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Supplemental Material

Table S1. Zircon O and Lu-Hf isotopic composition of the Zagros inner belt and outer belt ophiolitic rocks.

Table S2. Whole rock major and trace elements analysis of the Zagros inner belt and outer belt ophiolitic rocks.

Table S3. LA-ICPMS U-Pb analyses of zircons from the Zagros inner belt and outer belt ophiolites.

Table S4. SIMS U-Pb analyses of zircon from the Zagros inner belt and outer belt ophiolites.

SUPPLEMENTARY APPENDIX A

Major- and trace-element compositions of samples were analyzed both at the Centre de Géochimie de la Surface, Strasbourg (France) and Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing (China). An aliquot of each sample was crushed and powdered for 20 min with an electric mortar in agate to avoid contamination. About one gram of sample was dried at 110 °C and burnt at 1000 °C for 3 h for chemical preparation. 100 mg of each sample was then mixed with 750 mg lithium tetraborate in a vitreous graphite crucible. The mixture was later amalgamated at 1000 °C in a silica muffle furnace under an atmospheric pressure of argon for 30 min. After cooling, the glass bead obtained was dissolved at 70 °C in the crucible with diluted nitric acid and glycerine. The final dilution was 4 g/l (100 mg of sample in 25 ml solution). After filtering, the 4 g/l solution was analyzed by ICP-AES. The same solution was diluted 10 times for ICP-MS measurements. Calibration curves were carried out with five solutions: a blank (750 mg lithium tetraborate which amalgamated and put in solution) and four international standards of CRPG Nancy: AN-G, BE-N, GS-N and VS-N (Govindaraju, 1994). Standards were analyzed every six samples in order to control spectrometer drift and to refine the calibration. The uncertainty (1sigma) is ~2% for major elements and 5%–10% for trace elements (depending on concentration). Whole-rock major- and trace-elements data are presented in Table S2.

Radiogenic isotope ratios of Sr ($^{87}\text{Sr}/^{86}\text{Sr}$), Nd ($^{143}\text{Nd}/^{144}\text{Nd}$) and Pb ($^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, $^{208}\text{Pb}/^{204}\text{Pb}$) were measured at the Department of Earth Sciences, University of Geneva (Switzerland). The method is described in detail in (Béguelin et al., 2015). Between 100 and 120 mg of whole rock powder were dissolved during 7 days in Savillex® Teflon vials using 4 ml of concentrated HF and 1 ml of HNO₃ 14M, at a temperature of 140 °C and with the help of ultrasonication for 30 min twice a day. Subsequently, samples were dried and re-dissolved for 3 days (also with 30 min ultrasonication twice a day) in 3 ml of HNO₃ 14M and dried again. Sr, Nd and Pb were then separated using cascade columns with Sr-Spec, TRU-Spec and Ln-Spec resins according to a protocol modified from (Pin et al., 1994). Finally, the material was redissolved in 2% HNO₃ solutions and ratios were measured using a Thermo Neptune PLUS

Multi-Collector ICP-MS in static mode. Ratios used to monitor internal fractionation were: $^{88}\text{Sr}/^{86}\text{Sr} = 8.375209$ for the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio, $^{146}\text{Nd}/^{144}\text{Nd} = 0.7219$ for the $^{143}\text{Nd}/^{144}\text{Nd}$ ratio and $^{203}\text{Tl}/^{205}\text{Tl} = 0.418922$ for the three Pb ratios (a Tl standard was added to the solution). Used external standards were SRM987 ($^{87}\text{Sr}/^{86}\text{Sr} = 0.710248$, long-term external reproducibility: 10 ppm, 1SD), JNdi-1 ($^{143}\text{Nd}/^{144}\text{Nd} = 0.512115$; (Tanaka et al., 2000); long-term external reproducibility: 10 ppm, 1SD), and SRM981 (Baker et al., 2004) for Pb (long-term 1SD external reproducibility of 0.0048% for $^{206}\text{Pb}/^{204}\text{Pb}$, 0.0049% for $^{207}\text{Pb}/^{204}\text{Pb}$ and 0.0062% for $^{208}\text{Pb}/^{204}\text{Pb}$). $^{87}\text{Sr}/^{86}\text{Sr}$, $^{143}\text{Nd}/^{144}\text{Nd}$ and Pb isotope ratios were further corrected for external fractionation (due to a systematic difference between measured and accepted standard ratios) by a value of -0.021‰ , $+0.051\text{‰}$ and $+0.36\text{‰}$ amu respectively. Interferences at masses 84 (^{84}Kr), 86 (^{86}Kr) and 87 (^{87}Rb) were corrected by monitoring ^{83}Kr and ^{85}Rb , ^{144}Sm interference on ^{144}Nd was monitored on the mass ^{147}Sm and corrected by using a $^{144}\text{Sm}/^{147}\text{Sm}$ value of 0.206700 and ^{204}Hg interference on ^{204}Pb was corrected by monitoring ^{202}Hg . Total procedural blanks were <500 pg for Pb and <100 pg for Sr and Nd which are insignificant compared to the amounts of these elements purified from the whole rock samples investigated. Whole-rock Sr-Nd-Pb isotope data are presented in Table 2.

