Late Paleozoic tectonics of the Junggar-Altai–Sayan Foldbelt

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Abstract. This paper presents new tectonic model for the Late Palaeozoic evolution of the Jungar-Altai–Sayan Fold Belt in the context of large-amplitude (hundreds to several thousands of kilometres) strike-slip movement along regional NW-trending fault zones. These include the following regional fault zones: Chara, Irtysh, Northeast, Charysh–Terekta and Kurai-Teletsk, as well as the thrusts associated with them kinematically: Tangbale-Kolameili, Mayile, Barleik–Hongguleleng, Kaim, North Sayan thrust fault and Kurtushuba. 1. Introduction

The Junggar-Altai-Sayan Foldbelt (JASFB) forms the northwestern part of the Cenatral Asian Orogenic Belt (CAOB) and is situated between the Siberian and the Kazakhstan–Baikal continents (figure 1). It extends across the political boundary of Russia, Kazakhstan, Kyrgyzstan, China and Mongolia. Most of the above publications adopted the view presented in the article [1] that at the end of the Ordovician, the Kazakhstan (Kazakhstan-Kirghiz) continent, which formed by accretion of island arcs and Precambrian continental blocks of Gondwana, divided the Paleoasian ocean into four oceanic basins: Ural, Turkestan, Junggar-Balkhash and Ob’-Zaysan. The Ob-Zaisan ocean was located between the Kazakhstan and the Siberian continents (blocks). By the earliest Permian the continents amalgamated with each other. On the border of the two collided continents (Kazakhstan and Siberia), the Ob-Zaisan (Zaisan-Junggar) orogenic belt was formed. It is believed that the Chara ophiolitic belt is its suture zone of the Ob-Zaisan ocean. The Chara zone of the Eastern Kazakhstan in the Southern part can be traced as the territory of Northwestern China. Here the tectonic boundary between the Chinese Altai and the West Junggar is exposed to the approximately WNW-ESE–trending faults [2, 3]. It is assumed that the origin of the Chinese Altai was associated with northward subduction of the Ob-Zaisan oceanic crust. The closure of the Ob-Zaisan ocean between the Chinese Altai and the East/West Junggar in NW China commenced in the late Carboniferous. The subsequent arc collision occurred along the Irtysh Shear Zone and was characterized as the crustal thickening (ca. 323–295 Ma), orogen-parallel extension (ca. 295 Ma), and transpressional deformation (ca. 286–253 Ma).

Late Palaeozoic strike-slip deformation is a dominant feature in the structure of CAOB [4, 6-12]. This is responsible for the formation of an intricate orogenic collage of terranes that originated as a result of (a) Late Devonian to Early Carboniferous collision between the Kazakhstan (Kazakhstan–Baikal) composite continent and the Siberian Craton but also of (b) a Late Carboniferous to Permian collision between the East European and Siberian continents and the
Kazakhstan–Baikal continent [6,7,9,10,13,14-16]. As a consequence of these collisions, the Vendian (Ediacaran) to middle Palaeozoic margins of the Siberian and East European continents and the entire Kazakhstan–Baikal composite continent have been fragmented into several strike-slip terranes by large amplitude strike-slip faults and conjugate thrust faults (figures 1,2). These domains were consequently displaced, and their original geodynamic, tectonic, and palaeogeographic demarcation was disrupted.

2. Main tectonic and geodynamic elements of the Junggar-Altai–Sayan Foldbelt

The following tectonic elements of the of the Junggar-Altai-Sayan fold belt are distinguished in the publications [4,9,13,14,17-21] (figure 1):

1. The Neoproterozoic-Paleozoic continental margin complexes on the Western margin of the Siberian continent (in the present coordinates), which include the Neoproterozoic- Early Ordovician Kuznetsk-Altai island-arc, Ordovician-Early Devonian passive margin and Devonian-early Carboniferous active margin. The accretionary wedges of the island arcs contain only the oceanic crust fragments (paleoseamounts and ophiolites). New geochronological data on magmatic detrital zircons from Paleozoic sedimentary rocks of the Western margin of the Siberian craton [22] suggest their provenance from the Mesoarchean–Paleoproterozoic basement of the Siberian craton and from the Neoproterozoic- Early Ordovician Kuznetsk–Altai island arc. It should be noted that in these sedimentary rocks the Neoproterozoic (0.90-1.4 billion years) detrital zircons characteristic of the Grenvillian orogeny of Gondwana are completely absent. The absence of Gondwana-derived terranes on the Western margin of the Siberian craton assumes that it may have been formed at the convergent boundary with the Paleo-Pacific, which consists only of their oceanic crust.

