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Early Ordovician granites from the South Qiangtang terrane, northern Tibet: Implications for the early Paleozoic tectonic evolution along the Gondwanan proto-Tethyan margin

Pei-yuan Hu [a], Qing-guo Zhai [a,*], Bor-ming Jahn [b], Jun Wang [a], Cai Li [c], Hao-yang Lee [b], Suo-han Tang [b]

[a] Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037, China
[b] Department of Geosciences, National Taiwan University, Taipei 106, Taiwan
[c] School of Earth Science, Jilin University, Changchun, Jilin 130061, China

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ABSTRACT

Early Ordovician granites occur in the Gemuri and Bensong Co areas of the South Qiangtang terrane, northern Tibet, and LA-ICP-MS zircon U–Pb dating reveals that the magmatism took place between 486 and 480 Ma. The Geochemical features of these Early Ordovician granites are comparable to those of high-K, calc-alkaline S-type granites. They exhibit negative values of zircon $\varepsilon_{Hf}(t)$ (−8.5 to +1.7) and whole-rock $\varepsilon_{Nd}(t)$ (−8.1 to +0.5), as well as old zircon Hf model ages (T^{C}_{DM} = 1349–1992 Ma) and whole-rock Nd model ages (T^{C}_{DM} = 1145–1804 Ma). These Early Ordovician granites can be attributed to partial melting of the Paleoproterozoic metasedimentary rocks of the South Qiangtang terrane, while minor amounts of mantle-derived components were introduced into their magma sources. Taking into account previous data, we propose that the Early Ordovician granites developed in a post-collisional tectonic setting and that they were related to the collisional accretion of Asian microcontinental fragments (such as the South China, North China, Tarim, and Qaidam–Kunlun terranes) that took place as a result of oceanic subduction along the Gondwana proto-Tethyan margin during the early Paleozoic.

1. Introduction

The early Paleozoic (ca. 530–470 Ma) was a key period in the tectonic evolution of Gondwana. During this time, the amalgamation of the various components of the Gondwana supercontinent was completed, and subduction of the oceanic slab along the peri-Gondwana margin commenced (Cawood and Buchan, 2007; Cawood et al., 2007; Meert, 2003; Murphy et al., 2011; Zhang et al., 2008, 2012; Zhu et al., 2012). Some early Paleozoic magmatic rocks have recently been identified along the Gondwanan proto-Tethyan margin (Hu et al., 2013; Zhu et al., 2012, and the references therein) (Table 1), but their origins and tectonic settings remain debated. In general, there are two contrasting hypotheses: (1) that the Gondwanan proto-Tethyan margin was a passive continental margin during the early Paleozoic (Miller et al., 2001; Murphy and Nance, 1991), and that the early Paleozoic magmatic rocks were formed during post-collision extensional setting after the final stage of the Pan-African orogenic cycle (Baig et al., 1988; Gaetani and Garzanti, 1991; Hu et al., 2010a; Lin et al., 2012; Liu et al., 2012; Pan et al., 2012; Song et al., 2007; Xu et al., 2005; Yang et al., 2012); and (2) that there was an early Paleozoic Andean-type orogeny along the Gondwanan proto-Tethyan margin (Cawood et al., 2007; Hu et al., 2013; Zhu et al., 2012), and that the early Paleozoic magmatic rocks were related to oceanic subduction (Ding et al., 2014; Hu et al., 2013) and the collisional accretion of microcontinents derived from outboard of the Andean-type magmatic arc (Wang et al., 2011; Zhu et al., 2012). Geochronological and geochemical investigations of the early Paleozoic magmatic rocks along the Gondwanan proto-Tethyan margin would play a key role in resolving this discrepancy.

The South Qiangtang terrane, located in the north–central part of the Tibetan Plateau (Fig. 1), has commonly been considered to represent a microcontinent of the Gondwana supercontinent along the northern margin of the proto-Tethyan margin in the early Paleozoic (Metcalfe, 2009; Yin and Harrison, 2000). In the past decade, studies in this area have focused on high-pressure metamorphic rocks (eclogite and blueschist) (e.g., Li et al., 2006; Liu et al., 2011; Zhai et al., 2011, and the references therein), and these rocks have been attributed to the closure of the Paleo-Tethys Ocean in this area. Few studies have considered the early Paleozoic tectonic evolution of the South Qiangtang terrane. Recently, early Paleozoic granitoids were reported in the Duguer area of the South Qiangtang terrane (ca. 476–471 Ma, Pullen et al., 2011), but detailed geochemical and isotopic investigations are still lacking.

