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Late Triassic intra-oceanic arc system within Neotethys: evidence from cumulate appinite in the Gangdese Belt, southern Tibet

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southern Tibet, China

Table DR6 Biostratigraphical data from the Indus-Yarlung Tsangpo suture (mélange) zone, southern Tibet

Table DR7 Reported ages of Middle Triassic to Jurassic igneous rocks in the Gangdese magmatic belt, southern Tibet

Introduction

Data Repository Text DR1 presents the analytical procedures for analysis of bulk-rock major and trace elements, bulk-rock Sr-Nd isotopes, electron microprobe analysis (EMPA) of mineral compositions, LA-ICPMS zircon U-Pb dating and LA-MC-ICPMS zircon Lu-Hf isotopes. Tables DR1 to DR5 show the analytical results and relevant calculated parameters. Table DR6 shows compiled age constraints on ophiolites and/or radiolarites within the Indus-Yarlung Tsangpo suture (mélange) zone in the south of the Gangdese magmatic belt, southern Tibet. Table DR7 presents collected age data for the Middle Triassic to Jurassic igneous rocks in the Gangdese magmatic belt, southern Tibet.

Analytical Methods

1. Whole-rock geochemistry

Bulk-rock major and trace elements were measured by X-ray fluorescence spectrometer (ME-XRF), and inductively coupled plasma-mass spectrometry (ICP-MS) and inductively coupled plasma-atomic emission spectrometry (ICP-AES), respectively, at the ALS Chemex Co. Ltd., Guangzhou, China. Samples were fused with lithium metaborate–lithium tetraborate flux which also includes an oxidizing agent (Lithium nitrate), and then poured into a platinum mold. The resultant disk is in turn analyzed by XRF spectrometry. The XRF analysis is

determined in conjunction with a loss-on-ignition at 1000°C. The analytical data from both determinations are combined to produce a "total". A prepared sample is added to lithium metaborate/lithium tetraborate flux, mixed well and fused in a furnace at 1025°C. Then, the resulting melt is cooled and dissolved in an acid mixture containing nitric, hydrochloric and hydrofluoric acids. This solution is then analyzed by ICP-MS. A prepared sample is digested with perchloric, nitric, hydrofluoric and hydrochloric acids. The residue is topped up with dilute hydrochloric acid and the resulting solution is analyzed by inductively coupled plasma-atomic emission spectrometry (ICP-AES). Results are corrected for spectral interelement interferences. Detailed analytical procedures followed Ma et al. (2017). The analytical results are presented in Table DR1.

2. Whole-rock Sr-Nd analysis

High-precision isotopic (Sr and Nd) measurements were carried out at Nanjing FocuMS Technology Co. Ltd. Geological rock powder were decomposed by high-pressure PTFE bombs. Strontium, Nd were all purified from the same digestion solution by two steps column chemistry. The first exchange column combined with Bio-Rad AG50W×8 and Sr Spec resin was used to separate Sr and REEs from sample matrix. Neodymium was separated from the other REEs on the second column with Ln Spec-coated Teflon powder.

The Sr and Nd-bearing elution were dried down and re-dissolved in 1.0 ml 2 wt% HNO_3. Small aliquots of each were analyzed using Agilent Technologies 7700x quadrupole ICP-MS (Hachioji, Tokyo, Japan) to determine the exact contents of Sr, Nd available. Diluted solutions (50 ppb Sr, 50 ppb Nd doping with 10 ppb Tl) were introduced into Nu Instruments Nu Plasma II MC-ICP-MS (Wrexham, Wales, UK) by Teledyne Cetac Technologies Aridus II

desolvating nebulizer system (Omaha, Nebraska, USA).

Raw data of isotopic ratios were corrected for mass fractionation by normalizing to $^{86}Sr/^{88}Sr = 0.1194$ for Sr, $^{146}Nd/^{144}Nd = 0.7219$ for Nd with exponential law. International isotopic standards (NIST SRM 987 for Sr, JNdi-1 for Nd) were periodically analyzed to correct instrumental drift (Höppe, 1999; Tanaka and Toda, 2000). Geochemical reference materials of USGS BCR-2, BHVO-2, AVG-2, RGM-2 were treated as quality control (Weis et al., 2006). The analytical results are presented in Table DR2.

