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A ca. 2.60 Ga tectono-thermal event in Western Shandong Province, North China Craton from zircon U–Pb–O isotopic evidence: Plume or convergent plate boundary process

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ABSTRACT

Voluminous Neoarchean plutonic and supracrustal rocks are well developed in the Western Shandong Province of the North China Craton, which has been divided into a late Neoarchean crustally-derived granite belt, a middle to early Neoarchean ancient rock belt and a late Neoarchean juvenile rock belt. Earlier studies provided reconnaissance evidence for ~2.60 Ga metamorphism in some areas. This study presents SHRIMP zircon U–Pb dating and O isotope analysis on nine metamorphosed igneous rock samples (gneissic tonalite, gneissic trondhjemite, gneissic quartz diorite and meta-gabbro) from the ancient rock belt. Magmatic zircons vary in age from 2.74 Ga to 2.60 Ga, whereas metamorphic and anatectic zircons vary in age from 2.63 Ga to 2.59 Ga, with an age peak of 2.61 Ga. In this study, we identified 2.69–2.67 Ga metamorphic zircons for the first time. Most of zircons, whether magmatic or metamorphic, have $\delta^{18}O$ values of +4.5‰ to +6.5‰ (V-SMOW). However, the oldest tonalite sample with a protolith age of 2735 Ma has zircons showing low $\delta^{18}O$ (V-SMOW) values, particularly in recrystallized domains and overgrowths. This suggests at least in local crustal extension and influx of meteoric water during the evolution of the rocks. Combined with data from earlier studies, we draw the conclusion that the Western Shandong Province experienced a regional tectono-thermal event at ~2.60 Ga, as a result of high heat flow and crustal extension, perhaps caused by a mantle plume or mantle overturn activity. Therefore we conclude that 2.60 Ga can be regarded the break between early and late Neoarchean crustal accretion. The O isotope study indicates that in some cases, trondhjemitic leucosome was not derived from nearby gneissic tonalite, although they show a close relationship in outcrop.

1. Introduction

The North China Craton (NCC) is characterized by widespread ~2.50 Ga metamorphism, associated with extensive ~2.50 Ga magmatism which resulted in addition of significant juvenile material from the mantle and crustal recycling of older continental crust during a short period of time (Grant et al., 2009; Kröner et al., 2005; Liu et al., 2011; Nutman et al., 2011; Wan et al., 2012a, 2015a; Yang et al., 2008; Zhai and Santosh, 2011). This event is widely regarded to reflect crustal growth in suprasubduction zone settings at convergent plate boundaries (Condie, 2008; Praveen et al., 2014; Wang et al., 2004). However, in the Western Shandong Province (WSP), east of the NCC, successive magmatism ranged from 2.75 Ga to 2.60 Ga and 2.56 Ga to 2.50 Ga (Wan et al., 2010, 2011, 2012b). Like the ~2.5 Ga event, the one at ~2.7 Ga has been interpreted as crustal growth at a convergent plate boundary (Kerrich et al., 1998; Manikyamba et al., 2004; Polat and Kerrich, 2001). Combined with ~2.60 Ga metamorphism, the ~2.60 Ga magmatic event was considered to represent the end of early Neoarchean (2.75–2.60 Ga) geological evolution (Wan et al., 2014a). ~2.60 Ga magmatic event has been extensively recorded in the WSP, whereas it is still unknown how pervasive the ~2.60 Ga metamorphism was and what was its geodynamic significance. In this paper, we present SHRIMP U–Pb zircon dating and O isotope analysis on tonalite, trondhjemite and meta-gabbro from the WSP in order to determine the spatial distribution and timing of the ~2.6 Ga metamorphism, and its relationship with magmatism. We further discuss the meaning of this event for geological evolution of the WSP and NCC. This is the first report of oxygen iso-

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topic data from zircons in the WSP. Although most show mantle-like values, one anomalous sample has low $\delta^{18}O$ (V-SMOW) values. The origin and tectonic significance of this is discussed.

2. Geological background

The WSP is one of the typical Neoarchean granite-greenstone belts of the NCC, with an exposed area of >10,000 km^2. The terrane extends roughly in a northwest-southeast direction, being bounded by the Tanlu Fault in the east (Fig. 1). It was divided into three belts from northeast to southwest (Wan et al., 2010, 2011). Belt A: late Neoarchean (2.53–2.49 Ga) crustally-derived granites and anatectic rocks, resulted from metamorphism and anatexis during a ~2.50 Ga tectono-thermal event; Belt B: early Neoarchean (2.75–2.60 Ga) ancient rocks dominated by TTGs and supracrustal rocks; Belt C: late Neoarchean (2.56–2.50 Ga) magmatic rocks which are mostly granodiorite, representing juvenile additions to the crust.

