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From oblique accretion to transpression in the evolution of the Altaid collage: New insights from West Junggar, northwestern China

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ABSTRACT

Along active margins, tectonic features that develop in response to plate convergence are strongly controlled by subduction zone geometry. In West Junggar, a segment of the giant Palaeozoic collage of Central Asia, the West Karamay Unit represents a Carboniferous accretionary complex composed of fore-arc sedimentary rocks and ophiolitic mélanges. The occurrence of quasi-synchronous upright folds and folds with vertical axes suggests that transpression plays a significant role in the tectonic evolution of the West Junggar. Latest Carboniferous (ca. 300 Ma) alkaline plutons postdate this early phase of folding, which was synchronous with accretion of the Carboniferous complex. The Permian Dalabute sinistral fault overprints Carboniferous ductile shearing and split the West Karamay Unit ca. 100 km apart. Oblique convergence may have been provoked by the buckling of the Kazakh orocline and relative rotations between its segments. Depending upon the shape of the convergence zone, either upright folds and fold with vertical axes, or alternatively, strike–slip brittle faults developed in response to strain partitioning. Sinistral brittle faulting may account for the lateral imbrication of units in the West Junggar accretionary complex.

1. Introduction

In contrast with strictly frontal convergence, which is rarely observed, examples of oblique subduction are widespread (Chamot-Rooke and Rabaute, 2007), and often generate strike–slip faults parallel to the upper plate boundary (Allen, 1965; Katili, 1970). The western North American Cordilleras, Andes, Taiwan, and Sumatra are the best examples of such an oblique convergent setting. Fitch (1972) was the first to link the tectonic structures in the upper plate to the oblique slip of the lower plate. Based on earthquake focal mechanisms in western Pacific, he proposed that the total decoupling of the oblique slip would result into a component of convergence normal to the trench and a shearing component parallel to the trench marked by transcurrent faulting. Beck (1983) improved this model by establishing the geometric and thermal constraints that favour decoupling of oblique convergence. Very oblique convergence, gently dipping subduction and thermal softening of the upper plate are the main conditions that favour the decoupling of oblique slip in a subduction zone.

Because total decoupling of oblique convergence is rarely achieved at sites of oceanic subduction, McCaffrey (1992) proposed a partial decoupling model, and demonstrated that margin geometry could influence the tectonic response of the upper plate. Therefore, oblique convergence along a concave or a convex subduction zone toward the ocean will be accommodated by transpression or transtension, respectively. The present curvature of the western Sunda and Aleoutian subduction zones (Ekström and Engdahl, 1989; McCaffrey, 1991) are good paradigms of oblique slip partitioning that may also be reproduced by analogical modelling (Chemenda et al., 2000). The rheology of the accretionary wedge also influences the geometric variability of the subduction zone (Platt, 1993). Very oblique convergence would logically generate an intense slicing of the upper plate boundary (Martinez et al., 2002). Triple junctions and ridge subduction can also account for the initiation or reactivation of strike–slip faults in the overriding plate (Thorkelson, 1996; Roeske et al., 2003).

Lateral tectonic transport along the active margin is a direct consequence of decoupling (Coney et al., 1980; Beck, 1983; Jarrard, 1986); it is referred as "Sunda style" tectonics (Beck, 1983), and thousands of kilometres along-margin displacements have been evidenced in far-travelled allochthonous terranes of western North America (Beck, 1980; Coney et al., 1980). However, in most cases, terrane travelling is limited to a few tens of kilometres (Beck, 1986). This variability depends upon the age and obliquity of the subduction, and occurrence of a buttress or not (Beck, 1991). Therefore, oblique

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convergence that may result in lateral terrane transport significantly contributes to lateral growth of the continental margin and, consequently, to a reorganisation of the continental crust pattern.