For LA-ICP-MS zircon U-Pb analysis, zircons were separated following electrostatic disaggregation (selfFrag) of the rock sample, using standard gravimetric and magnetic techniques; grains were picked under a binocular microscope and mounted in epoxy discs for analysis. All grains were imaged by CL and BSE to provide maps to guide the choice of analytical spots. The discs were coated with carbon for analysis. Zircon U-Pb ages were obtained using a 193 nm ArF EXCIMER laser with an Agilent 7700 ICP-MS system in the Geochemical Analysis Unit of the ARC Centre of Excellence for Core to Crust Fluid Systems (CCFS/GEMOC) Macquarie University, Australia. Detailed method descriptions have been given by (Jackson et al., 2004). The ablation conditions included beam size (30 μm), pulse rate (5Hz) and energy density (7.59 J/cm²). Analytical runs comprised 16 analyses with 12 analyses of unknowns bracketed by two analyses of a standard zircon GJ-1 at the beginning and end of each run, using the established TIMS values ($^{207}\text{Pb}/^{206}\text{Pb}$ age = 608.5 Ma, (Jackson et al., 2004)).

U-Pb ages were calculated from the raw signal data using the online software package GLITTER (Griffin et al., 2008; www.mq.edu.au/GEMOC). GLITTER calculates the relevant isotopic ratios for each mass sweep and displays them as time-resolved data. This allows isotopically homogeneous segments of the signal to be selected for integration. GLITTER then corrects the integrated ratios for ablation-related fractionation and instrumental mass bias by calibration of each selected time-segment against the identical time-segments of the standard zircon analyses (standard GJ-1). U-Pb age data were subjected to a common-lead correction, except for those with common-Pb concentrations lower than detection limits. We have followed the correction procedure of (Andersen, 2002), which assumes that the observed $^{206}\text{Pb}/^{238}\text{U}$, $^{207}\text{Pb}/^{235}\text{U}$ and $^{208}\text{Pb}/^{232}\text{Th}$ ratios of a discordant zircon reflect a combination of common lead and lead loss at a defined time, and solves the resulting mass-balance equations. The amount of common lead and the common lead-corrected composition of the sample are determined simultaneously. This procedure yields common-lead corrections of similar magnitude to those obtained from measurements of ^{204}Pb in ion-probe analysis; the relative error in the amount of common lead is less than 10%. The uncertainty in common lead concentration contributes significantly to the uncertainty in the $^{207}\text{Pb}/^{206}\text{Pb}$ age only above 0.5% common lead. The analyses presented here have been corrected assuming recent lead-loss and a common lead composition corresponding to present-day average orogenic lead as given by the second-stage

growth curve of (Stacey and Kramers, 1975) for $^{238}\text{U}/^{204}\text{Pb} = 9.74$. No correction has been applied to analyses that are concordant within 2σ analytical errors in $^{206}\text{Pb}/^{238}\text{U}$ and $^{207}\text{Pb}/^{235}\text{U}$, or which have less than 0.2% common lead. The results were processed using the ISOPLOT program of (Ludwig, 2003). The external standards, zircons 91500 and Mud Tank, gave mean $^{206}\text{Pb}/^{238}\text{U}$ ages of 1063.5 ± 1.8 Ma (MSWD = 1.3) and 731.1 ± 1.2 Ma (MSWD = 0.77), respectively, which are similar to the recommended $^{206}\text{Pb}/^{238}\text{U}$ ages of 1062.4 ± 0.4 Ma and 731.9 ± 3.4 Ma respectively (Chang et al., 2006; Woodhead and Hergt, 2005; Yuan et al., 2008). Zircon LA-ICPMS U-Pb isotopic data are presented in Table S3.

