Ore Geology Reviews 56 (2014) 566–583

Contents lists available at ScienceDirect

Ore Geology Reviews

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

Petrogenesis and tectonic significance of Late Jurassic–Early Cretaceous volcanic-intrusive complex in the Tianhuashan basin, South China

Huimin Su [a,*], Jingwen Mao [b], M. Santosh [a,c], Guiqing Xie [b]

[a] State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Beijing 100083, PR China
[b] Institute of Mineral Resources, Chinese Academy of Geological Sciences, Beijing 100037, PR China
[c] Division of Interdisciplinary Science, Kochi University, Kochi 780-8520, Japan

ARTICLE INFO

Article history:
Received 15 December 2012
Received in revised form 16 May 2013
Accepted 17 May 2013
Available online 23 May 2013

Keywords:
Volcanic-intrusive complex
Geochemistry
Petrogenesis
Tianhuashan
Southeast China

ABSTRACT

The Late Mesozoic geological framework of South China is characterized by voluminous volcanic rocks and their intrusive counterparts. However, the ages, petrogenesis, and tectonic implications of the Late Mesozoic magmatism in South China, especially those in the Qinhang zone, are poorly constrained. The Tianhuashan basin is one of the important volcanic basins along the southern margin of the Qinhang zone, and is mainly composed of the Daguding and Ehuling Formations and their intrusive counterparts. Laser ablation-inductively coupled plasma-mass spectrometry (LA-ICPMS) U–Pb zircon data presented here in conjunction with our previously published data suggest that there are two distinct pulses of magmatism within the Tianhuashan basin. The granite porphyry was emplaced at ~158–157 Ma, whereas large-scale volcanic-intrusive rocks were formed at ~144–137 Ma, rather than in the Late Jurassic as previously regarded. The Tianhuashan volcanic-intrusive rocks have similar whole-rock element geochemical and Sr–Nd and zircon Hf isotopic compositions, suggesting that they were probably derived from similar source regions. These rocks exhibit clearly negative and variable bulk rock $\varepsilon_{Nd}(t)$ values in a range of −12.07 to −8.69 and low zircon $\varepsilon_{Hf}(t)$ values from −12.25 to +2.31, with Paleo- and Mesoproterozoic two-stage model ages for both Nd and Hf isotopes (1639–1915 Ma and 1051–1970 Ma, respectively), suggesting their derivation dominantly through partial melting of ancient crustal materials with involvement of a mantle-derived component in variable proportions and followed by differential assimilation of upper crust during magma ascent. An extensional setting associated with the roll-back of the Paleo-Pacific slab, is favored to explain the petrogenesis of the Tianhuashan volcanic-intrusive complex. The $\varepsilon_{Hf}(t)$ of zircon increases from Late Jurassic granite porphyry to Early Cretaceous magmatic rocks, suggesting progressive crust–mantle interaction in generating the episodic intermediate-felsic magma eruption during Late Mesozoic. Our results suggest that the continental extension along the Qinhang zone was weak during Late Jurassic and large-scale lithospheric extension did not take place until Early Cretaceous with ongoing development of slab roll-back.

1. Introduction

As an integral part of circum-Pacific Mesozoic tectono-magmatic belt, the South China block has attracted considerable interest of geologists worldwide over the last few decades not only because of their plentiful mineral resources, but also their complex geological history involving multiple stages of Mesozoic tectono-magmatic activity (Chen et al., 1989; Gilder et al., 1996; Jiang et al., 2011; Li et al., 2007; Mao et al., 2008, 2011, 2013; Wang, 2004; Wang and Zhou, 2002; Wong et al., 2009; Yuan et al., 2007, 2008, 2011; Zhang et al., 2011; Zhou and Li, 2000; Zhou et al., 2006). However, controversy surrounds the tectonic regime responsible for the extensive Late Mesozoic magmatism. Various geodynamic models, such as an Alpine-type collision, continental rifting and basin formation, as well as post-orogenic (Indosinian) extension (Chen et al., 2008; Gilder et al., 1996; Hsü et al., 1988, 1990; Li, 2000), have been proposed in the last two decades. Among these, the active continental margin model related to the subduction of the Paleo-Pacific plate beneath the Eurasia plate has been one of the widely accepted models, although the exact mechanism of the model has remained equivocal with various proposals (e.g., Charvet et al., 1994; Jahn et al., 1990; Jiang et al., 2009, 2011; Lan et al., 1996; Lapierre et al., 1997; Li and Li, 2007; Li et al., 2007; Martin et al., 1994; Yang et al., 2011; Zhou and Li, 2000; Zhou et al., 2006). Regardless of any models mentioned above, most researchers proposed that the Late Mesozoic was likely a time of transformation from convergence to extension. Extensive studies suggested that the initiation of extension in South China was considered to be at ca. 175 Ma (e.g., Li et al., 2006, 2007; Liu et al., 2012; Wang et al., 2003, 2005; Wang et al., 2006), yet the extent of lithospheric extension beneath South China is not well constrained

