EARLY PROTEROZOIC TECTONOTHERMAL EVENT SOUTH OF THE RED RIVER SHEAR ZONE IN VIETNAM: FIRST EVIDENCE FROM $^{40}AR/^{39}AR$ DATING OF SINGLE GRAIN HORNBLENDE

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Abstract: *Pre-Mesozoic metamorphic belt runs parallel to the Day Nui Con V - Red River shear zone in Vietnam to the south. The belt is mainly compose of hornblende-gneisses, amphibolite lenses and mica-schistose. Synkinematic horn blende separated from the gneiss and the associated amphibolite lens were previous dated by a conventional K/Ar method, yielding ca. 1700 Ma and ca. 2000 M respectively. The same hornblende separates were newly dated by the 40Ar/39A method using laser step heating of a single mineral grain. Well defined plateau ag of ca. 2000 Ma were obtained for the hornblende grains of both the gneiss and th amphibolite lens. This firmly indicates that the hornblende have recorded an Ear Proterozoic tectonothermal event without any significant disturbance of post-Ear Proterozoic tectonothermal activities, and strongly suggests the Early Proterozo terrain in Indochina.*

INTRODUCTION

The Indochina peninsula south of the Red River fault zone in Asia represents stable continental core of South East Asia (e.g., Hutchison, 1989). Recent geochronolo ical studies have documented three tectonothermal events widely appeared in the peni sula: Triassic Indosinian orogeny, Late Jurassic-Cretaceous Yenshanian orogeny and La Oligocene-Early Miocene India-Eurasian collision, which have been inferred mainly fro $^{40}Ar/^{39}Ar$ and K/Ar dating of rocks (e.g., Rangin *et al.*, 1995; Lepvrier *et al.*, 1997; Nar 1998; Jolivet *et al.*, 1999). Precambrian events have also been argued using geologic evidences with some K/Ar data of rocks for the last two decades (e.g., Tran Van T 1977; GGDVN, 1986; Hutchison, 1989). However, these events have been hardly accept because of poor geochronological data for the Precambrian. Recently, Nam T. N. *et*

998) dated hornblende separates from gneiss and amphibolite in the pre-Mesozoic meta-
orphic belt south of the Day Nui Con Voi in Vietnam, which gave apparent K/Ar ages
1700 - 2000, Ma. The hornblende ages may provide an evidence for an early Proterozoic
ctonothermal event in the Indochina peninsula. The Red River fault zone separating
ndochina from South China plays an important role to understand the tectonic evolution
East Asia (e.g., Hutchison, 1989; Lee & Lawver, 1995). The fault zone has been referred
a Tertiary left-lateral strike-slip zone (e.g., Tapponnier *et al.*, 1990; Schare *et al.*, 1990,
994; Harrison *et al.*, 1992, 1996; Leloup *et al.*, 1993, 1995; Nam T. N. *et al.*, 1998; Wang
al., 1998). Tapponnier *et al.* (1982) interpreted that Indochina as a rigid-block extruded
outheastward along the Red River fault zone during the India-Eurasian collision and Ter-
ary deformation of Indochina was negligible. Recently, the Tertiary deformation in the
ntinental core has also been documented (e.g., Rangin *et al.*, 1995; Lepvrier *et al.*, 1997;
olivet *et al.*, 1999). Hutchison (1989) argued that the Red River fault zone and Cenozoic
formation zones in the core were the tectonic zones re-activated during the collision
pre-existing deformed weakness zones in the Indochina continental core, though he
owed no geochronological data for the protolith of the deformed weakness zones. The
neiss and amphibolite for which Nam T. N. *et al.* (1998) gave K/Ar hornblende ages
early Proterozoic, were severely deformed rocks in the pre-Mesozoic metamorphic belt
outh of the Day Nui Con Voi. One of the protoliths of the weakness zone may be the
rly Proterozoic gneisses in the belt. This paper performs the $^{40}Ar/^{39}Ar$ dating using a
ngle mineral grain by laser step heating on the hornblende which have been previously
ated with K/Ar method by Nam T. N. *et al.* (1998) to confirm the early Proterozoic
vents, and discusses the protolith of the Red River fault zone as a pre-existing deformed
eakness zone in the South East Asia.

