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The South China block-Indochina collision: Where, when, and how?

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ABSTRACT

This study uses new field observations and existing studies to shed new light on the origin and significance of two NW–SE striking orogens in NW and NE Vietnam. We conclude that the architecture of each belt is a stack of NE-directed nappes formed either under deep ductile synmetamorphic conditions, or under shallow depth in the SW and NE parts, respectively. The Song Ma zone and Song Chay ophiolitic melange represent two ophiolitic sutures. However, the Late Permian Song Da and Babu mafic rocks are not ophiolites but intraplate basalts related to the Emeishan plume. A Late Triassic unconformity, the 225–205 Ma postorogenic plutonism, and the 250–230 Ma syntectonic metamorphism support an Early to Middle Triassic age for these tectonic events. Both NW and NE belts are due to SW-directed subduction with arc magmatism, ocean closure, and continental collision. Though two contemporary S-dipping subduction zones might explain the structural evolution of the two belts, a single convergent system, offset by the Tertiary Red River fault, is preferred as this S-directed subduction better accounts for the Late Permian intraplate magmatism. This scenario is discussed in the general geodynamic framework of SE Asia.

1. Introduction

Asia was formed during the Phanerozoic by the welding of several continental blocks including Siberia, Tarim, North China, South China, Indochina, India, and several small-sized microcontinents. All published models acknowledge subduction, and accretion of Gondwana derived fragments to the North, but in many cases the timing and nature of collision is poorly defined. Concerning the collision between the South China block (SCB) and Indochina, several aspects remain controversial, specifically: (1) Where is the ophiolitic suture corresponding to the intervening ocean? (2) When did the collision occur? (3) How the collision developed, i.e. what was the subduction polarity, and which structures accommodated the collision? The aim of this paper is to answer these questions on the basis of structural observations conducted in N. Vietnam and SW China, and to discuss the context of the rocks in N. Vietnam belts in the general tectonic framework of Asia.

The boundary between Indochina and SCB is often located along the Song Ma zone (Fig. 1; e.g. Helmcke, 1985; Hutchison, 1989; Findlay, 1997; Findlay and Pham, 1997; Lepvrier et al., 1997, 2004, 2008; Metcalfe, 1996, 2002, 2013; Tran Van Tri, 2011). However, some authors suggested that the Song Da (Sengor and Hsu, 1984) or the Babu mafic rocks in South China represent the ophiolitic suture (Zhong et al., 1998; Wu et al., 1999; Cai and Zhang, 2009). The age of the collision is generally considered as Triassic (Lepvrier et al., 1997, 2004, 2008; Liu et al., 2012), but older ages such as Early Paleozoic (Janvier et al., 1996; Tong-Dzuy et al., 1996; Findlay, 1997; Findlay and Pham, 1997; Carter et al., 2001), or Middle Carboniferous (Helmcke, 1985; Hutchison, 1989; Metcalfe, 1996, 2002, 2013) have been also put forward. Carter and Clift (2008) argue that contact between Indochina and South China, occurred before the Devonian, and that in N. Vietnam, the Triassic Indosinian orogeny was a thermo-tectonic reactivation event.

The Red River Fault (RRF) is the major continental-scale structure of northern Vietnam. This Cenozoic left-lateral shear zone that accommodated the extrusion of Sundaland due to Indian collision (e.g. Tapponnier et al., 1990; Leloup et al., 1995), it is not an ophiolitic suture (i.e. a plate boundary). To resolve this debate it is essential to define where ophiolitic suture zones are located in northern Vietnam and to define their age. Currently there is little information, indeed, structural studies dealing with the SCB-Indochina collision are rare (Findlay and Pham, 1997; Lepvrier et al., 1997, 2004, 2008, 2011). Although early works (e.g. Deprat, 1914, 1915; Jacob, 1921; Bourret, 1922; Fromaget, 1941), recognized two distinct fold belts in northern Vietnam, namely the NE and NW Vietnam belts, on both sides of the RRF (Fig. 1), their significance and the role of

