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Supplemental Material

Analytical Methods and Supporting Data

Tables S1–S4.

SUPPLEMENTAL MATERIAL

Timing of India–Asia collision and significant coupling between them around 51 Ma: Insights from the activation history of the Zhongba-Gyangze Thrust in Southern Tibet

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Analytical Methods:

1. Mineralogical Observation

Scanning electron microscopy (SEM) images were performed using a TESCAN MIRA3 field-emission scanning electron microprobe integrated with energy dispersive X-ray analyser at the Testing Center, Tuoyan Analytical Technology Co. Ltd. (Guangzhou, China). X-ray diffraction (XRD) patterns of random powder samples were used for mineral quantification. Random powder samples side-loaded into an Al sample holder were scanned over angles of $2\theta = 3\text{--}75^\circ$ by the X'Pert Pro multi-purpose diffractometer with $\text{CuK}\alpha$ radiation (45 kV, 40 mA) at the Marine Core Research Institute, Kochi University, Japan. BGMN® and Profex 5.1 are used for polytype quantification through Rietveld Refinement of the powder X-ray diffraction data (Doebelin and Kleeberg, 2015; Boles et al., 2018).

2. *K-Ar dating*

Isotopic dating analyses for selected fractions were undertaken in Hiruzen Institute for Geology and Chronology Co., Ltd., Japan. We used Teflon beakers containing a mixture of nitric acid and hydrofluoric acid to dissolve each fraction (~50 mg) for 12 h. The samples were then dried on a hot plate before being re-decomposed in HCl. The resulting solution was then used for potassium qualitative analysis by flame photometry. We ran each analysis twice, thus the reproducibility of our sample was confirmed. An average value was obtained for calculating the K-Ar age. Based on the multiple runs of two standards (JB-1 basalt and JG-1 granodiorite; [Imai et al., 1995](#)), the analytical error is within 2%. The analytical procedures are described in detail in [Nagao et al. \(1984\)](#).

For argon isotopic analysis, we first wrapped each fraction (~70–75 mg) in a thin aluminum foil and placed it in a sample holder and then used the ribbon and mantle heater to heat the sample for three days at 180–200 °C, thus the adsorption gas would release in a vacuum. Then we dropped the remaining sample into a molybdenum crucible and heated it to 1500 °C for half an hour, thus the activated gases (carbon, hydrogen, oxygen, and sulfur) were removed. Finally, we analyzed purified argon gas by using the mass spectrometer after the isotopic dilution method of [Itaya et al. \(1991\)](#). Multiple analyses of JG-1 biotite (ca. 91 Ma) were used as the standard ([Itaya et al., 1991](#); [Yagi et al., 2015](#)), the standard deviation of the ^{38}Ar spike calibrations was determined to be within 1%. The analytical methods for calculating the age are described in detail in [Nagao et al. \(1984\)](#) and [Nagao and Itaya \(1988\)](#). The decay constants for ^{40}K to ^{40}Ar ($0.581 \times 10^{-10}/\text{year}$), ^{40}Ca ($4.962 \times 10^{-10}/\text{year}$), and ^{40}K content (1.167×10^{-4}) were used for the age calculation in potassium ([Steiger and Jäger](#)

1977). Ages with the 2σ confidence level were obtained.

The York-type weighted linear regression was used for extrapolating the ages of 0% and 100% $2M_1$ illite (Thirumalai et al., 2011; Bailey et al., 2021). Errors on the ages include uncertainties from Ar measurements, K measurements, and XRD illite polytype determinations. The uncertainties on illite polytypes were calculated from the estimated standard deviations of each Rietveld refinement analysis (e.g., Bailey et al., 2021).

3. δD measurement

Samples (0.2-0.5mg) were dried in a constant-temperature oven at 105°C for at least 4 hours. Wrap the samples in clean, dry silver cups for later use. Begin by flushing the air inside the Flash EA elemental analyzer with high-purity helium gas to reduce the H_2 background. Once the temperature reaches 1400°C and the H_2 background drops below 100mV, the sample testing can be performed. Using the AS200 autosampler, the silver cup containing the mineral sample is placed into a ceramic tube with glassy carbon for high-temperature pyrolysis, releasing H_2O . The H_2O undergoes a reduction reaction with carbon at high temperatures, generating H_2 , which is carried into the MAT253 mass spectrometer by a high-purity helium gas stream for continuous flow analysis. The measurement results are reported as δD_{VSMOW} (relative to the IAEA-VSMOW standard with $\delta D_{VSMOW} = 0.0$), with an analytical precision better than $\pm 2.0\text{‰}$.

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