Application of the two-feldspar geothermometer to ultrahigh-temperature (UHT) rocks in the Khondalite belt, North China craton and its implications

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ABSTRACT

The Paleoproterozoic Khondalite belt in the North China craton preserves evidence for ultrahigh-temperature (UHT) crustal metamorphism associated with the collision of the Yinshan and Ordos Blocks. Here we apply two-feldspar geothermometry to UHT granulites from two localities newly reported in this study (Tuguishan and Xuwuji) and another two localities from previous studies (Dajing/Tuguiwula and Dongpo) in the Khondalite belt. The presence of abundant perthite/mesoperthite in these rocks reflects post-peak slow cooling. The minimum estimated peak metamorphic temperatures are 832–998, 819–952, 844–1037, and 966–1019 °C computed at 8 kbar for the Dajing/Tuguiwula, Dongpo, Tuguishan, and Xuwuji areas, respectively. These results confirm the previous report of extreme metamorphism at Dajing/Tuguiwula and Dongpo, and reveal similar conditions in the new localities reported here, suggesting that UHT metamorphism is widespread in the Khondalite belt of the North China craton. Our study demonstrates that UHT metamorphism can be recognized using the two-feldspar geothermometer in rocks that do not possess other key UHT assemblages.

Keywords: Ultrahigh-temperature (UHT) metamorphism, two-feldspar geothermometer, perthite/mesoperthite, Paleoproterozoic, Khondalite belt, North China craton

INTRODUCTION

Ultrahigh-temperature (UHT) metamorphism takes place in the deep crust at extreme temperature conditions of 900–1100 °C and medium pressures (7–13 kbar; Harley 1998). Understanding the conditions and processes of UHT metamorphism provides important constraints on the nature of coupling between the crust, sub-crustal lithosphere, and asthenospheric mantle, as well as the tectonic setting of regional metamorphic belts (Lund et al. 2006; Harley 1998, 2004, 2008; Kelsey 2008; Santosh and Kusky 2010). The UHT diagnostic minerals and assemblages, such as Spr+Qz, Opx+Sil±Qz, or osmiumite commonly occur in Mg-Al-rich rocks, and are rather scarce (Harley 1998, 2004, 2008). Since many of these minerals undergo retrogression, their original compositions are not often preserved, thereby narrowing the chance of direct evidence from diagnostic mineral assemblages. In this context, ternary feldspars (perthite, Per) provide a robust alternative, as they are more common than the diagnostic UHT assemblages and can be fairly resistant to retrograde resetting, making them useful for recognizing UHT metamorphism.

Recent studies in the Paleoproterozoic Khondalite belt of the North China craton have led to the discovery of UHT granulites, particularly from two localities at Dongpo and Dajing/Tuguiwula (Figs. 1 and 2) (Jin 1989; Liu et al. 2000; Guo et al. 2006, 2008; Santosh et al. 2006, 2007a, 2007b, 2009a; Liu et al. 2010). The UHT granulites at Dongpo are garnet-bearing and contain up to 30% sapphireine, as well as sillimanite, spinel, biotite, plagioclase, and minor cordierite, rutile, and ilmenite, but without quartz and orthopyroxene. Estimated peak UHT conditions are 910–980 °C and 8 kbar followed by a post-peak decompression (Fig. 2a) (Guo et al. 2006, 2008). In contrast, the UHT granulites at Dajing/Tuguiwula are Mg-Al-rich and contain the diagnostic UHT mineral assemblages of Spr+Qz, Al-rich Opx+Sil+Qz as well as ternary feldspar. Santosh et al. (2007a, 2009a) defined an anticlockwise P-T path with a peak metamorphic temperature of >970 °C at ~7–13 kbar (Fig. 2b).

It is difficult to evaluate the extent of UHT metamorphism in this region because apart from the two UHT localities discussed above, rocks with diagnostic UHT mineral assemblages have not been recognized throughout the Khondalite belt. However, feldspars, which are appropriate for the application of two-feldspar geothermometry are commonly present in the granulite-facies rocks of this region and could provide an ideal means for evaluating the regional extent of UHT metamorphism in the Khondalite belt. Application of the modified two-feldspar geothermometer (Raase 1998; Hokada 2001; Hokada and Suzuki 2006; Prakash et al. 2006; Pilugin et al. 2009) has successfully defined the peak temperature conditions of HT/UHT metamorphism worldwide, primarily using the thermometer of Fuhrman and Lindsley (1988).

In this paper, we report the application of the modified two-feldspar geothermometer to granulite-facies rocks from two known UHT localities (Dongpo and Dajing/Tuguiwula) and two other localities in adjacent areas (Tuguishan and Xuwuji). Based on the results, we discuss the implications on regional UHT metamorphism in the Khondalite belt of the North China craton.

GEOREGIOAL SETTING

The North China craton is considered to have formed during collision between the Eastern and Western blocks along the Trans-North China orogen at ~1.85 Ga (Zhao et al. 2002, 2008a,