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# No pre-eruptive uplift in the Emeishan large igneous province: New evidences from its 'inner zone', Dali area, Southwest China

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ABSTRACT

The Permian Emeishan large igneous province (ELIP) in Southwest China has been considered a typical example of crustal domal uplift caused by mantle plume upwelling prior to the onset of volcanism. However, this model has been questioned by the discovery of hydromagmatic volcaniclastic deposits formed in a marine environment, located near the central ELIP area (the 'inner zone') which is inferred to be the zone of maximum uplift. The volcanology of the inner zone has thus far been poorly documented, fueling the debate about whether or not pre-eruptive uplift occurred prior to plume upwelling. Understanding the volcanology of this inner zone is therefore critical in constraining the eruption environment of the central ELIP. Our work has revealed new volcanological observations in the inner zone (Dali area), which can systematically constrain volcanism and paleoenvironment. The Basal Succession of the sequence is a thick pillow lavas pile with hyaloclastites, implying an initial deeper submarine stage of eruptions. Limestones and submarine fallout tuffs are interbedded with these pillow lavas. Above that, abundant mafic volcaniclastic products developed, which contain palagonite-rimmed lapilli-tuffs, base surge deposits and peperites, suggesting hydroclastic volcanism in a shallower submarine environment. The Upper Succession of the sequence preserves columnar-jointed lava flows and subaerial fallout tuffs, reflecting subaerial volcanism after the volcanic center emerged above the sea level. These abundant and systematic natures of this evidence suggest that the initial volcanism of the central ELIP occurred in a deep submarine environment. The submarine-to-subaerial transition is caused by progressive emplacement of voluminous magmatic products infilling the inner zone during the continuous emplacement of ELIP, rather than by crustal doming prior to the onset of volcanisms.



## 1. Introduction

Large igneous provinces (LIP) refer to magmatic provinces (>0.1 $Mkm^3$ in volume) that are emplaced on the Earth's surface in extremely short durations (>75% developed in ~1–5 Myr) in geologic history (most recent definition from Bryan and Ernst, 2008). The generation of a LIP is widely accepted as a direct consequence of mantle plume upwelling (White and McKenzie, 1989; Griffiths and Campbell, 1991). Earlier studies have argued that a rising plume would produce domal uplift that extended more than 1000 m above the pre-volcanic surface. Because this uplift is theorized to occur prior to the generation of the LIP, it could affect the LIP's initial emplacement environment and hence its stratigraphic depositional record (Saunders et al., 2007 and references therein).

The Emeishan large igneous province (ELIP), a Permian LIP located in Southwest China, has become the focus of debate in recent years not only for its temporal link to the end-Guadalupian extinction (Wignall, 2001; Zhou et al., 2002; Wignall et al., 2009) but also because it has been proposed to provide the best-documented example for the crustal domal uplift effect (He et al., 2003a, 2003b, 2006; Campbell, 2005). He et al. (2003a, 2003b) postulated that the sedimentary pattern of the ELIP matches uplift records of other LIPs concluded by Rainbird and Ernst (2001). Three main observations have been provided as plausible evidences: (1) the fact that the Maokou Formation, the end-Guadalupian limestone platform formation directly underlies the ELIP sequences, shows a symmetric thickening from a suggested 'inner zone' to the 'outer zone' (Fig. 1a), which has been interpreted as subaerial erosion caused by crustal domal uplift (He et al., 2003a, 2003b), (2) that in the top of the Maokou Formation, there is surface reliefs associated with clay materials, which have been interpreted as paleokarst surfaces (He et al., 2006), and (3) a strata wedge made of clastic rocks developed surround the inner zone and was interpreted as alluvial fan deposit from the eroded materials in the maximum uplifted area (He et al., 2006). Ukstins Peate and Bryan (2008) re-evaluated an ELIP section in Daqiao and challenged this finding (Fig. 1a). They found that the 'alluvial fan' deposits surrounded the inner zone are hydromagmatic products such as bomb beds and base surge deposits with accretionary lapilli, and suggested that the local volcanism in Daqiao was generated at sea level in an active carbonate platform setting (Ukstins Peate and Bryan, 2008). He et al. (2009) responded to this point, suggesting that the Daqiao section is not actually located within the 'inner zone' and that these features

