**Supplementary material for:** U–Pb zircon age constraints for the Ordovician Fishguard Volcanic Group and further evidence for the provenance of the Stonehenge bluestones

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**Chemistry and mass spectrometry**

All U-Pb dating of zircons was carried out at the NERC Isotope Geoscience Laboratory based at the British Geological Survey. Zircons were separated from the initial rock samples using conventional mineral separation techniques. Selected inclusion free zircons were picked from the resulting high density (>3.27 g/cm3) diamagnetic fraction.

All selected zircons were chemically abraded following a protocol based on Mattinson (2005). This serves to eliminate radiation damaged zones that are susceptible to open system behaviour. Zircons were annealed in a quartz dish at 900°C for 60 hours, and then individual zircons were loaded into FEP Teflon beakers. The zircons were refluxed in 4M HNO3 for several hours at 120°C, and cleaned in an ultrasonic bath for 30 to 60 minutes. Following this, single crystals were rinsed in acetone, followed by 4M HNO3, and loaded into 300 µL Teflon microcapsules. Sets of 15 microcapsules were placed in a Teflon liner and loaded into a steel pressure vessel (Parr Vessel). Zircons were then leached in 29M HF at 180°C for 8 to 12 hours, rinsed in 4M HNO3 and leached on a hotplate in 6M HCl at 120°C overnight. A subsequent rinse step in 4M HNO3 was carried out, before spiking. All zircons were spiked with a 202Pb, 205Pb, 233U and 235U (ET2535) EARTHTIME tracer solution, and returned to the Parr Vessel for dissolution in 29M HF at 220°C for 60 hours. Zircon dissolution is assumed to be complete based on previous dissolution checks using the same time and temperature protocols.

Following dissolution, zircons were dried down on a hotplate at 140°C for several hours and converted from fluorides to chlorides via re-dissolution in 3M HCl in Parr vessels at 180°C overnight. U and Pb separation was carried out using 300 µL capacity columns and ~150 µL Eichrom AG-1 1x8 ion exchange resin. Pb was separated using 6M HCl and U was separated using MQ H2O and 1M HCl. Following separation from the rest of the zircon matrix, the U and Pb fractions were recombined and dried down with 10 µL 0.03M H3PO4, and loaded onto zone refined rhenium filaments for analysis in a silica gel matrix to enhance ionisation.

Isotope ratio measurements were made using a Thermo-Electron Triton thermal ionisation mass spectrometer. Pb measurements were made in dynamic mode using a MassCom secondary electron multiplier (SEM), and corrected for mass bias in real time using the measured 202Pb/205Pb ratio. U was measured as UO2 and corrected for isobaric interference using an 18O/16O ratio of 0.0205 (IUPAC value, also measured in house at NIGL). U was measured in dynamic mode on the SEM, or in static mode for signals greater than 4 mV. Static measurements were taken on Faraday detectors equipped with amplifiers fitted with 1012 Ω resistors. U mass fractionation was calculated in real time based on the isotopic composition of the ET2535 tracer solution.

**Data reduction and archiving**

Raw data was filtered using the Tripoli program (McLean *et al.* 2011), and dates and propagated uncertainties were calculated in ET\_Redux, based on algorithms of McLean *et al.* (2011), using decay constants of Jaffey *et al.* (1971), and the 238U/235U ratio of Hiess *et al.* (2012). Pb blanks ranged from 0.30 pg to 5.56 pg of common Pb, which was attributed to laboratory Pb and subtracted using a Pb isotopic composition of 206Pb/204Pb = 18.20 ± 0.50%, 207Pb/204Pb = 15.65 ± 0.40% and 208Pb/204Pb = 38.02 ± 0.75% (1σ uncertainties). 206Pb/238U dates were corrected for initial 230Th disequilibrium using a Th/Umagma composition of 2.8 ± 0.5. U blanks were assumed to be 0.1 ± 0.01 pg (1σ).

Analytical data are presented in this supplementary material. Uncertainties on the ages are given at a number of levels to reflect the analytical uncertainty plus other sources of systematic uncertainty (i.e. tracer calibration and decay constants).

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Sample ID** | **206Pb/238U zircon date (Ma)** | **± X (Ma)** | **± Y (Ma)** | **± Z (Ma)** | **MSWD** | **n** |
| Fishguard Volcanic Group | Top | SW54 |  |  |  |  |  |  |
| ‘Middle’ | SW52 | 462.64 | 0.13 | 0.17 | 0.52 | 1.1 | 6/6 |
| Bottom | SW55 | ~464 |  |  |  |  |  |
| Stonehenge debitage |  | SH08 | 462.20 | 0.26 | 0.128 | 0.57 | 2.8 | 5/6 |
|  | SH48d | 463.88 | 0.17 | 0.20 | 0.54 | 1.0 | 7/8 |

X represents the analytical error and should be applied to direct comparisons within this dataset. Y represents the analytical + tracer uncertainty, and z represents the analytical + tracer + decay constant uncertainty, and should be applied when making timescale comparisons, or comparisons with different studies. The default uncertainty used in this paper is Y, in other words the uncertainly appropriate to inter-laboratory comparison of U-Pb zircon sets. The larger uncertainties are appropriate for comparison with other decay system derived ages (e.g. K-Ar, Rb-Sr). The discussion of the match between the debitage and the potential source quarry is based on analytical uncertainties (type x) as this is a within laboratory data comparison.