During the last decades, Mesozoic and Cenozoic cases of oblique subduction have been established in the Circum-Pacific area, (Karig et al., 1978; Engebretson et al., 1985; Kimura, 1986; Reutter et al., 1991; Beck et al., 1994; Kusky et al., 1997a,b) by comparison with modern analogues (Malod et al., 1995; Goldfinger et al., 1996; Lallemand et al., 1999). In contrast, oblique subduction is rarely documented in older accretionary orogens (Henderson, 1987; Veevers, 2003). The purpose of this article is to report an example of Palaeozoic oblique convergence and to discuss its regional geodynamic controls.

The Altaids (Sengör et al., 1993; Sengör and Natal'in, 1996) or Central Asian Orogenic Belt (CAOB; Mossakovsky et al., 1993; Windley et al., 2007; Rojas-Agramonte et al., 2011) are a wide orogenic collage formed during the Palaeozoic as a result of the convergence of Siberia, Baltica, Tarim, and North China blocks (Fig. 1a). Because of post-Palaeozoic tectonics, the present structure exhibits a distorted pattern of accretionary complexes, magmatic arcs, and ribbon-like micro continents. Several conflicting models have been proposed for the Altaids (for a review see Windley et al., 2007 and Xiao et al., 2010). The Kipchak Arc model is characterised by a single long-lived subduction that was later shredded by strike–slip faults (Sengör et al., 1993; Sengör and Natal'in, 1996). An archipelago model was alternatively proposed (Filippova et al., 2001; Xiao et al., 2008); it consists of accreted and laterally docked pairs of associated accretionary complexes and magmatic arcs. A remarkable feature of the Altaids is the presence of horseshoe-shaped belts, such as the Kazakh Orocline (Fig. 1b; Abrajevitch et al., 2008), or the Central Mongol Orocline (Yakubchuk, 2008). These structures are intimately associated with lithosphere-scale strike–slip faults along which palaeomagnetic evidence document block rotations and displacements over thousands kilometres (Van der Voo et al., 2006; Wang et al., 2007; Choulet et al., in press); however, the link between oroclinal bending, transcurrent faulting and accretion remains poorly understood.

This study deals with the structural pattern of the Late Palaeozoic West Karamay accretionary complex, in order to document transcurrent tectonics and lateral docking. On the basis of new geochronological data and multi-scale structural analysis, we present the first evidence of an oblique convergent system in West Junggar. Considering the structural pattern of the Central Asian puzzle, we discuss the possible origin of oblique subduction, and the controls of regional geodynamics on the geometry of the convergent plate boundary.

2. Geological outline

2.1. Central Asia

In the central part of the Altaids, a region that extends from central Kazakhstan to Xinjiang (northwestern China), three main geological domains are recognised (Fig. 1b). To the northeast, (1) the Altai range is composed by Early and Late Palaeozoic units that were accreted and docked to the Siberian margin and affected by high-grade metamorphism (Windley et al., 2002; Xiao et al., 2004). To the south, the convergence between the Tarim Block and several micro continents such as Yili and Central Tianshan formed the (2) Palaeozoic Tianshan Orogen (Charvet et al., 2007). The central and northwestern parts of Central Asia display a horseshoe shape that can be followed from North Tianshan to West Junggar around the Balkash Lake area (Fig. 1b). This megastructure is termed the (3) Kazakh Orocline (Zonenshain et al., 1990). In central Kazakhstan, the outer part of the orocline is made of micro continents and intra-oceanic arcs, which amalgamated during the Early Palaeozoic (Kröner et al., 2008). In the inner part of the orocline, the subduction of the Junggar Ocean below the Kazakhstan active margin generated Late Palaeozoic accretionary complexes and magmatic arcs (Degtyarev, 1999; Wang et al., 2006; Windley et al., 2007). To the north of this domain (Fig. 1b), the Irtysh-Zaisan fold-and-thrust Belt results from the Late Carboniferous closure of the Ob-Zaisan Ocean that originally separated the Kazakh orocline and the south-western margin of Siberia (Buslov et al., 2004).

