Lithos 119 (2010) 1–9

Contents lists available at ScienceDirect

Lithos

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

Paleokarst on the top of the Maokou Formation: Further evidence for domal crustal uplift prior to the Emeishan flood volcanism

Bin He *, Yi-Gang Xu, Jun-Peng Guan, Yu-Ting Zhong

Key Laboratory of Isotope Geochronology and Geochemistry, Guangzhou Institute of Geochemistry, Chinese Academy of Science, Guangzhou, 510640, China

ARTICLE INFO

Article history:
Received 8 October 2009
Accepted 21 July 2010
Available online 11 August 2010

Keywords:
Paleokarst
Maokou Formation
Crustal uplift
Emeishan large igneous province
Mantle plume

ABSTRACT

The ~260 Ma Emeishan Large Igneous Province (ELIP) in southwest China has previously been demonstrated to provide compelling evidence for pre-volcanic crustal doming in support of the mantle plume hypothesis. However this has been questioned by Ukstins-Peate and Bryan (2008) by showing hydrothermal magmatic activity at the Daqiao section. To solve this argument, a detailed characterization of the contact between the Emeishan basalts and the Maokou Formation was carried out. The contact is shown to be an unconformity, which is characterized by paleokarst on top of the Maokou Formation, including paleokarst relief, sinkholes, caves, tower karst and its corresponding rocks (such as kaolinite, bauxite and ferruginous duricrust and collapsed breccias, etc.). This paleokarst unconformity was in turn covered or infilled by the Emeishan basalts and tuffs, suggesting that uplift and erosion occurred prior to the eruption of the ELIP. The extent of erosion of the Maokou Formation indicates the ELIP can be divided into three roughly concentric zones: the inner, intermediate, and outer zones. The paleokarst features on the top of Maokou Formation vary across the ELIP. In the inner zone, a likely sinkhole and an incision valley with 450 m relief in height are found. In the intermediate zone, various paleokarst landforms such as karst relief, sinkholes and tower karsts are well developed. Some sinkholes that developed in the Qixia Formation below the Maokou Formation imply that the paleorelief is more than 350 m in height. In the outer zone, the paleokarstic surface is a paleo-weathering layer with minor karstification and development of caves at 10–50 m. This spatial variation of the paleokarst reflects variation of uplift height across the ELIP. The extent of minimal uplift is estimated to be at least 450 m in the inner zone, 350 m in the intermediate zone, whereas uplift is minor (tens-50 m) in the outer zone. The magnitude and shape of the uplift is roughly consistent with that predicted by mantle plume models. The paleokarst was formed after the deposition of the Maokou Formation and the eruption of the Emeishan basalts at the end-Guadalupian and indicates a short duration of uplift. Thus this study lends further support to domal uplift prior to the Emeishan flood volcanism, but also to the mantle plume initiation model for the generation of the ELIP.

1. Introduction

Debate persists as to the existence of mantle plumes (Foulger and Natland, 2003; Depaolo and Manga, 2003). One of the important surface manifestations of a starting mantle plume is domal uplift of the Earth's surface (Rainbird and Ernst, 2001 and references therein; Campbell, 2007). Since plume-induced dynamic uplift should be pre-eruptive and basically transient, it is difficult to test for many large igneous provinces (LIPs). The Emeishan large igneous province (ELIP) of southwest China is critical in this documentation, providing field evidence of pre-volcanic domal uplift in response to mantle plume impact on the lithosphere (He et al., 2003). However, Ukstins-Peate and Bryan (2008), on the basis of observations on hydromagmatic deposits at Daqiao, cast doubt on an unconformity between the Maokou limestone and the Emeishan basalts, and argued that the initial eruption of the ELIP event was emplaced at or around sea level and deny any pre-eruptive uplift. Since the Emeishan basalts generally overlay the Maokou Formation, a carbonate platform facies, the nature of the contact between both units is important to determine if regional uplift occurred prior to eruption. For this purpose, a detailed characterization of the contact between the Emeishan basalts and the Maokou Formation has been carried out. Two positive aspects of such an investigation are: (1) excellent exposures of Middle Permian carbonate platform strata and the Emeishan basalts; and (2) large bodies of data on this contact are available in literature, due to the exploration for natural gas in the northeast of this LIP (e.g., Institute of Geology, Chinese Academy of Sciences, 1979; Huang and Wu, 1985; Li and Chen, 1993; Wang et al., 1994; Weng, 1996; Wang and Ji, 1997; Kang, 2000; Zhang and Liu, 2009) and ore deposits (e.g., Fan, 1993). Our study emphasizes the unconformity of the contact between the Maokou Formation and the Emeishan basalts, by providing new evidence of paleokarst on the top of the Maokou Formation.

* Corresponding author. Tel.: +86 020 85290133; fax: +86 020 85290130.
E-mail address: hebin@gig.ac.cn (B. He).

0024-4937/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.lithos.2010.07.019

Furthermore, the spatial variation of the paleokarst is documented and the cause of the different features across the ELIP is discussed in order to determine if domal crustal uplift occurred prior to the Emeishan flood volcanism.