2. The composite Kazakhstan-Baikal continent has a basement that was formed in the Neoproterozoic - Ordovician time during the subduction of the Paleoasian oceanic plate, comprising the collage of Precambrian Gondwana-derived microcontinents and terranes (Tuva-Mongolian, Dzabhan, Kokchetav, Karatau, Ulutau, Aktau-Moitin, Tarbagatai, Issyk-Kul’, Central Tianschan and others), beneath the Kazakhstan-Tuva-Mongolian island arc along the southeastern

Figure 1. Scheme showing major geodynamics units of the Altai-Junggar intracontinental orogeny.
margin of the Siberian craton (in the present coordinates). For the Gondwana blocks, orogenic events of the Grenville age (0.90-1.4 billion years) are characteristic. The Paleoasian oceanic plate subduction and the subsequent collision of microcontinents and terranes with the island arc led to the crustal growth and formation of the composite continent basement. In the Ordovician time, the basement of the Kazakhstan-Baikal composite continent consisted of the accretionary-collisional arcs collage, microcontinents (cratonic terranes), continental-margin terranes, and accretionary complexes (flysch, olistostromes, fragments of oceanic crust and UHP and HP rocks of paleo-subduction zones derived from the deep subducted parts of continental and oceanic terranes). In the Middle-Late Paleozoic time, the composite continent had active margins, and a part of sediments were deposited in its interior [10, 20].

3. The Middle Paleozoic Charysh-Terekta-Ulagan-Sayan suture-shear zone, which separates the continental-margin complexes of the Siberian and Kazakhstan-Baikal continents. In the Altai-Sayan segment (Charysh-Terekta, Ulagan, and Western Sayan), this zone consists of fragments of Late Ediacarian-Early Ordovician oceanic crust of the Ob’-Zaisan oceanic basin, Ordovician blueschists and Ordovician-Silurian turbidites, Late Silurian-Devonian high grade metamorphic rocks and granites. In the east the suture-shear zone is traced in the Early-Middle Paleozoic Ol’khon suture-shear zone [10]. The westward movement of the Kazakhstan-Baikal continental masses along the southeastern margin of Siberia brought the gradual closure of the Ob’-Zaisan oceanic basin (Figures 1, 2). The scientific articles [4, 9, 14, 22-27] have shown that the subduction of the oceanic crust took place beneath the Altai-Mongolian terrane with the Northern. The fragments of paleosubduction zone preserved in the Charysh-Terekta-Ulagan-Sayan and in the Junggar were strongly separated by Late Paleozoic faults. The preserved total length of the paleosubduction zone exceeds two thousand km from the Chinese Altai to the Western Sayan.

3. Tectonics and geodynamics of the Junggar-Altai–Sayan Foldbelt in the Late Paleozoic

A series of very large (up to many hundreds of kilometers) Late Paleozoic strike-slip faults systems were developed in the western CAOB [4-9, 29-35]. Late Paleozoic strike-slip faults controlled the orogenic collage of terranes which formed in two major events: (1) Late Devonian-early Carboniferous collision between Kazakhstan (Kazakhstan-Baikal) and Siberia and (2) Late Carboniferous-Permian collision of East Europe, Kazakhstan-Baikal, and Siberia [4, 9, 18, 19]. Late Carboniferous-Permian strike-slip faulting (Chingiz-Tarbagatai, Chara, Irtysh, and North Eastern) was the most intense in the East Kazakhstan and divided the composite continent into the Kazakhstan and Baikal blocks, which were deformed into large orocline folds. The Late Paleozoic strike-slip faults also divided the Early-Middle Paleozoic active marginal of the Ob-Zaisan ocean into a number fragments: Tangbale, Mailsk, Barkil-Khongulen-Khebukesair, Chara, Charysh-Terekta, Ulagan, Sayan (figures 1, 2).

Along the border of Kazakhstan and Baikal blocks of the Kazakhstan-Baikal continent, there are three sinistral-lateral shear fault systems (Chara, Irtysh Shear and North-East) that include tectonic plates (terranes) of accretion-collision complexes of the Siberian continent (Figures 1, 2). The Chara Shear Zone and the North-East Fault are merged into the Irtysh Shear Zone in NW China. Geochronological data shows that the major phase of sinistral shearing in Late Permian (~285-255 Ma), with a likely reactivation during the Meso-Cenozoic [27, 29, 33, 36-39]. The Chingiz-Targabatai Fault in the Central Kazakhstan and the Dalabute Fault in NW Chine were developed along the northern limb of the Kazakhstan block (Figures 1, 2) [6,7,31]. The Central Kazakhstan Fault trending ~N-S is characterized as a dextral kinematics. The geochronological data indicates that the age of dextral shearing is in the Permian-Middle Triassic (~290-240 Ma) [31, 40]. Local evidence of the dextral shearing has also been demonstrated along the Irtysh Shear Zone in NW China, but the time of deformation is poorly constrained [31,33].

