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Metamorphic P–T–water conditions of the Yushugou granulites from the southeastern Tianshan orogen: Implications for Paleozoic accretionary orogeny

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ABSTRACT

The South Tianshan Accretionary Complex (STAC), forming the southern segment of the Central Asian Orogenic Belt, underwent a long-lived and subduction-related accretionary orogenic process. The high-pressure (HP) and ultrahigh-pressure (UHP) metamorphic rocks within this complex are traditionally considered to be metamorphic ophiolitic slices. In this paper, we report a detailed study of petrology and water content of nominally anhydrous minerals (NAMs) of granulites from the Yushugou HP massif occurring as a fault-bounded tectonic slab in the Paleozoic accretionary complex. The studied granulites consist of garnet, orthopyroxene, plagioclase, K-feldspar, quartz, biotite, ilmenite and rutile and show distinct mylonitic foliation. The augen garnet is dominated by almandine and pyrope components, and has compositional zoning with increasing grossular content from the core to rim of the grain. The augen orthopyroxene has high Al_2O_3 content (up to 7.91 wt.%), and shows compositional zoning characterized by a decreasing Al_2O_3 content from core to rim. Phase equilibria modeling indicates that the granulite underwent ultrahigh-temperature (UHT) (>930 °C) and HP (10.5–14.5 kbar) metamorphism and partial melting under a high geothermal gradient of ca. 24 °C/km, and a possible prograde process characterized by heating and burial. Analyses of Fourier transform infrared spectroscopy indicate that hydrogen was incorporated in all NAMs of the granulites in the manner structural OH and sub-microscopic fluid inclusions and that the average water content (H_2O weight) is in the range of 63–215 ppm in garnet, 1–54 ppm in orthopyroxene, 172–533 ppm in feldspar and 34–66 ppm in quartz. The present results show that the Yushugou massif probably derived from the deep root of hot continental magmatic arc. The trace amounts of water in NAMs obviously affected ductile deformation of the near-dry granulites. This study indicates that the thickened lower crust of the Paleozoic Tianshan accretionary orogen is characterized by high-thermal flow, UHT granulite-facies metamorphism, anatexis, ductile deformation and coeval magmatism and crustal growth.

1. Introduction

The architecture of the Central Asian Orogenic Belt (CAOB) and the geodynamic implications for Phanerozoic continental growth have long been a major concern of the international community (Mossakovsky et al., 1993; Şengör et al., 1993; Xiao & Santosh, 2014 and references therein). Subduction-related accretion 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, and to Xinjiang in China (Xiao et al., 2013; Xiao & Santosh, 2014 and references therein). The northern part of the orogenic collage was developed by consumption of the Junggar–Balkash Ocean, forming the North Tianshan Accretionary Complex; the southern part of the orogenic collage was developed by consumption of the South Tianshan Ocean (Paleo-Asian Ocean) which gave rise to the formation of the South Tianshan (Kokshaal–Kumishi) Accretionary Complex, that separates the Central Tianshan from the Tarim craton (Fig. 1). This accretionary complex is characterized by a general southward and oceanward accretion by northward subduction in the early Paleozoic to Permian time. The initial docking of the southerly Tarim craton to this accretionary complex occurred in the Late Carboniferous–Early Permian in the eastern part of the Tianshan and in the Late Permian in the western part (Xiao et al., 2013).

The South Tianshan Accretionary Complex (STAC) is composed of various components with different origins, including microcontinents, magmatic arcs, oceanic plateaus, seamounts, ophiolitic mélanges and accretionary complexes (Windley et al., 1990; Jahn et al., 2004; Windley et al., 2007; Rojas-Agramonte et al., 2011; Kröner et al., 2013; Xiao et al., 2013). These rocks have partly undergone high-pressure (HP) and ultrahigh-pressure (UHP) metamorphism with various ages (Gao et al., 1999; Gao & Klemd, 2001, 2003; Klemd et al., 2005; Hegner et al., 2010; Su et al., 2010; Q.L. Li et al., 2011). There have been different views about the tectonic significance of these HP/UHP rocks in the STAC. Some workers have interpreted the ages of these HP/UHP rocks as syn-tectonic, or as a result of amalgamation of many

