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Paleozoic multiple accretionary and collisional tectonics of the Chinese Tianshan orogenic collage

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ABSTRACT

Subduction-related accretion in the Junggar–Balkash and South Tianshan Oceans (Paleo-Asian Ocean), mainly in the Paleozoic, gave rise to the present 2400 km-long Tianshan orogenic collage that extends from the Aral Sea eastwards through Uzbekistan, Tajikistan, Kyrgyzstan, to Xinjiang in China. This paper provides an up-to-date along-strike synthesis of this orogenic collage and a new tectonic model to explain its accretionary evolution.

The northern part of the orogenic collage developed by consumption of the Junggar–Balkash Ocean together with Paleozoic island arcs (Northern Ili, Issyk Kul, and Chatkal) located in the west, which may have amalgamated into a composite arc in the Paleozoic in the west and by addition of another two, roughly parallel, arcs (Dananhu and Central Tianshan) in the east. The western composite arc and the eastern Dananhu and Central Tianshan arcs formed a late Paleozoic archipelago with multiple subduction zones. The southern part of the orogenic collage developed by the consumption of the South Tianshan Ocean which gave rise to a continuous accretionary complex (Kokshaal–Kumishi), which separated the Central Tianshan in the east and other Paleozoic arcs in the west from cratons (Tarim and Karakum) to the south. Cross-border correlations of this accretionary complex indicate a general southward and oceanward accretion by northward subduction in the early Paleozoic to Permian as recorded by successive southward juxtaposition of ophiolites, slices of ophiolitic mélanges, cherts, island arcs, olistostromes, blueschists, and turbidites, which are mainly Paleozoic in age, with the youngest main phase being Late Carboniferous–Permian. The initial docking of the southerly Tarim and Karakum cratons to this complicated late Paleozoic archipelago and accretionary complexes occurred in the Late Carboniferous–Early Permian in the eastern part of the Tianshan and in the Late Permian in the western part, which might have terminated collisional deformation on this suture zone. The final stages of closure of the Junggar–Balkash Ocean resembled the small ocean basin scenario of the Mediterranean Sea in the Cenozoic. In summary, the history of the Altaids is characterized by complicated multiple accretionary and collisional tectonics.

1. Introduction

The architecture of the Central Asian accretionary orogenic collages and the geodynamic implications for Phanerozoic continental growth have long been a major concern of the international community (Zonenshain et al., 1990; Xiao and Tang, 1991; Xiao et al., 1992; Mossakovsky et al., 1993; Şengör et al., 1993; Cawood et al., 2009). The Tianshan (Tien Shan, or Tian Shan) orogenic collage records the long-lived, north-to-south (present coordinates) accretion of the Altaids (Şengör et al., 1993), or Central Asian Orogenic Belt (Windley et al., 2007), forming one of the largest accretionary orogens in the planet (Cawood et al., 2009).

Many international programs including IGCP and ILP (Seltmann et al., 2001; Jahn et al., 2004; Wang et al., 2010) and individual research groups have studied the geology and tectonic history of the Altaids. Earlier political divisions between the western and eastern parts delayed along-strike correlations and led to many tectonic units being described and interpreted differently in China, Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan and Russia. Subsequent disagreement about geological interpretations across and along the Tianshan led to a lack of current consensus. For example, emphasizing Precambrian microcontinents, closure of multiple oceans and formation of arcs, Zonenshain et al. (1990), Filippova et al. (2001), and Mossakovsky et al. (1993) proposed a general archipelago model for the Paleozoic paleogeography. This was followed and modified by several research

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groups (Shu et al., 2002; Charvet et al., 2007; Wang et al., 2007a, 2011). Meanwhile, Hsü and Haihong (1999) put forward an idiosyncratic backarc-collapse model for all the Paleozoic accretionary orogens of China. Recognizing the similarity of innumerable island arcs, Şengör et al. (1993) and Şengör and Natal'in (1996) suggested a strike-slip imbricated, single-arc, forearc accretion model. Yakubchuk (2004) placed less emphasis on strike-slip duplication and more on collisions, and recognized a greater number of arcs and back-arc basins. In contrast, further field investigations constrained by detailed geochronology of many parts of the Altaids found that the complex relationships could only be accounted for by the formation of multiple subduction zones of different polarity and of different age that were responsible for the formation of multiple episodes of subduction–accretion and eventual collision (e.g. Charvet et al., 2007, 2011; Kröner et al., 2007; Windley et al., 2007; Wang et al., 2010; Xiao et al., 2004b, 2009a, 2010b,c; Heubeck, 2001). Many fundamental problems remain to be addressed, in particular regarding the age and subduction polarities during accretion and final orogenic events.

The aim of this contribution is to present an along-strike synthesis and re-assessment of the orogen and a new model to explain its accretionary evolution from early subduction–accretion, via an Andean-stage of development, to final amalgamation that led to the Turkestan suture and termination of the orogenic collages. To help interpretation of the surface geology, we have used several, detailed geological–geophysical profiles (Burtman, 1975, 1980; Li and Cui, 1994; Mikolaichuk et al., 1997; Lesik and Mikolaichuk, 2001; Bazhenov and Mikolaichuk, 2004; Li et al., 2004b; Xiao et al., 2004b, d, 2010c; Biske and Seltmann, 2010; Makarov et al., 2010).

