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Supplemental Material

Supplemental Material 1. Materials and methods

Supplemental Material 2. Supplementary Data File B. Major (wt%) and trace (ppm) element concentrations of the Dongchagou metasedimentary rock samples

Supplemental Material 3. Characteristics and U-Pb ages of zircons from the Dongchagou, Moshigou, and Qingshipo formations

Supplemental Material 4. LA-ICPMS detrital zircon U-Pb age data for sandstone and SHRIMP zircon U-Pb age data for a dolerite samples

SUPPLEMENTAL MATERIAL 1: MATERIALS AND METHODS

Sample material

In order to identify potential source and reconstruct lithostratigraphic framework, sixteen metasedimentary rock samples of the Dongchagou, Moshigou, and Qingshipo formations were collected and processed for petrographic examination and zircon separation. Fourteen fine-grained metasedimentary samples, together with twelve analyzed mica schist, quartz-mica schist, and amphibolite samples by Guo (1999), were collected along the Baoku river and south of the Huangyuan-Huangzhong County from the Dongchagou Formation for whole-rock geochemical analyzing. In addition, five dolerite samples were also collected for geochemistry that intruded into interlayers of sandstone and muddy schist in the SW Huanyuan County. Particular care in sampling was taken to avoid zircon U-Pb age and geochemical data bias induced by post-stage magmatism and tectonism. Paleocurrent data were collected by extensive fieldwork. Detrital zircon grains were dated randomly to avoid omitting or overemphasizing potential source.

Geochemical analyses

Each sample for geochemical analyses was cleaned and vein material was removed prior to powder using an agate mill. All major and trace elements were analyzed at the National Research Center for Geoanalysis, Beijing. The concentration of major oxides was determined utilizing a Phillips PW 4400 X-ray fluorescence (XRF) spectrometer with a rhodium X-ray source. FeO was determined by digestion with HF and H₂SO₄ and titration with standard potassium dichromate solution using the diphenylamine sulphonate indicator. Loss on ignition (LOI) was measured by weighing before and after 1 h in a furnace at 1000 °C. Trace element concentrations were determined by inductively coupled plasma mass spectrometry (ICP-MS) using a VG Elemental PQII Plus system. All measurements of the trace elements were corrected

for instrumental drift using the peak intensities of ^{115}In and ^{185}Re internal monitors. International standards GSR1, GSR2 and GSR3 were used to monitor analytical quality control. Detection limits for major elements were $<0.01\%$ (except for TiO_2 and MnO , which had detection limits $<0.001\%$). Detection limits for minor and trace elements were 1–0.05 ppm. Based on the analyses of international reference materials, the analytical precision for all major oxides by XRF is estimated to be better than 1%. The results of standard analyses were consistent with their reference values within the published error ranges, respectively, with the differences for trace elements, including REE, within 5%–10%. Analyzed results see Supplemental Material 4.

SHRIMP and LA-ICPMS zircon U-Pb dating methods

Zircons were extracted from rock samples of *ca.* 5–8 kg using standard heavy liquid and magnetic separation techniques. Handpicked zircons were mounted in epoxy resin, ground to present grain half-sections, and then polished. Reflected and transmitted light photographs and cathodoluminescence (CL) images were acquired to obtain information on the internal structures of the grains and to target specific areas therein. The number of analyzed zircons reflects the abundance of grains with sufficient size and few enough defects to allow analysis. This is a function of the spot size of the laser equipment. Except dolerite sample 10HY41 dated using the SHRIMP II at the Beijing SHRIMP Center of the Institute of Geology, Chinese Academy of Geological Sciences (CAGS), U-Th-Pb analyses of other samples were carried out using the LA-ICPMS at the Institute of Mineral Resources, CAGS.