GEOLOGICAL SETTING

The Day Nui Con Voi – Red River shear zone in Vietnam appears as a narrow (<10
n) and elongated (250km) metamorphic zone trending from NW to SE (Fig.1). The
ne consists mainly of biotite-sillimanite-garnet gneiss, garnet-biotite gneiss, two-mica
hist with garnet and migmatite, and the associated mylonite bands and amphibolite
d marble lenses. Geothermobarometry using coexisting garnet- biotite-plagioclase of
limanite- bearing gneisses, and garnet-hornblende-plagioclase of amphibolite suggested
at the peak metamorphism occurred under amphibolite facies conditions of 690 ± 500C
d 0.65 ± 0.15 GPa (Nam T. N. *et al.*, 1998). K/Ar and $^{40}Ar/^{39}Ar$ analyses of hornblende
d biotite gave the cooling ages of 21-29 Ma (Harrison *et al.*, 1996; Nam T. N. *et al.*,
98; Wang *et al.*, 1998). The Red River shear zone is a left-lateral strike-slip zone and
metamorphic core complexes in the zone have exhumed in relation with the sinistral
otion (e.g., Tapponnier *et al.*, 1990; Leloup *et al.* 1995; Nam T. N. *et al.* 1998). Nam
N. *et al.* (1998) estimated the total exhumation of 23 km for the complexes in the Day
ui Con Voi.

The pre-Mesozoic belt, running parallel to the Day Nui Con Voi to the south,
composed mainly of hornblende-biotite gneisses coexisting with migmatite and small

