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Late Quaternary tectonics and seismotectonics along the Red River fault zone, North Vietnam

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ABSTRACT

A study of active tectonic development in Vietnam is of great importance. Right lateral strike-slip offsets along the Red River fault during the Pliocene-present are determined by analyzing tributaries, Quaternary alluvial fans, river valley from Landsat, SPOT images, detailed topographical maps and field observation. Along the SW fault of the Red River, right lateral offsets of stream channels range between 150 and 700 m (mean offsets of 300 m). Drainage offsets (170–450 m) are found on the eastern branch. Assuming the major phase of incision is visible in this area which is close to the Red River delta due to the onset of Riss glaciation. Using the average length of offset channels and a minimum rate of 100–150 mm/yr for river propagation, we estimate the horizontal slip rates of 2.9 ± 1.7 mm/yr for Song Chay fault, 2.3 ± 1.5 mm/yr for Red River left side fault and 2.1 ± 1.5 mm/yr for Red River left side fault. Several active faults associated with it are observed in Son La area. The Phong Tho-Nam Pia fault is clearly seen in the geomorphology which separates Tu Le and Song Da rift zones. In normal fault segments striking NW–SE, SW dipping is observed clearly from SPOT images. In the field, triangular facets indicate typical dip slip displacement. Based on different data, vertical slip rate of Phong Tho-Nam Pia fault is estimated to be 0.2–0.4 mm/y for Pliocene-present, 0.5–3 mm/y for Quaternary-present and 0.6–1.7 for the present time. Based on various methods, maximum credible earthquakes for different fault segments in Vietnam were estimated.

Contents

1. Introduction

A study of active tectonics in Vietnam and its surrounding areas is important not only for understanding tectonic development in Southeast Asia but also for the mitigation of seismic hazards in this region (Fig. 1). In particular, the study of active tectonic development of the Red River fault zone is of greatly scientific and practical significance. The mechanism of deformation of the lithosphere is currently a topic discussed by many international research groups. The first point of view suggests that due to the collision between the Indian continental block and the Asian block, the deformation is mainly found at the contact of the collision which is characterized by the compression and thickness of the lithosphere. This model believes that the extrusion is not significant and if any, it would be absorbed by the sub-meridian fault zone like the Shansuihe fault in Yunnan, China (Houseman and England, 1986, 1993). According to this model, the Asian block was not extruded by the collision. The second view is that the Indian block is a rigid one and the Asian block is deformed following an indentation mechanism (Tapponnier et al.,

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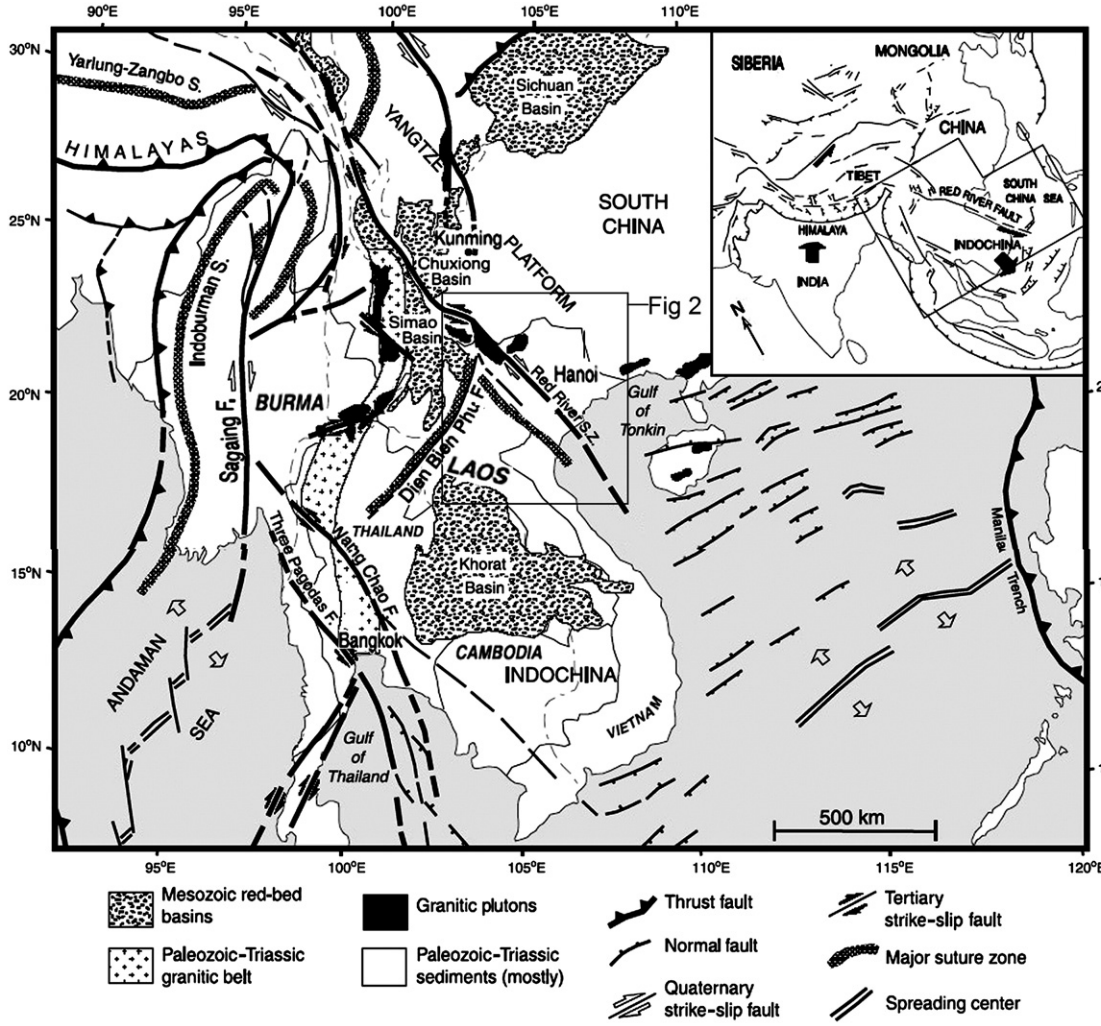

