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Hercynian post-collisional magmatism in the context of Paleozoic magmatic evolution of the Tien Shan orogenic belt

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ABSTRACT

The Hercynian Tien Shan (Tianshan) orogen formed during Late Palaeozoic collision between the Karakum–Tarim and the Kazakhstan paleo-continents. In order to constrain timing of Hercynian post-collisional magmatism, 27 intrusions were sampled for U–Pb zircon dating along a ca. 2000 km – long profile in Uzbekistan and Kyrgyzstan. The samples were dated utilizing sensitive high resolution ion microprobe (SHRIMP-II). The obtained ages, together with previously published age data, allowed the timing of Hercynian post-collisional magmatism to be constrained and interpreted in the context of the Paleozoic magmatic evolution of the region. Apart from Hercynian post-collisional magmatism, two older magmatic episodes have been recognized, and the following sequence of events has been established: (1) approximately 10 Ma after cessation of continuous Caledonian magmatism a number of Late Silurian–Early Devonian intrusions were emplaced in the Middle and Northern Tien Shan terranes between 420 and 390 Ma. The intrusions probably formed in an extensional back arc setting during coeval subduction under the margins of Caledonian Paleo-Kazakhstan continent; (2) the next relatively short Late Carboniferous episode of subduction under Paleo-Kazakhstan was registered in the Kurama range of the Middle Tien Shan. Calc-alkaline volcanics and granitoids with ages 315–300 Ma have distinct metallogenic affinities typical for subduction-related rocks and are not found anywhere outside the Middle Tien Shan terrane west of the Talas–Farghona fault; (3) the Early Permian Hercynian post-collisional magmatism culminated after the closure of the Paleo-Turkestan ocean and affected the whole region across terrane boundaries. The post-collisional intrusions formed within a relatively short time span between 295 and 280 Ma. The model for Hercynian post-collisional evolution suggests that after collision the Tien Shan was affected by trans-crustal strike-slip motions which provided suitable conduits for ascending asthenospheric material and heat influx in the crust. This produced both granitoid magmas and hydrothermal fluid flow. As a result post-collisional intrusions and orogenic Au deposits, known in the region, formed coevally and were tectonically controlled; (4) between 240 and 220 Ma a Triassic thermal event affected the region resulting in resetting and growth of new zircon grains which is detected on a regional scale. Probably the influx of heat into the crust during the Triassic was tectonically focused and varied significantly in different terranes. In the region under investigation the Triassic thermal event was not accompanied by any significant magmatic activity. Thus, after cessation of Hercynian post-collisional magmatism ca. 280 Ma ago there was a long magmatically quiet period in the Tien Shan.

1. Introduction

A post-collisional geodynamic setting represents a particular stage of the global tectonic cycle, characterized by large scale horizontal movements of terranes and by voluminous, mainly potassic magmatism (e.g. Liégeois et al., 1998 and references therein). The Hercynian Tien Shan accretionary orogen in Central Asia presents an example where post-collisional tectonics and magmatism are closely associated with large orogenic Au deposits making this region the richest gold province of Eurasia (Yakubchuk et al., 2002). The timing of the strike-slip motions and Au mineralization in the Tien Shan was recently defined in a series of publications (Laurent-Charvet et al., 2003; Mao et al., 2004; Morelli et al., 2007). However, the timing of post-collisional magmatism, and spacial and temporal relationships between subduction-related and post-collisional magmatism and between post-collisional magmatism and Au mineralization in the Hercynian Tien Shan are

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still poorly understood. Here we present sensitive high resolution ion microprobe (SHRIMP) U–Pb zircon ages for 27 granitoid and alkaline intrusions sampled along a ca. 2000 km – long profile from Aral Sea in Uzbekistan to Han-Tengry – Pobeda Peak in Kyrgyzstan (Fig. 1). Most sampled intrusions represent important tectonic indicators and/or are associated with major ore deposits. Recently published ion-probe U–Pb zircon ages for another 15 intrusions from the area are added to the dataset. The data obtained provide ages for several important mineralized systems, development of regional shear zones and extensional regimes, and allow us to constrain timing of the post-collisional magmatism and to propose a tectonic model for the post-collisional stage. Finally, using a broader dataset for Paleozoic intrusions we compare Hercynian and Caledonian magmatism, and discuss other magmatic episodes and the general tectonic evolution of the Tien Shan belt in former USSR. Voluminous age data for magmatic rocks in the Chinese Tien Shan are out of the scope of this paper. A synthesis involving the data for the Chinese Tien Shan and comparison of various tectonic subdivisions found in the literature will be a focus of a separate future work.

2. Geology of the Tien Shan orogenic belt

The Hercynian Tien Shan orogen formed during Late Palaeozoic collision between the Karakum–Tarim continent and the Paleo-Kazakhstan continent, a Caledonian component of the Altaid Collage (Zonenshain et al., 1990; Şengör et al., 1993). The western part of the Tien Shan in Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan is composed of three major structural units or terranes (Fig. 1): (1) the Northern Tien Shan, the deformed margin of the Paleo-Kazakhstan continent; (2) the Middle Tien Shan, a Late Paleozoic volcano-plutonic arc; and (3) the Southern Tien Shan, an intensely deformed fold and thrust belt formed during the final closure of the Paleo-Turkestan ocean (Zonenshain et al., 1990). In Chinese territory, the Borohoro arc and Paleo-Kazakhstan terranes bordering the Northern Tien Shan, are also considered as parts of the Tien Shan orogen (e.g. Chen et al., 1999; Zhou et al., 2001). These terranes are shown in Fig. 1 as the North-East Tien Shan.

