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Implications from zircon-saturation temperatures and lithological assemblages for Early Permian thermal anomaly in northwest China

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ABSTRACT

Despite considerable efforts, the Paleozoic tectonic setting (subduction vs. post-collision vs. mantle plume) in the Central Asian Orogenic Belt (CAOB) remains controversial. With aims of solving this issue, we examined zircon saturation temperatures of granitoids emplaced in different settings, and demonstrated that zircon saturation thermometry of felsic igneous rocks, especially when integrated with their lithology and geochemistry, can be a simple and powerful tool for tectonic discrimination. This method is then applied in northern Xinjiang where the Early Permian granitoids have higher saturation temperatures (>800 °C) than the Silurian–Carboniferous granitoids (mainly <800 °C). Moreover, the latter are mainly of I-type and are characterized by relatively narrow range of uniformly higher ε_{Nd}. Consistent with high ε_{Hf} in zircons from contemporaneous ultramafic–mafic complexes, they were most likely derived from subduction-related processes. In contrast, the high-temperature Early Permian granitoids and associated ultramafic–mafic rocks show a wide range in ε_{Nd} and ε_{Hf} in zircons, consistent with the involvement of a great variety of crustal and mantle materials in magma genesis. The thermal anomaly and diversity of Permian magmatic rocks in the CAOB can be ascribed to a mantle plume activity, in agreement with widespread contemporaneous flood basalts, and associated mafic dykes and ultramafic complex in Tarim. Therefore, the temporal variation in temperature and geochemistry of Paleozoic granitoids in northern Xinjiang mirrors a significant change in tectonic setting from a subduction–collision setting during Silurian–Carboniferous to an intra-plate setting since Early Permian.

1. Introduction

The Central Asian Orogenic Belt (CAOB), bounded by the Siberian craton to the north and the Tarim craton to the south, is now well known for its accretionary tectonics and for being the world's largest site of juvenile crustal growth in the Phanerozoic (Jahn, 2004; Sengör et al., 1993; Windley et al., 2007) (Fig. 1). However, considerable debates were raised recently focusing on tectonics of southern CAOB during Early Permian (Han et al., 1997, 2011; Xiao et al., 2009). Available models that interpret deep dynamic process during Early Permian include continuous southward accretion between Siberia and Tarim block (Xiao et al., 2009), post-collisional collapse under extensional environment (Han et al., 1997, 2011) and plume activity in northern Xinjiang (Borisenko et al., 2006; Pirajno et al., 2008; Su et al., 2011; Zhang et al., 2010a,b; Zhou et al., 2004).

These different opinions regarding geodynamic processes largely stemmed from studies on the widespread granitoids in the CAOB. However, it is well known that geochemical studies on highly evolved felsic rocks may yield ambiguous assessment on tectonic setting and geodynamic processes (Förster et al., 1997). The solution to the afore-mentioned debates lies in the essential question where the heating source that triggered crustal melting came from. The first model itself does not provide/introduce heat source because melting of subducting slab and overriding mantle wedge may have been induced by ingress of slab-derived fluids/volatiles which significantly lowers their solidus. The other two models involve heat transfer from upwelling asthenospheric mantle or plume. Therefore, geothermometry study may shed some light on granitoid petrogenesis (Claiborne et al., 2006; Miller et al., 2003; Watson and Harrison, 1983, 2005) as well as their tectonic settings because heat source is a key factor to trigger crustal melting.

One of the primary objectives of this study is to find out how geothermometry relates to geochemical features of granitoids, and more importantly to determine whether the formation of Early Permian granitoids in Northern Xinjiang was due to input of volatile components at a relatively low temperature, or due to extra heat from a great depth (Olafsson and Eggler, 1983; Wu et al., 2007). To this end, we first applied the Watson and Harrison (1983)'s thermometer to granitoids emplaced in known tectonic settings, and realized that plume-related granitoids