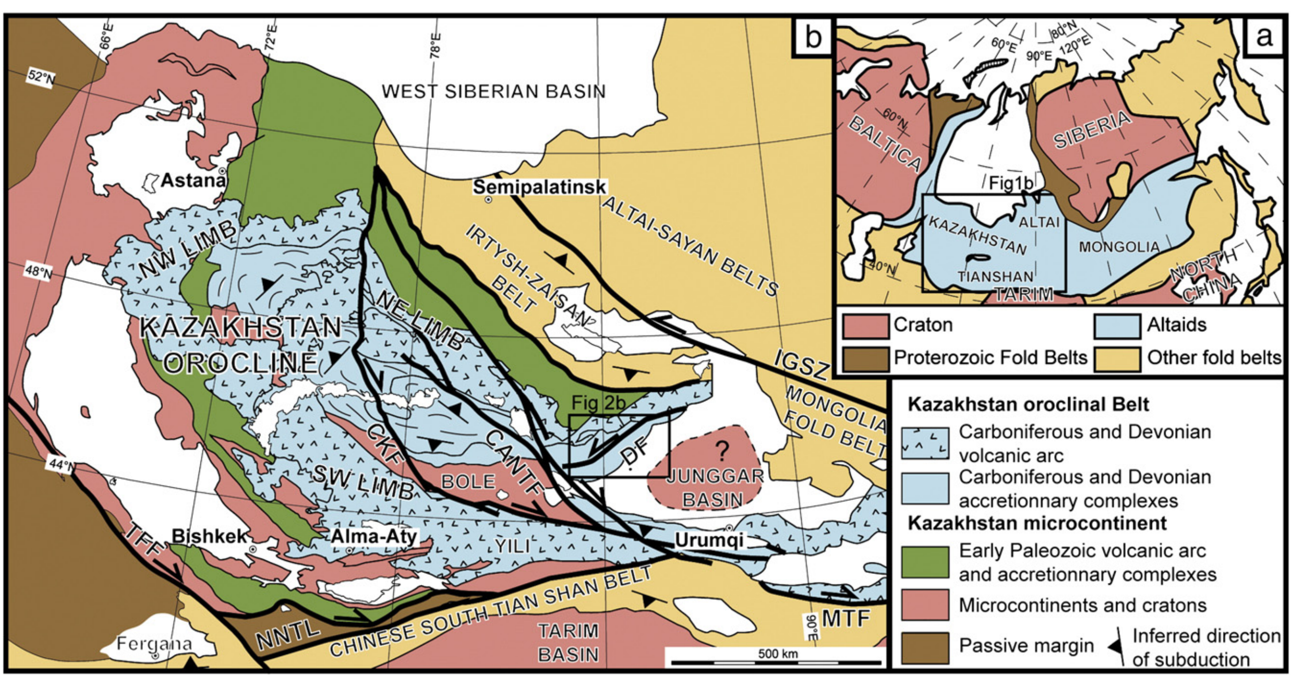

Fig. 1. a) location of the Altaids including major cratons and orogenic belts of Eurasia. b) structural map of western Altaids, modified after Windley et al. (2007) and Charvet et al. (2007). The Devonian to Carboniferous Kazakh orocline lying on the pre-Devonian Kazakhstan microcontinent is the major structure of this region. The nature of the microcontinent in the core of the orocline, below the Junggar basin is still controversial, and a discussion on this topic is beyond the scope of this paper. Major faults are also represented. BOLE: Bole Block, CANTF: Chingiz-Alakol-North Tianshan, CKF: Central Kazakhstan Fault, DF: Dalabute Fault, IGSZ: Irtysh-Gornotsaev Shear Zone, MTF: Main Tianshan Fault, NNTL: Nalati-Nikolaiev Teconic Line, TTF: Talas-Fergana Fault.