* Corresponding author at: School of Earth Sciences and Mineral Resources, China University of Geosciences, No. 29 Xueyuan Road, Beijing, 100083, PR China. Tel.: +86 10 8232 1153.
E-mail address: suhuimin1984@163.com (H. Su).

0169-1368/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.oregeorev.2013.05.004

for the Late Mesozoic. The most outstanding feature in South China is the massive expanse of Late Mesozoic volcanic-intrusive complex, covering more than 220,000 km^2 and therefore studies on these rocks are important in understanding the tectonic evolution of South China (Zhou et al., 2006). A coherent tectonic model for South China must account for the diverse compositional characteristics of the voluminous Late Mesozoic magmatic rocks.

Recently, we identified the volcanic-intrusive activity in the Tianhuashan basin, close to the southern margin of the Qinhang zone, in the South China interior, has been episodic and can be divided into two stages: ~157–158 Ma granite porphyry and 144–137 Ma volcanic and associated intrusive rocks (Su et al., 2013), although the precise timing of these volcanic-intrusive complex magmatism remains controversial (Meng et al., 2012a), they provide a rare opportunity to examine the Late Mesozoic tectonic evolution of the Qinhang zone. However, previous studies (Meng et al., 2012a; Su et al., 2013; Zuo et al., 2010) mainly focused on the geochronological aspects, therefore the origin of these rocks and the processes involved in their formation remains enigmatic. Consequently, it is apparent that the petrogenetic characteristics of the igneous rocks need to be studied in much greater detail in order to understand the Late Mesozoic magmatic activity and the process of crust–mantle interaction in the Qinhang zone. In this contribution, we present new zircon U–Pb age, whole-rock major and trace elements and Sr–Nd and zircon Hf isotopic compositions from the Tianhuashan volcanic-intrusive complex in an attempt to better constrain the ages and petrogenetic processes of these igneous rocks and their significance in understanding the geodynamic setting of Late Mesozoic tectonics and magmatism in the interior of South China.

2. Geological setting and sample description

The South China block has a complex tectonic history, and comprises two major Precambrian continental blocks: the Yangtze craton in the northwest, and the Cathaysia block in the southeast, divided by the Qinhang zone (also known as the Ganhang zone or Shihang zone) which starts from Jiangshan–Shaoxing suture in the northeast and extends to the Qinzhou, southeastern Guangxi, in the southwest (Gilder et al., 1996; Pirajno and Bagas, 2002; Yang et al., 2011). The Late Mesozoic period is marked by extensive magmatism including voluminous eruption of volcanic rocks and their intrusive counterparts in South China, particularly in Zhejiang, Fujian, Jiangxi and Guangdong provinces (Mao et al., 2008; Peng et al., 2008). A series of Late Mesozoic volcanic-intrusive complexes was emplaced in South China during three major stages from the early to late Yanshanian: 180–160 Ma; 160–135 Ma and 135–90 Ma (Li, 2000; Li et al., 2007; Zhou and Li, 2000; and references therein). Among these, felsic volcanic rocks and granitoids are volumetrically dominant, whereas intermediate-mafic rocks (e.g. basalts, andesites, gabbros and syenites) are rare (He et al., 2010; Li et al., 2003; Zhou and Li, 2000).

The Tianhuashan basin, containing a large-sized Ag–Pb–Zn deposit (Lengshuikeng deposit), is located on the border of Jiangxi and Fujian provinces, and is part of north Wuyi Mountain volcanic belt at the southern margin of the Qinhang zone. This zone is represented by a number of NNE-trending Mesozoic extensional volcanic basins that include the Tianhuashan, Xiangshan, Huanggangshan and Tongluoshan basins (Fig. 1b). The Tianhuashan basin, is ellipsoidal in shape and approximately 50 km long, 40 km wide with an area of ~1500 km^2 (Fig. 1c), and is one of the largest volcanic basins, and is composed of Tiantaishan and Yuefengshan subbasins. The basement metamorphic rocks are mainly exposed along the margins of the basin (Figs. 1c and 2) and comprise muscovite quartz schists, quartz-mica schists and biotite plagiogneisses of the Proterozoic Laohutang Formation (Fm.). The Paleozoic strata are sporadically exposed in the margins of the basin with dominant Carboniferous ages and include quartz rudites, muscovite quartz sandstones, siltstones and shales. The pre-Mesozoic rocks

