Tectonophysics 662 (2015) 385–397

Contents lists available at ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

Petrogenesis of Early-Permian sanukitoids from West Junggar, Northwest China: Implications for Late Paleozoic crustal growth in Central Asia

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ARTICLE INFO

Article history:
Received 2 September 2014
Received in revised form 5 January 2015
Accepted 10 January 2015
Available online 20 January 2015

Keywords:
Sanukitoid
Crustal growth
Late Paleozoic
West Junggar
Central Asia

ABSTRACT

Sanukitoids and their equivalents are rare subduction-related rock types that have been found in modern arc settings and in Late Archean sequences. The investigation of sanukitoids is of particular importance to a better understanding of crust-forming processes and continental growth. In this paper we report zircon U–Pb and Ar–Ar ages and major element, trace element, and Sr–Nd–Hf isotope data for the Bieluagaxi dioritic pluton and dikes from the southern part of the West Junggar, NW China. These rocks formed in the Early Permian and show a remarkable geochemical affinity with Cenozoic sanukitoids of the Setouchi Volcanic Belt of SW Japan with high $Mg^{\#}$ (48–73) values, Cr (54–539 ppm), Ni (21–197 ppm) contents and Th/La (0.15–0.37) ratios and low Sr/Y ratios (16–27) and Sr (263–442 ppm) contents. They may be generated by the partial melting of subducting sediments, and subsequent melt–mantle interaction. Additionally, the sanukitoids are also widespread in the Karamay–Baogutu area of West Junggar accompanied by high Sr (average 713 ppm) contents and Sr/Y (50–130) ratios, and low Y (6.9–12.6 ppm) contents. The difference in petrochemical characteristics between the Baogutu–Karamay and Bieluagaxi sanukitoids can be explained by the difference in depth of initial melting, origin composition and fractional crystallization. The Baogutu–Karamay sanukitoids were probably formed under eclogitic conditions, while the Bieluagaxi sanukitoids were at a shallower depth. Moreover, the compositional similarity between continental-crust forming rocks and the Bieluagaxi sanukitoids suggests that the sanukitoids genesis could be closely related to the process of continental crust formation. The Late Carboniferous–Early Permian sanukitoids in the West Junggar may be an indicator of anomalous thermal activity. Ridge subduction may play a crucial role in the evolution and growth of the continental crust in Central Asia.

1. Introduction

The term sanukitoid was first used by Koto (1916) for all textural modifications of volcanic rocks with the composition of Weinschenk's sanukite suite (bronzite-bearing glassy aphyric andesite) (Weinschenk, 1891). Tatsumi and Ishizaka (1981) used the term “sanukitoid” for a variety of relatively aphyric basalts and andesites with less than 20 vol.% phenocrysts. The sanukitoids mainly occurred in the Miocene (11–14 Ma) Setouchi volcanic belt (SVB), SW Japan (Appendix 1; Tatsumi and Ishizaka, 1981; Tatsumi, 2006). Shirey and Hanson (1984) first recognized a suite of Late Archaean felsic intrusive and volcanic rocks in the Superior Province which had clearly different characteristics from Tonalite–Trondhjemite–Granodiorite (TTG) (Appendix 1). Because the major element geochemistry of these rocks resembled that of Miocene high-Mg Andesite (Sanukite) from the Setouchi volcanic belt of Japan (Appendix 1) (e.g., Tatsumi and Ishizaka, 1982), Shirey and Hanson (1984) referred to them as “Archaean sanukitoids”. The sanukitoids are volumetrically rare in the modern Earth (Tatsumi, 2001; Tatsumi and Ishizaka, 1982; Tatsumi et al., 2003). However, they widely focused their attention, as the production of sanukitoids in the Earth's early history could be related closely to continental crust formation (Kelemen, 1995). In modern subduction zone, basaltic rather than High-Magnesium Andesite (HMA) magmas are formed (Tatsumi, 2001). Thus, Tatsumi (2001), Tatsumi et al. (2003) proposed that the genesis of sanukitoid magmas requires some unusual tectonic conditions. In order to better understand the origin of sanukitoid magmas, therefore, it is very critical to understand the knowledge of tectonic settings where sanukitoid magmatism has taken.

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http://dx.doi.org/10.1016/j.tecto.2015.01.005
0040-1951/

The West Junggar in the southwestern part of the CAOB is considered to be an important area for Phanerozoic crustal growth owing to the presence of voluminous Carboniferous to Permian particular magmatic association (e.g., adakites, A-type granites, charnockites and sanukitoid-like magmatism (Geng et al., 2009; Tang et al., 2010, 2012a, b, c; Yang et al., 2014; Yin et al., 2010, 2012, 2013; Zhang et al., 2011a,b)). There is a debate, however, on the tectonic setting from the Late Carboniferous to the Early Permian, such as, post-collisional setting (Chen and Jahn, 2004; Chen et al., 2010; Han et al., 2006; Zhou et al., 2008); ridge subduction (Geng et al., 2009; Tang et al., 2010, 2012a,b, c; Yang et al., 2012, 2014; Yin et al., 2010, 2013; Zhang et al., 2011a, b); mantle plume (Gao et al., 2014) and so on. The above special magmatic rock associations are generally generated under high geothermal gradient condition (Sisson et al., 2003; Windley et al., 2007). Such geothermal gradient would be a general phenomenon in the Archaean. Understanding the genesis of sanukitoid is thus an essential step towards understanding the tectonic setting and crustal growth processes in the West Junggar (Martin et al., 2010; Tatsumi, 2008).

