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CA-TIMS zircon U–Pb dating of felsic ignimbrite from the Binchuan section: Implications for the termination age of Emeishan large igneous province

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ABSTRACT

The age of the Emeishan lavas in SW China remains poorly constrained because the extrusive rocks are (1) thermally overprinted and so represent an open system unsuitable for $^{40}Ar/^{39}Ar$ geochronology and (2) in most cases devoid of zircon so that it is impossible for the application of U–Pb geochronology. Existing radiometric age constraints of Emeishan large igneous province are mainly from the application of SIMS and LA-ICP-MS U–Pb techniques to zircons from mafic and felsic intrusions, which represent indirect constraints for the lavas. In an attempt to directly determine the age of the Emeishan lava succession, high-resolution chemical abrasion-thermal ionization mass spectrometry (CA-TIMS) zircon U–Pb techniques have been used on the felsic ignimbrite at the uppermost part of the Emeishan lava succession. These techniques have yielded a weighted mean $^{206}Pb/^{238}U$ age of 259.1 ± 0.5 Ma (n = 6; MSWD = 0.7). We interpret this age as the termination age of the Emeishan flood basalts. The age of the Guadalupian–Lopingian boundary is still unconstrained by high-resolution geochronology but is likely to be close to our new age for this felsic ignimbrite.

1. Introduction

Numerous studies suggest a causal link between large igneous provinces (LIPs) and mass extinctions and/or global environmental changes in the history of the Earth (e.g., Courtillot and Renne, 2003; Wignall, 2001). Evidence for a temporal link comes mainly from high-resolution geochronology from both LIP products and altered claystones within fossil-bearing strata that record extinctions. The most striking example is the temporal coincidence of the Siberian Traps and the Permian–Triassic mass extinction (Bowring et al., 1998; Mundil et al., 2004; Reichow et al., 2009; Renne et al., 1995; Shen et al., 2011). It is therefore evident that the accurate geochronology of LIPs is pivotal in understanding both their geodynamic context as well as potential causal links with biotic crises (Courtillot and Renne, 2003; Wignall, 2001).

Despite numerous geochemical, paleontological, paleomagnetic, geophysical, and geochronological research on the Emeishan LIP (e.g., Ali et al., 2004; Chung and Jahn, 1995; He et al., 2003, 2007; Xiao et al., 2004a; Xu et al., 2001, 2004, 2008, 2010; Zhou et al., 2002), the age of the lavas is still debated (Shellnutt, in press; Shellnutt et al., 2012). Although the Emeishan LIP has been dated by $^{40}Ar/^{39}Ar$ and U–Pb techniques, many of the $^{40}Ar/^{39}Ar$ dating results yield Mesozoic–Cenozoic ages (Ali et al., 2004; Lo et al., 2002), most likely as a result of open system behavior of the analyzed minerals and rocks due to Mesozoic and Cenozoic thermotectonic events in the western Yangtze Block. Consequently, the timing of the Emeishan LIP magmatism is mainly constrained by U–Pb zircon dates from mafic–ultramafic and felsic intrusions (e.g., Shellnutt et al., 2012; Xu et al., 2008; Zhong et al., 2007, 2009, 2011; Zhou et al., 2002). It is assumed that these intrusive bodies are genetically related to the Emeishan LIP, and the acquired U–Pb ages imply that the main phase of the Emeishan LIP took place at ~257–260 Ma (Shellnutt et al., 2012; Xu et al., 2008; Zhou et al., 2002). This age is broadly consistent with the stratigraphic constraints that place the Emeishan basalts between the Middle and the Late Permian, around the Guadalupian–Lopingian (G–L) boundary (259.8 ± 0.4 Ma; Henderson et al., 2012).

Constraints for both the age and, in particular, the duration of the Emeishan volcanism are therefore still scarce and controversial. This is further complicated by ambiguous structural relationships of intrusions and mafic sills and dykes with respect to the extrusive rocks. It is unclear that the Emeishan volcanic event represents a single event or multiple phases of magmatism. This problem was partly resolved by He et al. (2007) who dated detrital zircon crystals by Sensitive High Resolution Ion Microprobe (SHRIMP) U–Pb methods from the clastic rocks from the Xuanwei Formation. He et al. (2007) demonstrated that these zircons (dated at 257 to 263 Ma) are mostly from acidic extrusives, which are the latest magmatic phase of the Emeishan LIP and so provides constraints on the termination age of the Emeishan volcanism.

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However, the SHRIMP techniques generally yield percent level uncertainty on individual spots analyses and 1–2% uncertainty on pooled ages but can be prone to inaccuracy if poorly calibrated or inhomogeneous standard materials are used or the calibration is inconsistent.

The application of TIMS zircon U–Pb techniques to chemically abraded single zircon crystals (CA-TIMS; Mattinson, 2005; Mundil et al., 2004) yields radiometric ages with superior precision and accuracy compared to those based on micro-beam analyses, i.e., Secondary Ion Mass Spectrometry (SIMS including SHRIMP) and Laser Ablation-Inductively Coupled Plasma-Mass Spectrometer (LA-ICP-MS) (Mundil et al., 2004; Shellnutt et al., 2012). In this study therefore, we use CA-TIMS to date zircons from the felsic ignimbrite in the uppermost part of the lava succession in the central part of the Emeishan LIP. The results yield a termination age for the Emeishan flood basalts that is in good agreement with the recently refined dates using the same method for the alkaline granitic plutons from the Emeishan LIP (Shellnutt et al., 2012). Potential implications of this age with regard to the G–L boundary age are also briefly discussed.