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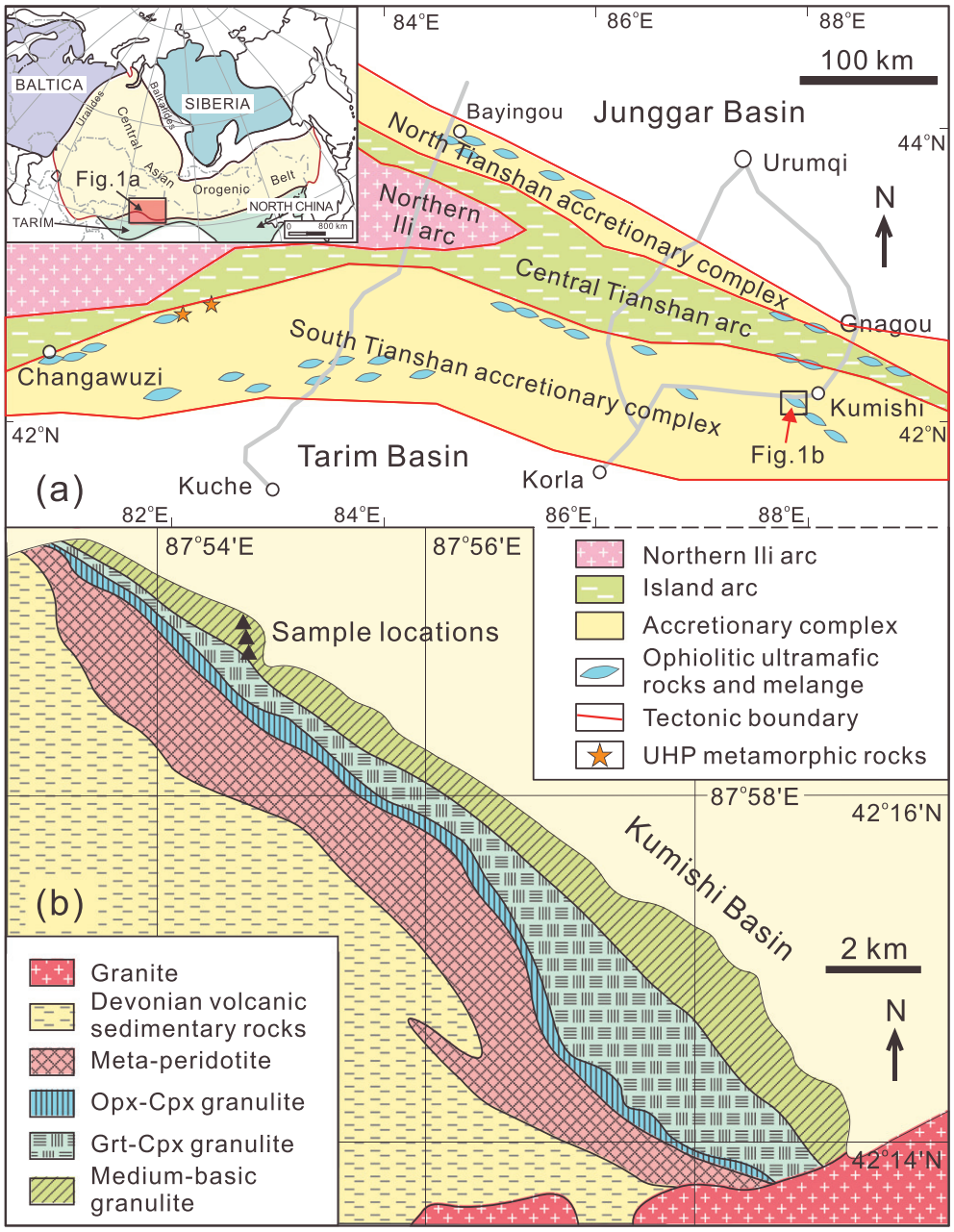

Fig. 1. (a) Tectonic map of the Chinese Western Tianshan showing major Early Paleozoic tectonic assemblages and structures (modified after Xiao et al. (2013)), and the location of b. Inset shows tectonic framework of the Central Asian Orogenic Belt and the location of a. (b) A sketch geological map of the Yushugou massif (modified after Zhou et al. (2004)).

terranes or arc-collision (Charvet et al., 2007; Wang et al., 2011), thus dating collision of the Tarim Craton with the southern Siberian accretionary system to the north. Some other investigators argued that these HP/UHP rocks occur as blocks (Zhang et al., 2007; Xiao et al., 2008), derived from different depths of the slab and mixed within a subduction channel during exhumation (e.g., Klemd et al., 2011). In this regard, the HP and UHP rocks should be predating the collision time of the Tarim Craton and Siberian accretionary system. In addition, Xiao et al. (2004, 2013) interpreted some units as backarc or arc-related sequences in the early Paleozoic and a forearc and accretionary complex in the Late Paleozoic, respectively. The formation of HP and UHP rocks was related to the subduction of the South Tianshan ocean plate instead of the collision of the Tarim craton. Therefore, more detailed investigations are required before the origin of HP and UHP rocks from the STAC is resolved (Xiao et al., 2013).

In this paper, we report a detailed study of petrology and water content of nominally anhydrous minerals of the granulites from the Yushugou massif, typical of HP granulites in the STAC. The present results show that the Yushugou granulites have undergone UHT and HP metamorphism and associated anatexis, the nominally anhydrous minerals (NAMs) contain certain amount of water. We conclude that the granulites formed in the deep root of hot magmatic arc, and water in NAMs obviously affected ductile deformation of thickened lower crust of magmatic arc.

2. Geological setting and samples

The Yushugou HP metamorphic massif, located at the eastern segment of the STAC (Fig. 1), was traditionally considered to be a granulite-facies metamorphic and deformed ophiolitic slice (e.g., R.S. Wang et al., 1999a, 1999b; J.L. Wang et al., 1999; Dong et al., 2001; Zhou et al., 2004). However, Shu et al. (2004) proposed that the protolith of the Yushugou granulites was formed in a volcanic arc setting. Most recently, Ji (2013) argued that this HP massif derived