

Continental Extrusion along the Red River Shear Zone, NW Vietnam: New Structural and Geochronological Data

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In SE Asia, the ca. 350 km long and up to 20 km wide Red River Shear Zone (RSZ) in NW Vietnam is commonly linked with the ca. 1000 km long Ailao Shan Shear Zone (ASZ), SW China, and considered to form one of the world's largest intra-continental strike-slip faults – the Ailao Shan-Red River Shear Zone (ARSZ). The NW-trending ARSZ has mainly been studied in China, where sinistral strike-slip displacement between South China and Indochina blocks (700–1000 km²) is timed by U-Pb, Ar-Ar, and K-Ar geochronology to occur between 36 and 16 Ma (Tapponier et al. 1990, Leloup et al. 1995, 2001, Harrison et al. 1996, Ta et al. 2000). The Oligocene-Miocene activity is usually explained by continental extrusion the Indochina block SE-ward relative to the South China block to accommodate post-collisional convergence of India and Asia. The Vietnamese section of the ARSZ, mostly exposed in the Day Nui Con Voi massif, is less known, yet scarce data reported so far generally conform observations made in three other metamorphic massifs which form the Chinese portion of the ARSZ (Leloup et al. 2001). Strain and thermal processes were strongly localized in the ARSZ whereas its wallrocks remained apparently unaffected. The peak metamorphic conditions (~700 °C, 6–7 kbar) were similar along strike and marked by sillimanite-grade mineral assemblages, leucogranite and leucosome layers/pods that developed in migmatized metapelites (Leloup and Kienast 1993, Zhang and Schärer 1999). Isotopic data (U-Pb) suggest that the high-grade metamorphism was diachronous, generally older in the northwest, and occurred in a sinistral transtensional regime followed by two cooling episodes (Ar-Ar, K-Ar data), of which the younger was accomplished in a dextral slip regime (Harrison et al. 1992, Leloup et al. 2001). In the RSZ, the high-grade synmetamorphic left-lateral slip is thought to have taken place between 27 Ma and 22 Ma, based on U-Pb zircon ages from leucocratic mobilizates (Leloup et al. 2001).

Our field and preliminary isotopic data suggest that the evolution of the RSZ was more complex than hitherto presented. The RSZ is herein understood as a ca. 350 km long belt of high-grade metasediments and orthogneisses bordered on the SW by the Song Hong (Red River) fault and on the NE by the Song Chay fault. Along these steep normal faults the RSZ rocks are juxtaposed against lower metamorphosed Palaeozoic rock units, thus the former actually occur in a long narrow horst.

The RSZ metasediments represented by metapelitic paragneisses, mica schists and subordinate quartzites underwent extensive migmatization, the effects of which differ along the RSZ. Orthogneisses mainly developed from sheared and mylonitized metagranites. Besides these two dominant lithologies, banded amphibole gneisses of unclear origin, metabasites, granites and numerous

pegmatites/leucocratic veins are in evidence. The latter, clearly related to the widespread migmatization and partial melting, show different degree of deformation (undeformed to strongly mylonitized) and some pegmatites contain xenoliths of mylonitic gneisses. Metabasites represent mafic veins which intruded the RSZ rocks as sills and dykes. They also show different degree of shear deformation. Using three different sets of the felsic veins, mafic bodies, intersection relationships between them and their relationships to (folded) mylonitic fabric of the host gneisses, a sequence of repeatedly occurring mylonitization and injections of felsic material has been established. materials were found.

Detailed observations of kinematic records in each of the three sets of pegmatitic/granitic veins as compared to the host gneisses allowed to discriminate consecutive shear increments which have otherwise been difficult to distinguish as they occurred mostly parallel to the foliation planes in these gneisses. A shallowly plunging stretching lineation testifies to the importance of generally strike-slip displacements while shear criteria indicate changeable kinematics. The polyphase ductile shear deformations recorded by the RSZ rocks were developed in overall wrench regimes which consecutively occurred: (1) dextral, (2) sinistral, (3) dextral transpression and (4) sinistral transtension. Such a kinematic pattern is only partly consistent with the previously reported observations and does not include further deformations of the RSZ rocks which have been accomplished till the Recent under brittle conditions (cf. Cuong and Zuchiewicz 2001).

To verify the structurally inferred deformational sequence, a preliminary series of U-Pb zircon analyses on SHRIMP II (RSES, Canberra) has been performed on samples coming from the rocks selected according to their kinematic records and position in the sequence. Such sampling strategy has proved reasonable as we have succeeded in dating different events that occurred along the RSZ. The results obtained so far constrain the tectonothermal activity associated with the ductile shearing at the RSZ to the time span between 136 Ma and 26 Ma. The oldest ages were yielded by a zircon sample collected from the leucosome layer of dextrally sheared HT migmatitic prx-gneisses (NW of Doan Hung, central part of the RSZ). This data suggests a distinct migmatization episode already in the Early Cretaceous, which would testify to much older tectonothermal activity on the RSZ than hitherto expected. Three other samples consistently yielded late Cretaceous ages of 77 Ma to 69 Ma. They come from pegmatite veins which had intruded the dextrally mylonitized gneisses and amphibolites (NW, central and SE parts of the RSZ) and underwent later ductile sinistral shearing. Based on the strict structural control, we conclude that the important, migmatite-producing thermal event

on the RSZ occurred entirely in Cretaceous times. The earliest dextral shearing is bracketed by 136 and 77 m.y. dates, while the successive sinistral shearing must have been younger than 69 Ma, i.e. it was a late Cretaceous /Palaeogene episode. Mylonitic foliations which developed during the two shear episodes were then subjected to folding in the dextral transpressive regime which triggered uplift within the RSZ. Folds and associated axial planar leucocratic veins were subsequently sheared in the sinistral-slip transtensional regime at distinctly lower temperatures. This occurred before characteristic unfoliated S-type granites, derived from molten RSZ metapelites (Tran et al. 2000), intruded the sinistraly sheared migmatitic gneisses not later than 26 Ma. A few oldest zircons in a sample from this granite (NW of Yen Bai) yielded ages of 33–31 Ma. These ages are interpreted to record the youngest tectonothermal increment in the RSZ during the Oligocene. In other zircon samples (those mentioned above inclusive) analysed by us on SHRIMP, the dated older grains have metamorphic outgrowths which yielded ages between 36 Ma and 31 Ma, thus represent the same episode. It is actually the very tectonothermal episode that has been reported by all previous workers in the RSZ who apparently overlooked the earlier events.

The 26 Ma age of the studied granite approximates termination of ductile activity in the presently exposed structural level of the RSZ, and corresponds with earlier Ar-Ar, K-Ar and fission track cooling ages (Leloup et al. 2001, Anczkiewicz et al. 2000). From the Miocene, the RSZ rocks have been undergoing mostly brittle deformations.

The combined structural and geochronological lines of evidence suggest that:

- the RSZ was tectonothermally active at least from the early Cretaceous to Miocene and continue to be active till Recent times;
- at that time span, the strike-slip movements repeatedly occurred on the RSZ but with kinematic reversals;
- tectonothermal activity at the RSZ has not been caused by India/Asia collision, but convergence between these continents probably have added to the polyphase deformations on the RSZ in the late Palaeogene;
- further confirmation of our preliminary data is required and U-Pb SHRIMP dating of several more zircon samples is under way.

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