For the calculation of initial $^{87}Sr/^{86}Sr$ ratios, $\varepsilon_{Nd}(t)$ values and Nd model ages, the used parameters are: decay constant of ^{147}Sm and $^{87}Rb = 6.54 \times 10^{-12}$ yr^{-1} (Lugmair and Marti, 1978) and 1.42×10^{-11} yr^{-1} (Steiger and Jäger, 1977), respectively; CHUR (chondrite uniform reservoir) $^{147}Sm/^{144}Nd$ ratio of 0.1967 (Jacobsen and Wasserburg, 1980); CHUR $^{143}Nd/^{147}Nd$ ratio of 0.512638 (Goldstein et al., 1984); $^{143}Nd/^{147}Nd$ and $^{147}Sm/^{144}Nd$ ratios of depleted mantle = 0.513151 and 0.2136 (Liew and Hofmann, 1988), respectively.

3. Electron microprobe analysis (EMPA)

On the basis of detailed petrographic observations, representative hornblendes, plagioclases, ilmenites and magnetites from thin sections were selected for electron microprobe analyses (EMPA). Mineral chemical compositions were determined using a JEOL JXA-8230 electron microprobe with a 5 μm beam spot (15.0 kV accelerating voltage, 20 nA beam current) at the Institute of Mineral Resources, Chinese Academy of Geological Sciences, Beijing 100037, China. The analytical results are presented in Table DR3.

4. Zircon LA-ICP-MS U-Pb dating

Zircon U–Pb ages were measured by using an Agilent 7500a ICP-MS attached to a NewWave 213 nm laser ablation system with an in-house sample cell at the State Key Laboratory for Mineral Deposits Research, Nanjing University, Nanjing, China. The laser light beam with a diameter of ca. 32 μm and a repetition rate of 5 Hz under 70% energy condition was chosen for the spot analysis. Isotope mass fractionation was normalized through an external standard GEMOC GJ-1 with $^{207}Pb/^{206}Pb$ age = 608.5 ± 1.5 Ma (Jackson et al., 2004) and analytical accuracy was monitored by zircon standards Mud Tank whose intercept age is 732 ± 5 Ma (Black and Gulson, 1978).

Zircon analyses were carried out in runs of fifteen analyses including 5 zircon standards and up to 10 sample spots. U–Pb age results were calculated from the raw signal data using the on-line software package GLITTER (ver. 4.4) (www.mq.edu.au/GEMOC). The ^{204}Pb could not be measured due to low signal and interference from ^{204}Hg in the gas supply, thus, common lead correction was performed using the EXCEL program ComPbCorr#3–15G (Andersen, 2002). U–Th–Pb age calculations and concordia plotting were made using the ISOPLOT/Ex program (ver. 2.49) (Ludwig, 2001). Zircon Th and U concentrations were calculated according to the comparison of relative signal intensity between the zircon samples and standard zircon GJ-1 (Th = 8 ppm, U = 330 ppm) using the EXCEL program Data Templatev2b from GEMOC. Analytical details and data acquisition are given in Wang et al. (2007). The analytical results are presented in Table DR4.

5. Zircon LA-MC-ICP-MS Hf isotopic analysis

Zircon Hf isotopes were analyzed by using a 193-nm laser attached to a Neptune multi-collector ICP-MS (Thermo Finnigan, Bremen, Germany) at Key Laboratory of

Continental Tectonics and Dynamics, Institute of Geology, Chinese Academy of Geological Sciences, Beijing, P.R. China. Most LAM analyses were carried out with a beam size of ca. 32 μm. A decay constant for ^{176}Lu of 1.867×10^{-11} yr^{-1} (Söderlund et al., 2004) was adopted to analyze initial $^{176}Lu/^{177}Hf$ ratios, while chondritic values of $^{176}Lu/^{177}Hf$ = 0.0336 and $^{176}Hf/^{177}Hf$ = 0.282785 were chosen to obtain the $\varepsilon_{Hf}(t)$ values (Bouvier et al., 2008). The single-stage model age (T_{DM1}) was calculated relative to the depleted mantle with a present-day $^{176}Hf/^{177}Hf$ = 0.28325 and $^{176}Lu/^{177}Hf$ = 0.0384 (Griffin et al., 2000). A two-stage continental model age (T_{DM}^{C}) was calculated by projecting the initial $^{176}Hf/^{177}Hf$ of zircon back to the depleted mantle growth curve using $^{176}Lu/^{177}Hf$ = 0.015 for the average continental crust (Griffin et al., 2000, 2002). The analytical results are presented in Table DR5.

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