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Jurassic Arc: Reconstructing the lost world of eastern Gondwana

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SUPPLEMENTARY PAPERS

Geology (2021)

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Supplementary file A. List of samples used for U-Pb geochronology in this study (PDF).

Supplementary file B. U-Pb geochronological datasets (Excel file).

Supplementary file C. List of samples used for Lu-Hf analysis in this study (PDF).

Supplementary file D. Lu-Hf isotope analytical datasets (Excel file).

Supplementary file E. Analytical setup and procedures used (PDF).

Supplementary file F. Crustal addition rate calculations (PDF).

Supplementary file G. Supplementary Figure 1. Plotted εHf data with isotopic evolution curves (PDF).

U-Pb isotopes by LA-SF-ICP-MS (UWA)

Zircon U-Pb isotope compositions were determined by LA-SF-ICPMS at The University of Western Australia. The LA-SF-ICPMS system used in this study consisted of an Element XR ICPMS coupled to a Cetac Analyte G2 193 nm ArF laser. During the course of this study we took advantage of the improved sensitivity of the Element XR′s higher vacuum interface and employed a Jet sample cone and X skimmer cone configuration, along with 4.5 mL/min N^2 introduced with a total of 1 L/min of He carrier gas through the laser cell and Helix sample cup. Laser ablation analysis were carried out using a fluence of 4 J/cm2, a laser repetition rate of 5Hz, and laser spot diameter of 15 um. Each analysis consisted of a 10 s gas blank, while the laser was firing on the shutter, follow by 30 seconds of ablation time for a total of 150 laser shots. Each analysis also consisted of a 20 s washout period before the next analysis began. This routine measured masses, ^{200}Hg, ^{202}Hg, ^{204}Hg+Pb, ^{206}Pb ^{207}Pb, ^{208}Pb, ^{232}Th, and ^{238}U. Daily ThO/Th was routinely less than 0.3**%** percent. While no common Pb correction was applied, samples with excess ^{204}Pb- beyond that of background- were rejected. All analyses were calibrated to the 1064 Ma 91500 zircon standard using the ID-TIMS data from Schoene et al., 2006. The 337 Ma Plešovice (Sláma et al., 2008) and the 416 Ma Temora 2 zircons were (Black et al., 2004) employed as a secondary standard to monitor the accuracy of the method. During this study, the weighted mean ^{206}Pb/^{238}U age of Plešovice was 335 ± 2 Ma (2SE), while the Temora 2 zircon yielded an age of 413 ± 3 Ma (2SE). U-Pb isotope data were reduced using the method described in Fisher et al. (2014.).

Thermo Fisher ELEMENT XR (SF-ICP-MS)	
Forward power	1350 W
Plasma gas	16 L/ min Argon
Auxiliary gas	0.95 L/min Argon
Make-up gas (He + N2)	1.00 L/min He (Cell 0.30 L/min, Cup 0.70 L/min); 4.5 mL/min N2
Monitored masses	238U, 232Th, 208Pb, 207Pb, 206Pb, 204Pb, 202Hg, 200Hg
Detector mode	Fixed in counting or analogue respective to count rate
Cycle time	310ms
Other notes	Quartz injector, Ni X skimmer & Jet sample cones, tuned for ThO+/Th+ <0.3%; Th/U ~1
Photon Machines Analyte.G2 ArF Excimer laser	
Wavelength	193 nm
Pulse length	~4 ns
Fluence	~4 J/cm^2
Cell	HelEx II 2 volume cell
Spot size	25 µm
Repetition rate	5 Hz
Delay between analyses	20s
Ablation duration	30s

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U-Pb isotopes by LA-ICP-MS (JCU)

For comprehensive details of the U-Pb LA-ICP-MS setup employed at James Cook University (JCU), see Todd et al. (2019).

Zircon standards employed were GJ1 (609 Ma; Jackson et al., 2004), TEMORA 2 (417 Ma; Black et al., 2004), Plešovice (337 Ma; Sláma et al., 2008) and 91500 (1064 Ma; Schoene et al, 2006).