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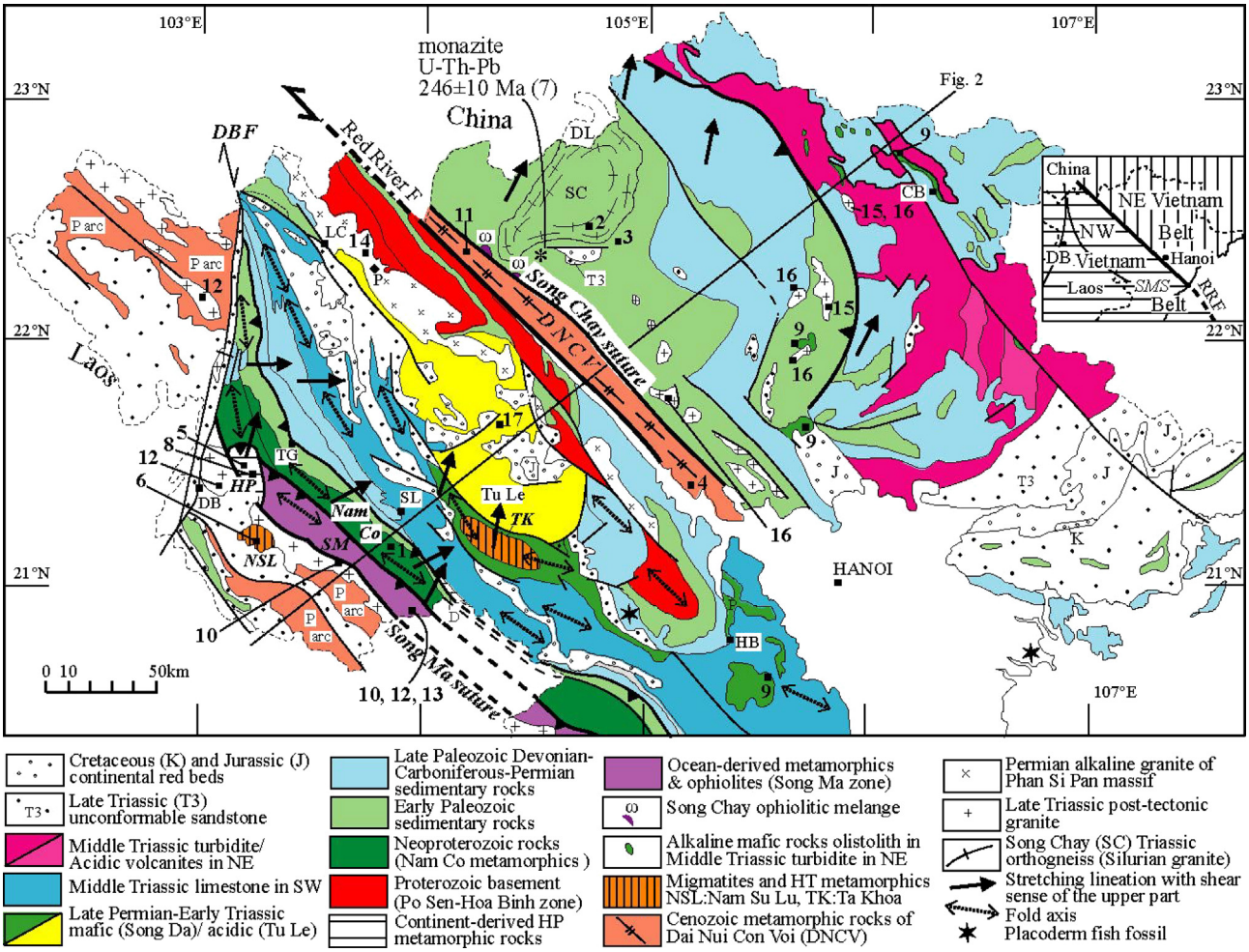

Fig. 1. Tectonic map of North Vietnam showing, on both sides of the Red River Fault (RRF), the two N-directed Triassic belts in NW and NE Vietnam, respectively. Pz arc refers to the Paleozoic arc rocks in the Sam Nua zone. DNCV: Dai Nui Con Voi; HB: Hoa Binh, SL: Son La, TG: Tong Giao, DB: Dien Bien, LC: Lao Cai, F: Fan Si Pan, CB: Cao Bang; DBF: Dien Bien Fault. Insert shows the location of the NE and NW Vietnam belts, on both sides of the Red River Fault (RRF). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

the RRF remains unclear. The goal of this study is therefore to integrate new field data and analyses with published work to better define the timing and nature of the South China-Indochina collision. As the two belts are separated by the RRF, their architecture will be presented separately, then their geodynamic relationships will be discussed.

2. The NW Vietnam belt

Despite Cenozoic deformation represented by high-angle brittle thrusts that placed the Triassic rocks upon Cretaceous continental red beds (Lacassin et al., 1998), most of the ductile structures observed SW of the RRF are older than the Late Triassic deposits that unconformably cover the Early Mesozoic-Paleozoic formations. This unconformity was the keystone for the definition of the "Indosinian" orogeny (Fromaget, 1941; Tran Van Tri, 2011).

The dominant NW–SE strike of the NW Vietnam belt is deflected to a NNW-SSE trend by the dextral Dien Bien Fault. As a result, the fold axes progressively turn to NW–SE and then to NNW–SSE strike. This 100 km-scale oroclinal bending, of probably Cenozoic age, does not significantly alter the primary structure of this orogen. The north-verging folds change to east verging ones, and the N–S striking streching lineation becomes NE–SW and E–W. In the NW Vietnam belt, from the NE to the SW, we identified the following litho-tectonic units (Figs. 1–3).

2.1. The Po Sen-Hoa Binh zone

Consists of a Precambrian metamorphic basement (Lan et al., 2001) conformably covered by Paleozoic-Early Triassic sedimentary and magmatic rocks. This series is unmetamorphozed but folded by NW–SE trending upright folds (Fig. 4A) with locally an axial planar cleavage. In contrast to the view of Deprat (1914), these rocks do not form the allochthonous unit called "nappe de la rivière Noire" but represent the deepest part of the NW Vietnam belt. To the NW, per-alkaline and meta-aluminous plutons that form part of the Phan Si Pan massif yield zircon U–Pb LA–ICP–MS ages at 253–251 Ma (Pham et al., 2012; Fig. 1, Table 1).

2.2. The Son La-Lai Chau zone

In vertical fault contact with the Po Sen-Hoa Binh zone, is represented by Devonian to Permian formations conformably overlain by Early to Middle Triassic series, and unconformably covered by Late Triassic conglomerates and sandstones, or by Cretaceous continental red beds. Gabbro, pillow basalt, mafic volcanic breccia are well developed particularly along the Da River (i. e. Song Da in