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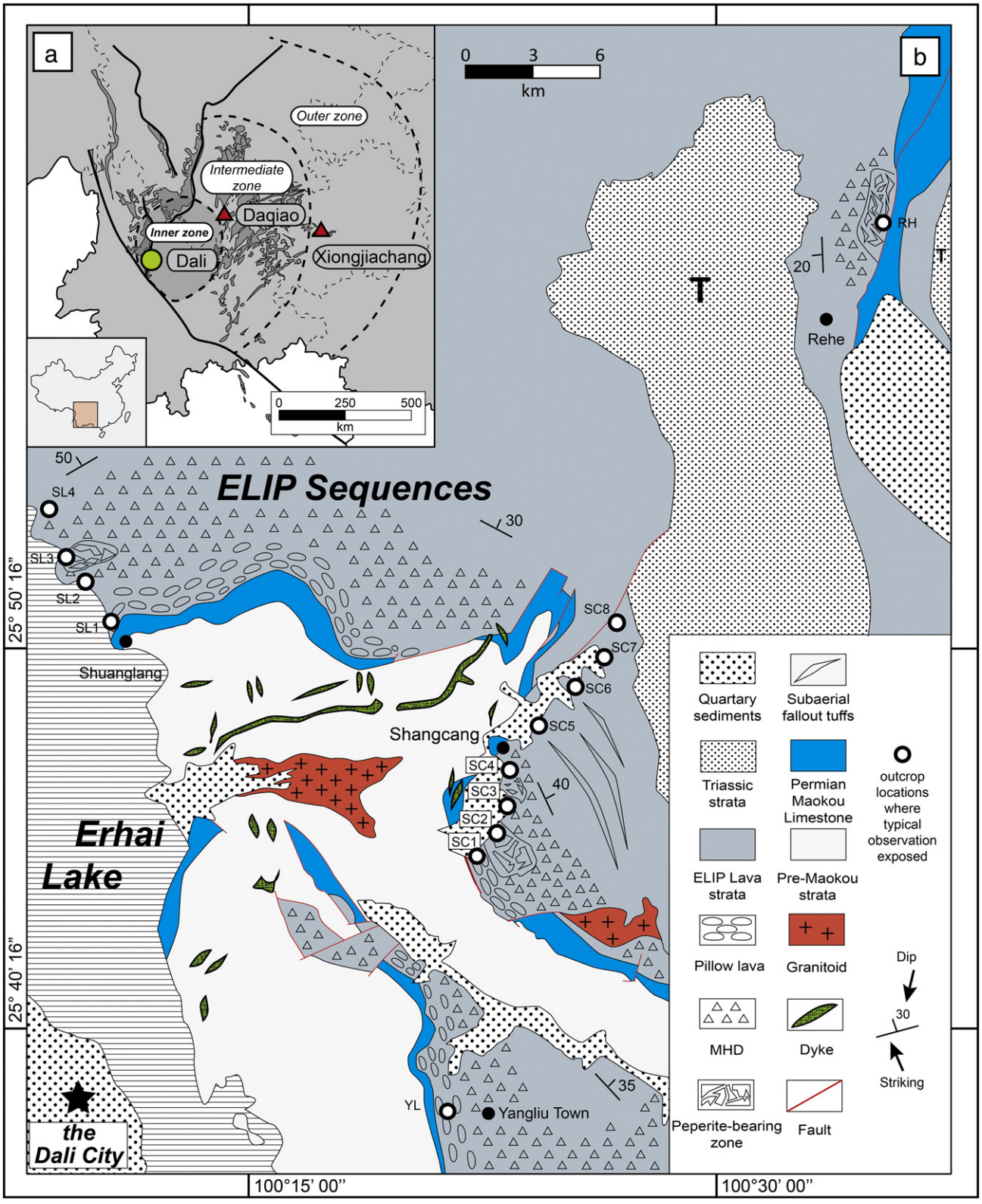


**Fig. 1.** (a) The regional distribution of the ELIP. The main body of the LIP, the Emeishan Basalts, is shown by the dark gray areas. The extent of the inner, intermediate and outer zone is sketched in dashed lines (after He et al., 2003a, 2003b). (b) The geological map of studied areas at Dali.

**Fig. 2.** The stratigraphic log of Dali the ELIP sequences. (a) Triassic conglomerates directly overlying the ELIP, with their deposits derived from the erosion of underlying ELIP volcanic materials. (b) Subaerial pahoehoe lava flows with elongated vesicles showing the flow direction. (c) Red, fine-grained subaerial fallout tuffs interbedded with a'a lavas. (d) The peperitic rim of a lava body bulldozed into altered volcaniclastic deposits. Close to the magma body, compacted blocky peperites developed, with sediments filled in their jigsaw-fit textures. Beyond the close-compacted rim, dispersed peperites are hosted by altered volcanic ash deposits. (e) Base surge layers showing load structures. (f) Pillow lavas with hyaloclastites filling in the interspaces.