For SIMS analysis, zircon concentrates were separated from *ca* 3 kg of crushed rock using standard density and magnetic separation techniques. Zircon unknowns together with standards were mounted in epoxy mounts, which were then polished to section the crystals in half for analysis. Both optical photomicrographs and cathodoluminescence (CL) images were taken to guide analytical spot selection. The mount was vacuum-coated with high-purity gold prior to SIMS analyses. U-Pb analyses were performed on a Cameca IMS-1280/HR SIMS at Institute of Geology and Geophysics, Chinese Academy of Sciences (IGG-CAS) using standard operating conditions (7-scan duty cycle, ~ 8 nA primary O_2^- beam, 20×30 μm analytical spot size, mass resolution ~ 5400). U-Th-Pb ratios and absolute abundances were determined relative to the standard zircon Plešovice (337 Ma, (Sláma et al., 2008)) and M257 (U = 840 ppm, Th/U = 0.27, (Nasdala et al., 2008)) respectively. Measured Pb-isotope compositions were corrected for common Pb using analyzed ^{204}Pb values. An average Pb of present-day crustal composition (Stacey and Kramers, 1975) was used for the common-Pb correction. A long-term uncertainty of 1.5% (1 RSD) for $^{206}\text{Pb}/^{238}\text{U}$ measurements of the standard zircon was propagated to the unknowns (Li et al., 2010b). In order to monitor the external uncertainties of SIMS U-Pb measurements, analyses of the in-house zircon standard Qinghu were interspersed with unknowns. Twenty-two analyses yield a weighted mean $^{206}\text{Pb}/^{238}\text{U}$ age of 159.3 ± 0.5 Ma (MSWD = 0.24), identical within error to the reported age of 159.5 ± 0.2 Ma (Li et al., 2013). Uncertainties on individual analyses are reported at the 2σ level; mean ages for pooled U/Pb and Pb/Pb analyses are quoted with 95% confidence interval. These data were processed using the Isoplot/Ex v. 2.49 program (Ludwig, 2003). Zircon SIMS U- Pb isotopic data are presented in Table S4.

In situ oxygen-isotope analyses for selected samples of Zagros ophiolitic rocks were conducted on zircons that were previously dated using the same Cameca IMS-1280 SIMS at IGG-CAS. After U-Pb dating, the sample mount was reground to ensure that any oxygen implanted in the zircon surface from the O_2^- beam used for U-Pb analysis was removed. The Cs^+ primary ion beam was accelerated to 10 kV, with an intensity of ~ 2 nA corresponding to a beam size of ~ 10 μm in diameter. A normal-incidence electron flood gun was used to compensate for sample charging during analysis. Negative secondary ions were extracted with a -10 kV potential. Oxygen isotopes were measured using the multi-collection mode on two off-axis Faraday cups. One analysis consists of 16 cycles, with an internal precision generally better than 0.4‰ (2SE) on the $^{18}\text{O}/^{16}\text{O}$ ratio. The detailed analytical procedures are similar to those reported by (Li et al., 2010a).

Oxygen isotope ratios are expressed as $\delta^{18}\text{O}$, representing deviation of measured $^{18}\text{O}/^{16}\text{O}$ values from that of the Vienna Standard Mean Ocean Water ($(^{18}\text{O}/^{16}\text{O})_{\text{VSMOW}} = 0.0020052$) in parts per thousand. The internal precision for each spot analysis is typically better than 0.4‰ for the $^{18}\text{O}/^{16}\text{O}$ ratio (2SE). The results are then corrected for instrumental mass fractionation factor (IMF), following the equation: $\delta^{18}\text{O}_{\text{Corrected}} = \delta^{18}\text{O}_{\text{Measured}} - \text{IMF}$. IMF is monitored in terms of the

difference between measured and recommended oxygen isotopic compositions of the Penglai zircon standard with a $\delta^{18}\text{O}$ value of 5.31‰ (Li et al., 2010b). The zircon O- isotope data are presented in Table S1.

Zircon Lu-Hf isotope compositions were acquired in both CCFS and IGG-CAS. For CCFS analysis, the zircon Lu-Hf isotopes were analyzed using a Nu Plasma MC-ICP-MS system coupled to a New Wave Research UP213 laser ablation micro-sampling system. The methods, including calibration and correction for mass bias, are described by (Griffin et al., 2004; Griffin et al., 2000).