The supracrustal rocks occur as strips and lenses of less than 10% aerial extent in a "sea" of granitic rocks and gneisses. They

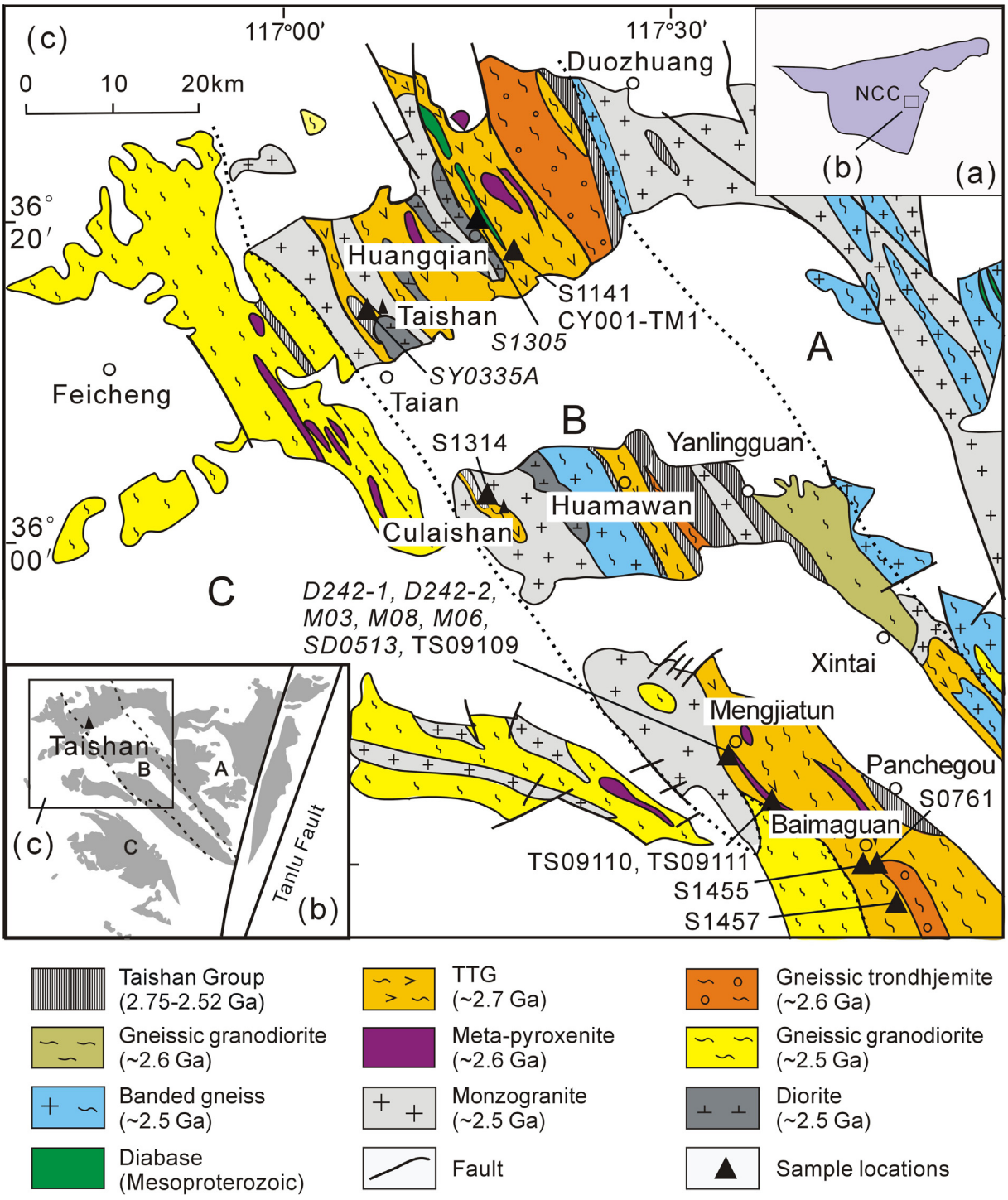

Fig. 1. Geological map of the Taishan-Xintai area, western Shandong Province. Modified after Cao (1996) and Wan et al. (2011). Insets (a) and (b) show the study area. Also shown are the locations of samples with ca. 2.60 Ga zircons in this study and by Du et al. (2003), Lu et al. (2008) and Ren et al. (2015) (italic).