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Late Permian basalts in the northwestern margin of the Emeishan Large Igneous Province: Implications for the origin of the Songpan-Ganzi terrane

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ABSTRACT

SHRIMP zircon U-Pb ages, geochemical and Sr-Nd isotopic data are reported for two types of basalts (Type I and Type II) from a Permian volcanic-pyroclastic succession in the Tubagou section, Baoxing area along the southeastern margin of the Songpan-Ganzi terrane (SGT) in the Sichuan province of SW China. Zircons from the uppermost basaltic flows yield crystallization age of 257.3 ± 2.0 Ma, which may represent the time of culmination the basaltic eruption. Type I shows alkaline affinity with $\varepsilon_{Nd}(t)$ values of +2.4 to +2.9, and is characterized by oceanic island basalt (OIB)-type light rare earth element (LREE) and trace-element patterns. In contrast, Type II rocks are tholeiitic, and close to initial rift tholeiite (IRT)-like REE and trace element patterns, and are relatively depleted in highly incompatible elements with slightly negative Nb-Ta anomaly. The $\varepsilon_{Nd}(t)$ values of Type II are between +1.8 to +2.2. The geochemical characteristics suggest the Type I has not been significantly crustally contaminated, whereas Type II maybe have experienced minor crustal contamination. Clinopyroxene crystallization temperature is ~80–120°C higher than that of the normal asthenospheric mantle, implying anomalous thermal input from mantle source and a possible plume-head origin for the Tubagou lava. The geochemical and isotopic fes, reflecting progressive lithosphere thinning probably through plume-lithosphere interaction. The spatial and temporal coincidence between the Dashibao basalt eruptions, reflecting progressive lithosphere thinning probably through plume-lithosphere interaction. The spatial and temporal coincidence between the Dashibao basalt eruption and continental rifting suggest that continental break-up and the opening of an extensional basin was probably related to the Late Permian Emeishan plume, which triggered the breakup between the SGT and the Yangtze craton.

1. Introduction

Large igneous provinces (LIPs) are the products of anomalously high melt production rates, and thus have been linked to the arrival of a mantle plume at the base of the lithosphere (e.g., Campbell and Griffiths, 1990; Ernst et al., 2005; Saunders et al., 2005). Moreover, rising plume head–lithosphere interaction could result in continental breakup, as illustrated by the example of major LIP eruptions during the last 200 Ma (e.g., Coffin and Eldholm, 1994; Courtillot et al., 1999; Nikishin et al., 2002). However, there are exceptions with some LIPs unrelated to rupturing continental lithosphere, such as the Siberian traps and the Ontong Java plateau (Condie, 2001).

Some key lines of evidence have been proposed to support that the Emeishan Large Igneous Province (ELIP) is a mantle plume-derived LIP including high magnesian picrites, giant radiating mafic dyke swarm, and >1 km of doming of the regional lithosphere shortly before volcanism, together with the short duration of volcanism as well as geophysical signatures (e.g., Ali et al., 2010; Chen et al., 2015; Chung and Jahn, 1995; He et al., 2003a; Li et al., 2015a; Shellnutt et al., 2012; Xu et al., 2001, 2004; Zhang et al., 2006; Zhong et al., 2014). Comparable with the Siberian trap, the ELIP is traditionally thought to be not associated with continental rift or fragmentation (He et al., 2003b). However, some researchers correlated the Emeishan mantle plume with the opening of the Songpan-Ganzi extensional basin, although this inference has not been corroborated by any robust evidence (e.g., Chang, 2000; Hou et al., 1996; Song et al., 2004; Yang et al., 1994; Zi et al., 2010).

The Baoxing area in the northwestern part of the ELIP belongs to the SGT, where late Permian marine basalts (Dashibao Formation) have been recognized and considered to be likely part of the Emeishan flood basalts (Fig. 1; Song et al., 2004; Xiao and Xu, 2005; Zi et al.,

