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Petrogenesis and tectonic implications of the early Jurassic Fe–Ti oxide-bearing Xialan mafic intrusion in SE China: Constraints from zircon Hf–O isotopes, mineral compositions and whole-rock geochemistry

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ABSTRACT

Abundant Jurassic bimodal igneous rocks are present in the Nanling region, southeastern China. Their relationship with the tectonic evolution of southeastern China in the Jurassic is still a matter of debate. The ~194 Ma Xialan gabbroic intrusion is the oldest mafic intrusion in the Jurassic Nanling igneous belt discovered to date. The intrusion also hosts a significant Fe–Ti oxide deposit. Thus, this intrusion is important for the studies of fundamental controls on the early Jurassic basaltic magmatism in the region and on the Fe–Ti oxide mineralization in this type of intrusion. In this paper we report Hf–O isotopic compositions of zircon for the intrusion and the stratigraphic variations of whole-rock and important mineral compositions in the intrusion. Based on variations in mineral assemblages and the compositions of cumulus minerals, the Xialan intrusion is divided into four cyclic units (I to IV from the base to the top). Our results indicate that each unit represents a new input of magma with composition more primitive than the resident magma. The contents of Fo in olivine, which occurs in the base of Units I and II, are ~66 mol%. This indicates that the parental magma for the intrusion is highly fractionated. Extensive fractional crystallization and density-driving crystal sorting appear to have played a critical role in the formation of important Fe–Ti oxide layers in the upper parts of Units I and II. Clinopyroxene trace element analyses indicate that the parental magma for the Xialan intrusion is characterized by pronounced negative Nb–Ta anomalies. Some of the zircon crystals from the Xialan intrusion have $\varepsilon_{Hf}(t) > 10$ and $\delta^{18}O$ between 5.2 and 5.8‰. This, together with the depleted Sr–Nd isotopic compositions in whole rocks reported previously by others, indicates a dominant asthenospheric mantle source with significant contribution of the overlying SCLM. The $\varepsilon_{Hf}(t)$ and $\delta^{18}O$ values of zircon from the intrusion are negatively correlated, consistent with contamination with crustal materials during magma ascent and final emplacement. Mixing calculation based on these data shows that <20 wt.% crustal contamination is required. The negative Nb–Ta anomalies in the Xialan magma can be attributed to crustal contamination. The Al_2O_3–TiO_2 compositions of clinopyroxene from the Xialan intrusion are consistent with those of clinopyroxene from mafic–ultramafic intrusions in continental rift zones. Based on the results from this study and previous studies by others, we propose that the basaltic magmatism in the early Jurassic in the Nanling region was related to continental rifting and asthenosphere upwelling. We interpret that the Paleo-Pacific plate flat subducted during Triassic and then the subducted Paleo-Pacific plate became delaminated and foundered at ca. 195 Ma. The early Jurassic mafic–ultramafic intrusions, syenites and bimodal volcanic rocks represent a rift-related magmatism in response to the upwelling of asthenospheric mantle, originating from different degrees of mixing of magma from partial melting of the asthenospheric mantle and overlying SCLM due to the break-up of subducted flat-slab beneath SE China continent.

1. Introduction

The Mesozoic igneous rocks, including granitoids, rhyolitic rocks, gabbros and basalts are widespread in southeastern China (e.g., Wang et al., 2013; Zhou and Li, 2000; Zhou et al., 2006a). Those with Cretaceous ages mainly occur in the coastal region (He and Xu, 2012; Wang et al., 2013; Zhou and Li, 2000; Zhou et al., 2006a) whereas those with Jurassic ages mainly occur in the inland region, such as the E–W trending igneous belt in the Nanling Range (Fig. 1) (Chen et al., 1998, 2002a, 2005; He et al., 2010; Kong et al., 2000; Li et al., 2003, 2007a,b; Meng et al., 2012; Xie et al., 2006). In this region, the bimodal volcanic rocks are distributed in small Mesozoic basins. The basaltic