2. Geological background

The Emeishan LIP in SW China (Fig. 1a), which consists of flood basalts and contemporaneous mafic–ultramafic intrusions and felsic plutons, covers an area of more than 2.5×10^5 km^2 with a total thickness ranging from several hundred meters at the margin up to 5 km in the central area (Xu et al., 2001). Relatively limited exposure is likely due to erosion along the Ailaoshan–Red River fault and the Longmenshan

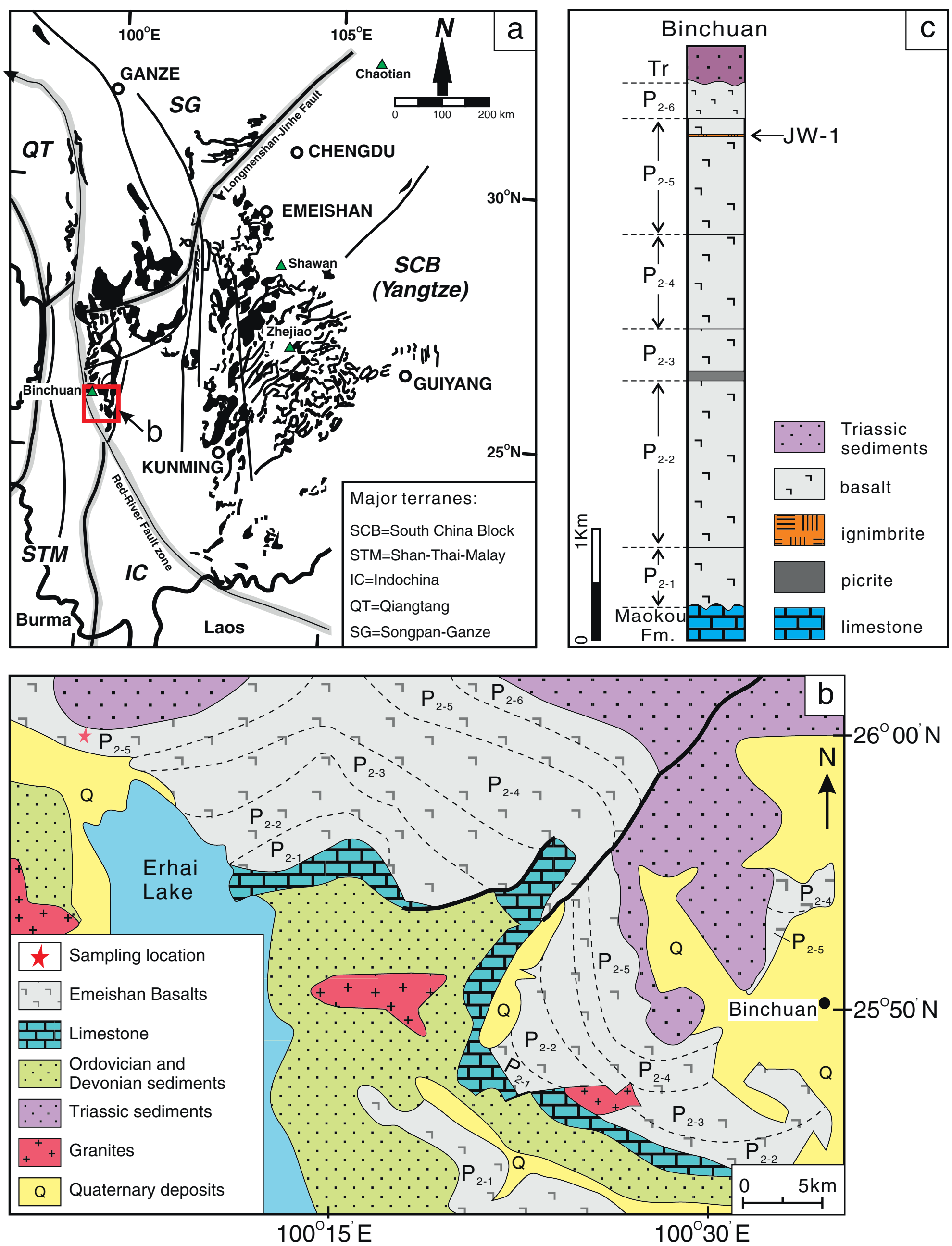

Fig. 1. (a) A schematic map showing the distribution of the Emeishan volcanic successions (after He et al., 2007). (b) A geological map showing the lava succession of the Emeishan LIP in the Binchuan area and sample locations. Note that $P_{2\text{-}1}$, $P_{2\text{-}2}$, $P_{2\text{-}3}$, $P_{2\text{-}4}$, $P_{2\text{-}5}$ and $P_{2\text{-}6}$ are sub-units of the Emeishan flood basalts. (c) A composite stratigraphic column showing the Emeishan lava succession in the Binchuan section and sample locations.