Data Repository

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ANALYTICAL METHODS

1. LA-ICP-MS U-Pb dating of zircon

LA-ICP-MS U-Pb dating of zircon was undertaken on an Agilent 7500a laser ablation inductively coupled plasma mass spectrometer using an excimer laser ablation system (GeoLas 2005). Detailed operating conditions and data reduction are outlined by Liu et al., 2010. Each analysis incorporated a background acquisition of ~20–30 s (gas blank) followed by 50 s of data acquisition from the sample. The Agilent Chemstation was utilized for the acquisition of each individual analysis. Off-line selection and integration of background and analytical signals, and time-drift correction and quantitative calibration for trace element analyses and U-Pb dating were performed by ICPMSDataCal (Liu et al., 2010). Zircon 91,500 was used as the calibration standard for U-Pb dating and was analyzed twice every eight analyses. Time-dependent drift of U-Th-Pb isotopic ratios were corrected using a linear interpolation (with time) for every eight analyses according to the variations of 91,500 (Liu et al., 2010). GJ-1 was analyzed as an unknown. Our measurements of 91,500 and GJ-1 yielded weighted mean $^{206}\text{Pb}/^{238}\text{U}$ ages of $1062.4 \pm 2.3$ Ma ($2\sigma$, MSWD = 0.06, n = 132) and $604.0 \pm 2.2$ ($2\sigma$, MSWD = 1.7, n = 50), respectively, which are in good agreement with the measured isotope dilution thermal ionization
mass spectrometry (ID-TIMS) $^{206}\text{Pb} / ^{238}\text{U}$ ages of 1062.4 ± 0.4 and 598.5–602.7 Ma (2σ) (Jackson et al., 2004). Common Pb correction was not performed. Concordia diagrams, probability distribution plots and weighted mean calculations were made using Isoplot/Ex_ver3 (Ludwig, 2003).

2. SHRIMP U-Pb dating of zircon

SHRIMP U-Pb dating of zircon from sample 18HN-14 was carried out using the Sensitive High Resolution Ion MicroProbe (SHRIMP) facility in the John de Laeter Centre at Curtin University Australia. During the session, an O$_2^-$ primary beam current of 1.3 nA, was used to produce an ellipsoidal spot of 15 μm in dimension, and a mass resolution of 5000, each analysis includes 6 cycles. U concentration and $^{206}\text{Pb} / ^{238}\text{U}$ ratio were calibrated using standard BR266 (Stern, 2001), and an Archean zircon standard OGC ($^{207}\text{Pb} / ^{206}\text{Pb}$ age of 3465 Ma) was used to monitor instrumental mass fractionation in $^{207}\text{Pb} / ^{206}\text{Pb}$. Detailed analytical procedure was similar to that described by Williams (1998). Data reduction and visualization was carried out using Squid v2.50 (Ludwig, 2001b) and Isoplot/Ex v2.49 (Ludwig, 2001a) packages.

3. In situ Lu-Hf isotope analysis of zircon

In situ zircon Lu-Hf isotopic analysis was undertaken on dated zircon grains using a Neptune Plus MC-ICP-MS in combination with a Geolas 2005 excimer ArF laser ablation system at the State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan.

The energy density of laser ablation that was used in this study was 5.3 J cm$^{-2}$. A “wire” signal smoothing device is included in this laser ablation system, by which smooth signals are produced even at very low laser repetition rates down to 1 Hz (Hu et al. 2012). Helium was used as the carrier gas within the ablation cell and was merged with argon (makeup gas) after the ablation cell. All data were acquired on zircon in single spot ablation mode at a spot size of 44 μm in this study. Each measurement consisted of 20 s of acquisition of the background signal followed by 50 s of ablation signal acquisition. Detailed instrument settings and analytical method were similar to those described by Hu et al. (2012). Analytical spots were located close to LA-ICP-MS spots, or in the same growth domain as inferred from CL images. Reference zircons 91500 and GJ-1 were used to monitor accuracy of interference correction during Hf analysis. Zircon 91500 yielded a $^{176}\text{Hf} / ^{177}\text{Hf}$ ratio of 0.282301 ± 5 (n = 32, 1σ) compared to the recommended value of 0.282308 ± 6 (Blichert-Toft, 2008) and 0.281992 ± 17 (n = 12, 1σ) for GJ-1 compared to the recommended value of 0.282015 ± 19 (Elhlou et al., 2006). The $^{176}\text{Hf} / ^{177}\text{Hf}$ and $^{173}\text{Yb} / ^{171}\text{Yb}$ ratios were used to calculate the mass bias of Hf (β$_{\text{Hf}}$) and Yb (β$_{\text{Yb}}$), which were normalized to $^{176}\text{Hf} / ^{177}\text{Hf} = 0.7325$ and $^{173}\text{Yb} / ^{171}\text{Yb} = 1.132685$ (Fisher et al., 2014) using an exponential correction for mass bias. Interference of $^{176}\text{Yb}$ on $^{176}\text{Hf}$ was corrected by measuring the interference-free $^{173}\text{Yb}$ isotope and using $^{176}\text{Yb} / ^{173}\text{Yb} = 0.79639$ (Fisher et al., 2014) to calculate $^{176}\text{Yb} / ^{177}\text{Hf}$.

