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High elevation of Jiaolai Basin during the Late Cretaceous: Implication for the coastal mountains along the East Asian margin

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ABSTRACT

A large body of evidence suggests that there were extensive coastal mountains along the East Asian margin during the Late Cretaceous. However, current knowledge of the paleo-mountains — the period, range, and elevation — is limited. Therefore, direct paleoaltimetry is needed to validate and evaluate the paleo-mountains in East Asia. Our study area is Jiaolai Basin, which is located at the East Asian continental margin. We estimate the paleoelevation of Jiaolai Basin during the Late Cretaceous using carbonate clumped isotope paleothermometry. After correcting for seasonal preference, latitudinal difference, and secular climate change, we conclude that the paleoelevation of Jiaolai Basin was almost certainly ≥2.0 km at ∼80 Ma. Combined with the evidence from stratigraphy, paleogeography, and paleoclimatology, our results suggest that the existence of coastal mountains along East Asia during the Late Cretaceous is likely and the model of Okhotomorsk–East Asia collision is preferred.

1. Introduction

During the Late Cretaceous, high-pressure metamorphic belts formed in the Taiwan, Japan, and the Sakhalin Islands (Fig. 1) (Isozaki et al., 2010). A great volume of volcanics and granites intruded along the East Asian continental margin (Yang, 2013). Simultaneously, the sedimentary basins in East Asia were uplifted and exhumed (Song et al., 2015). The regional hiatuses were widespread in these sedimentary basins, which extended from the continental margin to the hinterland (e.g. Nanhuabei Basin near Zhengzhou) (Li et al., 2014; Zhu et al., 2012). The evidence indicates that the orogeny during this period may have resulted in relatively extensive topographic changes along the East Asian margin.

Based on structural geology and geochronological evidences for collision and orogenic exhumation from 100–89 Ma, Yang (2013) proposed coastal mountains extending from Southeast China to South Korea and Southwest Japan (Fig. 1). Two models have been proposed to explain the orogeny, such as the Pacific-induced compression (Song et al., 2015), or a collision between the Okhotomorsk Continental Block and the South China Block (Yang, 2013). Based on the thickness of denuded molasses accumulations, Chen (2000) suggested that the coastal mountains attained elevations of between 3500 m and 4000 m above sea level and width of 500 km from east to west. However, precise estimates of paleoelevations and the timing of maximum elevation have not yet been independently determined. Therefore, we propose a direct estimation of the paleoelevation from the East Asian continental margin to fully evaluate the topographic changes during the Late Cretaceous.

Topography is a first-order expression of the buoyancy of the lithosphere and also strongly influences circulation of the atmosphere and global climate, therefore, paleoelevation change in the East Asian margin is one of the best available measures of Cretaceous continental dynamics and Cretaceous paleoclimate (Huntington and Lechler, 2015). However, given the conventional stable isotope paleoaltimetry, either based on temperature-elevation gradients or precipitation oxygen/hydrogen isotope-elevation gradients, it is difficult to unambiguously determine the paleoelevation (Huntington and Lechler, 2015; Peters et al., 2013). In practice, researchers have to assume one unknown (e.g., temperature) when estimating another unknown (e.g., $\delta^{18}O$ value