Analytical procedures for zircon dating followed methods described in Liu and Jian (2004) and Hou et al. (2007), respectively. Instrumental conditions and data acquisition procedures are comprehensively described by Hou et al. (2007). Zircon GJ-1, which was used as the reference standard, is distributed by GEMOC (ARC National Key Centre for Geochemical Evolution and Metallogeny of Continents, Macquarie University, Sydney, Australia) and comprises several *ca.* 1 cm-sized zircon crystals from African pegmatites (Elhlou et al., 2006) with an apparent crystallization age of 608.5 ± 0.4 Ma (Jackson et al., 2004). SHRIMP and LA-ICPMS raw data were reduced according to the procedure of Ludwig (2001) and Liu et al. (2010), respectively. The age of each sample was determined by calculating the weighted average of $^{206}\text{Pb}/^{238}\text{U}$ ages (Isoplot/Ex program of Ludwig, 2003), using the ^{207}Pb -correction method (Compston et al., 1984). In the presentation of figures, tables, and results we follow Gehrels et al. (2006) with $^{206}\text{Pb}/^{238}\text{U}$ ages quoted for zircons younger than 1.0 Ga, and older grains are quoted using their $^{207}\text{Pb}/^{206}\text{Pb}$ ages. The latter ages become increasingly imprecise younger than 1.0 Ga due to small amounts of ^{207}Pb . Data were screened prior to calculating a relative probability distribution, by plotting on a Tera-Wasserburg concordia diagram (using Isoplot/Ex; Ludwig, 2003). Discordant data were excluded from the relative probability calculation. Zircon analyses with $<10\%$ normal and $<5\%$ reverse discordance from the LA-ICPMS method are considered to be geologically meaningful (Dickinson and Gehrels, 2008) and are used to date the time of intrusion in igneous rocks or the maximum age of deposition in metasedimentary rock. Thus, the <1.0 Ga data are considered robust if it belongs to a cluster of three or more zircons with similar ages (Gehrels et al., 2006). U-Pb age data see Supplemental Material 4.

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Supplemental Material 3 Characteristics and U-Pb ages of zircons from the Dongchagou, Moshigou, and Qingshipo formations

Sample	GPS coordinates	Lithology	Zircon morphology	Zircon texture	U-Pb age	Th/U	Stratigraphic unit
10HY10	N36°39'6.4", E101°9'37.2"	garnet mica-quartz schist	Oblong and elongate grains with long axes of 50-150 µm and l/w of 1-2.	Slightly banded and concentric zoning with a much thinner bright or black rim in CL.	1151-2001 Ma ^a ; 1512 Ma ^b ; 1148 Ma ^c	0.27-1.45	Dongchagou Formation
10HY41	N36°40'26.5", E101°7'38.9"	dolerite	Short prismatic grains with longer axes of 70-150 µm and l/w of 1-2.	Faintly banded and sector zoning.	1099-1246 & 909 Ma ^a ; 432 ± 13 Ma ^c	0.32-1.20	Dongchagou Formation
10HY48	N36°40'26.5", E101°7'38.9"	mica-quartz schist	Stout and oblong grains with rounded and pitting surface and long axes of 90-200 µm and l/w of 1-2.	Oscillatory or faint and broad zoning with a very narrow bright overgrowth rim in CL.	1212-3074 Ma ^a ; 1742 Ma ^b ; 1269 Ma ^c ; 434 Ma ^d	0.19-6.26 0.67	Dongchagou Formation
10HY65	N36°33'59" E101°12'58"	phyllite	Elongate and stout grains with round surface and long axes of 50-100 µm and l/w of 1-2.	Oscillatory or faint and broad zoning with a narrow, bright or black overgrowth rim in CL.	819-2449 Ma ^a ; 1472 Ma ^b ; 819 Ma ^c ; 433 Ma ^c	0.21-3.17 1.99	Dongchagou Formation
15DT3	N37°5'11.8", E101°33'56.2"	quartzite	Pink, equant to elongate grains with rounded surface and long axes of 80-150 µm and l/w of 1-1.5.	Core-rim texture consisting of a core with banded or concentric oscillatory magmatic zoning and a narrow black rim in CL.	1214-3113 Ma ^a ; 1784 Ma ^b ; 1240 Ma ^c	0.07-2.99	Dongchagou Formation
17BK1	N37°9'53.8", E101°33'29.6"	garnet-bearing amphibolite	Oblong and equant grains with round and pitting surface and long axes of 80-120 µm and l/w of 1-1.3.	Oscillatory or faint and broad zoning with a narrow, bright or black overgrowth rim in CL.	1139-2588 Ma ^a ; 1421 Ma ^b ; 1752 Ma ^b ; 1155 Ma ^c	0.14-1.98	Dongchagou Formation
17BK4	N37°6'14.3", E101°33'41.4"	silty mylonite	Pink, stout and equant grains with round and pitting surface and long axes of 50-120 µm and l/w of 1-1.2.	Oscillatory and broad zoning in CL	1131-3237 Ma ^a ; 1780 Ma ^b ; 1237 Ma ^c	0.02-1.70	Dongchagou Formation
10HY11	N36°38'10.2", E101°7'2.8"	quartz arenite	Equant to elongate grains with long axes of 50-130 µm and l/w of 1-1.5.	Oscillatory, sector-banded or broad banded zoning with a very thin black rim in CL.	1190-3266 Ma ^a ; 1850 Ma ^b ; 1221 Ma ^c	0.05-2.37	Moshigou Formation
15DT1	N37°4'4.5", E101°34'23.0"	quartz arenite	Oblong to elongate grains with long axes of 80-100 µm and l/w of 1-1.2.	Faintly banded and oscillatory zoning with a much thinner bright rim in CL.	1183-3106 Ma ^a ; 1838 & 1786 Ma ^b ; 1209±40 Ma ^c	0.01-2.26	Moshigou Formation
15BK6	N36°56'18",	quartz arenite	Pink, stout and equant grains with	Faintly banded and oscillatory	1083-3246 Ma ^a ;	0.1-1.66	Moshigou