In this paper we present the results of our study into the Early Ordovician granites in the Gemuri and Bensong Co areas of the South

* Corresponding author at: Institute of Geology, Chinese Academy of Geological Sciences, 26 Baiwanzhuang Road, Beijing 100037, China. Tel.: +86 10 68999713; fax: +86 10 68997803.
E-mail address: zhaiqingguo@126.com (Q. Zhai).

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Table 1
Summary of age data for the early Paleozoic magmatic rocks in the terranes of the southern Tibetan Plateau.

Location	Tectonic terrane	Lithology	Dating method	Age (Ma)	References
Mafic volcanic rocks (492–496 Ma)					
Banglei	Lhasa	Metabasalt	Zircon U–Pb	492	Zhu et al. (2012)
Mandi	Himalaya	Basalt	Cpx–Plg Sm–Nd	496	Miller et al. (2001)
Longling	Baoshan	Metabasalt	Zircon U–Pb	499	Yang et al. (2012)
Silicic volcanic rocks (536–492 Ma)					
Banglei	Lhasa	Metarhyolite	Zircon U–Pb	492	Zhu et al. (2012)
Banglei	Lhasa	Metarhyolite	Zircon U–Pb	536	Pan et al. (2012)
Zhaqian	Lhasa	Metarhyolite	Zircon U–Pb	525 and 511	Hu et al. (2013)
Zhakang	Lhasa	Metarhyolite	Zircon U–Pb	510	Hu et al. (2013)
Zhakang	Lhasa	Metarhyolite	Zircon U–Pb	501	Ji et al. (2009)
Zhakang	Lhasa	Metarhyolite	Zircon U–Pb	512	Ding et al. (2014)
Granitoids (532–462 Ma)					
Duguer Range	Southern Qiangtang	Granitic gneiss	Zircon U–Pb	476–471	Pullen et al. (2011)
Gemuri	Southern Qiangtang	Granite	Zircon U–Pb	486 and 480	This study
Bensong Co	Southern Qiangtang	Granitic gneiss	Zircon U–Pb	486 and 481	This study
Amdo	Amdo	Granitic gneiss	Zircon U–Pb	531	Xu et al. (1985)
Amdo	Amdo	Granitic gneiss	Zircon U–Pb	488	Xie et al. (2010)
Amdo	Amdo	Granitic gneiss	Zircon U–Pb	517–505	Xie et al. (2013)
Amdo	Amdo	Granitic gneiss	Zircon U–Pb	532–483	Guynn et al. (2012)
Xainza	Lhasa	Granite	Zircon U–Pb	510	Gehrels et al. (2011)
Tongka	Lhasa	Granite	Zircon U–Pb	507	Li et al. (2008)
Kangmar	Himalaya	Granitic gneiss	Zircon U–Pb	508	Lee et al. (2000)
Kali Gandaki	Himalaya	Granitic gneiss	Monazite U–Pb	484	Godin et al. (2001)
Kathmandu	Himalaya	Granite	Zircon U–Pb	484–476	Gehrels et al. (2003)
Kathmandu	Himalaya	Granite	Zircon U–Pb	478 and 477	Cawood et al. (2007)
Mabja	Himalaya	Granitic gneiss	Zircon U–Pb	530	Lee and Whitehouse (2007)
Kampa	Himalaya	Granitic gneiss	Zircon U–Pb	506	Quigley et al. (2008)
Yadong	Himalaya	Granite	Zircon U–Pb	499	Shi et al. (2010)
Gyirong	Himalaya	Granitic gneiss	Zircon U–Pb	499	Wang et al. (2011)
Gyirong	Himalaya	Granitic gneiss	Zircon U–Pb	485–473	X.X. Wang et al. (2012)
Kangmar	Himalaya	Granitic gneiss	Zircon U–Pb	499-478	X.X. Wang et al. (2012)
Yalashangbo	Himalaya	Granitic gneiss	Zircon U–Pb	488	X.X. Wang et al. (2012)
Dadeldhura	Himalaya	Granite	Zircon U–Pb	512–474	Gehrels et al. (2006a)
Dadeldhura	Himalaya	Granite	Zircon U–Pb	484–476	Gehrels et al. (2006b)
Namche Barwa	Himalaya	Granitic gneiss	Zircon U–Pb	499 and 490	Zhang et al. (2008)
Mengnuo	Baoshan	Granite	Zircon U–Pb	502–499	Liu et al. (2009)
Pingdajie	Baoshan	Granite	Zircon U–Pb	472 and 466	Chen et al. (2007)
Pinghe	Baoshan	Granite	Zircon U–Pb	486–480	Dong et al. (2012)
Pingda	Baoshan	Granite	Zircon U–Pb	472–473	Wang et al. (2013)
Ximeng	Baoshan	Granite	Zircon U–Pb	460–463	Wang et al. (2013)
Fugong	Gongshan	Granite	Zircon U–Pb	487	Song et al. (2007)
Gongshan	Gongshan	Granite	Zircon U–Pb	474 and 462	Liu et al. (2012)
Luxi	Tengchong	Granitic gneiss	Zircon U–Pb	489	Lin et al. (2012)
Gaoligong	Tengchong	Granite	Zircon U–Pb	484–492	Wang et al. (2013)