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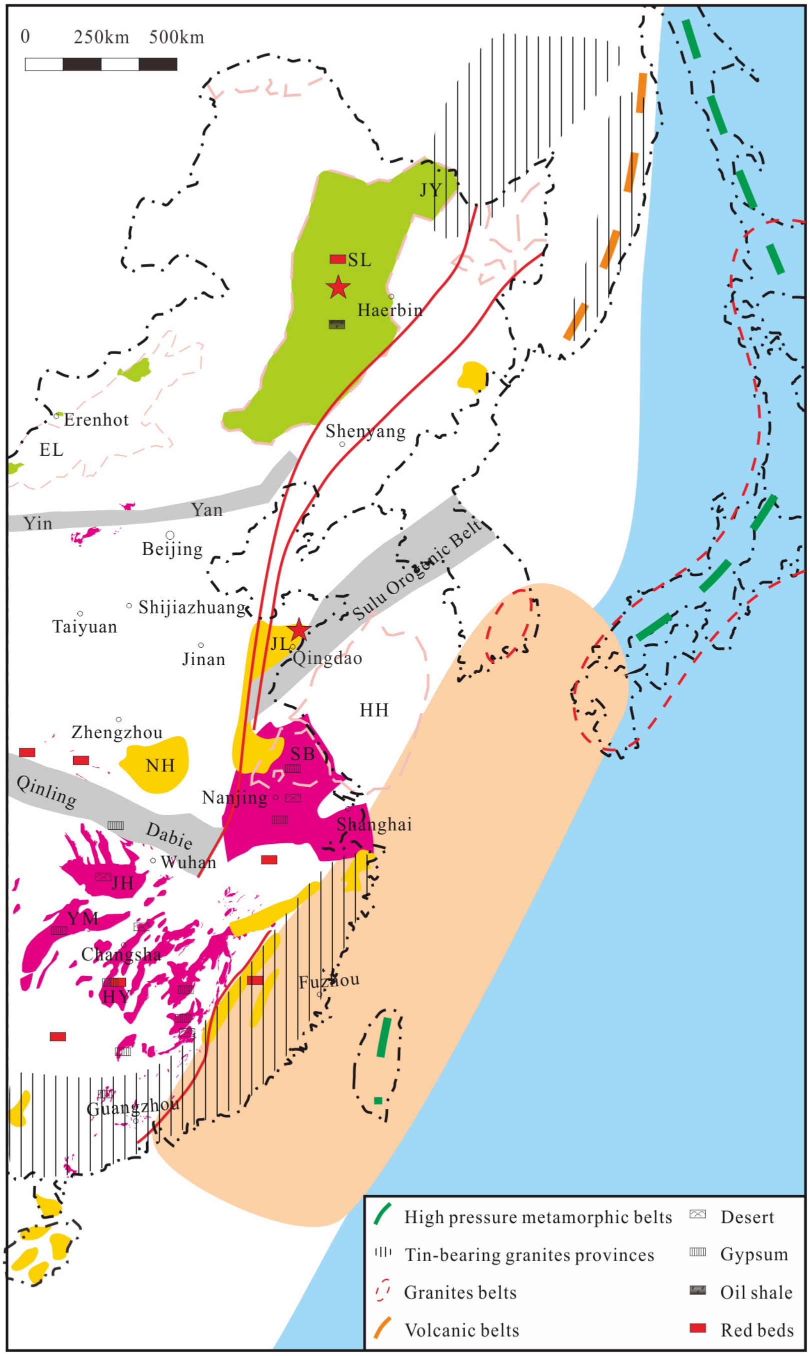

Fig. 1. Schematic geological map showing the key geological and geographical characteristics and the location of the study area (red star) during the Late Cretaceous. Yellow represents the piedmont basins of molasses sediments. Green represents the basins of dark-color sediments. Purple represents the basins of red-color sediments and brackish-saltwater sediments. The pink area shows the approximate range of the coastal mountains proposed by previous studies (Chen, 2000; Yang, 2013). JY = Jiayin Basin, SL = Songliao Basin, EL = Erlian Basin, JL = Jiaolai Basin, NH = Nanhuabei Basin, SB = Suibei Basin, HH = Nanhuanghai Basin, JH = Jianghan Basin, YM = Yuanma Basin, HY = Hengyang Basin. Modified after Song et al. (2015). (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

of the water) because the carbonate formation temperature and $\delta^{18}O$ value of the water from which it forms are interdependent (Kim and O'Neil, 1997). Moreover, the precipitation isotopic values ($\delta^{18}O$, $\delta^{2}H$, or δD) are also controlled by the evaporation, moisture source, and seasonality of the mineral formation (Chamberlain and Poage, 2000).

In this study, we use carbonate clumped isotope ($\Delta 47$) thermometry to estimate the paleoelevation of Jiaolai Basin during the Late Cretaceous (Fig. 1). This method can reconstruct the growth temperatures of the carbonate minerals by evaluating the extent to which ^{13}C and ^{18}O are chemically bound to each other (clumped) within the same carbonate ion group (Passey et al., 2010). It is based on a homogeneous isotope exchange equilibrium; therefore, the $\Delta 47$ temperatures are independent of the isotope compositions of the waters from which the carbonates grew (Passey et al., 2010). We first use carbonate clumped isotope ($\Delta 47$) thermometry to obtain the paleotemperatures in Jiaolai Basin, Shandong Province from the Early Cretaceous to the Paleocene. We then calculate the temperature differences between Jiaolai Basin and the presumed low elevation site (Songliao Basin) during the Late Cretaceous using the same paleothermometer. Finally, we calculate the elevation based on the temperature-elevation lapse rate.