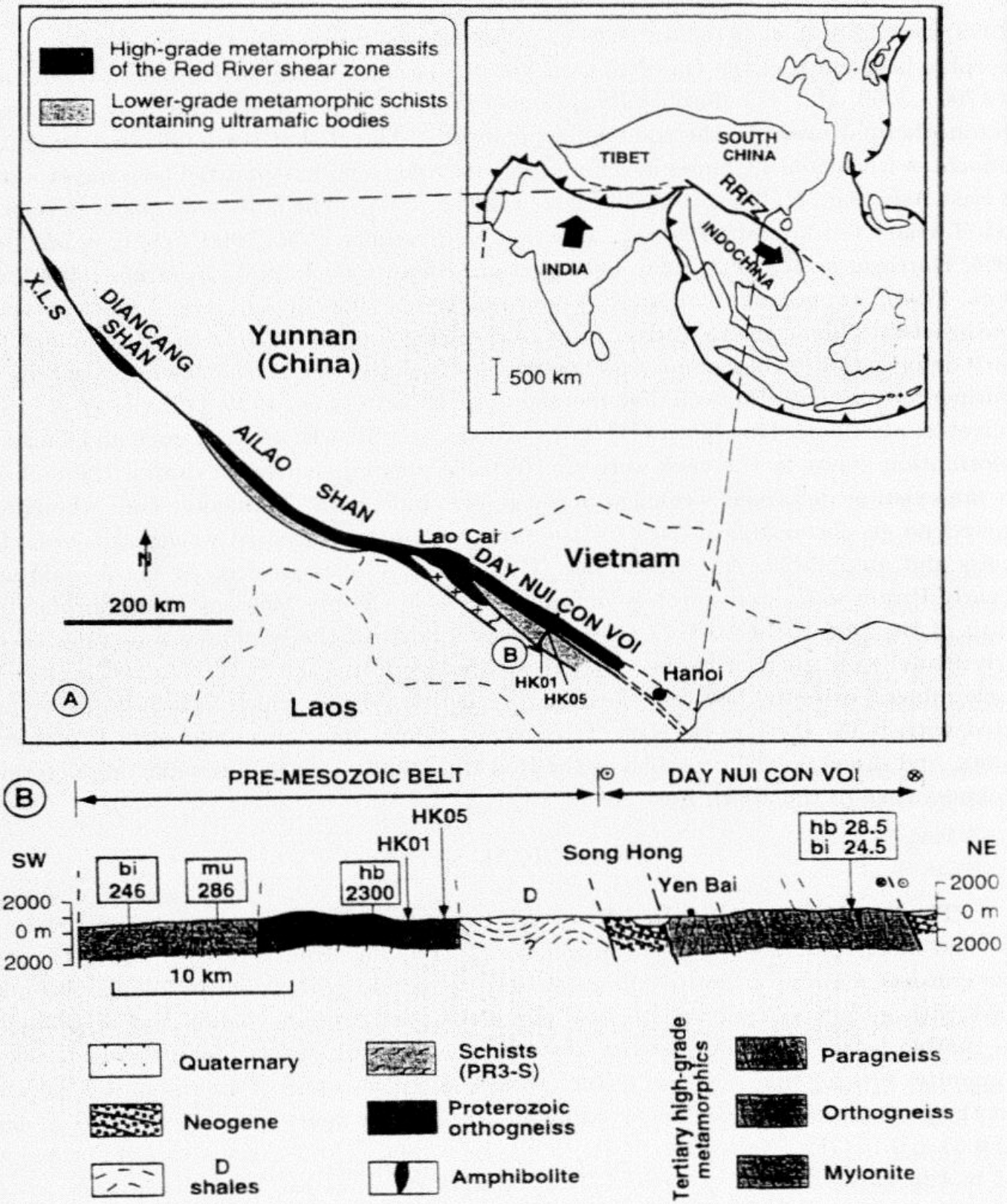

Fig.1. (A) The Red River fault zone (RRFZ) in Asia, and (B) cross-section throug the Day Nui Con Voi - Red River shear zone in Vietnam and pre-Mesozoic belt. K/Ar age (Ma) of biotite (bi), muscovite (mu) and hornblende (hb) (in boxes) within pre-Mesozoi belt from Tran Van Tri (1977), in the Day Nui Con Voi from Nam T. N. *et al.* (1998) Location of sampling of HK01 and HK05 are shown.

bodies of amphibolite, kyanite-bearing mica schist, almandine-bearing mica schist and Devonian shale- sandstone (Fig.1). They have been severely deformed (Fig.2) except the Devonian shale- sandstone, suggesting the significant ductile deformation of the belt like that of the Day Nui Con Voi. The hornblende-gneiss in the belt has the mineral assemblage of quartz, plagioclase, K-feldspar, hornblende, biotite, and epidote, indicating the epidote amphibolite facies metamorphic conditions. In the gneiss distribution zone, amphibolite lenses are sometimes observed. Nam T. N. *et al.* (1998) dated hornblende separates from the hornblende-gneiss (sample HK01) and amphibolite lens (sample HK05) by conventional K/Ar method, giving apparent early Proterozoic ages of 1700 Ma and 2000 Ma, respectively. Tran Van Tri (1977) has already reported the Proterozoic age with K/Ar dating of rocks in the belt but did not show any descriptions of sampling site and rock type as well as analytical data.

