2003b; Devyatkin, 1974; Jolivet et al., 2007; Owen et al., 1999). However, the exact age of these surfaces is still largely debated. To