2. Regional tectonic background and different terminologies

2.1. Regional tectonic background

The present geographical Tianshan is a mountain range that extends for more than 2400 km from the Aral Sea in Uzbekistan, via northern Tajikistan, Uzbekistan, and Kyrgyzstan to northern Xinjiang in China (Figs. 1 and 2). The geographical situation west of the bulwark of Tibet and north of the Pamirs syntaxis (Fig. 2) enabled maximum impact of the post-collisional tectonics of the India–Asia collision, which caused exhumation since at least the Oligocene of the modern Tianshan mountain belt (Windley et al., 1990; Hendrix et al., 1992). This deformation and uplift continues to the present-day (Allen et al., 1994; Bullen et al., 2001; Coutand et al., 2002; Poupinet et al., 2002; Bullen et al., 2003). Accepting that what we see today is only the result of Cenozoic uplift of a distinctive part of the Altaids, we use the term 'Tianshan orogenic collage' for the present uplifted mountain range of the Tianshan, which internally has extensive geological along-strike continuity.

However, a problem has arisen over many years, in particular because the Central Tianshan is wide in the west, but narrows eastwards to disappear in western China. As a result researchers in different parts of the Tianshan have identified and produced different subdivisions, which then have created problems of along-strike correlation of tectonic belts. This was done at a time with fewer time constraints by isotopic data than now, and as a result, there is little east–west consensus on the basic architecture of the Tianshan collage, and on across-strike correlations and therefore on the numbers of sutures and their polarities. Particularly controversial is the timing of collision of the Tarim and Karakum Cratons to the Tianshan collage: Latest Silurian to Devonian (Yue et al., 2001), middle to late Devonian (Tang, 1990), late Devonian to early Carboniferous (Graham et al., 1990, 1993), late Permian (Ruzhentsev et al., 1989), or Permian–Triassic (Zhang et al., 1984, 2007; Xiao et al., 2009b).

Furthermore, although there is little controversy about the southward subduction that closed the North Tianshan ocean, there are differences of opinion on the polarity of the subduction zone that closed the South Tianshan Ocean: northward (Burtman, 1975, 1980; Gao et al., 1995; Chen et al., 1999; Xiao et al., 2004d; Zhang et al., 2007; Gao et al., 2009b; Alexeiev et al., 2011), or southward (Shu et al., 2002; Charvet et al., 2007, 2011; Wang et al., 2007a, 2011). These differences reflect variations in interpretation of the geological and structural environments and the local, often limited, availability of fossil and isotopic age data. Therefore, it is timely to re-evaluate the nature, age constraints, and tectonic settings of the various tectonic units of the Tianshan orogenic collage.

2.2. Different terminologies

Before the major tectonic units are described, we clarify the different terminologies used along the length of the Tianshan (Figs. 2 and 3A and B).

The Paleozoic framework of the Tianshan orogenic collage is characterized by several tectonic belts that are separated by ophiolitic mélanges (Windley et al., 1990; Sun et al., 2008; Ren et al., 2011; Dong et al., 2011). Traditionally, a three-fold subdivision has been applied to the Tianshan orogenic collage: North, Central, and South Tianshan in China, and North, Middle and South Tienshan in Kyrgyzstan (Fig. 3). The South Tianshan Units contains ophiolitic mélanges, which separate the Tarim and Karakum Cratons (Fig. 1) to the south from the Central or Middle Tianshan and other similar units to the north. The North Tianshan Unit in China contains ophiolitic mélanges, which separate a mosaic of various units from the Dananhu Unit to the north (Figs. 2 and 3).

The Chinese Northern Tianshan has no exact equivalent but belongs to Northern Tianshan in across the border to the west, and the Chinese Central Tianshan is roughly part of the Northern Tianshan in Kyrgyzstan (Burtman, 2006b, 2010). The Middle Tianshan in Kyrgyzstan has no recognized equivalent in China and appears to wedge out near the Kyrgyz–Chinese border, but the South Tianshan is continuous from west to east along the whole length of the orogenic collage (Burtman, 2006a, 2008). As the terms Northern and Middle (Median) Tianshan may cause confusion due to the above-mentioned lack of continuity, we retain "North Tianshan" for the Chinese Tianshan, and "South Tianshan" for the only continuous tectonic unit, which has also been termed the "Kokshaal–Kumishi" mélange zone or accretionary complex (Xiao et al., 2004c). The term "Kazakhstan–North Tienshan" (Zonenshain et al., 1990) refers generally to terranes in Kazakhstan and Kyrgyzstan, which will be referred to by their local names in this paper (Fig. 5).

In the following we describe, successively from northeast to southwest, the major tectonic units in the North Tianshan, Central Tianshan, and South Tianshan (see Fig. 5), starting north of the North Tianshan fault (Fig. 2). The Chinese Central Tianshan, between the North Tianshan fault and the Kokshaal-Kumishi fault, narrows markedly to the east; therefore we use "Northern Ili" for its western counterpart (Figs. 4 and 5). Likewise, the South Tianshan, south of the Kokshasl–Kumish fault, narrows eastwards towards the Kokshaal–Kumishi accretionary complex. Then, we discuss the polarity of subduction that closed the South Tianshan Ocean, and finally we propose a new tectonic model and discuss its significance for the development of the Altaids.

3. Northern tectonic units

3.1. Dananhu Arc in China

The Dananhu (or Dananhu–Harlik) arc (Fig. 5) comprises from north to south, an Ordovician to Carboniferous–early Permian arc, a middle forearc mélange (Kanggurtag), and a southern Carboniferous forearc–arc (Yamansu) (Xiao et al., 2004c). The Dananhu arc is mainly composed of Ordovician to Devonian–Carboniferous volcanic and pyroclastic rocks and accretionary complexes composed of turbidites, basalts, cherts, and ultramafic rocks (Qin, 2000; Qin et al., 2002; Li et al., 2003; Xiao et al., 2004c). Ordovician–Silurian calc-alkaline