Thermo iCAP-RQ	
Forward power	1450 W
Plasma gas	15 L/ min Argon
Auxiliary gas	0.8 L/min Argon
Make-up gas	0.5 L/min Argon
Shield torch	none
Sampling depth	5 mm
Photon Machines Analyte.G2 193 nm ArF Excimer laser	
Wavelength	193 nm
Pulse length	< 5 ns
Energy density	~3 J/cm^2
Carrier gas	0.8 (MFC1) +0.3 (MFC2) L/min Helium
Nitrogen	4 mL/min
Ablation style	Line scan
Scan speed	3 µm/s
Spot size	30 µm
Repetition rate	5 Hz

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Lu-Hf isotopic Analysis (UWA)

For comprehensive details of the Lu-Hf isotope analytical setup and data processing procedures employed at the University of Western Australia (UWA), see Petersson et al., 2019, 2020).

ThermoScientific Neptune PLUS Multi-Collector Mass Spectrometer (LA-MC-ICP-MS)	
Forward power	1450 W
Plasma gas	15 L/ min Argon
Auxiliary gas	0.8 L/min Argon
Make-up gas	0.5 L/min Argon
Photon Machines Analyte.G2 193 nm ArF Excimer laser	
Wavelength	193 nm
Pulse length	< 5 ns
Energy density	~5 J/cm^2
Carrier gas	0.7 (MFC1) +0.3 (MFC2) L/min Helium
Nitrogen	9 mL/min
Scan speed	n/a
Spot size	40 to 50 µm
Ablation duration	60 s
Repetition rate	4 Hz

Ablation sites were selected to overlap those of the corresponding concordant U-Pb analysis for each zircon grain.

Corrections for isobaric interference of Lu and Yb on ^{176}Hf were performed by monitoring ^{175}Lu (^{176}Lu/^{175}Lu = 0.02655) (Vervoort et al., 2004) and ^{171}Yb (^{176}Yb/^{171}Yb = 0.897145) (Segal et al., 2003). Yb isotope ratios were normalized to ^{173}Yb/^{171}Yb = 1.130172 (Segal et al., 2003). Hf isotope ratios (^{179}Hf/^{177}Hf) were normalized to 0.7325 (Patchett and Tatsumoto, 1981), using an exponential law.

Uncertainties for reference and sample zircons are given at two standard errors and incorporate the reproducibility of the Mud Tank zircon analyses, added in quadrature. Four zircon references, Mud Tank (MTZ), FC-1, TEMORA 2 and 91500 were analysed concurrently with the unknowns to monitor instrumental accuracy and precision. Normalized (S1) ^{176}Hf/^{177}Hf values for MTZ, FC-1 and 91500 were 0.282488 ± 14, 0.282181 ± 19, and 0.282311 ± 24 respectively. Normalized (S5) ^{176}Hf/^{177}Hf values for MTZ, FC-1 and TEMORA 2 were 0.282494 ± 13, 0.282175 ± 19 and 0.282693 ± 19 respectively.

The solution ^{176}Hf/^{177}Hf value of FC-1 employed is 0.282184 ± 16 (Woodhead and Hergt, 2005), and the solution ^{176}Hf/^{177}Hf value of MTZ, to which all sample zircon analyses were normalized, is 0.282507 ± 6 (Woodhead and Hergt, 2005). The solution ^{176}Hf/^{177}Hf value of 91500 is 0.282306

± 8 (Woodhead and Hergt, 2005). The solution $^{176}Hf/^{177}Hf$ value of TEMORA 2 is 0.282686 ± 8 (Woodhead and Hergt, 2005).

Initial epsilon Hf values were calculated using the chondritic uniform reservoir (CHUR) parameters of Bouvier et al. (2008), $^{176}Hf/^{177}Hf = 0.282725$ and $^{176}Lu/^{177}Hf = 0.0336$ (Bouvier et al., 2008), and the ^{176}Lu decay constant of $1.867 \pm 0.008 \times 10^{-11}$ yr^{-1} published by Söderlund et al. (2004).

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Lu-Hf isotopic Analysis (JCU)

For comprehensive details of the Lu-Hf isotope analytical setup and data processing procedures employed at James Cook University (JCU), see Kemp et al. (2009), Næraa et al. (2012) and Tucker et al. (2016).