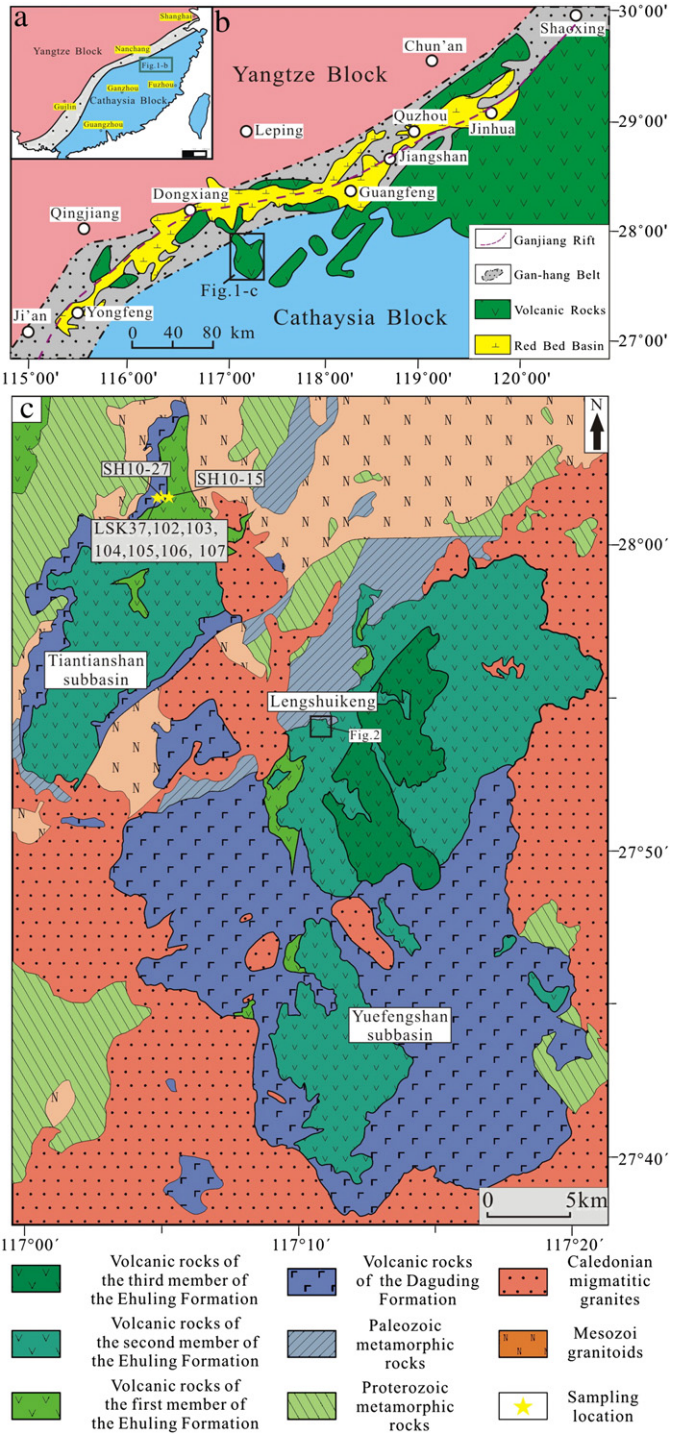

Fig. 1. (a) Main tectonic units of South China; (b) geological sketch map showing the Gan-Hang Belt in Southeast China (Modified after Yu et al., 2006); (c) regional tectonic sketch map of the Tianhuashan basin (modified from the 1:200,000 geological map of Guangze and Shangrao areas, 1972).

are discordantly overlain by the Early Cretaceous rocks, which can be divided into two magmatic cycles: the early stage Daguding Fm. and the late stage Ehuling Fm., with thicknesses of 425–520 m and 390–620 m, respectively (Figs. 2 and 3). These two formations are separated by ca. 10–15 m thick bright-red clays of a weathering crust (Fig. 4a). The Daguding Fm. volcanics contain two distinct members. The lower member is dominated by grayish-pink, coarse-grained, rhyolitic crystal tuff and pebbly crystal tuff, whereas the upper member consists primarily of andesite which is an important marker bed within the Daguding Fm.