The ε$_{\text{Hf}}$(t) values were calculated relative to the chondritic reservoir with a $^{176}\text{Hf} / ^{177}\text{Hf}$ ratio of 0.282772 and $^{176}\text{Lu} / ^{177}\text{Hf}$ of 0.0332 (Blichert-Toft and Albarède, 1997). The decay constant for $^{176}\text{Lu}$ of 1.865 × 10$^{-11}$ a$^{-1}$ was adopted (Scherer et al., 2001). Single-stage Hf model ages (T$_{DM}$) were calculated by reference to depleted mantle with a present-day $^{176}\text{Hf} / ^{177}\text{Hf}$ ratio of 0.28325 and $^{176}\text{Lu} / ^{177}\text{Hf}$ ratio of 0.0384 (Vervoort and Blichert-Toft, 1999). Two-stage Hf
4. In situ SHRMIP U-Pb dating of monazite

U–Pb analyses of monazite were conducted using a SHRMIP II ion microprobe in the John de Laeter Centre at Curtin University. Optical and BSE images were used to guide placement of the primary spot during SHRMIP analysis. The analytical procedures were similar to those described by Fletcher et al. (2010). During the analytical session, an O₂⁻ primary beam, with a spot size of ~10 μm, was focused through a 30 μm Kohler aperture with a beam intensity of 0.2–0.3 nA. A postcollector retardation lens was used to reduce background counts produced from stray ions. The secondary ion beam was focused onto an electron multiplier to produce mass peaks with flat tops and a mass resolution (1% peak heights) of ~5200.

Monazite was analyzed with a 13-peak run table as defined by Fletcher et al. (2010), including mass stations for the La, Ce and Nd (REEPO₂⁻), and Y (YCeO⁺). Count times per scan for Pb isotopes 204, background position 204.045, 206, 207 and 208 were 10, 10, 10, 30 and 10 s, respectively. The primary Pb/U standard used was French (²⁰⁶Pb/²³⁸U age of 514 ± 1 Ma), whereas Z2234 and Z2908 were used as secondary reference standards. Matrix effects in Pb/U data were corrected following protocols established by Fletcher et al. (2010). Z2908 was also used to monitor, and correct for, the instrumental mass fractionation in ²⁰⁷Pb/²⁰⁶Pb during the session.

ZIRCON TEXTURES

Features of zircon from metasedimentary units

Gezhencun succession
Zircon grains from two paragneiss samples (17PM01–5 and 15LJ-59) have an average size of 50–80 μm in length with aspect ratios of 1:1–1:3. Most grains are subhedral and CL images show core-rim structures with igneous or metamorphic cores enveloped by dark, faint zoning or homogeneous metamorphic rims. A few grains also show simple internal structures with either oscillatory zoning or dark, homogeneous internal structures, indicating igneous and metamorphic origins, respectively (Fig. DR2).

Ewenling succession
Zircon grains from two schist samples (17PM01–1 and 15LJ-51) generally have an average size of 50–100 μm in length with aspect ratios of 1:1–1:3. Most grains are prismatic euohedral to subhedral crystals. A few are oval with rounded rims, and have pitted surface, indicative of sedimentary transport. Internal structures of the grains, revealed by CL images, indicate that most exhibit complex structures with igneous or metamorphic cores enveloped by low luminescent, weakly zoned or homogeneous rims, but average widths of those metamorphic rims are relatively narrower than those of grains in the two paragneiss samples from the Gezhencun assemblage. Some grains also display oscillatory zoning, indicating an igneous origin, whereas a few grains have dark, homogeneous internal structures, and could represent recrystallized or metamorphic grains (Fig. DR2).
Features of zircon from igneous rocks

**Plagioclase amphibolite sample 18HN-14**

Zircon grains from plagioclase amphibolite (sample 18HN-14) are transparent and euhedral or subhedral crystals. They are 50–100 μm in length with aspect ratios of 1:2–1:3. In CL images, almost all grains display clear core-rim structures. The cores either show dark, broad-banded zoning originating from magmatic crystallization, or partially preserve growth zoning penetrated by transgressive zones of recrystallization, and are enveloped by bright, relatively wide homogeneous rims. A few grains show either thin and dense magmatic growth zoning, or irregular weak zoning (Fig. DR2).

**Plagioclase gneiss sample 15LJ-60**

Zircon grains from plagioclase gneiss sample 15LJ-60 are euhedral crystals with an average length of 100–150 μm and aspect ratios of 1:2–1:4. Almost all grains show core-rim structures with magmatic oscillatory zoned cores and narrow homogeneous metamorphic rims in CL images (Fig. DR2).

**Gneissic granite sample 18HN-17**

Zircon grains from gneissic granite sample 18HN-17 are euhedral prismatic crystals. They have an average size of 80–120 μm with aspect ratios of 1:2–1:3. Their CL images show uniform core-mantle-rim textures with igneous cores wrapped by low luminescent, weakly zoned mantles and a narrow, bright rim, reflective of a multiple-stage growth history (Fig. DR2).

**Leucogranitic dyke sample 17PM01–6**

Zircon grains from leucogranitic dyke 17PM01–6 are generally euhedral or subhedral, 100–200 μm in length with aspect ratios of 1:2–1:3. Almost half of the grains show low CL luminescence with heterogeneous patchy and mottled or spongy internal textures, likely a result of radiation damage due to the high-uranium concentration of the grains, but the remaining grains mainly show igneous cores with bright or dark oscillatory zones and are enclosed by homogeneous or oscillatory zoned rims. Several other grains occur as single igneous crystals (Fig. DR2).

REFERENCES CITED


(a) Paragneiss (15LJ–59) from the Gezhencun Formation, n=54

(b) Paragneiss (17PM01–5) from the Gezhencun Formation, n=70

(c) Quartz schist (17PM01–1) from the Ewenling Formation, n=70

(d) Mica schist (15LJ–51) from the Ewenling Formation, n=64