Fig. 1. Geologic and tectonic map of Southeast Asia.
Modified after Leloup et al. (1995).

1986, 1990). A part of the deformation in the Asian block was absorbed by the thickness of the lithospheres. Another part of the deformation is seen along strike-slip fault zones. The left lateral displacement occurred along the Antyl-tag fault and the right lateral movement seen along the Red River fault made the South China Block extrude toward the east (Tapponnier et al., 1982, 1986; Peltzer and Tapponnier, 1988). Since 1982, basing on plasticine experiments and field observations followed by detailed laboratory analyses, Tapponnier and his colleagues proposed that a large fraction of Asian deformation was taken up by successive extrusions of large continental masses along great strike-slip faults (Tapponnier et al., 1982, 1986). Such a point of view has been challenged by the one which believed that the Asian continent responded to the deformation as a viscous fluid (Houseman and England, 1986, 1993). Another point of view confirms that surface faults only separate upper crustal blocks whose relative motion is driven by lower crustal distributed flow, along a great N–S dextral discontinuity at the eastern margin of India. Therefore, the Red River fault zone is the key for verification of the models of lithosphere deformation. Besides the question about the direction of the lithosphere slip, one pays attention also to the size and slip rate of different blocks. At present, there is a big contradiction between active fault slip rate calculated from GPS and that calculated according to the geologic data (Allen et al., 1984, 1991; Weldon et al., 1994; Peltzer and Saucier, 1996; King et al., 1997; Duong Chi Cong and Feigle, 1999; Wang and Burchfiel, 2000; Replumaz et al., 2001; Schoenbohm et al., 2004a, 2004b; Shen et al., 2005; Simons et al., 2007). Studies of earthquake movement provide a precise understanding of the present deformation of continents. In Asia, slip rates on the largest active faults on the order of centimeters per year indicate that movements along a few narrow zones absorb much of the present-day convergence between India and Eurasia (Armijo et al., 1989; Avouac and Tapponnier, 1993). Studies of active faults also lead to more quantitative bounds on the relative importance of shortening mechanisms such as strike-slip faulting and over thrusting. The slip rates on faults in the western Tibet and the Tien Shan, for instance, suggest that 30–50% of the present-day convergence between India and Siberia is taken up by strike-slip faulting along the northern and southern edges of Tibet (Avouac and Tapponnier, 1993).

However, present-day tectonic styles and rates cannot be extrapolated for long into the past. Because the deformation of Asia started with the onset of collision, prior to ~50 Ma, instantaneous rates derived from earthquake moment tensors concern at most ~2.1–4% of the collision span, while rates deduced from morpho-tectonic studies characterize only the last few percent of that span. A full, quantitative understanding of the finite strain induced by collision evidently requires analysis of pre-Quaternary movements and deformation.

The value of slip rate of Altyl-tac shear calculated from seismic moment is several ten times smaller than that determined by the geomorphologic–geologic observed data. The GPS measurement showed that the South China Block and Indochina block are slipping eastward with a speed of more than 30 mm/yr (Michel et al., 2000, 2001; Iwakuni et al., 2004; Shen et al., 2005; Simons et al., 2007). If