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A review of the paleomagnetic data from Cretaceous to lower Tertiary rocks from Vietnam, Indochina and South China, and their implications for Cenozoic tectonism in Vietnam and adjacent areas

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ABSTRACT

Available paleomagnetic data from rock formations of Cretaceous age from Vietnam, Indochina and South China are compiled and reviewed in the context of their tectonic importance in a common reference frame with respect to Eurasia's coeval paleopoles. Key factors that play an important role in determining the reliability of a paleomagnetic result for utilization in tectonic studies have been taken into consideration and include the absence of evidence of remagnetization, which is a feature common to many rocks in this region.

Overall, the Cretaceous paleomagnetic data from the South China Block show that the present geographic position of the South China Block has been relatively stable with respect to Eurasia since the mid-Cretaceous and that the paleomagnetically detected motion of a coherent lithospheric block must be based on the representative data obtained from different specific localities across the block in order to separate more localized, smaller scale deformation from true lithosphere scale motion (translation and/or rotation) of a tectonic block.

Cretaceous to early Tertiary paleomagnetic data from the Indochina–Shan Thai Block reveal complex patterns of intra-plate deformation in response to the India–Eurasia collision. Paleomagnetically detected motions from the margins of tectonic blocks are interpreted to mainly reflect displacement of upper crustal blocks due to folding and faulting processes. Rigid, lithosphere scale block rotation is not necessarily supported by the paleomagnetic data. The paleomagnetic results from areas east and south of the Red River fault system suggest that this major transcurrent fault system has had a complicated slip history through much of the Cenozoic and that it does not demarcate completely non-rotated and significantly rotated parts of the crust in this area. However, most paleomagnetic results from areas east and south of the Red River fault system at the latitude of Yunnan Province are consistent with a very modest (about 800 km+−), yet paleomagnetically resolvable southward component of latitudinal translation. Accordingly, given the difficulty in separating actual lithosphere-scale plate motions from those of relatively thin, upper crustal blocks, we advocate extreme caution in interpreting paleomagnetic data from regions such as Indochina where block interaction and strong deformation are known to have occurred.

1. Introduction

The tectonic history of the Southeast Asia region has attracted the attention of numerous geoscientists for over a century. Active tectonic-geodynamic processes have affected the region in a prolonged and complicated fashion. These include the subduction of the Indo-Australian plate under the Eurasia plate along the Indonesia arc; the India–Eurasia collision and different intra-plate deformation processes associated with the formation and growth of the Tibetan Plateau. The Southeast Asian region is considered a natural laboratory for active tectonic and geodynamic processes, and thus can be used as an analog for studying more ancient tectonic processes. There are two general schools of thought regarding the effects of the collision between India and Eurasia on the subsequent tectonic history of eastern and southeast Asia. Proponents of extrusion tectonics suggest that convergence between the Indian subcontinent and the Eurasian plate was mainly accommodated by east–southeast directed translation and rotation of

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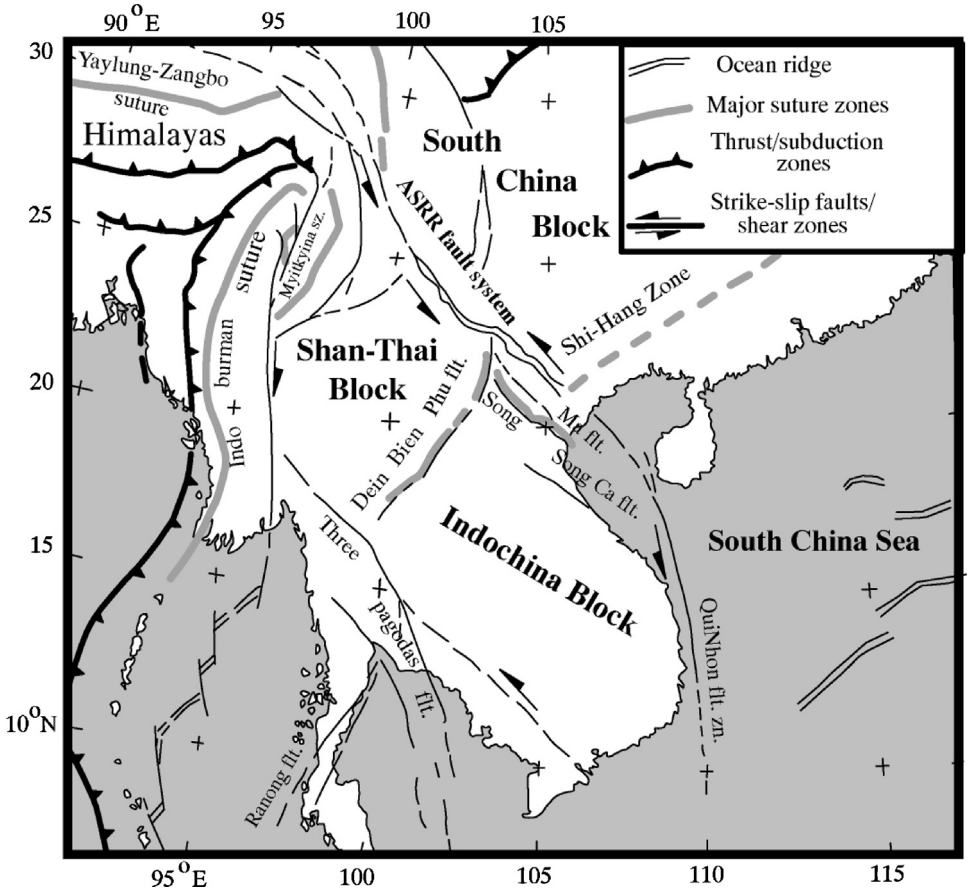