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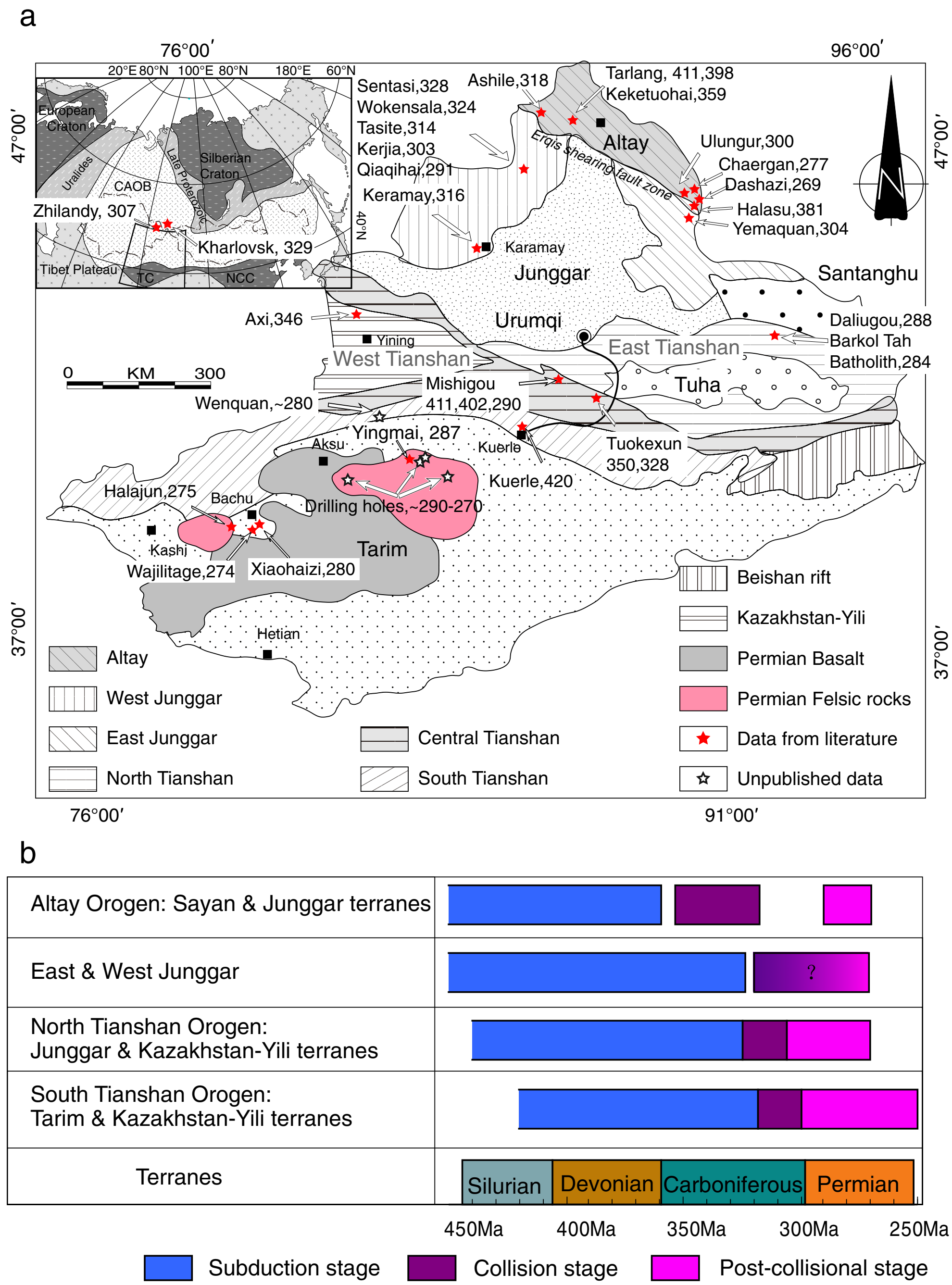

Fig. 1. a: Sketch tectonic map of northern Xinjiang (modified after Pirajno et al. (2008) and Jahn et al. (2000)) and distribution of samples used for estimation of zircon saturation temperature. b: Tectonic stages in the main terranes from northern Xinjiang. Numbers refer to emplacement/eruption ages in Ma.

generally exhibit higher zircon saturation temperatures than those produced in subduction processes and in orogenic belts. Using the same method, we then estimate and examine the temporal variation of zircon saturation temperature of Paleozoic granitoids from northern Xinjiang, and compare the results with those for subduction and plume-related igneous provinces. It is shown that the Early Permian (291–270 Ma) granitoids have higher zircon saturation temperatures than the older intrusions. This thermal anomaly, closely associated with contemporaneous A-type granitoids and flood basalts, is in accordance with the proposed Tarim mantle plume, which may also have affected the CAOB in northern Xinjiang.

2. Paleozoic tectonic evolution and syn-tectonic magmatism in northern Xinjiang

Tectonically, the Xinjiang Province is made of several blocks such as Tarim craton, Ili block, and Junggar and Tuha basins, which are surrounded by the network of the Chinese Altay in the north, Tianshan in the central and Kulun–Karakorum orogenic belt in the south part of Xinjiang, respectively (Fig. 1a). Tectonic evolution of the North Xinjiang during the Paleozoic is built mainly based on geologic studies on these terranes (Gao et al., 2011; Han et al., 1997, 2011; Hu et al., 2000; Wang et al., 2006, 2010; Xiao et al., 2009; Zhou et al., 2008). Three stages,