The beam used for ablation was produced by a 213 nm Nd-YAG laser, with a 55 μm spot size, a 5Hz pulse rate and 80% energy. The ablation spots for the Hf isotope analyses were situated close to the U-Pb age analysis positions on each grain. The accuracy of the Yb and Lu corrections during LA-MC-ICPMS analysis of zircon has been demonstrated by repeated analysis of standard zircons with a range in $^{176}\text{Yb}/^{177}\text{Hf}$ and $^{176}\text{Lu}/^{177}\text{Hf}$. Four secondary standards (Mud Tank, Temora, Qinghu and Plesovice) were analyzed between every ten unknowns to check instrumental stability. $^{176}\text{Hf}/^{177}\text{Hf}$ ratios of the Mud Tank zircon gave an average of 0.282522 ± 0.000042 (2SD; $n = 122$); those of Temora gave 0.282680 ± 0.000011 (2SD; $n = 42$). These values are identical to those recommended for Mud Tank (0.282523 ± 0.000010) and Temora (0.282693 ± 0.000052) (Fisher et al., 2014; Gain et al., 2019). The Plesovice and Qinghu zircons show a $^{176}\text{Hf}/^{177}\text{Hf}$ average ratio of 0.282489 ± 0.000015 (2SD; $n = 18$) and 0.283012 ± 0.000017 (2SD; $n = 29$) respectively, which are similar to the recommended values of 0.282482 ± 0.000003 and 0.283002 ± 0.000004 (Li et al., 2013; Sláma et al., 2008). The isobaric interferences of ^{176}Lu and ^{176}Yb on ^{176}Hf are very limited, because of the extremely low ratios of Lu/Hf and Yb/Hf in the measured standard zircons. Analyses of standard zircons, which have a wider range of $^{176}\text{Yb}/^{177}\text{Hf}$ and $^{176}\text{Lu}/^{177}\text{Hf}$, show no correlation between these ratios and $^{176}\text{Hf}/^{177}\text{Hf}$. For calculation of initial Hf ratios, $\varepsilon\text{Hf}(t)$ and TDM, we used the measured $^{206}\text{Pb}/^{238}\text{U}$ ages of each analysis point. Average crustal model ages (T_{crust}) were calculated by assuming that the protolith of the host-rock of a zircon was originally derived from the depleted mantle and then evolved as a reservoir with $^{176}\text{Lu}/^{177}\text{Hf}$ of 0.015, similar to the average continental crust (Griffin et al., 2002).

For IGG-CAS analysis, in situ zircon Lu-Hf isotopic analysis was carried out on a Neptune multi-collector ICP-MS equipped with a Geolas-193 laser-ablation system, and the analytical procedures were similar to those described by (Wu et al., 2006). Lu-Hf isotopic analyses were obtained on the same zircon grains that were previously analyzed for U-Pb, with ablation pits of 63 μm in diameter, ablation time of 26 seconds, repetition rate of 10 Hz, and laser beam energy density of $10 \text{ J}/\text{cm}^2$. During laser ablation analyses, the isobaric interference of ^{176}Lu on ^{176}Hf is negligible due to extremely low $^{176}\text{Lu}/^{177}\text{Hf}$ in zircons. Isobaric interference of ^{176}Yb on ^{176}Hf is corrected using independent mass bias factors for Hf and Yb for correction. During analysis, an isotopic ratio of $^{176}\text{Yb}/^{172}\text{Yb} = 0.5887$ was applied (Wu et al., 2006). Measured $^{176}\text{Hf}/^{177}\text{Hf}$ ratios were normalized to $^{179}\text{Hf}/^{177}\text{Hf} = 0.7325$. The zircon Lu-Hf isotopic results are listed in Table S8. For calculation of initial Hf ratios, $\varepsilon\text{Hf}(t)$ and T_{DM} , we used the measured $^{206}\text{Pb}/^{238}\text{U}$ ages of each analysis point. Average crustal model ages (T_{DM}^{C}) were calculated by assuming that the host-rock of a zircon was originally derived from the depleted mantle and then evolved as a reservoir with $^{176}\text{Lu}/^{177}\text{Hf}$ of 0.015, similar to the average continental crust (Griffin et al., 2002). Zircon Hf isotope data are presented in Table S1.

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