Paleokarst can be defined as 'fossil' karst, a remnant from a previous period of karstification, and characterized by the presence of ancient, buried surfaces and deposits (Miller and Mitchell, 2003). Most documented paleokarsts are surficial, epikarstic phenomena and cavernous features (James and Choquette, 1988; Bosak et al., 1989; Wright, 1991). The proposed methodology of Molina et al. (1999) and Esteban (1991) for palaeokarst analysis consists of the following: (a) the morphology of the surfaces, that is, karst landforms such as sinkholes and caves; (b) the nature of the materials filling in the cavities or directly covering the irregular surfaces (such as kaolins, bauxites, calcretes and collapse breccias); (c) study and interpretation of exposure environments; and (d) analysis of underlying and overlying rocks to recognize immediately pre- and post-unconformity events. Among the above criteria, the karst landforms are the most important features for the identification of paleokarst (James and Choquette, 1988; Wright, 1991; Molina et al., 1999). For this study we apply the methods described by Molina et al. (1999) and Esteban (1991) to examine the paleokarst features on top of the Maokou Formation.

2. Geological background and Permian stratigraphy

The ELIP in SW China, which consists of massive flood basalts and numerous contemporaneous mafic and felsic intrusions, covers an area of more than 2.5 10^5 km^2 with a total thickness ranging from several hundred meters to ~5 km (Fig. 1, Xu et al., 2001). The Emeishan volcanic successions unconformably overlie the late Middle Permian Maokou Formation (Fig. 2). The Maokou Formation has been extensively studied in China due to its widespread distribution and extremely abundant fossils (Wang et al., 1994; Feng et al., 1997; ECS, 2000). It mainly consists of medium bedded to massive biograin limestones and biograin micritic limestones. Based on the fusulinids assembly, the Maokou Formation was divided into three biostratigraphic units (i.e., *Neoschwagerina simplex, Neoschwagerina craticulifera-Afghanella schencki* and *Yabeina-Neomisellina* zones) (ECS, 2000; He et al., 2003). The original thickness of the Maokou limestone ranges from 250 m to 500 m with an average of 350 m (Wang et al., 1994; Feng et al., 1997). The Permian strata in South China may be divided, in ascending order, into Liangshan (Lower Permian), Qixia and Maokou (Middle Permian), and Wujiaping and Changxing (Upper Permian) Formations (Fig. 2). In the view of rock types as well as fossil variety of the Permian strata, its depositional environment was inferred to be a typical carbonate platform (e.g., Wang et al., 1994; Feng et al., 1997; ECS, 2000). However, at the end of the Middle Permian, the region experienced a rapid uplift, known as the Dongwu movement in Chinese geological community (Fig. 2) (ECS, 2000).

To characterize the crustal processes prior to the Emeishan volcanism, He et al. (2003) correlated biostratigraphic units and thickness of the Maokou Formation. Results showed a systematic thinning of the strata beneath the Emeishan basalts. In terms of the extent of erosion of the Maokou Formation, the domal structure associated with the Emeishan large igneous province can be divided into inner, intermediate, and outer zones (Fig. 1, He et al., 2003). In the following section, paleokarstic features on the top of the

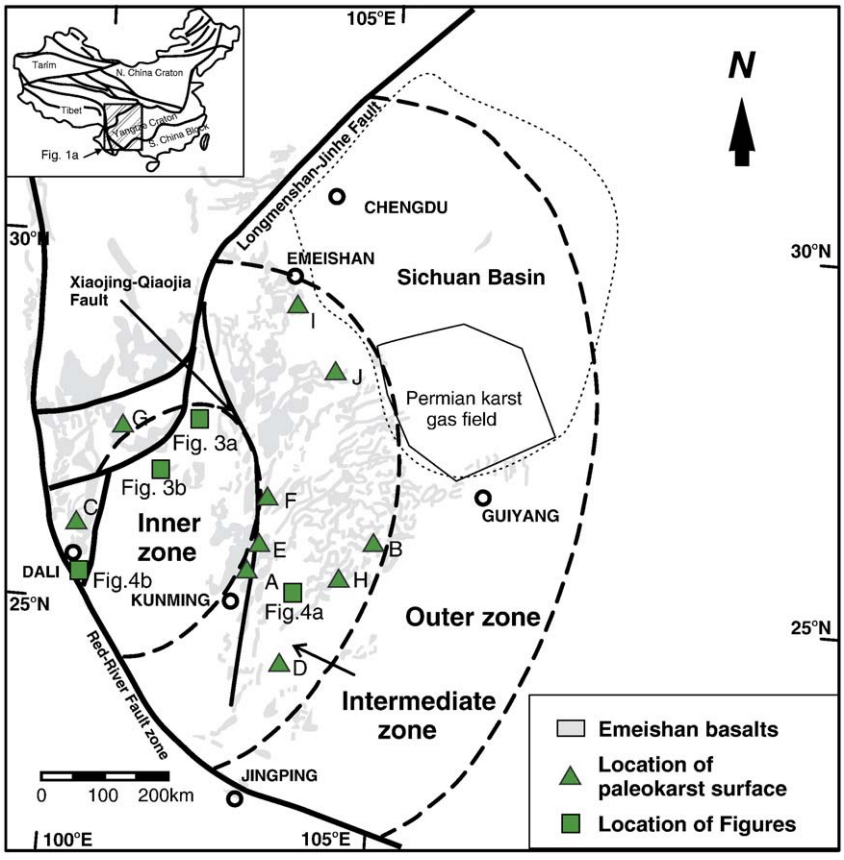

Fig. 1. Schematic illustration of the geological features of the Emeishan large igneous province and the locations of paleokarst surface on the top of Maokou formation. Dashed lines separate the inner, intermediate and outer zones, which are defined in terms of extent of erosion of the Maokou Formation (He et al., 2003).