The Northern Tien Shan in Kyrgyzstan is represented by the Early Palaeozoic continental arc and its Precambrian basement formed as a result of progressive subduction to the north (present day coordinates) and subsequent closure of the Terskey ocean in the Late Ordovician and accretion of the Middle Tien Shan to the Northern Tien Shan (Lomize et al., 1997; Ghes, 2008). In Kyrgyzstan, the Northern and Middle Tien Shan are separated by the Nikolaev Line, a Hercynian strike-slip fault generally following a Caledonian suture. The oldest ophiolites in the Northern Tien Shan have Cambrian ages (Lomize et al., 1997; Mikolaichuk et al., 1997) and are coeval with primitive sodic tonalites. Further development of the Northern Tien Shan arc is documented by continuous Andean type magmatism which created voluminous subduction-related Ordovician and post-collisional Early Silurian granitoids (Konopelko et al., 2008 and references therein). The main component of the Middle Tien Shan is the Beltau-Kurama volcano-plutonic belt developed west of the Talas–Farghona fault. This belt is a complex structure consisting of Late Carboniferous volcano-plutonic arc rocks which unconformably overlay and crosscut similar arc-related Silurian–Early Devonian arc series. All these rocks were probably formed on a Caledonian and/or Precambrian basement as a result of northward subduction during the evolution and closure of the Paleo-Turkestan ocean to the south (present day coordinates). The subduction-related series in the Kurama and Chatkal ranges west of the Talas–Farghona fault form two discrete short lived associations of Silurian–Early Devonian and Late Carboniferous ages. East of the Talas–Farghona fault the subduction was amagmatic or its evidence was eroded or hidden under the cover of younger rocks (Alekseev et al., 2009). The Beltau-Kurama belt is usually considered as a southern active continental margin of the Palaeo-Kazakhstan (e.g. Shayakubov and Dalimov, 1998). The Southern Tien Shan includes intensely deformed fore-arc accretionary complexes together with passive margin sediments of the Karakum–Tarim continent. The Middle and Southern Tien Shan terranes are separated by the Southern Tien Shan Suture defined by ophiolites with ages ranging from the Early Ordovician to Early Carboniferous (Kurenkov and Aristov, 1995; Gao et al., 1998; Chen et al., 1999). In Uzbekistan and Kyrgyzstan the Southern Tien Shan is traditionally divided into three segments from west to east: the Kyzylkum segment, the Alay segment and the Kokshaal segment (Fig. 1). Despite the similarities, the three segments have rather different geological structures (Biske and Seltmann, 2010 and references there in). The Kyzylkum segment is built up on a Neoproterozoic–Caledonian basement with no or

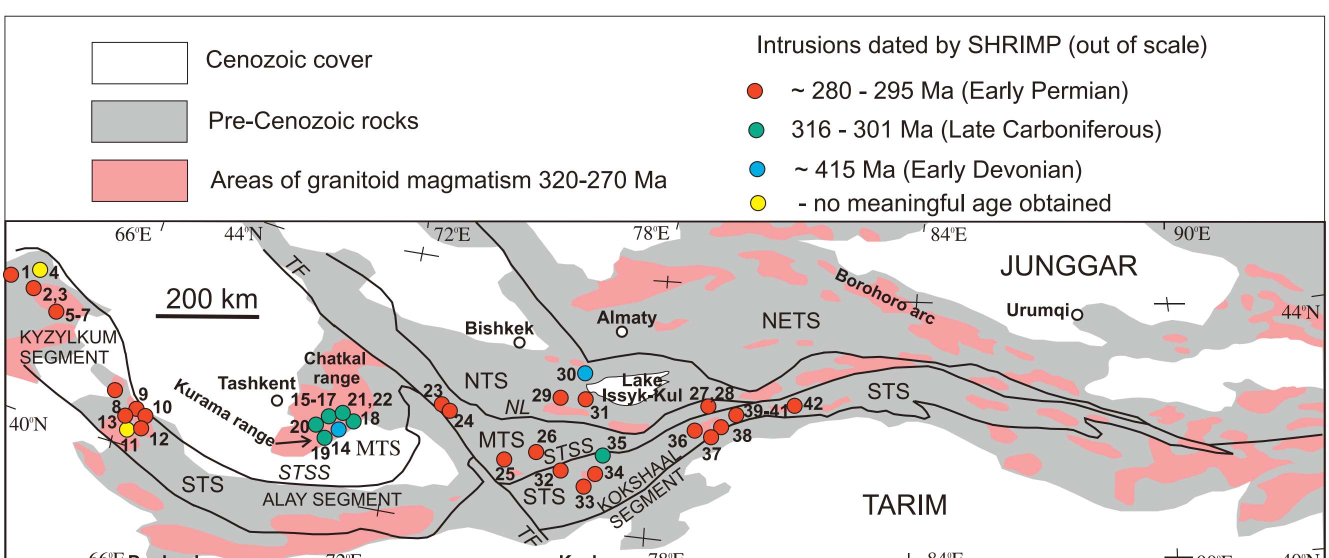

Fig. 1. Principal terranes and tectonic lineaments of the Tien Shan, and distribution of Hercynian granites. Intrusions dated by ion-probe are shown out of scale. Numbers of intrusions (1–42) correspond to running numbers in Table 1. Muruntau dike, Nr. 7, has a Triassic age not shown in the legend. Abbreviations: NTS – Northern Tien Shan, NETS – North-Eastern Tien Shan, MTS – Middle Tien Shan, STS – Southern Tien Shan, NL – Nikolaev Line, STSS – Southern Tien Shan Suture, TF – Talas–Farghona strike-slip fault.