In this paper, we report and discuss zircon U–Pb and Ar–Ar ages and major element, trace element, and Sr–Nd–Hf isotope data for the Bieluagaxi dioritic pluton and dikes from the southern part of the West Junggar, China. The geochemistry of those rocks is analogous to those of Cenozoic sanukites at Setouchi Volcanic Belt of SW Japan. The purpose of this paper is to discuss the petrogenesis of the sanukitoids in the West Junggar and crustal growth processes.

2. Geological setting and petrological characteristics

The West Junggar is a triangular-shaped area that is situated between Siberian, Kazakhstan, and Tarim plates (Fig. 1a). The West Junggar can be divided into northern and southern parts by the Xiemisitai Fault (Xu et al., 2012). Several Paleozoic ophiolitic mélanges (ca. 523–332 Ma) have been reported in this area but no Precambrian basement rocks have been discovered (Feng et al., 1989; Kwon et al., 1989; Liu et al., 2014; Xiao et al., 2008; Xu et al., 2006; Yang et al., 2012; Zhang and Huang, 1992). The strata mainly consist of Carboniferous and Devonian andesitic basalt, andesite, felsic tuff and tuffite in the southern West Junggar (Fig. 1b; An and Zhu, 2009; Choulet et al., 2012; Geng et al., 2011). Plutons in West Junggar mostly consist of granitoids, emplaced mostly by three distinct epochs, i.e., 422–405 Ma, 346–321 Ma, and 316–281 Ma (Chen and Jahn, 2004;

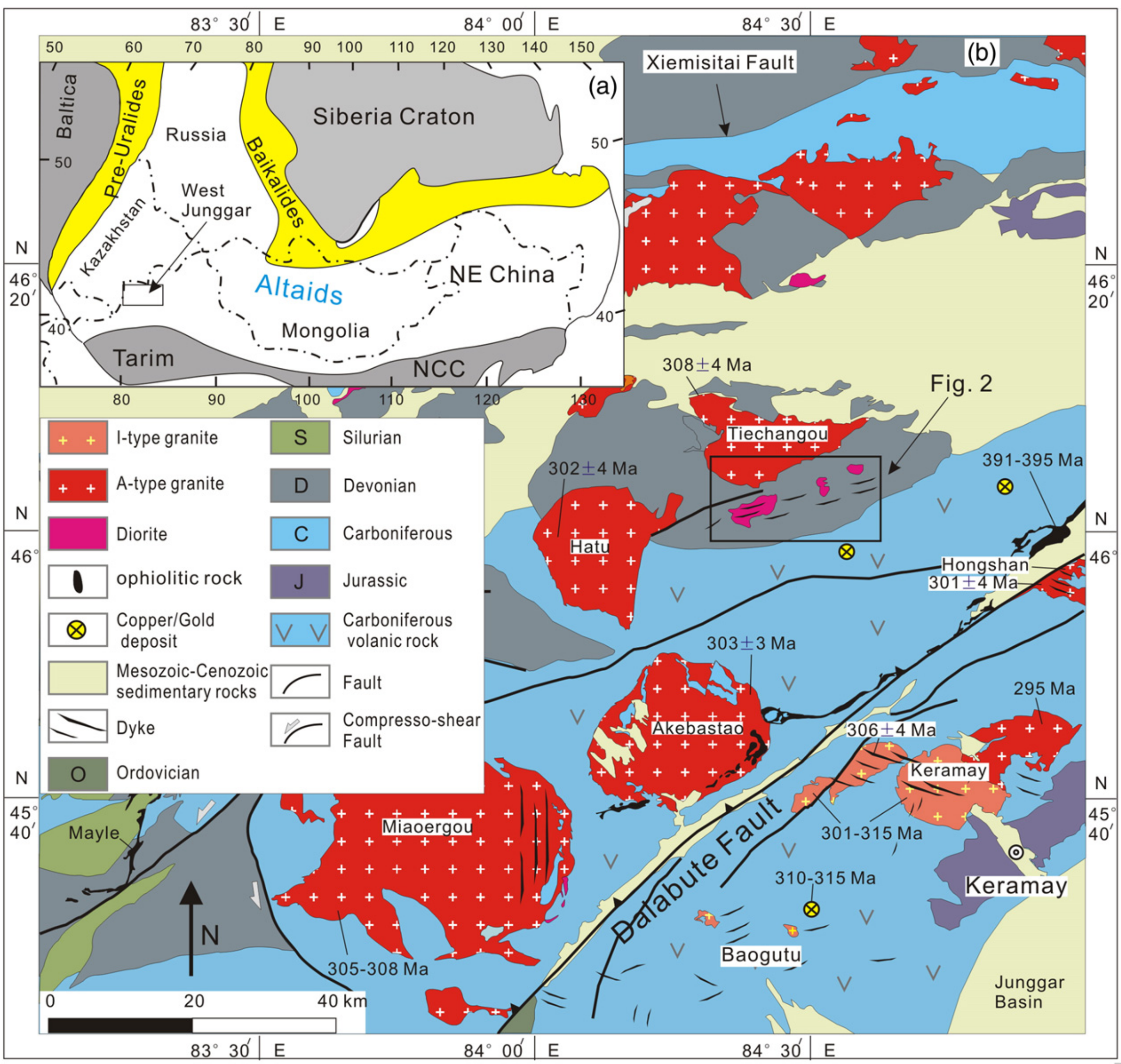

Fig. 1. (a). Simplified tectonic map of the Central Asian Orogenic Belt (Jahn et al., 2000). (b) Geological map of the western Junggar region (modified after Yin et al., 2013). Age data for mafic–ultramafic or ophiolitic rocks are from Yang et al. (2012), Xu et al. (2006), and Zhang and Huang (1992). Age data for granite intrusions and volcanic rocks are from Geng et al. (2009), Han et al. (2006), and Su et al. (2006). Age data for Baogutu diorite–granodiorite porphyry plutons are from Tang et al. (2010).