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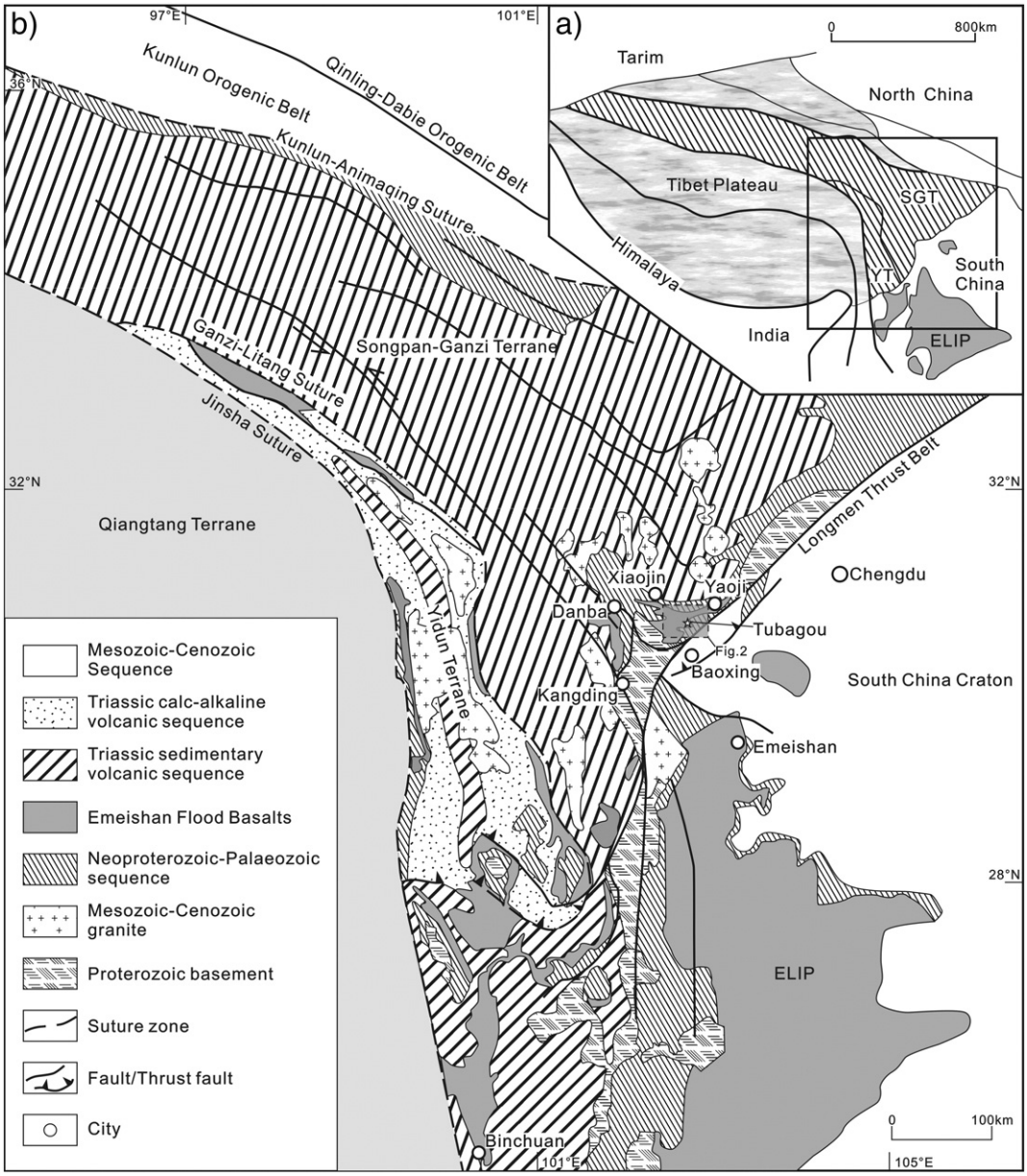

Fig. 1. Regional geological map of the SGT and the ELIP, modified from Song et al., (2004). YT, Yidun Terrane. Stars represent the locations of the sampling and columns.

2010). Therefore, precise geochronologic and geochemical data and a comprehensive petrogenetic study of the petrogenesis of the Dashibao basalts can provide some key constraints on the nature of mantle sources and the relationship between the Emeishan LIP/mantle plume and the derivation of the SGT. In this paper, we present mineral chemical, bulk-rock major and trace element and Sr-Nd isotopic compositions, and a new SHRIMP zircon U-Pb age of the Dashibao basalts from the Tubagou area in the SGT. Based on these results, we attempt to: (1) track the petrogenesis of the Tubagou basalts (Dashibao Formation) and the plume–lithosphere interaction, and (2) shed new lights on the origin of the SGT.

2. Geological background

2.1. Emeishan large igneous province

The ELIP is located to the east of Tibetan plateau and the western margin of the Yangtze craton, SW China (Fig. 1). The basement of the Yangtze craton is locally composed of the Paleoproterozoic Kangding Complex comprising granulite-amphibolite facies metamorphic rocks, the Paleo-Mesoproterozoic Huili Group or its equivalents, and the Yanbian or Kunyang Groups which consist of low-grade metasedimentary rocks interbedded with felsic and mafic metavolcanic rocks. The basement is overlain by a thick sequence (>9 km) of late Neoproterozoic (~600 Ma) to Permian clastic, carbonate, and metavolcanic rocks (Sichuan BGMR, 1991).

The extensive Emeishan flood basalts are exposed over an area of ~3.0×10^5 km^2 (Fig. 1b). The volcanic sequence has a thickness decreasing from west (>5km) to east (several hundred meters), and contains picrite, tholeiite and andesitic basalt (e.g., Chung and Jahn, 1995; Xu et al., 2001; Zhang et al., 2006). The distribution of units belonging to the ELIP has been subsequently affected by Mesozoic and Cenozoic post-emplacement faulting (Chung and Jahn, 1995), such as the Jinshajiang-Ailaoshan-Red river strike-slip fault (or suture zone). Recent studies suggested that basalts and mafic complexes exposed in the SGT, the Qiangtang terrain, the Simao basin, and in northern Vietnam might form an extension setting of the ELIP displaced by these faults (e.g., Fan et al., 2008; Hanski et al., 2010; Lai et al., 2012).