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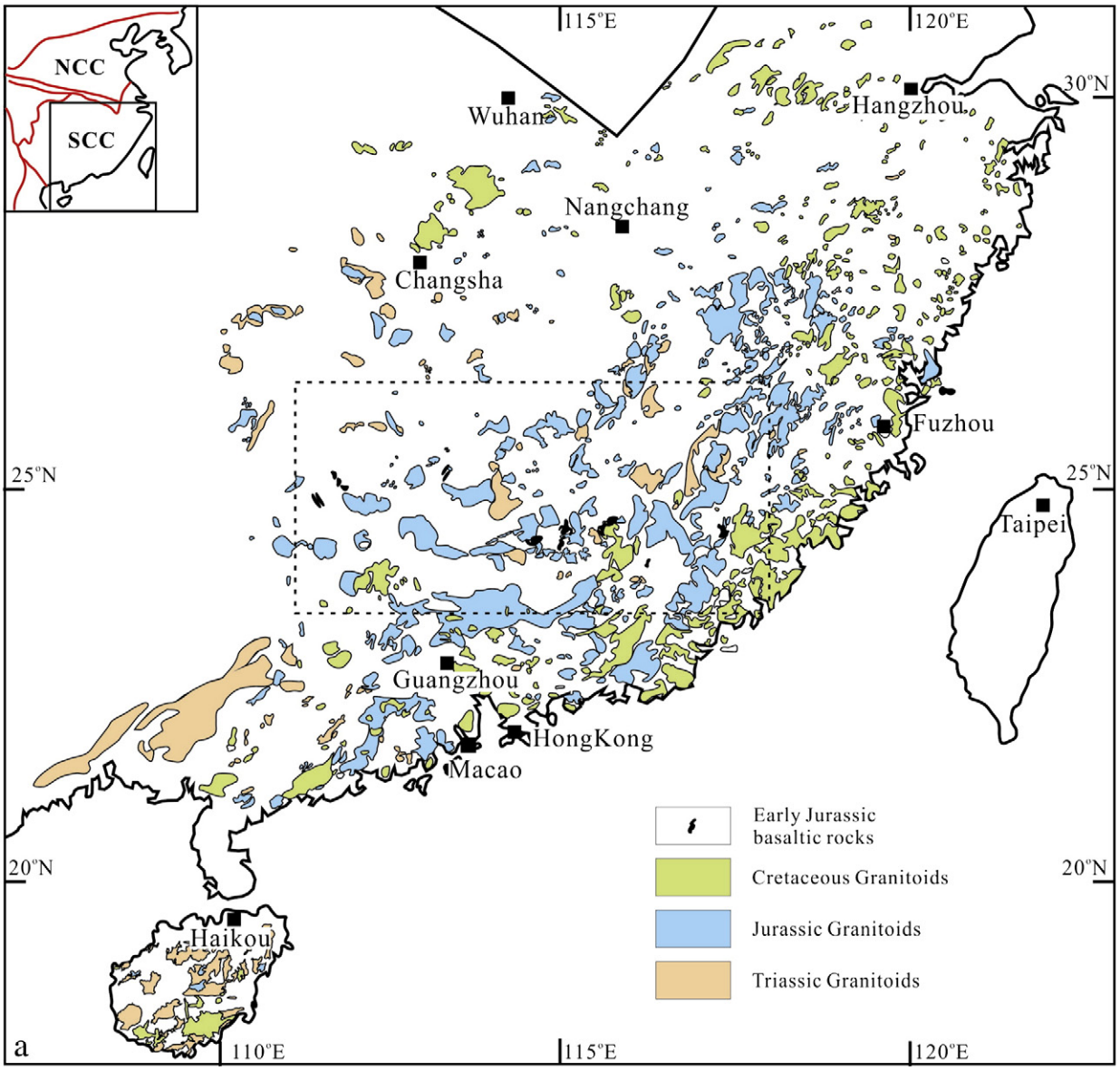
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Guangzhou
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Macao
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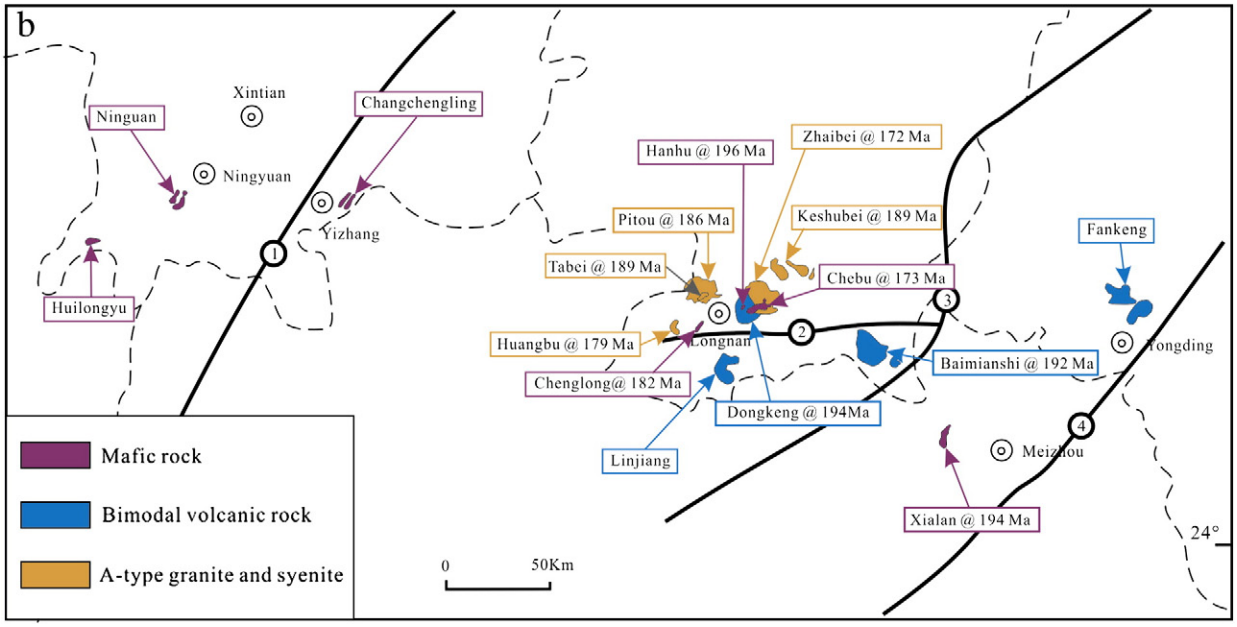
Haikou
110°E
Early Jurassic basaltic rocks
Cretaceous Granitoids
Jurassic Granitoids
Triassic Granitoids
a


b
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Ninguan
Changchengling
Ningyuan
Yizhang
Huilongyu
Hanhu @ 196 Ma
Zhaibei @ 172 Ma
Pitou @ 186 Ma
Keshubei @ 189 Ma
Tabei @ 189 Ma
Chebu @ 173 Ma
Fankeng
Huangbu @ 179 Ma
Longnan
Tongding
Baimianshi @ 192 Ma
Chenglong@ 182 Ma
Dongkeng @ 194Ma
Linjiang
Meizhou
Xialan @ 194 Ma
24°
0
50Km
Mafic rock
Bimodal volcanic rock
A-type granite and syenite