Fig. 1. Generalized tectonic framework map of Southeast Asia, modified from Leloup et al. (2001) and Takemoto et al. (2005). Arrows adjacent to several major structures show overall sense of shear prior to ~16 Ma along these structures.

large-scale, discrete continental lithospheric blocks such as 'Sundaland' (i.e. Indochina, Shan-Thai, the southwest East Vietnam Sea, and southwest Borneo), South China, and Tibet along major left-lateral strike-slip faults (Tapponnier et al., 1982, 1986; Peltzer and Tapponnier, 1988; Replumaz and Tapponnier, 2003) (Fig. 1). In contrast, other workers argue that crustal shortening and thickening in the Himalaya and Tibet is the principal mechanism for accommodating this collision (Dewey et al., 1989; England and Houseman, 1989; England and Molnar, 1990). One major consequence predicted by both models, however, is a large-magnitude clockwise rotation of Sundaland, which behaved either as a rigid lithospheric block (a basic tenet of the extrusion model) or as a series of upper-crustal blocks that were translated southeastward along laterally continuous, north–south–trending dextral shear zones and rotated in a clockwise sense (as in crustal shortening models).

Over the past few decades, paleomagnetic results from rocks of different ages and origins from the Southeast Asian region have increased both in quantity and quality, and the data obtained contribute to elucidating the tectonic history of this region over time, by providing increasingly accurate paleogeographic reconstructions of lithosphere-scale and smaller blocks that were welded together as microcontinents to form the Eurasian continent (Fig. 2). However, the interpretation of paleomagnetic results from an actively deforming region such as Southeast Asia is not straightforward, because early acquired, essentially primary magnetizations may be modified by subsequent tectonic effects, involving enhanced fluid migration, increased burial and thus enhanced temperatures, penetrative deformation, as well as other processes (Lowrie et al., 1986; McCabe and Elmore, 1989; Fuller et al., 1991; Gillett and Geissman, 1993; Pares et al., 1999; Van der Voo and Torsvik, 2011). Paleomagnetically detected rotations, as documented by discrepancies or discordances in declination between observed and expected (or "reference") declinations may sometimes reflect spatially localized components of deformation related to shear zones (Ron et al., 1984; Jackson and Molnar, 1990), differential shortening within thrust sheets (Stamatakos and Hirt, 1994; Roperch et al., 2000; Sussman et al., 2004; Pueyo et al., 2004), or arc related deformation (MacDonald, 1980; Minyuk and Stone, 2009). Therefore, rigid body, internally coherent rotations of plates, or microplates, cannot always be assumed on the basis of the data available.

This paper synthesizes the available paleomagnetic data from Cretaceous to Paleogene continental red bed formations from the Indochina and South China regions obtained in several studies by different researchers and evaluates their tectonic importance, especially paleomagnetically detected deformation (specifically rotation and translation) of crustal elements that is likely related to the India–Eurasia collision during the Cenozoic. Space does not allow us to focus attention on the details of the accuracy and reliability of each specific paleomagnetic data set; rather, we concentrate on the tectonic interpretation of these data, and consider such factors as the origin and nature of magnetization characteristic of the rocks examined (e.g., primary or secondary, i.e., the extent of possible remagnetization), the age of the rock formation, and the effects that tectonic deformation may have played in defining the tectonic importance.

The relative rotation and translation of any structural block or domain that have been identified on the basis of paleomagnetic directions from rocks located within that block are determined by comparing the observed directions with the coeval expected