ThermoScientific Neptune Plasma Multi-Collector Mass Spectrometer (LA-MC-ICP-MS)	
Forward power	1450 W
Plasma gas	15 L/ min Argon
Auxiliary gas	0.8 L/min Argon
Make-up gas	0.5 L/min Argon
Photon Machines Analyte.G2 193 nm ArF Excimer laser	
Wavelength	193 nm
Pulse length	< 5 ns
Energy density	~3 J/cm^2
Carrier gas	0.8 (MFC1) +0.3 (MFC2) L/min Helium
Nitrogen	4 mL/min
Scan speed	3 µm/s
Spot size	50 µm
Ablation duration	60 s
Time between analyses	60s
Repetition rate	4 Hz

Ablation sites were selected to overlap those of the corresponding concordant U-Pb analysis for each zircon.

Corrections for isobaric interference of Lu and Yb on ^{176}Hf were performed by monitoring ^{175}Lu (^{176}Lu/^{175}Lu = 0.026549) (Vervoort et al., 2004) and ^{171}Yb (^{176}Yb/^{171}Yb = 0.897145) (Segal et al., 2003). Yb isotope ratios were normalized to ^{173}Yb/^{171}Yb = 1.130172 (Segal et al., 2003). Hf isotope ratios (^{179}Hf/^{177}Hf) were normalized to 0.7325 (Patchett and Tatsumoto, 1981).

Mass bias was corrected by exponential law (Fisher et al., 2011). Lu-Hf datasets were subsequently processed offline.

Measured average ^{176}Hf/^{177}Hf from four zircon standards, Mud Tank (MTZ), FC-1, Plešovice and 91500 were analysed concurrently with the unknowns to monitor instrumental accuracy and precision (Fisher et al., 2014). Uncertainties for unknowns and standards are given at two standard deviations. Four zircon references, Mud Tank (MTZ), FC-1, Plešovice and 91500 were analysed concurrently with the unknowns to monitor instrumental accuracy and precision. Normalized (S2) ^{176}Hf/^{177}Hf values for MTZ and FC-1 were 0.282494 ± 11 and 0.282183 ± 11 respectively.

Normalized (S3) $^{176}Hf/^{177}Hf$ values for MTZ, FC-1 and Plešovice were 0.282509 ± 15, 0.282166 ± 24 and 0.282478 ± 22 respectively. Normalized (S4) $^{176}Hf/^{177}Hf$ values for MTZ, FC-1, 91500 and Plešovice were 0.282505 ± 15, 0.282173 ± 25, 0.282285 ± 28 and 0.282478 ± 22 respectively.

The solution $^{176}Hf/^{177}Hf$ value of FC-1 employed is 0.282184 ± 16 (Woodhead and Hergt, 2005), and the solution $^{176}Hf/^{177}Hf$ value of MTZ, to which all unknown analyses were normalized, is 0.282507 ± 6 (Woodhead and Hergt, 2005). The solution $^{176}Hf/^{177}Hf$ value of 91500 is 0.282306 ± 8 (Woodhead and Hergt, 2005) and the solution $^{176}Hf/^{177}Hf$ value of Plešovice is 0.282482 ± 13 (Sláma et al., 2008).

Based on average $^{176}Hf/^{177}Hf$ MTZ values for each session, an individual normalization factor (calculated using the average $^{176}Hf/^{177}Hf$ value of MTZ relative for each session relative to the solution value) was applied to the unknown analyses (Fisher et al., 2014). Constants employed in these calculations were the chondritic uniform reservoir (CHUR) $^{176}Hf/^{177}Hf$ value of 0.282725 and the $^{176}Lu/^{177}Hf$ value of 0.0336 (Bouvier et al., 2008), and the ^{176}Lu decay constant of $1.867 \pm 0.008 \times 10^{-11}$ yr^{-1} published by Söderlund et al. (2004). Given εHf uncertainties in unknown analyses encompass analytical/instrumental drift errors added in quadrature with the reproducibility of MTZ.

Spurious results, such as those described below, were excluded from further interpretation.

- with uncertainties/errors > 1.5 εHf units
- with εHf unit values which plotted above the depleted mantle (DM) line
- with Lu^{176}/Hf^{177} ratios > 0.003, indicating a high REE content. As a high REE zircon standard (e.g. R33) was not employed, any interference correction applied may have been insufficient.

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