	E101°32'15.9"		round and pitting surface and long axes of 50-100 µm and l/w of 1-1.2.	zoning with a much thinner bright rim in CL	1750 Ma ^b ; 1175 Ma ^c		Formation
10LGS1	N36°22'4.1", E101°28'5.2"	lithic greywacke	Stout and oblong grains with pitting surface and long axes of 50-120 µm and l/w of 1-1.2.	Well-developed banded and oscillatory zoning; minor grains have a much thinner bright rim in CL.	428-1894 Ma ^a ; 906 & 463 Ma ^b ; 428 Ma ^c	0.17-2.19	Qingshipo Formation
10LGS2	N36°22'9.2", E101°29'11.9"	quartz arenite	Oblong and mostly elongate grains with long axes of 100-250 µm and l/w of 1-2.1.	Well-developed banded, sector-zoned and oscillatory zoning; minor grains have a much thinner black rim in CL.	507-2712 Ma ^a ; 915 & 633Ma ^b ; 505 & 541 Ma ^c	0.08-1.5	Qingshipo Formation
10LGS5	N36°21'55.5", E101°30'43.3"	calcareous sandstone	Stout and mostly elongate grains with pitting surface and long axes of 40-150 µm and l/w of 1-2.5.	Well-developed banded and oscillatory zoning; minor grains have a much thinner bright or black rim in CL.	417-2573 Ma ^a ; 446 Ma ^b ; 417 Ma ^c	0.12-3.59	Qingshipo Formation
11LJS1	N36°22'10.2", E101°28'35.2"	lithic greywacke	Elongate grains with long axes of 80-140 µm and l/w ratio of 1-1.2.	Oscillatory, banded and sector zoning with a much thinner bright or black rim in CL.	436-2779 Ma ^a ; 458 Ma ^b ; 434 Ma ^c	0.12-3.39	Qingshipo Formation
11LJS5	N36°22'12", E101°28'40"	lithic greywacke	Equant and elongate grains with with long axes of 50-120 µm and l/w of 1-1.2.	Faint banded and concentric zoning with a much thinner bright rim in CL.	450-2508 Ma ^a ; 460 Ma ^b	0.09-1.49	Qingshipo Formation
11LJS9	N36°22'8.7", E101°29'14.2"	quartz arenite	Oblong and elongate grains with pitting surfaces and long axes of 80-200µm and l/w of 1-2.	Well-developed oscillatory and banded zoning with a narrow black or bright rim in CL.	598-1454 Ma ^a ; 905 Ma ^b ; 603 Ma ^c	0.12-3.59	Qingshipo Formation
10HSZ3	N36°24'16.9", E101°20'5.2"	feldspathic greywacke	Elongate grains with pitting surfaces and long axes of 100-250µm and l/w of 1.2-2.5	Banded, concentric and sector zoning with a much thinner bright or black rim in CL	471-3284 Ma ^a ; 488 Ma ^b ; 471 Ma ^c	0.02-1.25	Qingshipo Formation

^a U-Pb ages of detrital zircons; ^b Peak age of detrital zircons; ^c Youngest age of detrital zircons; ^d Age of overgrowth rim; ^e Crystalline age.