Note: the abbreviation Cpx and Plg in the line of dating method represents clinopyroxene and plagioclase, respectively.

Qiangtang terrane, including new laser ablation–inductively coupled plasma–mass spectrometer (LA-ICP-MS) zircon U–Pb ages, whole-rock geochemical and Sr–Nd isotope data, and zircon Hf isotope compositions. These new age and geochemical data are used to discuss the provenance and petrogenesis of the Early Ordovician granites, as well as the tectonic evolution of the Gondwanan proto-Tethys margin during the early Paleozoic.

2. Geologic background and sample descriptions

The Tibetan Plateau lies in the eastern part of the Himalayan–Alpine orogen. Geologically, it comprises five extensive E–W trending terranes. From north to south, they are the Bayan Har–Garze, North Qiangtang, South Qiangtang, Lhasa, and Himalaya terranes, separated by the Jinsha, Longmu Co–Shuanghu, Bangong–Nujiang, and Indus–Yarlung Zangbo suture zones (Yin and Harrison, 2000) (Fig. 1). The South Qiangtang, Lhasa, and Himalaya terranes are generally thought to have originated from Gondwana (BGMR, 1993; Li, 2008; Metcalfe, 2009, 2013), whereas the Bayan Har–Garze and North Qiangtang terranes are considered to have Cathaysian affinities (BGMR, 1993; Jin, 2002; Li, 2008; Zhang et al., 2009).

The South Qiangtang terrane is bound by the Longmu Co–Shuanghu suture zone to the north and the Bangong–Nujiang suture zone to the south (Fig. 1), and the main rock units exposed are sedimentary sequences of pre-Ordovician, Carboniferous, and Permian age. The pre-Ordovician rocks have undergone low-grade metamorphism, and mainly comprise meta-sandstone and mica–quartz schist (Pan et al., 2004). The Carboniferous–Permian rocks are mainly sandstone and limestone, and some have also undergone a low-grade metamorphism (Li, 2008). Glaciomarine deposits and fossils of cold-water biota have been recognized within the Carboniferous–Permian sedimentary rocks, supporting a Gondwana affinity for the South Qiangtang terrane (Jin, 2002; Li and Zheng, 1993).

The Gemuri and Bensong Co areas are located in the core of the South Qiangtang terrane, and 1:25,0000 mapping and various investigations have shown that numerous granitoids are present, with ages ranging from Early Ordovician to Late Triassic (Fig. 2). The Late Triassic granites that form the Bensong Co batholith resulted from Triassic collision between the South and North Qiangtang terranes (Hu et al., 2010b; Huang et al., 2007). Notably, the Early Ordovician granites were first reported from the Gemuri and Besong Co areas. These Early Ordovician granites, emplaced in pre-Ordovician metasedimentary rocks (Fig. 3a), are cut by later granitic dikes (Fig. 3e).

We collected 25 samples for whole-rock geochemical analyses, and 5 of these were selected for LA-ICP-MS zircon U–Pb dating (sample locations are given in Fig. 2). The Early Ordovician granites in the Gemuri