In the Gorny Altai (figures 1,2), the geodynamic complexes of the Western margin in the Siberian continent are mostly fully represented, which characterizes the early stages of the Paleo-Pacific ocean evolution, beginning from the Ediacarian era. They are represented in the central and northern part of the Gorny-Altai (Gorny-Altai terrane), as well as in Salir and Kuznetsk Alatau.
The Charysh-Terekta-Ulagan-Sayan suture-shear zone in the south separates the Gorno-Altai terrain from the Altai-Mongolian terrane, which is also located in the territory of the Mongolian and Chinese Altai. In the east the suture-shear zone is traced quite clearly in Lake Baikal (Ol’khon suture-shear zone) [10], and then in the Western direction it is deformed by transverse Late Paleozoic strike-slip faults, such as the Chingiz-Tarbagatai faults, Chara, Irtysh (Ergis), Northeast strike-slip faults and thrusts in the Junggar.

Figure 2. Schematic terrane structure of the East Kazakhstan, NW China and Altai–Sayan regions [4]. 1-Cenozoic–Quaternary deposits; 2-Siberian Craton; 3- strike-slip terranes of the Siberia continent; 4- Kazakhstan–Baikal composite continent; 5- Palaeozoic accretion complex in the Charysh–Terekta - Ulagan Sayan suture-shear zone, East Kazakhstan and Junggar, reactivated in the Late Paleozoic; 6- late Carboniferous to early Permian strike-slip terranes zones, 7- strike-slip fault and the direction of displacement; 8- thrust fault; 9- fault zones: Tangbale-Kolameili (1), Mayile(2), Barleik–Hongguleleng (3),Chara (4), Irtysh(5), Northeast(6), Charysh–Terekta (7), Kurai-Teletsk (8), Kaim (9), North Sayan thrust fault (10), Kurtushuba (11), and Main Sayan Fault (12).

Late Paleozoic deformations in Gorny Altai (figures 1,2) seem to have reactivated a complex structure, comprising the Neoproterozoic-Early Ordovician island-arc rock complexes of the Kuznetsk-Altai arc, overlain by Ordovician-Early Devonian successions of the passive margin and Devonian successions of the active margin, which compose the Kurai, Biya-Katun’ and Anyui-Chuya zones. Structurally, the geodynamic complexes of the above zones form an autochthon and are the characteristic features of the Late Precambrian-Paleozoic history of the Siberian continental margin. These complexes are bounded from the southwest, north, and east by the Late Paleozoic allochthons of the Charysh-Terekta, Kurai-Teletsk, and Kaim fault nappes. The most strongly deformed rocks of the autochthon (steep isoclinal locally overturned folds of different orders) where the Late Paleozoic thrust-nappes impinge on them [9].

4. Summary and conclusions
The results of this study improve our understanding of the evolution in the Jurassic-Altai–Sayan folded area and adjacent regions as a large Late Paleozoic strike-slip structure formed by intracontinental deformations. This orogeny resulted from the collision between the composite Kazakhstan–Baikal continent and Siberia with the formation of North Asia continent during the Late Devonian–early Carboniferous, and between the East European continent and North Asia
during the late Carboniferous–Permian. An important implication is the coeval development of Late Paleozoic major strike-slip faults and related nappes in the Junngar–Altai–Sayan folded area. Several Late Paleozoic deformation events have been identified in a vast area, from the Chinghiz–Tarbagatai strike-slip in the eastern Kazakhstan and associated thrusts in the NW China to the Major Sayan Fault the East Sayan along the margins of the Siberian craton. The correlation of structural and geochronological data in the Eastern Kazakhstan, NW China and the Altai–Sayan Foldbelt reveal the importance of Late Palaeozoic large-amplitude horizontal movements, particularly strike-slip, in the formation of the resulting structure of these regions once the intervening oceanic basins were closed (figure 1, 2).

The Early-Middle Paleozoic Charysh-Terekta-Ulagan-Sayan suture-shear zone was active until the Late Devonian - early Carboniferous as a result of the continental margins collision of the Siberian and Kazakhstan–Baikal continents. In the late Carboniferous-early Permian this sublatitudinal zone were separated by NW direction strike-slip faults into numerous terranes within a broad zone extending for 1500 km from Chingiz-Tarbagatai fault in Kazakhstan to Main Sayan fault in the East Sayan. This was accompanied by NW sinistral displacement along the Chara ophiolite zone as well as the Irtysh, Northeastern, Kurai, Teletsk–Bashkaua and the Main Sayan Fault (figure 1, 2) Late Palaeozoic strike-slip deformation is abundant in the structure of Central Asia. It disturbed (a) structural and formational zones that characterize the growth of continental crust, (b) the history of oceanic basins separating the East European continent (Baltica), Siberia, and Gondwana, and (c) accretionary and collisional processes associated with the growth of Central Asian crust. Late Devonian and early Carboniferous shearing produced a collage of terranes as a result of the collision between the Kazakhstan–Baikal composite continent (including continental blocks of Gondwana), Siberia and the subsequent formation of the North Asian continent. Late Carboniferous to Permian collision between the East European continent and Northern Asia led to fragmentation of the Southern part in the Ediacaran–Paleozoic margin of Siberia and of the entire Kazakhstan–Baikal composite continent by strike-slip and associated thrust faults. Consequently, a series of terranes formed that now constitute the structure of the Central Asian Orogenic Belt.

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