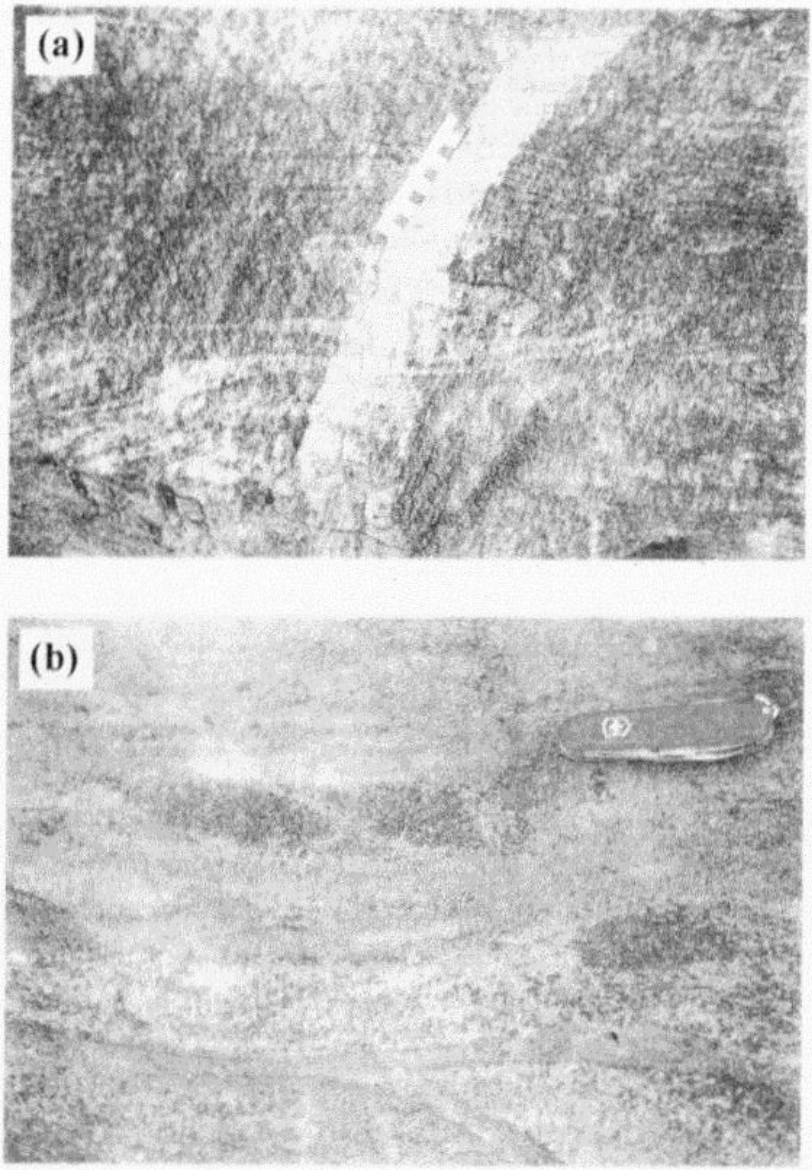

Fig.2. Characteristics of ductile deformation at an early Proterozoic hornblende neiss out-crop (HK01), see from above. Strongly laminated foliation (a) and small lens f hornblende-rich domain affected by sinistral shear (b). Scale-ruler in (a) is 10 cm long.

Hornblende grains to be dated by $^{40}Ar/^{39}Ar$ method in this study are the same mineral separates from the hornblende-biotite gneiss (HK01) and amphibolite lens (HK05) by Nam T. N. *et al.* (1998). Detailed sampling sites and petrography of the samples studied have been described in Nam T. N. *et al.* (1998). Hornblende grains of 250-500 m size fraction are used for dating.

$^{40}Ar/^{39}Ar$ SINGLE GRAIN DATING AND RESULTS

Each hornblende grain was placed in a 2 mm drill hole on an aluminum tray together with three age standard grains (3gr hornblende; Roddick, 1983), calcium ($CaSi_2$) and potassium (synthetic $KAlSi_3O_8$ glass) standard grains, and was vacuum sealed in a quartz tube. Neutron irradiation of the sample was carried out in the core of 5 MW Research Reactor at Kyoto University (KUR) for 24 hours using the hydraulic rabbit facility which has the fast neutron flux density of 3.9x1013 $n/cm^2/sec$. The neutron flux is confirmed to be uniform in the dimension of the sample holder (16 x 15 mm^3) as little variation in J-values of the evenly spaced age standards was observed (Hyodo *et al.*, 1998). Averaged J-values, potassium and calcium correction factors are J = 0.02343 ± 0.00004, (40/39) K = 0.0291 ± 0.0034, (36/37) Ca = 0.000242 ± 0.000015 and (39/37) Ca = 0.000580 ± 0.000040, respectively.

Three grains of HK01 sample and two grains of HK05 samples were analyzed by step-heating technique using a 5 W continuous argon ion laser. Temperatures of samples was monitored by an infrared thermometer with a precision of 3 degrees within an area of 0.3 mm diameter (Hyodo *et al.*, 1995). The hornblende grains were heated under a defocused laser beam at a given temperature for 30 seconds, and the extracted gas was purified with a SAES Zr-Al getter (St 101) kept at 400^0C for 5 minutes. Argon isotopes were measured using the custom-made mass spectrometer with a high resolution (>400), which allows to separate hydrocarbon peaks except mass 36 (Hyodo *et al.*, 1994). Typical blanks of extraction lines are $5 \times 10^{-14}, 3 \times 10^{-14}, 3 \times 10^{-14}, 3 \times 10^{-14}, 2 \times 10^{-12}$ ccSTP for ^{36}Ar, ^{37}Ar, ^{38}Ar, ^{39}Ar and ^{40}Ar, respectively.

