

Two-stage formation model of the Junggar basin basement: Constraints to the growth style of Central Asian Orogenic Belt

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Junggar Basin is located in the central part of the Central Asian Orogenic Belt (CAOB). Its basement nature is a highly controversial scientific topic, involving the basic style and processes of crustal growth. Some researchers considered the basement of the Junggar Basin as a Precambrian continental crust, which is not consistent with the petrological compositions of the adjacent orogenic belts and the crust isotopic compositions revealed by the volcanic rocks in the basin. Others, on the contrary, proposed an oceanic crust basement model that does not match with the crustal thickness and geophysical characteristics of the Junggar area. Additionally, there are several viewpoints, such as the duplex basement with the underlying Precambrian crystalline rocks and the overlying pre-Carboniferous folded basement, and the collaged basement by the Precambrian micro-continent block in the central part and the Hercynian accretionary folded belts circling it. Anyway, it is necessary to explain the property of basement rock, its strong inhomogeneous compositions as well as the geophysical features.

In this paper, based on the borehole data from more than 300 industry wells drilled into the Carboniferous System, together with the high-resolution gravity and magnetic data (in a scale of 1:50,000), we made a detailed analysis of the basement structure, formation timing and processes and its later evolution on a basis of core geochemical and isotopic analysis. Firstly, we defined the Mahu Pre-Cambrian micro-continental block in the juvenile crust of Junggar Basin according to the Hf isotopic analysis of the Carboniferous volcanic rocks. Secondly, the results of the tectonic setting and basin analysis suggest that the Junggar area incorporates three approximately E-W trending island arc belts (from north to south: Yemaquan–Wulungu–Chingiz, Jiangjunmiao–Luliang–Darbut and Zhongguai–Mosuowan–Baijiahai–Qitai island arcs respectively) and intervened three approximately E-W trending retro-arc or inter-arc basin belts from north to south, such as Santanghu–Suosuoquan–Emin, Wucaiwan–Dongdaohaizi–Mahu (Mahu block sunk as a bathyal basin during this phase) and Fukang–western well Pen1 sag accordingly. Thirdly, the closure of these retro-arc or inter-arc basins migrating gradually toward the south led to the collision and amalgamation between the above-mentioned island arcs during the Carboniferous, constituting the basic framework of the Junggar ‘block’. Fourthly, the emplacement of large-scale mantle-derived magmas occurred in the latest Carboniferous to Early Permian. For instance, the well Mahu 5 penetrate the latest Carboniferous basalts with a thickness of over 20 m, and these mantle-derived magmas consolidated the above-mentioned island arc-collaged blocks. Therefore, the Junggar basin basement mainly comprises pre-Carboniferous collaged basement, and its formation is characterized by two-stage growth model, involving the Carboniferous lateral growth of island arcs and the latest Carboniferous to Early Permian vertical crustal growth related to emplacement and underplating of the mantle-derived magmas.

In the Middle Permian, the Junggar Basin is dominated by a series of stable intra-continental sag basins from west to east, such as Mahu, Shawan, western Well Pen1, Dongdaohaizi–Wucaiwan–Dajing, Fukang–Jimusaer sag lake-basins and so on. The Middle Permian (e.g., Lower Wu’erhe, Lucaogou, and Pingdiquan Formations) thick source rocks developed in these basins, suggesting that the Junggar Basin had been entered ‘intra-cratonic sag’ basin evolution stage. Since then, no strong thermal tectonic event could result in crust growth. The present crustal thickness of Junggar Basin is 45–52 km, which was mainly formed before the latest Early Permian. Subsequently, the Junggar Basin experienced a rapid cooling process during the Late Permian to Triassic. These events constrain the formation timing of the Junggar basin basement to be before the latest Early Permian.

It is inferred that the crustal thickness of Carboniferous island arc belts and associated back-arc basins is of 30–35 km or less. The latest Carboniferous to Early Permian vertical crust growth should have a thickness of 15–20 km or more. Viewed from the deep seismic reflection profile across the basin, the Junggar crust does not contain the large-scale imbricate thrust systems, but shows well-layered property. Thus, the vertical growth rate reached 0.75~1 km/Ma in the latest Carboniferous to Early Permian time, a period approximately of 20Ma. It indicates a very rapid crustal growth style which could be named as the Junggar-type vertical growth of continental crust. Its formation mechanism and geodynamic implications need to be further explored later.