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A-type granite and adakitic magmatism association in Songpan–Garze fold belt, eastern Tibetan Plateau: Implication for lithospheric delamination

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Abstract

The Songpan–Garze fold belt covers a huge triangular area (>200,000 km^2), confined by the South China (Yangtze), North China and Tibetan Plateau continental blocks. In the Songpan–Garze fold belt, Triassic adakitic granitoids have been identified. However, whether there are Triassic A-type granites is unclear. Here, we report our first finding of an A-type granite (Nianbaoyeche), which occurs in the central part of the Songpan–Garze fold belt. The Nianbaoyeche granite (~820 km^2) is characterized by arfvedsonite in its mineral assemblage. Using both LA-ICPMS and TIMS U–Pb zircon dating methods, we obtain a magma crystallization age of 211±1 Ma, which is slightly younger than Triassic adakitic granitoids (216–221 Ma) in the Songpan–Garze fold belt. The Nianbaoyeche granite is enriched in Si, K, Na, Rb, REE, HFSE (Nb, Ta, Zr, Hf), with elevated $FeO^{tot}/(FeO^{tot}+MgO)$ and Ga/Al ratios, but is depleted in Al, Mg, Ca, Ba and Sr. The REE compositions show moderately fractionated patterns with $(La/Yb)_N=2.67–7.54$ and $Eu^*/Eu=0.09–0.34$. These geochemical characteristics indicate that the Nianbaoyeche granite has an A-type affinity. Geochemical data and U–Pb zircon age, combined with regional studies, show that the Nianbaoyeche granite formed in a post-collisional tectonic setting. Sr–Nd isotopic data for the granite exhibit $I_{Sr}=0.7090–0.7123$ and $\varepsilon_{Nd}(t)=-2.72$ to -4.26 with $T_{DM}=1.15–1.51$ Ga, suggesting that the magma has a dominantly crustal source, though a minor contribution from the mantle cannot be ruled out. Melting to produce an A-type granite may have resulted from Triassic lithospheric delamination after Triassic crustal thickening of the Songpan–Garze fold belt due to convergence between the Yangtze, North China and North Tibet continental blocks. The lithospheric delamination model also helps to explain the Triassic adakitic magma generation in the Songpan–Garze belt. We conclude that association of A-type granite and adakitic granitoids in post-collisional environment could be a useful indicator of lithospheric delamination.

Keywords: A-type granite; U–Pb age; Magmatism association; Post-collision; Lithospheric delamination; Songpan–Garze fold belt, West China

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1. Introduction

Lithospheric delamination can lead to extensional collapse of mountains, basin formation and associated magmatism (Bird, 1979; Sacks and Secor, 1990; Nelson, 1992; Kay and Kay, 1993; Gao et al., 1998; Manley et al., 2000; Gao et al., 2004). In continental settings, crustal thickening results from collision between continental plates. The thickened lower crust and upper mantle would be characterized in part by high grade metamorphic rocks, resulting in an increased density, which could lead to lithospheric delamination (Kay and Kay, 1991; Rudnick and Fountain, 1995; Jull and Kelemen, 2001). In post-collisional (or post-orogenic) settings, lithospheric delamination and asthenospheric upwelling, accompanied by extentional tectonics, are often invoked to explain the origin of post-collisional granites (Jung et al., 1998; Wu et al., 2002; Chung et al., 2003; Ilbeyli et al., 2004; Chung et al., 2005; Wu et al., 2005). Magmatism in post-orogenic settings can provide insights into the composition of the lower crust and processes involving crustal thickening and lithospheric extension. Adakitic magmas in continental settings can be a fingerprint of crustal thickening (Xu et al., 2002a; Chung et al., 2003; Hou et al., 2004; Wang et al., 2005, 2006), and in some cases, high Mg adakite may be linked directly to lithospheric delamination (Xu et al., 2002a; Gao et al., 2004). A-type granitic magma is generally accepted to reflect lithospheric extension (Collins et al., 1982; Whalen et al., 1987; Sylvester, 1989; Rogers and Greenberg, 1990). Adakitic and A-type granitic magmas may therefore be closely associated or coeval in this tectonic context. A linked association between adakite and A-granite magmatism could potentially provide a strong evidence for regional lithospheric delamination, but unfortunately, the adakite and A-granite magmatism association in the same tectonic regime is uncommon or rare.

In the Songpan–Garze fold belt of the eastern part of the Tibetan Plateau, granitoids are widespread. Recent U–Pb zircon dating shows that most granitoids in the Songpan–Garze fold belt formed in the Triassic (Roger et al., 2004; Hu et al., 2005; Zhang et al., 2006; Xiao et al., 2007) with minor granitoids formed in Early Jurassic time (Roger et al., 2004; Hu et al., 2005). Published studies show that most Triassic granitoids are adakitic (Zhang et al., 2006; Xiao et al., 2007), though A-type granitoids also occur but are as yet undated. In this paper, we report geochemical, Sr–Nd isotope and U–Pb dating evidence for a Triassic A-type granite in the Songpan–Garze fold belt, and we use these data to discuss a geodynamic process for their formation.

2. Geological background and A-type granite description

The Songpan–Garze fold belt is located in the eastern part of the Tibetan Plateau. The belt, covering a huge triangular area with an area of more than 200,000 km^2, is a folded Triassic flysch basin, which formed during closure of the Paleo-Tethys ocean (Xu et al., 1992; Mattauer et al., 1992; Sengör and Natalin, 1996; Brugier et al., 1997). The belt is also a tectonic junction between three major continental blocks (South China, North China and Tibetan Plateau) (Fig. 1). To the east, the Longmenshan thrust-nappe belt separates the Songpan–Garze belt from the Sichuan basin. The northern limit of the belt is marked by the A'nimaque-Mianlue suture zone, which is considered to be a Paleo-Tethys oceanic subduction zone dipping to the north in Late Paleozoic (Li et al., 1996; Xu et al., 2002b; Elena et al., 2003). To the southwest, the Songpan–Garze belt is bounded by the Jinshajian suture zone, which is also considered to be a Late Paleozoic Paleo-Tethys oceanic subduction zone dipping to the west (Sengör, 1985; Wang et al., 2000; Reid et al., 2005).

In the Songpan–Garze belt, the sediments are almost exclusively marine Triassic flysch deposits, which reach a thickness of 5–15 km (Xu et al., 1992; Calassou, 1994). The pre-Triassic strata, forming an antiform with a core of Neoproterozoic sediments, are distributed in the Danba area of the southern Songpan–Garze belt. These pre-Triassic strata have experienced metamorphism of greenschist to upper amphibolite-facies conditions (Huang et al., 2003). In contrast, the Triassic flysch sediments have only experienced greenschist-facies metamorphism but they were intensively folded during the Indosinian (Late Triassic) compressional tectonism due to convergence between the North China, Yangtze and Tibetan continental blocks (Xu et al., 1992; Brugier et al., 1997; Reid et al., 2005). The Triassic flysch sediments are separated from the Paleozoic sedimentary cover and the crystalline basement of the Yangtze block by a large-scale décollement near the eastern and southeastern margin of the Songpan–Garze basin (Xu et al., 1992; Mattauer et al., 1992; Calassou, 1994). Based on new U–Pb chronological study of detrital zircons (870 zircon grains) from the Triassic sediments (Weislogel et al., 2006), the provenance of the Triassic sediments includes the Qinling–Dabie orogen, North China block and Yangtze block.

Widespread granitoids in the Songpan–Garze belt intrude the folded Triassic sediments, implying that they are post-orogenic or post-collisional granitoids. In the northeastern part of the belt, the Yanggon and Maoergai