The age spectrum and Ca/K ratio of representative grains are shown in Fig. 3. Grain HK01aH1 has a homogeneous phase between 9500C and fusion (>1300^0C). About 70% of the total fractions in the age spectrum define a plateau of 1977 ± 19 Ma, and the integrated age is 1908 ± 14 Ma (Fig. 3a). In the same temperature range, grain HK05aH2 has a well-defined plateau of 2044 ± 21 Ma, which occupies more than 90% of the total, and its integrated age is 2233 ± 20 Ma (Fig. 3b). Both grains have excess ages in the first few fractions on low temperatures, and Ca/K ratios indicate some disturbed phases. The two plateau ages do not agree within the 1- σ error, but other hornblende grains from HK01 sample have less disturbed spectra and their plateau ages agree with HK05aH2 within the error. The $^{40}Ar/^{39}Ar$ plateau age of 2044 Ma for the amphibolite (HK05) was the same as K/Ar age of 2000 Ma by Nam T. N. *et al.* (1998). On the other hand, the plateau age for the gneiss (HK01) was about 300 Ma older than the K/Ar age of 1700 Ma. This is due to a little disturbance by a later stage of thermal effect as suggested from age spectrum in Fig. 3a, which shows younging in the low temperature fractions.

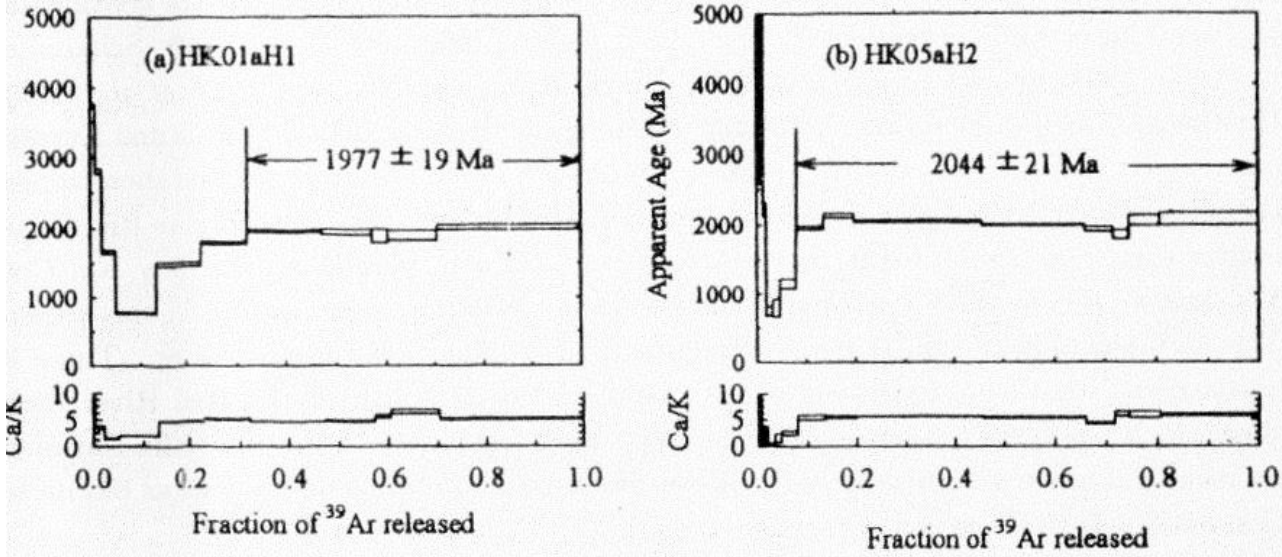

Fig. 3. $^{40}Ar/^{39}Ar$ age spectra and Ca/K plots of representative hornblende grains from sample HK01 (a) and HK05 (b).

DISCUSSIONS

Recent geochronological studies have confirmed significant roles of the Indosinian rogeny and India-Eurasian collision in geological structures of the Indochina continental ore (e.g., Rangin *et al.*, 1995; Maluski *et al.*, 1997; Nam T. N., 1998; Jolivet *et al.*, 1999) hough previous workers (Tran Van Tri, 1977; GGDVN, 1986; Hutchison 1989) have proosed the existence of Precambrian high-grade metamorphic terraines. However, Nam T. . *et al.* (1998) reported early Proterozoic K/Ar ages of hornblende from the hornblende neiss and the associated amphibolite lens in the pre-Mesozoic belt south of the Day Nui on Voi as mentioned above. The gneisses have been severely deformed and display well eveloped L-S tectonic fabrics and have augengneiss structure with large feldspar porphyoblast. The foliation (S) defined by preferred orientation of planar minerals (amphibole nd biotite) and by flattened quartz or feldspar ribbons is parallel to the compositional anding (Fig.2). These observations indicate intensive ductile deformation of the gneisses. he mineral assemblage of quartz, plagioclase, K-feldspar, hornblende, biotite and epidote uggests that the ductile deformation has taken place under the amphibolite facies condions (>500^{0}C). The $^{40}Ar/^{39}Ar$ ages of ca. 2000Ma for the synkinematic hornblende newly btained in this study strongly suggest the formation and the subsequent exhumation of e gneisses in early Proterozoic, showing the first strong evidence for an early Proterozoic etamorphic terrain in Indochina. As suggested from the $^{40}Ar/^{39}Ar$ age spectrum of Fig. the amphibolite lens of the hornblende gneiss zone in the pre-Mesozoic belt have suffered significant disturbance by post-early Proterozoic tectonothermal events, in particular, the Tertiary India-Eurasian collision.

Recent advanced geological and geochronological studies have shown that the Red River fault zone was a Tertiary left-lateral strike-slip zone and supported the continental extrusion model of Tapponnier *et al.* (1982) (e.g., Tapponnier *et al.*, 1990; Scharer *et al.*, 1990, 1994; Leloup *et al.*, 1993, 1995; Harrison *et al.*, 1996; Nam T. N. *et al.*, 1998). Hutchison (1989) argued that the Tertiary convergence process between India and Eurasia has re-activated the pre-existing weakness zones such as old suture zones and shear zones, though no body has ever observed the protolith of such weakness zone for the Red River fault zone. The pre-Mesozoic metamorphic belt, running parallel to the Day Nui Con Voi, has preserved early Proterozoic metamorphic terrain as documented in this paper. The metamorphic terrain is mainly composed of severely deformed gneisses. There is a possibility that the gneiss complexes could be the protolith of the Red River fault zone which has been re-activated by the Tertiary deformation during the India-Eurasian collision and has reset completely the K- Ar systematic of hornblende as well as biotite to give middle Tertiary ages.

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TẠP CHÍ KHOA HỌC ĐHQGHN, KHTN, t.XVI, n°2 - 2000

SỰ KIỆN NHIỆT KIẾN SINH PROTEROZOI SỚM Ở PHÍA NAM ĐỚI TRƯỢT BẰNG SÔNG HỒNG Ở VIỆT NAM: CHỨNG LIỆU ĐẦU TIÊN ĐỊNH TUỔI BẰNG $^{40}Ar/^{39}Ar$ CỦA HẠT HORNBLEND

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Đai biến chất trước Mesozoi, thuộc đới trượt bằng Sông Hồng, chạy song song th dãy Núi Con Voi ở Miền Bắc Việt Nam. Đai này gồm chủ yếu là đá gneis hornblen các thấu kính amphibol và đá phiến mica. Hornblend tách từ gneis và các thấu kí amphibol trước đây từng được định tuổi theo phương pháp K/Ar cho tuổi tương ứ với từng loại là 1700 và 2000 triệu năm. Cũng hornblend đó mới đây được phân tí theo phương pháp $^{40}Ar/^{39}Ar$ dùng nhiệt laser với hạt đơn khoáng. Tuổi 2000 triệu nă đã đạt được với cả gneis và thấu kính amphibol. Điều này chứng tỏ chắc chắn rằ hornblend do nhiệt kiến sinh Proterozoi sớm không chịu tác động của bất cứ sự xáo tr nhiệt kiến sinh nào sau Proterozoi sớm và cho phép định tuổi địa khu Proterozoi sớ chắc chắn ở Đông Dương.